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# Co-creating valuations and valuating co-creation in sustainable public infrastructures : the case of district heating

Johanna Ayrault

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**THÈSE DE DOCTORAT**  
**DE L'UNIVERSITÉ PSL**

Préparée à Mines Paris-PSL

**Co-cr er des valuations et valoriser la co-cr ation pour des  
infrastructures publiques durables - le cas du r seau de  
chaleur**

***Co-creating valuations and valuating co-creation in sustainable  
public infrastructures–The case of district heating***

Soutenue par

**Johanna AYRAULT**

Le 16 d cembre 2022

Ecole doctorale n  543

**Sciences de la D cision,  
des Organisations, de la  
Soci t  et de l' change**

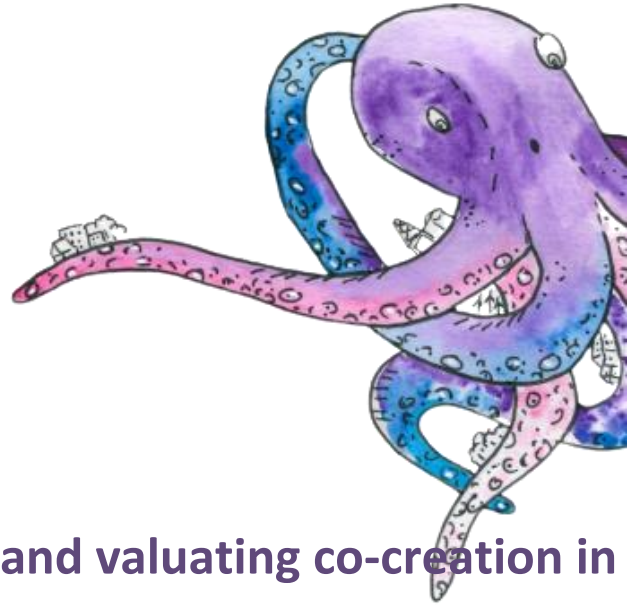
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# Co-creating valuations and valuating co-creation in sustainable public infrastructures

## The case of district heating

*A journey into the world of district heating: initiatory investigation to be read with a tab of (dark) chocolate*



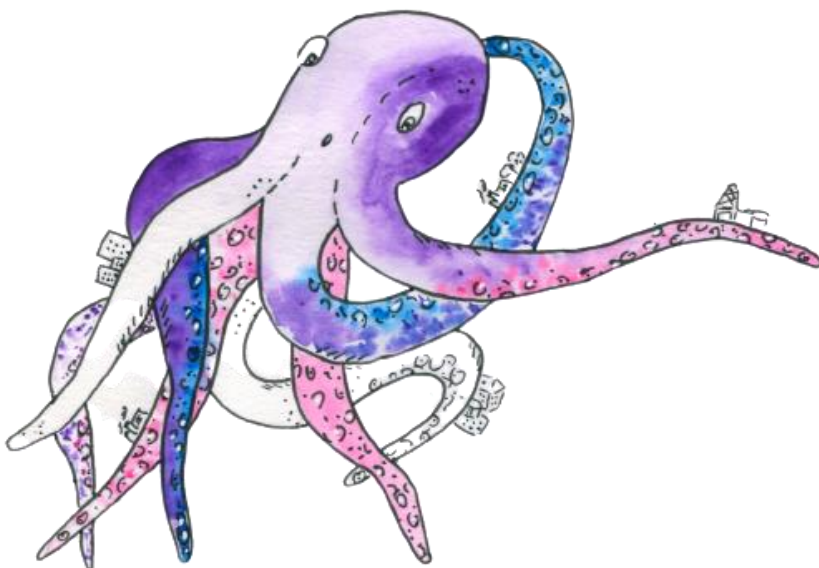
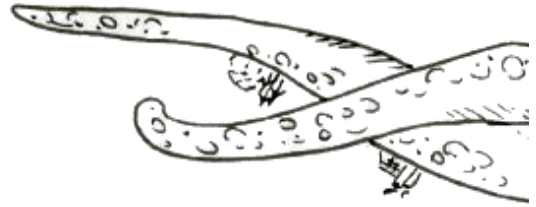
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*Mines Paris - PSL n'entend donner aucune approbation ni improbation aux opinions émises dans cette thèse. Ces opinions doivent être considérées comme propres à l'auteur.*



*“N’oublie jamais, celui qui croit savoir n’apprends plus.”* (Pierre Bottero)  
*“Never forget, the one who thinks he knows no longer learns.”* (own translation)







## Abstract

Sustainability is a challenge faced by many sectors. Among them, infrastructures and their shift towards greater sustainability are a necessary lever in meeting sustainable development goals. In this PhD, I study this dynamic through the example of sustainable district heating. District heating, like most infrastructures, is embedded in multiple existing networks, institutions, and regulations. A single project gathers together many stakeholders, such as owners, financiers, operators, suppliers, consumers and citizens. This is all the more so when the technical system shifts towards more locally-anchored and sustainable setups. Sustainable district heating does not exist per se, but is locally constructed depending on the resources and actors' interests in a project.

I chose to study two interrelated processes shaping sustainable district heating—valuation and co-creation—focusing on the question: *how are actors co-creating sustainable valuations for infrastructure projects?* Valuation studies look into the social construction of values, while public sector co-creation analyzes the processes of collaborative public innovation. Both processes can be seen at work when studying sustainable district heating, as actors need to collectively find what has worth, and how to value it. To do so, actors engage in three mediating activities: framing, i.e., defining the boundaries and rules to act; instrumenting, i.e., designing or adapting policy instruments, management dispositive or calculation tools to support the action; and building expertise, i.e., creating a network connecting the devices, institutions, knowledge, actors, etc.

During the PhD, I worked at the Research & Innovation department of Engie, a major French energy company, under a CIFRE partnership. I used these three mediating activities as an analysis framework to study the situation in France and Denmark; to analyze various case studies and to shed light on Engie's activities.

On a theoretical side, I found that valuation and co-creation processes are interrelated. As framing is constantly being challenged and updated, the valuation process is continuous and it is through co-creation activities that some valuations are stabilized at a project level. Instrumentation is both an arena of co-creation and valuation. Actors co-create instruments into which they integrate new values and, by doing so, they challenge and update existing frames and expertise. To perform sustainable infrastructures, actors

build up locally-anchored expertise, which may become global if supported by global actors.

On the empirical side, I showed the importance of co-creation processes for setting up sustainable infrastructures, and sketched out some first method paths for implementing them in district heating projects. Following my analysis of the French policy instruments supporting district heating, I pointed out some gaps and ways forward to better integrate it with other sectors.

## Acknowledgments

The PhD is a solitary road. Students are left in an unknown world where they try to study an unknown question with unapplicable methods. It is usually said that the PhD is a unique moment in one's life (but so are all the moments in everyone's life), and that the student should take the most out of it. It is also said that the PhD is something special and personal. I have felt the frame of the PhD quite a heavy burden to carry for three years, but have tried my best to create fun out of it, follow my ideas, and achieve something that is truly me. In this process, I was of course supported by many people, enjoying the collaborative processes and attempting to set up them whenever possible.

I start with a very special thanks to my family, who was the steadiest support one could dream of, and especially my parents who were always there housing me (strange times of COVID-19), comforting me, reading me, listening to me and most of all taking me outside! It is of course the continuity of long years of support for which I thank you with all my heart. I also want to give a huge thank to my boyfriend, who has been by my side during these three years and has endured all my "humeurs", and to his welcoming family.

Of course, the PhD could not have existed without my PhD director. Thank you, Franck, for letting me find my own safe way to the top of this tricky mountain. Thank you for sharing some of your research experiences with me and for your even-tempered oversight of my research attempts.

On Engie side, I thank Anne for her facilitating supervision: thank you for trusting me with my projects, and helping me get my way through Engie's bureaucracy. Thanks also for your knowledge and expertise, for your hindsight on my work leading to precious insights. I cannot think about Anne without thanking all the welcoming teams of Engie: my colleagues at the Lab Environment & Society, Olivier and the (former) ATF team, Elodie, the PhD committee, and of course all the colleagues who spent some time answering my questions during these three years, and sharing coffee breaks.

A special thanks to the PhD committee, my rapporteurs and my co-authors for all their relevant comments. And a big thank also to all the people I have met during this PhD, who have helped me through it, welcomed me, answered me and given some of their time:

the Copenhagen teams (Susse, Peter, Theis, Soren, Maëlle, Ask, Signe, Virginie, Trine and all the others), Gregor and the COST-Action participants, for all the great opportunities. Obviously, all the people involved in my case studies and in the multiple interviews I've conducted: I cannot list you all there but you all have a role in the result of this PhD.

I want of course to thank all the PhD, former PhD student and friends that have been by my side during mine. Joël and later Rémi, who have been my mentors during the process, sharing their experience, answering all my concerns, creating great opportunities, and a lot more. Fred, for all our long conversations mingling complains, brainstorming sessions, English sessions, and caustic descriptions of research and life. Farah and Chloé, for the shared discovery of this strange experience, the laughter and the listening. And of course, all the PhD from the CGS and from Engie. Justine, Raphaëlle, Alix, Antoine, Corentin, Louise, Mariane, Jean and all the others, thank you for all the discussions on your experience and your time.

And finally, thank you to Delphine for her incredible corrections, comments and time spent on my PhD.

## Preface

Dear reader, you are here standing at the edge of a manuscript aiming at retracing a three-year industrial PhD. You may find the format and style quite unconventional, but I do hope it reflects this period of my life and that it will still be enjoyable to read. Before starting, a few things you need to know.

First, this PhD is the opportunistic result of an unpredictable series of event, not really a carefully thought life-orientation. This list of events comprises the decision to do a master (first in order to learn more about sustainable development, but it ended being a master in management of organizations and public policies), some round-trips between Vienna and Paris, a new boyfriend, a random answer to an email and various interviews in May and June 2019. I can of course recreate a lot of sense out of it ex-post, but this story-telling is for the core of the manuscript. However, it does not mean I regret taking this adventure. I have found it full of unimagined enlightening experiences. As a consequence of this strange start in the PhD, I cannot say the frame and the subject were something I really thought about prior starting. I knew next to nothing of PhD before the beginning of mine and I sure did not know a thing about district heating prior to the PhD. I signed up with a research center in management when my experience in management research was limited to this research master and tainted of STS (science and technology studies) on the sociology side. More than that, I never had any experience working in a private company before the PhD... Whole new worlds to discover, which took part of my first year to adapt to and the work is still under process.

Secondly, the PhD took place at a special time: 5 months after I have had started, France went under its first lock-down, premises of a long sanitary crisis of which we are not out yet as I write down these words. It causes a lot of uncertainty, postponed visits, limited exchanges with fellow researchers: all in all, a strange working environment. I am sure you are all well aware of the possible consequences for a PhD work so I will not comment any further on that.

And finally, I know that the PhD is just the beginning of the research journey. It can never be considered as fully completed. But here is the actual state of my research on

sustainable district heating! I will now let you take this journey into the strange universe of district heating management.

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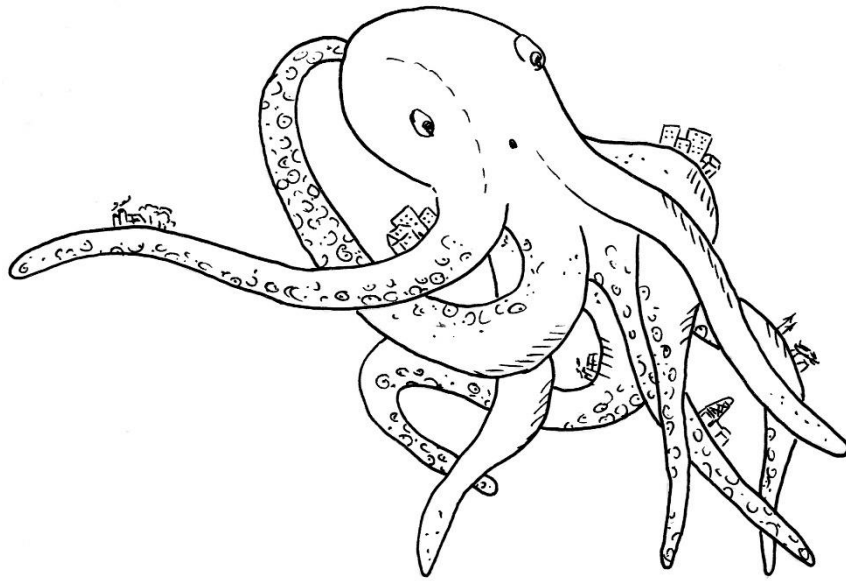
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**Introduction – What, why, how?**





## Sustainable infrastructures?

The sustainability dynamic has risen in most sectors: mobility, energy, and consumption to name but three. All aspects of our lives are under scrutiny and sustainability has almost become a new branding. One sector that presents many challenges when it comes to sustainability is that of public infrastructures.

Public infrastructures are infrastructures that are owned by a public body or made available for citizens' use. They are an essential part of society and play a part in the achievement of sustainable development goals (Thacker et al., 2019). This shift towards sustainability can come from the private partners that are usually in charge of the operation and maintenance of the infrastructures (Koppenjan and Enserink, 2009; Hueskes et al., 2017). It can also come from changes in established public practices (Ntsondé and Aggeri, 2021). However, some of the infrastructures' characteristics—embeddedness in other structures, links with conventions of practice, invisibility (Star, 1999)—may become barriers to the setting up of more sustainable infrastructures (Corvellec et al., 2013).

In this PhD, I will try to unbundle some aspects of sustainable infrastructures through the study of one specific energy infrastructure: district heating.

## Diving into the world of district heating

Energy infrastructures are facing unprecedented crises, partly due to the challenge of climate change, but also for societal and geopolitical reasons. The war between Russia and Ukraine has recently shown the energy systems' limits and how the globalized solutions based on fossil fuels could lack resiliency in a crisis.

District heating systems appear to be a great lever for decarbonization (International Energy Agency, 2021). While energy is known to be an important source of emissions, heat and hot water account for about half of the global energy consumption and are dominated by fossil fuel production (International Energy Agency, 2020). Most of the existing district heating systems are also based on technologies using fossil fuels (International Energy Agency, 2021). Therefore, the idea of district heating decarbonization appeared to be the perfect answer to the current crisis: switching fossil fuel-based heat production to a decarbonized one. However, though the principle sounds simple practice quickly revealed itself to be more complicated than expected... But before diving into the mysterious world of sustainable district heating systems, it is time for a brief presentation of “conventional” district heating.

Almost no one knows about district heating. You have all heard about the electricity grid, gas pipes, or water supply, but hardly ever about district heating systems. This world lives hidden from sight, but it is far from quiet. A district heating system is basically a heat distribution system that uses hot water or steam (*Figure 1*). It is a system of pipes and valves usually conveying hot water. Depending on the organizations, it can also comprise the production units, e.g., boilers where you burn gas / biomass / fuel oil / coal to create heat; electric boilers; geothermal plants where you use the heat from the ground to heat the water; waste incineration plants; or Combined Heat and Power (CHP) units, where you utilize the heat coming from electricity generation. The pipes run from the production units towards the ETS (Energy Transfer Station) located in a building. The ETS is where the secondary network starts. This network, which is separate from the district heating system, provides apartments or offices with heating and hot water.

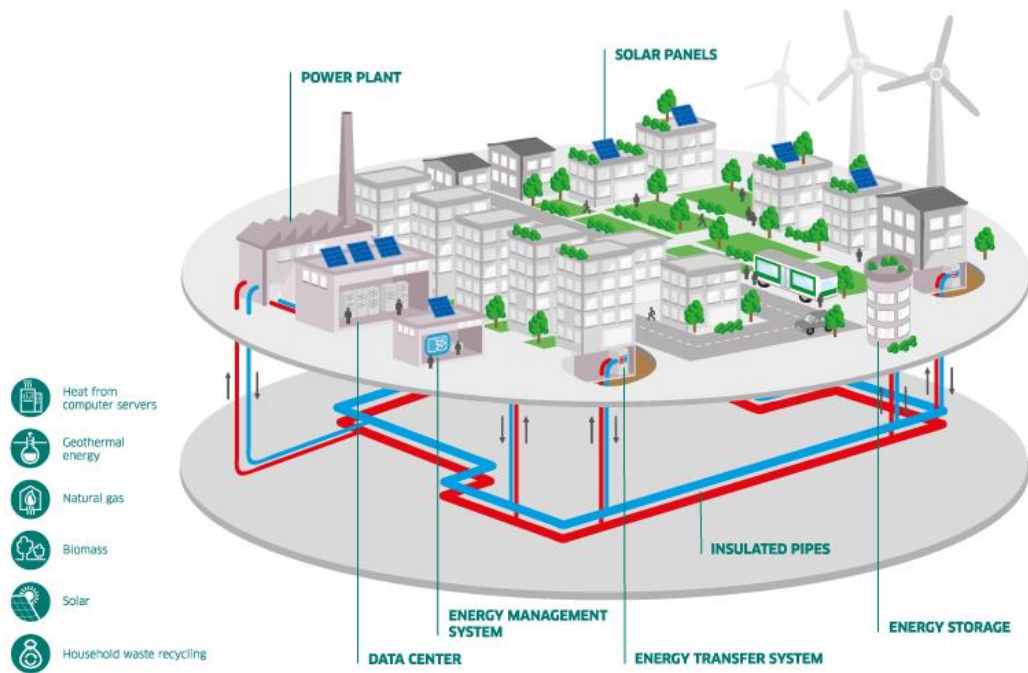


Figure 7 District heating (Engie, 2013)

The system is fairly simple but a number of issues arise when we start talking about sustainable district heating.... One first approach of sustainable district heating is a technical one: introducing more decarbonized heat into the supply system. This requires lowering the supply temperature, as the heating power of decarbonized heat production unit is usually lower than that of fossil fuel boilers. Also, the number of heat production units to be connected to the system will grow, as each unit can produce less energy than the centralized fossil fuel-based boilers. Thus, introducing decarbonized heat requires changes in the infrastructure: new pipes, new optimization rules, etc. It can go as far as what is called 5<sup>th</sup>-generation district heating and cooling systems: entirely decentralized systems working at ambient air temperature and providing both heating and cooling (Figure 2).

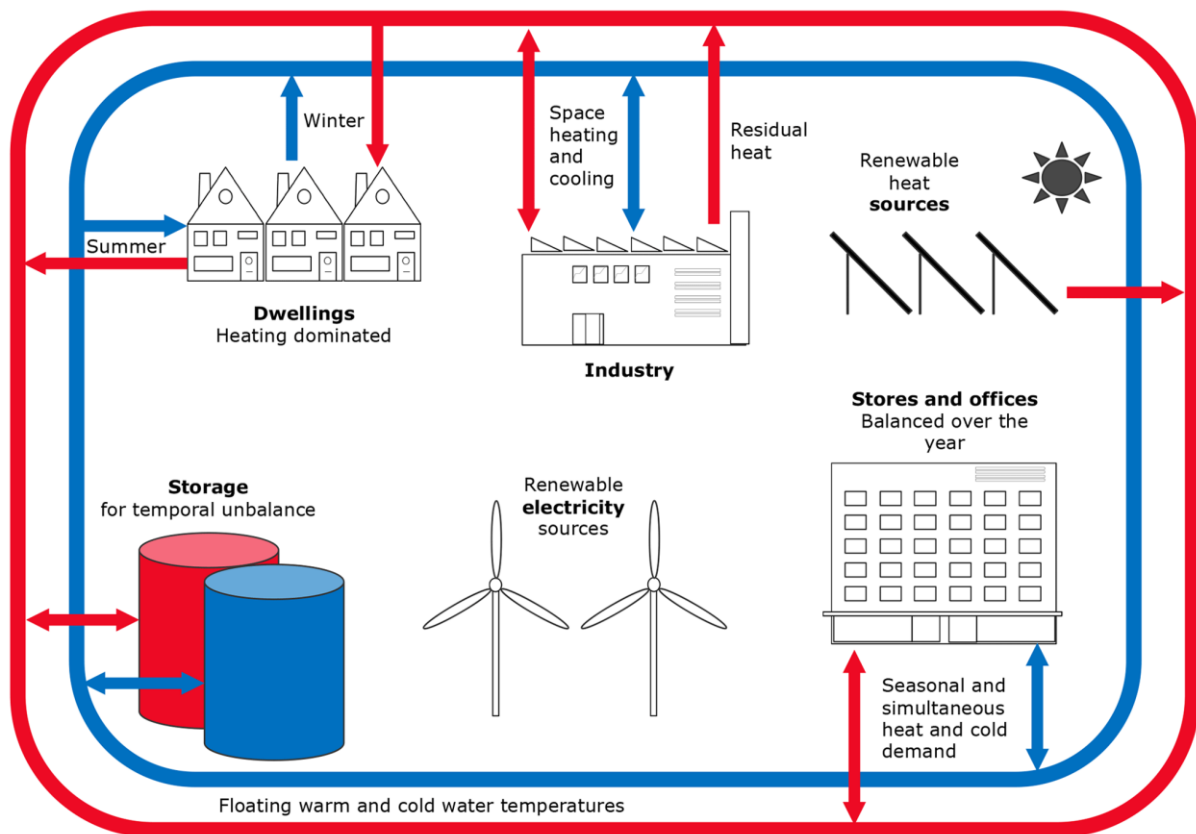


Figure 8 5<sup>th</sup>-generation district heating and cooling systems (Boesten et al., 2019)

But more than a technical change, the introduction of decarbonized heat means integrating more stakeholders into the governance... Different decarbonized heat production sources can be owned and operated by different stakeholders (a supermarket producing waste heat, a consumer with a heat pump connected to the district heating network, etc.).

The only way to keep the centralized architecture of the network while decarbonizing heat is to use biomass... But biomass may not be a magic bullet. There is increasing controversy over the carbon neutrality of biomass, and the conditions under which it may be considered sustainable. For instance, Denmark has recently changed its decarbonization strategy, cutting the subsidies for biomass-fueled boilers, after several years during which the demand for biomass outgrew its national resources (Johansen and Werner, 2022). The valuations for “sustainable” are moving, anchored in historical national paths and international contexts.

So, what I want to point out here, is that district heating is not only a technical network, but a sociotechnical network embedded in a complex set of policies, institutions, material infrastructures, natural and informational resources, expertise, etc. It stands at the crossroads of many transformations: e.g., urban transformation, with cities committing to “carbon-neutral” objectives and engaging in a “fair transition”; energy transformation with the whole energy market being reconfigured to meet the continuity of supply while answering social and environmental challenges. Moving away from conventional district heating—a centralized heat production system based on fossil fuels—towards a sustainable version requires building up a new governance of collective actions. The transformations gather many stakeholders, each one with its own approach to its own concerns: e.g., policy-makers, European institutions, researchers in social sciences, technical experts, interest groups, citizens. Each stakeholder has their own frame for the values associated with “sustainable”: e.g., decarbonization, local attractiveness, etc. These values complement the classical ones of a public service like district heating, such as continuity of supply or affordability. There are stakes involved in collectively building the values and securing local resources. This demands rethinking the stakeholders of district heating systems, building new types of partnership, gaining new competences and creating a collaborative organization around the infrastructure. The historical actors of district heating, which include private operators and municipalities, are now facing unprecedented issues, where the usual ways of working are no longer relevant. The technical and economic performance indicators can be challenged, and the plug-in solutions of collective fossil fuel-based heating do not answer contemporary challenges. All in all, district heating—like any infrastructure—raises the organizational challenge of creating a collective action governance supporting its sustainable transformation.



## How to design an investigation journey?

I guess that by now, you have understood that, when talking about sustainable district heating, lots of questions quickly arise. The district heating sector, invisible in everyday life, is questioning its very future.

To study district heating, I was employed by a major French energy company: Engie. The research setting was governed by a CIFRE contract, a three-party research contract linking an academic research institute, an industrial firm and the National Association for Research and Technology. Under this partnership, I was employed by Engie where I was supervised by the head of the Lab Environment & Society, a research lab. I also had an academic PhD supervisor from the Center for Management Science at the Mines Paris Graduate School. I was in charge of the investigation and did not need to answer an industrial demand. However, the research topic needed to be both an empirical concern of the company and of academic relevance. Within this framework, I settled for a comprehensive research approach anchored in a pragmatic paradigm. The research problem and its related methods were constructed hand-in-hand with the empirical field studies. From this process, two literature streams emerged: valuation studies and public sector co-creation.

Scholars of valuation studies have a processual approach to valuations, contrasting with a more static approach to values. In the latter, the goal is to quantify existing values, whereas valuation studies look at the social construction of what is worth valuating and how to value it (Kjellberg et al., 2013). Valuation is analyzed as an action (Muniesa, 2011) embedded in actors' practices and institutions, among others. In relation with this literature, I will analyze how sustainable infrastructures are valued by different actors. Public sector co-creation literature stems from the meeting point of public innovation and public collaborative governance literatures. Its scholars are interested in the processes gathering multiple actors in the attempt to produce public innovation and improve public value delivery (Torfing et al., 2019). The properties of public infrastructures make them a challenging object when implementing co-creation processes, but the sustainability dynamic creates opportunities to innovate for more sustainable infrastructures. I will study this tension by looking at the implementation of co-creation processes in public infrastructure projects.

While both these streams of literature present an interesting angle to approach sustainable infrastructure, in this PhD I wish to bridge both literatures, studying *How do actors co-create sustainable valuations for public infrastructure projects?*

To do so, I have used three mediating activities, forming an analysis framework. These three activities are framing, instrumenting and building expertise. They came out of the empirical investigation as cornerstones for understanding sustainable district heating. I will use them as tools to obtain results in the valuation and co-creation processes. When it comes to framing, I mainly build on Callon's (1998) view of framing where he understands it as the making of boundaries and rules within which actors can interact. He also points out that the resulting frames are constantly overflowed and re-framed by the actors, taking into account externalities that were not integrated in the first frame. When it comes to instrumenting, I look at the performing power of two main types of instruments; policy instruments (Lascoumes and Le Galès, 2007) and management dispositive (Aggeri, 2017). I also analyze some calculation tools that can be used to design other instruments. Finally, I use Eyal's definition of expertise (2013), understanding it as *"a network connecting together actors, devices, concepts, and institutional and spatial arrangements."*

With this analysis framework outlined, I could divide my main research problem into two separate research questions 1) *How do actors frame and instrument sustainable valuations?* and 2) *How do actors frame and instrument co-creation for sustainable infrastructures?*

I have studied them with a research method inspired by a processual approach. Process studies are aligned with the comprehensive and pragmatic paradigm taken for the research, studying the objects in the making and analyzing the actors' perceptions to gain results. I have used various methods for data collection—e.g., case studies, semi-directive interviews, situated research—and for data analysis—e.g., narration, grounded coding process.

## The manuscript's outline

The manuscript is structured as followed (*Figure 3*)

Introduction—What, why, how?	
<b>PART 1: Setting the stage</b>	
Chapter 0: The investigation journey	Chapter 1: Where do I begin? From a tour of Besançon's boiler rooms to a history of French district heating...
Chapter 2: Building the theoretical framework	
<b><i>How do actors co-create sustainable valuations for infrastructure projects?</i></b>	
Chapter 3: The framework of analysis and the investigation process	
<b><i>RQ1: How do actors frame and instrument sustainable valuations?</i></b>	<b><i>RQ2: How do actors frame and instrument co-creation for sustainable infrastructures?</i></b>
<b>PART 2: Following Mrs.G.'s investigation</b>	
Chapter 4: A global sustainable value proposition?	Chapter 5: Diving into projects
Chapter 6: Instrumenting the collaboration	
Conclusion—Valuation and co-creation processes for sustainable infrastructures	

*Figure 9 Manuscript structure*

The first part, “Setting the stage” explains the basis of the investigation. It is composed of a reading guide of the manuscript (chapter 0); an overview of the empirical concerns based on a French historical district heating system (chapter 1); the definition of the theoretical framework (chapter 2;) and the data collection and analysis (chapter 3).

The second part, “Following Mrs. G.’s investigation” presents the actual investigation process and the first results. Each chapter in this part answers an empirical research question, linked to the main academic research questions (*Table 1*).

<b>Research problem</b>	<b>How do actors co-create sustainable valuations for infrastructure projects?</b>	
<i>Research questions</i>	<i>How do actors frame and instrument sustainable valuations?</i>	<i>How do actors frame and instrument co-creation for sustainable infrastructures</i>
<i>Research level</i>		
<i>Global</i>	How is sustainable district heating frame constructed through instrumentation at	

	the national level and translated at more local levels? (Chapter 4)	
<i>Local</i>		How are co-creation practices framed in projects? (Chapter 5)
<i>Local</i>	How is co-creation instrumented in district heating projects and how is this instrumentation impacting the framing of sustainable district heating valuations? (Chapter 6)	

Table 11 Empirical questions and their link to the research questions

In Chapter 4, I study the historical valuations supporting district heating in France and Denmark, and the French instrumentation of sustainable district heating. In Chapter 5, I focus on the project level to assess co-creation processes in various district heating projects. In Chapter 6, I delve further into co-creation, analyzing its instrumentation and the impacts it has on sustainable valuations.

Finally, I discuss and conclude on the investigation. I come back to the research questions to explicit the theoretical and empirical contributions of this PhD, and discuss their perimeter of validity. I also sketch out some future research prospects.



## PART 1: Setting the stage





## Chapter 0: The investigation journey

*“On ne va jamais si loin que lorsqu’on ne sait pas où l’on va.”* (attribué à Christophe Colomb et Olivier Cromwell)

*“One never goes as far as when one does not know where one is going.”* (own translation)





## Chapitre 0 : Le parcours d'investigation

Ce chapitre décrit dans un premier temps le dispositif de la thèse CIFRE, un partenariat entre un laboratoire de recherche, l'ANRT et une entreprise privée. Au cours de la thèse CIFRE, le doctorant est employé par l'entreprise et encadré à la fois au sein de cette entreprise et par un directeur de thèse académique. Lors de ma thèse, j'étais encadrée par le CGS, laboratoire de sciences de gestion des Mines Paris-PSL, tout en étant intégrée à l'équipe Environnement & Société du CRIGEN, une entité de recherche d'Engie. Le sujet de thèse découle à la fois des attentes empiriques de l'entreprise et d'un ancrage dans une communauté académique. J'ai donc mis en place une recherche compréhensive : l'objet de recherche et le dispositif de recherche ont été définis au cours du processus de thèse afin de s'adapter aux retours empiriques et théoriques. Pour rendre compte de cette démarche, le manuscrit de thèse met en scène un personnage, Mrs. G., représentant une enquêtrice junior. J'ai également mis en place des dialogues entre l'auteure (moi) et Mrs. G. (le moi qui a fait les terrains de recherche empiriques) afin d'exposer les rouages amenant aux choix (de cadre théorique, méthode, etc.) que j'ai pu faire.



Before diving into the investigation process, let me begin with the presentation of the PhD research setup and its stakeholders. This PhD was conducted in the framework of a French CIFRE PhD partnership, which is a mechanism specific to France but widely used nationally. However, it may be surprising to a foreign reader. It is a kind of collaborative research (Shani et al., 2007) where the PhD student is immersed in a private organization for three years.

## A French setup: the CIFRE partnership

As I have just mentioned, this PhD was conducted within a specific setup called a CIFRE partnership. CIFRE PhD is a French policy put in place by the government to encourage collaborative research between an academic and a private partner, and supported by the National Association for Research and Technology (ANRT)<sup>1</sup>—a French national agency. The process is the following. First, the partners submit a formal project to the ANRT. Second, it is assessed by reviewers according to various criteria, including scientific rigor and the relevance regarding societal issues, theoretical potential and the company's interest. Third, if the project is approved, both partners sign a contractual arrangement between them and with the ANRT, and they receive public subsidies. Finally, the candidate is hired by the private company to conduct the three-year research project.

The project submitted to the ANRT aimed at designing sustainable business models accounting for environmental externalities. To do so, an analysis of the current organization of two sectors—district heating and cooling systems, and electrical smart-grids—was planned, focusing on the relationship between the different stakeholders and the challenges and benefits of introducing environmental externalities into a business model. From there, a sustainable business model was intended to be designed and tested, to better understand the operational challenges and outcomes it may have for an organization. As the project was accepted by the ANRT, I was employed by Engie and supervised by the Center for Management Science (CGS) at the Mines Paris Graduate School. The research thus needed to be both relevant at the academic and company levels, developing useful contributions for Engie and for a theoretical community.

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<sup>1</sup> A report on the CIFRE setup for social sciences was published in 2021, presenting the mechanism, the specific working conditions of PhD students and professional prospects. (de Feraudy et al., 2021)

Although I was leading the investigation, I had regular meetings with both of my supervisors, Anne Prieur-Vernat at Engie, and Franck Aggeri, my academic supervisor. Both were heavily involved in the investigation process, and attended most meetings. At least once every two months, I presented the latest development of my investigation, and we could discuss its content and the next steps to be taken. On Engie's side, Anne was the one providing me with contacts within the company, ensuring that I could access all the needed information, keeping me informed of the company's re-organizations and the projects launched. She also made sure that I could present my work to relevant internal actors, keeping my investigation aligned with the interests of Engie and the sector's development, working on my empirical results and how they could be spread inside the company. Franck was more committed to the academic part, guiding me on the problematization process, helping me to structure the manuscript and to formalize some contributions. While most of the meetings were between the three of us, I also had some one-to-one meetings on specific points: preparing a presentation at Engie with Anne or discussing a draft for the manuscript structure with Franck.

Apart from these exchanges, the PhD setting included the organization of formal meetings with Engie executives and experts interested in the project. I organized meetings within Engie twice a year where I presented my work to this internal committee. The committee was composed of internal actors related to the work: a leader of district heating and cooling systems strategic teams, a member of the research and development department, an operational director, etc. These meetings reassessed Engie's interest in the research. Similarly, I presented my work at least once a year to colleagues at the CGS to get insights on the academic relevance of my research and possible future research paths.

## Dual supervision: Engie and the CGS

Now that I have presented the CIFRE PhD partnership, let me give some more information about the partners.

### *Engie, the ambition of becoming leader in the energy transition*

Engie is a major French energy company. Historically specialized in natural gas in France, it has diversified its activities and extended its geographic implantation. It now aims at being a leader in the energy transition through three key activities: gas, renewable energies and energy services. It is established in five main regions: France, Europe (excluding France), North America, South and Central America and Asia-Middle East-Africa. The group is organized into different units and departments, including four Global Business Units (GBUs): renewables, energy solutions, networks, thermal and supply. The activities of district heating and cooling systems come under by the Energy Solutions GBU, supported by the group support functions (Corporate Social Responsibility, communication, legal, etc.) and the Research & Innovation department (see *Figure 4*).

# AN ORGANISATION TO GROW FURTHER

## Corporate Departments

set policies and guidelines for the Group



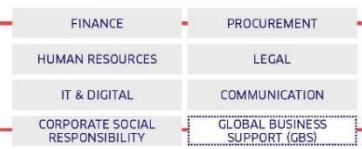
## 4 Global Business Units (GBU)

Drive operations and results



## Group support functions

Drive functional excellence

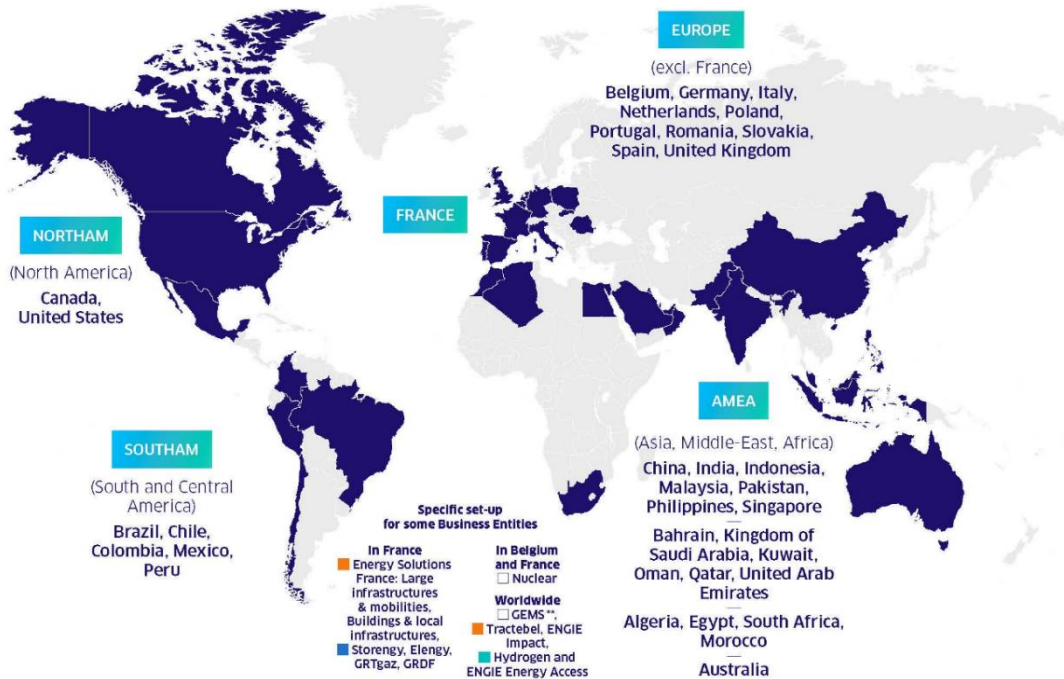


Transformation & Geographies

Outside of France, GBU and Group support functions are organized by regions and countries. At those 2 levels, **Transformation & Geographies** manages for the GBU the pooled support functions, jointly with the Group Functions, and the local stakeholders.

## A strong footprint in France and in 4 regions\*

France, Europe (excl. France), SOUTHAM, NORTHAM, AMEA



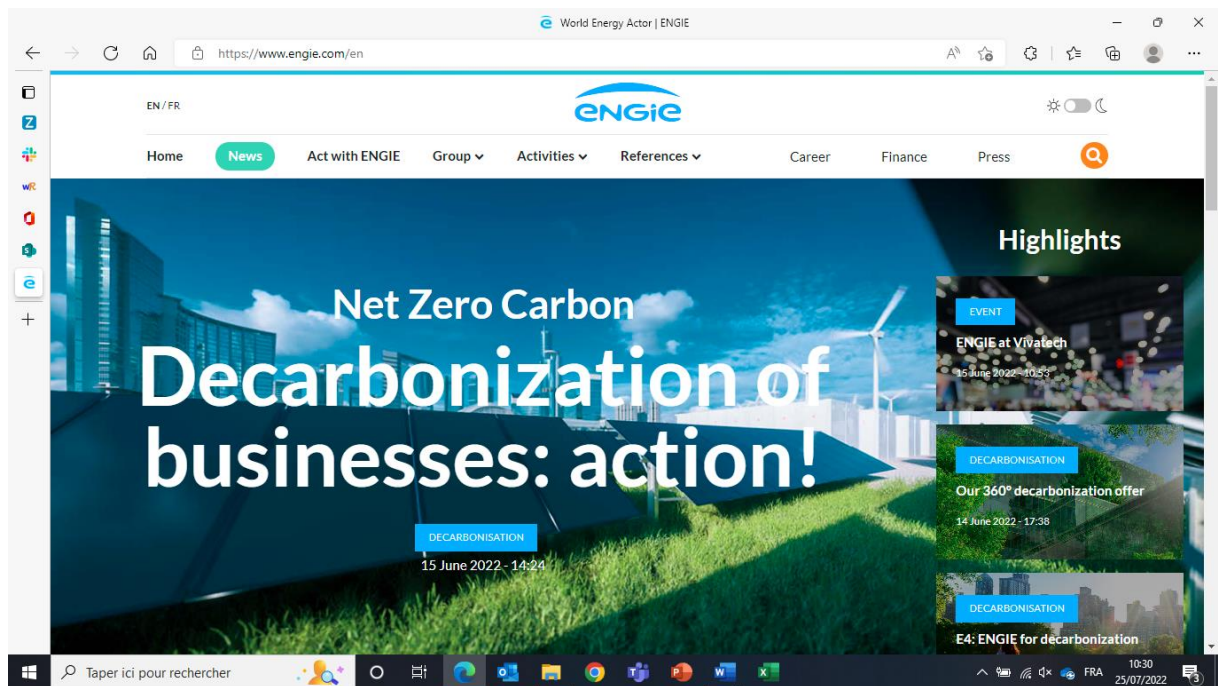
\* Organisation presented excludes EQUANS.

FEBRUARY 2022



Figure 10 Organization of Engie (Engie, 2022)

In 2020, Engie’s purpose was included in its bylaws: “*Engie’s purpose (“raison d’être”) is to act to accelerate the transition towards a carbon-neutral economy, through reduced energy consumption and more environmentally-friendly solutions. The purpose brings together the company, its employees, its clients and its shareholders, and reconciles economic performance with a positive impact on people and the planet. Engie’s actions are assessed in their entirety and over time.*”. The group has operated a transition towards decarbonization of its activities and now aims at becoming the leader in the energy transition (see *Picture 1*). It acts both to decarbonize its own activities and decarbonize those of its clients. To do so, various projects have been launched, which I describe in chapter 6.



Picture 6 Screenshot of Engie's website

I was employed as a research engineer by the Research & Innovation department, more precisely within the Lab Environment & Society of the CRIGEN. This lab, led by Anne, is developing tools and processes to help the group on its journey towards carbon neutrality. For instance, it has developed a tool to support the development of the circular economy and industrial and territorial ecology. After modeling an area, this tool recommends complementary activities to set up there. The lab also advocates going beyond carbon neutrality, through studies on biodiversity conservation, controversies analysis,



sustainable business models or green accounting practices. The PhD investigation is part of a research focus on the development of sustainable business models and practices, within the case study of more sustainable district heating and cooling systems.

### *The CGS, a tradition of “recherche intervention” within organizations*

On the other hand, I was also integrated in the CGS. This research center for the Mines Paris Graduate School has a long history in management sciences. It was founded in 1967 and has specialized in two main areas: 1) management tools, from their design to the analysis the role of instrumentation in the dynamic of organizations; 2) the modelling of design activities with the C-K theory. Its approach is characterized by strong links with the organizations under study leading to rich empirical fields. It was at the origin of the “recherche intervention” method (intervention research), a form of collaborative and engaged research (Hatchuel, 1994; David, 2012). This management science approach aims both at creating useful empirical knowledge and participating in academic theories (David, 2012). By immersing themselves in the organization under study, researchers can study ongoing transformations, understand the organization’s structure and act within this organization. In this type of research, the overall research problem and research questions are constructed throughout the investigation. Researchers also act on the organization by analyzing ongoing transformation processes or even supporting them. They can provide the organization with recommendations, experiment with new management models, or co-design instrumentation (Aggeri, 2016).

I was under the supervision of Franck, whose research interest revolves around sustainable innovation dynamics in organizations. He has a specific interest in two dimensions: the strategy processes involved in organizational change and the managerial capabilities developed to explore and sustain this change.

## A comprehensive research design anchored in a private partner

The research setting, with the strong involvement of a private partner and the research history of the CGS, leads to a specific investigation process. The research stems from an empirical question asked by Engie: What could their business model be in the market of sustainable district heating? From this starting point, I was able to slowly build a theoretical question, following a pragmatic approach. The pragmatic and exploratory approach based on field work allowed me to easily pass between the field and the theory, each part feeding the other. It is through this abductive process that I could finally formulate the overall research problem and questions. I will detail this problematization process in chapter 2. This process is typical of the constructivist paradigm inherent to a comprehensive research process in social sciences (Dana and Dumez, 2015; Dumez, 2016; Volat, 2020). I will present this methodological setting in chapter 3.

To help the reader's comprehension, let me say that the purpose of the comprehensive method I used during these studies consisted in approaching the object under study—sustainable district heating—through the actors' experiences thanks to semi-directive interviews, documentary analysis, and more. Thus, I will present and justify in chapter 3 the comprehensive and qualitative investigation process aimed at studying the stakeholders' discourses and practices through a variety of methods. I did not look at sustainable district heating and its supporting organization as “taken for granted”, but as concepts still under construction by a variety of stakeholders.

As I was employed by Engie, some method precautions needed to be taken. By doing intervention research, I was part of the organization I was studying. First, it is important to underline that the PhD was not a commissioned work: Engie was a research partner, but my investigation did not follow specifications given by them. The investigation was anchored in Engie's concerns, and had empirical and operational objectives. The operational concerns of Engie were used as a guidance for the research, but the investigation did not focus on finding an answer to these concerns. I used the empirical concerns as an entry point to understand the organization. Second, as I was immersed in the organization, I took specific care to make notes or recordings of all interviews. I also took notes and made observations of day-to-day life in the organization: informal discussions, meetings, etc. I kept in mind that my interaction with the organization could

modify the way it was behaving. I thus complemented these primary data sets with secondary data like contract documents, reports, websites, etc. Data collection will be detailed in chapter 3. Finally, to step back from the organization and extract myself from it, I had regular interactions with academic colleagues through conferences, presentations and informal discussions. I took care to extract myself from the field when analyzing the data or writing the manuscript. To facilitate this detachment, I did not go to Engie or have meetings and calls during the data analysis period.

A discussion on the reflexivity of my positioning during the PhD will be held in chapter 3.

## The manuscript

To account for the pragmatic approach used in the research setting, this manuscript will be written as a kind of detective story. The analogy between social science narratives and novels is not new. Czarniawska (1999) makes an analogy between organization studies and a subgenre of the novel: the detective story. She argues that *“the detective, much like the researcher, must untangle the social tissue to arrive at an explanation.”* (Czarniawska, 1999, p. 13). In both organization studies and detective stories, the main character has to solve an enigma that is not fully defined when the investigation starts. He uses specific methods to collect data and analyze them, finally coming—or not—to a conclusion on the mystery at hand.

In this manuscript, I will not push the analogy as far as to write a fully-fledged detective novel. While keeping some markers of academic literature (e.g., a presentation of the theoretical framework, a methods section), I will try to give a realistic account of the investigation and introduce some narrative parts. This style allows me to show how the investigation developed and evolved. Moving away from more conventional styles for a PhD manuscript is an attempt to explicit the flow of the investigation and to really account for the constructivist process used for the investigation itself. This manuscript will not be a chronological account of the three-year investigation, but the narrative and dialog parts will shed light on the temporality aspects (e.g., the theoretical framework or method construction and the data collection). Thanks to this style, I can also use my hindsight on the organization of the manuscript compared with the actual investigation process. I will explicitly show the choices made in the presentation of the investigation and the reconstruction of a common thread for the second part of the manuscript. Moreover, this manuscript’s style reflects my position as a junior researcher going through my first investigation, supervised by Franck—a senior detective—and Anne—a representative of Engie. As I will explain in the following paragraph, this style allows me to present the dynamics and mechanisms of a junior researcher’s first investigation: the choices to be made, the questioning, the dead-ends explored, the discovery of some analysis methods, etc. More than the development of the investigation, it also embodies my personal development from a freshly graduated engineer of the Mines de Paris to a junior detective in organization studies. Finally, this manuscript is directed towards at least two different

worlds: the sociotechnical-economic world of district heating systems and all its experts, and the academic world. For the first one, it aspires to give insights from a management perspective on the challenges met by district heating. For the second, I wish to show the technical system and its challenges, linking it to relevant research avenues. In the mid to long term, I hope to break new ground for multi-disciplinary research both for furthering the understanding of district heating systems and supporting their sustainability journey. To be able to discuss matters with both worlds, and keep the manuscript readable, I chose to go for the detective novel style, showing the investigation process. Without going as far as Latour (1992) with the *scientifiction*, a hybrid style showing all the conflicting realities around a technical object, I wish to show some of the realities around district heating, as I have discovered them in the twists and turns of the investigation process.

A character known as Mrs. G. will be introduced, giving life to the empirical part of the PhD. Mrs. G. embodies one of my research positions, the field detective employed by Engie. Introducing her will allow me to make a clearer distinction between the empirical part of the research and the more theoretical part. It is also a way of extracting myself from the field and gaining some self-awareness of my research positioning. Mrs. G. will be a reflection of my position during the investigation process, while I, as an actor and narrator of this manuscript, will present the structuring of the findings in a relevant and coherent way. It will also be a way to present the struggles I sometimes had as a junior detective to structure my research: dialogs between Mrs. G. and I will be staged to show the construction of the investigation and the choices made around the manuscript's structure. Introducing Mrs. G. also amplifies the narrative style that will be given to the investigation, especially the description of the case studies and field work, by following the story of Mrs. G., the junior detective.

Discussions will take place between Mrs. G. and I in the first part of the manuscript: based on her empirical observations (chapter 1), I will slowly build a theoretical (chapter 2) and methodological frameworks (chapter 3). This methodological framework will then be used by Mrs. G. in her investigation in part 2. This investigation will take place at three different levels: national and regional levels (chapter 4) and the project level (chapters 5 and 6). All of these empirical investigations will follow a common thread stated at the beginning of the chapter through an empirical question. These empirical questions will give results on specific aspects of the research questions, which will themselves answer the overall

research problem. I will discuss Mrs. G.'s analysis and results in a more theoretical way in the concluding section, going back to the theoretical research questions and discussing the overall problem.

One last key to reading: to help distinguish between the various elements of the manuscript, the narrative descriptions of Mrs. G.'s investigation will be in italic characters and the dialogs taking place between Mrs. G. and I will be indented so that they have a wider margin than the rest of the manuscript. I have also put some boxes in the manuscript: these are a focus description of an instrument, organization or controversy. They are not necessary to understand the main thread of the manuscript but add some extra contextual details that can be interesting on a second reading.



## Chapter 1: Where do I begin? From a tour of Besançon's boiler rooms to a history of French district heating...

*“Chaque progrès donne un nouvel espoir suspendu à la solution d’une nouvelle difficulté.*

*Le dossier n’est jamais clos.” (Claude Lévi-Strauss)*

*“Every progress gives a new hope hanging on the solution of a new difficulty. The file is never closed.” (own translation)*





# **Chapitre 1 : Par où commencer ? D'une visite à la chaufferie de Besançon à une histoire des réseaux de chaleur en France...**

Ce chapitre offre une première lecture des réseaux de chaleur, au travers une narration de la visite de Mrs. G. à la chaufferie de Besançon. Il permet de mettre en évidence les caractéristiques et enjeux majeurs de réseaux de chaleur, notamment pour une transition vers des réseaux de chaleur durables.

Le principe technique de base du réseau de chaleur est assez simple : une production collective de chaleur fournie à différents bâtiments (par exemple, des hôpitaux, des bureaux, des logements sociaux) par des tuyaux. Historiquement, la chaleur pouvait être transportée via de la vapeur, puis de l'eau surchauffée, et plus récemment de l'eau chaude. La chaleur peut être produite par des chaudières à fioul, charbon, gaz ou encore biomasse. Il est également courant d'utiliser la chaleur produite par les incinérateurs de déchets. Cette chaleur est acheminée vers les bâtiments où un réseau secondaire répartit la chaleur entre les utilisateurs finaux.

La mise en place du système nécessite des investissements à fonds perdus et la durée de vie du système est de plusieurs décennies. Le système technique est régi par un contrat entre le propriétaire du réseau (dans notre cas une autorité publique) et l'exploitant de ce réseau (dans notre cas une société de chauffage urbain). Ce contrat couvre généralement la durée de vie du système technique, engageant les deux parties dans une relation à long terme.

Le chauffage urbain a évolué au fil du temps en raison d'avancées technologiques et d'une pression pour des solutions plus respectueuses de l'environnement : la température de l'eau baisse et une plus grande variété de sources peut être intégrée – y compris des sources plus renouvelables ou de récupération. De nouvelles technologies sont apparues pour faciliter cette intégration, comme le stockage de la chaleur. Plus qu'un changement technique, cette évolution implique une décentralisation de la production de chaleur (due à l'intégration de sources multiples, chacune produisant moins de chaleur) et une reconfiguration du réseau d'acteurs : de nouveaux producteurs entrent en scène et une

gouvernance de cette action collective doit être mise en place. Cette évolution est fortement ancrée dans l'histoire du développement (par exemple, les institutions existantes, la matérialité de la production et de la fourniture de chaleur, le cadre juridique) et s'inscrit dans un réseau d'instruments (par exemple, des subventions, des réglementations, des feuilles de route, des contrats) qui peuvent être conçus pour soutenir cette évolution ou peuvent devoir évoluer pour répondre à de nouveaux défis. La voie empruntée pour développer le réseau de chaleur durable varie considérablement d'un pays à l'autre et d'une partie prenante à l'autre.

To give you a preliminary grasp of sustainable district heating—both the concept of collective heating and the technical system—I will now narrate Mrs. G.'s first exploratory investigation that took place during her first PhD year in 2020.

## **A tour of Besançon's boilers**

*It was June 18, 2020. Mrs. G. had been working on this research project for two thirds of a year. She was longing for action... The COVID-19 health crisis had locked her up in front of her computer, with little interaction with stakeholders from the system under study... When getting out of the car, in Besançon, Mrs. G. was a bit anxious but excited. She would finally see a district heating system with her own eyes! It hadn't been easy: the director of Celsius—the company in charge of operating Besançon's boilers—did not really understand why Mrs. G. was coming and asking questions. The director mentioned the fact that her hierarchy had not warned her that Mrs. G. was coming, that she didn't know what Mrs. G. wanted, and that the operators were extremely busy. Fortunately, when Mrs. G. arrived, she was welcomed by a young employee, apparently sent by the director, who had planned a visit with the person in charge of the boilers. It was incredible: the history of district heating took shape before her eyes.*

### **The history of the district heating system**

*It all started with a bit of history. Mrs. G. had done some preliminary research, searching for information on Besançon and its district heating network. But listening to passionate people was always more interesting than fastidious reading... Besançon district heating (DH) system dated back to 1968, and used a lot of different technologies. It was developed alongs with the waste incinerator to use the surplus heat. However, it has always needed some boilers to be able to supply the connected consumers with heat and domestic hot water even during winter, when the heat from the waste incinerator is not enough to meet the demand. It was first based on fuel oil, as oil was cheap at that time... Three oil boilers were built in 1970. The oil boilers and oil tank are still in place but used as a last resort. Due to the oil crisis, a coal boiler was later added in the same boiler room. It was in parallel with a plan to revitalize the mines in the East of France. In 2000, a combined heat and power plant was set up, with a turbine changed in 2017. Besançon DH now relies on three*

biomass boilers: the first one was built in 2006, and in 2013 two more biomass boilers were installed. A new boiler room was set up in 2016 with these two biomass boilers and a gas boiler. The diagram of this plant clearly shows the different boiler rooms, boilers, and other production units (Figure 5). All these boilers may sound a bit technical, but it will become clearer as the visit goes on.

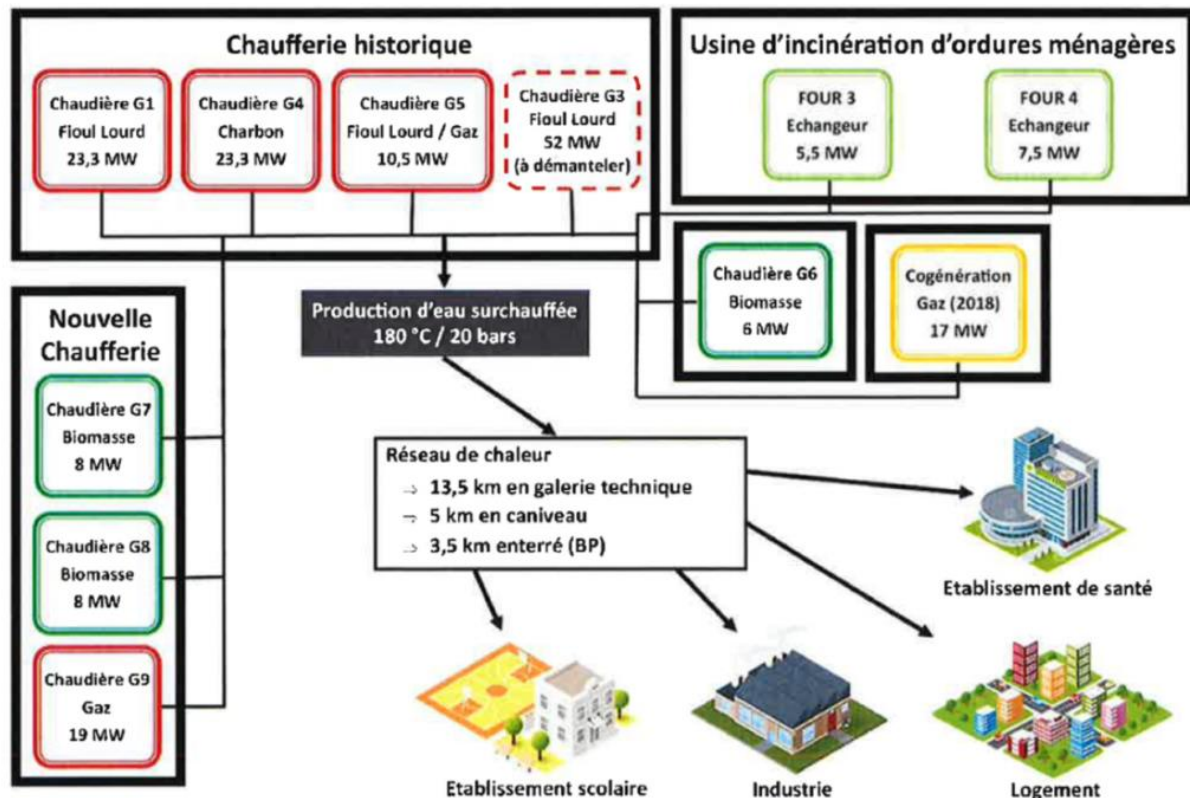


Figure 5 Besançon boiler rooms (Celsius, 2019)

As you may already have understood, the district heating in Besançon is very centralized: all the heat comes from this one place Mrs. G. was about to visit. There is no other production unit elsewhere in the city. In this plant, water inside pipes is heated up (to about 180°C, with a pressure of 20 bar), and from this plant big pipes convey this hot water towards the buildings of two neighborhoods: “Planoise” and the “Hauts du Chazal”. There are almost 22 kilometers of underground pipes carrying the hot water across to the neighborhoods. When it arrives at the buildings, the water is injected into the “secondary network”: pipes in the building that heat the different apartments and rooms. This secondary network is not in the legal perimeter of the district heating system, and the boundary is at the Energy Transfer Station (ETS). But we’ll come back to the questions of ownership and contracts later. For now, let’s move on with the tour of the plant.

### ***Following Mrs. G.'s visit***

*The tour started with the new boiler room. First, the gas boiler: According to Mrs. G.'s guide, the gas boiler is fairly simple. You can easily and rapidly turn it on and off, and so it is used for winter peaks and in case of failure. Moreover, thanks to sensors, there is an automatic control of the various operational parameters. The other two boilers in the same boiler room are the new biomass boilers. They are less flexible: it takes time to heat them, and they need more maintenance as they have more mechanical parts. The biomass boiler is quite impressive to see: there are lots of different components and it takes up a lot of space. The day of her visit, they were under maintenance: during the summer, the demand (domestic hot water, and the hospital) can be supplied thanks to the waste incinerator and the biomass boilers can be stopped and maintained. Mrs. G. wanted to know more about the operation of this boiler, but first here is a description of the boiler from Mrs. G.'s journal:*

The heart of the biomass boiler looks like a large cage, cloaked with thick pipes. At the core of this cage, lies the combustion chamber, where wood is transformed into ashes. All around is a big system of intertwined pipes and chimneys.

*Answering Mrs. G.'s questions, the guide explained the operation: the wood is put on a heated conveyor belt, to get humidity out of the wood and have a more controlled combustion. The wood then comes to the combustion chamber, the ashes are recovered under the hearth. The combustion heats up the pipes in the cage (both thanks to radiation and conduction). Pipes are thick to support the pressure, and are inspected every 18 months by external organizations. About half of the boiler room space is taken up by the smoke treatment. Here, the principle is simple: exhaust smoke needs to be as clean as possible. First, it goes through a centrifuge to remove the bigger particles, then through a magnetic field–electro-filters–to filter the dust. All these particles and dust are gathered in big white bags (Picture 2). Part of the heat from the smoke is used for the district heating, and the cleaned smoke is reinjected into the combustion chamber to help control the combustion.*



Picture 7 White bags to collect the smoke particles

*When leaving the new boiler room, Mrs. G.'s attention was caught by big tanks. The guide explained: "these are the fuel tanks. Fuel is really convenient, because it can be easily stored. However, there is an obvious fire risk... due to the tanks full of fuel..." From the fuel storage, he went on to the biomass storage section. Biomass requires complex logistics... But let's keep this part for later on, as Mrs. G. would work specifically on this question for some time. No spoiler here, all you have to know is that the plant has a specific place, near the old biomass boiler, dedicated to biomass storage.*

*Then, Mrs. G. and her guide entered the old boiler room. This boiler is like a museum of district heating production technologies. Like in a museum, you can find the main characteristics of all boilers on signs (Picture 3) and the guide explained to Mrs. G. that there were tours almost every month prior to the COVID crisis. This old boiler room is on two stories: on the underground floor, you can find heat exchange stations from the boilers to the supply pipes, and on the main floor are the boilers. Most of the boilers here are not used anymore, and are just turned on for the maintenance and pollution checks. One of*

*the boilers (boiler G5, which you can see on Picture 2) is a gas and fuel oil boiler, meaning that it can be heated by one or the other. It is used to produce steam, in order to complement and replace the waste incineration plant. It is not used much and has to be turned off in the evening because it needs permanent monitoring and is not equipped with remote control. The coal boiler was stopped about five years ago and had been running under a three-shift system. One of the fuel oil boilers was to be dismantled in 2021, and the other is also unused. The old boiler room is also where the pumps and spare pumps are kept.*

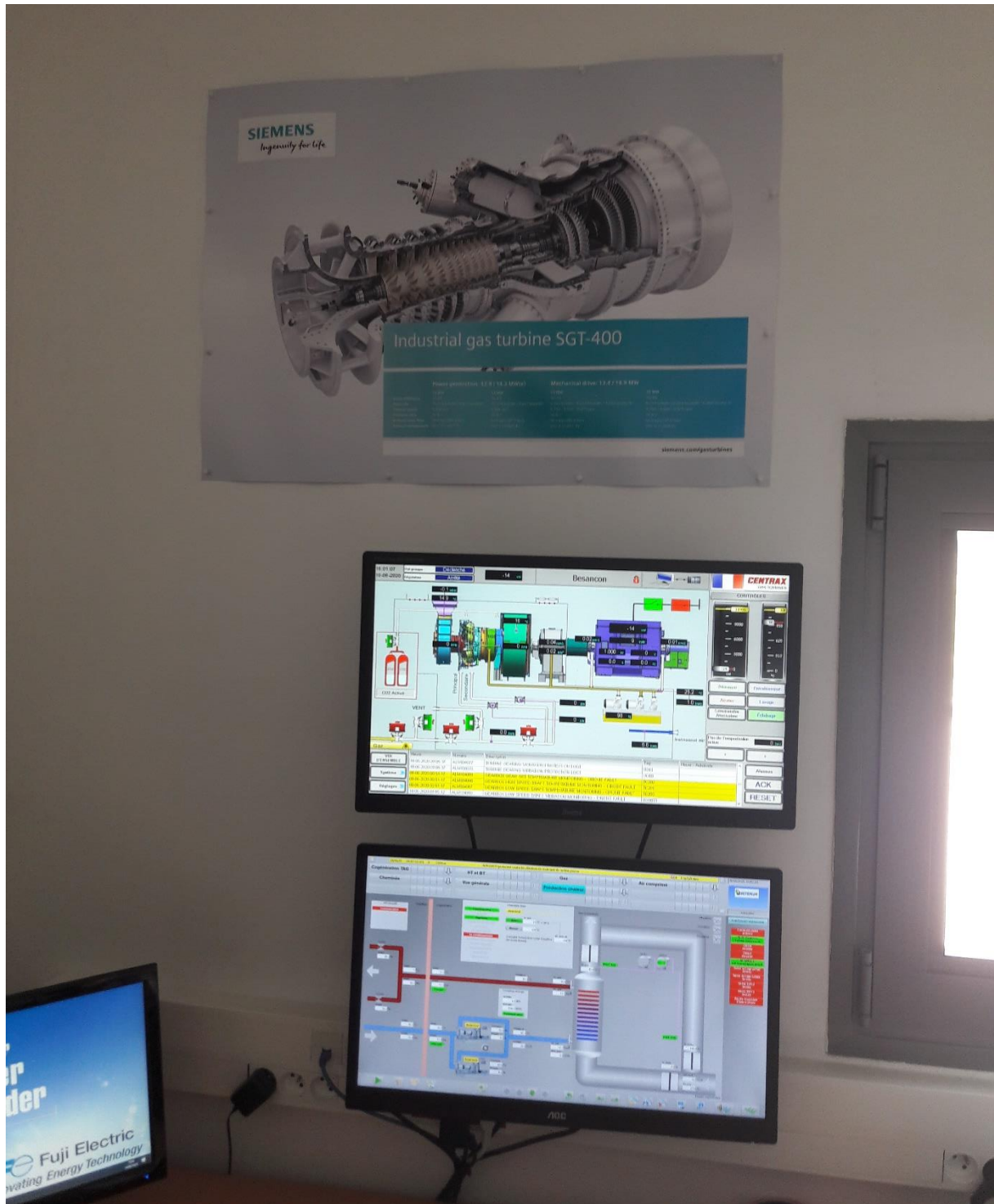


*Picture 8 The explanatory signs for boiler G5*

*Once the tour of the old boiler room was over, the guide went to show his little favorite: the combined heat and power unit, which has its specific control room (Picture 4). This combined heat and power is “like an airplane turbine working with gas, where you use the smoke to heat”. Unfortunately, it cannot be used that much: there is a contract with EDF (French electricity supplier) and it can only be turned on under two conditions: 1) if EDF needs some surplus electricity for its network, they have to quickly turn on the turbine for*

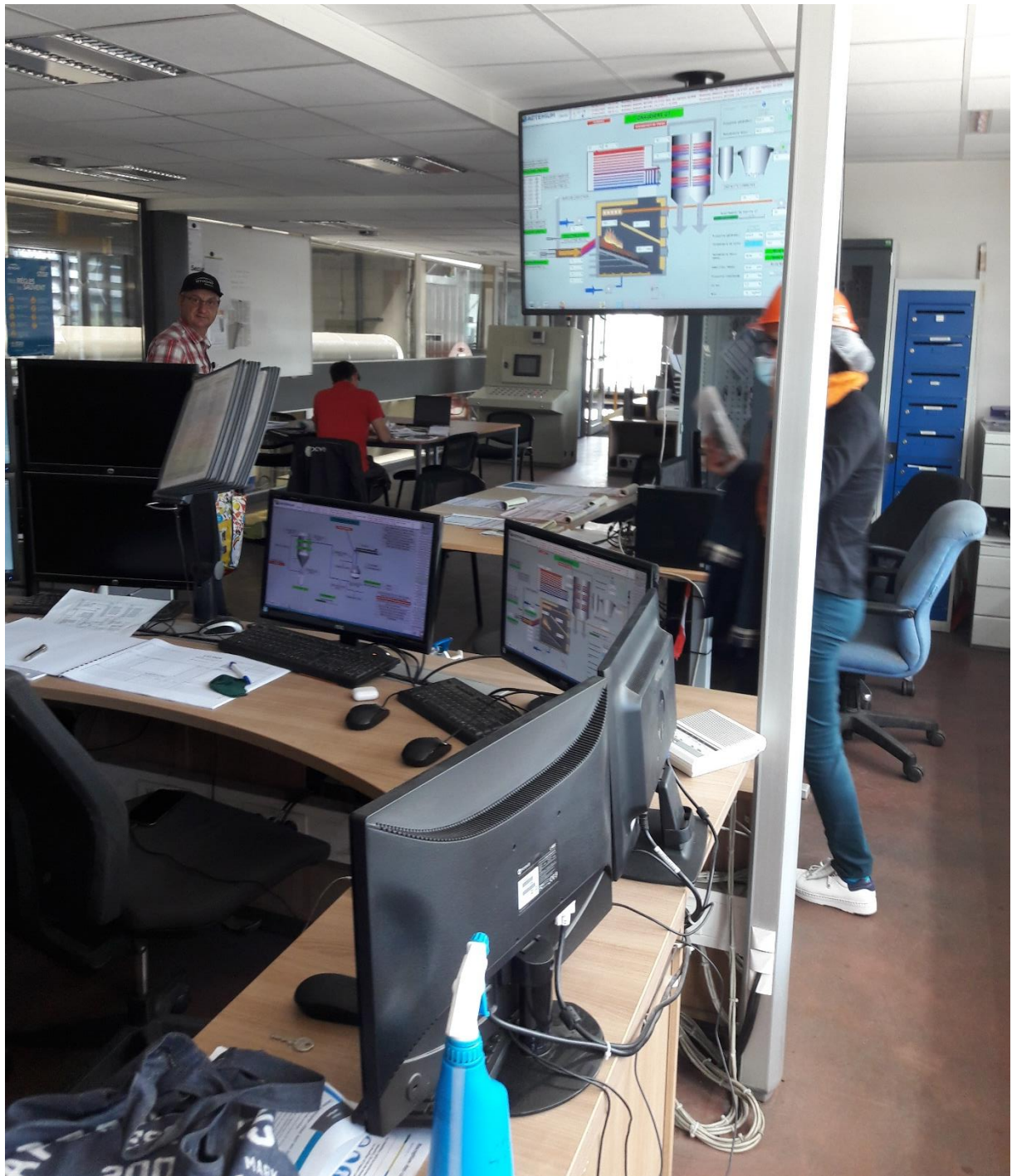


at least 48h, 2) they have the right to use it one month a year (and they chose January, as it is a peak month for heat). To ensure the economic equilibrium, they receive some fixed payments from EDF to ensure the maintenance and that the turbine is ready to be turned on whenever they need it. This type of partnership is far less usual in France than it is in other countries like Germany.



Picture 9 The Combined Heat and Power control room

*The visit ended in the control room (Picture 5). It is in this place, full of screens, that all the data collected from the sensors arrives, are recorded and analyzed. All the boilers can be monitored from this room: e.g., the flows, temperatures, pollutant emissions, pressure.*



*Picture 10 Control room*

*Mrs. G. was quite impressed by the control room. When exiting it, she tried to learn more about the various parameters that were monitored. Why these ones? Were there only technical parameters? She had in mind her mission, and thought it was time to dig into*

*the “sustainable stuff”. The guide was prone to answer: they of course controlled the technical operation of the boilers and of the network, as it was their first duty to ensure good continuity in the service. Apart from that, they had to monitor a lot of parameters and to report them to various organizations (e.g., the delegating authority to monitor the operations, the DREAL to check compliance with national emission standards, the ADEME to verify compliance with subsidies’ criteria, Apave to test the safety parameters). At the beginning, it was more about ensuring safety, but it became more and more complicated, with a lot of reporting to different organizations, inspections to plan, etc. The answer could sound a bit disappointing: apart from the technical monitoring, the others sounded more like a burden than a glorious transition... but it unveiled another aspect of district heating. These systems were not merely technical systems, with pipes, boilers, and various fuels. They were sociotechnical systems, embedded in a social context and staging various stakeholders... Going back to the sustainability aspect, the guide answered that in Besançon it was ensured by the prioritization of the production mix: first they used the waste heat from the waste incinerator, then the biomass boiler, if needed the gas boiler and as a last resort fuel oil. He made it sound like a mere “production mix issue”, but as they kept discussing, Mrs. G. understood that it was not that simple. First, biomass supply involved complex logistics; then the production mix was framed by a yearly contract; and finally concerns on the actual sustainability of the sustainable sources was rising. The more Mrs. G. was understanding about sustainable district heating, the more she was realizing that it was definitely not a mere technical issue.*

*This first tour of a production plant gave Mrs. G. the first real stepping stones to understanding district heating. Or at least, it helped her concretize some discussions she had had at Engie on district heating. Here is the recap she made after her visit.*

OK, so it is not as messy as I thought. Basically, a district heating system is a production unit (a boiler where you burn something to heat water up), a distribution network (some pipes to ensure the routing of the hot water) and it goes to buildings where the secondary network brings this hot water to consumers. To heat up the water, there are various technologies: fuel oil, coal, gas, biomass or waste heat. But I’m not quite sure that’s all... People I’ve talked to said “low-temperature district heating”, “district cooling”, “sector-coupling”, “prosumers”, “urban heat”, etc. And so far, I haven’t quite been able to link

these to what I've seen... It feels like in Besançon, "sustainable" is all about using waste heat from the incinerator and biomass, but this view is not shared by all. I also had some discussions on enablers and barriers, like policies, contracts, roadmaps, etc. And this first visit did not give me that many clues on where it all comes in. I have to do some more digging.

*Mrs. G. thought she could get some answers by talking to Celsius' director. Here, she learnt more about the contract: the district heating system is owned by the "Grand Besançon Metropole" (GBM), a gathering of municipalities including Besançon. First it was owned only by the municipality of Besançon, but a new law gave responsibility for it to the association of municipalities. This owner launches a bidding process to delegate the network operation to a private operator, in this case Celsius, an entity created by Engie to answer the bidding process. Both are linked by a public service delegation contract. Several types of contracts exist, mostly known under the denomination "Public-Private Partnerships" (PPPs). In Besançon, it is a leasing contract as the public authority bears all the investments. Celsius also has contracts with its customers: the owners of buildings connected to the district heating. In this last contract lies the pricing. Pricing is usually divided into two parts: 1) the fixed part, depending on the power subscription and covering the investment for the infrastructure, maintenance and other fixed costs; 2) the variable part based on actual consumption.*

*Mrs. G. found this arrangement fairly easy to understand. But the more she thought about it, the more she got the impression that sustainable district heating entailed a lot more complexity than what had been presented so far...*

## Sketching the network of stakeholders

To get a better understanding, she first tried to sketch the network of stakeholders around Besançon's district heating system. The first layer was fairly simple, as it was a mere visualization of the presentations made during this first visit. She just put the district heating operator, the local government owning the network and the consumers. She added the affiliation of the stakeholders with blue boxes, the contracting links between the stakeholders and the roles of each one when necessary (Figure 6).

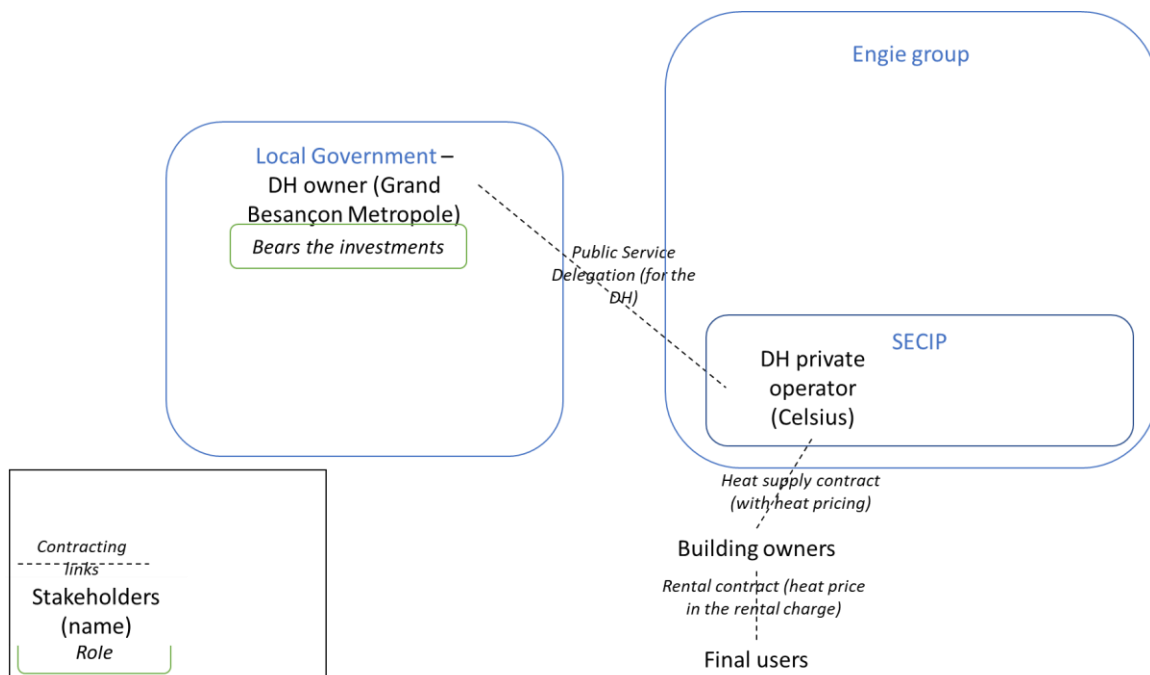


Figure 6 Network of Besançon stakeholders–V1

A first layer of complexity<sup>2</sup> came when she tried to link Celsius with Engie. Indeed, the interviews she had done within Engie gave her the feeling that there were multiple layers here, trying to connect the global strategy—done by the “Corporate” level—to the operations done by Celsius. Moreover, the private company could also work with consulting firms on specific aspects.

The same complexity applied to the local government level. When trying to get interviews, she was guided towards several people, from various services. The local government also worked with other public including the ADEME, the State center of expertise on the “ecological transition”, and could be advised by private consulting firms.

The links between the stakeholders were complex, and Mrs. G. stuck to the basic contracting ones, stating the organizations’ role to help visualize the stakeholder network’s configuration (Figure 7).

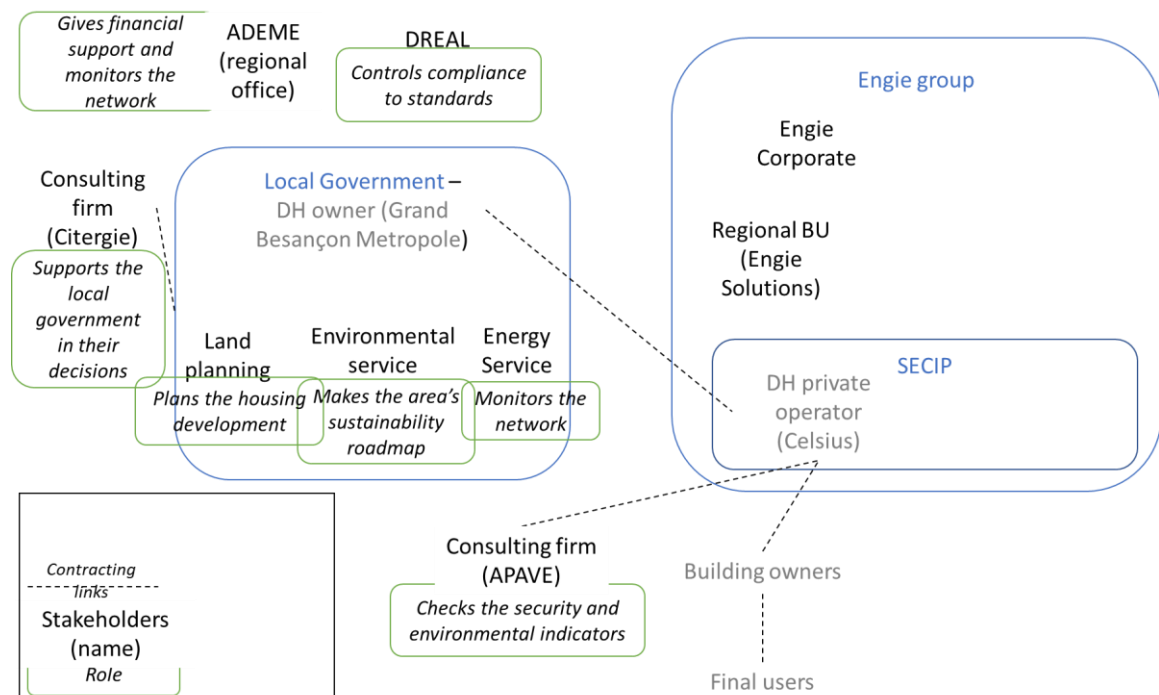


Figure 7 Network of Besançon stakeholders—V2

<sup>2</sup> Complexity is understood here as “the quality or state of being complex” with complex being “hard to separate, analyze or solve”. Definition from the Webster’s New Collegiate Dictionary of 1979 (Webster, 1979).

And then came all the complexity from the different production units, owned by various stakeholders, and supplied by others. For instance, the waste incinerator was also managed by Engie through another entity, but was not owned by the local government but by a local energy syndicate. Also, the Combined Heat and Power plant required a specific partnership with EDF. And obviously, as mentioned before, the biomass supply chain was complex. Mrs. G. chose to put some of the local stakeholders on the diagram<sup>3</sup> (Figure 8).

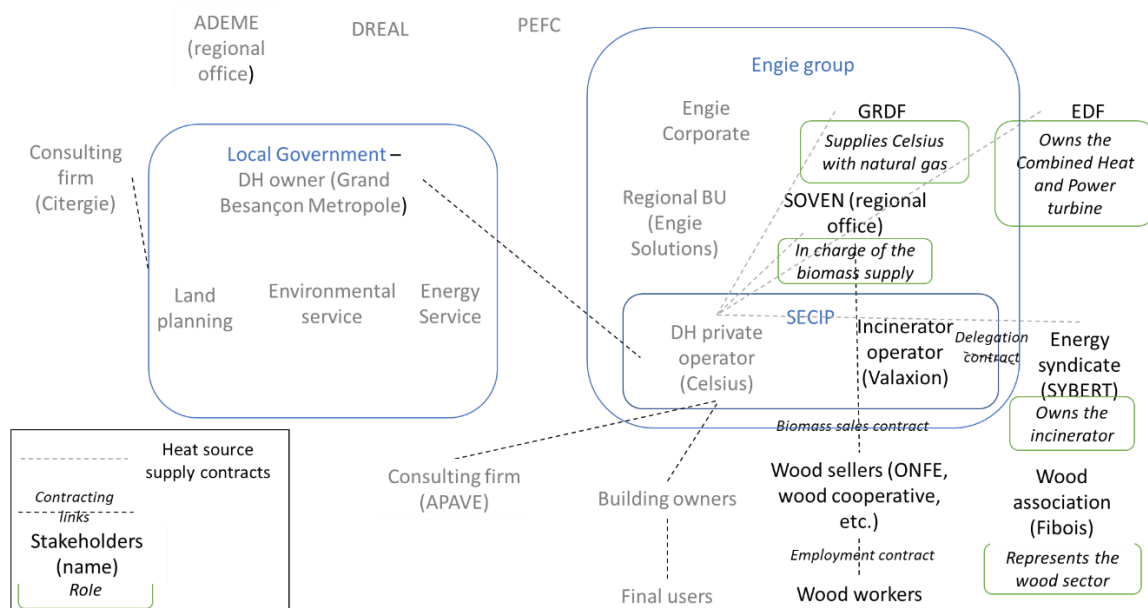


Figure 8 Network of Besançon stakeholders–V3

<sup>3</sup> You will learn more about each of them during another of her field adventures, dedicated to forest biomass and related in chapter 6.

As the graph was getting more and more complicated, she gave up on linking this case study to all the organizations she had met so far. Here you can find the complete diagram she had made, not simplified to show the step-by-step process (Figure 9).

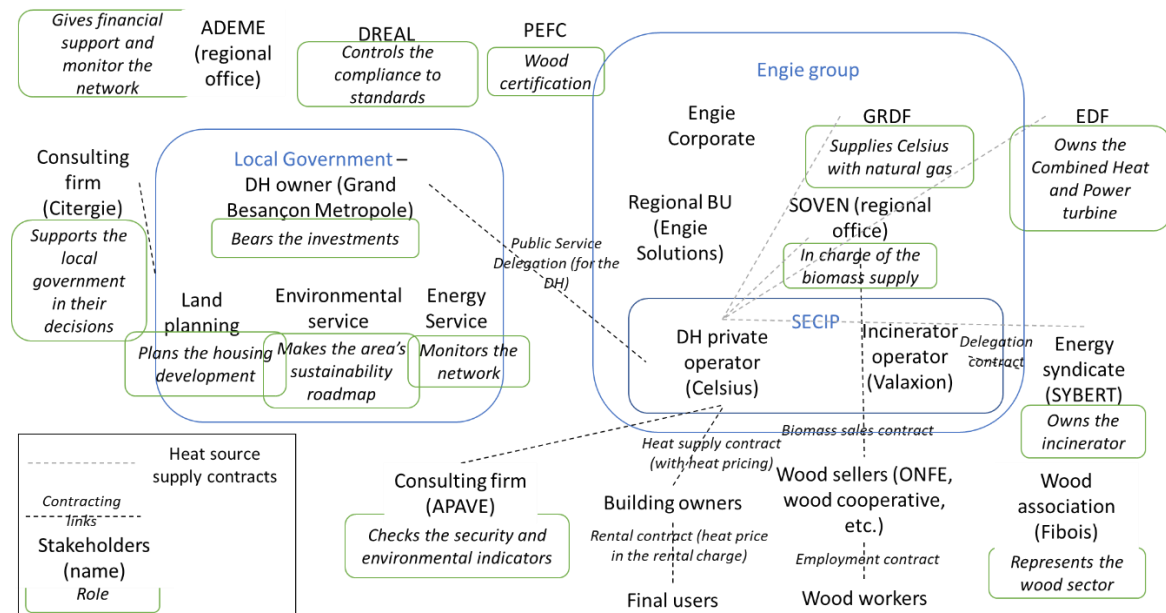


Figure 9 Network of Besançon stakeholders

While completing this diagram, she realized that both the link between the stakeholders—including those she could not put in the diagram, as she was sure that transnational and national stakeholders also had an indirect local impact, through lobbying, regulations, knowledge sharing, etc.—and the shape of the network was heavily reliant on some instruments. District heating was surrounded by multiple instruments: contracts, roadmaps, laws, etc. Designed by some stakeholders to be used by others, the instruments had different objectives: formalizing relationships, giving a quantitative basis for discussion, framing the role of stakeholders, etc. At that point, Mrs. G. decided that this multiplicity of interrelated instruments was worth digging into, and could be an interesting opening to unbundle the mystery of sustainable district heating. It was clear that instruments had already played a big part in the development of district heating, and it seemed they were now trying to frame the development of sustainable district heating.



*However, this network of instruments did not come out of the blue: they were related to the history of district heating development, to the existing institutions, to the materiality of the district heating network, etc.*

## French district heating

*Mrs. G deemed it necessary to dive into history to gain essential background context, before studying sustainable district heating. Thanks to preliminary interviews and various national reports (mostly summary sheets on the Cerema's website, the 2021 yearly report of the SNCU and a 2021 report from the General Accounting Office), it was possible for her to draw the outlines of French district heating history. Let me give you the highlights of this history before we move on with Mrs. G.'s investigation.*

### ***A short history of French district heating development***

The technology of district heating—in the sense of a collective hot water circuit to heat collective places—dates back to the Roman Empire. Traces of geothermal network dating back to the 14<sup>th</sup> century were discovered in Chaudes-Aigues in the Massif Central, central France. Now coming back to our area: before the 1950s there were only a few district heating systems in France to supply big cities, like the pioneer one of Paris which dates back to 1927. The first “real” development era was seen between 1960 and 1970, with urban planning and the creation of district heating near waste incinerators. These connections were mostly for social housing. The development of district heating was thus connected to the idea of using “waste” heat for the heating of collective housing. In the 1980s, after the oil crisis, a second wave of district heating development can be noted to become independent from the price variation of fossil fuels for heat. During that period, district heating systems based on deep geothermal energy were implemented in Ile-de-France. However, these networks soon had financial difficulties: the investments needed were substantial but the fossil fuel prices lowered again, making them less competitive. One of the first actions of the Heat Fund (a national subsidy fund created in 2009) was to revitalize these district heating systems. The last noticeable evolution in France began at the end of the 2000s and is still gaining momentum, with the use of more renewable and recovered heat to supply district heating, and validation that they can be used as a tool for regional decarbonization. This history may give the idea that the French development of district heating was strongly based on renewable energies: waste incineration, then geothermal energy and finally all types of renewable and recovery resources. However, these sources were never the only sources used: to complement such sources, there was

a need for a fossil fuel base. This base could come from coal or fuel oil in the early times of district heating, then it turned mainly to gas. Moreover, in many places no geothermal energy or waste heat was available, leading to the development of district heating systems using 100% fossil fuels. Also, district heating has always represented a small part of French heating. In 2020 there were 833 listed district heating networks in France (Fedene-SNCU, 2021). Most parts of regional capital cities have a district heating system, but which only supplies a small part of the city with heating. Indeed, in 2017 less than 5% of the residential energy demand was supplied by district heating, far below the almost 40% supplied by Danish district heating (Euroheat and Power, 2022). The remaining 95% is mainly shared between gas heating, electrical heating and fuel oil individual boilers (ADEME, 2018). Despite the 2020 national plan to strongly develop district heating networks based on renewable and recovered heat (Cerema, 2021), their share in district heating remains small.

### ***A multi-stakeholder governance?***

As Mrs. G. discovered during her visit to Besançon, district heating is more than a technical system. In this investigation, the objects of study are publicly\_ owned and planned district heating networks operated by a district heating company. This company can be of various forms: publicly-owned utilities, an incorporated company, etc. Speaking a bit about governance, in France, heat delivery is a public service, and the municipalities—or EPCI<sup>4</sup> if the municipality is part of one—are responsible for the planning, creation and operation of district heating and cooling networks. The planning is done through mandatory roadmaps, but they usually delegate the operating authority through Public Service Delegation Contracts (PSDs). Of all the heat provided by French district heating, 75% comes from concession contracts, where the private partner in charge of the operations bears the tremendous investments needed to build and operate a district heating system. Leasing contracts, like the contractual setup Mrs. G. saw in Besançon are a minority (only 5% of the networks, and 5% of the heat delivered) (Fedene-SNCU, 2021). Five groups (and

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<sup>4</sup> *Etablissement Public de Coopération Intercommunale*: These public institutions for intercommunal cooperation group together different municipalities. They have the authority on heating in their area since the 2014 MAPTAM Act (*Modernisation de l'Action Publique Territoriale et Affirmation des Métropoles - Modernization of Local Public Action Affiliation of Metropolitan Areas*).

their subsidiaries) currently dominate the French market: Engie, EDF, VEOLIA, IDEX and CORIANCE (Cour des Comptes, 2021). To make these partnerships, public market bidding is mandatory, with competition between private entities on several aspects (whether technical, financial, or whatever seems necessary for the public authority). This bidding process, at the heart of the delegation dynamic, will be of great interest for Mrs. G. The General Accounting Office (2021) gave a schematic view of the stakeholders involved in the governance of district heating in France, which was adapted by Mrs. G (Figure 10). The subscription contract encompasses pricing, which is similar in structure to the twofold price discovered by Mrs. G. in Besançon. The subscription contract is made with building owners (public or private) which then make their tenant pay if relevant. Several stakeholders (hospitals, tenant associations, co-ownership trustees, etc.) can become involved in this process.

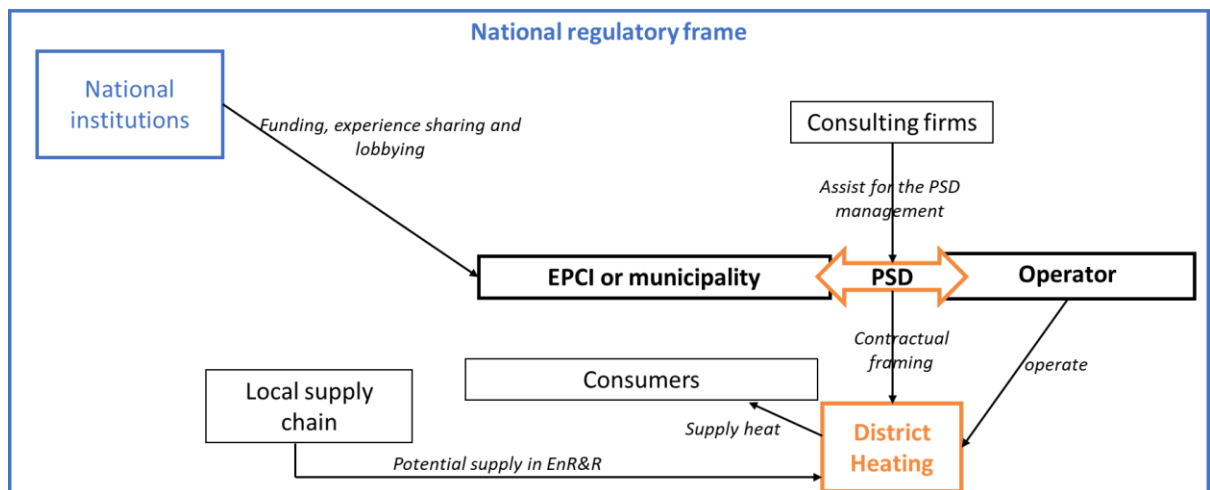


Figure 10 French district heating organization

Apart from these local stakeholders, some national organizations also have an impact on the development of district heating. Indeed, a number of national organizations are related to the heating market, with various objectives: enforcing the framework, funding district heating projects, sharing knowledge or lobbying. Of the main organizations we can cite the following:

- ADEME<sup>5</sup> (Ecological Transition Agency): the State’s center of expertise on the “ecological transition”. It is an EPIC<sup>6</sup>, which is a public organization for industry and business, and lies under the supervision of two Ministries: the Ministry for the Ecological and Fair Transition<sup>7</sup>; and the Ministry for Higher Education, Research and Innovation<sup>8</sup>. Among their missions, they support local authorities wishing to create district heating systems. They can offer technical and financial support (through the Heat Fund). The financial support is subject to various criteria (partly from national legislation) and much needed to create a new district heating system. Thus, these criteria impact project design. For instance, the ADEME demands at least 50 % of renewable or recovered heat and the public authority has to present a district heating master plan showing that the district heating network is integrated in the future territorial planification and has been studied thoroughly (ADEME, 2012). The ADEME also has a supporting database for e.g., project creation, “best practices”, summary sheets.
- DREAL (Regional Board for the Environment, Planning and Housing)<sup>9</sup>: decentralized services of the State under the supervision of two Ministries: the Ministry for the Ecological and Fair Transition<sup>10</sup>; and the Ministry for regional cohesion and relationship with regional authorities<sup>11</sup>. One of their missions is to make sure the regulatory framework is respected. They receive a set of data on each district heating project and send recommendations on its creation and management to make sure the system will meet national thresholds.
- Cerema (Studies and expertise center on risks, environment, mobility and planning)<sup>12</sup>: public organization under the supervision of the Ministry for the Ecological and Fair Transition; and the Ministry for regional cohesion and relationship with regional authorities. They have a comprehensive database, with “best practices” and other helpful documents for understanding the regulatory

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<sup>5</sup> *Agence de la transition écologique*

<sup>6</sup> *Etablissement Public à caractère Industriel et Commercial*

<sup>7</sup> *Ministère de la Transition écologique et solidaire*

<sup>8</sup> *Ministère de l’Enseignement supérieur, de la Recherche et de l’Innovation*

<sup>9</sup> *Direction régionale de l’Environnement, de l’Aménagement et du Logement*

<sup>10</sup> *Ministère de la Transition écologique et solidaire*

<sup>11</sup> *Ministère de la Cohésion des territoires et des relations avec les collectivités territoriales*

<sup>12</sup> *Centre d’études et d’expertise sur les risques, l’environnement, la mobilité et l’aménagement*

framework or the district heating systems. They act a lot on the experience sharing part.

- SNCU / Fedene: the Fedene (Federation of Energy and Environment Services)<sup>13</sup> encompasses seven syndicates, among which is the SNCU (National Syndicate of Urban Heating and Cooling)<sup>14</sup>. They act as representatives of the energy companies. They do some lobbying, manage working groups (on business models for instance), and are part of information actions with other organizations. They are also in charge of the yearly national survey on district heating and cooling.
- AMORCE: association created in 1987, which supports local stakeholders for the energy transition, waste and water management. They act as representatives of the public authority owning the network and their partners. They manage an experience sharing network and have various work streams on collective financing.
- FNCCR (National Federation of the concession and leasing public authorities)<sup>15</sup>: association of public authorities managing public networks (e.g., energy, water, waste and telecommunications). They act as representatives of the public authority owning the network. They manage different work streams: one on contractual aspects and one on pricing, for instance.

Many of these organizations also tackle areas other than heating (waste, electricity networks, etc.). Concerning these stakeholders, here is an extract from Mrs. G.'s notes.

*“District heating in France lacks strong and clear representatives. And—you won’t believe me—no research network seems to be structured around this public service! It looks like district heating doesn’t have a real existence. It is not considered like electricity or gas. It’s a kind of hybrid still struggling to find its place on the energy stage. It is a neglected, monstrous little brother. Even if some policies support its development, others seem to forget about it. It is too strongly linked to too many things: housing refurbishment, urban planning, energy planning... It can have a finger in every pie: electrical heat pumps,*

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<sup>13</sup> Fédération des services énergie environnement

<sup>14</sup> Syndicat National du Chauffage Urbain et de la Climatisation Urbaine

<sup>15</sup> Fédération nationale des collectivités concédantes et régies

*industrial heat, natural gas, sewage water, etc.; and needs the collaboration of too many stakeholders. Its boundaries are constantly moving, like an overwhelming entity.”*

So, here was the outline of the French history of district heating: the development, the heat production resources, the edges of the legal framework, the various local stakeholders and national institutions surrounding this sociotechnical system and the actual state of the network. Before moving on, I would like to draw your attention to a great success of French district heating: I have mentioned the setting up of the Heat Fund in 2009. This fund aims to support the development of sustainable district heating. And from 2009 to 2020, the share of renewable or recovered heat rose from slightly more than 30% to 60%!

## District heating in Europe

So far, this part has been strongly focused on France. Obviously, I will not attempt to do the same description for every country on the planet. However, some information is worth mentioning if you want to understand the path taken by Mrs. G. Heating is a major stake as it is the largest energy sector, representing 50% of final consumption (International Energy Agency, 2020). District heating, at various stages of development, can be found in all European countries and covers about 12-13% of the heat demand with about 6,000 networks (Werner, 2017). It is much more developed in Northern countries, surely due to their hard winters. District heating suffers from competition with other heating systems, like natural gas or, more recently, electricity. For instance, in Sweden, district heating has suffered from competition with cheap electricity. More than these technical disparities, European countries also have diverse regulatory frameworks that are more or less adapted to the development of district heating. The existence of supporting and dedicated organizations also varies from one country to the other: in Denmark for instance, district heating is an established heating solution, well-recognized by the Danish Energy Agency and represented by dedicated organizations. The European Commission has noted that district heating is an effective way of cutting down on energy sector carbon emissions—where 75 % of the heat is still produced by fossil fuels. Many countries, like Denmark, France and Latvia, have already taken the road of district heating sustainability, mostly by increasing the share of heat production by biomass for their district heating. To support this development, one major organization is Euroheat and Power (EHP), an association acting as a representative of the various district heating stakeholders. They also publish country by country reports every two years, to give information on the development path taken by European countries. Many projects supported by the European Union (e.g., funded through the H2020 program) also participate in the development of district heating and sustainable district heating in Europe. Taking advantage of this pool of projects, Mrs. G. will investigate various projects in Europe and meet with some supporting organizations and local stakeholders. But that's a story for another chapter...



## In a nutshell

Now that this first glance at district heating is almost done, let me do a quick recap of Mrs. G.'s first findings:

- 1) The core technical principle of district heating is a fairly simple one: a collective production of heat supplied to various buildings (e.g., hospitals, offices, social housing) through pipes. Heat could historically be conveyed by steam, then by overheated water, and more recently by hot water. Heat could be produced inside boilers through the burning of oil fuel, coal, gas or biomass; or by using waste heat from waste incinerators. It is conveyed to the buildings where a secondary network divides the heat between the final users.
- 2) The setting up of the system involves sunk costs (unrecoverable investments) and the system's lifespan lasts for several decades. The technical system is governed by a contract between the owner of the network (in our case a public authority) and the operator of this network (in our case a district heating company). This contract usually covers the lifespan of the technical system engaging both parties in a long-term relationship.
- 3) District heating has evolved through time due to technological breakthroughs and a pressure for more environmental-friendly solutions: the water temperature is going down and a greater variety of sources may be integrated, including more renewable or recovered sources. More technologies have emerged to ease this integration, like heat storage.
- 4) More than a technical shift, this evolution implies a decentralization of heat production (due to the integration of multiple sources, each producing less heat) and a reconfiguration of the stakeholders' network: new producers enter the stage and a governance of this collective action has to be built up.
- 5) This evolution is strongly anchored in a development history (e.g., existing institutions, materiality of the heat production and supply, legal framework) and embedded into a network of instruments (e.g., subsidies, regulations, roadmaps, contracts) which can be designed to support this evolution or may have to evolve to answer new challenges.

- 6) The path taken to develop sustainable district heating greatly varies from country to country and from stakeholders to stakeholders. A diversity of situations and heating solutions can be found within a country and throughout the world.

Mrs. G. had a better grasp of the materiality of district heating thanks to her trio to Besançon, and a preliminary understanding of district heating characteristics. She was also beginning to be able to outline the major challenges and stakes of sustainable district heating, a complex sociotechnical system gathering a large variety of stakeholders. One major stake was the collective action governance of this system, in the context of transformation for more sustainability.



## Chapter 2: Building the theoretical framework

*“Le doute est une force. Une vraie et belle force. Veille simplement qu’elle te pousse  
toujours en l’avant.” (Pierre Bottero)*

*“Doubt is a strength. A true and beautiful force. Just make sure it always pushes you  
forward.” (own translation)*



## Chapitre 2 : Construire le cadre théorique

Dans ce chapitre, j'ai tout d'abord complété les caractéristiques du réseau de chaleur mises en lumière par Mrs. G. au chapitre 1 en définissant le périmètre de l'objet d'étude : le réseau de chaleur durable. Par réseau de chaleur j'entends, à la fois le concept de chauffage collectif et le système technique ancré localement. Le périmètre de la thèse se limite aux réseaux de chaleur planifiés et détenus par une entité publique, exploités et entretenus par un opérateur de chauffage urbain. Je m'intéresse au réseau de chaleur comme infrastructure publique fournissant un service public. J'étudie le réseau de chaleur durable comme un système en cours de définition par les acteurs, ce qui remet en cause le système technique, son équilibre économique et sa gouvernance en intégrant de nouveaux moyens de production, de nouveaux acteurs et de nouvelles valeurs dans un système établi.

Ensuite, j'ai défini le cadre théorique de cette thèse. En commençant par creuser le concept de modèles d'affaires durables – notion au cœur des préoccupations d'Engie. Je l'ai rapidement quittée pour me pencher sur les *valuation studies*, qui analysent les processus sociaux de construction de la valeur. Pour prendre en compte les caractéristiques collaboratives du réseau de chaleur durable, je me suis également intéressée à la littérature sur la gouvernance collaborative et la gouvernance des collaborations avant de me fixer sur le concept de cocréation dans le secteur public. Ce concept allie à la fois les notions de gouvernance collective et d'innovation dans le secteur public.

En bref, j'ai axé mon enquête sur deux processus : la construction de valuations en tant que pratique sociale et la cocréation dans le secteur public en tant que processus d'innovation multi-acteurs. La problématique qui guidera mon enquête est la suivante : *Comment les acteurs cocréent-ils des valuations durables pour les projets d'infrastructures publiques ?* Répondre à cette question permet de contribuer aux communautés académiques des études de valuation et de la cocréation du secteur public, mais aussi d'élargir les connaissances sur les infrastructures durables en tant qu'objet d'étude académique. L'enquête sur ces deux processus donnera également des indications aux praticiens des réseaux de chaleur sur les valuations émergentes du réseau de chaleur

durable, avec des recommandations empiriques et opérationnelles sur les actions de collaboration pour développer ces systèmes.

The first chapter introduces the reader to the world of district heating, through a story of Mrs. G.'s investigation. This second chapter is divided into two parts: first, the literature on district heating to complement the description made in chapter 1; then an account of the research journey leading to the theoretical framework.

The description of Mrs. G.'s first field investigation highlighted several characteristics of district heating, hopefully allowing the reader to better understand the empirical stakes around sustainable district heating. To complement her investigation, I have made a literature review on district heating. This focused literature review is to better understand how the object of study district heating has been tackled by academics.

I will then narrate how the problematic and theoretical frameworks for my investigation were built. They emerged from the alignment of several interests: those of Engie, a key partner in the investigation; the empirical interests of Mrs. G.; and a more theoretical approach anchored in the academic world. Throughout the investigation, I have tried to find a guiding thread that would lead to interesting results for all three parties. This guiding thread did not come upfront but was built in relationship with all the members of the PhD and kept being refocused based on the investigation's development. To show how this thread was built, I will make focused literature reviews of academic fields that were studied. I will also relate imaginary dialogs taking place between Mrs. G. and I, where we discuss this diverse literature and decide on our positioning.



## A fascinating object of study, district heating systems

Mrs. G. had already discovered that district heating was a collective heat distribution system which brings heating from a production unit to the end user's buildings. Most existing district heating systems are based on technology where fossil fuel (gas, oil, coal) is burnt in centralized boilers to heat up heating fluid (International Energy Agency, 2021). District heating systems are a predominant leverage for heating decarbonization (International Energy Agency, 2021) as they can integrate multiple renewable sources into their heating mix (Lund et al., 2014; Morvaj, 2016; Schmidt, 2018). What I wanted to see now was the most recent stream of literature on sustainable district heating.

### *A technical system to decarbonize*

The literature does not refer to “sustainable district heating” or “sustainable energy systems”. The main angle taken is decarbonization, through the introduction of renewable heat sources. This decarbonization can be through one of district heating itself, but mostly district heating is seen as a component that may be used to decarbonize the energy system. Morvaj et al. (2016) study “*less carbon-intensive urban energy systems*” (Morvaj et al., 2016, p. 619) while Lund et al. (2014) see “*future renewable non-fossil heat supply as part of the implementation of overall sustainable energy systems.*” (Lund et al., 2014, p. 1). The focus is mostly technical: to decarbonize district heating, conventional systems have to be optimized (Morvaj et al., 2016) and transformed into so-called fourth-generation district heating systems (Lund et al., 2014). This shift requires new techniques for network optimization, for instance through the integration of thermal storage (Lesko et al., 2018). The term “generation” is widely used in the literature to describe the evolution of district heating systems and was introduced by Lund et al. (2014). The different generations correspond to a decrease in the temperature supply and an integration of more resources to the system (*Figure 11*). However, when it comes to an innovative transition path for decarbonizing of district heating, the terminology is subject to controversy between 4<sup>th</sup> and 5<sup>th</sup> generation, some arguing that what some authors term “5<sup>th</sup>-generation” is actually just a complementary technology to 4<sup>th</sup>-generation district heating but not another generation on its own (Lund et al., 2021).

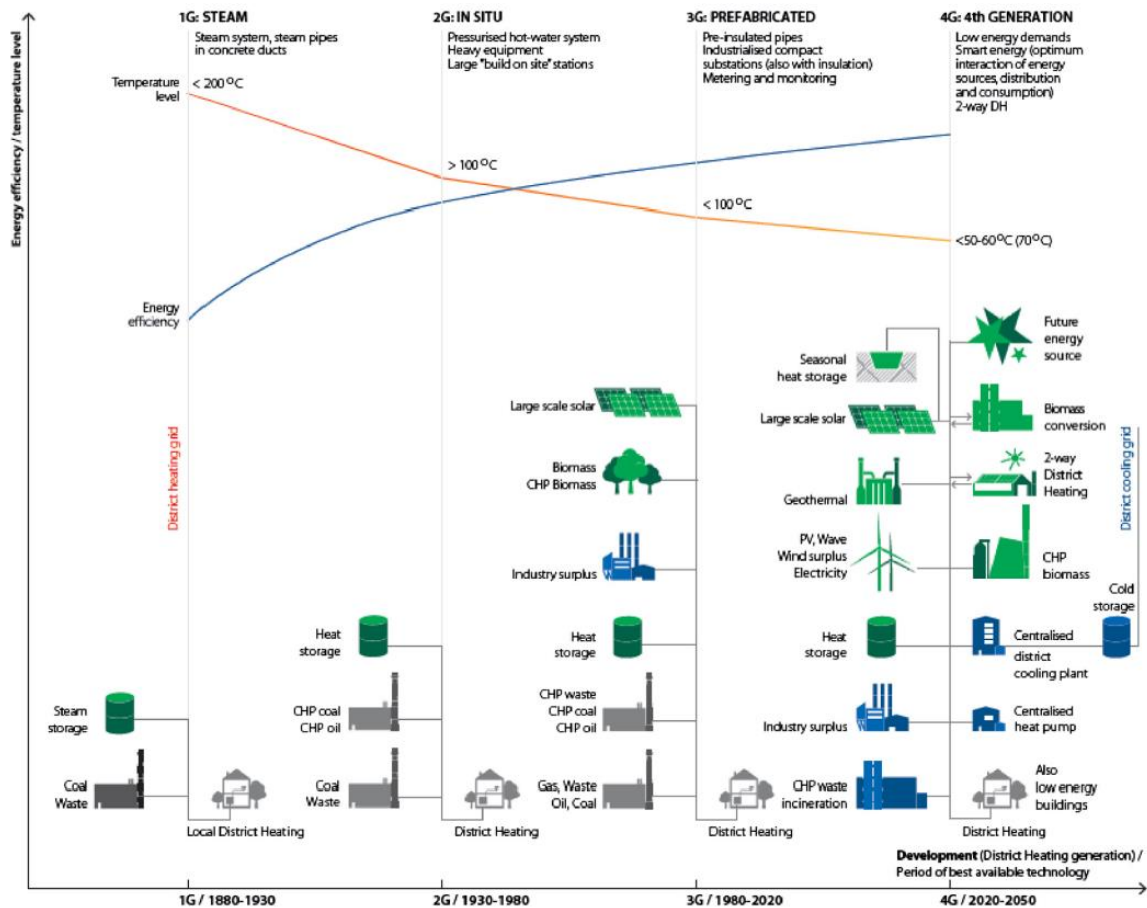


Figure 11 Illustration of the concept of 4<sup>th</sup>-generation district heating compared with the previous three generations (Lund et al., 2014)

The technical view on district heating is enhanced by the perimeter taken for the studies: the authors consider “district heating systems”, meaning the technical and physical system of heat supply, and not “district heating”, the concept and marketing of local and collective heat supply.

Complementary to this modeling view on sustainable district heating, a stream of literature tackles the evaluation of sustainable district heating with regards to social, environmental and economic criteria (Ghafghazi et al., 2010; Dorotic et al., 2021). This evaluation can be based on Life Cycle Assessment (Bartolozzi et al., 2017). Fahlén and Ahlgren (2010) analyze the integration of the environmental cost in Swedish policies. The integration of new renewable resources can also threaten the economic equilibrium of the network. This statement led to a literature stream on price optimization for a better integration of sustainable district heating into the heating market (Aki et al., 2000; Becchis et al., 2008; Odgaard and Djorup, 2020; Djorup et al., 2020). Planning tools and scenarios

to integrate sustainable district heating into the heating market were designed and compared (Hast et al., 2018)

All these papers have a technical (modelling and assessment) or economic lens, looking at challenges for the implementation of sustainable district heating. However, they do not make it possible to understand district heating as a sociotechnical system, in which the place of actors and organizations is a key lever of analysis.

*“I find in this literature a lot that I have found when talking with Engie or practitioners”, analyzed Mrs. G. “They see district heating as a technical system. I mean... They do see what they call “market challenges”, but the solution they want to apply is mostly technical. And all that is not technical would be economic. For example: You need to decarbonize thanks to district heating? Then we will optimize the network temperature and connect the network to some renewable heat production units. Or: We need to integrate the citizens and users in the system’s management! Then, we just have to put more sensors, create an app to show them their consumption live and make some incentive tariffication for them to change their way of consuming. Most of the problems are seemingly solved through technical improvements, modeling, creating technical tools or with the magic bullet of changing the business model. Are you sure there is nothing more to it?”*

- *“From what you have described, there is... If it was that easy, then why is almost no one doing it?”*
- *“Because we do not have the right business model for now. Because we need huge investments to change such systems and no one is ready to take the risk unless they have some assurances.”*
- *“So, it is not only technical. It is also about collectively finding solutions to be able to make these investments. To find the mechanisms for sharing the risks providing assurances. To commit people in the long-term to their district heating. It is also social and institutional.”*

### ***A sociotechnical transition***

I tried to move away from the literature that had a mere technical economic vision of sustainability, and look at papers introducing some social components into their analysis.

One is based on a historical perspective of district heating developmens, trying to understand the key point for the success of sustainable transitions for district heating (Lake et al., 2017). This approach can be divided into several streams depending on the

theoretical background taken. For instance, Jensen and Karnøe (2018) looked at the historicity of knowledge assemblages supporting the development of district heating in Denmark while Di Lucia and Ericsson (2014) built on the multi-level perspective to analyze district heating evolutions in Sweden.

Transition studies and sociotechnical transitions were the basis for a whole stream of literature. This literature developed on the concept of multi-level perspective (Geels, 2002) used to describe sociotechnical transitions, including some sustainable transitions.

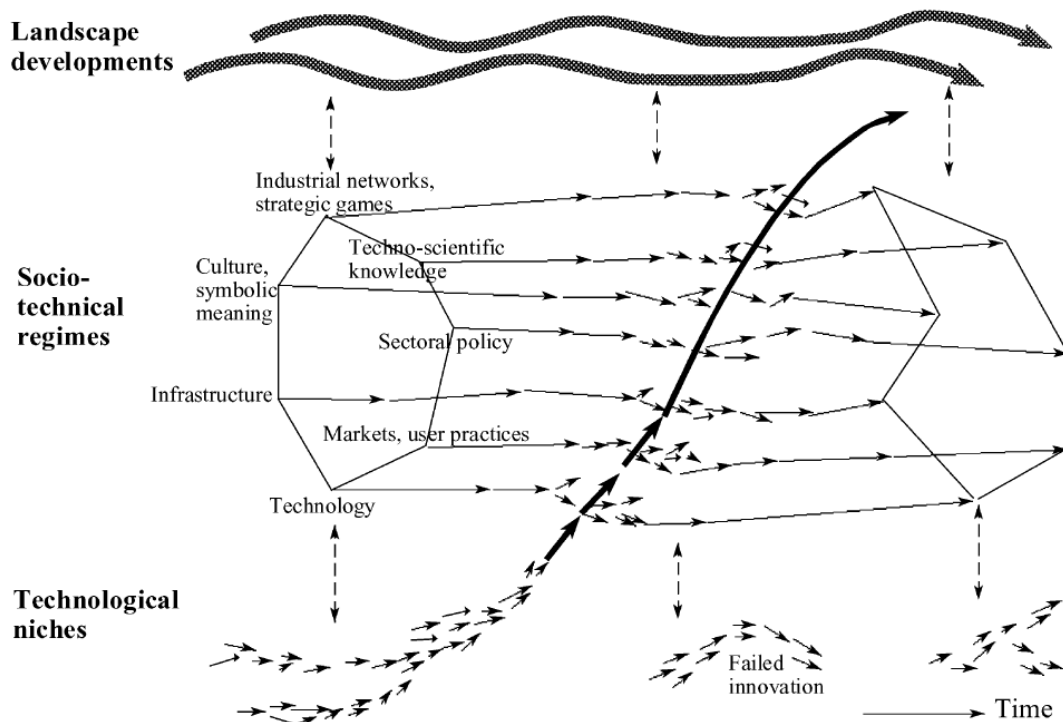


Figure 12 Multi-level perspective (Geels, 2002)

In fact, one subtheme of transition studies is “sustainable transitions”, defined as “long-term, multidimensional and fundamental transformation processes through which established sociotechnical systems shift to more sustainable modes of production and consumption.” (Markard et al., 2012, p. 956). This part of the literature first tried to analyze how sustainable and innovative technologies could be managed thanks to strategic niche management in order to transition to a new regime (Kemp et al., 1998). This analysis can be applied to different sociotechnical systems, such as energy systems. According to Krupnik et al. (2022), “the energy sector can be conceptualized as a coupled, sociotechnical system consisting of technologies, actors and institutional structures

*undergoing a fundamental shift of becoming decarbonized from a carbon-intensive to a carbon-neutral state*". Sustainable district heating is thus considered as a technological niche needing support to become a dominant design and integrate the sociotechnical regime (*Figure 12*). Different authors studied strategic niche management: Bush and Bale (2019), for example, studied the design of energy planning decision-making tools and Bush et al. (2017) the role of intermediaries. Another approach of sustainable transition within these transition studies is "transition management", a multilevel mode of governance combining both mutual adaptation and long-term objectives (Kemp et al., 2007). They identify a transition management cycle in four steps: (1) problem structuring, envisioning, and establishment of the transition arena; (2) developing coalitions, images, and transition agendas; (3) mobilizing actors, and executing projects and experiments; (4) evaluating, monitoring, and learning (Loorbach, 2010). Transition studies tackle some sociotechnical and organizational challenges that resonated with Mrs. G.'s first understanding of district heating. However, while they give some interesting understanding of the global dynamic of transitions, they do not provide keys for understanding the project level and its interrelation with a more global market. The process of sustainability is not studied in a micro and pragmatic way through the situated discourses and practices of the stakeholders. Within the transition studies framework, the solutions already exist, and are not constructed by the different actors. While all literature on sustainability shifts agrees that they involve the integration of a variety of stakeholders, the transition studies literature—due to its macro level of analysis—does not analyze the role and organization of actors supporting the change.

### ***District heating as a sustainable infrastructure***

To account for the local anchorage of district heating while still keeping in mind the influence of the global environment, I looked into similar objects undergoing a sustainability shift.

Some authors have shown interest in the social organization and structure linked specifically to the renewable heat transition. The integration of new stakeholders into the heat delivery system raises new concerns on the ownership, sharing of risks,

responsibilities and benefits (Lygnerud et al., 2019). Hvelplund and Djorup (2019) looked at consumer-ownership as a way to support low-carbon transition for a natural monopoly like district heating. Moreover, the role of public authorities as owners, planners, and sometimes investors, is challenged (Hawkey et al., 2013; Hvelplund and Djorup, 2019). They have to build capacities to 1) plan and invest in systems answering the sustainability concern, 2) keep up with the technical challenges produced by the new systems, 3) ensure the continuity and quality of heat delivery. Some authors have investigated the social and political processes leading to the setting up of sustainable district heating (Webb, 2015) and pointed out the need to design appropriate business models for these new systems (Bolton and Hannon, 2016; Lygnerud, 2018).

This literature highlights several challenges regarding the organization of collective action for district heating that still requires some complementary research. These challenges resonate with those of urban infrastructure governance (Graham and Marvin, 2001; Corvellec et al., 2013). District heating is a form of public infrastructure, a part of the energy infrastructure.

### Some properties of public infrastructures...

Public infrastructures are hard to define, as they encompass a variety of realities e.g., communication networks, health services, energy production and transmission, railroad transportation, and governmental buildings. They are both the materiality of the technical networks (pipes, cables, concrete, etc.) and a part of a global human organization (users, engineers, policy makers, institutions, citizens, etc.). Star (1999) proposes the following properties to define infrastructures, which I will use for the rest of the manuscript:

- Embeddedness into e.g., other structures, social organizations, arrangements, technologies making it complex to define the perimeter of the infrastructure under study. This embeddedness often leads to intricate interrelationships between the infrastructure and other systems.
- Transparency in its use, as the actors of the system do not need to reinvent the system all the time for it to work.

- Reach or scope, as the infrastructure has a spatial and/or temporal scale. For instance, district heating systems have a spatial outreach through the pipes, and a long-term scale due to the system lifespan.
- Learned as part of membership. The actors of the infrastructure share a common understanding of the objects within their community. When new stakeholders try to integrate this community, they need to learn about these objects. For instance, some knowledge on district heating pipes is shared within the community of engineers, but is unfamiliar to district heating users.
- Links with conventions of practice. The different communities have their own conventions and routines that both shape and are shaped by the infrastructure. For instance, the day-night work cycles of users result in a specific energy demand map that impacts the management of the energy system.
- Embodiment of standards. Infrastructures embody standards from the different communities and systems. For instance, the use of economic indicators to assess the performance of the system is standardized in many public services and thus used for district heating systems as well.
- Built on an installed base. The infrastructures are developed through an existing environment: pipes will be developed in priority where underground tunnels already exist and where building density is high; district heating will not be developed in places where several energy offers already compete, etc.
- Become visible upon breakdown. One major performance of infrastructures is their continuity of service, making them invisible to the user. When this continuity comes to a halt, the system becomes visible. Similarly, when facing a crisis or an unexpected event, the service delivery of the infrastructure may become unstable and the infrastructure gains visibility.
- Is fixed in modular increments, not all at once or globally. *“Because infrastructure is big, layered, and complex, and because it means different things locally, it is never changed from above. Changes take time and negotiation, and adjustment with other aspects of the system are involved. Nobody is really in charge of infrastructure.”* (Star, 1999, p. 382).

Public infrastructures are owned by a public body or made available for citizens' use. Specialized companies have usually been involved in the management of public infrastructures, due both to the high financial power needed to bear the investments necessary for their setting up, operation, and maintenance; and the technical knowledge needed for their operation and maintenance. Depending on the country, these companies can be fully public, fully private, or even a mix. The involvement of the private sector in the operation and management of public infrastructures, and lately in the shift for sustainable infrastructures has been discussed by scholars, both as a potential solution and a barrier to better management of public infrastructures.

Graham and Marvin (2001) show how the privatization of the public utility networks in Britain (following a period of nationalization after the second world war) has led to the development of splintering networks. These networks are characterized by competition between various private actors to access the most profitable markets, creating an uneven access to services across the country. This questions the planning and governing role of public authorities when it comes to public infrastructures; as well as the involvement of the private sector in the delivery of public services.

One widespread vector for such involvement is the Public-Private Partnership (PPP). If PPPs are loosely defined as *"cooperative institutional arrangements between public and private sector actors"* (Hodge and Greve, 2007, p. 545), there are several understandings of what PPPs are: e.g., a new governance tool, a twist of language to describe old contracting practices, or a new way to handle infrastructure projects (Hodge and Greve, 2007). In the case of public infrastructures, I will go with the definition of van den Hurk (2018), *"a form of project finance wherein the private sector handles the upfront costs for the provision of public infrastructures and facilities, and also takes care of their design, construction and maintenance."* (van den Hurk, 2018, p. 275).

Despite the governance challenges entailed in PPPs, some economic works argue for the benefits of large-scale infrastructures being managed by the private sectors, and the relevance of PPP contracts to govern such partnerships. For instance, Conrad and Seitz (1994) have studied the economics of public infrastructure on the private economic activity, arguing that the provision of public infrastructure services allows significant cost savings to private economic activities. Similarly, Cui et al. (2018), point out that the PPP



approach increases the economic value of infrastructure outputs and facilitates infrastructure development. Van den Hurk and Hueskes (2017) argue that PPPs can be an opportunity to create social value if other considerations than financial value are integrated into the project.

### ... adapted for a sustainability shift?

These public infrastructures have not been left behind the global urge for more sustainability. As essential parts of society, delivering primary services, they are a lever to meet sustainable development goals (Thacker et al., 2019). Research on sustainable infrastructure has been growing since the beginning of the twenty-first century in multiple research communities, including engineering, environmental sciences, and construction, and are structured around two main research fronts, namely “assessment tools and international standards for sustainable buildings” and “green infrastructures in cities”, the latter integrating more and more triple bottom line sustainability values (Thomé et al., 2016).

One stream of literature has focused on the role of the private sector in delivering sustainable infrastructures. The need to integrate sustainability concerns into these PPPs (Lenferink et al., 2013; Hueskes et al., 2017) and reconcile private sector participation and urban infrastructure sustainability (Koppenjan and Enserink, 2009) has been studied for more sustainable infrastructures. Another linked dynamic that has been studied is the integration of sustainability concerns into established public practices such as procurement practices (Hueskes et al., 2017; Ntsondé and Aggeri, 2021) or decision-making processes (Yang et al., 2016) through the study of pioneer projects or the development of planning tools.

However, this shift towards more sustainability does not come without barriers, some of which are slinked to the very properties of public infrastructures. Corvellec et al. (2013) analyze through a case study of waste incineration in Sweden, how lock-ins can be a barrier to the emergence of sustainable urban infrastructures. They point out four lock-in rationales: institutional, technical, cultural and material. These rationales are linked to characteristics of public infrastructures, like their embeddedness and their physical materiality.

Finally, it is worth highlighting that the notion of sustainable infrastructure— just like the notion of sustainable district heating—does not come with a clear view of the future infrastructures and their sustainable dimension. Some technical parts are presented as future components of sustainable infrastructures, some instruments as potential support of their transition, but no fully-fledged vision is offered. Sustainability can be linked to the global attainment of sustainable development goals (without giving any clear picture of which infrastructure can take us there) (Thacker et al., 2019), and to the decarbonization of infrastructure construction (Lingegard et al., 2021). I will borrow here a notion introduced by Corvellec (2016) of “sustainability objects” that carry a performative definition of sustainability (Latour, 1986). By claiming to be developing sustainable infrastructures and offering the promise of more sustainability, the actors are developing a definition of sustainability not defined *ex ante*, but taking life through the project’s development.

All in all, sustainable infrastructures are yet to be invented and implemented at a global scale. Their setting up will require reconfiguring the current management of public infrastructures and finding new ways of collaborating with various stakeholders like the private sector and citizens. The properties of public infrastructure, like their embeddedness in other networks, communities and standards or their usual invisibility, seem to make them unfit for radical changes towards sustainability.

*“Studying district heating systems as a public infrastructure is interesting”, said Mrs. G. happily. “They have many characteristics in common.”*

- “Yes, the district heating network is a public energy network and infrastructure. It is facing the same challenges as the other infrastructures. Also, as the literature on public infrastructure is more developed than the one on district heating, we can learn much from other scholars. On the results, of course, but also on the methods used to study such objects. In this investigation, we will not look into the economic evaluation of public infrastructure, but build on Star’s (1999) understanding of infrastructures as technical networks embedded into several human organizations and institutions.”

- *“Energy networks are like urban monsters. They are composed of multiple interrelated parts, it is hard to grasp them whole, they are partly visible but mostly invisible, they have a huge impact on our everyday life, they are strong and weak, stable yet flexible. We can feel they are there, we can imagine them, but we never really see them. But at the same time, they have a sturdy materiality. They are like a gigantic underground octopus which sprawls in every direction and needs careful maintenance.”*
- “They have two invisibilities. The first one is the material one, as only part of the infrastructure is visible. Most of the pipes, energy transfer stations, etc. are underground and not seen by the user. The other is invisible as in unsexy, unworthy of attention. The infrastructures are not agile and innovative start-up systems, but old sturdy assemblages of pipes and concrete. This is how they can hide from public attention. Just like you do not notice anymore the old, but handy, coat rack in the entrance hall. With the ongoing crises—climate change, energy crisis—I wonder how actors can define, design and implement sustainable public infrastructures.”
- “True, Mrs. G. And it is also a monster in the sense that it is nobody’s concern. It is so big and interconnected with other structures that no one can—or wants—to take decisions. And you cannot change it without risking disturbing the service continuity, so... better stick with the current operation and maintenance.”
- *“It reminds me that during the field work, I noticed two approaches for sustainable district heating: transforming the existing systems and creating new systems. The issue of making an existing infrastructure change is not the same as developing a new infrastructure project. Even if both are complicated.”*

### ***Defining the object of study and perimeter of analysis***

This first dive into the literature made me aware of the variety of systems that can be found under the description “district heating”. I needed to clarify the perimeter of the investigation: publicly owned and planned systems operated by a district heating company. The latter could integrate a variety of partners, including private ones. As I was doing my investigation in and with Engie, the role of private partners was obviously a key point to consider. While there were some fully private district heating systems—for instance for an industrial complex heat supply—I found that the “public service” dimension of district heating systems opened a world of interesting challenges, especially under the constraint of making more sustainable systems: What type of collective action is needed

to make public infrastructures sustainable? What is the role of private partners in the delivery of sustainable public services?

In the investigation, I will be looking both at “district heating”, i.e., the concept of local and collective heat delivery; and “district heating systems” (also referred to as “district heating network”) i.e., the technical system used to supply heat. The notion of “sustainable” will be used according to what the stakeholders consider as “sustainable”, from decarbonization of heat sources to integration of societal concerns in the design of district heating.

This perimeter is stable enough to allow some investigation, but still not entirely defined so as to integrate the different realities perceived by the various actors. I will not consider here that the district heating perimeter stops where the pipes stop, or where the contract ends, but where the actors consider it ends. Despite establishing a perimeter of the object of study, I will study its specifications as a sociotechnical system through the actor’s statements and actions.

## A PhD on sustainable business models?

With the object of study outlined I can now present the construction of a theoretical framework to analyze it.

The subject was first defined by Engie and Franck in a very open way. It was a blank page, an open door to current concerns. The first formulation of the subject was “integrating externalities in sustainable business models”, with a case study of district heating systems. Engie’s influence was very apparent in this first formulation. The economic language of “externalities” coupled with the strategic term of “business models” was an indicator of the company’s vision and its framing of concerns.

Engie is one of the three main district heating and cooling operators worldwide (Engie, 2022a). It sees district heating as a market, where new opportunities can arise and different operators compete to keep or gain new markets. In its “business as usual” way of doing things, Engie operates district heating systems owned by a client through a subsidiary created for the project. It answers a bidding process launched by this client. With its proposition, Engie tries to put forward a competitive advantage: better maintenance, fewer heating costs for the final user, etc. Once it has gained the market, Engie’s subsidiary will sign a contract with the client. As I am only studying publicly owned district heating, the client would be a public authority (e.g., local government, municipality) and the contract between the client and Engie usually a PPP (see *box 1*).

### **Box 1: Public-Private Partnerships (PPPs) on the Operational side**

PPPs have been studied in the academic literature, and are also an operational terminology used within Engie. I will here make a short summary of the PPP Handbook (Engie, 2019), describing the various types of PPP.

Engie defines a PPP as a “range of possible contractual relationships between public and private entities in the context of infrastructures and/or services (mostly public services) procurement” (Engie, 2019). The PPP can cover different steps of the project: designing, financing, construction, operation and maintenance. In the long-term contract regulating the PPP, risks, responsibilities and benefits are allocated and the specific outcomes and/or performances of the contract are also stated. Ownership of the infrastructures may differ from one PPP to the other.

PPPs are supposed to help achieve better public service quality and efficiency, while overcoming the limited investment capacity of public bodies.

With the rise of sustainable concerns, exemplified by the United Nations' Sustainable Development Goals (United Nations Department of Economic and Social Affairs, 2022), new legislation, decarbonization commitments, etc., Engie forecasts a change in the district heating market. In several recent projects, the client's demands have shifted e.g., from the mere technical operation of the network to its integration in a local decarbonization strategy. Engie's concern is fairly simple: how to remain competitive in this new market of sustainable district heating? One path was under investigation by Engie, and explains the origin of my PhD: monetization of externalities to propose new sustainable business models. I will now narrate Mrs. G.'s first interaction with externalities at Engie.

Mrs. G. arrived at Engie in the late fall of 2019. With almost no economic knowledge, she was struggling to understand the idea of "externalities" and how they could be integrated into business models. Discussions within her lab, and with Olivier helped her understand Engie's vision. Olivier was a dynamic lobbyist for innovative district heating and cooling systems at a strategic level. He wanted Engie to be leader of sustainable district heating, and to be differentiated by its business model. His idea was fairly simple: for now, Engie's offers were evaluated on technical and economic indicators, without taking into account all the environmental (better air quality, fewer carbon emissions, etc.) and social benefits (fighting fuel poverty, creating local jobs, etc.) of the system. He wanted to find a way to identify and quantify these positive externalities and integrate them into the offers. In the best-case scenario, these externalities could be monetized and integrated into the business model. Otherwise, other ways of integrating these externalities would have to be designed. And that was Mrs. G.'s job with her PhD... The lab had already conducted some studies on the quantification and monetization of environmental and social externalities. But the ways of integrating them into business models were still to be constructed.

When Mrs. G. explained to me this interest in business models, I started delving into the literature to learn more on the academic conceptualization of business models.

### *A holistic approach of value?...*

*Business model* is a concept which emerged from business practices and gained momentum in literature in the mid-1990s with the emergence of the e-business.

Several scholars have tried to define it, but its definition is not consensual and some point out the lack of definitional clarity (Zott et al., 2011). For instance, a widespread definition of business models is the one of Osterwalder and Pigneur (2010), where they state that *“business models describe the rationale of how an organization creates, delivers, and captures value.”* However, the business model is not only seen as a passive description, but also as a tool to quantify, analyze or act on companies. Doganova and Eyquem-Renault (2009) analyze it as a market device, which *“works as both a calculative and a narrative device”* (Doganova and Eyquem-Renault, 2009, p. 1560). Baden-Fuller and Morgan (2010) study business models as a variety of “models”, each with different aims: describing businesses, classifying businesses, recipe for creative managers, or sites for scientific investigations. Due to this multiple nature, various models have been developed by scholars to visualize business models. One widely used model, both in the academic and company worlds, is the business model canvas developed by Osterwalder and Pigneur (2010). Aligned with their definition of a business model as a description of the company’s value process, this canvas is a simple visualization of this process through nine building blocks: value proposition, customer segment, customer relationships, channels, key activities, key resources, key partnerships, cost structure, revenue streams. This static and descriptive overview of a company’s value process has several limits, like the exclusion of all external drivers (e.g., regulation, competition) and their impact on the business model, the lack of details on the interrelation between the different blocks of the business models, or the absence of a clear link between the business model and the company’s strategy and organization (Coes, 2014).

Despite the multiplicity of understanding business models, Zott et al. (2011) have highlighted some common themes in business model literature: (1) the business model is

a relevant unit of analysis focusing on a specific company but whose boundaries go beyond those of the company, (2) it gives a system-level and holistic approach on how firms “do” business, (3) conceptualization of business models give an importance to “activities” and (4) business models analyze value creation and value capture. I soon realized that an invariable of business models was the value process. In all definitions of business models and ways to tackle it, the central part was to understand the value process: value proposition, value creation and value capture (Clauss, 2016). Value proposition represents the solutions, goods or services offered to the customers by the company (Demil and Lecocq, 2010; Osterwalder and Pigneur, 2010); value creation encompasses the means and mechanisms designed by the company to create value from the proposition (Osterwalder and Pigneur, 2010; Teece, 2010); and finally, value capture is the conversion of the value proposition into revenues for the company (Osterwalder and Pigneur, 2010; Teece, 2010; Clauss, 2016).

As I was studying the dynamics of sustainable district heating, I found it relevant to specifically dig into the literature on *business model innovation* and *dynamic business models*. My interest was not to describe the business model of something already set up, but to look into designing something new.

### ***... that is reconfiguring and integrating sustainability concerns***

Business model innovation is seen as a way to remain competitive in a changing market, and to ensure firms’ performance (Teece, 2010; Lygnerud, 2018; Hamelink and Opendakker, 2019; Yi et al., 2022). This literature mainly considers this innovation as a change in the value process (Hamelink and Opendakker, 2019). This change in one part of the value process then affects the other dimensions, making the whole business model change. To become innovative and adapt to innovations, business models are dynamic. Demil and Lecocq (2010) designed the RCOV framework to explain how a business model can evolve through an inductive approach. It is based on three core components: (1) propositions for value delivery (V), (2) organizational structure (O), and (3) resources and competences (RC). One focus of Demil and Lecoq (2010) with this frame was to account for the interrelations between the three components of their model, and their



coevolution under internal and external factors. They also applied this frame to present arguments on the articulation between the organization and its ecosystem, through business model choices (Demil et al., 2018). To help generate innovative business models and understand business model innovation, literature has developed around business modeling, i.e., the act of creating a business model. Ballon (2007) develops a business model design matrix, explaining the scope of choices to be made when designing a business model. Aversa et al. (2015) divide business modeling into three phases: thinking, articulating and doing. This literature on business modeling looks at processes, not taking the business model as granted but as a construction done by one or more stakeholders.

One specific type of innovation has gathered a growing interest in the academic community in the last decade: *sustainable business model innovation*. As sustainability was at the heart of Engie's interest, I started to read the articles published on the subject. Bocken et al. (2014) defines sustainable business model innovations as "*innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organization and its value-network create, deliver and capture value in their value-propositions.*" (Bocken et al., 2014, p. 44). Literature on sustainable business can be divided into three main streams, whose concerns are strongly interlinked (Boons and Lüdeke-Freund, 2013): technological, organizational and social innovations. To theorize sustainable business models, scholars have attempted to classify and cluster them into patterns and archetypes (Bocken et al., 2014; Lüdeke-Freund et al., 2018). Closed loops (like circular business models or industrial ecology), or repurposing for society (like cooperatives and social enterprises) are examples of sustainable archetypes and patterns (Yunus et al., 2010; Bocken et al., 2014; Lüdeke-Freund, 2018; Geissdoerfer et al., 2018). However, the operational setup of such business models remains full of barriers and challenges at multiple levels: e.g., lock-ins, need for legislation, focus on shareholder value maximization (Teece, 2010; Lygnerud, 2018; Hamelink and Opdenakker, 2019; Bocken and Geradts, 2020).

### ***Business model: the right angle for studying district heating?***

Dynamic business models appeared to be a relevant lens through which to study organizational change for the design of a new value process. But one major limitation was the focus on a company, when I was, on the contrary, focusing on a system gathering several actors together. Even sustainable business models were mainly developed for and adapted to the company perimeter. The holistic approach of business models was widening the boundaries of the company as an object of study, but still focusing on a specific company and only taking into account external stakeholders in a limited way. Furthermore, if literature on business models focuses on the value process, most of the frameworks for actually analyzing the business model were centered on the economic value. Many were created to study the competitive advantage that a specific model could give to a company, with the idea of winning market shares and capturing some financial value. The type of value taken into account seems to be wider within the stream of sustainable business models, but here again was this logic of capturing this value as a benefit for the company, and winning a competitive advantage. These limits were pointed out by several authors (Coes, 2014; Fehrer and Wieland, 2021; Yi et al., 2022) and have led to a new literature focus on *systemic logic business models* (Fehrer and Wieland, 2021) and *collaborative ones* (de Man and Luvison, 2019). More than taking into account a wider value than the economic one, these business models try to integrate several companies within the scope of the business model. Finally, even when studying business models as a mediating tool between different stakeholders (Doganova and Eyquem-Renault, 2009), I was faced with the issue that sustainable district heating does not exist *per se*. Instead, district heating systems are constructed locally on a project basis. Therefore, the values they deliver are not stabilized in a global sustainable business model, making the latter impossible to study even in its performative effects.

Below is an extract from a discussion I had with Mrs. G. on business models as a theoretical framework for the investigation.

“I am not absolutely sure that the business model could be a theoretical frame for the investigation”, *I doubtfully said*. “It is more the conceptualization of an empirical object than an academic theory.”

- *“But it is an important aspect of district heating. It could be the angle we use. We could try to design a sustainable business model for the new generations of district heating. Maybe using the literature on business modeling? Zott and Amit (2010) say that designing a business model can be broken down into designing an activity-system, “a set of interdependent organizational activities”. And even the limits you have pointed out earlier, on the minimal integration of stakeholders, are not valid in all cases. Some scholars have highlighted the interaction between the company and the external stakeholders. Buur et al. (2013) question the contributions of participatory approaches to business modeling. Demil et al. (2018) highlight the interaction between the firm and its environment through “business model thinking”, arguing that (1) the environment of an organization depends on the stakeholders around the organization, (2) the stakeholders participate in the design of the organization’s business model through negotiations between the organization and its ecosystem, and (3) the ecosystem and the business model co-evolve over time. And what about the systemic and collaborative business models? I think we just have to find the right model to use, and we could analyze district heating through this lens and use this abductive process to then re-adapt the model for last generation district heating. Look, several academics have used business models to study district heating. Lygnerud (2018), used the business model canvas to conduct her study of the Swedish district heating business models. This canvas offers a global and static view of the business model through nine building blocks, overlooking the organizational aspects. It is centered on the district heating companies, and not on the district heating system itself. However, Lygnerud (2018) points out some interesting results, like the shift towards service-oriented companies, due to changes in customer expectations. Some scholars have also tried to apply business models for (energy) public utilities (Richter, 2013; Helms, 2016; Bolton and Hannon, 2016; Bryson et al., 2018). Bryson et al. (2018) have developed their own framework for such analysis: alternative-substitute business models, whereas the others have built on existing frames, e.g., servitization for Helms (2016), joint-venture for Richter (2013) and system approaches for Bolton and Hannon (2016). I think the model of Demil and Lecocq (2010) could be the right one for us. It can be applied to district heating projects: it looks at the dynamics of business models and its evolution, the value proposition is not necessarily economic and there is a clear focus on the organization including the external one.”*
- “I don’t like this reasoning, Mrs. G. The goal of the investigation is not to create the perfect off-the-shelf business model for Engie. First, I don’t think it is possible, as district heating—like most sustainable infrastructures—has a strong local anchorage. Each project depends on the available local resources and on the local specificities. It is no longer about building and operating a gas boiler

that could be implemented anywhere. It is about creating and sustaining some local sectors to deliver sustainable heat. And second, the investigation is not only for Engie, not only operational. We need to be able to talk to an academic community and make some contributions to this community. Do you really think that we can improve Demil and Lecocq's model? That it would be relevant here? Look, if we take your idea of Demil and Lecocq's model, we could not even use it directly to analyze district heating projects. The value propositions are under construction. They do not exist right now so how could we study them? We have already said that the perimeter of district heating can vary depending on who we talk to, so what organization do we study? Who is part of the internal organization and who is part of the external one? And for the resources and competences: how do we study them when even the actors do not know what they need to be doing for future systems? We are here investigating a transition to a future system not yet defined and stabilized. Some technical solutions exist, or will probably exist soon, but the integrated system, with its organization and institutions, does not exist. However, I agree that business models highlight one important aspect: the valuation process. It seems to center most of the challenges of sustainable district heating, and more globally, sustainable infrastructures. The problem is, with our system, we are talking about undefined values. We feel that the value proposition is changing, but we don't know exactly what the new values are."

- *"Then, what can we do? Is there any literature on the process of creating values?"*

## Valuation or values in the making

In the case of public services, like district heating, the value proposition is multiple, and addressed to the variety of stakeholders gathered around the district heating system. Corvellec and Hultman (2014) claim *“that organizations make not only one (Hultman and Ek, 2011) but several value propositions that address different institutionalized activities, processes, or practices of valuation (Muniesa, 2011), in other words regimes of value.”* (Corvellec and Hultman, 2014, p. 356). Value is not something that is given, but that is being constructed through the actors’ practices.

So, how do we study the making of values? To analyze the social practice of valuation? These questions have been a concern of *valuation studies* among academics.

### *Different approaches to value*

Value and its making have been a long-standing interest of academics in various fields like economics, finance, sociology or management. Two principal approaches to value have been developed by different fields. The first one is static, where values are already determined or objectively constructed through quantitative calculations. I was searching for literature focusing on the construction of value by the actors involved. This led me to a second approach where scholars analyze the making of value—i.e., the study of evaluation and valuation—as a social process. I will now quickly present both approaches, before diving more into valuation studies, a dynamic analysis of valuation processes as a social practice.

As presented before, business model academics focus on the value process, and more particularly on the means to deliver and capture value (Zott et al., 2011). However, their vision of value is a static one, where the values are already given and determined. This literature does not try to unbundle the value-making process or the valuation processes. Staying in the field of organization studies, some scholars have looked at the cultural context of evaluation and their evolution over time (Cattani et al., 2013). Similarly, academics in economics are interested by the results of calculation, giving value to different objects. With the rise of societal, social, and environmental concerns, methods for non-market valuations were developed by economists (Freeman, 2003). The

contingent valuation method (CVM), a survey-based method to determine consumers' monetary valuations, was for instance used by Diener et al. (1998) in the healthcare sector. Boyer and Polasky (2004) review studies on wetland valuations, i.e., estimating the value of wetlands in monetary terms, and show that five major methods are used including CVM. These different approaches to studying value and valuations have focused on monetary value, trying to understand the value processes, evaluate the monetary value of nonmarket items, and take into account the cultural context in value evolution. They mainly see value as a stabilized characteristic that can be measured and observed at any time.

A more dynamic and constructivist approach has grown in the social science community and especially in the various sociology communities. Economic sociology has started to study how valuations were created, apart from the market. For instance, Zelizer (1979) has analyzed the American health insurance system by making a historical study of the values given to life and death. She has also studied the social meanings given to money, analyzing the case of married women's money between the 1870s and the 1930s (Zelizer, 1989). Following this pioneer work, several streams of literature on valuation and evaluation have developed (Lamont, 2012). Among them, a community of scholars has developed *the sociology of valuation* or *valuation studies*, which takes a pragmatic view by analyzing valuation as an action, based on Dewey's work (Muniesa, 2011). Valuation can be briefly defined as a process of giving worth, while evaluation aims at assessing. These approaches look at valuation and evaluation as social and cultural processes happening through practices and experiences.

### ***The sociology of valuation***

In this manuscript, I build on the sociology of valuation or valuation studies. This community has a social approach to valuation, analyzing the social practices, tools, models, and organizational inputs leading to the making of values, i.e., giving worth. Valuation here is neither understood as an objective set of criteria or constructed assessment method, but as an action. This action is embedded in the actor's practices, institutions, and overall expertise (Boholm and Corvellec, 2016). Valuation is linked with

the notion of value(s), studying the process through which values are created by the actors, for example, or how several values converge into an economic value.

Valuation studies bring together scholars from multiple disciplines, e.g., sociologists, anthropologists, and philosophers. In 2013, the journal *Valuation Studies* was created, highlighting the growing interest in the study of valuations. In their first issue, Kjellberg and Mallard—two members of the editorial board—have attempted to sketch out the perimeter of valuation studies and its relevance as an academic topic (Kjellberg et al., 2013). Concerning its relevance, they pointed out the empirical and theoretical interest in valuations: e.g., changes happening in the value structure and processes due to new technologies or controversies arising in valuation practices for empirical interest; limitation of the mainstream view of pricing as the main regime of valuation or the paradoxical search for objective value even as the social construction of value is widely acknowledged as theoretical challenges. Linked to this interest, the authors point out a shared belief that valuation studies can allow researchers to do fun and useful research. Concerning the perimeter, three issues related to the valuation process have been presented as the most important to tackle: 1) How are valuation processes interrelated? 2) What are the organizational and technological supports of valuation? And 3) How does valuation contribute to the realization of various democratic values? Several interesting sites to study these issues are mentioned in the article, but I just want to mark one: *“large infrastructure projects, both because their valuation exhibits complexity and because they engage the evolution of important societal concerns (Tryggestad)”* (Kjellberg et al., 2013, p. 25). From the first issue, a wide variety of cases have been studied by scholars in valuation studies, from valuing a good tomato (Heuts and Mol, 2013) to more current concerns like carbon valuation and prices (Dalsgaard, 2016; Engels and Wang, 2018). The predominance of quantification and economic value as a paradoxical object of fascination and concern in the field of valuation studies is pointed out both in the first issue (Kjellberg et al., 2013) and by young researchers in valuation studies (Haywood et al., 2014). This concern is partly related to the various methodological approaches of valuation studies, from a fully pragmatic approach, to more normative ones.

Even within valuation studies, several approaches to valuation coexist, each shedding a different light on valuation processes (Doganova et al., 2014).

The one I will position my manuscript in has taken insights from science and technology studies (STS). First, valuation studies *“examine one or several sites of valuation while refraining from presuming that one or the other produces an inherently more true valuation than the other.”* (Doganova et al., 2014, p. 89). And second, like science and technology studies, valuation studies analyze moments of controversy and innovation (Doganova et al., 2014). For the first point, this STS-based approach within valuation studies stresses the importance of looking in a similar way at different sites of valuation, arguing that the principle of symmetry makes valuation and its consequences open to discussion. For the second point, looking at controversy arenas makes it easier to identify the stakeholders, their positions, their relationships and the arguments or tools they use to support their position, as they place themselves in visible positions and make their claim public.

Building on this STS-based approach within valuation studies, I will study the valuation processes of sustainable district heating. This approach will offer some methodological challenges which I will describe more at length in the next chapter.

### *Valuation, yes... but is that enough?*

Valuation will be a cornerstone of the investigation. The stream of literature I will position myself in is interested in the making of value by actors, taking insights for science and technology studies. For district heating, the value of sustainability is still under definition. Different stakeholder groups are arguing on the values of sustainable district heating. By analyzing the actor’s activities around the valuation of sustainable district heating, I hope to contribute to the field of valuation studies and unbundle the process through which actors are constructing these values.

I discussed this new perspective with Mrs. G.

*“So”, I asked, “what do you think of valuation studies as a theoretical framework? Is it aligned with your empirical findings?”*

- *“Yes, one major challenge is to understand how the values of sustainability are constructed by different groups of actors, and how these different values are*



*competing in controversy arenas. I have already felt that in the field, with the different expectations of actors when talking about district heating. Thinking back to my first interviews with district heating operators, the business model was not that much used. It was more something they needed to fill in when describing a project, rather than a discussed concept where there were challenges. I think it is at a higher level within Engie that the business model per se was seen as a challenge. However, at all levels there were discussions on the value. The economic value, the local value, the environmental value. What were the values? How can we ensure the delivery of these values? It felt like the “old” valuations—cheap heating price, continuity of supply—were just the basics but that new things needed to be added. The local authorities kept talking about local attractiveness, inclusiveness, and energy sovereignty. Everyone agreed on the importance of decarbonization and the environmental impact. Some suppliers were talking about the structuration of local sectors. So, yes, valuation as a social process made by various groups of stakeholders seems perfectly relevant!”*

- *“So now we have our theoretical framework, we can move on...”*
- *“Not necessarily. I think one major challenge still needs to be addressed. Remember how the last generations of district heating are decentralized? The multiplicity of actors that could be integrated? For each project, all these actors need to work together. More than the valuation process, collective action is an important concern for these sustainable infrastructures. It is also about aligning the interest of the stakeholders, coming to a conclusion with all the different valuations, finding the right governance to sustain the project in the long term. Remember that public infrastructures usually have a long lifespan... for district heating it is at least thirty years... All the stakeholders need to commit to the project, to share the risks and responsibilities, to have collaborative processes in case of a change. And you see how the system they are working on is unstable? They do not know what the good solution for decarbonization is. They are dabbling with existing technologies and technologies to come. They have the fear that maybe, what they have invested in for the next twenty-five years will be outdated within ten years. Their world is becoming more turbulent. Also, collaboration is usual rhetoric inside organizations. As Engie wants to offer its customers more complex solutions that require various sectors working together, it needs to find ways to collaborate both within and outside the organization. This collaborative dimension could be really interesting to dig into don’t you think?”*
- *“Sure, but how could it be put into a theoretical framework?”*

## Collaborating and co-creating sustainable infrastructures

With this idea of collaboration in mind, I headed back to the literature. My first idea was to look at collaborative governance, as a mean to spur and manage collaboration: how do you foster collaboration within the new stakeholders' network around sustainable district heating, and how do you govern the resulting collaborative network?

But first, I needed to specify the perimeter, as collaborative governance encompasses a multiplicity of research communities. Staying aligned with the object of study defined, I chose to focus on public sector governance. In particular, I looked at the public administration literature on public governance, a community which developed a literature stream on the governance of the public sector, from public administrations to public infrastructures.

### Studying governance?

Some scholars have investigated the *governance of collaboration* or the *governance of collaborative networks*. A distinction can be made between the *governance of collaboration* and *collective governance*. The latter is interested in ways to govern through inter-organization collaboration while the *governance of collaboration* studies the governance of collaborative entities (Vangen et al., 2014). Despite this major difference, both the *governance of collaboration* and *collective governance* could be interesting for analyzing sustainable district heating governance.

Vangen et al. (2014) conceptualize the *governance of collaboration* through three key design elements: structure, processes, and actors (Figure 13).

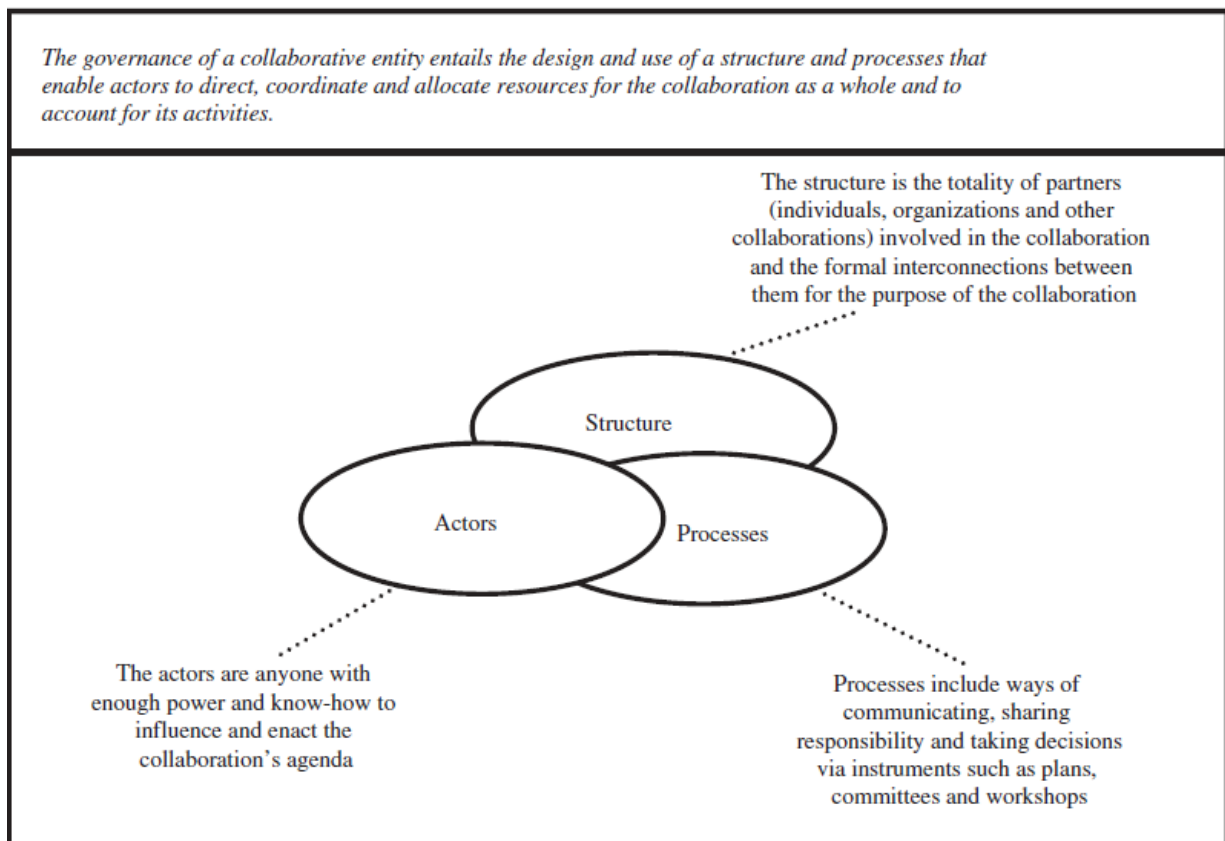


Figure 13 Governance of collaboration: key design elements (Vangen et al., 2014)

Similarly, Bryson et al., (2006) designed a framework for understanding *cross-sector collaboration*, composed of five components: initial conditions, the process, the structure and governance, the contingencies and constraints, and finally the outcomes and accountabilities. They point out the interrelations between these five components.

“Process” and “structure and governance” are at the heart of their framework. They focus on six processes: forging initial agreements, building a relationship, building legitimacy, building trust, managing conflict, and planning. They think of the governance as a “*set of coordinating and monitoring activities*” that need to occur for the collaboration to survive. To complement this literature, I wanted to see how collaboration could emerge, and through which activities. While sustainable district heating involves a variety of actors, they are not collaborative *per se*: the collaboration needs to be built through governance. The public authority managing the system aims to enhance participation. Literature on *collaborative governance* is strongly anchored in the public world, making it relevant for the study of public services. Collaborative governance can be defined as “*the processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or public, private and civil spheres in order to carry out a public purpose that could not otherwise be accomplished.*” (Emerson et al., 2011, p. 2). Ansell and Gash (2007) propose a more restrictive definition of collective governance, arguing that collaborative governance needs to be formally organized. However, as collaboration relies on trust and internal legitimacy, informal arrangements are required for collaboration to succeed. Thus, the wider definition of Emerson et al. (2011) seemed more suited to the investigation.

Implementing collaborative governance is nothing to do with spontaneity. The literature on collaborative governance offers frameworks for analyzing or fostering collaboration in existing networks, building from experience to formalize models and highlight challenges (Bianchi et al., 2021). Emerson et al. (2011) formalize collaborative governance through the notion of collaborative governance regimes, embedded in a system context. This model shows the need of a shared motivation, based on trust and legitimacy, to deliver a common output. It also highlights that the capacity for collaborative action relies on arrangements, resources, and knowledge, which could be summarized as a well-suited instrumentation and expertise. The regime comprises the collaboration dynamics which lead to actions that can then have an impact on the system. Wegner and Verschoore (2021), based on a comprehensive literature review, propose a research framework on actions to foster collaboration. They consider that, to govern collaborative networks, the network leader needs to perform the following actions: aligning, mobilizing, organizing,

integrating, arbitrating, and monitoring. These actions are completed through practices of agreement, arrangement and engagement. The outcome of these actions will depend on contextual factors, but aim at building an internal environment based on trust, learning, legitimacy, power symmetry, and fairness (Figure 14).

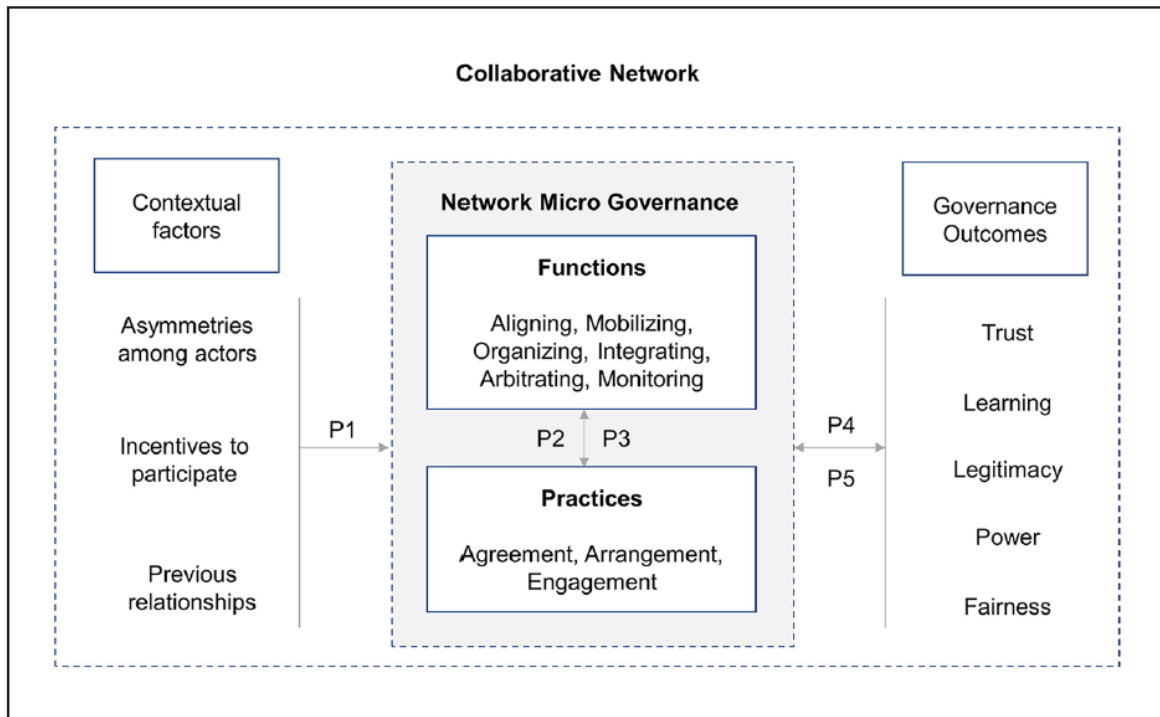


Figure 14 The micro-governance of collaborative networks (Wegner and Verschoore, 2021)

This literature gives a global overview of collaborative management in the public sector, but I see several limits. First, they are very global concepts, which means it will be hard to contribute to them using the specific case study on sustainable district heating. This literature does not show the collective action in the making, but describes and analyzes existing collaborative settings. When studying the means to spur collaboration, this literature remains generic and focused on the role of the leader—which is not always defined in innovative projects. Second, and I refer here to the work of Ansell and Torfing (2021), they do not work on the proactive making of new systems and their governance. There is no focus on innovation management within this literature. Linked to that, they both predominantly focus on collaboration as a solution to current public sector limitations, such as more effective cooperation, public acceptance, and conflict mediation rather than as something that the public sector can proactively engage in. The literature on the governance of collaboration and that on collaborative governance both formalize

various processes linked to the management of collective and collaborative projects. I will use some of these actions and processes in chapter 5 to develop a model of how to assess the setting up of collaborative and co-creation activities in public infrastructures.

*“I cannot really see how this concept of collaborative management will help you analyze sustainable district heating”, said Mrs. G. doubtfully. “It seems very a long way from the field.”*

- *“Still, it might give some interesting insights on characteristics of collaboration in the public sector, and actions to be put in place, don’t you think?”*
- *“Maybe... but it seems like they are mostly looking at making current solutions more collaborative by appointing a leader who will take action and solve problems. It looks a bit like a quick fix. For sustainable district heating you need to collaboratively innovate. You create the innovation and the collaborative governance hand-in-hand. It is a process anchored in the action. And there is not necessarily one established leader. There are multiple stakeholders, that I do not really see in collaborative governance. Can’t you find something less formal and more processual? Collaborative governance almost sounds like a new management paradigm, like new public management or bureaucracy... “*

For now, I wanted to find a less generic concept, not a new type of governance that would be hard to observe in our case, but a concept on collaboration to innovate in the public sector. Recently, scholars of public management have picked up on co-creation as a topic of interest, leading to the concept of *public sector co-creation*.

### ***Public sector co-creation***

Co-creation as a concept was coined in the private sector to describe a process in which customers contribute to the creation of services or products that they eventually purchase (de Koning et al. 2016). It represents a shift from the single-organization innovation process to a distributed one (Durugbo and Pawar, 2014). Just like for collaborative governance, I here focus on public sector co-creation, not building on the multiple understandings of co-creation that are developed by several research communities, from marketing research (Ramaswamy, 2011) to innovation theories (Siaw and Sarpong, 2021). When writing about the public sector, I mean institutions, infrastructures or administrations that are owned by a public authority or deliver a public service. Not all

the actors in the sector are necessarily public ones: Engie, by operating public infrastructures and delivering a public service becomes a public sector actor.

For the public sector, Torfing et al. (2019), define co-creation as:

*“[A] process through which two or more public and private actors attempt to solve a shared problem, challenge, or task, through a constructive exchange of different kinds of knowledge, resources, competences, and ideas, that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it.”* (Torfing et al., 2019, p. 802)

Co-creation in the public sector can happen in several core functions of the public sector, like service provision (e.g., with parents being involved in the running of childcare facilities), public problem solving (e.g., projects to combat homelessness), and public regulation (frequently used in the field of water management).

Even though public sector co-creation still represents a multitude of different models (Dudau et al., 2019), scholars agree on a few features of the concept. First, all cases of public sector co-creation are characterized by a *complex network* of stakeholders involved. The literature distinguishes between several categories of actors and groups of actors involved in co-creation processes. The basic categories of actors are the state, the market, the community, and the third sector (Sillak et al., 2021). Second, the implementation of public sector co-creation requires that stakeholders adopt *new roles* (Torfing et al., 2019; van Gestel et al., 2019). Third, the main goal of public sector co-creation is to respond to a *public concern*, seeking to create public value creation.

Scholars from this community have put efforts into defining public sector co-creation and positioning it in comparison with other concepts, like co-production—coming from service production—or collaborative governance (Torfing et al., 2019; Ansell and Torfing, 2021). With this definition clarified, case studies of public sector co-creation were analyzed—like the climate governance in Oslo or Copenhagen (Hofstad et al., 2020; Sorensen and Torfing, 2020)—leading to the design of a framework to study public sector co-creation

(Torfing et al., 2021). These co-creation projects also allowed scholars to study the enablers, barriers, and limitations to co-creation in the public-sector (Torfing et al., 2019). The design of appropriate dimensions, criteria, and indicators to evaluate public sector co-creation has been an important aspect of this research (Sillak et al., 2021). Attempts to theorize co-creation have often focused on stakeholders' identification and on defining a model, typology or phases for co-creation (Sillak et al., 2021). Some authors have tried to go even more operational by defining activities fostering or supporting co-creation, with here again a focus on aligning the network and building trusted relationships (Sillak et al., 2021). More than looking at mechanisms to evaluate and support co-creation, scholars have also studied how co-creation can force actors into new roles, especially when it comes to leaders (van Gestel et al., 2019).

The literature indicates several expected benefits of public sector co-creation, including better democratic deliberations, the empowerment of local actors, better public authority legitimacy, and the opportunities that co-creation creates for locally efficient solutions (Torfing et al., 2019; Sillak et al., 2021). Barriers to and problems of co-creation in the public sector have not been thoroughly discussed in the literature. They include the lack of participation or poor democratic representation, the difficulty in refining stakeholders' identities and role perceptions, the expense and large number of resources needed for building up expertise and implementing practices (Torfing et al., 2019).

Several research avenues for advancing the public sector co-creation community were put forward in conferences I was able to participate in this year. Among them was the need to work on the strategic efforts of public organizations to spur co-creation. Another research focus is unbundling the role of leaders and the types of leaders needed to spur co-creation. Finally, co-creation scholars urge researchers to work on the role of platforms as arenas of co-creation. Globally, the field points out a need to understand the processes of co-creation and their impact to deliver public values, especially in turbulent times.

All in all, I position the PhD in the field of public sector co-creation as defined by Torfing et al. (2019). I aim to participate in this community by studying the process of co-creation in sustainable infrastructures.



*“I like this concept of public sector co-creation”, smiled Mrs. G. “It is collaborative, multi-stakeholders, it focuses on innovation, is proactive, linked to the creation of public values. It is a process, that exists through the actor’s practices, not something static and already institutionalized. It is everything we needed.”*

- “Yes, by linking it to valuation I think we can get somewhere. The investigation is about two interlinked things: the valuation of sustainable district heating and the co-creation of both these valuations and the resulting values. We aim to answer the following research problem: How do actors co-create sustainable valuations for public infrastructure projects?”

## In a nutshell

To conclude this chapter and before going into the methods, let me quickly summarize what has happened so far.

First, I supplemented the characteristics of district heating brought to light by Mrs. G.'s investigation in chapter 1 by defining the perimeter of the object of study: sustainable district heating. Here are the main features of the object of study. District heating as both a concept of collective heating and as a locally-anchored technical system. Publicly planned and owned district heating operated and maintained by a district heating operator. District heating as a public infrastructure delivering a public service. Sustainable district heating as a system still undergoing definition by the actors, a process that challenges the technical system, its economic equilibrium and its governance by integrating new production means, new actors and new values into an established system. I have then defined the theoretical framework for this PhD. Starting by digging into the concept of sustainable business models at the heart of Engie's concerns, I soon left it to go into valuation studies. To take into account the collaborative characteristics of sustainable heating, I looked into collaborative governance and governance of collaborations before settling on the concept of public sector co-creation.

I have tried to show in this chapter the process through which the theoretical framework was constructed. But even here, I had to simplify the steps and make it all more linear than it actually was. Below is a short imaginary dialog between Mrs. G. and I that reflects more realistically this building process.

*"It took time to arrive at this theoretical framework and research problem", reminisced Mrs. G... "I feel like we kept changing the focus of the investigation along the way."*

- "I don't think the focus has changed that much. You started with exploratory research on district heating, trying to define the object of study and the challenges. It took time just to acclimatize to this new world. The discussion we have had on the characteristics of district heating and its challenges led me to research the literature on sustainable district heating. Discussions with Anne, Franck, and all the others around the PhD helped to define the study's boundaries. This stabilized quite rapidly. After one year of investigation, the main characteristics of sustainable district heating and the resulting challenges

were quite clear, even if I don't think we can consider ourselves as specialists of the technical system."

- *"It is true that the scope of the investigation was quite clear. And the interest in the valuation of sustainable district heating emerged at the very beginning of the investigation, even if it was first through Engie's prism of business models."*
- *"Yes, the challenge was not so much on what the investigation was about, but more on how to conceptualize what it was about. On how to position the PhD. This positioning came quite late. We kept searching different areas of literature to see which one was the most relevant for the investigation."*
- *"Valuation studies kept coming and going in and out of our field of view but it is only at the very end that we managed to stabilize the framework. Franck played a big part in this construction."*
- *"And the presentations to other researchers, and most of all to the thesis committee rapporteurs. Don't forget them Mrs. G, their insights really helped the manuscript to come to a conclusion."*
- *"Same for co-creation. The collaborative aspect was of major interest from the beginning, but then we struggled to find the right community to discuss it."*
- *"I remember looking at so many bodies of literature for the collaborative aspects: urban governance, industrial ecology, network governance..."*
- *"Yes, and there were so many aspects we wanted to integrate into the investigation: pricing, collaboration in the unknown, crisis management, public governance. All the empirical concerns I have pushed forward, all the literature you have flipped through..."*
- *"Even for tackling district heating... You know with this question of being more global than one specific case study, we didn't know in which category to put district heating: an industrial ecology system? An energy system? A utility? An infrastructure? A PPP? A bit of everything?"*
- *"I am glad we have finally found a positioning. I am sure it is not the only relevant one, but it was very interesting to go through this construction process. And anyway, you can discuss the limitations of this positioning in the discussion section."*

In a nutshell, I have positioned my investigation on both processes: valuation as a social practice and public sector co-creation as a multi-stakeholder innovation process. The research problem that will guide my investigation is the following: *How do the actors co-create sustainable valuations for public infrastructure projects?* Answering this question allows contributions to the academic communities of valuation studies and public sector co-creation, but will also expand knowledge on sustainable infrastructures as an academic

object of study. The investigation into these two processes will also give insights for district heating practitioners on the emerging valuations of sustainable district heating, with empirical and operational recommendations on collaborative actions to develop these systems. Finally, by positioning the PhD within the field of study of two processes, it gives it a strong empirical anchorage, lending importance to Mrs. G.'s field investigations and nurturing her curiosity.

Now, I will present the analysis framework linking the field with the theory. This framework allowed us to gain results on the two processes under study, and to make sense of the data collected.



## Chapter 3: The framework of analysis and the investigation process

*“La vraie moralité ne consiste pas à suivre les sentiers battus, mais à découvrir ce qui est pour nous-mêmes la vraie voie et à la suivre avec intrépidité. Tout véritable progrès est impossible sans une telle poursuite acharnée de la vérité.” (Gandhi)*

*“True morality does not consist in following marked path, but in discovering what is for ourselves the true path and following it with fearlessness. All real progress is impossible without such a relentless pursuit of truth.” (own translation)*



## Chapitre 3 : Le cadre d'analyse et le processus d'investigation

Dans ce chapitre, je détaille les méthodes utilisées pour mettre en place la recherche compréhensive.

Dans un premier temps je rappelle que le processus de recherche est basé sur une approche compréhensive, très liée aux méthodes de recherche processuelle. Je présente alors le cadre d'analyse me permettant d'accéder aux processus de valuation et cocréation. Ce cadre se compose de trois activités médiatrices : le cadrage, l'instrumentation et la construction d'une expertise collective. C'est en étudiant les interactions entre ces trois activités mises en place par les acteurs que je compte obtenir des éclairages sur les processus de valuation et de cocréation.

Dans un second temps, je présente la collecte de données. Cette collecte se fait à plusieurs niveaux : au sein de l'entreprise via une recherche située ; au niveau national via des entretiens semi-directifs, de l'étude documentaire et un atelier avec des praticiens ; et enfin au niveau de projets de réseaux de chaleur via des études de cas. Ces-dernières peuvent être longitudinales ou axées sur un aspect particulier de la recherche.

Enfin je conclus le chapitre en abordant la question de l'analyse des données et les risques associés. Dans cette thèse l'analyse de données se fait via des descriptions détaillées et narrations, complétées par un codage inductif et thématique. Pour éviter les risques de biais, j'ai pris soin de m'extraire du terrain lors des analyses de données et de régulièrement présenter les méthodes et résultats à des personnes extérieurs à l'investigation.





With the object of study defined and the theoretical framework presented, I will now dive into the investigation process. In this chapter, I will first present the framework of analysis that was used for the investigation and clearly state the resulting research questions. I will then develop on the methods that were used by Mrs. G. for data collection and finally explain how I analyzed the data.

When discussing the manuscript structure with Mrs. G., she was surprised by the reconstruction in the narrative. By presenting first the theoretical framework, then the methods and then the results, she did not recognize the logic of her empirical investigation. This structure felt more like a deductive investigation where the theoretical framework and the methods were decided upfront without linking them to a specific field. But as this manuscript is an attempt to make the investigation understandable to various communities, rather than a daily journal of the investigation, I will here explain the investigation process. However, I will try to make the construction of the method as transparent as possible, to stay true to Mrs. G.'s investigation.

Below is a discussion where she opened up on her concerns about this specific chapter.

*“I don’t really get what you will be presenting here”, grumbled Mrs. G. “We did not sit down to define the methods at the beginning of the investigation... For the theoretical framework I can understand that you need to present it before diving into the investigation process, so that the reader understands where you are going with the manuscript. But for the methods, why not present them along the way? How can you show the construction process? It was even more fuzzy than the theoretical framework.”*

- “Just like for the construction of the theoretical framework, I will present how we built the analysis framework, and how it is linked with the methods you used to collect data, and the way I analyzed them. As I said earlier, the challenges we wanted to tackle with the investigation emerged quite soon. After a first phase of exploratory research, some more focused data collection was set up. And the logics of the investigation remained the same throughout the three years. The type of methods used did not change much because it was linked to our type of research, to your interests, and these methods worked well to investigate the challenges you had come up across.”

## A comprehensive processual approach to the investigation based on three mediating activities

### *Delving into process studies*

I tackled this investigation through a comprehensive approach (Dana and Dumez, 2015). This approach acknowledges that qualitative research does not exclude quantitative data study. Dana and Dumez specify that *“comprehensive research [is] capable of handling the quantitative all-the-while maintaining its qualitative objective of understanding the actors, taking into account what they say of what they do”*. (Dana and Dumez, 2015, p. 157). Studying sustainable infrastructure requires looking at quantitative and technical data, like indicators or pricing, while my investigation aimed at a qualitative understanding of how actors approached and apprehended sustainability. A comprehensive approach goes hand in hand with a pragmatism epistemology, focusing on concrete issues through actors’ actions and perceptions. This approach shaped my research process into an investigation process, where I studied sustainable district heating in the making, through rich field work and abductive loops.

As Mrs. G. highlighted, district heating is a collective energy infrastructure under transformation. Two processes are integrated and important components of this transformation towards sustainable district heating: valuation and co-creation. I needed now to find the right method to analyze this system, and gain insights on the valuation and co-creation processes. “Processes”. That could be the first key to building the method... I indeed needed to analyze processes. According to Langley et al. (2013), *“process studies focus attention on how and why things emerge, develop, grow, or terminate over time.”* (Langley et al., 2013, p. 1). Both valuations and co-creation are processes in which things—worth or collaborative settings—emerge, develop, grow, and sometimes terminate. The study of processes is empirically focused, and shows an explicit emphasis on temporality. This research orientation meets several challenges and requires specific methods (Langley and Tsoukas, 2016). Among the challenges, the SAGE handbook of process organization studies (Langley and Tsoukas, 2016) highlights the need to link several levels of analysis, to develop points of convergence between several perspectives (e.g., practice-based or narrative perspectives), and to explore the context-dependent

socio-material interactions over time. On the methodological side, rich data on longitudinal cases, mixing a historical perspective through the study of archives and a contemporary view thanks to interviews or document analysis, are a good basis for the analysis of processes.

All in all, process studies aligned both with the comprehensive approach taken in the CIFRE PhD—Dana and Dumez (2015) argued that comprehensive research is necessarily processual—and the theoretical framework I had chosen. The operational concerns of the company which fed the investigation process required a careful analysis of the actual situation and the actor's practices. The CIFRE setting resulted in a privileged access to data, especially within Engie. On the theoretical side, both valuation and co-creation are processes. As mentioned in chapter 2, the valuation approach used requires looking at values in the making, studying the social practices influencing this valuation process. Similarly, by choosing to study co-creation processes and their interrelation with valuation processes, I needed to unbundle the co-creation actions and the design of tools or institutions to support them. The investigation was about studying the actors in their practices. This study will look at how different groups of actors shape these processes through their actions, and how they may argue on the practices to be set up and on the outcomes to attain. It will take a process orientation and a practice-based perspective at different analysis levels; focusing also on socio-material interactions. The three levels of analysis will be developed below in the chapter, but basically, I will look at the national, local and company levels. This position is aligned with pragmatism as a research approach, where the detective investigates the social making of things through actions, not taking them for granted. It is also the approach I will use for district heating itself. As mentioned in chapter 2, I will look at the construction of sustainable district heating by the various actors, and at their interpretation of sustainable district heating.

*“This way of looking at things is interesting”, said Mrs. G. “But how do I remain neutral when collecting data, and how do you remain neutral when analyzing it? Because by talking to different people about district heating, even if you know nothing about it at the beginning, you will end up having a representation of it which may pollute your positioning?”*

- “This is indeed something to be careful about. It is balanced by the methods used: by using the same questions in the interviews with the different stakeholders, you allow them to develop their view of sustainable district heating without letting in your own vision of district heating. Even if during semi-directive interviews the flow of the interview may be very different from one interviewee to the other, you keep the same global guidelines and introductory questions. Also, when analyzing the data you try to mitigate your biases by coding the data, applying the same grid to all of your interviews. Of course, the choice of codes itself is biased... But then, research is also human so I guess you have to take into account the fact that you are, as a detective, interacting with your field and not being only an omniscient, neutral and external figure.”
- “Yes, I guess detectives are also social beings and their research a social process and a social construction...”
- “For sure, but using the social part is what makes the research lively and interesting! But you know, we were not alone in the investigation. The regular meetings with Anne, Franck, but also the presentations to different people were opportunities to rise above the research and challenge our vision of the investigation.”

### *Three mediating activities...*

To study the processes, I needed to find a framework of analysis. Like the theoretical framework, this framework of analysis was built during the investigation. Mrs. G.’s exploratory research pointed out some characteristics of district heating and the two main challenges of sustainable district heating. These two challenges—the valuation process of sustainable infrastructures and the co-creation processes set up to value and deliver value—were the backbone of the investigation. But Mrs. G.’s first empirical studies highlighted three areas of tension with respect to these challenges. Three arenas, three activities that could shed light on the valuation and co-creation processes. These three activities are: *framing*, *instrumenting*, and *building collective expertise*. All together, they form the framework of analysis for the investigation. They are the angle used both by Mrs. G. to orientate her data collection, and by me to analyze this data.

These three activities are relevant on an empirical basis; as Mrs. G. found out they were cornerstones of sustainable district heating. An interviewee from the FNCCR (an association representing public authorities owning a district heating system) stated that

different tools could be used by public authorities to manage their district heating, and some new interesting tools (like new forms of project companies, different indicators and pricing methods) were changing public involvement in district heating. He pointed out how the existing logics and vision of district heating could prevent the use of these new tools. He explained that the FNCCR worked on building the local public authorities' expertise to help them familiarize themselves with the tools, thanks to work groups, webinars, a website, etc. Similarly, the coordinator of the Heat Fund (a public fund supporting renewable heat) explained how the funds shaped the development of district heating in France. One last example: In Denmark, discussions with Danish researchers on district heating highlighted the importance of the Danish regulation on the type of district heating developed, and an interview conducted with a consultant showed how the local expertise of municipalities could support or impede the setting up of new district heating projects. These examples show the importance of the frames and framing processes to understand transformation; the place of instruments to shape, support or impede change; and the role of expertise to allow and sustain change.

The three mediating activities are also coherent on the methodological side, as they link the theoretical framework with socio-material concerns, in line with the process studies orientation: *"the more we realize that the social world overlaps deeply with the material world, the more important it will be for us to understand how such overlap is accomplished, and with what results."* (Langley and Tsoukas, 2016, p. 16).

I argue that, by studying these three activities, I can obtain results on the valuation and co-creation processes, and unbundle some of their intricacy. My interest here is neither to position myself in academic communities of framing, instrumenting or building collective expertise; nor to contribute to these communities. I will use these three mediating activities as tools for the investigation. In the next sessions, I will (1) introduce each activity justifying their advantages for the investigation and (2) present their interrelations.

## F for “Framing”

*Framing* is a widespread concept in management and organization literature streams. It was popularized by Goffman (1974) through his stage performance metaphor and has spread to a large variety of social sciences. Within the field of management and organization, many different applications of framing have been made: e.g., strategic frames, technological frames, cognitive frames used to study a variety of topics from social contests to institutional processes (Cornelissen & Werner, 2014). Callon summarizes the concept thus: *“the frame established a boundary within which interactions – the significance and content of which are self-evident to the protagonists–take place more or less independently of their surrounding context.”* (Callon, 1998, p. 249). Within these boundaries, stakeholders are using a shared lens to interpret information and act. The making of these frames is costly, as it requires multiple actors to align their interest, but also their processes and tools so that all actions remain within the defined frame. Callon (1998) associates this concept with that of “overflowing”, which is a phenomenon when external factors come and interact with the frame, forcing the latter to be readapted. These overflows are often designated as “externalities” in the economic world and relate strongly to the environmental and social concerns related to district heating. For the frames to adapt, the externalities have to be clearly identified and quantified; this has to be consensual, leading to two types of negotiations: (1) negotiations to identify the overflows, which are usually controversial; and (2) negotiations to reframe.

I will here build on Callon’s view of framing for the analysis framework, applying it to sustainable district heating: what are the boundaries within which actors can interact, and what are the rules of these interactions?

Framing is done through negotiations between the stakeholders, particularly on the practices of valuations. One key point of framing is to decide what is worth valuating and how to value it. Doganova and Karnøe (2015) show how boundaries are created through instrumentation in order to take into account the concerns that arise (here the cleanliness of manure), and how multiple valuations can be made by different stakeholders for these concerns. As a consequence, studying the frames and their making gives a view of the valuation processes, but also the points of tensions that can emerge. Moreover, it gives the boundaries and the logics within which organizational activities are set up. For the co-

creation part, framing is collective as it happens in negotiation areas, where several frames can compete. Aligning these frames to co-create a common one is part of the framing process.

*“I think framing is something very empirical too”, commented Mrs. G. while reading my paragraph about framing. “It is really based on discussions, instruments, contextual aspects, and institutions, and has an effect on reality. For sustainable district heating, I remember that the different interviewees had very different views on what sustainability actually is and what actions could and should be taken. Their perimeter for cooperation and action was different and some were trying to act on another actor’s perimeter to make practices change. It was almost like changing the definition of the technical system, changing the paradigm. And when they had too different or incompatible frames, they could not really interact and work together.”*

- *“I remember when you told me about the Danish company advocating for fifth generation district heating. He was really saying that his technical system was not only technical, but demanded all the actors to undergo a paradigm shift. And the example he gave was of the insulated pipes.”*
- *“Yes! He said that for most district heating professionals, insulated pipes are a core component. It is almost by principle, by definition, that the pipes are insulated. And he wanted to lower the temperature to go for uninsulated pipes. And I don’t know if you remember, but when I talked to a senior Danish consultant, he told me that systems with uninsulated pipes could not be considered district heating because you could not carry the heat over a long distance, and they were not collective. So, the definition of collective was on a different scale...”*
- *“... and the frames were different!”*

### I for “Instrumenting”

Framing boils down to designing the perimeter of what is possible and desirable for the system under study according to the actors. To do so, actors can rely on various instruments and tools to do things like negotiate (contracts), quantify or visualize the issue (statistics, models, maps), and take decisions (comparative analysis, decision-making processes, tendering processes).

The interest in devices and instruments to understand the conduct of collective action comes from Foucault (1975) and gives way to a variety of literature (Aggeri, 2021). Instruments can encompass a large variety of objects, e.g., technical devices, techniques



and language (Aggeri, 2014). They have been used in different fields: hospital management, human resources, marketing or policy design (Aggeri, 2021).

The benefit of studying instruments is mostly due to their performative aspect, meaning that they have an impact on reality. The concept of performativity comes from linguistics, where it means that some deliberate statements act on reality. For instance, a vicar saying in an Anglican church and in some particular circumstances “I baptize you” will make a statement that will impact reality. By saying this he changes the status of the child in the eyes of his Church, making him an Anglican.

The performative power of instruments and their role in shaping policies and governance has been well-documented. Berry (1983) describes management tools as an “invisible technology”, with a preponderant role in the decision-making process. Muniesa et al. (2007) develop a parallel pragmatic approach with the development of “market devices” as a concept to study the shaping of markets. Similarly, Miller and O’Leary (2007) point out the importance of “mediating tools” in decision-making processes. More globally, they study the importance of technologies to account for and organize collective action (Miller and Power, 2013). The link between management tools and governance has been studied in France (Moisdon, 2005; Aggeri and Labatut, 2010), with a particular focus on the performativity of instruments in organizations (Aggeri, 2017). Concerning public policies, Lascoumes and Le Galès (2007) have pointed out the role of instruments for the development and success of public policies, drawing inspiration from literature on management tools. Public policies are increasingly supported by market-based and management instruments for their operationalization (Doganova and Laurent, 2016). The study of instruments thus gives access to friction points on the design of the policies and their implementation.

The literature on instruments in social sciences is multiple. I will here build on three types of instruments described in the literature: (1) policy instruments; (2) management dispositives; (3) calculation tools. Lascoumes and Le Galès (2007) define a policy instrument as *“a device that is both technical and social, that organizes specific relations between the state and those it is addressed to, according to the representations and meanings it carries. It is a particular type of institution, a technical device with the generic purpose of carrying a concrete concept of the politics/society relationship and sustained by a concept of regulation”*. (Lascoumes and Le Galès, 2007, p. 4). These instruments have

a national or international strategic intent, and they help define a global frame. Policy instruments can be legislative and regulatory (laws, directives, etc.) or economic and fiscal (e.g., taxes), for example. On the other hand, management dispositives have a more focused overreach. Aggeri (2017) defines them as *“the agencing of heterogenous physical, cognitive and discursive elements designed to frame the behavior of governed subjects and to guide it towards specific goals.”* (Aggeri, 2017, p. 50). These dispositives will perform through processes involving different elementary acts (speech, calculation, and writing) that may or may not lead to the expected goal (Aggeri, 2017). Among the various elements composing management dispositives are management tools integrated in collective action management; these include business plans, or key performance indicators. In both policy instruments and management dispositives, the calculation is a structuring dimension. In the case of policy instruments, calculation tools are used both for their design—e.g., for the quantification of the situation and the expected impact—and their implementation—e.g., through mandatory calculation acts and reporting. For management dispositives, calculation is an elementary act allowing the dispositive to perform. When not integrated in the definition of policy goals or a collective management process, calculation tools can exist *per se* to quantify reality. For instance, a carbon accounting tool may be developed but not used to change practices or support collective discussions. The calculation act influences many instruments’ design and decision-making processes. It is seen as objective and scientific; despite being built (Reinertsen and Asdal, 2019).

All three instruments impact sustainable district heating, and they account for the different levels of analysis that I will employ. Policy instruments participate in framing the global environment within which district heating is developed. It acts at the international or national level and is then translated at the project level. Management dispositives are used to manage projects both at the local level and within companies. And finally, calculation tools are used at all levels, as a basis for the development of instruments.

According to the pragmatists, instruments are a relevant unit of design, as they are strongly anchored in the actor’s practices. They are grounded, making them visible during both document analysis and interviews. Based on this typology of three instruments, I will

study the instrumenting of sustainable district heating: How are instruments created and used to support the definition, development, and growth of sustainable district heating? Instrumenting will also play a part in the valuation and co-creation processes: Both are based on some instruments but also influence the way instruments are created. For instance, a valuation of sustainable district heating can be based on a particular model of district heating impacts (a first tool) and lead to the design of specific indicators (a second tool). Co-creation, like most social processes, also uses instruments to collaborate (like interactive platforms) and to stabilize a relationship between stakeholders (for instance through a contract).

*“Instruments are everywhere in your empirical reports”, I explained to Mrs. G. “Even from your very first and exploratory interviews you started talking about contracts, funds, indicators, etc.”*

- *“That is true. It was a point underlined by most interviewees, and also something standing out in the discussions you’ve had with other researchers. It started with management dispositive, to follow projects, report on the indicators and be accountable for the objectives. And when I started discussing things with more global actors, the importance of policy instruments like regulations or taxation became obvious.”*
- *“Except in the conferences about co-creation. I was always surprised by how little focus they seemed to have in the instruments supporting co-creation, with the exception of platforms. We could make a useful contribution to co-creation literature if we can show the impact of instrumentation on co-creation practices.”*

### E for “building collective Expertise”

If framing and instrumenting sets the stage and the tools with which stakeholders will act, they do not necessarily give rise to actions. For the stakeholders to act, they need to build up an expertise allowing them to appropriate the framing particularly for complex and embedded systems like district heating (Loorbach, 2010).

As developed before, district heating networks are a sociotechnical system, embedded in an urban spatiality, materiality, and subject to regulations (Marvin et al., 1999; Corvellec et al., 2013). The development of such systems requires the creation of knowledge and institutions (Jensen and Karnøe, 2018). Sustainable transition literature— showing specific characteristics of sustainable transitions like multi-dimensionality and co-evolution, multi-

actor processes, and normative directionality (Köhler et al., 2019)—acknowledges the embeddedness of sustainability transitions in a complex background and the need to build expertise and organizational capabilities (Hamann and April, 2013). Capabilities and competencies are also a component of regime rules (Geels, 2011). All in all, the building of knowledge and capabilities is a key point for transition and change processes (Kemp and Loorbach, 2003).

A way to tackle expertise is through the sociology of expertise, explicitly framed by Eyal (2013). He understands expertise as *“a network connecting together actors, devices, concepts, and institutional and spatial arrangements.”* (Eyal, 2013, p. 863). It is his definition I will use for the remainder of the manuscript. This comprehensive approach dates back to Foucault and his concept of a *“dispositive”* as an exchange network between various components (e.g., discourses, regulations, scientific norms, institutions) and key instruments of governmentality, the latter being seen as a network of institutions, processes and calculations (Foucault, 1994; Foucault, 2004; Aggeri, 2017; Raffnsøe et al., 2014). It argues that every type of action is embedded in a background of practices, material, organizational, social and conceptual arrangements. This holistic approach can also be compared with Callon’s work on the dynamics of technical and economic networks (Callon, 1990): he studied the way different networks align and interlink, creating this complex technical and economic network comprising actors, organizations, and intermediaries (e.g., technical artefacts, literary descriptions, skills).

For the case of district heating, this expertise needs to be collective: the complex actor-network will require specific collective action governance, supported by collective expertise. Callon (1990) highlights the important of coordination—and its associated expertise—to allow a translation process, leading to the convergence and alignment of different networks.

Both valuation and co-creation processes require specific types of expertise, such as institutions to legitimate the valuations, and new roles for actors to engage in co-creation processes.

*“Building collective expertise is very important”, agreed Mrs. G. “In the interviews, the lack of expertise was pointed out as a major barrier for the development of sustainable district heating: the lack of knowledge among public authorities, the lack of institutions supporting the development of sustainable district heating. In short, the lack of collective expertise around district heating.”*

- *“Building collective expertise may be less obvious to study than framing and instrumenting, but it is a pre-requisite for frames and instruments to perform.”*
- *“Indeed, and anyway, all three actions are strongly interlinked, aren’t they?”*

### **... with multiple reciprocal interrelations**

As you may have started to notice, even if I have presented here the three activities in separate paragraphs, they have strong interrelations that I will explicit below. These interrelations are very important for the framework of analysis to grasp the intricate aspect of infrastructure development and contribute to both the valuation and co-creation processes. Sustainable infrastructures are not just competing frames or a bunch of instruments. They are not even a mere network of instruments, actors, and arrangements. They are a complex material system embedded in a social, cultural, and institutional context. The interrelation between the three mediating activities can help us access some of these intricacies.

### **Framing and instrumenting**

Framing results in the production of a collective frame within which the actors can act. The process is done through negotiations (Callon, 1998; Lefsrud and Meyer, 2012), which are supported by various instruments. Instrumenting the negotiation creates mediating tools rendering the world quantifiable and giving a basis for discussions. During controversies, different valuations can be in tension, each supported by a set of instruments. This valuation work can be done differently by different stakeholders, with different visions on what values to integrate and how to integrate them (Doganova and Karnøe, 2015). Similarly, the development of instruments can create arenas where collective framing is done. Völker et al. (2020) analyze the example of the co-production of desirable circular futures. They argue that the development of a monitoring framework and indicators can become a place where the collective imagination is stimulated and where futures are collectively framed.

Although framing is supported by instruments, framing entails instrumenting: to act within the boundaries defined by framing, actors need to design proper instruments supporting the action. These instruments allow the actors to interpret and appropriate the boundaries. Moreover, the framing process entails the making of boundaries, which are manufactured, maintained, and contested based on various instruments (Doganova and Laurent, 2019). These instruments are shaped through the framing process and by its outcomes. Their design bears assumptions linked to the designer's framing of the systems. To summarize this interrelation, Garud and Rappa (1994) state that *"beliefs are externalized as artefacts, which in turn shape the belief of the researchers associated with the development of these artefacts."* (Garud and Rappa, 1994, p. 347).

### Framing and building expertise

Framing and building expertise are two co-evolving activities. Framing is based on the stakeholders' current frames (from individual actors' frames to collective ones) which are anchored in the state of expertise, e.g., the existing logics and institutions (Kaplan and Tripsas, 2008). On the other hand, framing assigns different roles and capacities to the actors, within which they can act and build their expertise. Lefsrud and Meyer (2012) specify that *"frames also define social identities [...] and position actors in power/dependency relations to other categories to actors, associating with them a range of social expectations and capacities for actions."* (Lefsrud and Meyer, 2012, p. 1480). Callon and Rip (1992) state that the building of scientific expertise can modify the norms and frame, as experts act as mediators during negotiations.

In order to perform, frames usually require the development of a new set of capabilities—for the actors to appropriate the frames—but also supporting organizations, and thus, the building of expertise.

### Instrumenting and building expertise

Here again, instrumenting and building the expertise are co-evolving activities. Devices, comprising instruments, are an important driver of expertise building: they support its development by helping build actor's capabilities, and reciprocally they are built based on the existing expertise. Iuel-Stissing et al. (2020) suggest that a crucial point in transitions of energy systems is the *"capacity to continuously modulate and transform ecologies of*

*epistemic equipment used by situated actors to make sense of their relations with systems in ways that are actionable.*” Epistemic equipment and devices are instruments creating knowledge and are a key component of expertise (Eyal, 2013). Similarly, the development of calculation tools is a way to build expertise, which can then be translated into various instruments. Finally, expertise encompasses all the mechanisms, instruments and devices that allow negotiations and alignment between policies and science (Callon and Rip, 1992).

### **... Shedding new light on what is at stake**

In a nutshell, I will here use the framework of analysis composed of three mediating activities—framing, instrumenting and building expertise—to study sustainable district heating. This investigation should allow me to contribute to the understanding of two global processes—valuation and co-creation—especially in the case of sustainable infrastructures.

The research problem, stated in the previous chapter, is *How do actors co-create sustainable valuations for public infrastructure projects?* With the analysis framework presented, I can now reveal the two research questions I will tackle to answer this overall research problem. The first one is *(RQ1) How do actors frame and instrument sustainable valuations?* This first research thread will focus on the valuation processes, unbundling the actions of actors to frame and instrument the values implied by sustainable infrastructures. The second research question is *(RQ2) How do actors frame and instrument co-creation for sustainable infrastructures?* This second thread will focus on co-creation processes, looking at the way co-creation is understood for sustainable infrastructures and what this understanding implies for instrumentation. While building collective expertise is not explicitly mentioned in the research questions, it is a key component of the framework of analysis. It links not only framing and instrumenting, but also both research questions. The expertise built around sustainable district heating will impact and be impacted both by the valuation and co-creation processes. If the two processes are studied under two research questions, I acknowledge the relationship between both and it will be highlighted throughout the investigation.

In the first part of this chapter, I have presented the framework of analysis, composed of three mediating activities: *framing, instrumenting and building expertise*. This framework allowed me to break down the overall research problem into two research questions. In the next section, I will continue to present the method by giving you an overview of the data collection conducted by Mrs. G.



## Obtaining data!

One major part of the investigation process is to collect data. In this part, I will present the various means used by Mrs. G. to collect data, what was at stake during this data collection and the challenges she faced.

Data collection was of course discussed with Anne and Franck, both to create field opportunities and to think about the data collection methods to use.

The research is qualitative, both due to the cultural background—I have had discovered research through qualitative studies and was interested to learn more about it; and Franck was working mostly in qualitative research—and to the research orientation taken. Studying the processes in infrastructure projects requires a rich dataset, giving access to the actors' practices, concerns, and frames (Star, 1999). The approach taken shares some similarities with ethnographic studies, in the sense that it aims at *“surfacing silenced voices, juggling disparate meanings, and understanding the gap between words and deeds.”* (Star, 1999, p. 383).

The investigation spread over three levels of analysis: 1) the analysis of the global background and environment, through national studies; 2) the local level through project studies; 3) the company level, looking inside Engie's activities. The choice of doing three levels of analysis is aligned with process studies: to study a process, you need to understand how the micro-level connects with larger level. Langley and Tsoukas (2016), when presenting some challenges of process studies state that: *“In particular, finding ways to dynamically explore the micro-foundations of meso- or macro-level phenomena, such as, respectively, for example, organizational capabilities and global changes in the form of the developments of standards, sustainability, community decline and regeneration, social movements, risks, etc., will add value to our search for a more holistic understanding.”* (Langley and Tsoukas, 2016, p. 16). It is also linked with the constructivist view where *“ongoing interactions among different individuals, between individuals and organizations, and between multiple levels across organizations and contexts permeate and orient change processes.”* (Langley et al., 2013, p. 9). Moreover, looking at different levels of analysis allows the multiple temporalities of infrastructures to be taken into account. Indeed, these are a key component of process studies. It also enables us to grasp

the complex intertwined temporalities and interests in the transition (Labussière and Nadaï, 2020).

On a more empirical footing, data collection was not strictly organized according to three levels of analysis. Mrs. G. started with some exploratory research, trying to understand what district heating really was and what the main concerns of the actors were. To do so, she did some semi-directive interviews within Engie and with national stakeholders of French district heating. From this base, new contacts were given—for instance at the European level—complementing the investigation. However, the first findings lacked a link with operations, leading Mrs. G. to move down to the local level, mainly through case studies. Understanding some concerns of the local level, she could go back to the more global level to understand the roots of these concerns, and the relationship between both levels. As the focus of the investigation and the analysis framework were being specified, there were a few tos and fros between the three levels of analysis on the three mediating activities (framing, instrumenting, and building collective expertise).

In this part, I will present the data collection organized per level, but just as the two research questions are linked, so are the three levels of analysis. I will start by talking about Engie: the CIFRE setting entails a particular positioning of the researcher inside the company, and thus a particular access to data. I will also conduct an analysis on the stakes of this research for the organization. From there, I will go on to the data collection at the national level and I will finish with the project level. For each level, I will link data collection with the framework of analysis, asking myself to what extent is this specific method aligned with the research approach? The presentation of each level of analysis will be here quite global. In the next part of the manuscript, at the beginning of each chapter, the data used will be stated along with its interest for the chapter at hand.

*“The process of data collection was beyond doubt the most interesting part of the investigation don’t you think?” asked Mrs. G. “I really had fun especially with the interviews and the small field journeys.”*

- *“You definitely looked passionate about that! Your curiosity always pushed you to search for more. But sometimes we needed more focused data and to narrow down the spectrum of investigation.”*
- *“That was hard. Everything was interesting, especially as I knew nothing about district heating. So, I wanted to discover, to understand it!”*

- “One thing that I found difficult was to justify the data collection in relation to the theoretical framework and the research questions. I mean, the theoretical framework was constructed along the way, and the research problem was only formalized at the very end of the process. We had some thoughts about what to look for—as the main concerns, valuation and co-creation, emerged early in the investigation process—but it was not directly linked with the actual problem.”
- *“And it was strongly linked to the opportunities that arose... Sometimes, fields I wanted to go into were not accessible but another one was offered and I just jumped right in.”*
- “But in the end, they were all beneficial to the investigation. Even the fact that some were not accessible was an interesting insight.”

### ***A focus on Engie***

To explain the data collection, I have to start with Engie. Mrs. G. was employed within the company as a research engineer, due to the CIFRE partnership. Her first dive into district heating was thus done within Engie.

### **Research on Engie**

The advantage of being inside Engie was threefold, as it offered: 1) a global view on the internal challenges and practices of the company, allowing Mrs. G. to gain some “interactional expertise” (Collins, 2004) on district heating; 2) an overview of operational district heating projects, with sometimes a privileged access to fields and data; 3) the opportunity to study the three mediating activities within Engie, analyzing how the company was tackling the challenge of sustainable infrastructure.

For the first part, it was mostly done by participating in meetings, having informal discussions with colleagues or some exploratory semi-directive interviews with experts within the company. These exchanges also allowed me to learn about the national and international context of district heating, for instance through interactions with the lobbying part of Engie.

The access to field and data will be developed when talking about the project level. However, it is worth noticing that being immersed within Engie did not always mean a privileged access to case studies and field investigation. The organization of the company, the temporality of bidding processes and the secrecy around business practices—even internally—made it difficult to interact with operation practitioners. It was for the internal

organization around sustainability that Mrs. G. could gain more insight, as Anne (or the Lab in general) was involved in many of these projects. There, she could have meetings with the stakeholders, see the presentations, and analyze how Engie was instrumenting sustainability and with what result on the framing of sustainable district heating. She could also see how these instruments were spreading—or not—in the company and participating in the building collective expertise.

I will now give a short narrative of Engie's internal organization on the research side, to explain the field access.

*As mentioned earlier, Mrs. G. was part of a Research & Innovation team (previously Research & Development affiliated with the corporate side of Engie, but a re-organization recently changed that). She thought that by being inside Engie, she could spend some time with different teams, watch them work and help them if possible. As she was a freshly graduated engineer, she imagined that with a little time and explanation, she could be of some concrete help to teams. With the research lab of Mines Paris (the CGS), she had also been beguiled with sweet dreams of research-intervention, and thought the CIFRE PhD was a good setting to do some. She arrived at Engie full of hope, and quickly asked how she could “get into the field” to see some action and some district heating. Her colleagues looked puzzled at this idea. Their interactions with the operational units of Engie were limited to mail exchanges and meetings. Organizing anything more long-term, where a research engineer was going full-time into another team fell under another jurisdiction. It was a provisional assignment, and meant that some kind of agreement needed to be signed between the Lab Environment & Society and the operational unit. Usually, they worked through projects, with defined schedules, actions and deliverables. All these interactions were contractualized. What Mrs. G. was asking seemed complicated. However, full of good will, they called their contacts in operational units to see if anything was possible: integrate her into existing projects, put her in support of ongoing actions, etc. Mrs. G. was excited: different possibilities were under examination, so maybe she could indeed do research-intervention! And then came the disillusion: she had to explain the benefits she could bring to the operational unit, to justify why she should go there and what deliverables she could give. She was taken aback: she knew almost nothing of their*

*activities, concerns, challenges, and could not see how she was supposed to write a page on the help she could provide. She tried the exercise, explaining that they could work together to define her work, but that she would first need to see and understand their work. That did not do. The operational units were under such time constraints that they did not have time to go into “fancy research projects” with no clear benefit for them. Even when the units did have the time and the interest, the contractualization was too complex—defining the objectives, the type of collaboration, agreeing on the money and knowledge exchanges—for the project to actually start. One major disappointment was that she could never actually see a team working on a bidding process. The teams were working under huge time and secrecy constraints, and had very little interactions with the world outside their own team.*

### Research within and for Engie?

Mrs. G. could not really go for research-intervention or research-action inside Engie. However, her situated research allowed an acculturation, helping her to understand the logics of action and internal organization. Nevertheless, this position of being employed by the company to study sustainable infrastructures gave rise to challenges. First, by studying Engie’s processes to instrument sustainability, she was studying an organization she was part of. Second, even if Mrs. G. was not part of any practical team working on specific projects, she was still making presentations and sharing knowledge from her investigation within the organization, thus “acting” inside the system under study.

These challenges were intensified by the CIFRE setting—the fact that Engie was partly paying for the PhD, and that Mrs. G. was employed by Engie—and called for some reflexivity.

I already mentioned at the very beginning of this manuscript the major challenge of the CIFRE partnership: the need to reconcile the academic research agenda and Engie’s agenda, Engie being a major actor of the research setting. These agendas encompass different temporalities and interests, each coming with its own established structures, expectations and characteristics. Several visions of the PhD student coexist among the various CIFRE stakeholders—a junior researcher conducting his or her first investigation, a consultant answering a strategic problem, an engineer participating in daily operational tasks—and the PhD student has to find some legitimacy in each one. This challenge has

been discussed by various scholars based on their own experience with a CIFRE PhD (Rouchi, 2017; Rouchi, 2018; Volat, 2020). Another major challenge, especially for social sciences, is having a critic's position on the organization the PhD student is committed to; and legitimating the involvement of the PhD student (Ferchaud et al., 2016; Hellec, 2014). This latter challenge is a common challenge of social sciences, which I will discuss more at length in the paragraph about data analysis.

Reflexivity is mentioned as one way to tackle these challenges and create opportunities out of them, both on the academic and empirical sides. If reflexivity is a major concern of all social science work, the way to deal with it in a CIFRE setting may be interesting to discuss. Rouchi (2017) points out the role of work restitution arenas for reflexivity. The restitutions to practitioners are not only a transmission of information or knowledge, but an opportunity for new perspectives on the organization. Instead of merely comforting the company on its practices, keeping some distance and objectivity on the organization can open up learning opportunities for the company. Demoulin and Tribout (2014) also studied the CIFRE setting as an opportunity to build reflexivity spaces both for researchers and practitioners: by performing research on the actor's practices, the PhD student opens up opportunities to work on these practices on the company side and open spaces for discussions and co-construction.

Concretely, tackling these challenges was facilitated by the liberty left during the investigation. Although Mrs. G. was expected to do some presentations to Engie, no strict deliverable was required, and the liberty to conduct her research was left to Mrs. G. Also, as regards the study of Engie's processes, Mrs. G. was not part of any of these processes. Even if she was inside the company, she was not part of the project teams. Her position was thus more external than a researcher doing research-action, but quite similar to any qualitative data collection. The fact that she was not integrated in a project team also limited the amount of operational work and meetings she had to deal with, leaving a lot of time to conduct her research. For the presentations made within the company, and the fact that Mrs. G. was accountable for her PhD results, she made clear that some of her data collection could not be shared directly with the company. Discussing matters with Franck, I also drew a limit on what could be shared and what fell under data protection. Similarly, some of the documents she could have access to within Engie were confidential,

and I made sure that none of the sensitive information was disclosed in the papers, manuscripts or other. Finally, the plurality of identities I experienced during the CIFRE partnership (leading to the birth of Mrs. G.) was also an opportunity to use several data collection methods depending on the actors we were talking to. Mrs. G.'s legitimacy was questioned by some actors—for instance, she did not manage to access some of Engie's projects because her legitimacy as a helpful engineer was not strong enough—but overall, she managed to juggle with her different hats, legitimate them through her actions and restitutions, and take advantage of them.

I have here discussed the particular challenges of the CIFRE setting. The global challenges of qualitative research and process studies—being committed to the empirical object of study and having regular discussions with practitioners—will be discussed further below. I will present how, even if Mrs. G. was integrated in the field, I could gain some hindsight and partly keep her empirical commitment at a distance for analysis. I will also discuss three risks of qualitative research highlighted by Dumez (2012) and Dana and Dumez (2015): working with abstract actors, working in a circular way, and working with one favored interpretation of the data.

### Sustainability, a new organization concern

Before shifting to the national level, I will conduct an analysis on the stakes of sustainability for Engie, going further than the organization presentation of Chapter 0. First, I will list the data used for the analysis and present how it was collected by Mrs. G. Then I will summarize Engie's position and strategy when it comes to sustainability, outlining my first results on Engie's framing of sustainable infrastructures.

Studying Engie, Mrs. G. benefitted from a privileged position as an employee of the company. During her first months at Engie, she tried to understand Engie's shift towards sustainability. To do so, she used several internal channels: documents stored online, semi-directive interviews, and informal discussions. Thanks to her position, she had access to Engie's Sharepoint, an online internal webpage where many global presentations are stored. She could have discussions on a daily basis with many colleagues and attend many meetings where projects and strategies were presented. Engie also organized several webinars for its employees, to help them understand the strategy and linked

reorganizations. Similarly, the PhD committee meeting held twice a year within Engie during the first two years of the PhD gave her opportunities to exchange on Engie's strategy and improve her knowledge of the group. Finally, with Anne, her supervisor at Engie, she organized some semi-directive interviews with targeted actors of the strategy. These semi-directive interviews focused on understanding Engie's strategy, and how it was translated for different businesses within the company.

Once Mrs. G. had a better vision of Engie's strategy, she focused her investigation on how this strategy was instrumented to make it perform. To do so, she tracked the instruments designed and used by Engie. Most were already mentioned in her first data collection but she complemented this with specific documentation, semi-directive interviews and discussions on the aforementioned tools. As the lab she was employed by played a part in the making of many instruments, she had a lot of informal discussions with her colleagues to learn more about the instruments they were developing. She wanted to know who asked for the instruments, how was the design and perimeter decided, and what was the expected use of the instrument. She could also read several final reports made on projects linked to Engie's strategy: e.g., a report of district heating Life Cycle Analysis, presentations on the monetization of externalities, and a report on the emission factor of biogenic carbon.

*Table 2* gives an overview of this stream of investigation inside the company. Only the semi-directive interviews and documents external to the lab are mentioned in this table.

Type of data	Objective	Description
Semi-directive interview–strategy direction (03-05-2020)	Understanding the strategy and reorganizations	Stages of the strategy's implementation and description of the supporting organization.
Semi-directive interview–CLIMESPACE (03-26-2020)	Understanding how the strategy is translated at the operational level	Organization of the local entity and project development process.



Semi-directive interview– Engie Solutions (04-07-2020)	Understanding how the strategy is translated at the operational level	Changes in the heating and cooling market and Engie’s positioning.
Semi-directive interview– GBL client solutions (09-09- 2020)	Understanding how the strategy is implemented	Carbon indicators for the carbon neutral strategy and client decarbonization strategy. Translation of these strategies for the GBLs (Global Business Lines <sup>16</sup> ).
Semi-directive interview– CSR department (09-21- 2020)	Understanding how the strategy is implemented	“Carbon Neutral” Working Group focusing on Engie’s carbon neutrality and the CSR (Corporate Social responsibility) department work streams to operationalize the group’s purpose.
Press release–“Capital Markets Day d’ENGIE”. 02- 28-2019 (Engie, 2019a)	Communicating on the strategy	Presentation of the strategy “global leader of the zero- carbon transition”
Internal presentation–“Our strategy in action”. 03-01- 2019 (Engie, 2019b)	Presenting the group strategy	Presenting the group’s strategy to all Engie’s employees
Document “Éléments de langage–Stratégie ENGIE 2019-2021”. 04-30-2019 (Engie, 2019c)	Framing the strategy	Communicating on the new language for Engie’s strategy of being a “global leader of the zero-carbon transition as- a-service”

<sup>16</sup> GBL were global entities at Engie but disappeared during the last reorganization.

Q&A document with ENGIE50–“Questions et réponses sur la Stratégie”. 05-06-2019 (Engie, 2019d)	Communicating on the strategy	Explaining the strategy and supporting reorganization to Engie’s major leaders.
Presentation to the investors (slides + text)–“Engie Renewables Investor Seminar”. 07-09-2019 (Engie, 2019e; Engie, 2019f)	Presenting the strategy of the Global Renewable Business Line	Presenting the Global Renewable Business Line and its strategy.
Internal presentation–“ENGIE présentation corporate 2019”. 09-05-2019 (Engie, 2019g)	Communicating on the group strategy	Presenting the group’s strategy to all Engie’s employees
Presentation to the investors–“Accelerating our client solutions development”. 11-14-2019 (Engie, 2019h)	Presenting the strategy of the Client Solutions GBL	Presenting the GBL “Clients Solutions” and its strategy through four key priorities (focus the development around three customer segments, shape the geographical footprint, drive the rapid growth of Asset-Based Solutions, boost operational and financial performances).
Presentation by Engie University–“Creating value in a decarbonized world”. 11-27-2019 (Engie University, 2019)	Translating the strategy at the operational level	Presenting “business model as-a-service” to all Engie’s employees registered for the training session.

Presentation by a working group inside Engie–“Intégrer la sobriété énergétique dans nos offres ». 12-04-2019 (Engie, 2019j)	Framing the strategy and translating it at the operational level	Integrating sobriety as a pillar in the “as-a-service” proposition. Presentation from a working group (follow-up from a report in 2018).
Presentation by Engie Impact–“ENGIE’s Carbon Neutral Transformation”. 04-07-2020 (Engie Impact, 2020)	Instrumenting the strategy	Presenting three pillars of the carbon neutrality strategy designed by Engie Impact.
Internal document–“Accounting guidelines for the contribution of ENGIE’s products and services to the decarbonization of clients”. 04-22-2020 (Engie, 2020)	Instrumenting the strategy	Guidelines and indicators to decarbonize customers and account for Engie’s contribution in this decarbonization.
Presentation by Engie Solutions–“Montages publics-privés pour offres multi-services ». 05-29-2020 (Engie Solutions, 2020)	Instrumenting the strategy	Presenting different types of PPP contracts and how to adapt them for the integrated strategy in the context of the Engie Solutions Business Unit (French entity).
Report from Engie, Saint-Gobain and Suez–“Establishing Standards for Decarbonization of Customers”. 01-2021 (Engie et al., 2021)	Instrumenting the strategy	Creating collective guidelines to account for the decarbonization of customers.
Internal presentation–“Leading the energy transition. Corporate	Communicating on the group strategy	Presenting the group’s strategy to all Engie’s employees

presentation, Update". 05-18-2022 (Engie, 2022)		
Integrated reports 2016, 2017, 2018, 2019, 2020, 2021, 2022 (Engie, 2016; Engie, 2017; Engie, 2018; Engie, 2019j; Engie, 2020a; Engie, 2021 ; Engie, 2022b)	Communicating (and reporting) on its strategy	Yearly report (each report is about the previous years, so the years covered here are 2015 to 2021) on the group's strategy, governance, organization and performance.

Table 12 List of the data collected within Engie

The informal internal discussions Mrs. G. had with colleagues within Engie were not recorded, nor were the project discussions and semi-directive interviews. But she took comprehensive notes for all but the informal discussions.

The basis of Engie's endeavor to become leaders of the energy transition is written in their bylaws through their purpose: *"Engie's purpose ("raison d'être") is to act to accelerate the transition towards a carbon-neutral economy, through reduced energy consumption and more environmentally-friendly solutions. The purpose brings together the company, its employees, its clients and its shareholders, and reconciles economic performance with a positive impact on people and the planet. Engie's actions are assessed in their entirety and over time."* This purpose was enacted in 2020 by the shareholders.

Several phases of the strategy can be pointed out, and tracked through the integrated reports. The integrated reports start in 2016, reporting on the year 2015: the year when GDF Suez became Engie.

The first attempt to transform the sustainability challenge into a competitive advantage appears to date back to Engie's former executive director, Isabelle Kocher. Under the "Kocher era", starting in 2016, the sustainability strategy was clearly framed through the three Ds: Decarbonization, Digitalization and Decentralization. For each of Engie's activities, the group was moving towards decarbonized solutions, thanks to the digitalization of their activities. The local anchorage was one pillar of the strategy, with more importance given to the geographical entities names BUs (Business Units). Isabelle Kocher writes in the 2016 report: *"And since the beginning of 2016, we have reorganized*

*all our activities around local Business Units, which are closer to our customers and encourage innovation on a daily basis.*" (Engie, 2016). Engie was thus structured into twenty-four regional BUs, five global BUs and five business lines. This transformation plan ended in 2018. This first phase laid out the Engie2030 objective: to meet the UN's development goals in 2030. More than a restructuration, Engie also aimed in this phase to develop integrated solutions, a strategic orientation in the 2016, 2017 and 2018 integrated reports. The 2019 report starts with a summary of the past three years, stating that *"ENGIE has successfully completed its Transformation and Repositioning Plan for its activities in three high-potential segments: client solutions, renewables, networks."* (Engie, 2019j). Engie's activities have been focused on renewable energy sources, energy efficiency, and gas.

In 2019, a major restructuration took place. The interviewee from the strategy presented the situation: in 2018 an analysis showed that Engie's organization was efficient in managing infrastructures but not services. Still based on the 3D, new elements were used to structure the strategy: "0-carbon transition as a service" through "asset-based client solutions" which aims at reproducing the infrastructure model for all client solutions. In this latter proposition, Engie manages the clients' infrastructure with the aim of decarbonizing them. In the editorial of the 2019 integrated report, Isabelle Kocher presents this new phase: *"The new strategic plan, presented on February 28 this year, states that we are focusing our resources and our dual expertise—that of managing complex infrastructures and offering bespoke services to our customers around the world—to support corporates and territories in their zero-carbon transition"* (Engie, 2019j). To support this strategy, the group chose to focus on four activities: client solutions, renewables, networks, and generation and supply. It also changed the group's organization, going for twenty-four BUs and four transversal GBLs (Global Business Lines). This organization kept the decentralized structure—through the BUs—while increasing the *"consistency and transparency of the Group's actions in its four main areas of activity [...]* to accelerate cross-functional performance" (Engie, 2019j)—through the four GBLs: client solutions, networks, renewables, and thermal. This phase was strongly communicated both internally and externally (press release, presentation to investors).

The last phase of this transition started in 2020 with the change of executive director (Catherine MacGregor replaced Isabelle Kocher after a transition period). In the 2020

report, a partial shift from “zero-carbon transition” to “carbon-neutral transition” can be noted; together with the disappearance of the “as-a-service” strategy. In 2021, the new direction is explicitly given. Ambitious objectives are stated: achieving carbon neutrality by 2045 (with the Net Zero Carbon by 2045 goal), aligning with a well-below 2°C trajectory, withdrawing from coal-fired electricity production and helping customers to decarbonize. This phase is still based on the four core businesses, but with a refocus of the client solutions activities. Engie disengaged from parts of the group, like Suez. Similarly, part of Engie’s activities were detached from the group and led to the creation of a new group, Equans, a leader in multi-technical services. Finally, the geographic presence of Engie was refocused into strategic areas (fewer than thirty countries) and the organization simplified with four Global Business Units (GBUs) replacing the four Global Business Lines (GBLs). To explain this reorganization to the employees, several webinars and Q&A sessions were organized by the strategy department. Since the 2021 report, the integrated reports position the group in regard to a multiplicity of collective initiatives, in addition to the UN SDGs (Sustainable Development Goals) introduced in the reports in 2018.

Figure 15 summarizes all these phases and their associated organization.

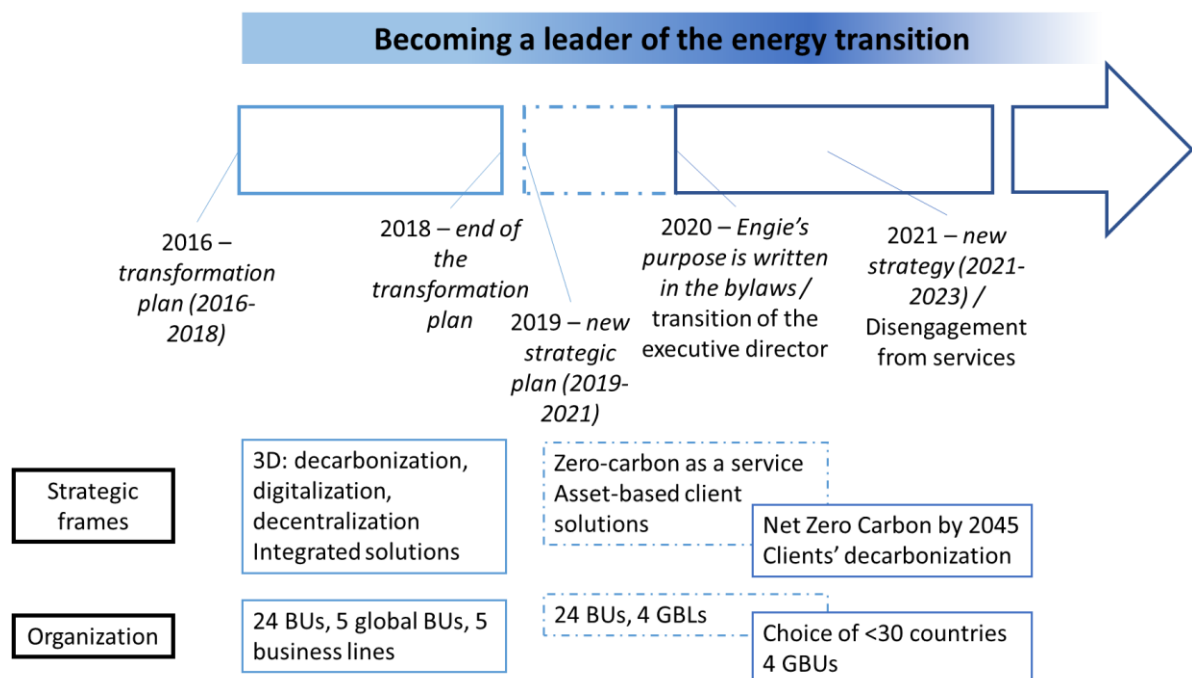


Figure 15 Engie’s strategic phases from 2016 to today

To cut a long story short, a continuity in the sustainability dynamics can be seen since 2016, driven by the “energy transition”. Although decarbonization remains a pillar of Engie’s strategy, the strategic frames have varied through the years: several refocuses have taken place, complemented by reorganizations of the group.

In the past 6 years Engie has been working on the framing of its strategy, constantly adapting it to external and internal challenges. Each strategy has been based on different valuations of sustainability and sustainable infrastructures, with a common guiding thread of decarbonization. The first phase framed the energy transition through the 3Ds, valuating digitalization and decentralization along with decarbonization. In the following phase, the valuations varied. For instance, decarbonization moved from zero-carbon as a service to the decarbonization of clients. If zero-carbon was first valuated, it then moved to carbon neutrality and net zero carbon. To perform all these valuations, restructuring was undergone to improve the group’s collective expertise and have a “strategy in action”. In addition, since 2020 the group has put an emphasis on translating this strategy at an operational level, using and designing instruments to do so. This instrumenting process is still ongoing, but I will now sketch out some first characteristics of the process, and their consequences on valuations and co-creation.

*“I remember all the fuzziness when I arrived at Engie”, frowned Mrs. G. “The first couple of months were very busy, with the launching of the “as-a-service” strategy. Then, all of a sudden everything became unstable and unclear...”*

- “The transition time?”
- *“Exactly... The end of an era. But we didn’t know what was going to happen next, whether the actions already taken would be continued. And we were just coming out of a first restructuring. Those were really uncertain times.”*
- “Then the new strategy came out.”
- *“Yes. It was both worrying and reassuring. Reassuring because the ambition seemed to stay aligned. Even if the vocabulary had changed, the sustainability focus was still a thing. But at the same time, there were rumors of restructuring. Refocusing on gas.”*
- “Engie’s leadership put a focus on communication at this time...”
- *“Yes and no. There was a lot of communication, but not a lot of clarity until mid-2021, when the organization started to stabilize again.”*
- “So, 2019-2021 were turbulent times.”

- *“It was a framing time, to borrow your words! We were straddling two strategies, one we wished to move away from, and one which was still not entirely formalized!”*



### *The national level...*

I will now continue the presentation of Mrs. G.'s data collection, focusing on the country level. It was important for Mrs. G. to fully grasp what I call here the “national level” i.e., environment within which sustainable district heating was being developed, as it impacts operational actors and local project development.

### Two countries under study: Denmark and France

First, she studied some countries, to understand the history of district heating development and the specific framing of “sustainable district heating”. This study was focused on France and Denmark, two very different countries when it comes to district heating. If the interest in France was fueled by geographic criteria, and the interest of Engie in this market, the comparison with Denmark soon emerged as a promising path. Denmark was often cited—both by academics and practitioners—as an example when it comes to district heating, due to its widespread use throughout the country (66 % of the heat supply sources) and their exploration of new generations of sustainable district heating concepts. Within Engie, it was a country they kept looking at, trying to understand how it had succeeded in developing district heating systems, and what path it was taking for sustainability. It was also an inspiration regularly cited by its public clients. Even on the academic side, the Northern countries had a particular place, being seen as advanced countries when it came to district heating. District heating systems are widespread in Denmark and well-integrated into the energy design. Moreover, environmental awareness was early integrated into the political concern: the Danish government was the first worldwide to publish a low-carbon energy transition strategy in 1990 (Johansen and Werner, 2022). A lot of research around district heating decarbonization has taken and indeed still takes place in Denmark: both 4<sup>th</sup> and 5<sup>th</sup> generation district heating systems emerged in the country. The country's organization also seemed to be very different from the French one, with a lot of planning historically done at the municipal level, and the presence of “customer-owned companies” as district heating suppliers.

To help you grasp the differences between France and Denmark, let me give you a narrated overview of Mrs. G.'s investigation in Copenhagen, the capital city of Denmark...

*Mrs. G. arrived in Denmark in June 2021. She was so glad to escape for a few weeks French society, which had turned virtual due to the health crisis. It had been a complicated fight to find a host and get the authorization to go. But it all ended well: she was to spend a month in Aalborg University (the Copenhagen offices), within a team making some interesting investigations into district heating as a sociotechnical system, and all the various evolutions of the devices around Danish energy policies. She did not know exactly what to expect: she had planned to discuss her own investigation, learn more about their work and theoretical frames, get some insights on the Danish organization around district heating to prepare her field on a Danish case study (planned for fall 2021). She quickly discovered some Danish peculiarities... First peculiarity: district heating companies were municipality-owned! If in France the system was municipality-owned, its management and operation was usually delegated to a private operator. In Denmark however, people were proud to state that everything was public. When it was not municipality-owned, it was consumer-owned: "I think it is close to all district heating that are owned by the consumer by one or the other way. In some of the large cities it's municipality-owned, so it's indirect ownership you can say because the municipality is public." (Consultant at PlanEnergi). For a consumer-owned company to be able to bear the investments of such a huge infrastructure, the municipalities can guarantee the loan and have access to low-interest loans: "it's low interest loans where the municipality guarantees for district heating projects" (Consultant at PlanEnergi).*

*From her first Danish discussions, she understood that district heating was by law non-profit in Denmark, no matter if you were a consumer-owned company, a municipal one or one of the few private ones. That was a second huge difference with France! To complement this organization, district heating companies could get access to low-interest loans in order to invest in the systems. Moreover, to ensure the quick development of district heating systems throughout the territory, zoning was set up between gas and district heating, based on the mapping of demand by municipalities and the cost-effectiveness of both solutions: "civilized war in the city council [...] we should have one grid for heating: the zoning for district heating and gas." (Consultant at Ramboll). To secure the financial balance of these infrastructures, connection to the district heating network was made mandatory. These principles were really far from what she had seen in*

France! She could not wait to learn more, and get a real example of how they managed such a system.

All these peculiarities (Table 3) arouse the interest of Mrs. G. and, as she soon discovered, of French municipalities and industrial firms. Denmark seemed to have succeeded where France was having difficulties<sup>17</sup>, making the comparison all the more interesting.

Characteristics	France	Denmark
Coverage	About 5 % of France's residential heat demand	64 % of all Danish homes
Place of the private sector in DH operations	Delegation	Contractors
Monopoly	No, competitive process	Yes, natural monopoly
Allowed to make profit on heat production and distribution	Yes	No
Zoning	No, competition between heat sources	Yes, between district heating and natural gas (until 2019)
Obligation to connect if there is DH	No	Yes (until 2019)

Table 13 Comparison of district heating organization between France and Denmark

Moreover, Denmark was now a step further than where France was, giving some important insights on the coming sustainability concerns France may face.

This first level gave an overview of the countries' development path regarding district heating. The development was studied in its historicity, from the construction of institutions around district heating to embeddedness in the materiality of existing infrastructures. This study was mostly made prior to the case studies, in order to get the

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<sup>17</sup> As pointed out in the previous part, district heating development in France was stated in a national masterplan but had trouble getting operationalized. An interest in different types of partnerships and organizations was a path under study to help achieve the development goals.

general context in which district heating systems were designed and operated. A link with the European background was also made, through a study of the latest European publications (e.g., the Green Deal, the Renewable Energy Directive) related to district heating, and interviews with major stakeholders (see *Table 4*).

<b>Organization</b>	<b>Role</b>	<b>Link between the organization and district heating</b>	<b>Date of the interview</b>
European Geothermal Energy Council	President	Lobbying for a better integration of geothermal energy in the European energy market	10-19-20
European Commission (DG Energy)	Policy officer in the Renewable Energy Unit	Work on climate target plan, try to integrate heating and cooling in the modeling and legislation	11-04-20
Euroheat & Power	Policy officer	Lobbying for DHCSs and support for European projects	11-06-20
European Commission (DG Energy)	Policy officer in the Renewable Energy Unit	Work on the general management principle to foster the development of renewable district heating and cooling systems (DHCSs), that could be integrated in EU legislation. Main	11-18-20

		point of contact for lobbying groups regarding DHCSs	
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Table 14 Stakeholder interviews on the DHCSs' European background

The country study was based on policy documents (e.g., laws, national roadmaps, national guidelines) and complemented by interviews with national stakeholders. The interviews were semi-directive and exploratory. A first part of the interview focused on an understanding of the organization: its history, role and place within the network of organizations surrounding district heating. The second part focused on the evolutions seen or forecast for the district heating market, with a specific interest on all subjects linked to sustainability. This second part gave access to data on the framing of future district heating, but also on the instruments and expertise needed to support this vision. Table 5 summarizes the national stakeholders interviewed in France and Denmark. Example of interview guides can be found in Annex 2.

<i>Type of organization</i>	France			Denmark		
	Organization	Role	Date of the interview	Organization	Role	Date of the interview
<i>State organization</i>	ADEME	Former project manager at the Ile-de-France regional directorate	06-04-20	Danish Energy Agency	Chief Advisor–Center for utilities and supply	09-30-21
	ADEME	National project leader of	05-20-20			

		the Heat Fund				
<i>Lobby groups</i>	AMORCE	Project manager on DHC and thermal renewables	07-10-20	DBDH	Business development manager	07-12-21
	Fedene / SNCU	Board member	04-08-20 – 01-08-21	DDHA	Senior analyst	10-20-21
	Cerema	Working group energy, land and buildings	05-18-20			
	FNCCR	Manager of the DHC service (energy department)	06-12-20			
<i>Consultancy firms</i>				Ramboll	Senior market manager	07-13-21
				PlanEnergy	Consultant	07-15-21
<i>Private operators</i>	Engie	Working group on	Recurrent informal	GeoDrilling	CEO	07-13-21

		DHC innovation	discussio ns			
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*Table 15 Stakeholder interviews on the national DHCSs in France and Denmark*

To access the stakeholders, Mrs. G. started by discussions inside Engie. There, people working on district heating could give her some French and European contact information they deemed relevant when talking about district heating. At the end of each interview, Mrs. G. asked which organization she could interview next, and if her interviewee had a contact within that organization. She also conducted an online search on the stakeholders of district heating, looking at institutions publishing reports of fact sheets on it.

This data is strongly linked with all the other data Mrs. G. collected throughout her investigation. If she usually started by trying to understand the countrywide context before going into the case studies, she also came back to this context after studying the projects. The data gathered when studying the projects also gave insights on the importance given to various instruments at an operational level, and on the use of these instruments. The project actors could also point her to some other organization impacting their work. Mrs. G. also learnt a great deal on district heating and projects through informal discussions with her colleagues at Engie and other detectives working in similar fields. Data from these discussions could be extracted from hand notes and added to the analysis. More globally, it participated in building Mrs. G.'s culture and expertise on district heating systems.

### [A series of workshops](#)

To complement her national and European investigation, Mrs. G. took the opportunity of working with a COST-Action to better understand their vision of future district heating. It is a network working on geothermal district heating projects: "COST-Action Geothermal DHC". A COST-Action is an EU-funded interdisciplinary research network that brings together researchers on a specific topic for four years. This network was composed of various researchers—working mainly on technical aspects—from a variety of European countries (Austria, Denmark, Italy, Greece, etc.). The chair of the action network was Gregor Goetzl, from the Austrian Geothermal Survey. He was primarily a scientist on

geothermics and hydrogeology, as were most COST-Action members. The network had contacts in many European countries through its members, and many of the members participated in actual district heating projects: e.g., experimentations on innovative systems, setting up of networks, optimization projects on existing networks.

Mrs. G. discovered this COST-Action network through an interview with the head of the European lobby group for geothermal energy. He gave her the contact information for Gregor Goetzl, who was keen on integrating her in the network. He was having some thoughts about giving more space to social sciences in the network, having the intuition that they could shed a new light on the barriers for geothermal projects. There, Mrs. G. could conduct research-action, as she attended and participated in the design of several of the network's actions.

One of her main actions was to design, with the COST-Action chair, a series of two workshops about the latest generation district heating and cooling systems. The role of this series of workshops was to gain insight on the framing of latest generation district heating and cooling systems, and launch discussions on potential instruments to support this framing. The results of these workshops do not give access to national frames, but provide an overview of the dominant frames among researchers from the COST-Action network, who come from a variety of countries. As the workshop series is not related to specific case studies, and that the COST-Action network has a European overreach, I chose to present it in this part about national level data collection.

First, a SWOT (Strength-Weaknesses-Opportunities-Threats) survey was sent to all the COST-Action participants where they could state their main concerns and hopes when it came to low-temperature district heating and cooling systems. The survey was separated into five sections, adapted from a PESTLE analysis: (1) the technological part to comfort the participants who mostly had a technical background (T), (2) the political and legal ones (PL), (3) the economic aspects (E), (4) the social ones (S), and finally (5) the environmental ones (E). Ten participants filled in the survey. These different aspects gave Mrs. G. access to the framing of low-temperature district heating and cooling systems, and how this framing challenged—or not—a vision of conventional district heating systems.



Mrs. G. used the results of the survey for the first workshop. It took place virtually in October 2021 and gathered 16 participants from a variety of European countries. For the first part of the workshop, three speakers gave an overview of projects related to low-temperature district heating and cooling networks integrating geothermal energy. The first one presented CROWD THERMAL, a European project on community-based development schemes for geothermal energy. The second speaker gave an overview of 5<sup>th</sup>-generation district heating and cooling systems in Denmark. The last speaker described an experimentation project of “smart block” in Vienna. The second part was an interactive one based on the SWOT/PESTLE analysis. The results of the online survey were summarized by Mrs. G to be used as a discussion launcher during the workshop. The technological part was taken out of the summary as the focus there was on the non-technical aspects impacting the development of low-temperature district heating and cooling systems. Mrs. G. renamed the categories depending on their key focus, as stated by the participants. For instance, the social one became “social context: multi-stakeholder integration and social acceptance” as the two main concerns for the development of the systems were: 1) integration of a variety of stakeholders into a collaborative action, 2) social acceptance by the consumers and local stakeholders of such systems. The final categories were the following:

- Legal and political issues
- Social context: multi-stakeholder integration and social acceptance
- Economic aspects: pricing and business model
- Environmental impact

During the interactive parts, the participants were in small groups, each group working on one category. They could add more ideas on the SWOT analysis for their category, and discuss interesting practices that could be replicable. This interactive part was based on PADLET, an online interactive tool (see *Picture 6*), so that the participants could add ideas, change the color, add pictures, etc.



Picture 6 Screenshot from the PADLET used in the first workshop

This workshop gave Mrs. G. an overview of future opportunities, current facilitators, points for attention, and barriers regarding low-temperature district heating and cooling systems. A summary of these findings can be found in *Annex 5*. However, the workshop gave neither concrete practices nor a holistic vision of future district heating and cooling. Thus, the second workshop, which took place in January 2022, was specifically focused on the setting up of partnerships and contracts for future district heating and cooling systems. This aspect was underlined as a paramount point of attention during the first workshop, without being thoroughly tackled by the participants. Mrs. G. also hoped to gain insights on the instrumentation and expertise needed for future district heating and cooling systems.

The second online workshop gathered five participants from the pool of participants having attended the first workshop. Building on an imaginary situation, the goal was twofold: (1) define the stakeholders who it could be beneficial to integrate into the design and operation of the system and (2) create a possible organization of the stakeholders' network (making explicit their links, roles, responsibilities, etc.). The imaginary situation gave the boundaries of the system–context, basic stakeholders, and ambition of the system–trying to be open enough to allow creativity, and focused enough to launch discussions. Using Miro (an online black board), the participants first added all the stakeholders they found relevant (*Picture 7*). Based on this stakeholder map, a common story was then built with the participants. Starting with one stakeholder a first participant

gave some specifications about his role and his interaction with another stakeholders. A second participant then continued the story by adding some new interactions with another stakeholder, and so on.



Picture 7 Screenshot of the Miro board of the stakeholders' map in workshop 2

The online setting made it difficult to interact, but two points stood out: (1) biomass was not considered as an advantageous resource for low-temperature district heating systems due not just to technical specificities but also to logistic and environmental issues, and (2) the most important part for the participants was to have a project leader with a clear vision and concept, which could then properly integrate the needed stakeholders. A summary of the workshop, with the given imaginary situation and the co-created story can be found in *Annex 5*.

Mrs. G. drew several lessons from this series of workshops:

- Most of the participants had a technical background and found it difficult to shift from this technical frame. Thus, the solutions were mostly discussed in terms of technical issues, the organization and governance staying very conventional. For instance, citizens were highlighted as major stakeholders who could be prosumers and participate in the network's design, but at the end of the day they were merely considered as consumers.

- A predominance of the *“once we have the right technical system it will work”* philosophy among the participants. Without all the technical specificities of the network, the participants were unable to co-create a solution, but at the same time they seemed to consider that the “right” technical system will make the rest of the solution appear quite logically.
- Participants each had their own technical focus and stayed within their own zone of competence without trying to integrate the bricks developed by the other participants. Even if interdisciplinarity and a need to co-create was pointed out, almost no cross-sector discussions took place.

These workshops provided a link between the national findings and the very local ones, by going into the details of the stakeholders’ framings and showing the difficulties in envisioning future district heating. It showed the benefits to be obtained by studying how these frames could align on a specific project and build innovative solutions.

### *Projects: A tour of Western Europe, with a detour by Canada*

The last level of investigation took place on actual projects to see how the national or the internal processes inside Engie could lead to concrete projects.

Case studies are the basis of the empirical data collection, representing a contemporary study unit (Yin, 2018). However, the definition and boundary of a case study are not that clear, and its uses have been multiple in qualitative research (Dumez, 2016). Using multiple case studies to then build a theoretical framework was formalized by Eisenhardt and Graebner (2007): the in-depth study of case studies, with their extensive description, may be used to develop assumptions and shed light on key points which can later be linked to theoretical literature streams. Yin (2018) describes the research situation favorable to the use of case studies: *“you might favor choosing case study research, compared with the others, when (1) your main research questions are “how” or “why” questions, (2) you have little or no control over behavioral events, and (3) your focus of study is a contemporary - as opposed to entirely historical phenomenon—a “case”.*” (Yin, 2018, p. 33). Mrs. G.’s focus when doing the case studies filled all three conditions.

The different cases were chosen to present a variety of situations. Indeed, the investigation was designed to study the process of “sustainable district heating” in the making (Langley, 1999). However, the lifespan of the technical system is far longer than the 3-year investigation granted to Mrs. G. Studying historical district heating gave interesting insights on the historicity of the systems’ evolution. Another way to have access to this process was to choose cases at different phases of their lifecycle. Depending on the phases, Mrs. G. assumed that the sustainability strategy would be different, from designing from scratch an innovative and carbon-neutral system to decarbonizing a system already operating. As the projects under study are characterized by a partnership between a public owner and a private operator, Mrs. G. decided to characterize the phases of the lifecycle as the one of a Public Private Partnership for public infrastructures: project identification, detailed preparation, procurement, project implementation and operation (European PPP Expertise Center, 2011). As the object of study was a public infrastructure owned by a public partner and operated by a district heating company, these phases could apply to most projects. Even in Denmark where the district heating is

publicly operated, the district heating company has to propose a project to the municipality and sign a project agreement. Pettigrew (1990) also describes comparative case study method as a means to do longitudinal research: a study of change linking content, contexts and processes of change.

Part of the choice depended on the opportunities given by the investigation: Mrs. G. had access to some of Engie's projects, and others were accessed through the COST-Action network.

### A variety of case studies

Both Engie and COST-Action gave Mrs. G. a pool of projects to look into. Obviously, a first selection was made on the "accessible" projects, meaning that some documents were available and interviews could be conducted. From the remaining projects, the choice was made to have a diversity of lifecycle phases represented, and also to get an overview of various western countries to grasp the diversity and point out what is invariable. In the end, due to the level of data available for each case, some specifications were made on the analysis level for the projects. Some were studied comprehensively whereas others were only looked at for a specific aspect or to confirm and illustrate results.

*Table 6* summarizes the main projects and their specifications both concerning the lifecycle phases studied and the project analysis level. They are classified by access to data: from the most comprehensive data collection to the scarcest ones.

Case study	Country	Network of access	Lifecycle phases studied	Level of analysis	Description	Remark
Hornsby – “Therm o- road”	Denmark	COST- Action	project identification, detailed preparation, procurement, project implementation	Comprehensive study	Recent, small-scale (6 houses) experimentation of shallow geothermal heating and cooling coupled with cross- sector integration under a roadbed (e.g., wastewater and rainwater management).	Comprehensive access to stakeholders.

Besançon	France	Engie	operation	Exploratory case: focus on the operation and the biomass supply	Historical district heating (1968) based on waste heat recovery and biomass. Pioneer in the integration of biomass (2006, 2013). Public service delegation (leasing).	Limited access to the network history but good access to stakeholders of the biomass supply chain.
Dunkirk	France	Engie: autonomous research	identification, detailed preparation, procurement, project implementation, operation	Exploratory case	Historical district heating (1985) with historical integration of industrial waste heat. Public service delegation.	No access to the main district heating company.



Greater Copenhagen	Denmark	Academic visiting	operation	Study of the Danish organization around district heating	Regional district heating covering 20 municipalities with heat transmission and distribution networks. Ambitious decarbonization roadmap.	Limited study but access to studies from a previous PhD.
Ottawa	Canada	Engie	identification, detailed preparation, procurement, project implementation, operation	Focus on the making of the PPP contract and the co-creation activities.	Publicly managed district heating which shifted to public service delegation in 2020. Push for co-creation and decarbonization in the tendering process.	Limited access to Engie's stakeholders and no access to external ones. Good access to documentation.

Table 16 A variety of case studies

Depending on how the projects were identified, data availability and the interviewees were different. Some projects were “failures” in the sense that Mrs. G. could not follow their development due to internal or external reorganizations and delays.

I will give some narrative accounts of Mrs. G.’s investigation in these case studies throughout the manuscript, justifying the interest in each project for the investigation. The people interviewed for each case study will also be stated at the beginning of the first chapter where the case is used.

The projects mentioned are only the projects that were part of Mrs. G.’s investigation (through some limited or more comprehensive data collection). However, other projects were also encountered through webinars, reading or informal discussions. These projects were also important for Mrs. G. as they participated in her cultural integration in the world of district heating systems and could guide her investigations. Moreover, some initiatives linked to district heating—experimentations, research projects, challenges—were also closely followed by Mrs. G. She conducted a specific investigation of two of them (see *Table 7*). They are not part of the case studies mentioned before as they were not intended to become operational in the short-term and to lead to direct practical application in district heating projects. They stood out as interesting cases to study for the ambitious and innovative approach to district heating. The one concerning Helsinki is an open challenge in which Engie participated, aimed at producing ideas for the design of Helsinki’s district heating. The one concerning Vienna is a project Gregor Goetzl was working upon when Mrs. G. first contacted him. It aimed at developing low-temperature district heating and cooling systems in urban areas, and investigating the possibility of connecting it to conventional district heating. Mrs. G. found both projects to be forerunners in their field.

Case study	Country	Network of access	Presentation
Helsinki Energy Challenge	Finland	Engie	“A global one-million-euro challenge competition to answer the question: How can we decarbonize the heating of Helsinki, using as little biomass as possible?” (extracted from <a href="#">Home   Helsinki Energy Challenge</a> ).
AnergieUrban Lighthouse projects	Austria	COST-Action	Research project on the integration of 5 <sup>th</sup> generation DHC networks into existing buildings (no practical application).

Table 7 Complementary case studies

To give you a vision of Mrs. G.’s investigation into the Helsinki Energy Challenge, let me now give you a narrative account of this unusual opportunity...

*It was early 2020 when there was a flurry of activity at Engie! Something quite unusual was afoot. An open challenge had been launched by the city of Helsinki... Mrs. G. was intrigued. What was so different about this call for projects? Was this challenge really something new compared to all the bidding processes Engie was involved in?*

*The city of Helsinki relies heavily on coal and fossil fuel for its heating. Nevertheless, it claims to be “one of the leading cities in the transition towards a sustainable future, with the goal of becoming carbon-neutral by 2035” (Helsinki Energy Challenge, 2021). For its sustainable future, the city wants to go beyond burning biomass... In order to get ideas for its sustainable future, the city had launched an open challenge: anyone could participate and create a project to decarbonize Helsinki’s heating system.*

*Engie wanted to apply and create an offer, with some European partners. Mrs. G. was soon contacted to participate in one of Engie’s working groups on incentive pricing: how could consumers be motivated to change their heating habits? She had encountered various attempts at incentive pricing, rewarding customers who consumed “well”–*

*meaning that their return temperature was low enough for the system to be optimized. However, such clauses were hard to set up, as the secondary network ensuring the heating inside the building is outside the district heating company's perimeter: the final consumer is out of reach. Apart from this group, several others were working on technical aspects of the solution: the idea was to go for a fully electrical solution, working with the assumption of Helsinki that electricity would be decarbonized and cheap by 2035.*

*The summary of the solution was accepted to go forward into "phase 2" in November 2020. Engie was one of the finalists! Phase 2 was a "co-creation phase": dialogs with city experts, etc. At this point, the team was refocused on the core actors. Mrs. G. was not part of meetings anymore. But from discussion with her colleagues, she learnt a few things... The team had several discussions with experts (employees from the current district heating company, experts from Finnish ministries, etc.). While the dialog was interesting, the technical specifications remained blurred: some very specific data were needed to build a complete solution and make relevant assumptions, but these data were never fully available.*

*The structure of the final entry Engie submitted in January 2021 was aligned with seven criteria stated by the municipality of Helsinki: climate impact, impact in natural resources, cost impact, implementation schedule, implementation feasibility, reliability and security of supply, capacity. As the development space was limited (about 25 pages), the team could not go deep into the details on innovative aspects, including the pricing...*

*All in all, four teams—including Engie's—were awarded out of the ten finalists. Of course, Engie was interested in the next steps... Will the city launch a call for proposals to actually make the transition? For now, the municipality of Helsinki has not done so. Due to the COVID pandemic there were some restrictions on collaboration during the challenge, and no strong relationship could be created between the municipality and the finalists.*

*This challenge interested Mrs. G. for several reasons:*

- It was launched very early in the identification phase of potential projects.*
- It was very open: anyone worldwide could participate; all the projects were publicly available after the challenge (apart from technical appendices).*
- It offered an interesting view on sustainability beyond biomass: the pool of solutions seemed limited, and highly dependent on the local knowledge of the experts working on the project.*

For all these projects—the district heating case studies and the two initiatives—data was gathered through semi-directive interviews and project documents. A list of primary and secondary data is developed at the beginning of each chapter. The interview guides were designed differently depending on the level of analysis for each case and the stakeholders interviewed (see for example Annexes 2 and 6). A major part of the interviews was recorded and transcribed. For those that could not be recorded, a comprehensive summary of the interview was made, based on notes taken during the interview.

For comprehensive case studies, part of the investigation focused on the historical development of the system—e.g., description, barriers, successes—the role of the stakeholder in its operation or during its development (with questions on the system’s organization) and its possible future evolutions. This structure allowed Mrs. G. to gain insights on the instruments that helped the historical development of the network and its current organization, and also the framing of the system. It also gave some insights on the vision of future district heating, and the expertise that would be needed to be built to support this vision. In these cases, a large variety of stakeholders were interviewed: Mrs. G. started with the first contact given by the COST-Action network or Engie, which was usually the operational project leader. From there, she accessed the other stakeholders through two means: 1) a stakeholder map created online and through project documents; 2) questions after each interview on other relevant stakeholders and their contact information.

For more focused case studies, the investigation process was very similar, except that the perimeter was narrowed down. The questions focused on one particular aspect. For instance, for the Ottawa case, the questions were about the genesis of the request for proposal, the organization of the team to answer, interactions during the answer, and finally, operations. For all these stages, Mrs. G. concentrated on the instrumentation and the expertise supporting the actions. Usually, during focused case studies, the pool of stakeholders Mrs. G. could access was more limited, and she could only interview one or two people indicated to her by the project leader or hierarchy.

A difficulty encountered by Mrs. G. was on the perimeter of her study. An example of the impact of such a difficulty was a semantic one. She kept on speaking about stakeholders, but had trouble defining who the core actors of the project were. Another difficulty was methodological, who should she interview? Who was part of the project? She mapped the stakeholders by specifying the core actors of the district heating project (the public owners of the district heating company, as they were the focus of her study), the other project stakeholders (e.g., suppliers, customers, contractors, consultants), and the external stakeholders having an indirect impact on the project (like European and national institutions) (*Figure 16*). The actors are the focal point of the study as they design the system, its governance, activities, and strategy. The other project stakeholders can be seen as key partners in the project. Depending on the project design, this typology can vary: for instance, in Denmark, consumers are core actors as they are the ones owning the system. Depending on the level of analysis for the project, and the specificities of the project, Mrs. G. only interviewed core actors, or could go to other stakeholders. Only humans are stated here, but as we have already highlighted, a lot of instruments structured the relationship in the stakeholder network. The diagram shows a possible pool of interviewees during case studies, hence the choice to focus on humans. Similarly, the technical system and the natural and built environment are not stated as stakeholders but I acknowledge their influence on the development of sustainable infrastructures (Latour, 1992; Star, 1999; Driscoll and Starik, 2004).

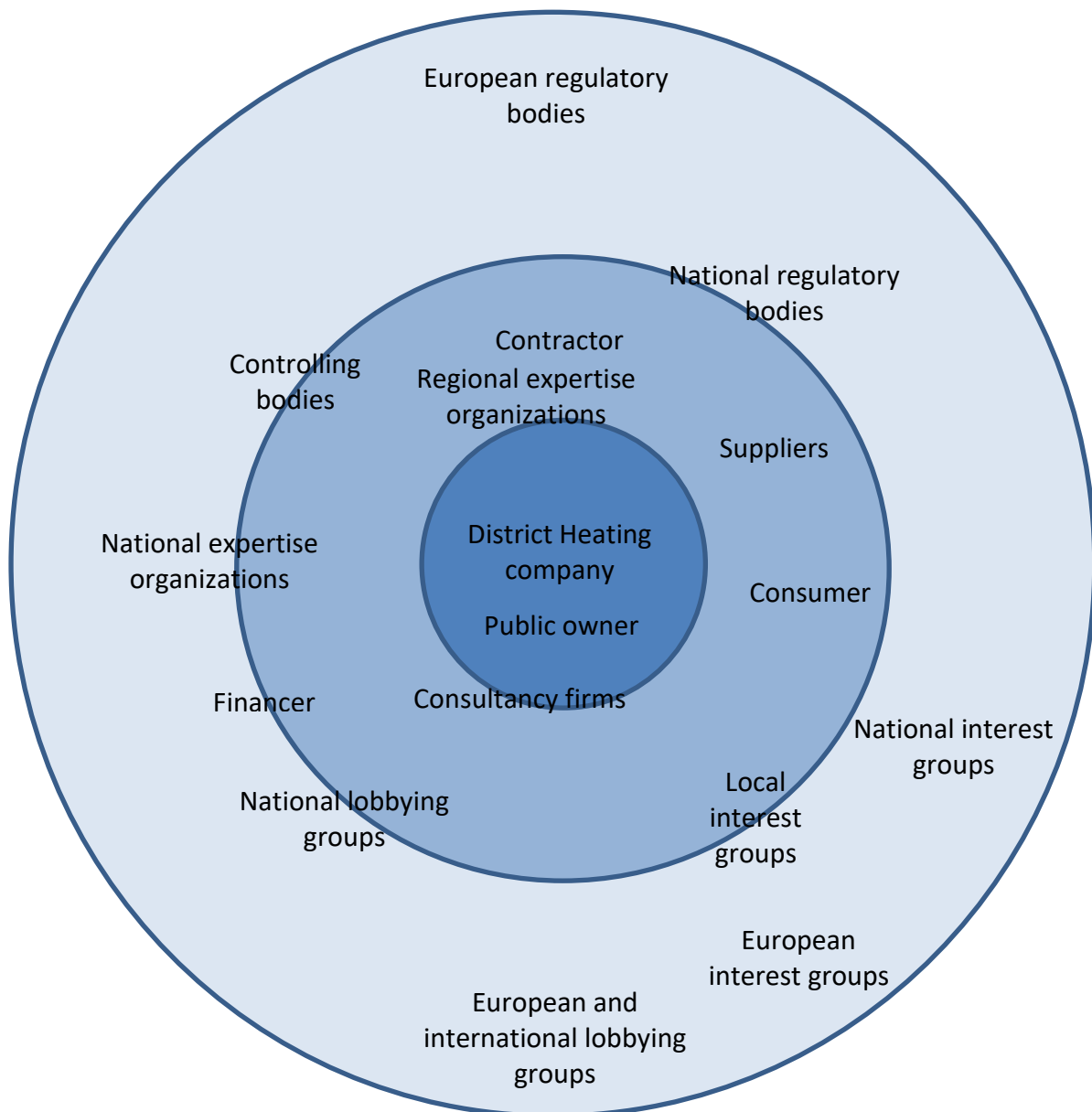


Figure 16 The stakeholder ecosystem

To complement these interviews, many documents related to the project were studied. For some cases, Mrs. G. had access to internal documents like working documents on bidding processes or final contracts. For the others, it could be the public call for tender or project presentations. Like for the list of interviewees, the list of secondary sources used will be stated at the beginning of the relevant chapters. These secondary sources were important for accessing some stakeholders that could not be interviewed and to gain objectivity on the case by limiting interview bias. In all cases, the documents were primarily opensource documents on the project that could be found online (e.g., project

description, district heating website). They were complemented for Engie cases by internal documents the actors gave me access to (e.g., project presentations, answer to a request for proposal, contract) and in some cases by presentations sent by the interviewees.

Some interview memos and transcripts can be found respectively in *Annex 3* and *Annex 4*, alongside a complete overview of all the interviews made (*Annex 1*).

*“I have collected such a disparate set of data!”* exclaimed Mrs. G. *“And some were in French, some in English. I even had some documents in Spanish.”*

- *“That certainly raises some challenges for the analysis... The temporality, levels of analysis, countries, type of data, all was different...”*
- *“Yes, but it is part of the investigation. Public infrastructures spread through the institutions, the actors, the instruments. It can take different shapes, be visualized or accounted for through different means. It is what makes it so exciting to study!”*



## The challenges of data analysis

Mrs. G. benefited from a rich set of data, but I needed to analyze these data in order to answer the research problem. Even if I had the guiding thread of the analysis framework, the data analysis presented various challenges inherent to process studies. The research approach builds on the empirical work where the researcher dives into the object of study to participate in theory (Langley, 1999). Some back and forths between practice and theory are then conducted to narrow down the investigation and build up the contributions.

### *A variety of sensemaking strategies*

The process studies approach comes with its own challenges. The data covered multiple units of analysis whose boundaries were unclear: which data should be included in the analysis of the framing process? The data were eclectic: events, quotes, documents, etc. and had various temporal embeddedness: archives, discourses on past events, etc. To make sense and analyze such data, Langley (1999) proposes seven strategies. Among these seven strategies, I chose to build on two a narrative strategy and a grounded theory strategy.

First, I made several empirical descriptions (Dumez, 2016) throughout the document. These non-theoretical descriptions allowed me to structure Mrs. G.'s data around specific events or cases, and to give the reader a concrete view of the investigation. In addition to these descriptions, I used narration (Langley, 1999; Dumez, 2016) to problematize some historical processes, highlighting their turning points. For instance, chapter 4 offers a narration of valuations in France and Denmark when it comes to sustainable district heating. Similarly, in chapter 6 I narrate of the instrumentation process in Greater Copenhagen and Ottawa. These narrations highlight some tensions to elucidate, which could then be analyzed from a more theoretical angle. I here want to draw the reader's attention to the fact that not all narrations and descriptions are made through the "narrative style" where I show Mrs. G.'s actions. They will still be put in italics, but I will explicitly tag all the narrations of the manuscript.

As another way to bridge theory and empirical data, I mainly used grounded theory strategy (Langley, 1999; Emerson et al., 2011a), with coding processes. The process was abductive, with a reiterative, back-and-forth process between theory and empirical data. It builds on the idea of methodological bricolage (Pratt et al., 2020): I did not merely use some “off-the-shelf” methods, but building a coding process suited to the investigation. First all the interview memos and transcripts were “open-coded” to make some major themes stand out. These themes allowed me to build both the research questions—with the major themes to be investigated—and the analysis framework, looking at interesting activities supporting these themes.

Then, I made some focused coding processes (Locke et al., 2022). In chapter 4 and chapter 5, I went through Mrs. G.’s material on French district heating and made some inductive coding of the instrumentation (Point, 2018). Each instrument was extracted from the data, and described. From this empirical description some categories were coded, giving access to points of tension in the instruments’ design and purpose. Similarly in chapter 8, I analyzed several instruments from Mrs. G.’s investigation at Engie with an inductive coding process. The data were structured to access the design and implementation processes of each instrument. Each step of the process was described and coded, building a theoretical three-step process of expertise building. This focused coding builds on the instrumentation process to analyze data, and to then obtain results on the other two processes.

In chapter 5, I went for more abductive coding. I drew on collaborative governance and co-creation literature to find some main co-creation activities. In a different stream, I coded collaborative activities in some case study data. I then tried to see if these activities aligned with the main co-creation activities of the literature, gaining insights on the framing of the co-creation processes for infrastructure projects.

In each chapter, the analysis used will be recalled and developed before going into results.

### *The risks of data analysis*

Using some sensemaking methods for data analysis does not entirely prevent the risk of not finding interesting or robust results.

Dumez (2012) and Dana and Dumez (2015) point out three major risks of qualitative research. The first one is to deal with abstract actors. Instead of showing the actions and practices, the researcher can go for an indirect and passive style, where the reader sees things happening, but no actors. This does not allow analysis of the processes, because they appear as natural things happening without human intervention. Nothing shows the validity of the results, as no actor practice or discourse supports them. The first version of this manuscript fell foul of this risk, and the reviewers called for more actors. I tackled this problem by using descriptions and narrations, shifting from the indirect, impersonal style to a direct one.

The second risk is the risk of circularity: finding in the data what you were searching for. The data only serve to confirm pre-established ideas and do not provide anything new. This risk is particularly significant when using coding methods. To take into account this risk, I chose to discuss the coding with Anne, Franck and Martijn (a co-author), to limit the influence of my own biases. I sent the raw material to them prior to the discussion, so that they could read them without having heard about my coding. During a CIFRE PhD, or any kind of research-action, staying objective is a challenge as the researcher dives into the empirical case. Losing this neutrality can impact data collection (the interview guide can be biased) and analysis (not looking at the different valuations in a neutral way but considering one as better, which is in contradiction with the approach of valuation studies taken). For instance, I was immersed in the practitioners' technical view of district heating. To step back a little from view, I took the habit of going in the opposite direction—downsizing the importance of technical concerns—instead of remaining neutral. Thanks to comments from other researchers, I realized my mistake, and finally managed to position my research so as to see the technical viewpoint as one frame made by the actors that influences the valuation and co-creation processes. Instead of moving away from it, or on the contrary trying to understand all the details of the technical activities, I analyzed how this dominant frame shaped the instrumentation and expertise. To counterbalance this

risk, all my interview guides were read by Franck, who had an outsider's view of the investigation.

The last risk stated by Dumez (2012) and Dana and Dumez (2015) is not to take into account the equifinality phenomenon. In this case, the researcher only looks at one explanation to the phenomenon, not looking at any other hypotheses. I have tackled this risk by looking at various theoretical frameworks, and explicitly accounting for the problematization process. I have tried to justify the choices made, while acknowledging that other choices could have led to interesting results.

Globally, being immersed in the field for three years has been a great opportunity. It allowed Mrs. G. to gain some "interactional expertise" (Collins, 2004), being able to have discussions with the practitioners and understand what they were saying. To stay reflexive on this positioning, the supervision by an external researcher is fundamental. He has some distance from the field and can better see if the research is tending to fall foul of one of the abovementioned risks. Similarly, presentations to other researchers and collaborative work with them on Mrs. G.'s empirical fields were opportunities to gain some reflexivity on the data collection and analysis (Langley et al., 2013).



## Part 1 in a nutshell

To summarize this first part of the manuscript, I started by narrating a field investigation that Mrs. G. made in Besançon during the first year of the research. Continuing with this narration, I gave some preliminary descriptions of French and European district heating. The first chapter allowed me to highlight some characteristics of district heating, like its technical anchorage, the long-term partnership between a public authority and an operator to manage the infrastructure, or the sustainability change it appears to be undergoing.

In the second chapter, I defined the object of study, i.e., district heating owned by a public authority and operated by a district heating company, as a public infrastructure. I also stated that I will approach sustainable district heating as a sociotechnical system performing a definition of sustainability. I then developed the problematization process: from the empirical concern of Engie for sustainable business models, I moved on to a theoretical framework combining valuation studies as a social practice and public sector co-creation. This led me to the following research problem: *How do actors co-create sustainable valuations for public infrastructure projects?*

Finally, in the third chapter, I developed the method used, with a process studies orientation. First, the framework of analysis composed of three mediating activities: framing, instrumenting and building expertise. With this framework, I broke the research problem down into two research questions: *(RQ1) How do actors frame and instrument sustainable valuations? (RQ2) How do actors frame and instrument co-creation for sustainable infrastructures?* Afterwards, I presented the variety of data collected, organized into three level of analysis: the corporate level through Engie, the national level illustrated by France and Denmark and the project level through seven case studies. I finished with the challenges of data analysis, presenting the sensemaking strategies used—description, narration, and grounded coding—and taking a reflexive stance on my position and the risks of qualitative research.

In the next part, I will present Mrs. G.'s investigation. Part 2 is structured following the two of the three levels of analysis (national and project levels), and I will show how Mrs. G. went from one level to the other, and how each level interacted with the other. The corporate level intertwines both levels, thus does not have a chapter of its own. Organizing part 2 per analysis level will give me an opportunity to show the interrelation between the two research questions. Each chapter will investigate an empirical issue, linked to one or both research questions (*Table 8*). I will link these empirical issues to more theoretical contributions in the last part of the manuscript.

	<b>How are actors co-creating sustainable valuations for infrastructure projects?</b>	
<i>Research questions</i>	<i>How do actors frame and instrument sustainable valuations?</i>	<i>How do actors frame and instrument co-creation for sustainable infrastructures?</i>
<i>Research level</i>		
<i>Global</i>	Chapter 4	/
<i>Local</i>	Chapter 6	Chapter 5 Chapter 6

*Table 8 Structure of Part 2 in relation to the research questions*

## PART 2: Following Mrs. G's investigation







## Chapter 4: A global sustainable value proposition?

*“Les hommes n'acceptent le changement que dans la nécessité et ils ne voient la nécessité que dans la crise.” (Jean Monnet)*

*“Mankind only accepts change when necessary, and it only sees necessity in crisis.” (own translation)*



## Chapitre 4 : Une proposition de valeur durable et globale ?

Au cours de cette première étape de l'enquête, j'ai voulu répondre à la question empirique suivante : *Comment le cadre des réseaux de chaleur durables est-il construit via des instruments au niveau national puis traduit aux niveaux plus locaux ?*

Pour ce faire, j'ai mené deux analyses. La première était une analyse historique du cadrage national du réseau de chaleur en France et au Danemark, étudié à travers des instruments structurants conçus par le gouvernement. En France, j'ai étudié les Fonds Chaleur, un dispositif de subvention de la chaleur renouvelable, et au Danemark les dispositifs incitatifs lancés successivement par le gouvernement pour soutenir des moyens de production spécifiques. Les processus de cadrage historique diffèrent dans les deux pays, mais tant en France qu'au Danemark, la valorisation du réseau de chaleur durable s'est faite par la décarbonisation et l'intégration de sources de chaleur renouvelables dans le mix du système.

La deuxième analyse visait à détailler le processus de cadrage français du réseau de chaleur durable. Cette analyse a été faite à travers l'instrumentation du réseau de chaleur durable, des instruments de politique publique aux outils de gestion soutenant son développement. L'analyse a montré que la valuation n'était pas seulement axée sur la décarbonation. Le cadre du réseau de chaleur durable est encore en construction, les valuations étant remises en question par d'autres qui émergent au niveau local.

En conclusion, le processus de cadrage est sans fin, car les cadres sont constamment débordés (Callon, 1998). Le cadre national français du réseau de chaleur durable est basé sur une expertise existante et son instrumentation. Des instruments spécifiques peuvent être développés pour soutenir le développement du réseau de chaleur durable, mais ils découlent toujours de la logique existante – ici la logique technico-économique. La traduction de ces instruments en instruments opérationnels constitue un terrain de controverse : des cadres alternatifs peuvent émerger du niveau local. Certains acteurs non gouvernementaux jouent un rôle dans l'instrumentation de ces cadres alternatifs et dans la valorisation du réseau de chaleur durable. Ils participent à la construction d'une

expertise collective locale. Cependant, le manque d'expertise globale partagée sur le réseau de chaleur durable empêche l'alignement de l'instrumentation vers un cadrage commun et les valuations qui en résultent.

In this chapter I will present the investigation of Mrs. G. at the national level. This investigation was to understand the background in which district heating projects could be developed, and some frames of sustainable district heating. She tried to answer the following empirical question: *How is the frame of sustainable district heating constructed through instruments at the national level and translated at more local levels?*

To do so, she investigated two countries: France and Denmark. Her investigation is based on a study of instrumentation. It is twofold: a historical account of district heating development in both countries and a focused analysis on the French instrumentation of sustainable district heating. The historical account will be presented as a problematized narration first in France, then in Denmark. From there I will highlight some of the main characteristics of this development that have an influence on the current framing of sustainable district heating. The historical detour explains the instruments currently in place, built on existing instruments, rationales, and expertise on district heating. The institutions and their role were actually designed as this history unfolded. It allowed me to take into account the temporal aspect of valuation processes and the embeddedness of public infrastructures in reality. The focused analysis of the French instrumentation I will present was achieved through the coding of various documents gathered by Mrs. G. At first, the goal was to understand what frames of sustainable district heating are being developed through various instruments, and based on what actually exists. Three points of tension stand out from this analysis—linked to the translation of the sustainable district heating frame from the global to the more local level—which I will discuss in the chapter. For each part, before going into the analysis process and results, I will quickly go through the data collected by Mrs. G. and make a list of all the analyzed data.

Before diving into the history of district heating in France and Denmark, I will do a short account of a dominant international framing within which energy infrastructures and district heating are embedded. Just like looking at national frames is important to understand local ones, international frames have a strong influence on national ones through e.g., acculturation, legislation, and funding programs. This next paragraph is based on a literature review on the impact of climate change in shaping energy policies and collective action.

## *The energy transition as an answer to climate change*

In the 1990s, a policy debate arose in the USA on the relationship between environmental issues and economics. Hoffman and Ventresca (1999) studied how the debate was framed and possible solutions for its reframing, building on institutional theory. They showed that the regulatory structure for the environment was based on standards, giving a partial understanding of environmental issues and potential solutions. The operational and engineering aspects built on these standards and norms to create instruments, which in turn fed the standards. This institutionalization was supported by a cognitive aspect reinforced by the given education and international regimes. These international regimes were recently studied by Low and Boettcher (2020). They analyzed how climate governmentalities emerged around the Copenhagen Accord of 2009 embedded into the “green governmentality” and “ecological modernization” governmentalities of the Kyoto Protocol era (Figure 17).

Governmentalities of Kyoto era	Emerging rationalities in the Copenhagen era	‘A fixing strategy ...’
<p><i>Green Governmentality</i>: a post-1970s tradition of centralized and managerial environmental regime design</p> <p><i>Ecological modernization</i>: cost-effective, market facing climate governance based on offsets and credit trading</p>	<p><i>Polycentrism</i> or fragmentation of climate governance in a time of austerity; reflects wider governance trends</p>	<p>... primarily maintains infrastructures and rationalities for the exploitation and usage of carbon resources, often referencing the pragmatism of avoiding or easing <u>profound changes to the carbon economy.</u></p>
	<p><i>Co-benefits</i> with economy and development, energy and food security, forestry, air pollution</p>	<p>... is operative through projections and promises as well as implementation in industry practice or institutionalization in governmental policy.</p>
	<p><i>Time-buying</i>: easing carbon transitions, dampening near-term climate impacts, catalyzing more deep-lying mitigation</p>	<p>... benefits from dominant market-facing rationalities entrenched during Kyoto era.</p>
	<p><i>Relative gains</i>: lower-hanging fruit on the negotiations agenda to sustain momentum</p> <p><i>Appeals to vulnerable demographics</i> and civil society as anchors for legitimacy</p>	<p>... presents nearer-term opportunities for the reduction of GHG or emerging proxies harms – but that functionally <u>delays deep-lying mitigation.</u></p> <p>... no longer needs to mark success solely from achieving climate goals and metrics, but from a hazier balance of interests between global issues.</p>

Column 1 describes two governmentalities (ensembles of governance rationalities and sociotechnical strategies) of the Kyoto Protocol era (Bäckstrand & Lövbrand, 2006; 2016). Column 2 describes emerging rationalities in the Copenhagen era, emphasizing that these are not mutually exclusive, and reinforce each other in ways specific to different sociotechnical strategies. Column 3 describes elements of ‘fixing’ the carbon economy, or carbon ‘lock-in’ that can be embodied by entwined governance rationalities and sociotechnical strategies.

Figure 17 Emerging rationalities from Kyoto to Copenhagen eras (Low and Boettcher, 2020)

While a variety of rationalities have emerged in the 2000s, they share some common features: a strong technical (carbon capture, biofuels, geoengineering, etc.) or market anchorage (e.g, CCS, REDD + to finance carbon emission reductions) and a focus on greenhouse gas emissions.

These governmentalities are based on specific expertise and knowledge. Jasanoff (2010) argues that climate change scientists are seeking to stabilize new knowledge, creating a new type of representation of natural and social worlds. This knowledge will be stabilized through the interaction between fact-finding and meaning-making, not only through scientific activities. Similarly, Adant et al. (2005) studied how collective expertise can be built through negotiations, contestations, and controversies. Actors each have their own strategy and interest, impacting the collectively-built expertise in the field of contested issues. Working on climate change as a contested issue, Lefsrud and Meyer (2015) analyze how experts' discourses are constructed. They argue that the framing process participates in the definition of the expert's identities. The expertise is also constructed relative (e.g., supportive, defensive) to the other frames and expert's identities in the field. Knowledge and expertise are key components of the international and national frames regarding climate change. These scholars demonstrate that expertise is not only scientific, but also social. It is being built and embedded within existing frames, while seeking to stabilize new representations of the world.

The energy transition builds on these environmental concerns and its governmentalities to transform them into a roadmap. The basic idea is to transition the energy system in order to cut down on greenhouse gas emissions. It draws on the idea that the energy system has experienced various transitions (e.g., from coal to gas) and that it now needs to transition from fossil fuel-based energy to "clean" energy. But the frames and valuations supporting the storytelling around the energy transition are partial. There is no holistic vision of sustainable solutions' social and environmental impact, apart from their carbon emission or footprint. There is a distortion of the historical energy paths and difficulty in acting collaboratively and cross-sectorally for decision-making (Birat, 2020). This storytelling is also challenged by Aykut and Evrard (2017) who point out the historical background in which the energy transition is embedded. They argue that the choices of policy-makers frame the issue and its solutions based on the existing institutional context.



This idea is in line with the study of technical-economic network dynamics by Callon (1990): these complex networks do not follow a straightforward change process, but are dependent on actors' alignments, translation processes and long-lasting existing elements. Despite these analyses of the energy transition and energy system, the dominant frame remains a technical one, focused on decarbonization and embedded in the market. The go-to solution is that of renewable energies replacing fossil fuels once they become competitive enough. Decision-making at the international and national levels is still heavily based on this frame (Birat, 2020; Low and Boettcher, 2020).

These studies demonstrate how district heating—an operational lever to tackle environmental challenges—is embedded in global frames and institutions. The valuation of district heating is partly determined by other local, national, and international valuations like the technical-economic frame of climate change, and the storytelling of the energy transition. Specific expertise and instrumenting are being built around these valuations, and impact district heating. These global frames are translated at the national level and have their own dynamics, controversies, and arenas of negotiation. They can sintrgly influence the national frames of district heating.

*“I actually found these frames when looking at policy documents or municipal transition plans”, acknowledged Mrs. G. “The energy system was to be decarbonized to tackle climate change and remain aligned with the Paris Agreement. The lens of decarbonization was everywhere, with cities committing to be carbon neutral, zero carbon, etc.”*

- *“And it was supported by the way policies are framed. These global agreements (the Paris Agreement, EU objectives), were translated into national legislation and policy tools.”*
- *“Yes, that is part of what I wanted to see when talking about the national level.”*
- *“Don’t do too much reconstruction Mrs. G. When doing the first interviews, you only vaguely knew about these frames!”*
- *“Vaguely, but still, these frames are becoming very cultural. They are quite media-oriented, and the climate change / carbon emissions pair is by far the most famous when it comes to sustainability.”*

## A little bit of history...

The first step of the investigation on the national framing of sustainable district heating entailed Mrs. G. looking at the history of district heating development. Boholm and Corvellec (2016) state that *“valuation reflects agreements as well as trade-offs or conflicts among stakeholders about what matters. It is an activity that takes place over time, and that is as much tuned to a past experience as it is to scenarios about the future or a sense of the present”*. (Boholm and Corvellec, 2016, p. 9). Thus, to understand the current network of stakeholders, and the tensions around the evolution of district heating value propositions, it is necessary to make a historical detour. In this first subpart of chapter 4, I will present a problematized history of French and Danish district heating development, presenting various phases of governmental frames that came out of the analysis. This history will be based on the analysis of specific instruments shaping the development of the system. For each country, I will go through three steps: 1) a presentation of Mrs. G.’s data collection; 2) a description of the instruments analyzed and 3) the analysis and problematized history for the country.

### *History of the Heat Fund in France*

To access the French historical framing of district heating, Mrs. G. investigated the Heat Fund, a public fund intended to support the development of renewable heat production and supply. The Heat Fund was highlighted both within and outside Engie as a major lever for the historical and future development of district heating in Mrs. G.’s interviews. *“The Heat Fund is a major lever, a trigger to launch new projects”* (Cerema, May 2020, own translation). This statement was reinforced when talking with project leaders: the Heat Fund was necessary to ensure the economic viability of projects, and asking for Heat Fund subsidy was just a normal step in the development of projects. When attending to the *“Rencontres des reseaux de chaleur et de froid”* in 2020 (a yearly meeting between French stakeholders of district heating and cooling, from municipalities to policy makers), Mrs. G. saw the following figure to explain the development of district heating projects (*Figure 18*).

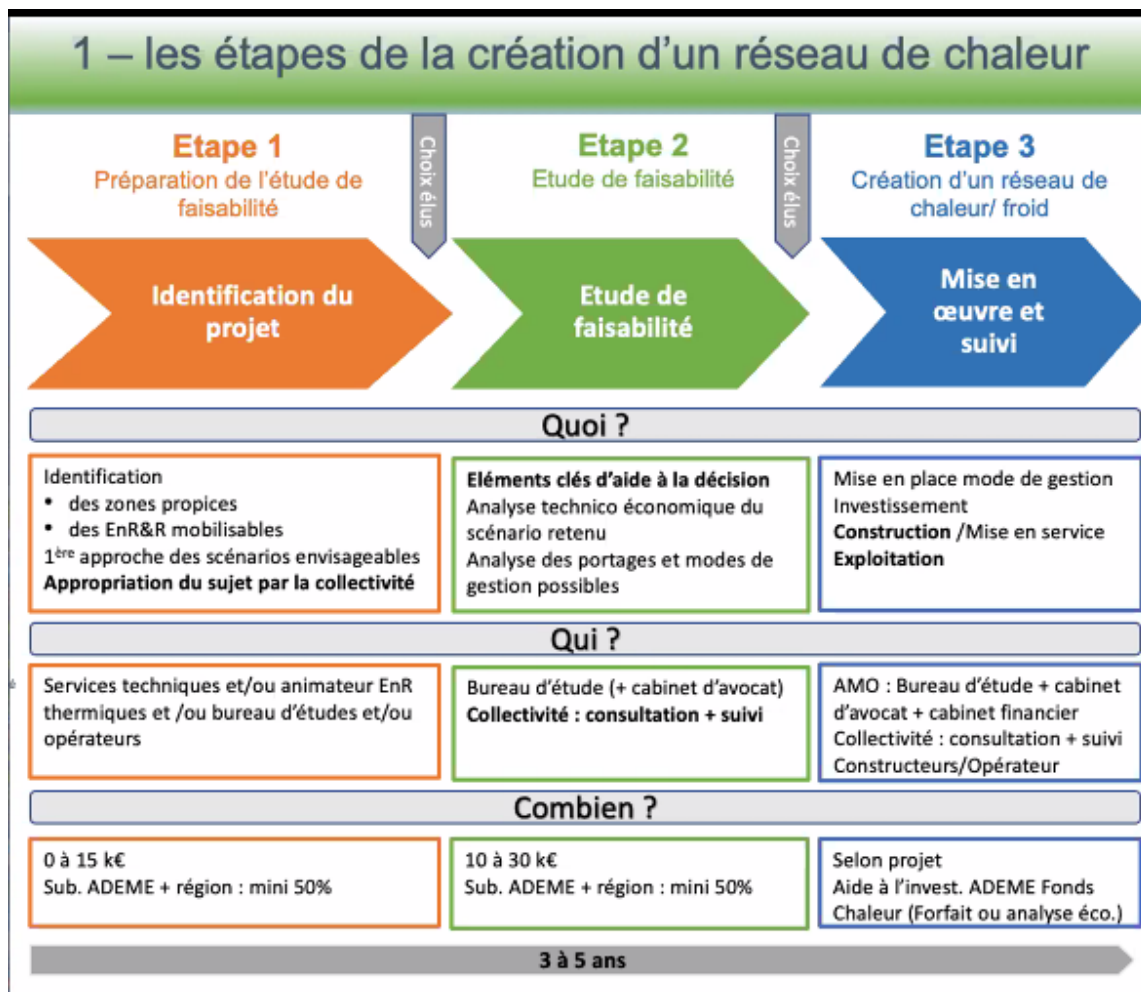


Figure 18 A three-step process to develop a district heating system (Rencontre des réseaux de chaleur et de froid, 2020)

In this figure, subsidies—including the Heat Fund managed by the ADEME—are presented as part of the normal project development process.

Finally, an independent study conducted by the General Accounting Office highlighted this fund as a structuring instrument supporting the development of district heating in France, and a major vector for its decarbonization (Cour des Comptes, 2021).

All these signals pointed Mrs. G. in the direction of the Heat Fund. She thus tried to collect more data about this instrument. Obviously, with her interview with the national coordinator of the Heat Fund, Mrs. G. was perfectly aware that district heating did not wait for the Heat Fund to be established. Some pioneer systems had already been set up, and different waves of implementation taken place:

*“When the Heat Fund was put into operation at the beginning of the 2010s, most of the district heating systems were using wood biomass or deep geothermal energy—especially*

*around Paris. But the geothermal networks were having some financial—and even technical—difficulties, with the aftermaths of the oil crisis and the cheap cost of fossil fuels. As the use of deep geothermal energy requires huge investments with a long payback time, one of the first moves by the Heat Fund was to revitalize these systems in difficulty. And there were also a few other networks already in operation in Priority Urban Development Zones (ZUP: Zones à Urbaniser en Priorité), for instance when a waste incinerator was created, a network was set up to heat the surrounding social housing.”* (extract from Mrs. G.’s notes after the interview with the coordinator of the Heat Fund, 2020, own translation). The Cerema summarizes the development of district heating in France during the twentieth century in four main phases (Cerema, 2021a):

- Before 1950, a few district heating networks were established in major cities (like Paris or Strasbourg)
- Between 1950 and 1970, district heating supported urbanization
- After the oil crisis, they benefited from a resurgence of interest and some district heating networks based on deep geothermal energy were created around Paris.
- By the end of the 2000s, district heating was perceived as a tool for developing renewable energies.

Despite not being set up from the very first French district heating system, the Heat Fund had a major top-down structuring role in French district heating. From the moment it became operational, it was used to strengthen existing networks and allowed the development of more networks based on renewable and recovered heat. The fund has also kept a historical trace of the French government action on district heating during the past decade, and how this action is situated in the energy transition frame.

*“It is funny how the interviewees always made the history of French district heating more detailed once the Heat Fund were created”, noted Mrs. G. “The first part of the history is presented in a very passive way, like the systems existed but no one really knew who put them there. Look at how Cerema only uses the passive style in its website: “district heating systems were created in France” or “they benefit from a resurgence of interest”<sup>18</sup>. “Once the Heat Fund became operational, the actors suddenly appeared and the details too. Or at least, that’s what it felt like during the investigation.”*

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<sup>18</sup> Cerema, 2021a

- “It shows how sustainable district heating was created on top of an existing situation. But maybe the shift to more details is only due to the Heat Fund being more contemporary, so the development process is not lost in history. And the Heat Fund allowed the collection of centralized data on district heating, with the subsidy files.”
- “True... It is like a play. You set the stage and then the actors can begin to play their roles.”
- “Shhh! Don’t spoil the play, the curtain is about to go up.”

### Data about the Heat Fund: presentation and analysis

To investigate the Heat Fund, Mrs. G. collected data through an interview with the French coordinator of the Heat Fund—as you may have already understood. This interviewee made a summary of district heating development in France and the role of the Heat Fund in this development. To complement this interview, she searched on the internet for 1) public documents presenting and assessing the Heat Fund that I then used to draw up a description of the Heat Fund; 2) calculation guidelines for the Heat Fund subsidies and related publications throughout the years that I analyzed to show the different phases in the Heat Fund history. *Table 9* summarizes the data collected by Mrs. G. The secondary sources (reports and website), are cited in the following paragraphs and referenced at the end of the manuscript.

<b>Data</b>	<b>Description</b>	<b>Use</b>
Interview with the Heat Fund coordinator	About one hour interview in May 2020 about the Heat Fund (genesis, rationale, evolution) and district heating in France (regulation, transition)	Presentation of the Heat Fund Analysis of the Heat Fund
Report from the CGE (Council on Economy, Industry, Energy and Technologies) and CGEDD (Council on Environment and Sustainable Development)	Report published in 2018 after a mission on the possible transformation of the Heat Fund delegated by the Ministry of Ecological and Solidarity Transition.	Presenting the Heat Fund

<p><i>“Mission portant sur la transformation des aides à l’investissement du Fonds chaleur en aides à la production de chaleur renouvelable”</i></p>		
<p>Report from the General Accounting Office <i>“Le chauffage urbain : une contribution efficace à la transition énergétique insuffisamment exploitée”</i></p>	<p>Report published in 2021 on French district heating with a part on the different tools supporting district heating, in particular the Heat Fund.</p>	<p>Presenting the Heat Fund</p>
<p>ADEME Website</p>	<p>Presentation of district heating and the Heat Fund  Communication on regulation evolutions, and the Heat Fund assessment and evolutions (criteria, projects supported, money accessible for the following year)</p>	<p>Presenting the Heat Fund  Analysis of the Heat Fund</p>
<p>Heat Fund website</p>	<p>Presenting the various categories, but without the history of their evolution.  Form to test the eligibility and the amount of the subsidies</p>	<p>Analyzing the Heat Fund</p>
<p>Heat Fund calculation guidelines, published by the ADEME</p>	<p>Guidelines from 2009, 2012, 2013, 2014 to calculate the amount of the subsidy from the Heat Fund.</p>	<p>Analyzing the Heat Fund</p>

Table 9 Data used to analyze the Heat Fund

## What is the Heat Fund?

Due to their high investments and fragile economic balance, several instruments (technical, financial, and regulatory) were designed by the French government over the years to support the development of district heating systems. In 2009, the Heat Fund was created during the French “Grenelle de l’Environnement” roundtable (see *box 2*) as the main instrument to support “renewable heat” production and supply.

The Heat Fund came into operation in 2009, under the supervision of the ADEME. During the Grenelle de l’Environnement roundtable the mission of the Heat Fund was described as followed:

*“The creation of a renewable Heat Fund is designed to give visibility to companies and local authorities on the financial aids available to ensure normal profitability to projects promoting the thermal use of renewable energy.*

*The energies in question are: solar energy, geothermal energy used directly or through heat pumps, forestry or agricultural biomass including biogas, waste incineration, and heat recovered from refuse-derived fuel (RDF).” (CGE and CGEDD, 2018; own translation).*

It has three objectives: (1) financing projects with renewable or recovered heat production, as well as the district heating and cooling systems linked to these installations so that the heat delivered can be competitive compared with heat produced through “conventional energies”; (2) promoting local employment and investment in renewable and recovered heat; (3) experimenting new technologies and methods to support the scaling-up of renewable and recovered energy uses (ADEME, 2021).

During the Grenelle de l’Environnement roundtable, it was decided to grant the Heat Fund 175 million euros in 2009, 500 million euros in 2012 and 800 million euros in 2020. In 2021, it benefited from 350 million euros and will be granted 370 million in 2022 (ADEME, 2022).

**Box 2: Grenelle de l'Environnement roundtable**

The Grenelle de l'Environnement roundtable encompasses a series of political initiatives on the environment and sustainable development. It took place in France in 2007 under the French President Nicolas Sarkozy. During this roundtable, several working groups and workshops were created with a variety of stakeholders (companies, NGOs, public authorities, experts, etc.) interested in sustainable development issues. It led in 2009 to a first law (known as "Grenelle I") and to a second law in 2020 (known as "Grenelle II"), both aiming at formalizing and operationalizing the commitments taken during the Grenelle de l'Environnement roundtable. Due to the variety of interests represented, the roundtable managed to create a common basis but the most controversial issues and ambitious solutions did not lead to actual consensus and regulations.

The Heat Fund is not exclusively dedicated to district heating: many heating projects are eligible (wood boilers, biogas, heat recovery, thermal solar panels, etc.). For the 2009-2017 period, district heating accounted for 38.4% of the fund for investment operations (CGE and CGEDD, 2018) and this figure rose to 43% in 2021 (ADEME, 2022).

Based on the list of relevant renewable and recovered energies for heat production stated during the Grenelle de l'Environnement roundtable, several categories were drawn up for the Fund.

First, a specific request for proposals for big biomass plants greater than 1,000 tonnes of oil equivalent per year (TOE/y) was put in place in the industrial or agricultural fields. This call for proposals is managed at a national level. Second, a category encompassing all the other eligible projects (including smaller biomass plants) was also set up. The Fund for this second category of projects is managed at a regional level by the ADEME, hand in hand with local authorities. The subsidies can be combined with the European Regional Development Fund. The renewal of a production unit which had already benefited from the funds is not eligible. In addition to the abovementioned renewable and recovered energies, the heat recovered from industrial processes can benefit from subsidies. The waste heat from electricity production (without a regulated electricity price) can be



eligible but only for the setting up of a district heating network and for the equipment required to utilize the heat. Cooling projects are studied on a case-by-case basis.

The proposals can be sent at an early stage of the project, and the amount of the subsidy is then calculated based on the feasibility studies. The payment of the subsidies is usually staggered in three steps: 50% after the contract's signature with the ADEME; 30% when the equipment is received; 20% dependent on the real production and compliance with the supply plan (when relevant). A yearly report on the production (and the supply plant when relevant) is to be sent to the ADEME for ten years.

For district heating, the Heat Fund can financially support both the decision support studies (diagnosis, preliminary studies, etc.) and the investment operations (i.e., setting up and extending the pipe network). In 2019, the Heat Fund financed fifty-six decision support studies for a total cost of €900,000 and ninety-four investment operations for a total cost of 109 million euros (Cour des comptes, 2021). For small-scale projects, the subsidy can be inclusive, and for bigger projects it will be based on a study of the projects. The ADEME has developed a grid of upper limits for subsidies depending on several criteria, e.g., the length and diameter of the pipes. The subsidy for the investment operations is calculated so that the production cost of heat is 5% less than the fossil fuel reference (usually gas). As district heating projects usually combine a production unit and a supply system, they can benefit from public subsidies both for the district heating (the distribution system) and investments in the production units. For the distribution system to be eligible, it has to be supplied by at least 50 % of renewable or recovered heat.

To gain access to this subsidy, district heating projects have to fulfill different criteria. These criteria are aligned with the framing of district heating at the national level. As Mrs. G. gathered data and investigated the evolution of these criteria, I could access the successive valuations of district heating in France over the last decade.

Now that this instrument has been presented, let us move to the last step and analyze its evolution over time, from the first framing of renewable heat to the evolution of the criteria valuating renewable and recovered heat projects.

### A major support for renewable heat developed in three phases

For her study of the Heat Fund criteria, Mrs. G. chose to focus on the regional subsidies (not the request for proposals for big biomass plants), which is the one district heating systems fell under: what were the energies eligible and the main criteria for eligibility?

When the Heat Fund was created, the idea that district heating could be a lever for the energy transition was becoming more and more popular at the political level. The framing of the Heat Fund presented in the previous paragraph makes it clear that the Heat Fund was about supporting the production and use of renewable and recovered heat. Within this rationale, district heating systems are a means to convey this sustainable heat: the main eligibility criteria for district heating to receive subsidies is to be supplied by at least 50 % of renewable or recovered heat. So, even if Mrs. G.'s investigation revolved around district heating systems, she also looked at heat production and the criteria to be considered as renewable or recovered heat.

To study the evolution of the Heat Fund, she analyzed the accessible documents on its calculation methods between 2009 and 2021. A calculation method was published by the ADEME in 2009 for the launching of the Heat Fund. It was revised in 2012, 2013 and 2014. Since 2015, a website to test the eligibility of a project has been set up. This website did not allow Mrs. G. to track the evolution of the Heat Fund. It only gave her access to several forms to get an estimation of the subsidy for a project, which she could not complete. The following forms were available in 2022: biomass, geothermal, district heating, thermal solar panels, waste heat (ADEME, 2021). However, some online content published by regional and national stakeholders of district heating painted a picture of some of the major Heat Fund evolutions (see *Table 9*).

The calculation method guidelines show how to calculate the level of subsidy that can be given to a specific project. According to the coordinator of the Heat Fund: *“At the beginning, the subsidies were just a percentage of the investments, but at the ADEME they soon realized there were major differences between the claimed investments for similar projects. The investment costs were valuated by the project leader, using their own safety margins and calculation methods but there was no national frame. The ADEME thus tried*

to build a systematic grid with the help of the SNCU<sup>19</sup> by analyzing a lot of projects between 2012 and 2013. The idea was to specify the percentage of aid available depending on technical specificities and to ensure that the contribution will just be sufficient to make the project profitable and feasible” (extract from Mrs. G.’s notes after the interview with the coordinator of the Heat Fund, 2020, own translation). With this rationale, the less mature technologies and those requiring more investments can benefit from more subsidies. These calculation guidelines are updated yearly.

Figure 19 hereafter presents the main evolutions of the Heat Fund.

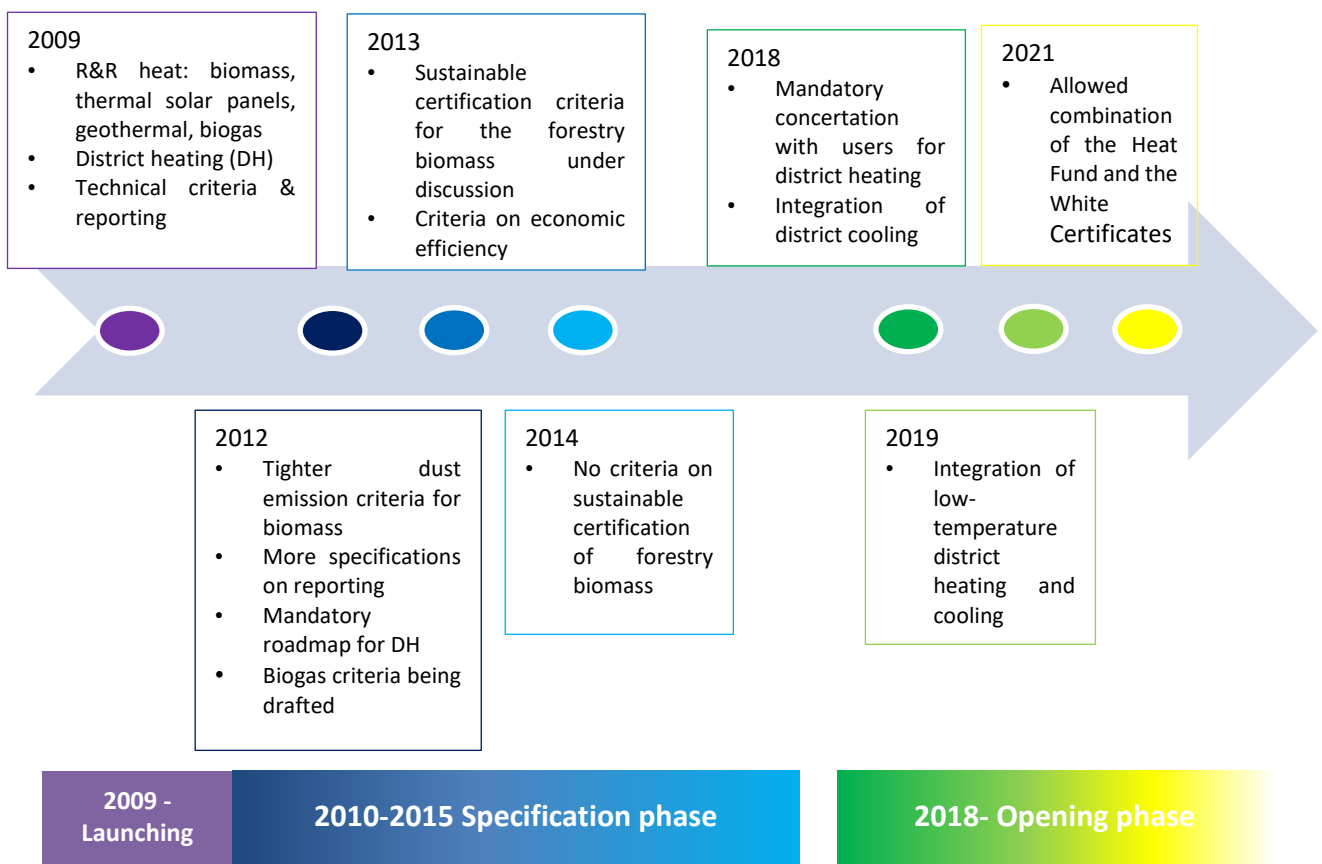


Figure 19 Evolution of the Heat Fund, 2009-2022

Four milestones stand out in this evolution.

- The launching of the Heat Fund in 2009, with the framing of sustainable heat in production and supply categories but loose criteria in each category.
- A specification phase from 2010 to 2015, where the calculation method was slowly specified and led to the launching of the online calculation form in 2015. During this

<sup>19</sup> Association representing the interests of district heating operators in France

specification phase, knowledge of existing technologies seems to have been built, as some more refined criteria depending on the type of technology—even within a category—were added. The specification (especially of the reporting process) and updating of the criteria and methods continued from 2015 on, but a stabilized frame seems to have been found.

- *An opening phase from 2018 until now*, with the integration of new technologies and the coupling between the Heat Fund and other instruments. During this phase, there is ongoing questioning on the efficiency and future evolutions of the Heat Fund. For instance, a reporting mission on the Heat Fund delegated by the Ministry of Ecological and Solidarity Transition to the Council on Environment and Sustainable Development and the Council on Economy, Industry, Energy and Technologies was conducted. During this mission, fourteen recommendations were made to the ADEME and other national authorities, e.g., general authority for energy and climate (DGEC<sup>20</sup>), general competitiveness authority (DGE<sup>21</sup>), general authority for housing, urbanism and landscapes (DHUP<sup>22</sup>). Some recommendations were about insurance instruments on heat delivery, the development of sustainable heat production sectors, the integration of the Heat Fund with other regulations and policy tools, the reporting on the use of the Heat Fund, and updating some calculation grids.

The phase between 2015 and 2018 could not be studied in depth with the documentation collected by Mrs. G.

*“It is interesting how you have organized the data around the Heat Fund into different periods”, said Mrs. G. appreciatively. “But even if there have been lots of discussions on evolutions, it remained very incremental. Some measures were never applied, like the certification to ensure the renewable management of forestry biomass; doubling the subsidies for the Heat Fund.”*

- *“That’s true, but it shows some ideas of frames that did not made it through the instrument, but that may still be represented within the stakeholders.”*
- *“Also, something that really struck me is heat recovery. You know, they talk about renewable and recovered heat. And there is a category of recovered or*

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<sup>20</sup> Direction Générale de l’Energie et du Climat

<sup>21</sup> Direction Générale des Entreprises

<sup>22</sup> Direction de l’Habitat, de l’Urbanisme et des Paysages

*industrial heat for the subsidies. But there is no specification. It is like they do not know how to frame it...”*

- *“Yes, and when you studied the Dunkirk case, I think you saw how it impedes actors from acting! The regional coordinator said it was very difficult to launch projects based on heat recovery because you have to prove your point each time. There is almost no standardization.”*
- *“The monster is not tamed yet...”*

### Valuating renewable and recovered heat

From this presentation of the Heat Fund and its problematized history, several points stand out. From the first attempt to frame sustainable heat in 2009, the dominant frame has been a technical one for renewable and recovered heat production. This frame shaped the subsidies and the frame of sustainable district heating. While district heating is considered important for the development of sustainable heating, it is only for conveying renewable or recovered heat. The main specification to be considered as a sustainable district heating system is to have at least 50% of renewable or recovered heat in the mix. The valuation of renewable and recovered heat was rationalized through a limited number of categories. In each of these categories, standardized criteria were designed and updated, through an incremental learning process, to specify the frame of sustainable heat.

*“The valuation process of district heating, leading to sustainable district heating is very interesting”, I started. “A loose frame is made, based on which instruments are designed. The instruments are then refined, as the expertise is being built. Through these successive refinements, the frame is specified and solidified and the valuation evolves within this new frame.”*

- *“Still, it is not only incremental. Some discussions were almost like challenges to the frame. The mission on the Heat Fund was about shifting from a subsidy for investments to a subsidy for the production, based on the example of electricity... This shift, by changing the structuring instrument supporting district heating, would question the vision of district heating and the project organization.”*
- *“The instruments have a huge impact on the projects, setting a frame within which the actors can do their projects.”*
- *“It is something to be further developed, especially as the local level may sometimes be in tension with the national frame and challenge the valuations... But for now, shall we go to Denmark?”*

### *History of the legislation and incentive schemes in Denmark*

To give a counterpoint to the French valuations, Mrs. G. also looked at the Danish situation. As mentioned in Chapter 3, Denmark is considered an example in the development of district heating. In Denmark, the government's interest in district heating is older than the French one and is expressed through different instruments. The one presented as the beginning of Danish national interest in the development of district heating systems is the Heat Supply Act dating back to 1979, which set the frame of district heating development (OECD, 2000; Danish Energy Agency, 2017) Jensen and Karnøe (2018) state that it flags the beginning of heating being "articulated in a coherent manner as a matter of national policy concern" (p.91). This frame was set after the energy crisis, which hit Denmark hard. The structuring rationale in the development of Danish district heating has been the need to rationalize the use of waste heat, to gain energy sovereignty. VEKS' vice-director described the development of district heating in Denmark as follows: *"During the second energy crisis in the late 70s when the regime in Iran changed and the [...] oil was suddenly a commodity difficult to use, difficult to get, and the prices were increasing. In Denmark, you probably know this already, we pushed in the legislation the First Energy Act which says that when you have a CHP, when you have big waste incineration plants, you need to utilize the heat."* Mrs. G. wanted to see how this frame might have evolved over time, leading to Denmark being considered at the forefront of sustainable district heating.

She soon realized that state assistance was not structured the same way as it was in France. In France, production and distribution were often considered together. In Denmark, a clear distinction was made between production (combined heat and power plants for instance) and distribution (district heating). One instrument structured actors' relationships both on the production and distribution side: the socioeconomic calculation (see *box 3*).

### **Box 3: The socioeconomic calculation or how to choose the “best” solution...**

In Denmark, the municipalities bear the responsibility for planning the heating supply. The Ministry of Energy, through the Danish Energy Agency, has created an instrument to help them choose the best solution for Danish society when facing different heating projects. As mentioned on the Danish Energy Agency website: *“The aim of making socioeconomic analyses of projects is to improve the basis for a qualified societal prioritization of resources.”* (Danish Energy Agency, 2022).

Using a methodology fixed by the Danish Energy Agency each year, the team proposing a project to the municipality has to give the socioeconomic calculation of its projects. This calculation is based on a number of price assumptions given by the Danish Energy Agency: e.g., a price for heating from different production means in twenty years’ time, a carbon cost. The municipality, then, has to choose the project with the best socioeconomic result compared with other project proposals, existing solutions or alternative scenarios.

Several limitations of this instrument have been put forward. In 2018, Jensen and Karnøe (2018) pointed out that the socioeconomic prices used in the calculations did not take into account the costs outside Denmark, and the global externalities. Moreover, on the subject of carbon cost *“CO2 emissions were for example categorized by the Danish ministry of Finance as a ‘policy cost’—i.e., as a cost-imposed policy objective to reduce CO2 emissions rather than a cost related to real-world damages from climate change.”* (Jensen and Karnøe, 2018, à. 95). Moreover, some aspects of heat supply—like security of supply, the environment, or technological developments—are not priced; and some assumptions on future prices suffer from great uncertainty (Danish Energy Agency, 2022). Until last year, gas was still competing with district heating and other renewable resources on the socioeconomic calculation. As taxation is not taken into account in this calculation, the gas price did not reflect its real price, and could be considered as better than alternative renewable solutions. To avoid such situations, the government has recently decided that the municipalities could ban gas from the alternatives to look at when doing the socioeconomic comparison. *“Even though we have high taxation on natural gas, that would not mean anything in the socioeconomic calculation analysis, actually it would have a slightly... it would slightly improve the gas scenario, which was even worse [...] Then last year it was decided to remove this restriction, saying that now it should be able for the municipality when receiving this project proposal to say that... you still need to show*

*alternative proposals to what you want to do, but the municipality could say they do not need to see any alternative using fossil fuel.”* (chief advisor in the center for utilities and supply, Danish Energy Agency, 2021).

Moreover, the municipalities do not always have the right skills to properly evaluate the different projects, and assess the socioeconomic calculation for the projects. They can rely on district heating operators or consultancy firms to assess the calculations. This difficulty in assessing the calculations made is enhanced by the imprecision of the guidelines. Even if some assumptions are fixed by the Danish Energy Agency, the methodology is a *“procedure on how to do it”* (risk manager & energy planning, HOFOR, 2021), with some assumptions left to the one making the calculation. Thus, with the same project, different assumptions can lead to different results, *“and sometimes it’s a problem, that depending on [...] your assumptions you can get many different things.”* (risk manager & energy planning, HOFOR, 2021). In such cases, the municipality has the final word. In the case of the Copenhagen municipality, it sometimes asks advice from HOFOR, their utility company, to get an assessment of the assumptions used in the calculations.

Finally, despite the methodology given by the Danish Energy Agency, the actor seems to find the frame loose enough not to be restrictive on the possible solutions. *“It’s also quite easy to bypass some of these things”* (chief advisor in the center for utilities and supply, Danish Energy Agency, 2021). In places where the municipality has a clear view of what it wants to do, the socioeconomic calculation can be used so that the wanted solution is presented as the one with the most socioeconomic benefits, mostly by choosing the right alternatives to compare it with.

Different regulations apply in Denmark compared with France, with of course different instruments. However, in both cases, the low-carbon energy transition revolves around an evolution in the production mix, with the integration of low-carbon heat. The instrumentation concerning the distribution network itself is focused on the development of district heating, with planning tools, zoning or mandatory connection to the network. Mrs. G. thus chose not to focus here on instrumenting for the distribution network, but on the subsidies or economic instruments supporting various renewable energy production means as the sustainability issues are more often framed through instrumenting the production means. Jensen and Karnøe (2018) consider that from the



1990s, the governance of heating in Denmark became based on a “market-imitating rationality” with the development of such a knowledge assemblage and instrumentation. Among this instrumentation were some incentive schemes based on subsidies and taxes, which Mrs. G. would investigate. To encourage some energy resources, Jensen and Karnøe (2018) noted that “*some energy resources were heavily taxed, while others were not taxed at all*” (Jensen and Karnøe, 2018, p. 93), making the investigation into the evolution of these incentive schemes relevant.

### Data about the Danish market instrument

To gain access to these structuring instruments, Mrs. G. relied on published research on the Danish district heating system, and some semi-directive interviews (see *Table 10*).

At the time of her visiting, Mrs. G. was integrated in a research team at the Copenhagen campus of Aalborg University. Some researchers within this team had been doing some work on the valuation of the Danish energy system, and some focused their research on district heating. They led Mrs. G. to some major articles tracing back the history of heat and district heating in Denmark. Some informal discussions with these researchers also gave her keys to understanding and helped her gain the “interactional expertise” (Collins, 2004) needed to discuss matters with Danish practitioners. To understand the development of Danish district heating, she conducted five interviews with consultants, lobbying groups, and national agencies. From these five interviews, the one with the National Energy Agency gave her the most details on the legislation and instruments around Danish district heating. She also collected data for two case studies in Denmark, one in Greater Copenhagen and one in Hornsyld. Some of the semi-directive interviews she conducted for these cases also gave insights on the national frame for district heating, especially three from Greater Copenhagen case study. All these semi-directive interviews were recorded and transcribed. She completed this investigation by reading several reports and online communications on district heating development, regulations and taxation; she also consulted Danish government websites. As a multiplicity of regulations and incentive schemes are studied here, I will not write down a specific paragraph on their presentation but rather a problematized description of district heating development in Denmark.

Data	Description
3 academic articles on the development of Danish district heating	<p>Jensen and Karnøe, 2018 on Danish heat governance and the knowledge assemblages supporting this governance.</p> <p>Bertelsen et al., 2021 on the implementation of large-scale heating infrastructures in Denmark.</p> <p>Johansen and Werner, 2022 on a history of sustainable district heating in Denmark.</p>
1 semi-directive interview with the Danish Energy Agency (ENS)	53-minute interview in September 2021 on the incentives and tools supporting the development of district heating in Denmark.
3 semi-directive interviews with Greater Copenhagen district heating practitioners	<p>VEKS and CTR, two transmission operators. Semi-directive interviews of respectively 1:21 and 00:43. Varmelast the heat load dispatch organization, a semi-directive interview of 1:33.</p> <p>The three interviews were about the organization employing each interviewee and the future development they forecast in Greater Copenhagen.</p>
Government websites (SKAT and ENS)	<p>Presentation of district heating development and supporting legislation.</p> <p>Presentation of energy taxation.</p>
OECD report from 2000 “Regulatory Reform in Denmark–Regulatory Reform in the Electricity Sector”	Report on the Danish Electricity sector, with a summary of the policy objectives and supporting regulations.
Danish Energy Agency report from 2017 “Regulation and planning of district heating in Denmark”	Report on the regulation and planning of district heating in Denmark presenting its

	main characteristics, development, regulation, and future trends.
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Table 10 Data used to study the Danish incentive schemes

**A low-carbon transition heavily based on biomass...**

Johansen and Werner (2022) pointed out different drivers for district heating development and instrumenting: offering a stable, available and affordable heating for all; achieving higher energy efficiency in the system; reducing energy import dependency and increasing energy diversification; and finally contributing to the environmental agenda. This last motivation grew throughout the 1980s and 1990s, leading to some evolution in the heat production valuations.

The first systems were primarily based on oil fuel, but after the oil crisis of 1973, the Danish district heating system shifted towards coal, then natural gas (Bertelsen et al., 2021). These different phases are related to different regulation acts and supporting instruments (see Figure 20).

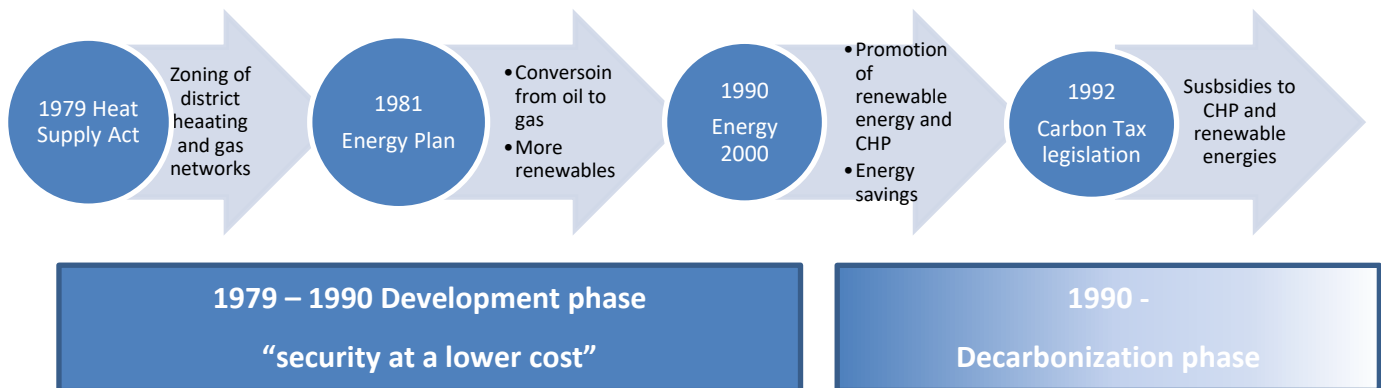


Figure 20 Major energy acts and objectives (adapted from OECD, 2000)

From 1979 to 1990, Danish district heating was under development, with natural gas being valued as a key energy resource. This natural gas was used in combined heat and power plants, which developed alongside district heating systems. This first phase is strongly linked to the framing made after the oil crisis, and the political ambition to develop energy security while keeping the energy affordable. Since 1990, more environmental concerns entered the frame, and Denmark entered a second phase of decarbonization of its energy system. During the last two decades, biomass became a major heat production fuel, in compliance with the objective of achieving a low-carbon

energy transition (Johansen and Werner, 2022). This focus was operated through the design of financial incentives to encourage the conversion from coal-fired plants to biomass-fired plants, and the building of new biomass-fired plants. This shift was presented by the chief advisor for utilities and supply of the Danish Energy Agency: *“I think during the 2010s, last ten years, there has been a major focus actually on converting the fossil-fuel based DH systems towards... these larger ones... towards biomass-based CHP. [...] Some of these developments was made interesting by subsidy of power production from biomass-based CHP and also by having no tax on biomass for energy production but having quite high tax on fossil fuels.”* The tax on fossil fuels has been high for several years—with the integration of a carbon tax in 1992—without having the expected effect on consumption. A complementary financial aid for biomass—through both subsidies and low taxes—triggered the transition towards this specific means of energy production (see Figure 21).

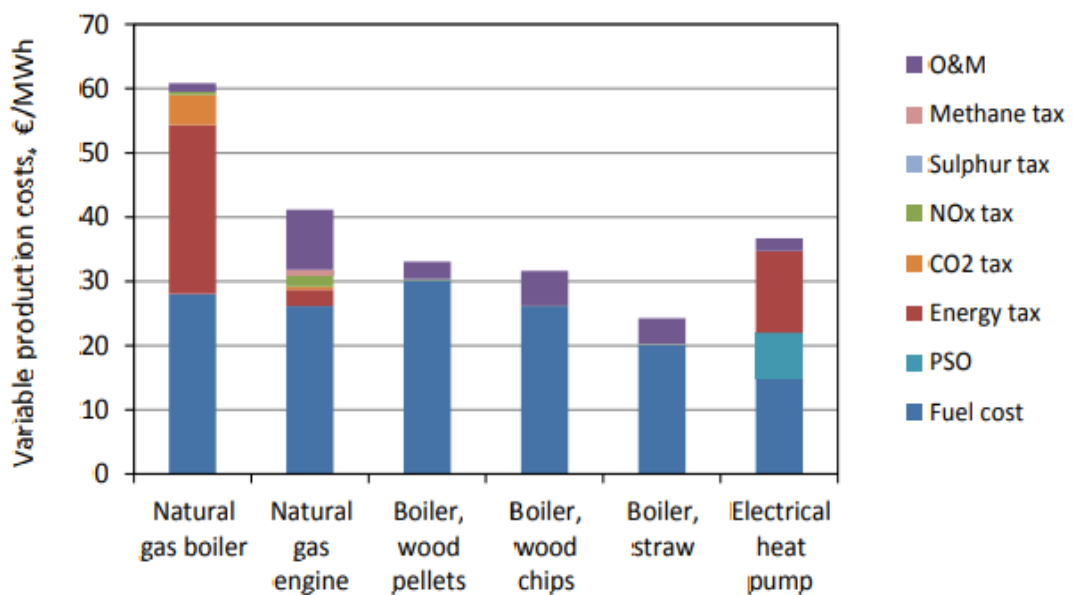


Figure 21 Fuel costs for heating production including taxes and VAT (ENS, 2017)

From Mrs. G.'s data, I found that three major points stood out:

- 1) The characteristics of the Danish heating market are strongly interrelated with the electricity market through combined heat and power (CHP) plants. From the early days of district heating planning in Denmark, they have been framed as a means to utilize waste heat, including heat produced during electricity production.
- 2) Taxation and subsidy schemes are used as instruments to encourage the development of specific means of energy production and discourage the use of others.
- 3) The valuation of biomass is a pillar of the low-carbon transition in Denmark.

### ... but that is starting to show its limitations

Mrs. G. discovered, thanks to her interviews, that a shift was now occurring towards electrification, as policy-makers are starting to consider biomass as a non-renewable heat source. A controversy around the sustainability of biomass as an alternative fuel for a low-carbon transition is growing in Denmark. Due to the development of incentive schemes supporting biomass, the biomass demand has outgrown national biomass resources, leading to imports from various other countries (Johansen and Werner, 2022). Despite certification on the sustainable management of these biomass resources, some concerns have arisen on the sustainability of the resource. The vice-director of VEKS explained that *“a lot of it is imported. And that’s part of the reason... Of course, it’s already certified SBP, FSC, all of these international standards. It should be sustainable and carbon neutral, but there’s an ongoing discussion.”* This concern echoes some ongoing global discussions on the ways to value wood biomass, and the calculation instruments to do so (see box 4).

#### **Box 4: Forest biomass, the perfect fuel for a decarbonized heating system?**

In a majority of European countries, biomass is considered as the most efficient way to decarbonize district heating. Coal boilers can be converted to biomass boilers, and the management of the system remains centralized. Biomass is one of the very few renewable or recovered heat sources that does not require completely rearranging the system. Among the different types of biomass, forest biomass is the most frequently used for heating systems, with wood being the leading source of renewable energy (United Nations Economic Commission for Europe, 2020).

However, the sustainability of wood-energy is being questioned at different levels. First, the growing need for wood (for energy, but also for industry, housing, etc.) can endanger the sustainable management of forests. Forest managers need to harvest more to answer the growing demand, grow enough trees to sustain the offer, and take into account biodiversity protection (variety of species, impact of forest work on the ecosystem, etc.) (Verkerk, 2016). Some certifications are set up at an international level to account for the sustainable management and transformation of wood. However, as for all certifications, the specification bill to receive the certification is subject to controversies. For instance, the impact on biodiversity is multiple, making it difficult to evaluate management practices (Schulze et al., 2020). The very idea of assessing biodiversity is challenging, as biodiversity encompasses a multiplicity of dimensions and interrelations (Chiarucci et al., 2011). Similarly, the context of each forest makes it difficult to translate global indicators to local specificities. For example, what is acceptable in one place, due to the type of soil, may have a great impact in another place. Moreover, many international certifications only take into account the management of forests, not the origin of wood to promote local use. Denmark imports certified wood from other European countries but also from America (Johansen and Werner, 2022).

Secondly, wood biomass is considered to be entirely carbon neutral: This is because the carbon emitted when burning wood was already captured by the wood during its lifetime. This vision is more and more challenged. The effects of carbon emission during the burning of biomass in a specific place are not entirely compensated by the growth of trees elsewhere. This controversy finds its arena in the emission factors and substitution indexes for biogenic carbon (carbon emitted when burning wood-energy). Although there is ongoing research on how to take into account biogenic carbon emissions, for now no consensus can be found on the different international methods for Life Cycle Assessment (LCA) of greenhouse gas (GHG) accounting guidelines (Jeandaux, 2019).

Finally, at a local level, policy-makers can become cautious on the setting up of new biomass boilers, even in forest areas<sup>23</sup>. They are often unaware of the local stakes around biomass: the amount of local biomass available, the formalization of a supply chain

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<sup>23</sup> For a livelier description of the local management of wood-energy, and related controversies, see the investigation of Mrs. G. in the Bourgogne Franche-Comté forest area in Chapter 6.

around wood-energy, etc. This can be due to the strong criticism communicated by environmental associations and the lack of communication from forest representatives. Apart from the sustainable management aspects, and the carbon-neutrality controversy, some citizens and policy-makers are also dubious about the local air pollution due to combustion dust, and soil pollution due to the ashes. The legislation on the treatment of smoke and ashes is becoming increasingly tighter, with filters and specific waste management.

All in all, the valuation of forests and biomass is being questioned. Different stakeholders prioritize different values: e.g., biomass as a sustainable resource *per se*, biomass as a sustainable resource if it is sustainably managed, biomass as a sustainable resource if it is locally managed. These valuations lack instrumentation. Quantified impacts of biomass used for heating are still non-consensual, both for the emission aspects (carbon and dust) and for the socioeconomic and environmental ones (creation of local jobs, impact on biodiversity, etc.). Even the indicators to quantify such impacts are not stabilized. Different representations of biomass coexist at all levels, based on the partial expertise of stakeholders (from the international to the local level).

Even discussions are ongoing, all of the interviewees highlight a strategic political will to shift from biomass towards electrification. The vice-director of VEKS states that *“In Denmark there’s a quite big political push towards electrical based heat that comes. And there’s a political pressure to reduce our dependence on biomass.”* Similarly, the administrative director of CTR explains: *“There’s a lot of possibilities ahead, but the main thing is that the political want the biomass to decrease over the next years. Yes, for finally stop using it for heat.”* This feeling is reinforced by an economist from Varmelast saying that *“in Denmark, I mean, our politicians they don’t want waste incineration, they don’t want biomass. [...] Then they want heat pumps”*.

Moreover, the subsidies and taxation have already shifted from biomass to electricity. According to the Danish Energy Agency interviewee *“that subsidy scheme was also taken out of the system two years ago. So those who had already received or built a plant based on this subsidy would have some 20 years, I think, where they could keep receiving this subsidy and then this subsidy will stop.”* Due to this decision, the economic balance of biomass-fired plants is questioned and few new plants will be built, as they will not be

competitive anymore with other resources. On the other hand, the tax on power has been decreasing in the last years (SKAT, 2020), making it possible to integrate electrical means of heat production in the district heating mix, such as heat pumps or heat-only electrical boilers. Both interviewees and scholars highlight the increase in the setting up of heat pumps in the Danish district heating systems (Johansen and Werner, 2022).

Jensen and Karnøe (2018) point out that these controversies make the future uncertain, as the outcome of the controversy is not determined yet and may strongly impact the economic balance of projects.

### A phase-by-phase valuation of sustainable heat

In a nutshell, the Danish national interest in district heating development could be understood as divided into two main phases. The first one starts after the oil crisis, with a district heating development phase as a means to ensure a cheap and secured heat supply. This first phase created the basis of the district heating structure, with a strong interdependence between electricity and heating. As the expertise was being built, the instrumentation became more market-based, with incentives to go for more energy efficiency and phase out oil and coal. The second phase is what I have called the decarbonization phase. It started in the early 1990s, with district heating being reframed as a lever for the energy transition and the attainment of carbon reduction goals. The instrumentation of this phase built on what currently exists, with more economic incentives, this time pushing for an increase in the biomass-based energy production share. As knowledge changes, the valuation of biomass as a fuel for decarbonization is being challenged. This controversy seems likely to lead to a subphase in the decarbonization phase: the electrical era. Here again, this era is supported by market-based instruments, like low taxation on electricity. Throughout the Danish history, a shift from one dominant fuel to the other was regularly made, heavily helped by massive incentive schemes focused on one specific production means.



*The Danish history is so different from the French one”, sighed Mrs. G. “The role of combined heat and power is dominant. I remember how the Danish interviewees were surprised when they heard we did not go for CHP plants in France.”*

- *“Yes, but our electricity is produced mainly in nuclear plants. And these are political objects... It is not easy to connect them to heating networks.”*
- *“Sure, usually nuclear plants are far from major cities and also, I am not sure citizens would want to be connected to heat coming from a nuclear plant.”*
- *“But for their electricity, no problem.”*
- *“That is part of the paradox. We prefer to use electric radiators in our houses, so much for the efficiency!”*

### *Different national framing processes, but a similar valuation?*

In this first part, I have given an account of the historical national valuations of district heating in France and Denmark by looking at how district heating was framed and instrumented in both countries.

The interest of the French and Danish governments in district heating stems from different roots, shaping different district heating networks.

In Denmark, where district heating has a longer history, the governments first framed district heating as a means to become independent from oil fuel, in the context of the oil crisis. About two decades ago, this frame changed towards a means to reach sustainability goals. To support these frames, the Danish government has designed a variety of instruments, and built up strong expertise on district heating. These frames were also supported by the valuation of production means—with a strong incentive to use heat from combined heat and power plants—and the valuation of different heat resources: first coal and natural gas, then biomass, and more recently, electricity. These shifts in valuations were expressed through shifts in instrumentation, especially subsidy schemes and taxation. The last shift seems to point towards a change in the valuation of renewable heat: biomass is no longer considered as the magic bullet, but an electrification of district heating would be the way to decarbonize.

On the French side, the action of the government on district heating was structured later, at the end of the 2000s. The surge of interest was framed through the ecological transition, with district heating being a means to supply sustainable heat. Here again, a variety of instruments were designed, revolving around one dominant subsidy scheme: the Heat Fund. The valuation of renewable heat was here more incremental than in Denmark, with a number of resources being considered as renewable, and some specifications or new categories being added as the expertise was being built. Contrary to Denmark, this development was quite independent from the one of electricity or gas networks and led to a dominance of heat-only-boilers.

Despite these differences, the approach to district heating valuation in both countries is shaped by the production means. Since the 2000s, district heating, just like the rest of the

energy world, has been challenged by the energy transition frame. The approach of both countries for an “ecological” or “low-carbon” energy transition revolved around the integration of renewable resources in the district heating production mix. In both countries a shift away from fossil fuel heat production occurred, supported by market-based instruments. On the common point of sustainable heat valuation, I can highlight waste heat and geothermal energy. Utilizing waste heat has been a strategic focus both in France and Denmark. In Denmark it was the utilization of both waste heat from electricity production and waste incineration. In France it was only heat from waste incineration. The perimeter is now enlarged to industrial and urban waste heat, but with a limited integration into the incentive schemes. Geothermal energy is considered a suitable solution but with strong technical and economic barriers—especially the high risk and high upfront investments. If biomass was considered in the 2010s the major vector of decarbonizing of the heating system, this valuation is starting to be strongly questioned in Denmark and—to a lesser extent—in France (*see box 5*). Solutions that are not yet mature are also being studied in both countries, like biogas, waste heat from Power-to-X or large-scale heat pumps.

This study gives a first view of how the frame of sustainable district heating was instrumented, based on international frames and previous valuations of district heating. Through this comparison, I found out that (1) national valuations for sustainable district heating were primarily made through a typology of “renewable” heat, framing district heating as a vector of renewable heat; (2) this valuation is interrelated with previously existing instruments and a supporting instrumentation currently being developed; (3) it evolves over time, as the expertise is being built, and also differs from one country to the other.

Aykut and Evrard (2017) showed that the framing of the energy transition differed from country to country, embedded in existing frames, instruments and practices. All of them are re-appropriated to fit with the discourse of the transition. For instance, in France, the political framing focused on going from an “energy transition” to a “decarbonization of the energy”, with a top-down setting up of the transition. It allowed French policy-makers to internalize the controversies rising in the public debate concerning the energy

transition, through public consultations that were then integrated into national policies translated at the regional and local levels.

*“You don’t really see the monster here”, criticized Mrs. G. “Everything looks nice and smooth. You go from one frame to the other, from one valuation of renewable heat to the other, and all the instruments adapt. You don’t really see who is doing the framing.”*

- “Don’t worry, I will go into the arena soon enough. For now, I am just setting the scene, so that the real show can begin. “

These national frames are produced by the governments and their agencies, based on various inputs and expertise. But, from her interviews with national stakeholders of district heating in France and Denmark, Mrs. G. also highlighted that the valuation was still evolving. New negotiations were taking place, and local concerns were also influencing the framing process. I thus decided to have a closer look at what was happening when these national instruments—mostly policy tools—were translated into operational tools like a management dispositive. For this, I chose to focus specifically on sustainable district heating in France, for which Mrs. G. uncovered local concerns challenging the current design of instruments.

## Framing French district heating for a carbon neutrality path

In the last part, I narrated a story of national district heating frames in France and Denmark. In both countries, the last frame is related to sustainability, with a strong angle on decarbonization. In France, it has been supported by various instruments since 2009, structured around the Heat Fund. In this part, I will do a close-up on France, to look more into the details of this national framing of sustainable district heating and its instrumentation. How is this frame translated through instruments? Aykut and Evrard (2017), when analyzing the French energy transition, state that *“the French case is characterized by the upholding of a significant ambiguity between ambitious goals suggesting a rupture with the existing national energy policy path, and implementation instruments showing more a kind of inertia.”* (Aykut and Evrard, 2017, p. 27, own translation). I will particularly look for any tension in the design assumptions and expected use of instruments that could give a more refined view on the actual framing process and its negotiation arenas.

In this part, I will first briefly present the variety of instruments analyzed and go through Mrs. G.’s data collection, before delving more deeply into the analysis process and finally presenting the tension points highlighted by the analysis.

*“I don’t want to spoil anything”, smiled Mrs. G., “but this was maybe the hardest and most rewarding part! It was like finally finding the right spot to unknot the yarn ball. Or the monster’s tentacles maybe...”*

- *“It was a start, a first step towards shedding a bit of light on the monster.”*

## *Mrs. G.'s data collection, a stack of plans and regulations*

### A multiplicity of instruments...

The French government is committed to carbon neutrality by 2050 and has pointed out sustainable district heating and cooling system as an essential lever to reach this goal. More precisely, the 2015 law on the energy transition for a green development set up the objective of multiplying by five the amount of renewable heat and cold delivered by district heating and cooling between 2012 and 2030. This objective was reasserted in the 2020 national energy plan (PPE, see *box 5*). As Mrs. G. discovered previously, multiple instruments have been put in place to support the development of district heating and cooling systems in the context of the “ecological energy transition”, including the Heat Fund and several subsidies managed by the ADEME. These instruments are not just financial instruments like tax reductions or state assistance, but also planning instruments such as national heat maps or mandatory local energy roadmaps and district heating roadmaps. These instruments specifically acting on district heating interact with others, like the 2012 Thermal Regulation on Buildings (renewed in 2020) or White Certificates. They are also embedded in existing processes, like public market bidding, framed by regulations and based on management tools such as Public Service Delegation contracts.

#### **Box 5: 2020 and beyond – national planning with the PPE**

The Heat Fund tries to operationalize national ambitions on renewable and recovered heat. These ambitions are integrated in the national energy roadmap (PPE), updated every five years. The latest one, adopted in 2020 after a public consultation in 2018, covers the 2019-2028 period (Ministère de la Transition écologique, 2022). It reasserts the objective to strongly develop district heating and cooling systems based on renewable and recovered heat. A national prioritization of resources is stated: the use of biomass needs to double before 2023 and the of geothermal energy to increase fourfold. Waste heat (both from waste incineration and industrial production) needs to become an important part of the future heating mix. To complement this mix, biogas and thermal solar panels will be used. An annual assessment of this energy transition will be conducted every year, to modify the instrumentation according to the results (Cerema, 2021).

Several lessons can be drawn from this specific instrument:

- 1) The valuation of biomass as a key renewable heat source.
- 2) The embeddedness of energy planning into a variety of other regulations: the PPE is supposed to be structured with different national and local plans, programs and strategies e.g., the national low-carbon strategy, the national energy research strategy and local planning on climate, air, and energy (Ministère de la Transition écologique, 2022).
- 3) The alignment between national planning and operational tools: while some instruments were identified as enablers for this transition (like the Heat Fund), the criteria to access the Heat Fund are not fully aligned with the objectives. For instance, the lack of standardized criteria on industrial heat, highlighted by Mrs. G. in the previous section, may prevent the development of its use.

Despite a variety of instruments aiming at operationalizing the French ambition of developing renewable heat, Mrs. G. found that district heating systems were not living up to expectations. The General Accounting Office published a report in 2021 showing that even if district heating systems were significantly developing in France, the development rate was not sufficient to reach the objectives of the 2015 law. Among the explanations provided by the report, three areas for improvement were highlighted: (1) the planning and management of this public service by the public authority; (2) the transparency of economic data from private operators; (3) national assistance supporting the development of district heating (mainly financial tools, with a resort to other types of national assistance and integration in other areas like urbanism). These improvement areas are linked to existing (or lacking) planning, reporting and market instruments.

#### [... collected through interviews and policy documents for analysis](#)

To analyze this network of instruments, I needed to gain data on them. This data collection was conducted by Mrs. G., who had the idea of investigating instruments. It all started by several interviews with French national stakeholders. The role of the Heat Fund, the ambitious French plans, the development of new tools, all of these topics were mentioned by the interviewees. The Cerema and ADEME highlighted the role of the 2015 law to set

objectives on district heating. All national stakeholders mentioned the work group launched by Emmanuelle Wargon and the resulting 25 measures to reach the objectives released in 2019. The FNCCR talked about the RE2020 as a door to shift a bit the regulatory frame for district heating. From there, Mrs. G. decided to look at the actual legislation stating the objectives, the tools to be used, the mandatory planning, etc. Looking into the documents, she realized the intricacy between different legislation, pushing her to look into more policy documents.

This first round of data collection was supplemented by a second round after the French case studies. In June 2020, Mrs. G. investigated two French case studies, Dunkirk and Besançon. Through interviews with project actors, she realized that more legislation was impacting the development of district heating network, and that—despite the multiplicity of instruments—some gaps were still unfilled or incorrectly filled. In particular, she discovered how national laws were translated into management tools like mandatory roadmaps, and the impact of existing settings like public market regulations. Both Besançon and Dunkirk metropolitan areas were thinking about the renewal of their local energy roadmap, and the role district heating systems could play in reaching their objectives. However, the making of these plans did not go without difficulties, like working with other departments and gaining the right competencies. Similarly, the renewal of Public Delegation Contracts, strictly regulated by law, brings its own challenges. The interviewees from the Dunkirk Urban Community admitted to facing “*huge difficulties*” when preparing their renewal. Mrs. G.’s contact from Besançon also highlighted that “*the concession has been renewed in 2019 for 6 years. The durations are decided by Europe [...] five years is really too short to build something, all the more as the renewal takes almost two years to prepare...*” (extract from Mrs. G.’s notes on the interview with the public manager of Besançon’s district heating, own translation). Based on these insights, she thus completed her first round of analysis by looking into even more legislation and its operational translations.

Finally, reports on district heating, in particular the one from the General Accounting Office, made a summary of major policy and management tools supporting district heating. Mrs. G. also attended a conference of French practitioners on district heating and cooling, where several instruments were discussed.



Table 11 presents the interviews made, the conference attended, and the instruments mentioned. The perimeter of the instruments analyzed is the French one, meaning that no European instrument and law will be discussed here, but only their translation in national regulations.

Please see Annex 1 for I have put more details on the interviews conducted.

Interviewee's organization or case study	Date	Policy tools mentioned	Management tools mentioned
AMORCE	07-10-2020	Ranking of district heating	Performance indicators, contracts, legal setup
FNCCR	06-12-2020	Public market, RE2020 <sup>24</sup> , GT Wargon <sup>25</sup>	Legal setup, performance indicators, contracts (pricing)
Cerema	05-18-2020	GT Wargon, PPE <sup>26</sup> , SNBC <sup>27</sup> , Heat Fund	SRADET <sup>28</sup>
ADEME	05-20-2020	2015 LTECV <sup>29</sup> , PPE, tax reduction, CPE <sup>30</sup> and CEE <sup>31</sup>	PCAET <sup>32</sup> , district heating roadmap
Cerema (Hauts-de-France regional office)	06-03-2020	ADEME subsidies, PPE, SNBC	SRADET, PCAET, contracts

<sup>24</sup> Thermal and environmental regulation for new buildings (Réglementation Environnementale 2020)

<sup>25</sup> Working group for the development of district heating and cooling systems

<sup>26</sup> National energy planning (Programmations pluriannuelles de l'énergie)

<sup>27</sup> National Low-Carbon strategy (Stratégie Nationale Bas Carbone)

<sup>28</sup> Regional roadmap for urban planning, sustainable development and local equity (Schéma regional d'aménagement, de développement durable et d'égalité des territoires)

<sup>29</sup> Law on the ecological transition for green growth (Loi de Transition Energétique pour la Croissance Verte)

<sup>30</sup> Energy Performance Contract (Contrat de Performance Energetique)

<sup>31</sup> Energy Economy Certificate (Certificat d'Economie d'Énergie)

<sup>32</sup> Local plan for climate, air and energy (Plan climat-air-énergie territorial)

Grande-Synthe district heating	06-04-2020	Law MAPTAM <sup>33</sup>	contracts
Grande-Synthe municipality	06-10-2020	ADEME subsidies	Contracts, SRADETT, PCAET
Dunkirk Urban Community	05-28-2020	Law MAPTAM, 2015 LTECV, Heat Fund,	Agenda 21, contracts, district heating roadmap, legal setup
ADEME (Hauts-de-France regional office)	05-29-2020	Heat Fund, CO2 quota	District heating roadmap, contracts
Besançon metropolitan area (energy office)	06-18-2020	Tax reduction, tax on natural gas (TICGN) <sup>34</sup> , CO2 quota	Contracts, NPRU <sup>35</sup> , district heating roadmap, performance and emission indicators
Besançon district heating operator	06-18-2020		Contracts, performance indicators, internal indicators
ADEME (Bourgogne Franche-Comté regional office)	06-19-2020	MAPTAM law, tax reduction, ADEME subsidies	District heating roadmap, energy roadmap, contract, environmental indicators
Besançon metropolitan area	06-19-2020	Law MAPTAM, climate law,	PCAET (including district heating roadmap and

<sup>33</sup> Modernization of Local Public Action and Affiliation of Metropolitan Areas (Modernisation de l'Action Publique Territoriale et Affirmation des Métropoles)

<sup>34</sup> Domestic tax on natural gas consumption (Taxe Intérieure de Consommation sur le Gaz Naturel)

<sup>35</sup> New plan for urban renewal (Nouveau Programme de Renouvellement Urbain)

(environmental office)			energy roadmap), SRADETT, SCoT <sup>36</sup> , PLU <sup>37</sup> , PLH <sup>38</sup> , Agenda 21
Journées des réseaux de chaleur et de froid	12-10-2020	CEE, ranking of district heating, RE2020, refurbishment bonus, 2015 LTECV, PPE, Heat Fund, taxes	Contract, legal setup

Table 11 List of the interviews made in relation with district heating instrumentation

Due to the complexity of French administration, I have not cited all the laws regulating and having an impact on district heating, but only the main laws setting a frame for district heating and the policy instruments—part of the energy, construction, urbanism or environment codes—that are then translated into management tools. The modification of these policy instruments is made by law, which is then translated into an implementing decree modifying the relevant codes. Mrs. G. had gone through a significant number of these laws and decrees to complement communication on the ADEME, Cerema or Ministries’ websites and better understand the making of the policy tools. For instance, the ranking of district heating is a process which is part of the Energy Code. Two laws have modified it respectively in 2019 and 2021, facilitating the mandatory connection but only to sustainable district heating systems. The implementation decree to actually change the energy code—and the urbanism and building codes—was passed in April 2022 (Decree no.2022-666 dated April 26<sup>th</sup>, 2022 related to the ranking of district heating and cooling systems<sup>39</sup>). For the same reasons, I have not flagged all the environmental and health

<sup>36</sup> Local cohesion plan (Schéma de cohérence territoriale)

<sup>37</sup> Local urbanism plan (Plan local d’urbanisme)

<sup>38</sup> Local housing program (Programme local de l’habitat)

<sup>39</sup> [Décret n° 2022-666 du 26 avril 2022 relatif au classement des réseaux de chaleur et de froid - Légifrance \(legifrance.gouv.fr\)](https://www.legifrance.gouv.fr/decrets/2022-666)

regulations on emission thresholds, even if they have an impact on the key performance indicators followed by the operators.

Mrs. G.'s data collection was strongly linked to the analysis framework developed. Her rounds of semi-directive interviews steered the investigation towards specific instruments. To analyze these documents, data was collected through secondary sources. The data collection focused on two main types of instruments previously presented: policy tools and management tools. In this study, we will shift from the management dispositive—which is a complex assemblage—to management tools, a part of the dispositive. I consider that policy tools set the national frame, while management tools turn them into action at a more local level. For instance, a district heating roadmap is a management tool, whose design is required by a national law—i.e., a policy tool. I also analyzed some calculation tools that were used to design specific instruments, as they explicit the assumptions made during the design. In the analysis of these instruments, I wanted to explicit their frame—what was the perimeter for action that they sketched out?—to see if these perimeters were aligned and coherent, or overlapping and in tension. Thus, I needed to know what was the intended effect of the instrument and the expected user of the instrument. This guided Mrs. G.'s data collection, and she filled in the following table (see *Table 12*).

Instruments				Framing		Stakeholders			
Name	Type	Description	Date	Intended effect	Underlying assumption	Designer	Quote / comment	Intended user	Quote / comment

*Table 12 Data collection table*

For each instrument, Mrs. G. described three dimensions: (1) the instrument itself; (2) the framing; (3) the related stakeholders.

For the first dimension, Mrs. G. wrote a short description of the *instrument* and its date of implementation. The description is mainly based on the documents and completed by explanations from the interviewees. It shows the interrelation between the instrument

and others. The date of implementation allowed Mrs. G. to roughly keep track of the chronology in the instrumenting of district heating.

To explicit the *framing*, she looked at the intended effect, as understood from the instrument's description, and at the underlying assumptions embedded in the instruments' design. Let me give you an example of two assumptions taken at a national level—and partly challenged by the interviewees—which have an impact on the instrumentation of district heating: district heating systems development is the responsibility of local public authorities; and district heating is in competition with natural gas. Mrs. G. picked up these assumptions by reading between the lines of her interviews. A number of interviewees (the national coordinator of the Heat Fund, an interviewee from the FNCCR and some from the Cerema) pointed out that since the MAPTAM law, a number of local public authorities needed to “take over the reins of energy and infrastructures” for French district heating to really take off. The national coordinator of the Heat Fund also regretted the competition with gas, making it difficult for district heating systems to stay competitive despite national subsidies. This view was supported by the interviewee from the FNCCR, who thought that *“it might be interesting to get away from the systematic comparison with gas”* (own translation). The interviewees from the Cerema agreed with this statement, adding that *“the price of fossil fuels fell during the pandemic, in particular the price of gas. It makes it very difficult for district heating and may jeopardize some of the projects being considered”* (extract from notes taken during the interview with the Cerema in May 2020, own translation). Mrs. G. found the same two assumptions when collecting data on the instruments. The MAPTAM law gives the responsibility of district heating development to municipalities. Several management tools were designed to support their action like mandatory energy roadmaps (made mandatory by the 2019 law on energy and climate).

Finally, concerning the *stakeholders*, Mrs. G. separated the designer from the intended / real users. Depending on the type of instruments analyzed, some categories did not apply or needed specifications. For instance, laws do not have a “user” but may impact some specific stakeholders, like local authorities, by giving them new missions. To specify these cases, Mrs. G. added a column “quote / comment” to her analysis table, giving space for interviewee quotes related to instrument use, and her own comments on the stakeholders.

Instruments				Framing		Stakeholders			
Name	Type	Description	Date	Intended effect	Underlying assumption	Designer	Quote / comment	Intended user	Quote / comment
Heat Fund	Policy tool	Subsidy to develop sustainable DH created during the Grenelle de l'Environnement roundtable	2009	Allow sustainable DH to be competitive	Sustainability > 50 % renewable or recovered heat  Competition with gas  Market regulation for "natural monopolies"	ADE ME	<i>"to speed up the development of renewable heat, there is a need for massive state aid to district heating"</i> (head of the Heat Fund, own	DH owner	Aid goes through the DH operators

							transl ation) <i>“for the projec ts to be profit able”</i> (head of the Heat Fund, own transl ation)		
DH master plans	Manag ement tool	Ten-year masterpl an (in the PCAET) outlining the evolution of DH (different scenarios ). Mandato ry to be eligible for the	20 15	Integra te DH into local planni ng	DH as a local concern	DH own er	Usuall y made hand- in- hand with the DH opera tor	DH owne r and ADEM E	DH owner: for the develop ment of DH ADEME : to get subsidi es

		Heat Fund subsidies							
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Table 13 Data collection table—example

Table 13 provides an example of the analysis table for a few instruments, but the full table can be found in Annex 7.

*“This table was a nightmare to complete”, grumbled Mrs. G. “I felt like I was drowning in all the legislation, and interviews, and all.”*

- *“I can understand, but it was a very useful table. And it showed a glimpse of the intricacy of district heating.”*
- *“There was a mountain of abstruse policies. Each one referring to a number of others. Every other one as abstruse as the first. And no indication on where to stop tracing back the policies.”*
- *“The perimeter was really an issue for the data collection, but also a result. Going into the details of energy policies about heating, but only to the first layer of related policies (like the ones on electricity, or housing, etc.) was a good approach.”*

Once Mrs. G had painstakingly completed the table, I analyzed different processes: (1) the operationalization of the policies into different instruments, to see if the intended effect of the policy instruments was realized through the management tools supporting it; (2) the levels at which the calculation tools were used, to better understand who were the acting stakeholders using the calculation tools to design or use other instruments; (3) the consistency between the assumptions embedded in the design of the instruments.



### *An analysis underlying three points of tension*

Through this analysis, I discovered three different tensions: a tension in the translation of national policies at the operational level; a tension in local expertise building and finally, a tension as to the role of sustainable district systems.

#### The framing and performativity of valuation processes

This first tension is strongly linked to the history of valuations Mrs. G. investigated earlier. Historically, district heating networks were seen as a natural monopoly providing a public service: heat supply. It was mostly framed through a technical economic angle: the system needed to reach a technical performance in an economically efficient way. To value the economic performance, the cost-benefit analysis was, and is still, a widely used calculation.

Most of the key performance indicators of Public Service Delegation contracts, and the specifications of state subsidies are inherited from this framing. This frame can still be found in the way the “ecological energy transition” is approached; that is through a quantified decarbonization of the energy system, with integration of renewable and recovered heat in the energy mix of district heating. This valuation is written in policy documents and supported by market instruments: to get access to subsidies or tax reductions, a specific amount of renewable and recovered heat is to be reached by the system. It had a great impact, as French district heating went from 40% of renewable and recovered heat in its energy mix to 60% between 2011 and 2019 (Euroheat and Power, 2022).

However, controversies may arise with local authorities on what is considered a “renewable energy” and “heat recovery energy”, and what values should be taken into account for this typology. For instance, some surplus heat sources are not part of the renewable and recovered heat typology, and thus cannot give access to the instruments supporting the development of district heating systems. The Hauts-de-France regional coordinator of the Heat Fund regretted that *“there was a challenge to prove that mine gas was indeed waste heat for the ADEME national office or the ministries, even if it is stated by law that it is indeed waste heat”* (own translation). On the other hand, biomass,

considered as renewable at a national level, can be classified as non-renewable by local authorities, preventing the development of district heating networks (see *box 4* on the biomass controversy and chapter 6 on the expression of this controversy in Bourgogne Franche-Comté). Going one step further, a will to reconsider the performance indicators used, and the current procurement processes is starting to emerge, questioning the very frame of district heating. Some working groups—alternatives to the government-led ones—have been set up to work on such themes as tariffication of district heating, legal setups or to list services provided by district heating. These working groups were mentioned by the interviewees from the FNCCR and Amorce. With the same idea, the public manager of the Besançon's district heating insisted on the importance of designing the right performance indicators and right contract during the contract renewal process. If these themes may seem very focused, they question several processes that are currently taken for granted, such as the public procurement for the Delegation of Public Service or the local desired outcomes of heat delivery.

Moreover, despite the great increase in the use of renewable and recovered heat, the national objectives set up by the 2015 energy-climate law and reasserted by the PPE are far from being reached. The translation of national policies and objectives into the operational frame goes through the meanders of French policy making. To make a law, an Act has to be adopted, which is then translated into an implementation decree specifying the management tools to be set up in order to reach the objectives. Both the objectives and their instrumentation are then translated at the regional level. From there, the instrumentation can be set up. However, this translation is not necessarily well-integrated. Contrary to the Danish development, where a process of knowledge exchange from the local to national level led to what was considered a well-thought-out national plan (Jensen and Karnøe, 2018), the French development lacks some inter-level coherence. The Hauts-de-France regional office of the Cerema admitted that the regional decarbonization and district heating development objectives, as stated in their regional roadmaps, the SRADETT, were not sufficient to reach the national objectives: *“in 2014, the Cerema tried to sum up the ambitions of every region (through the figures stated in their PCAET) and it was not even a tenth of the national objectives. And it would have been even worse by going more local. There is no real link between each level”* (notes the

interview with the Cerema Hauts-de-France, own translation). The same phenomenon appears between the national roadmaps and the local ones. Also, the administrative time to translate a law down to the operational level can induce some barriers to action, as pointed out by Amorce: *“The ranking of district heating is a huge worksite right now. The translation of systematic ranking is not very specific, there is a need for a regulatory frame to make it operational. For now, there is only a legal frame”* (notes from the interview with Amorce, own translation). On the other hand, new regulations can have immediate effect: The Besançon district heating manager also criticized these regulation changes that could threaten the district heating system balance. He said that *“it can cost a lot not to follow the regulation, or the need to update infrastructure to follow new regulations”* (notes from the interview with the public manager of Besançon district heating, own translation). It highlights how the political and public policy times are very different from those of public infrastructures.

These gaps in the valuation—between what is valued at a national level and what is valued at the local level, and the operational translation of national valuations—highlights the multiplicity of stakeholders and frames revolving around district heating. It shows the difficulty in developing both a common valuation of district heating that will lead the actors to action; and the organization needed to properly instrument the valuations and make them perform. It also questions the management of such public services e.g., its temporality, its organization, under the pressure of new challenges, like the objective to go for a carbon-neutral energy system.

### The development of local expertise

This first tension leads to an “expertise crisis”. At a national level, policy makers mainly rely on existing expertise to design their instruments. Their efforts to integrate local concerns is embodied by working groups doing consultations whose outputs may then be integrated into instrument design. In 2019, the state secretary to the French Ministry of Ecological and Solidarity Transition launched the “GT Wargon”, a working group on renewable heating and cooling, gathering many stakeholders, including national organizations, associations, representatives from the local authorities, and

representatives of private companies. It led to twenty-five actions to accelerate the development of renewable heating and cooling systems.

The interviewees from the Cerema<sup>40</sup>, a national expertise organization, pointed out that despite the actions listed as outputs from the GT Wargon working group, few resources were given to local stakeholders to actually set up these actions. For instance, the first action is to communicate with all municipalities of more than 10,000 inhabitants to help them develop district heating systems. Amorce, the Cerema and ADEME are supposed to lead this action, but they do not have sufficient human resources to actually do it.

Despite these attempts to integrate local concerns, the instruments developed are still embedded in a technical economic frame. They were designed with a global goal of expanding district heating systems but do not translate into empowering tools for local public authorities. The local public authorities need to make a local energy plan integrating district heating as they are the ones owning the systems, but lack appropriate tools. For instance, a 2012 European regulation required each country to map heat demand. It was done in 2015 in France, based on European assumptions and heat demand models. However, this national mapping could not be used at the local level to develop district heating projects or energy planning, due to its lack of precision. The first publication of the ADEME even explained that *“Globally, this heat map needs to be used with precaution, as a very upfront tool for infrastructure or public work project.”* (Cerema, 2015). Through the interviews, Mrs. G. understood that the local authorities sometimes did not have the right resources (e.g., human resources, reliable heat demand maps, etc.) to produce comprehensive planning. In addition, they often lacked the right internal organization. The interviewees from the Cerema stated that *“there is a lack of structuring between the urban development policies, especially between the operational urban services and energy planning ones”* (notes from the interview with the Cerema, own translation). The different departments were not used to working together, making it difficult to tackle complex issues like heat demand mapping which can concern the urban planning, environment, finance, and energy departments. An interviewee from the environment department of the “Grand Besançon Métropole” pointed out that it was just

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<sup>40</sup> A description of the organizations mentioned in this section can be found in Chapter 1.

one and a half years ago that they set up a coordinating body for the different roadmaps. The change in the distribution of responsibilities between the cities and metropolitan area also required more cross-cutting work, as the teams grew very quickly and the processes relying on interpersonal relationships no longer suitable. The General Accounting Office (2021) pointed out the difficulties in producing the documents they have to design—like the mandatory local energy planning, or the masterplans—and to have coherent planning between the national, regional, and local levels. This difficult alignment highlights the weaknesses of the collective local expertise around district heating, with the relationships between stakeholders not being instrumented in favor of the development of the district heating system.

Moreover, the operation of district heating systems is usually delegated to private partners through Public Service Delegation due to the local authorities' lack of resources and competence. The market-based instruments, even if designed for the local authority owning the networks, are usually taken over by the private operators to economically optimize their projects. The national coordinator of the Heat Fund observed that *“the files put forward by the operators are optimized to get subsidies, but not to use as much renewable and recovered heat as possible. Some even push for files where waste heat is not used to its full potential, justified through technical problems, in order to improve the share of gas heating, as many of the parent companies sell gas”* (notes from the interview with the national coordinator of the Heat Fund, own translation). The private operators historically have a strong influence on the development of French district heating, as the French market is dominated by five private companies (Cour des Comptes, 2021). They have built their own expertise and instruments to manage the systems. The operator of the Besançon district heating system mentioned the internal reporting processes, with their specific indicators. Despite the dynamism of some local operators, private companies are not considered to be willing to change their way of doing things by the national coordinator of the Heat Fund and the FNCCR. The latter stated that *“at the local level, operators have a lot of ideas, but there are barriers from the corporate level to push further innovation in business models”* (notes from the interview with the FNCCR, own translation). Both the interviewees and the General Accounting Office's report on district heating (2021) highlighted the lack of resources and knowledge of local authorities, preventing them from fulfilling their managing role. The public manager of the Dunkirk

district heating system admitted that they have very little expertise on the district heating and have difficulties building internal expertise.

Despite these difficulties, all the interviews showed that local authorities were interested in becoming more committed to their district heating, when a system existed. The national Heat Fund coordinator, the interviewees from the FNCCR and the Cerema expressed that public authorities are very motivated and most of them are willing to follow the momentum if the local benefits are shown to them. Some are even forerunners, like Dunkirk which was a leader in the setting up of its district heating. Their dynamism was highlighted by the Hauts-de-France regional offices of the Cerema and the ADEME. To fill the gap in current instruments, and complement the supporting organizations (like the ADEME), the local authorities organized knowledge-design, and knowledge-sharing practices both at a national and European level. They also work with alternative frames and labels (like TEPOS or Cit'ergie, two schemes for local ecological transitions). Associations, like the FNCCR—representatives of public authorities owning public supply infrastructures—have grasped these new concerns and initiated working groups and conferences to build up the local authorities' capabilities. For instance, the Cerema and ADEME produce many short notes to help public authorities. They also participate in the “heating and cooling network days” (*journées des réseaux de chaleur et de froid*) held each year with many stakeholders of French district heating. They advocate for the design of new national instruments, work on the “best practices” that can be standardized and shared through their members, and some also offer some technical support to interested local authorities. Through these processes, new expertise is being built (even if mainly restricted to those local authorities that are already aware), and other frames and valuations can emerge. Part of this support was already given by national state organizations, like the ADEME or Cerema, who work at a regional level to translate the national instruments and support local stakeholders. These organizations can also raise awareness about district heating, by reaching smaller local authorities that are not part of current networks. They are supported by consultancy firms, who also improve their expertise on district heating systems and develop tools for the public authorities to gain competencies. Nonetheless, their role is ambivalent as they do not necessarily allow internal upskilling, as mentioned by the Dunkirk Urban Community.

To conclude, this tension points out the difficulties in developing the right expertise to make a frame perform. Even though district heating is being framed as a local concern, tools created at a global scale fail to develop a local competency on district heating, both for their planning and their management. The analysis showed that few instruments were specifically addressing the issue of expanding district heating systems, and directly addressed to local authorities. Most of the instruments were focused on the renewable energy and heat recovery resources aspects.

At the same time, a competing knowledge-assemblage (Jensen and Karnøe, 2018) is being shaped by the local authorities, through the development of knowledge-design and sharing practices, supported by growing networks of actors. Such local expertise building can play a role in the legitimation of competing valuations, integrating other ideas of public values.

#### Finding the right boundaries for integrating of district heating into the energy system

Finally, while district heating is considered an essential lever for the “ecological energy transition”, it still has blurred boundaries, both physically and as a political object. This tension is symptomatic of the difficult framing of district heating: even if there is a strategic intent to frame it as a key component in the energy transition, its boundaries and interactions with other energy vectors are not entirely thought out. The lack of instrumentation, organization and competencies (both at the personal and organizational levels) reveals that district heating suffers from a weak “expertise network” (Eyal, 2013).

Despite the PPE’s ambitious objectives in district heating development, district heating still has to compete with other energy means. Different conflicting instruments are designed within the energy sector: for instance, the gas price is frozen but the national subsidies for district heating compensate for the difference between gas prices and district heating prices. The public manager of Besançon’s district heating regretted that some industrial firms did not connect to district heating due to their very low tax on natural gas consumption. Similarly, France has created a kind of competition between district heating and electric heating: the market will regulate and chose the better socio-economic alternative, but the energy sector is still regulated and the RE2020 has given an advantage to electricity. During the heating and cooling network days in 2020, several

associations and local authorities expressed concerns. Nicolas Garnier, from Amorce, even warned in an interview for *Lagazettedescommunes* (2022) that *“this movement is done at the expense of the collective renewable heat. The balance of some heating networks will be threatened”* (own translation). This competition between energy networks is in tension with some visions of sustainable district heating as a vector of multi-energy networks. The FNCCR explained its vision *“we are driving a multi-network rationale for tomorrow, and the day after tomorrow a global approach at the scale of the city”* (notes from the interview with the FNCCR, own translation).

When it comes to energy policies, most are structured around gas and electricity networks. This structuration is accentuated by the European and national stakeholder ecosystem, with strong industrialists and associations in both fields. When tackling district heating, the system is much less institutionalized and the instruments supporting district heating not well integrated in the existing energy instruments. Mrs. G. found out that most of the organizations revolving around district heating are also stakeholders in other energy vectors or public networks. No institutions or organizations are solely devoted to the representation of district heating at the national level, and French district heating lacks strong representatives that can make it exist and compete with other energy vectors in the political arena. Despite being defined as a lever for transition, district heating remains quite invisible in the public debate. This is a classical problem with public infrastructures, *“whilst all aspects of the functioning of cities and regions rely intensely and continuously on such networks at every stage, they are largely invisible and ignored in debates about the contemporary urban and regional development”* (Marvin and Graham, 1999, p. 101).

Beyond this political framing of district heating, the physical boundary of the system is also challenged. For now, the legal boundary of district heating stops at the energy transfer station (ETS) and does not go inside the building. This legal boundary performs a physical boundary: all the pipes after the ETS are not district heating pipes. With district heating being seen as a lever for the energy transition, this boundary is challenged by some stakeholders. The mission mandated by the Ministry for the Ecological Transition recommended investigating the possibility for district heating operators to operate the



secondary network too. The FNCCR also mentioned that *“some metropolitan areas have started to think about a common management of district heating networks and secondary networks but this idea did not go as far as being integrated into the bidding processes. There are of course technical and economic reasons, but nothing insurmountable. The main bias is psychological”* (notes from the interview with the FNCCR, own translation). This issue of the legal and physical boundaries of the network questions all the expertise around district heating: its stakeholders, its regulation, its management tools, and its institutions.

This last tension clearly shows the trouble in finding the right perimeter to frame district heating: it is an unregulated market, a supply infrastructure, which can be based on various resources, and which is strongly interlinked (through competition and supply) with many regulated sectors. It has to participate in the global “ecological energy transition” and the boundaries within which the system performs in order to reach its objectives are wider than just the technical ones. One way for it to perform is to interact with other energy vectors, but this challenges its current frame as a renewable heat supply means. This tension in finding a stabilized frame for district heating is aggravated by its invisibility as a relevant subject of debate, and the lack of institutions representing it—all in all by the lack of global expertise around French district heating. The fact that the district heating frame is not stabilized partially clarifies the difficulties encountered for its instrumentation to perform: in which frame should this instrumentation be built?

## *The French framing of sustainable district heating*

With the analysis completed, I will now offer a brief summary and conclusion on the French framing of sustainable district heating, with a short update to take into account more recent changes.

### An ongoing framing process?

The analysis showed that French district heating is still undergoing framing. The historical framing of district heating is being overflowed (Callon, 1998) and the current instrumentation is no longer suitable. Seeing district heating as a lever for the ecological energy transition questions the boundaries of what is valued in such system, the role of local stakeholders, but also the perimeter of district heating in an integrated energy system. To take into account this overflow, a new frame is under construction through negotiations between the various stakeholders of district heating. However, the framing process is made difficult by the invisibility of district heating as a relevant object for political and public debates, and the lack of global expertise.

The supporting instruments were historically based on a technical economic angle, leading to a view of the “ecological energy transition” framed through the integration of renewable and recovered heat. New values are now being integrated as desirable outcomes of district heating, partly due to the local development of the systems and the negotiations around the framing of renewable energies and sources of heat recovery. The national instrumentation of these values lacks performativity as it is not properly translated down to the operational level.

As a result, local development suffers from difficulties in building expertise, with few instruments helping to broaden the actors’ capabilities. Different interest groups are producing competing knowledge-assemblage aiming at solving some of the tension points, like experience-sharing associations creating tools to build local authority expertise. This expertise building goes hand in hand with the emergence and legitimation of local valuation and framing of district heating.

Finally, even though district heating is promoted as a lever for the “ecological energy transition”, it is not clearly integrated with other energy vectors (like gas or electricity)

and others sectors (like housing). District heating instruments lack coherency with other regulations and the system is put into competition with other energy vectors. Its legal and physical boundaries are also challenged by the integration of sustainable values in its frame. This challenge in the framing of district heating is accentuated by the lack of structuration and representatives of the sector, leading to a weak global expertise on the subject.

In a nutshell, French district heating is still in the framing process. As the frame is not stabilized, neither are the values. While the dominant frame of sustainable district heating is a means to supply renewable heat, negotiations are still ongoing. Sustainability being valued as a percentage of renewable and recovered heat is only part of the global picture. The characteristics of district heating systems—e.g., local anchorage, interrelation with other sectors—facilitate the emergence of competing frames integrating locally designed values.

### A new dynamic in a turbulent context?

The conclusions I have drawn so far need to be updated to the fast-moving context. In the last year, under the pressure of the gas crisis and the concerns about the electricity sector, the cards have been partly reshuffled. Even though the institutional environment has not changed—so there is still no full-time representative of district heating in France—the focus on district heating development has been reasserted and supported by unblocking new means of action. One major instrument set up in 2022 is the “one city, one network” call for proposals, plugged into the Heat Fund. This specific call for proposals is directed towards municipalities with fewer than 50,000 inhabitants, providing them financial and technical support in the completion of studies to implement district heating and cooling systems, including low-temperature ones. The studies can be feasibility studies, for example, or the development of a district heating roadmap. This call for proposals is supplemented by an update of the current level of Heat Fund subsidies for project investments.

Still, the public procurement laws and the regulations around the public service delegation (the 1982 ministerial memorandum on heat supply) have not been updated. In 2011, a

working group worked on modifying of the public service delegation regulations to integrate more contemporary concerns, without any result so far (Amorce, 2011).

*“This part was hard”, recalled Mrs. G. “Both to investigate and to analyze.”*

- *“It was quite frustrating because every indication was pointing in the direction of the tensions we finally discovered, but still we could not properly explicit where they were coming from.”*
- *“And also, everything kept moving, I felt like new regulations and tools were falling from the sky every time I turned my back on data collection.”*
- *“True, it was maybe the first time I saw this aspect of the monster... It was spreading in every direction, and still, we could not catch it.”*

## In a nutshell: From “sustainable” value propositions to a variety of valuations

During this first step of the investigation, I wanted to answer the following empirical question: *How is the frame of sustainable district heating constructed through instruments at the national level and translated at the more local levels?*

To do so, I conducted two analyses. The first one was a historical analysis of national district heating framing in France and Denmark, studied through structuring government-designed instruments. In France, I studied the Heat Fund, a structuring subsidy scheme, and in Denmark the successive incentive schemes launched by the government to support specific production means. The historical framing processes differ in both countries, but in both France and Denmark, sustainable district heating was valued through decarbonization and integration of renewable heat sources into the system mix.

The second analysis aimed at unbundling the French framing process of sustainable district heating. This analysis was made through the instrumentation of sustainable district heating, from the policy to the management tools supporting its development. The analysis showed that the valuation was not as simple as it might seem at first glance. The framing of sustainable district heating is still under construction, with valuations being challenged by alternative ones emerging at the local level.

To cut a long story short, the framing process is never-ending, as the frames keep being overflowed (Callon, 1998). The French national frame of sustainable district heating is based on existing expertise and its instrumentation. Specific instruments can be developed to support the development of sustainable district heating, but they still stem from the existing rationale—here the technical economic one. The translation of these instruments into operational takes place against a background of controversy: alternative and challenging frames may emerge from the local level. Some non-governmental actors play a part in instrumenting these alternative frames and valuing sustainable district heating. They participate in the construction of local collective expertise. However, the lack of global expertise on sustainable district heating impedes the alignment of instrumentation towards a common framing and its resulting valuation.

Despite this ongoing framing process, a number of district heating projects are launched every year, a lot of them claiming to integrate sustainability concerns. I thus wanted to see how, despite the blurred global environment and the multiplicity of local actors involved in the making of a district heating system, sustainable district heating systems could be implemented and operated.



## Chapter 5: Diving into projects

*“La pierre n'a point d'espoir d'être autre chose que pierre. Mais de collaborer, elle s'assemble et devient temple.” (Antoine de Saint-Exupéry)*

*“The stone has not hope to be anything other than stone. But from collaborating, it assembles and becomes temple.” (own translation)*





## Chapitre 5 : une plongée au coeur des projets

Dans ce chapitre, j'ai étudié des projets afin de comprendre comment des réseaux de chaleur durables ont pu être mis en place. Plus précisément, j'ai pris voulu analyser les pratiques de cocréation qui influencent sur la mise en œuvre du projet. Le problème empirique à résoudre était d'étudier *comment les pratiques de cocréation sont cadrées dans les projets ?* Pour ce faire, j'ai construit un cadre d'évaluation de la cocréation basé sur la littérature et je l'ai appliqué à cinq études de cas pour comprendre dans quelle mesure des activités de cocréation ont été mises en œuvre et l'influence du contexte dans cette mise en œuvre. Le cadre d'évaluation se compose de trois activités de cocréation : mise en place d'un réseau de collaboration, définition d'une gouvernance collective et évaluation du projet pour en tirer des enseignements.

Trois cas sont des partenariats public-privé et ne présentent qu'un nombre limité d'activités de cocréation. Les processus de marchés publics ont partiellement entravé la mise en œuvre de pratique de cocréation. Cependant, il est intéressant de noter que même dans ce contexte déjà formalisé, les acteurs se sont engagés dans des discussions informelles pour résoudre collectivement les problèmes. Les deux derniers cas sont deux contextes non conventionnels - une expérimentation et un défi ouvert. Dans ces deux cas, un accent particulier mis sur la cocréation a conduit à la mise en œuvre de plus d'activités diversifiées de cocréation. Cependant, dans tous les cas, cette mise en place visait principalement à créer un réseau de collaboration, au détriment des deux autres activités (définition d'une gouvernance collaborative et évaluation et apprentissage des résultats du projet), remettant en question la continuité future des processus. De plus, les activités de cocréation étaient généralement basées sur des discussions informelles, et seulement certaines débouchaient sur des processus plus instrumentés.

Enfin, deux caractéristiques méritent d'être soulignées. Premièrement, à l'échelle d'un seul projet, plusieurs nœuds de cocréation ont pu être mis en lumière, chacun ayant sa propre expertise et son propre cadre. Deuxièmement, même dans des contextes avec une dynamique collective de collaboration, la cocréation pourrait souffrir d'obstacles si aucune expertise collective n'était construite.

En bref, la cocréation au niveau du projet est principalement cadrée via la mise en place d'un réseau de collaboration. Les chefs de projet et les acteurs du réseau se sont efforcés de trouver et d'engager les parties prenantes concernées. Ce processus est principalement basé sur des discussions informelles mais peut également être instrumenté et intégré dans des processus existants. La construction d'un cadre commun de cocréation semble être un défi majeur, et à l'échelle du projet, de multiples nœuds de cocréation ont pu émerger.

From the first step of Mrs. G.'s investigation, I realized that sustainable district heating was still undergoing the framing process at a national level. Sustainability is usually understood at a national level through the prism of decarbonization and a low-carbon future. However, new values are overflowing this frame, especially coming from the local level. Despite this blurred framing process and associated negotiations, new district heating projects, integrated in decarbonization roadmaps or local strategies, are set up every year. I thus wanted to delve deeper into some of these projects, to understand how they framed and performed sustainable district heating.

In this chapter, I will present the project level, through the angle of public sector co-creation. One major characteristic that Mrs. G. insisted on when talking about sustainable district heating, is its local anchorage and the number of actors it brings together. By analyzing the co-creation process in five case studies, I will try to solve the following mystery: *How are co-creation practices framed in projects?*

I will first give some insights on Mrs. G.'s data collection, then I will present the data analysis and how I operationalized the public sector co-creation literature into an assessment frame for public infrastructures. I will finally describe the main characteristics of co-creation processes in the five cases studied.

*“Looking into projects is the most interesting and fun part of the investigation”, observed Mrs. G. happily. “You get to see a diversity of people gathered around a project. You listen to their story of the very beginning of the projects. You discover the project’s evolution. It is so concrete and human.”*

- *“You also see the problems, you relive the failed expectations, misunderstandings, etc.”*
- *“That’s part of the monster’s life.”*

## Choosing and analyzing the cases

The first step for investigating co-creation in projects was to find the right projects and collect data. This is what I will present here. I will then take a step back in history, with a reminder of co-creation's theoretical framework, and how it was operationalized to analyze the data.

### *Five cases under study*

Among the variety of cases investigated by Mrs. G., I decided to focus here on five. Choosing various cases helped me to take into account the different contexts and objectives of public infrastructures, from the operation of conventional systems and the renewal of contracts for existing networks to transitions from public to private management of district heating and state-of-the-art experimentations on district heating. The cases are all different and the objective here is not to compare them. The aim is to assess co-creation processes in various contexts and settings, and see if some common characteristics can be found in the processes despite the heterogeneity of cases.

### Three PPPs and two experimentations

To show a variety of settings, I chose five cases from Mrs. G.'s investigation: Besançon, Dunkirk, Ottawa, Hornsyld and Helsinki. The first three are managed under a public-private partnership (PPP) and are subject to the laws of public market bidding. Hornsyld is a research experimentation in Denmark where a latest-generation district heating system was set up for a future neighborhood. The last one is an international challenge launched by the municipality of Helsinki to brainstorm on their decarbonized district heating system. The Ottawa, Hornsyld, and Helsinki cases were selected because they included a focus on co-creation processes from the outset. They are recent cases presenting an explicit ambition on the part of the public actor to implement innovations, create value or act on their infrastructure's decarbonization. The other two cases date back further, are in the operational phase and based on a formalized contract. In these cases, actors have now turned towards decarbonization, but this was not the plan at the time these contracts were created.

The cases chosen have several benefits: they are not all at the same phase of the project lifecycle allowing me to partly tackle the long temporality of infrastructure projects; they fall under different national and regulatory settings to tackle a diversity of contexts, they showcase different approaches to sustainability (e.g., experimentations of latest-generation technologies, contract renewal to find the right partner for decarbonization, integration of local resources into an existing system).

Table 14 gives an overview of case characteristics.

<b>Case study</b>	<b>Type of case</b>	<b>Characteristics</b>	<b>Milestones</b>	<b>Phases studied</b>
Dunkirk (France)	Conventional	Use of industrial waste heat (integration of a third party from the beginning of the PPP); PPP (concession)	1985: creation of the district heating system	Project operation
Besançon (France)	Conventional	Based on waste heat recovery and biomass; PPP (leasing)	1968: creation of the district heating system Renewal every 6 years. Last renewal in 2019.	Procurement, project operation
Ottawa (Canada)	Innovative	Lots of resources dedicated to the procurement process by the Government of Canada; co-creation of a decarbonization	The public management was transformed into a PPP in 2020.	Identification, detailed preparation, procurement, project operation

		roadmap for the district heating; PPP (concession)		
Hornslyd (Denmark)	Innovative	“Thermo-road” experimentation research project based on cross-sector integration; partners included a research institute, a private company, a municipality and consulting engineers	2019: submission of the project for funds (accepted in December). 2020-2021: setting up of the system	Identification, detailed preparation
Helsinki (Finland)	Innovative	Energy challenge launched by the municipality of Helsinki for the future of their heating network; anyone could answer the challenge (e.g., students, private companies, research institutes, consortiums)	2020: application phase (February-September) Co-creation phase for finalists (Nov. 2020) 2021: Award ceremony (March)	Identification phase

Table 14 Case study characteristics

To give you an idea of these cases, I will now give you a narrative account of Mrs. G.'s investigation in Dunkirk and Hornsyld. Thanks to her interviews, she will describe each project's evolution through its history and governance.

*Mrs. G. came from the North of France. She knew that many people considered the region as poor and unattractive. However, it was a place full of innovation if one deigned to look below the surface.*

*She had of course heard about Dunkirk for its pioneering dynamic of industrial ecology in France. The Opal Coast was well-known for the synergies it had set up, both between private partners and between public and private ones. It was a place of experimentation and aimed at being a leader in the energy transition. But all these synergies and dynamic stem from one first ambitious partnership: the Dunkirk district heating network. Due to the pandemic, Mrs. G. could not go to Dunkirk. However, she managed to find some of the historical stakeholders who participated in the setting up of the district heating system. One phone call after the other, she reconstructed the story of this partnership...*

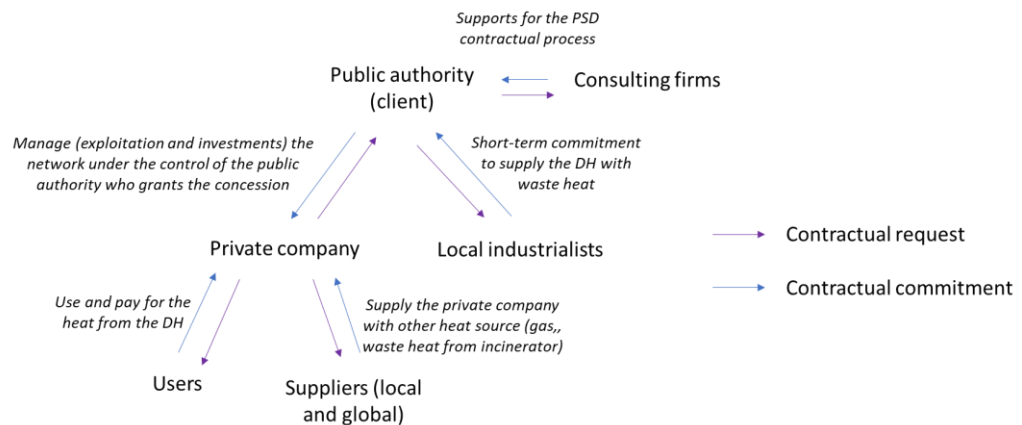
*It all started in 1986, after the oil crisis of the seventies. Dunkirk wanted to become independent from fossil fuel heating. There was a will for new heat production, whose cost could be controlled. The regional ADEME came up with the idea of a district heating system using waste heat: Usinor (that later became ArcelorMittal) was releasing a lot of heat into the atmosphere through its chimney and this had already raised concerns about air quality. The partnership around district heating allowed the company to green its image and anchor its activities in the region in a way that created sense and value for its citizens. In 1983, the SICURD—an intercommunal syndicate for the Dunkirk district heating system—was created under the impulse of Dunkirk. It was composed of three municipalities: Dunkirk, Grande-Synthe and Saint-Pôl and was in charge of the future district heating system's management.*

*The AFME (now ADEME) helped a lot with the creation of the district heating system (feasibility studies for instance) and the discussions with all stakeholders. They helped the SICURD to forecast heating needs, and thus the sizing and design of the network. They then got in touch with Usinor, so that they could tell whether it was possible for the plant to supply the needed heat. Next, Usinor conducted internal studies to see the conditions required to be able to answer the demand: how could it affect their industrial processes,*



*which technology would be needed to capture and convey heat, what would be the variability and reliability of the supply, etc. Once these studies were completed, there was a phase of discussions with the SICURD explicit the project details. The SICURD was helped by the AFME but they also requested consulting engineers' help. Finally, the waste heat was to be captured from the blast furnaces (during the agglomeration of iron and coal). As there was no assurance of supply from Usinor, gas boilers were also set up as an emergency heat supply. They would be used during the demand peaks and whenever Usinor was unable to supply sufficient heat.*

*Once this preliminary phase was completed, and the first partnerships set up, the SICURD launched a request for proposals to find a private company which could build, operate, and maintain the district heating system. The Compagnie Générale de Chauffage (now Dalkia) was chosen by the SICURD. The concession contract, a type of Public Service Delegation where the private company bears the investments, was signed in 1985 for twenty-four years. However, the economic equilibrium of the district heating system was soon to be questioned as fossil fuel prices got really low despite the projections. Moreover, Grande-Synthe finally chose not to participate in the district heating development, so there were less connections to the district heating network than expected. In order to compensate for this drawback and allow Dalkia to pay back its investments, the concession time was extended in 1992 up to 2024. Another imbalance could be provoked by the industrialist: ArcelorMittal only committed to a five-year contractual agreement for heat delivery, as the industrial temporality is different from the public service one. They did not wish to take risks in the supply and made it clear that their operations will always come first. However, the partnership continues to be renewed. It is made directly between ArcelorMittal and the CUD, though its operation is delegated to the private partner (see Figure 22).*



**Governance and contractual network  
- Dunkirk**

Figure 22 Contractual arrangements for the Dunkirk district heating system

*Dunkirk district heating is really a success story: a local authority has managed to create a strong partnership with an industrialist to supply the city with heat. Inspired by this example, several initiatives with such partnerships were launched in the Dunkirk region, making it a leader in the industrial ecology dynamic.*

*Concerning the district heating system, Mrs. G. discovered it had continued to be improved over the years, with new connections to users and new industrial supplies. In 2001, a new amendment transferred the service concession arrangement to Energie Grand Littoral (EGL), a wholly-owned Dalkia subsidiary. Changes in the arrangement led to upgrades in the production facilities and the distribution network, in particular to recover more heat produced by the ArcelorMittal plant. In 2015, after the MAPTAM law, the CUD (Dunkirk Urban Community) took over responsibility for the network. They had already started in 2013 a study of the opportunities for the network (connections to private buildings for instance) and worked on their district heating roadmap. In 2018 an energy node connecting the district heating, an energy recovery unit and an industrial firm (Daudruy), was linked to the network, and increased its share of recovered heat.*

*Lately, the Urban Community of Dunkirk launched a new district heating system on Grande-Synthe's territory, operated by Engie through its subsidiary Arsyel. It is a short concession ending the same year as Dunkirk's. It was not possible to integrate Grande-Synthe as an extension of the current concession as it was outside the perimeter defined on the contract, but after the renewal both contracts will be merged. The public service delegation contract in Grande-Synthe was quite prescriptive and little initiatives could be*

*taken by the delegate. The way to get heat was already decided: most of it will come from ArcelorMittal (former Usinor) but from another process than the one supplying Dunkirk's network. The emergency heat will come from Dunkirk's network, starting the binding of the two contracts. One particularity of this last concession is the strong will of the municipality to cover all its infrastructures with the district heating. Indeed, they represent some 50% of Engie's client, and undertake a transition from their old individual boilers towards a technology compatible with district heating. The remaining connections come mainly from social housing. In Dunkirk, about 38% of subscribed power is shared between the city of Dunkirk, Partenord Habitat (a social housing body) and the hospital. The history of Dunkirk district heating showed Mrs. G. the process through which long-term partnerships can be established between public and private actors for the delivery of public services. The collaborative dynamic created by the district heating system is based on a long common history, and formalized through different contracts.*

Now that you are familiarized with Dunkirk's district heating systems, let us follow Mrs. G. to Denmark. She went there in search for cutting-edge innovation in district heating and finally found the Hornsyld project.

*Mrs. G. was standing in front of a road in the middle of nowhere. Was that supposed to be the famous Thermoroad? A state-of-the-art innovation encompassing heating, cooling, water management, and delivering telecommunications to the houses? The best of the best? A cross-sector experimentation?*

*The project was small but ambitious: to build a latest-generation heating and cooling system and couple it with a permeable road able to store water underneath to support water management. The COST-Action network presented it as very innovative, and when Mrs. G. talked with VIA College, the research team at the origin of the project, it sounded really fancy. So, when she could finally go there to see it for herself, she was really excited... But it just looked like any other road. The consultant from Land&Plan who drove her there seemed amused: "It just looks like a normal road eh?". But then, he started to tell the story of the project, and the magic happened...<sup>41</sup>*

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<sup>41</sup> The description below is not a quote from one of Mrs. G.'s interviews, but a narrative of the project based on the interview with the consultant from Land&Plan in October 2021. Details from both other interviews

*“In 2017, the municipality of Hedensted and VIA College worked on a “Climate-road”: A permeable road to manage surface water, integrating some geothermal pipes that were to heat up a nearby kindergarten. The experimentation was part of a regional adaptation project (the Coast-to-Coast Climate Challenge) and gathered several actors, including VIA College and the Hedensted municipality. After the success of this first experimentation, the municipality was interested in participating in other experimentations with the same partners. Two main challenges for the Danish municipalities are mitigating floods, and ensuring low-carbon heating for all their citizens. Although district heating is widespread in Denmark, all the small villages cannot be connected. The Thermoroad idea is to create a small low-temperature district heating and cooling system (known as “thermonet”), combined with a water mitigation road. VIA College had this idea, and the municipality was willing to provide a new housing area to implement the experimentation. This is where I came in. I am part of a consultancy firm helping the municipality for urban planning. When I arrived in the project, I thought it was another classical urban planning project: create new plots for housing, connect the water management system, the light, the internet, etc. And then I attended a meeting with the partners from VIA College... They wanted to make a research project out of it: put heating and cooling pipes under the main road, which would be permeable and allow water to be stored! They already had a partner that could set up the pipes and all the heating and cooling system; and they had a bunch of performance criteria to monitor during system operation. What I needed to do was to integrate their idea into the urban planning of the area and find all the right contractors to do the job!*

*At first, I was a bit lost about the idea. I could not understand exactly what the project was all about, so I had lots of calls with the team from VIA College University. And from there I could start participating in the discussions. We decided to go further than surface water mitigation but to size the project on the 100-year flood. We also applied for research funds, and worked on the specificities of the system. Of course, there were some technical issues: How should we size the system, could we connect it to other networks? etc. The water management utility was brought into the discussions, to make sure the surface under the*

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with project stakeholders and project documents were added to give a more comprehensive overview of the project.

*road could help their whole system. We also talked with a local district heating company—for the ownership and maintenance of the district heating and cooling system—but they did not want to take the risk of joining the project.*

*And then came the tricky part: finding all the right contractors to actually achieve the project. I had to write all the specifications for the tendering process with VIA College, and then I chose all the contractors one by one. I wanted to make sure they would all pull together in the same direction, and in a collaborative spirit. “I needed to know that they are... they have the capacity and they have the cooperation.” And also, I needed the project description to be very accurate, so that the contractors knew what they were committing to, and would give us the right prices. The contractors could participate in the meetings when they were relevant. And then I supervised all the work myself, and it all went very well, it was quite fun!”*

*In the end, the road comprises the water storage beneath, the pipes for the heating and cooling system and the sewage water pipes. It is all working together to mitigate the water flooding and to provide heating and cooling. Under the stored water you have all the telecommunication, and electricity utilities, etc. And then you also have the geothermal borehole with all the sensors and all, to measure the amount of heat we take from the ground in winter and give back to the ground in summer.*

*Having learnt all this story, Mrs. G. was amazed by the level of collaboration and cooperation between the partners. They all seemed to find it natural to work together and try out new projects. Of course, their interests varied, but as one of the actors stated: “all the companies have been very good at saying, ‘OK let’s do this, we don’t know where we will end, we don’t know what our end costs will be with the project, but we have to do something different from today in the future, so let’s try it out.’” (employee from the water management utility of Hedensted, 2021). Similarly, the municipality pointed out the great collaboration between the partners: “We were lucky to have consultants and constructors that were willing to go in this type of project, and also willing to find solutions together with us.” The various stakeholders were even interested in participating in other similar projects, and eventually to replicate these projects and integrate them into their business.*

*As Mrs. G. had expected, one tricky part had been the sharing of risks and investments, but also defining who will be responsible and own what. Even if the stakeholders were*

*interested in collaborating for the project, they did not want to bear such risks. Indeed, most of the partners and contractors—no matter if they were for profit or not—just wanted to invest about the same amount of money as for a conventional project. The only uncertainty they managed was in the maintenance costs. The research funds they applied for financed most of the “research overcost”, like the setting up of sensors and meters in the borehole. On the ownership side, the municipality stated that “it makes it necessary to find new ways of ownership in this” as a variety of stakeholders were putting technical gear under the same road. The municipality was used to conducting projects in a standardized way, but the Thermoroad did not fit in with any of the conventional types of project. In the end, it was Geodrilling, the private company responsible for the geothermal system, that bore most of the risks and ended up as the owner of the heating and cooling system. When Mrs. G. raised the issue with the head of Geodrilling, he laughed and answered: “I’m bearing very, very much of the risk. There are not a lot of partners who are taking a risk in this project. And I think that’s why they have the impression that whenever there is a risk, there’s always someone who’s prepared to handle it.”*

*Now that the system is implemented, only the customers are missing... The municipality is in charge of selling the plots. The homeowners will have to pay for the setting up of a heat pump and connection to the geothermal system. The municipality is making a homeowners’ association on behalf of the future customers. With Geodrilling they are currently writing a delivery agreement between this association and Geodrilling, to regulate the costs. One expectation of Geodrilling, is that the association will take over ownership of the system, which is a current practice in Denmark. To do so, they could benefit from the municipality’s experience in taking low-interest loans for buying the system.*

*All in all, Mrs. G. was impressed by the ambition of the project. More than a research project on a new technical system, it was a small-scale experimentation on the collaborative organization around such cross-sector systems. It raised various issues, which were solved by collective problem-solving: What values can be created out of the project? Which partners are needed to participate in the project? How can we make long-term agreements for the heating and cooling delivery? It also demonstrated that there were not so many regulatory barriers for implementing such projects, especially at such a*

*small scale. Many lessons could be learned from this first attempt, and Mrs. G. saw that there was a strong dynamic to disseminate among the project's partners.*

**Mrs. G.'s data collection**

As mentioned in chapter 3, data came from both document analysis and semi-directive interviews. Mrs. G. conducted of such interviews with the stakeholders of the Besançon case, ten with the ones of Dunkirk, and five for the Hornsyld case. The interviewees represented the diversity of stakeholders surrounding the district heating system, e.g., district heating owners, district heating operators, members of local authorities, suppliers, and regional state representatives. The interviews were mostly exploratory in the Besançon and Dunkirk cases, with open questions on subjects like the technical system, the history of the network, its governance and the stakeholders involved, the latest innovations implemented and performance criteria. Questions on the stakeholder network and its governance gave some insights into the co-creation and collaborative processes set up, but there was no explicit mention of co-creation. For Hornsyld, the importance of the collaborative process was highlighted by stakeholders during the interviews, leading to results on the implicit co-creation process set up. The Ottawa and Helsinki cases were studied through documents (e.g., bidding documents and contracts) and informal discussions. For Ottawa, a focus was placed during the discussions on the co-creation strategy set up by the Government of Canada.

All of the data, were coded, but not all produced results. In *Table 15*, I will present the data used for the analysis.

Case study	Data analyzed
Besançon	7 semi-directive interviews: biomass supplier, consultant, ADEME, 2 employees or the public authority, 2 employees of the district heating operator  1 informal discussion with an Engie employee who worked on contract renewal

Dunkirk	10 semi-directive interviews: 3 employees of the public authority, ADEME, industrial, municipality, 2 employees of the district heating operators
Ottawa	4 documents: Bidding documents, answer to the bid, monthly report on the projects' operation 3 informal discussions with Engie's employees: 2 who worked on the setting up of the contract, 1 who manages the operations Project website
Hornsyld	5 semi-directive interviews: geothermal system operator, municipality, water utility, road constructor, consultant
Helsinki	Project website 1 informal discussion with Engie's employee who worked on the project Participation to some project meetings

*Table 15 Data analyzed for the five case studies*

The variety in the data used is due to the different case study settings. While interviews could be conducted for three of the cases, no contact could be reached for the other two. For the case of Ottawa, the setting was a private consortium (including Engie) and the Government of Canada. The size and political aspects of the project—which had just been launched—prevented Mrs. G. from accessing potential interviewees outside Engie. However, she benefited from full access to the project documents: bidding documents (produced by the Government of Canada), the answer to the bid (from the private consortium) and reporting documents. She could also conduct interviews with internal actors of the project. She thus managed to get a partial picture of co-creation and collaboration in the Canadian case. In the case of Helsinki, the challenge was mostly an online challenge, managed through the website. Mrs. G. thus looked into the details of



this website and talked with the Engie team that had taken up the challenge. For one step of the answer, she was even integrated into the team. She also tried to reach out to the municipality of Helsinki but without any success. Despite this differentiated access to data, she managed to find some hints on how co-creation was framed by the municipality and how it was experienced by the Engie team.

Even for the cases for which data were collected through interviews, the number of interviews differed, as did the typology of actors interviewed. This depended strongly on the case characteristics. For instance, Hornsyld was a small-scale experimentation, and the five interviews gave an almost comprehensive account of the actors. Some people were contacted but not available for interviews, reducing the number of interviews that could be conducted. Finally, depending on the cases, the interviews were conducted on site, online or by phone. This was mostly due to the health crisis context and the personal availabilities of the interviewees. In all cases, detailed notes were taken by Mrs. G. during the meeting, and most of them were recorded for transcription.

### ***Public sector co-creation for public infrastructures***

The aim of this chapter is to understand how public sector co-creation is framed by the actors at the project level. To conduct an analysis on the data collected by Mrs. G., I wanted first to extract and code all the parts related to co-creation processes. With this extracted data, I would assess the types of co-creation activities conducted in the projects. I thus conducted two phases in parallel: 1) building an assessment frame for public sector co-creation activities in infrastructure projects, based on the literature presented in chapter 2; 2) extracting the data from Mrs. G.'s collection and following an inductive, grounded and focused coding process (Emerson et al., 2011a). I then confronted the activities extracted from the data to the assessment frame of co-creation to draw out results on the framing of co-creation by project actors.

### **Operationalizing public sector co-creation for project assessment**

To design an assessment frame for public sector co-creation activities in infrastructure projects, I drew on the literature on public collaborative governance and public sector co-creation presented in chapter 2. I also added authors working specifically on co-creation in PPPs or for sustainable infrastructures (Torvinen and Ulkuniemi, 2016; Itten et al., 2021; dos Reis and Gomes, 2022).

One key point of public sector co-creation is to create a common purpose uniting all the network actors, but more than that, to maintain and manage collaboration throughout the project (Itten et al., 2021). To do so, the literature proposes various activities. *Table 16* summarizes all the co-creation activities explicitly mentioned in the public sector co-creation and collaborative governance literature.

<b>Type of activities</b>	<b>Activities</b>	<b>Literature</b>
Processes for cross-sector collaboration	Forging initial agreements Building relationships Building legitimacy Building trust Managing conflict Planning	Bryson et al., 2006
Co-creation activities	Forming groups and networks for interactive discussion Distributing information	Torvinen and Ulkuniemi, 2016

	Training users Measuring user satisfaction Evaluating risks of user proposals Building trust and personal relationships	
Activities that foster transformative power	Articulation and alignment of expectations Social learning Resource acquisition Assessment and evaluation	Sillak et al. 2021
Actions to govern collaborative networks	Aligning Mobilizing Organizing Integrating Arbitrating Monitoring	Wegner and Verschoore, 2021
Mechanisms to participate in public co-creation	Information sharing Building of public and private capabilities Risk governance Stakeholder orientation	dos Reis and Gomes (2022)

Table 16 Literature review on co-creation and collaborative activities

With this first step, I had activities to be set up to implement, foster and manage collaboration and co-creation of public values. I gathered these activities into three main co-creation activities that can be applied to public infrastructure projects: (1) setting up a collaborative network; (2) defining the collaborative governance; (3) assessing and learning from project outcomes (Table 17).

Main co-creation activities	Co-creation activities	Literature
Setting up a collaborative network	Co-creation involvement strategy Identifying and selecting partners Building trust and personal relationships Building relationships Building legitimacy  Aligning partners through a shared purpose Identifying need and articulating intent to collaborate	Bryson et al., 2006 Torvinen and Ulkuniemi, 2016 Sillak et al. 2021 Wegner and Verschoore, 2021 dos Reis and Gomez (2022)

	<p>Stakeholder orientation  Articulation and alignment of expectations  Determining the core values</p> <p>Forming groups and networks for interactive discussion  Knowledge and idea sharing  Information sharing  Distributing information  Co-creation dialog  Interaction and dialog</p>	
Defining the collaborative governance	<p>Defining collaborative value capture  Developing structural and procedural governance  Arbitrating model</p> <p>Creation of interdependence  Identifying value co-creation opportunities</p> <p>Forging initial agreements  Power-sharing and engagement  Resource acquisition  Building public and private capabilities</p> <p>Evaluating risks of user proposals  Risk governance  Managing incentives</p>	<p>Bryson et al., 2006  Torvinen and Ulkuniemi, 2016  Sillak et al. 2021  Wegner and Verschoore, 2021  dos Reis and Gomes (2022)</p>
Assessing and learning from project outcomes	<p>Training users  Social learning</p> <p>Creating accountability and decision-making processes</p> <p>Measuring user satisfaction  Monitoring</p> <p>Reporting  Assessment and evaluation</p>	<p>Torvinen and Ulkuniemi, 2016  Sillak et al. 2021  Wegner and Verschoore, 2021</p>

Table 17 Construction of four main co-creation activities

*Setting up a collaborative network* corresponds to the gathering of stakeholders into a network where they build relationships and exchange information. This activity is understood as a first step to gather stakeholders around a common purpose and for collaborative problem-solving. *Defining the collaborative governance* is a process through which different stakeholders agree on a sharing of the resources, roles within the network, and the related risks and responsibilities. This process clarifies the governance of the network of stakeholders. Finally, *assessing and learning from project outcomes* corresponds to the co-design of performance criteria the project should be evaluated on, and the joint assessment of these criteria throughout the lifecycle. From this evaluation, expertise could be built both at the actor and network levels.

Co-creation and collaborative activities can be based on formal processes like procurement activities, or more informal ones depending on the stakeholders involved (Torvinen and Ulkuniemi, 2016). They can rely on a variety of methods: living lab, workshops, mapping tools or design thinking. Moreover, literature presents public sector co-creation as an ongoing process throughout the project's lifecycle. Thus, these activities can be applied in different phases of the lifecycles of infrastructure projects: project identification, preparation, procurement, and operation. Looking at the lifecycle of an infrastructure gives access to a processual approach to public sector co-creation.

The three co-creation activities constitute an assessment framework for infrastructure projects, adding to the existing literature on public sector co-creation.

### Extracting and analyzing data

In parallel with the making of this assessment framework, I also extracted and coded data from Mrs. G.'s data collection.

From this data, the various co-creation methods were extracted (*Table 18*). The literature does not provide a comprehensive list of co-creation and collaborative methods—particularly as some may be implicit—so I defined them through two main features highlighted in the definition of public sector co-creation (Torfing et al. 2019): they (1) gathered multiple stakeholders to (2) participate in the innovative design of the infrastructure. *Table 18* gives an example of data collection: one method for each case is shown here, but the completed tables for each case can be found in *Annex 8*.

Case study	Project	Stage of the lifecycle	Description of the co-creation method	Stakeholders	Formal / informal	Quote	Data	Remarks
Besaçon	Historical DH	operation	Continuous dialog between the operator and the owner to solve problems, follow the performance and discuss future investments	DH owner, DH operator	informal	<i>"the city is very present alongside us [the DH operator], they exchange about 2 or 3 emails per week, and they closely follow the process. [...] there are constructive dialogs."</i>	Interview with an employee of the DH operator	Very context-dependent, interpersonal relationship
Dunkirk	Historical DH	operation	Creation of tools to integrate the final users	Social housing owner, customers,	formal	<i>"Tools for client relationships are being set up via the operator</i>	Employee from the public DH owner	Final users are informed more than

				DH operators, DH owner		<i>and social housing owners that are OK to open up communication"</i>		involved
Ottawa	Public Service Delegation	procurement	Confidential meetings with the contestants during the project design	contestant, DH owner	formal	<i>"the purpose of Commercially Confidential Meetings is to provide a process that fosters open, candid and frank discussions between Canada and each of the Proponents in order to enable</i>	Request for Proposals	

						<i>Proponents to develop optimal solutions for the project."</i>		
Hornsyld	Hornsyld experimentation	preparation	Collaborative discussions for problem-solving with consultants, contractors and all stakeholders	VIA college, Geodri lling, NCC, Heden sted municipality, water utility, Land & Plan	informal	<i>"we were lucky to have consultants and constructors that were willing to go into this type of projects, and also willing to find solutions together with us"</i> <i>"One thing is that we were able to make</i>	Representative of the municipality	



						<i>this in that project because there were some good people together."</i>		
Helsinki	Helsinki transition	preparation	Webinar on the learning process and feedback	Anyone interested	formal	<i>"This webinar will focus on the lessons learnt through the challenge competition process"</i>	Website of the Helsinki Energy Challenge	

Table 18 Data collection table

For each co-creation method collected from the raw data, I filled in several pieces of information, the most important being: which case study it came from, which project within the case study (for instance, in one district heating network there can be an extension planned for which specific co-creation methods are set up), at which stage of the project the method was implemented, a description of the co-creation method used, which stakeholders were participating in the co-creation method, and how formal the method was. The stakeholders gathered gave an indication of the inclusivity of the co-creation method and the communities involved. The level of formality gave access to the

integration of co-creation into processes. It was also an element highlighted by the literature that I found worth digging into (Torvinen and Ulkuniemi, 2016).

The co-creation methods were then gathered per stage of the lifecycle, to follow the evolution during the projects' lifecycle. From each description, a "co-creation activity" was extracted which was a more general way of describing the method.

The last step was to confront the assessment framework designed for public sector co-creation activities, with the different activities extracted from the data. As each of the three main co-creation activities from the assessment framework is composed of a variety of sub-activities, I tried to align these activities with those extracted from the data. *Table 19* shows an example of the coding process for the data presented in *Table 18*. The completed table of analysis can be found in *Annex 9*.

Stage of the lifecycle	Case study	Project	Summary	Formal / informal	Stakeholders	Code 1 (co-creation activity)	Code 2 (literature)	Code 3 (main co-creation activity)
operation	Besançon	historical DH	Continuous dialog between the operator and the owner to solve problems, monitor the performance of the	informal	DH owner, DH operator	Discussions for collective problem-solving	Co-creation dialog	Setting up a collaborative network

			network and discuss future investments					
operation	Dunkirk	historical DH	Creation of tools to integrate the final users	formal	social housing landlords, customers, DH operator, intercommunality	involvement of the final users through tools	Managing incentives	Defining the collaborative governance
procurement	Ottawa	Public Service Delegation	Confidential meetings with the contestants during project design	formal	contestant, DH owner	Dialog to help design the proposition	Interaction and dialog	Setting up a collaborative network
preparation	Hornby	Hornby's experimentation	Collective problem-solving with consultants, contractors and all the	informal	VIA college, Geodrilling, NCC, Hedensted municipality,	collaborative discussions for problem-solving	Co-creation dialog	Setting up a collaborative network

			stakeholders		water utility, Land & Plan			
Preparation	Helsinki	Helsinki transition	Webinar on the learning process and feedbacks	formal	open to all	experience sharing and learning process	Social learning	Assessing and learning from project outcomes

Table 19 Data analysis table

The coded data gave me an overview of the implementation of the three main co-creation activities, and their distribution between the various project stages. From there, I also analyzed the facilitating contexts and challenges around public sector co-creation implementation (based on the type of stakeholders involved, or the implementation of the co-creation activities into formalized processes), in relation to the three mediating activities from the analysis framework.

*“I guess collecting the data was more fun than coding them, right?”* laughed Mrs. G.

- *“I guess it was, but I could not have coded the interviews if you had not gone through the tedious process of transcription...”*
- *“And did you find interesting things at least? When doing the interviews, I could feel the importance of collaboration and how it participated in the building of a collective expertise. But, depending on the projects, I think the means to co-create or the frame to co-create were different.”*
- *“One major difference is between the fully-fledged projects like PPPs compared with more “unconventional” types of projects. Let’s jump in to the next part!”*
- *“Wait, I also designed a series of workshops to try to implement co-creation practices. Isn’t that part of the data collection?”*

To supplement these case studies, Mrs. G. also designed a series of workshops. Although the main purpose of the workshops was to access the stakeholders' frame on low-temperature district heating and cooling networks, it also gave her some first-hand impressions on co-creation settings. With the participants of the workshops, she tried to co-create a common vision of future district heating and cooling systems. Her experience from the workshops will be used in the following part to illustrate the difficulties that may be encountered when in setting up a collaborative network and trying to align different frames into a common vision.

## Public sector co-creation and collaborative processes in district heating projects

Now that I have presented the data collection and analysis, I will move on to the results. First, I will present the main findings, separating the conventional from the unconventional projects, and then I will develop some of the surprising aspects and challenges of co-creation in these projects, relating them to the framework of analysis.

### *Public sector co-creation both in conventional and unconventional projects?*

#### Public-Private Partnerships as a limited form of collaboration and co-creation

In three cases (Besançon, Dunkirk and Ottawa), the relationship between the district heating owner and its operator was formalized through a PPP. This partnership formalized some co-creation activities at each step of the projects' lifecycle: collaborative discussions were often set up between both partners, allowing collaborative problem-solving but also the identification of relevant values to be captured. Based on the latter, a collaborative governance was implemented to govern the PPP. Moreover, a reporting process was formalized through some Key Performance Indicators (KPIs) and various specifications and requirements. At each new project—e.g., contract renewal in Besançon, district heating extension in Dunkirk—collaborative discussions are set up to frame the project and its outcomes, giving opportunities for co-creation activities.

*Figure 23 to Figure 26* are visualizations of the codes for each project. Blue stands for “setting up a collaborative network”, green for “defining the collaborative governance” and yellow for “assessing and learning from project outcomes”. The more codes of one activity during a stage of the project lifecycle, the more the color is present in the diagram. The font sizes account for the relative number of codes for each stage of the project lifecycle: the more codes, the bigger the font size. This last characteristic may be more related to the type of data collected than to the actual co-creation process, but allows the reader to balance some of the results. For instance, for historical cases it was easier to

access data on operations than on the identification of the project, hence the higher number of codes for this stage.

The district heating operator in Besançon mentioned that *“the city is very present alongside us; they exchange about two or three emails per week, and they closely follow the process [...] there are constructive dialogs”* (own translation). This leads to co-creation activities during the operation of the historical network, mainly setting up a collaborative network. Some efforts to assess and learn from the historical project outcomes were even formalized when the municipality launched the contract renewal process. Also, the first stages of an extension project linked to Besançon’s network were supported by co-creation activities: finding the right resources (defining the collaborative governance) and integrating citizens into local planning (setting up a collaborative network).

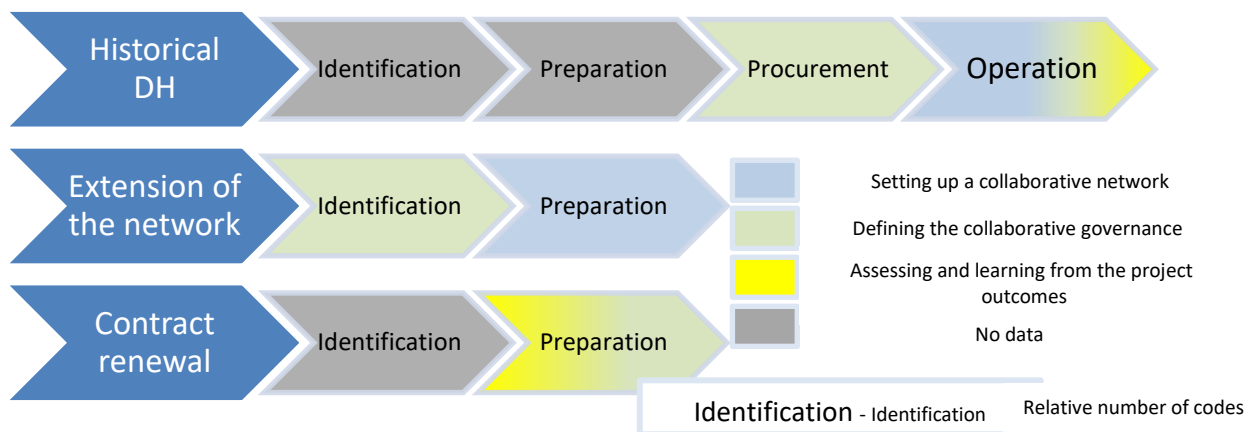


Figure 23 Co-creation activities in Besançon's district heating projects

Similarly, when setting up the Dunkirk district heating “*the stakeholders met at the urban planning office of Dunkirk, the project leader.*” (own translation, notes from the interview with an employee of the Dunkirk Urban Community). The early years of the project were heavily based on the setting up of a collaborative network, while defining the collaborative governance appeared mostly in the later phases. A similar process was set up for the extension project (Figure 24).

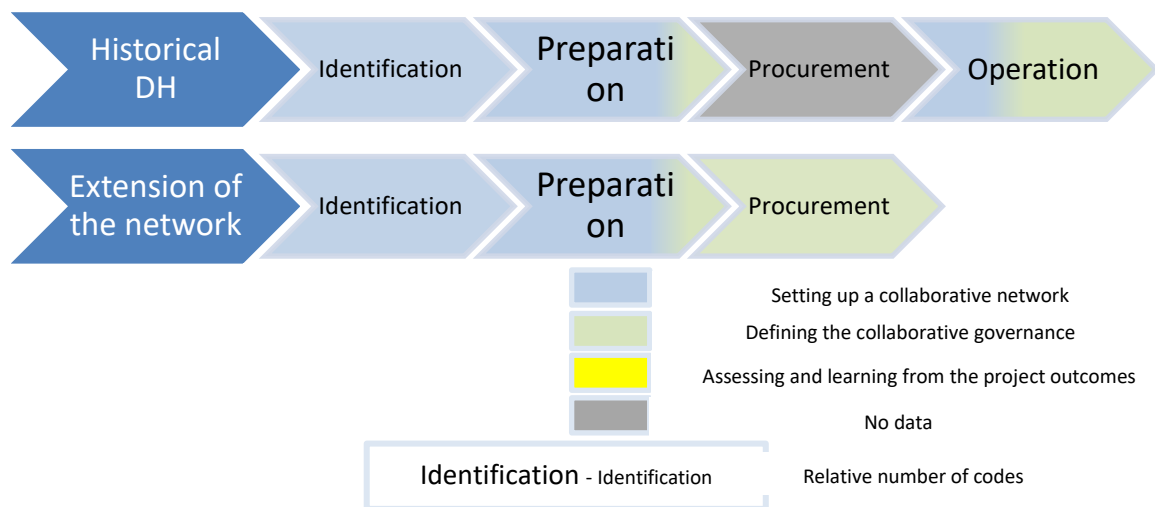


Figure 24 Co-creation activities in Dunkirk's district heating projects

In Ottawa (a recent PPP), the collaboration was pushed even further, with an emphasis on the collaborative discussions at each step of the project lifecycle: during the project's identification the district heating owner engaged with multiple stakeholders to frame an suitable bidding process. They conducted a visit to some French district heating and cooling networks at the beginning of the 2010s to understand the benefits and challenges of PPPs. Project preparation was seized as an opportunity to build relationships with the future competitors, as a member from Engie recalled “*an advantage is the very good relationship with the Government. It's a relationship that was created during years, even before the procurement phase.*” During the procurement phase, collaborative sessions were set up to discuss the right performance indicators and the district heating network design. It was stated in the request for proposals that “*the purpose of Commercially Confidential Meetings is to provide access that foster open, candid, and frank discussions*



between Canada and each of the Proponents in order to enable the Proponents to develop optimal solutions for the projects.” Finally, during the operation a trust relationship between the district heating owner and its operator is maintained through both formal and informal discussions for problem-solving and reporting. The district heating operator explained that “the problems are negotiated upfront during informal discussions. The meeting minutes can even be redacted together.” All in all, a lot of effort went into setting up a collaborative network. In the contracts, some activities related to reporting and measuring user satisfaction hint that some assessing and learning from the project outcomes activities will be implemented (Figure 25). When it comes to defining the collaborative governance, the contract covered the main aspects and no specific co-creation activities could be extracted from the data.

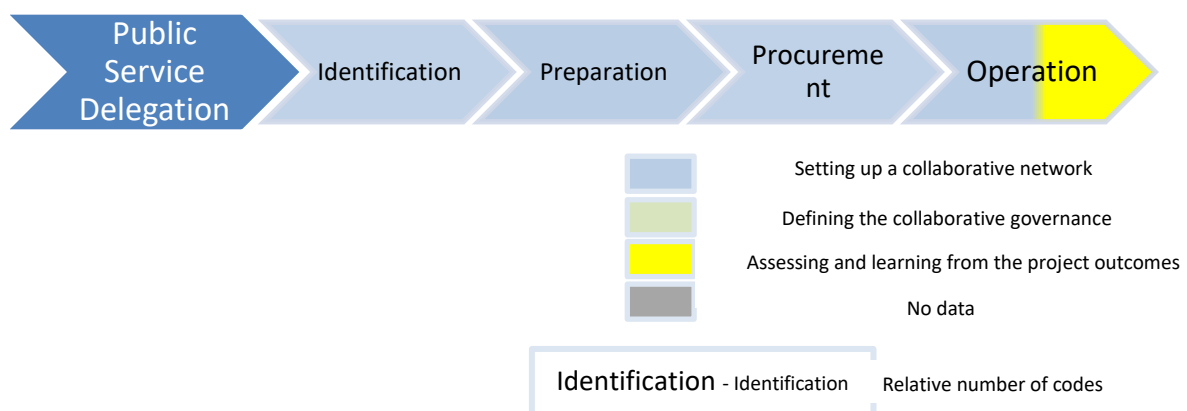
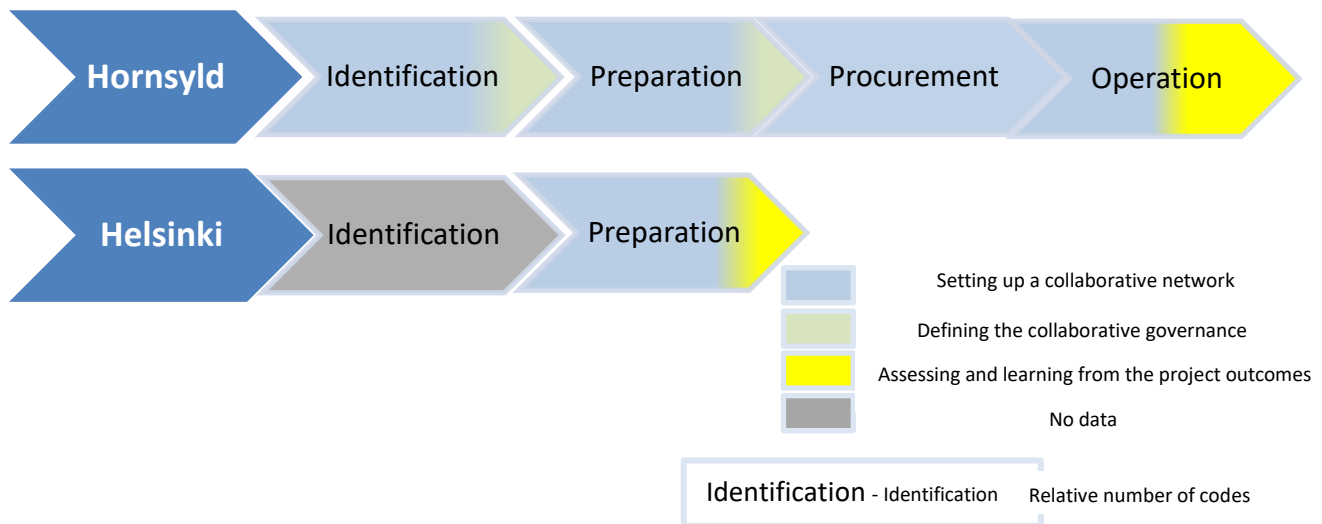


Figure 25 Co-creation activities in Ottawa's Public Service Delegation

However, the collaboration and co-creation in PPPs appear to remain limited, as the main actors are the district heating owner and the operator. The other actors (e.g., suppliers, consumers) are not integrated in the formal collaborative activities. Even when activities are designed to involve customers and final users, it is mostly through communication directed at them, without engaging in fully-fledged collaborative activities.

### A higher level of collaboration and co-creation in innovative projects?

In innovative projects focused on sustainability, a higher level of collaboration and co-creation was noted (see *Figure 26*).



*Figure 26 Co-creation activities in the Hornsyld and Helsinki's projects*

First, collaboration was explicitly presented as an important positive point for the development of the district heating networks. In addition, in the Hornsyld and Helsinki cases, a large variety of actors were involved in the co-creation activities. For the Hornsyld case, the whole project—apart from the very early identification of the project, which was proposed and supported by a specific actor—was collaborative. Regular formal and informal discussions created strong links between the actors and allowed both collaborative framing of the project, and problem-solving. All the issues could be discussed collaboratively, as no formal process pre-existed for solving them: *"All the companies have been very good at saying, 'OK let's do this, we don't know where we will end, we don't know what our end costs will be with the project, but we have to do something different from today in the future, so let's try it out.'"* (Hedensted water utility, 2021). In Helsinki, the municipality of Helsinki wanted the challenge to be as open as possible, with any interested stakeholder welcome to integrate the challenge. A three-day bootcamp explicitly focusing on collaboration and co-creation was even organized *"during the bootcamp, the teams will have joint sessions with all participants, local*

*industry experts and representatives from the City of Helsinki*” (extract from the project’s website).

These results can be qualified by the level of maturity of the different projects. As mentioned earlier, not all stages of the lifecycle could be equally accessed through the data. It is likely that the first stages of the conventional PPPs also relied implicitly on co-creation activities. The data on the most innovative projects do not allow an assessment of how sustained the co-creation activities are over time.

### Informal processes focusing on the setting up of a collaborative network

In all the cases studied, collaborative and co-creation activities were set up. Although formal processes were usually implemented, the activities were often supported by informal collaborative discussions that built up a relationship between the actors outside the formal frame of the setup partnership. Several arenas for collaboration and co-creation emerged (even in formal partnerships), especially during project preparation. The co-creation activities often focused on the alignment of the core actors around common values and governance processes. In almost all the projects, the interviewees highlighted the importance of informal discussions: the Hornsyld project leader talked about “*discussions on how to do it*” and the project consultant about the multiple calls outside the meetings to frame the project. For the Ottawa and Besançon cases, the private operator mentioned discussions with the public authority as a basis for their partnership.

Moreover, compared with the main co-creation activities extracted from the literature, Mrs. G. noted that *setting up a collaborative network* was the most represented activity (45 codes out of 70), followed by *defining a collaborative governance* (15 codes) and *assessing and learning from the project outcomes* (10 codes). This imbalance threatens the collaborative business models: the focus is put on its setting up but not on its long-term formalization and governance. Even if the governance and the assessment were formalized (e.g., in PPP contracts), it did not necessarily lead to collective activities and learning. On the setting up of a collaborative governance, it was mentioned in the Dunkirk and Hornsyld cases mostly through risk governance, while Besançon provided a wider variety of co-creation activities linked to collaborative governance (e.g., resource

acquisition, forging initial agreements). Concerning the assessment and learning processes, only Helsinki explicitly mentioned a *“focus on the lessons learnt through the challenge competition process”* (Helsinki Energy Challenge, 2020). The only other mentions of learning processes were internal to actors: the collaborative project was seen as an experimentation from which a specific organization could learn—mostly technical knowledge—to make its own projects. For instance, one contractor from the Hornsyld project stated that his company was thinking of scaling-up this type of project and integrating it into its offer. If collaboration was mentioned for this scaling-up, it was only through the conventional partnerships already standardized within the company. *“we’ve done it with some other partnerships from other construction. Especially for our buildings construction we’ve made a lot of partnerships. So, we know how to do it and we’d like to [...] to know how to do to be the one who is connecting all the others to us, so we are the firm who goes out and sell it.”* (NCC sales manager, 2021).

To conclude, the predominance of *setting up a collaborative network* shows that most of the co-creation activities seem to focus on the framing process, with little effort spent on specific expertise building and instrumenting. Collaborative and co-creation activities were usually made through discussions, or embedded in existing formalized processes. Apart from the case of Ottawa, where the setting up of the collaborative network was formalized in the procurement process, the other projects mainly relied on informal discussions when setting up the network.

*“This first set of results is not utterly surprising”,* sighed Mrs. G., disappointed. *“All this work to see that when there is a focus on co-creation there are actually more co-creation activities... And that in conventional PPPs there are fewer co-creation activities. Even the role of informality and the setting up of a collaborative network seemed to be commonplace in the academic community of public sector co-creation.”*

- *“It is true that these were not the most interesting results. When I presented them in conferences, I could feel that it was not going far enough. Still, the coding process was a way to objectivize these results and spot them in our case studies.”*
- *“Please, tell me there is more...”*

Some surprising characteristics of co-creation for sustainable district heating... and their limitations

If these first results merely confirmed commonplace ideas, the analysis also shed light on some unexpected aspects of co-creation that had never previously been discussed in public sector co-creation literature.

### The unexpected level of co-creation in PPPs... and its limitations

One first surprise was the extent of collaboration and co-creation in PPP cases. Despite the limitations of the conventional frame, actors engaged in PPPs are setting up informal co-creation activities, gathering more stakeholders and allowing more systemic problem-solving. Consumers are increasingly considered as important actors to engage in the network governance and optimization. The interviewee from the Bourgogne Franche-Comté regional office of the ADEME mentioned that *“Besançon has a habit of concertation with users, or at least to associate with them.”* Similarly, the interviewees from the Dunkirk Urban Community said that *“tools for client relationships are set up thanks to operators, and the social housing landlords are more and more willing to open up communication.”* During informal discussions within Engie on the Ottawa case study, the employees highlighted a dynamic to increase the integration of final users and citizens.

Depending on the partnerships between the actors, the type of co-creation activities differed: They ranged from formal processes (sometimes supported by informal discussions) in the case of actors engaged in contractual relationships to more informal and collaborative discussions when the partnership was less formalized (for instance between the district heating owner and the operator before the contract renewal, or between the district heating owner and the secondary network operators).

Depending on the instrumentation of the partnership, specific collective expertise is being built at the project level. However, this expertise is embedded in the existing processes of public market procurement which may impede the setting up of some co-creation settings.

### The multiple co-creation nodes and their (mis)alignment

Another surprising element is the multiplicity of co-creation nodes that stood out in a single project. There is not one co-creation community but several.

Different networks of collaboration and co-creation could be spotted within the same project: for instance, in Besançon, a strong collaborative network was set up between the public authority and the district heating operator. In parallel, collaboration was set up between the biomass suppliers and with the district heating operator. Similarly, in the Hornsyld case, a collaborative network was set up between the core actors of the project (e.g., researchers, geothermal company, public authority, and its consultants) and another one was set up for operations between all the contractors. These different networks follow different rules—e.g., a different network governance, a different leader—but can interact on co-creation activities.

While the setting up of these different networks improves the global level of co-creation, the different networks could be based on different frames of co-creation and have difficulties aligning. In the Besançon case study, the interests and expectations of the two co-creation nodes were not aligned: the suppliers wanted to be more integrated in district heating management, but co-creation with suppliers was not seen as a priority by the public authority and private operator. In these cases, local expertise is being built but it is not collective.

### The barriers to co-creation even in dynamic contexts

Finally, even though unconventional projects and dynamic actors facilitate the setting up of more collaboration and co-creation, some challenges can be noted.

One major challenge that was pointed out was the difficulty in identifying and aligning all the relevant actors (e.g., services inside a public authority, contractors) in order to support the development of the network. The consultant working on the Hornsyld case explained the high stakes in finding the right partners and contractors. In the same project, the municipality highlighted that, despite the momentum of the project, *“what I’ve found has been difficult is that we have to find a new way of ownership”*. In the case of Besançon, there were no shared planning tools or communication between the urban and energy services, so it was difficult to correctly size the district heating network and ensure its economic and technical optimization. Co-creation has to integrate an existing expertise

network and take up the challenge of public infrastructure embeddedness in multiple processes.

Also, both in Dunkirk and Besançon, the role of the actors' technical expertise was mentioned as a key point for engaging in co-creation activities. With the public authorities lacking this expertise (for instance in the case of Dunkirk), less collaboration could be set up. The public authority regretted the difficulty encountered to upskill due to their almost systematic call on consultancy firms. On the contrary, too much involvement of the public authority like in the case of Besançon could also impede co-creation as the public authority was finally the only one to take decisions.

Finally, in some cases, getting some of the stakeholders to commit to the co-creation activities revealed to be harder than first thought by the actors. For instance, employees from Engie admitted that even if they were impressed by the setting of the Helsinki Energy Challenge, they did not see the point in committing to the collaborative activities. Co-creation was only framed by them as a mean to access data from the municipality more easily, and set up a partnership with it. This vision was not aligned with the municipality, which wanted the challenge to be as open as possible. Even in the case of Hornsyld, where collaboration was presented as a basis for the project, the actors seemed to have different frames of co-creation. For instance, the road contractor despite appreciating the collaboration for the experimentation was keen to go back to business as usual, even for implementing such a project, saying that *"Especially for our building constructions we've made a lot of partnerships. So, we know how to do it"*. Collaborating was only framed through conventional and established processes, not through collective innovation. Similarly, when Mrs. G. tried to co-create a common vision during the workshops, she encountered difficulties aligning the actors' frames. Here is an extract from her notes on the workshop: *"One barrier encountered was the limited diversity of stakeholders from the district heating world: all were from the technical side (researchers, operators, etc.). They already had difficulties talking with each other within the technical field, but it became even more difficult when getting into non-technical aspects. One thing that came over often was "once we have the right technical system it will work" or "this cannot be defined until we have the technical system". We see that the complexity of district heating is mainly seen through the lens of technical issues and solutions, and that organization came afterwards, as a logical consequence of technical aspects. It points out the lack of*

*interdisciplinarity when talking about district heating, and the difficulties of going in the same direction when everyone has different languages and angles. Moreover, the participants of the workshop encountered difficulties getting creative in a given imaginary situation without all the specifications of the technical system. It would have thus required a specific design of the brainstorming session, and maybe some more preparation of the context with some participants or specialists ahead of time. The fact that the workshop was held online also made it difficult for the participants to interact and co-construct, with everyone staying within their comfort zone and building their own solution.”* During the workshop, participants remained within their field of expertise and did not really succeed in co-creating a common vision. Their technical frame for a district heating system impedes the building of a common global frame encompassing other dimensions.

*“Ah, now these results are much more interesting!”* exclaimed Mrs. G. *“Although some expertise is being built at the local level, it looks as though the actors’ frames of co-creation are different. Within the same project, different frames exist and do not always align. It really shows the multiple tentacles of our monster here. So many different stakeholders, with their own interests and their own frames.”*

- *“Still, some common features of co-creation frames can be perceived; all the tentacles are part of the same monster. Typically, the focus on the setting up of a collaborative network, or the importance of informal discussions. And for some specific projects the actors succeed in implementing co-creation activities even in what could be considered an unfavorable environment.”*



## In a nutshell: Framing co-creation for sustainable district heating

In this chapter, I have to assess the project level, in order to understand how sustainable district heating systems were implemented. Specifically, I took the angle of co-creation. The empirical problem at hand was to study *How are co-creation practices framed in projects?* To do so, I built an assessment framework for co-creation based on available literature and assessed five case studies to understand the extent to which co-creation activities were implemented and the influence of the context on this implementation.

Three cases were within the context of PPPs and only showcase a limited number of co-creation settings. The processes of public market procurement partly impeded the implementation of co-creation. However, it is worth noting that even in this already formalized context, actors engaged in informal discussions for collective problem solving. The current public procurement processes could even be adapted to integrate more co-creation arenas—like in the case of Ottawa with the Competitive Dialogs. In the two unconventional settings (an experimentation and an open challenge), a specific focus on co-creation led to the implementation of more co-creation activities. In all cases, this activity was mostly aimed at *setting up a collaborative network* at the expense of the other two activities (*defining a collaborative governance* and *assessing and learning from the project outcomes*), questioning the future continuity of co-creation processes. It was usually based on informal discussion, some of which could lead into more instrumented processes.

Finally, two characteristics are worth highlighting. First, at the scale of a single project, several co-creation nodes could be uncovered, each with its own expertise and frame. Second, even in contexts with a collective collaborative dynamic, co-creation could suffer from obstacles if no collective expertise was being built around co-creation activities.

In a nutshell, co-creation at the project level is mostly framed through the setting up of a collaborative network. The efforts of the project leaders and network actors were focused on finding and engaging the relevant stakeholders. This process was mostly based on informal discussions but could also be instrumented and integrated into existing

processes. Building a common co-creation frame was a major challenge, and at the project scale multiple co-creation nodes could emerge.

Setting up co-creation activities is an operational way to implement sustainable district heating<sup>42</sup>. However, the embeddedness of public infrastructure in already formalized processes can make it difficult to implement such practices. Building local collective expertise around co-creation could be a way to overcome such barriers. Through this expertise, a specific instrumentation of co-creation could be designed, from innovative instruments to be implemented to the adaptation of current processes. Jukic et al. (2021) point out criteria to assess the organization's maturity for co-creation: the aptitude of organizations (structure, culture, competence and resources), the staff's capabilities (knowledge and skills, attitudes, autonomy) and the wider political and normative context. Dos Reis and Gomes (2022) argue that there is a need to build specific capabilities when engaging in a public private partnership. I thus decided to look more closely at the instrumentation supporting collaborative practices in various projects.

*“Co-creation seems to be a difficult process to set-up, and to be quite fragile”,*  
observed Mrs. G.

- *“Still, even in a highly regulated context like a public market, co-creation emerged. So, it means that some instruments could be adapted or implemented.”*
- *“In most cases, co-creation seemed to be mainly based on interpersonal trust and informal processes, I am not sure...”*
- *“But you have also seen cases where it was then instrumented as contracts, partnerships, or even reporting processes! Or cases where it was based on existing processes. Do you see what it means?”*
- *“It means we must keep on investigating... As we always do. The monster has not yet revealed all its secrets, and is still hiding in the shadows”*

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<sup>42</sup> Due to the temporality of the data collected, it was not possible to conduct an analysis on the outcomes of the co-creation process, especially when it comes to the performative effects of the co-created valuations and solutions.



## Chapter 6: Instrumenting the collaboration

*“L'homme est toujours le même : les systèmes qu'il crée sont toujours imparfaits, et d'autant plus imparfaits qu'il est sûr de lui.” (Jean- Paul II)*

*“Mankind is always the same: the systems it creates are imperfect, all the more imperfect as he is sure of itself.” (own translation)*



## Chapitre 6 : instrumenter la collaboration

Dans le chapitre précédent, j'ai montré qu'une faiblesse du processus de cocréation était sa dépendance en des relations interpersonnelles. Dans ce chapitre, j'analyse quatre cas où la cocréation a pu être instrumentée (ou où cette instrumentation a été en partie pensée) et s'extraire de cette dépendance.

En instrumentant la cocréation, les acteurs instrumentent également leurs valuations de manière collaborative. Réciproquement, la cocréation est valorisée par les instruments. Le processus contractuel (de l'appel d'offres à l'exécution du contrat) est l'une des principales arènes cadrant ces processus. Ce dispositif de gestion repose sur – et est intégré dans – une multitude d'instruments allant des indicateurs aux règlements. Dans tous les cas étudiés, le processus d'instrumentation s'intègre dans des cadres existants (à l'exception du cas du Grand Copenhague où la cocréation semblait faire partie du cadre dès le départ) : il s'agit davantage d'intégrer de nouvelles préoccupations dans le cadre que de trouver un cadre stable entièrement nouveau. En s'appuyant sur l'expertise existante et sur les connaissances en cours de construction, les acteurs intègrent en collaboration de nouvelles valuations dans les instruments existants. Ils coconçoivent également les valuations pour le projet spécifique, par exemple en créant des critères ou des indicateurs à évaluer pendant le projet. Grâce à ce processus, ils créent et réalisent leur valuation locale du réseau de chaleur durable. Au-delà des critères techniques ou environnementaux, le processus contractuel est également l'occasion pour les acteurs de valoriser la cocréation et de décider de la gestion collaborative de l'infrastructure : comment partager les risques, les responsabilités et gérer l'incertitude. La généralisation des contrats à long terme est également un moyen d'instrumenter la valeur accordée aux partenariats stables. Les acteurs construisent les règles partenariales, en concevant des instruments complémentaires à intégrer dans le dispositif de gestion. Enfin, cette instrumentation a également un impact sur le réseau d'expertise, en donnant de nouveaux rôles aux partenaires par rapport aux contextes conventionnels.



In the last chapter, I assessed co-creation in five case studies. Through this analysis, I showed that while some common characteristics could be drawn out, there were several co-creation frames in the very same case. Moreover, although co-creation was highly context-dependent, some attempts at instrumenting were spotted in most cases. Instrumenting co-creation seems to be a way of stabilizing the processes and managing the different interests. However, it could also limit the extent of co-creation by merely integrating it in existing instrumentation.

In this chapter, I will further investigate this instrumenting process and the resulting instrumentation, trying to answer the following concern: *How is co-creation instrumented in district heating projects and how is this instrumentation impacting the framing of sustainable district heating valuations?*

To investigate this concern, I will use problematized descriptions of four case studies: Besançon, Greater Copenhagen, Ottawa, and Vienna. In Besançon, I will focus on the wood sector, and how it was organized for district heating supply. This structuration followed the need to manage to work collectively and manage the risks. Similarly, in Greater Copenhagen, multiple stakeholders are working together in the energy system. This network is regulated by common rules which govern the collaboration, and which each stakeholder has agreed upon. Although the system does not describe itself as a “co-creation arena”, some of Mrs. G.’s contacts in other countries saw it as an example of collaboration in district heating. In Ottawa, the Government of Canada has attempted to use the PPP framework in order to create a collaborative partnership. However, PPPs are already regulated and may impede the implementation of innovative collaboration. Finally, in Vienna a group of actors has worked on an experimentation to build a latest-generation urban district heating system. They forecast the need for collaboration with established stakeholders, and a shift of roles within the network (compared with conventional systems). I chose these four case studies as they present different aspects of collaboration and co-creation: the collaborative structuration of a sector, the historical collaborative management of a district heating network and co-creation of new partnerships for decarbonization. For each of them, more than co-creation settings, there are attempts to stabilize and integrate the co-creation practices into instruments. In all the cases studied for co-creation, similar settings could be identified—to different extents—



but not always analyzed: in the case of Dunkirk, confidentiality measures prevented the investigation from really studying the instruments (like the contractual setting) and in the Hornsyld case, the documents were only available in Danish.

For each of the four cases of this chapter, I will summarize the data collected by Mrs. G, give a problematized description of the case, and finally sketch out some conclusions on the instrumentation of co-creation and its results. I will wrap up and analyze these results in the chapter's conclusion.

*“These four descriptions can be very insightful”, agreed Mrs. G. “But it also questions the definition of co-creation. The one from the literature is quite clear, but is it really what we can see in these cases?”*

- *“I know... In fact, they are all cases of collaboration (or attempted collaboration). And they are turning into cases of co-creation when they tackle innovation. In all cases, there is a point where they try to build together something that does not already exist, and in most cases this is a sustainable district heating system. This, I believe, is co-creating.”*
- *“And to do so, they use or create some instruments, which will impact what they co-create. So that's why you also looked at the framing process. By instrumenting their collaboration, they also frame the valuation of sustainable district heating.”*
- *“That is what I want to investigate...”*

## Wood-energy in Bourgogne Franche-Comté, co-creating a new sector?

### *Data collection*

I have already mentioned some of the interviews made for the Besançon case, but I will now reveal the second part of these interviews: eight interviewees from the wood-energy sector. When talking with the interviewees, Mrs. G. soon realized that the wood-energy sector was strongly interlinked with the district heating system. She thus made some complementary interviews focusing especially on this topic (*Table 20*).

<b>Interviewee(s) role</b>	<b>Focus of the interview</b>	<b>Date and place</b>
ONF-E East office manager	Organization of the wood-energy supply and regional planification, development of the wood-energy (certification, controversy, price)	06-25-2020–call
ONF-E East office manager Wood worker Truck driver Member of a local wood cooperative	Wood-energy supply chain (organization, pricing, specifications). Presentation of the worksite.	06-29-2020–wood platform + forest worksite
Fibois, wood-energy mission leader	History of wood as energy and link with other sectors, local context (needs, suppliers, etc.), sustainability of wood-energy	06-30-2020–local Fibois office in Besançon (Forest and Wood House)
Representative of SOVEN (Engie’s purchasing center)	Wood specifications and their evolutions (e.g.,	07-02-2020–call

	technical and environmental), suppliers and contracts	
2 PEFC employees (technical manager of PEFC France; leader of PEFC certification in Franche-Comté)	PEFC certification (presentation, process and requirements), link with other initiatives and French regulations	07-07-2020–call

*Table 20 List of the interviewees*

Her first interviews were focused on the district heating system, trying to understand where the wood biomass used in Besançon came from and which specifications were required. From there, she dug more into the wood-energy sector in Bourgogne Franche-Comté, investigating its history, structuration and interaction with other sectors. She also tried to flesh out the controversy around wood biomass, searching for tensions around its sustainability. For each interview, she first asked questions on the organization itself (its role, history, etc.), then went into more specific and focused questions.

Most of the interviews could be face-to-face, and Mrs. G. was even given the opportunity to visit a forest worksite. Due to the conditions of these onsite interviews, they were not prepared semi-directive interviews but more open discussions. The organizer of this visit was an employee from the ONF-E (the National Forestry Office–Energy division). Some questions for this employee and the forest worker were prepared beforehand, but different unplanned actors were met during the visit (like the truck driver and a member of a wood cooperative). During every interview (both the semi-directive ones and the open discussions), detailed notes were taken and added to Mrs. G.’s database.

### *Mrs. G.'s visit to Bourgogne Franche-Comté*

Through her different interviews, Mrs. G learnt a lot about the wood-energy sector, and its links to heat supply. Let me now complement the narration of Chapter 1, diving into the forests near Besançon with Mrs. G.

*In Besançon, Mrs. G. discovered the immense amount of biomass needed to assure heat delivery. During the winter, no fewer than ten to twelve trucks came to deliver woodchips each day! The woodchips were stored near the building with the biomass boilers (Picture 8).*



*Picture 8 Woodchip storage*

*Mrs. G.'s guide was proud to explain that: the unloading of the trucks is fully automated and sensors analyze the air continuously to ensure there is no smoke. The storage can last for a weekend, as trucks cannot deliver during weekends or nights. From the storage, a conveyor belt conveys the woodchips to the boiler where they are burnt. The boilers cannot burn all types of wood: 90% of the wood supply is woodchips (P63 with 40 % humidity),*

coming directly from the chipping of wood trunks. The remaining ten percent is waste from dry sawmills. As the size of the woodchips and percentage of humidity are important specifications having an impact on combustion, a sample is checked when the trucks come in.

### Besançon supply

One major point of interest when talking about the biomass supply was that the trucks came directly from forest worksites or storage platforms. Mrs. G. decided to investigate more the supply chain ensuring the delivery of about 38,000 tons of wood every year...

She started by talking to SOVEN, that a part of Engie responsible for energy purchases. Since 2013 SOVEN is in charge of the wood supply for the Besançon biomass boilers; this purchasing center, acts as an interface between the client (the district heating operator) and the supplier (wood-energy producers or traders). Fifty percent of the wood for Besançon district heating is governed by a long-term contract between SOVEN, Sylvowatt and the ONF-E. Sylvowatt is a gathering of wood cooperatives (FBL, NORCEL Forêts, Unisylva and Forêt et Bois de l'Est) and the ONF-E is a part of the National Forest Office (ONF) working on wood-energy. These multi-year contracts make the ONF-E and Sylvowatt priority suppliers: the contract specifies an annual number of megawatt equivalent that SOVEN has to buy (with 15% flexibility). The remaining supply comes from short-term contracts (from one to three years). This flexibility allows SOVEN to get better prices, and to adapt its orders to the amount of woodchips needed for the year (specified by Celsius each year). The constraint on prices is huge, as woodchip prices affect the price of heating for the final consumer... Even if local wood supply is not mandatory in the case of Besançon, most of the suppliers are from the region. In fact, transporting the wood is an important part of the wood's final price... About 30% of the price is for transportation and 70% for the wood itself. The prices are indexed on a quarterly index published by the Wood-energy Interprofessional Committee (CIBE). In order to have a competitive price, the wood usually comes from nearby. To ensure the traceability of the wood, SOVEN has software for monitoring all the orders and their specificities (woodchips humidity, supplier, transporter, origin, etc.). It is needed, among other things, to justify the ADEME subsidies. Thanks to this close monitoring of the supply, SOVEN could answer a request from the

*metropolis of Besançon: what was the percentage of PEFC wood in the district heating supply? The answer was 48.7% of certified wood... PEFC certification ensures the “sustainable management” of forests (based on international criteria which are then translated at the national level) and the traceability of this wood through the supply chain. Although it was part of the early specifications in the Besançon contract, there was no monitoring of this indicator, due to the fact that the wood-energy supply chain was not fully professionalized...*

*Once this context was clearer, Mrs. G. decided to dig into the supplier side. SOVEN mentioned that the balance of power had changed between suppliers and clients: before, the supply chain was not fully structured, but clients were in need of wood. Now, the suppliers can supply more wood than needed, especially as the winters are getting warmer and shorter. Similarly, when interviewing the PEFC employees, it was mentioned that the wood-energy supply chain took time to be structured... Mrs. G. wanted to understand this structuration of the wood-energy supply chain. To do so, she had discussions with actors of the supply chain: a representative of the ONF-E, a wood worker and the person responsible for wood-energy at the wood sector’s regional association (Fibois). Of course, not all her discoveries can be summarized here. I will only focus on the actual supply process for wood chips and briefly summarize Fibois’s view on wood-energy.*

### [The actual woodchip supply from the ONF-E](#)

*Mrs. G. could access a forest worksite, where she saw an impressive chipping machine loading trucks (Pictures 9&10). A mechanical arm takes the drying trunks and feeds them onto a conveyor belt. The belt conveys the timber to a six-knife rotor where it is chipped. It is then expelled directly into the truck at high speed. The sight was truly stunning: the noise, the smell, the dust in the air...*



Picture 9 Chipping machine



Picture 10 Woodchip truck

*The ONF-E can buy growing trees or “roadside trunks”. In the case of growing trees they are then responsible for cutting them and putting them to dry on the roadside. In both cases they need to transform the drying trunks into woodchips, after six months to one year. The humidity percentage of the wood depends on the drying time, but as they work only with deciduous trees, they know the drying time of their trunks. The dryer the trunks, the more megawatt equivalent woodchips they can load into the trucks... The trucks then directly go to the boiler rooms, and the drying platforms are only used for the surplus: if the forest worksite makes nine trucks of woodchips, but the boiler only wants eight, the last one goes to a drying platform. Complex logistics are required to ensure optimization: the orders come at the end of each week, and a team decides how many chipping machines are necessary and which forest worksite they will be working on. The idea is to minimize the machines’ transportation and optimize their use. The chipping machines are owned by entrepreneurs paid by the ONF-E, and the transport is also paid by the ONF-E. They have to borrow money to pay all their contractors and give an advance to the forest owner, while they are only paid upon woodchip delivery once the quality check is made. The units for payment can be quite diverse: e.g., dry ton, input megawatt hour, output megawatt*

hour or gross ton. This diversity can change the final price (depending on the boiler output, the humidity rate, etc.). Being a forest entrepreneur or a transporter requires huge investments, and the ONF-E concludes some long-term contracts with them to offer some job security and to work with them on continuous improvement (different tires to limit the impact on forest soils, etc.). Wood-energy prices are not very high (about €30 per tonne) and their transportation costs a lot (about €1000 for a 26-tonne truck). Usually, they only allow the forest owner to repay the work costs to manage the forest (felling for health reasons, path maintenance, etc.). As the specifications on wood-energy become tighter, it is very difficult to be profitable with wood.

### The structuration of wood-energy in Franche-Comté

To finish her investigation on wood in Bourgogne Franche-Comté, Mrs. G. went to interview Fibois, an interprofessional network for the forest sector. The interviewee described the development of wood-energy to Mrs. G. District heating has been a major influence on the wood sector. District heating systems are long-term projects which allow partnerships to be built throughout the supply chain, and the right investments to be made for wood-energy. The private and public forestry managers work together to avoid competition between each other: They answer the orders together. However, when the first industrial-size biomass boilers came out, the forestry sector was not ready to supply the amounts of wood needed: Waste wood was being sent to the paper or panel industries and the right logistics and infrastructure to ensure the boilers' supply and wood traceability were not yet implemented.

In 2006, when the first biomass-based district heating system was implemented, Fibois set up a wood-energy observatory to analyze the production and consumption of wood-energy. First, there was a fear that the woodchips needed would prevent the paper and panel industries from having enough wood resources. But as Bourgogne Franche-Comté has abundant forestry resources, wood-energy created opportunities for exploiting waste wood, felling for health reasons, etc. and facilitated good forest management while creating local employment. The wood sector has a fragile balance; every change has an impact on the whole sector. In 2014, the paper and panel industries increased the share of recycled wood in their resources: thus, there was an overproduction of woodchips and no market for them. Similarly, COVID led to an overproduction of woodchips: many boilers



were shut down due to the lockdown, but the wood was already drying on the roadside and needed to be chipped... The last crisis to date is: the public's perception of wood biomass, which is heavily influenced by some major environmental organizations. Despite their attempt at communicating, the wood sector is less visible than these associations and they have to do a lot of work locally to reassure policy-makers on the feasibility and sustainability of wood biomass projects.

To support the structuration of the wood sector, including wood-energy, the region has a wood masterplan. Fibois and other wood stakeholders also communicate with local politicians to assess possible future projects. Moreover, Fibois advocates for the setting up of long-term contracts whenever possible. This facilitates the traceability of wood and secures the partnerships. They see wood-energy as a necessary side revenue stream for the wood sector, which complements the core activity and ensures an outlet for waste wood. Finally, the ashes from combustion can be used in various local businesses or in the agricultural sector (e.g., compost, purification). All in all, the use of wood-energy creates a complex local, circular network of stakeholders (Figure 27).

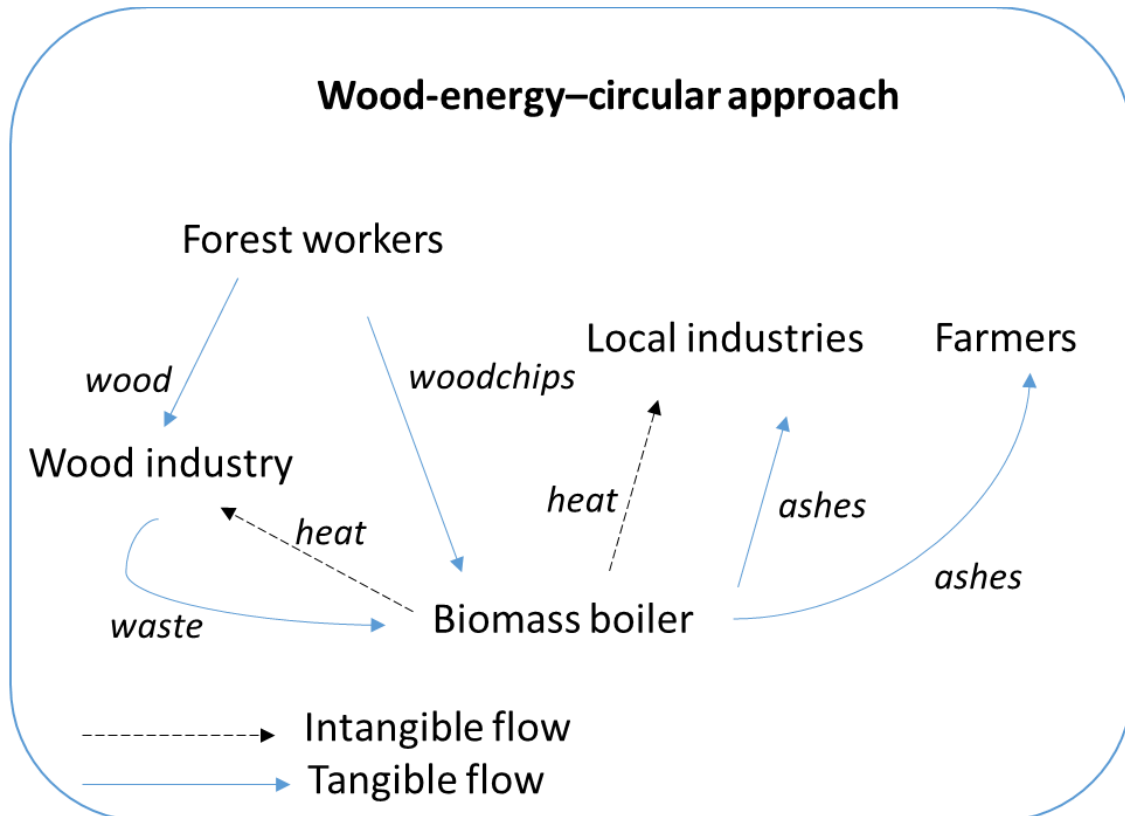


Figure 27 Wood-energy ecosystem of stakeholders

*Mrs. G. came out of this investigation with her head full of stars. Discovering the wood sector was a dive into the unknown and she was bewildered by this discovery.*

*“I really liked investigating wood-energy”, smiled Mrs. G. “It felt very refreshing to go to this forest worksite and discover this new world. But why talk about it here, it was a bit peripheral to the investigation, don’t you think?”*

- *“Well, it’s true that it is not strictly speaking about district heating, but it tells us so much about it! About the effort needed to set up local heat supply, about the interactions between district heating projects and the local sectors of activity, about the coordination needed to plan local supply, about the framing of biomass as a sustainable resource, about the...”*
- *“Okay, okay, I think I’ve got the point. But why put it here, in this chapter about instrumenting co-creation?”*
- *“Because to implement such a sector, and to successfully make a transition towards wood biomass supply for district heating, there is a need to work with local actors in order to structure a collaborative network, to govern this network, and to learn from this collaboration... And also, because it gives insights on co-creation and valuation: in Besançon they value (or don’t value, depending on the actors) wood biomass as a sustainable heat resource. This valuation is strongly linked to the local dimension of this biomass. For this valuation to perform, the actors need to co-create. In doing so, they structure a collaborative network based on instruments!”*
- *“And so, studying this can shed light on how these co-creation networks can be instrumented...”*
- *“Exactly!”*

Now that the narration of Mrs. G.’s adventures in Bourgogne Franche-Comté is complete, let us analyze the instrumentation of this node of co-creation around wood-energy.

### *Outlining some preliminary insights into instrumentating co-creation*

The above description shows how technical the wood sector is. Choosing for biomass means initiating a complex relationship between the district heating operator and the local ecosystem of suppliers based on such things as technical and legal specifications, market prices, and long-term contracts. All these aspects perform through instruments that mediate and shape the relationship between the different actors. *Table 21* gathers all the instruments I presented in the previous description.

<b>Instrument</b>	<b>Role</b>	<b>Comments</b>
<i>International, national, and local policies</i>	Give some objectives on the amount of wood biomass to be used, frame the financing schemes	The national objectives are translated down to the local level but do not seem to have a major impact on the local actors of the wood sector, more on the local policy-makers
<i>International, national, and local policies</i>	Frame the main specifications and indicators when it comes to wood quality, market rules, reporting, etc.	Has a great impact on the local wood sector structure, by opening or closing opportunities to sell wood-energy
<i>Technical indicators (percentage of humidity, amount of wood, etc.)</i>	Mediate the relationship between the different actors when building an agreement.	Required to build some common local norms (e.g., what unit to use when measuring wood-energy?)
<i>Traceability processes</i>	Structure the wood-energy sector, making all actors accountable	Process demanded by the private operator for internal reporting, but has an effect on all the supply chain

<i>Long-term contracts</i>	Stabilize partnerships throughout the supply chain	Secure collaboration between stakeholders
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*Table 21 Instruments shaping the wood-energy sector in Bourgogne Franche-Comté*

Out of reach of local stakeholders, specifications could change e.g., introduction of mandatory certification of sustainable wood biomass, or specifications on the supply perimeter. These do have an impact at the local level, but do not participate in co-creation instrumentation: these instruments are designed by other actors and cannot be adapted by local ones. They may threaten some co-creation processes by opening up more profitable opportunities.

At the local level, actors are co-creating the local wood-energy sector. To do so, several instrumenting processes have been put in place. First, a common language is being stabilized through technical indicators. Standardization takes place between the different actors of the supply chain to be able to structure the whole supply chain. Second, some dominant actors spread their instrumentation throughout the supply chain. This is the case of Engie for Besançon district heating, whose reporting and traceability process structured the relationship with suppliers. Finally, long-term contracts participated in the structuration of a supply channel: the wood sector had to get organized to be able to deliver the needed wood quantities and quality. These contracts also enable partnerships to be secured and responsibilities shared between the different actors. These three instrumenting processes participate in the co-creation of a wood-energy sector in Bourgogne Franche-Comté.

Nonetheless, this co-instrumentation process comes with challenges and limitations. The process caused an imbalance in the wood sector due to the different uses. And once it was all organized it could supply even more than the demand, which caused new issues, particularly because the demand may decrease due to climatic, economic or political reasons... Despite the instrumentation set up, the wood-energy sector is not entirely secured and the relationships may not be strong enough to properly share the risks between the different actors. Warmer winters or a demand for cheaper heat resources can threaten wood-energy.

Moreover, wood professionals are not reputed for their communication skills, and some local politicians could be unsure about the potential of local wood-energy or the management of local forests. Both the ONF-E and Fibois noticed that local politicians were reluctant to launch new projects, partly due to their lack of knowledge on wood resources and partly due to the loud communication from some associations advocating against wood-energy. Hence, the instrumentation alone is not enough if it is not supported by local expertise engaging all the relevant actors (including decisionmakers and municipalities).

Following this first case, some preliminary insights can be outlined on the instrumentation of co-creation. The structuration of the wood-energy sector in Bourgogne Franche-Comté required different actors—mainly from the wood sector, but also some boiler owners—to collaborate and co-create a sector embedded in existing institutions. Co-creating a sector to answer a new demand (wood-energy for the energy transition) requires different processes: framing the new sector and adding on existing expertise to perform the frame. To do so, the wood-energy sector actors (from the forest workers to the boiler owner) instrumented both wood-energy (e.g., its specifications, pricing) and partnerships (e.g., with reporting processes or long-term contracts). Through this instrumentation they are creating a common valuation of wood-energy. The making of this valuation came with a lot of challenges, such as finding the right unit to describe wood-energy (would it be tons or kilowatt-hour? would it be when the wood is dried or when it still has a certain moisture content?). Similarly, the valuation of wood-energy questions the role of the different actors: what type of partnership would be the most efficient to secure the supply of high-quality wood? Which actors should be engaged in the building of collective expertise? Finally, what is valued is also a major challenge: is it only wood-energy as a fuel, or is it the local wood as an economic sector? Is all wood biomass renewable and sustainable or are more criteria and certifications needed?

*“I am bewildered”, exclaimed Mrs. G., “by instrumenting co-creation, the actors instrument valuations. But they also value co-creation!”*

- *“Yes, co-creation becomes a value gathering the actors together, not only a tool they set up.”*

- *“I think something similar can be seen in every project... All the processes are interlinked and interact with each other.”*
- *“True, lets jump in!”*

## Greater Copenhagen—a historical example of instrumented collaboration

### *Data collection*

Studying Greater Copenhagen was not part of Mrs. G.'s initial plan. She was merely doing a comparison between the Danish national setting and the French one. But when she spent a few weeks visiting there, she felt the need to understand more how the district heating network actually worked. After making a few contacts during her first stay, she came back in October to conduct the interviews. As she was only there for a few weeks she focused the interviews on the structuration of the network of actors: How was the network of actors around the district heating system managed? In particular, she investigated the contracts stabilizing the bonds between the partners. She did not have time to interview all the actors, and could not interview the local ones as she did not speak Danish. She targeted the transmission companies of the network: a specificity of Greater Copenhagen's organization. There are two transmission companies operating in the area, and HOFOR working for the municipality of Copenhagen. After the first interviews, she was pointed towards Varmelast, in charge of heat dispatch. Varmelast was a central actor in the network structure and operation. All in all, she interviewed four actors through semi-directive interviews and also had informal discussions with researchers from the Copenhagen campus of Aalborg University. She complemented these data by information from the websites of the interviewees' organization, and by reading presentations sent by the interviewees. The semi-directive interviews were recorded and transcribed. All the data collected are reported in *Table 22*.

Type of data	Organization	Role of the organization	Date of the interview and place (if applicable)
Semi-directive interview	CTR	Heat transmission company	10-06-2021 (online video call)
Semi-directive interview	VEKS	Heat transmission company	10-19-2021 (VEKS office)

Semi-directive interview	HOFOR	Heat transmission & distribution company	10-19-2021 (HOFOR office)
Semi-directive interview	Varmelast	Energy dispatch center	10-20-2021 (Varmelast office)
Presentation (slides)	CTR	Heat transmission company	
Presentation (slides)	Vermelast	Energy dispatch center	
Websites	VEKS & CTR	Heat transmission companies	

Table 22 Data collection–Greater Copenhagen

### ***Mrs. G.'s field trip overseas***

Now that I have introduced the data collected during Mrs. G.'s investigation in Greater Copenhagen, let me narrate this investigation and describe the district heating system...

*When formally introduced to the team, Mrs. G. had a surprise: a junior detective was just finishing her investigation into Greater Copenhagen's district heating! They spent hours discussing this system and Mrs. G. even decided to conduct a few interviews of her own to get first-hand information on Copenhagen's district heating. In her previous discussion with French and European stakeholders, Denmark—and especially the city of Copenhagen—were often presented as an example when it came to the development of urban district heating, and it was no wonder... 98 % of the capital city's buildings were supplied by district heating (C40, 2015)! However, when studying Copenhagen district heating, Mrs. G. quickly discovered that she had to discuss Greater Copenhagen and not only Copenhagen... From the 1980s on, Copenhagen joined forces with neighboring municipalities to create Greater Copenhagen, one of the world's largest district heating systems. Mrs. G. contacted a few district heating companies (VEKS, HOFOR, CTR) to get a better understanding of how this huge system was governed. It turned out that due to the huge surface area covered by the district heating system, two types of companies were created: transmission companies and distribution companies. The transmission companies transport heat from the suppliers (which operate production units like Combined Heat and Power) to heat exchangers. They*



then sell heat to distribution companies that are in charge of the supply from the heat exchangers to the customers (Figure 28). The transmission company has to secure heat delivery to the distribution companies. Both the transmission and the distribution companies are in charge of the operation and maintenance of their supply system. Depending on the size of the company and the technical issues it may face, operation and maintenance can be made contracted out.

Although distribution companies are local and usually municipality-owned, transmission companies are owned by a group of several municipalities. If you take the example of the ownership of CTR, one of the transmission companies, this is what Mrs. G. found out during her interview with them: “we are all municipality-owned [...] it’s five municipalities that own my company and I sell the heat to each of these five municipality-owned distribution companies.”.

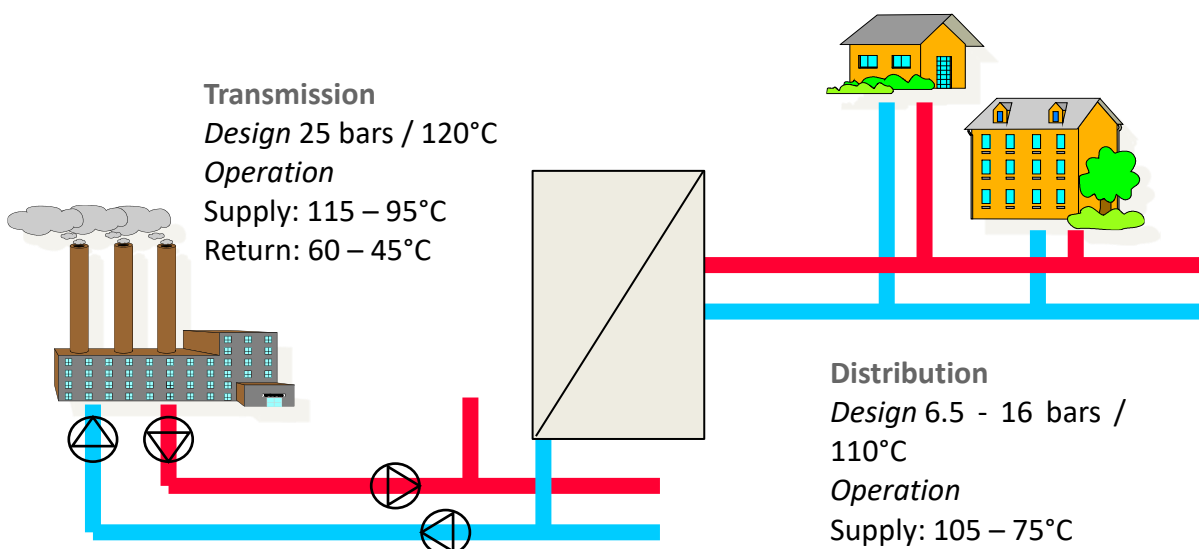


Figure 211 Design of Greater Copenhagen system—adapted from CTR (2019)

The transmission companies are CTR and VEKS. HOFOR is both a transmission and a distribution company, focused on Copenhagen. There are about 20 distribution companies covering the whole Greater Copenhagen area (Figure 29).

Heat may be produced by private actors, but here again, no profit can be made on the selling of heat. For Copenhagen, heat is produced by combined heat and power units, incineration plants, and peak load boilers. In 2017, 73% of heat production came from the combined heat and power units (mostly fueled by biomass). Some of the production plants are co-owned by the transmission companies, and others are private. But here again, no profit can be made on the selling of heat...

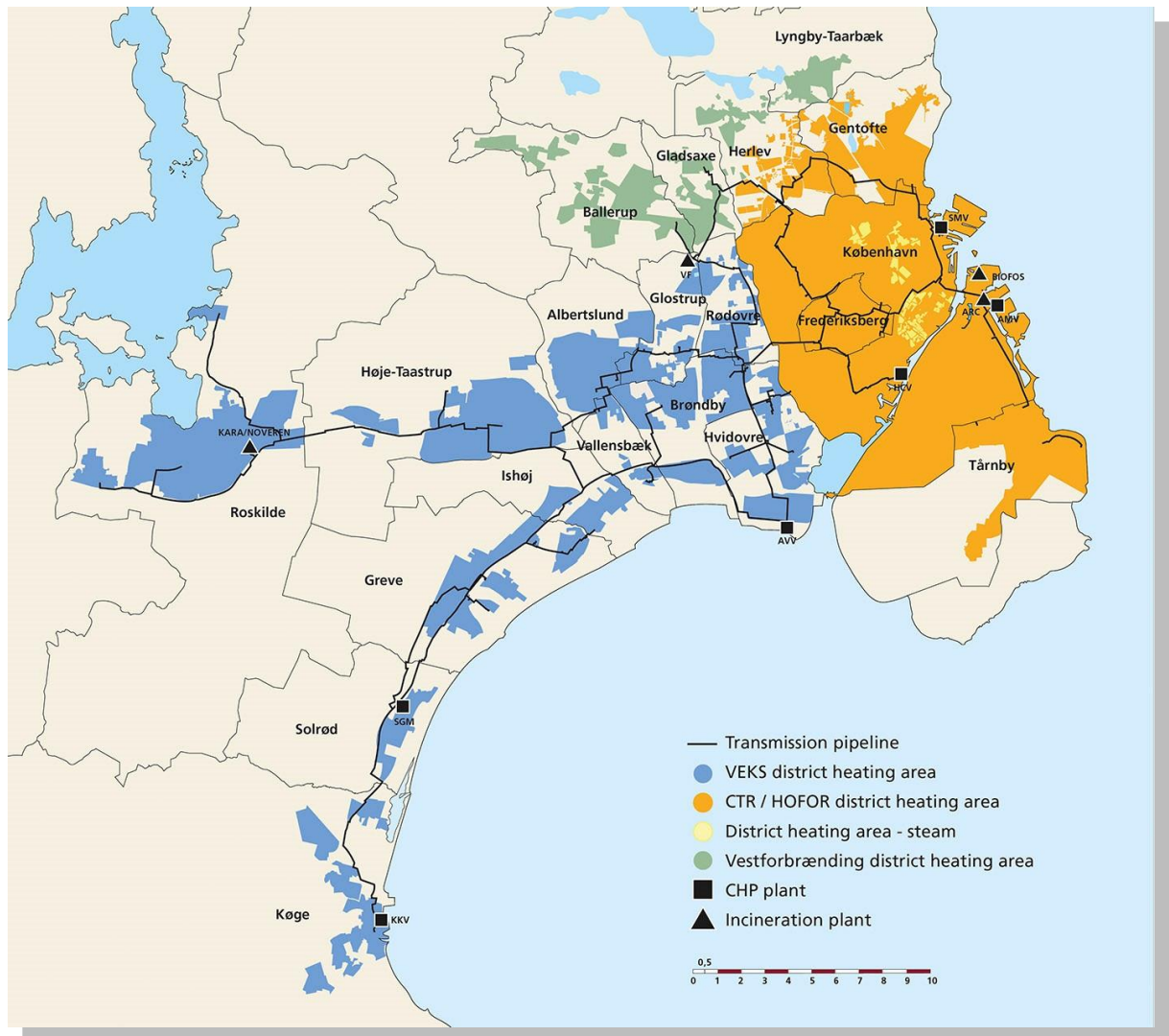


Figure 29 Map of Greater Copenhagen district heating system (Varmelast, 2022)

*To complement this ecosystem, consultancy firms can be employed to advise the transmission or distribution companies*

*Mrs. G. was impressed by the organization of the heat supply network in Greater Copenhagen. There were so many municipalities working together, creating entities to transmit and distribute heat and partnering with private companies when necessary! However, while the system was theoretically easy to understand, Mrs. G. could not help but wonder how the system was working on a daily basis, and what type of partnerships linked all the stakeholders. She soon discovered the complexity of the contracts surrounding the system... Basically, transmission companies buy heat from heat producers. They have a contract with all their producers where they agree on a price of heat*

*(dependent on production costs, as all is non-profit) and they invest in a part of their capacity, to ensure they can receive the heat when they need to but also to ensure that the producer will get paid even if no heat is needed. At the end of each month, the producer charges the transmission company for the amount of heat delivered with the price stated in the contract. Usually, the transmission companies also pay for the production unit investments, as they have access to low-interest loans and can have long payback times. The transmission companies then charge the distribution companies: Each distribution company pays the share of heat they are supplied. Each year, they have to give a 5-year projection plan on their heat demand. The price is made up of two parts: fixed costs (comprising the investment costs and shared depending on the expected heat demand of each municipality) and the price of heat. The latter can vary over the year (depending on the energy mix) but all prices are set up in the yearly contract, based on scenarios and future prospects. The transmission companies can also exchange heat between each other if one needs more capacity than its producer can provide: "Between us and VEKS we have exchange contracts, but it only means that what they pay for the heat we will pay. Again, you're not allowed to have any profit so it doesn't matter if it is VEKS or us who buy the heat, we will pay the same price anyway." (CTR). While the prices are discussed every year, the contracts last for the lifespan of the infrastructures. The last step of the contract is between the distribution companies and the consumer. Mrs. G. was surprised to know that the consumer was also a building in Denmark, not necessarily the final user. However, contrary to France where the vast majority of the consumers are big buildings (e.g., offices, hospitals, social housings) the building connected in Denmark can be a house owned by a family. As she had heard in France and in Europe about a will to integrate more final consumers, and connect the primary distribution network to the secondary one (inside the buildings), she asked HOFOR if that was something they were thinking about. Just like in Besançon, she was told that they did not want to come too much inside the buildings "We have some testing: if you own an apartment, we could then provide heat directly to the owner of the apartment. But, we're not very fond of it. Because it gives a lot of troubles in different ways." (HOFOR, October 2021)*

*To optimize the power and heat production, Varmelast was created. It is an organization gathering the three transmission companies and taking care of the heating mix. It is in charge of the contracts with suppliers and ensures the heat is produced at the cheapest*

*price both for heating and power systems. Every day, Varmelast calls every supplier to get their production price for both power and heat, and chooses which suppliers will be delivering the heat for the day hour per hour. This price is not the actual price stated in contracts and being the basis of payment, but only a variable production price. This production price is highly dependent on the NordPool market, as a huge part of the heat comes from Combined Heat and Power plants, selling their heat to the NordPool market. The procedure relies on data sharing between Varmelast and the different producers. The interviewee tried to explain the procedure to Mrs. G., first with the easy version: "The heat plan is made every day before the spot market. So, the producers have to send their bids to Nordpool at 12, noon every day. So, we finish our heat plan at 10:30, so they have approximately 1 and a half hour to do their own optimization. So, we tell them "This is the amount of heat you produce, you have to produce tomorrow" and then they can say "OK we have to produce this amount of heat, then the power will cost me this much and then this is my bids". And then he went into the details of the actual planning procedure, introducing it this way "But the planning procedure is not as simple as that. Because, we have to get a lot of information from the producers... they won't let us do everything, they won't let us know everything. So, we do a 2-step optimization...". In this real-life planning, there was a lot of back-and-forth between Varmelast and the producers to optimize both the heat and power productions in addition of the price.*

*Varmelast is one clear example of the actors' ability to work together. Another one was given by HOFOR for the utilization of waste heat. Mrs. G. asked how the investments to utilize the heat were shared, and here is what HOFOR answered: "It's shared in the way that we start looking at the initiative as an opportunity for both parties. So, it's open book approach. So, we discuss with the company what are the upsides, what are the downsides, what kind of costs are involved and what kind of costs will be suppressed by the new plant. And then we can find out if this project is actually a good project. [...] In most cases we are sharing the investments with the company and... and this is because they are saving a lot of energy for cooling. So, it's worth for them to invest something. [...] and the business case is made for the project as a whole, and for each of the parties. And it has to be... the project has to be good economy and the same for each of the parties." This first step already opened up prospects for Mrs. G., but she was curious to learn how this partnership was secured, especially as partnerships with industrial partners can be very unstable. The*

*HOFOR interviewee explained a mechanism set up in their contracts: “Let’s say, the business case is made on the basis of some assumptions on how will the electricity price develop in the future, different kinds of things. And a number of other assumptions. Then we say to each other “well, we don’t know how the world will develop, what we know is that we develop the internal rate of return for each of the parties”. [...] And it means that if one of the parties is unlucky about the assumptions, then they will... then they will lose money to begin with. But when the first party is paid off, then all of the gains will be passed on to the other party. [...] Then we have some exit clauses, and basically the exit clauses are arranged so that if one of the parties leaves the arrangement, then this party will compensate the other parties for the economy that is still lacking.” Mrs. G. was awestricken by the mechanisms put in place: the transparency in co-creating a partnership, instrumenting it as a contract, and creating clauses to make sure that all the partners benefit from the partnership and that their risks are covered.*

*Although this system already seemed really complex to Mrs. G., she was not yet at the end of her surprises. When discussing district heating with her interviewees, she realized that they were all concerned about future evolutions of the system, but did not all have the same vision (Table 23). While the phasing out of biomass was in the minds of all interviewees, the implications for the network are still uncertain. For now, Denmark had based its “sustainability” politics on the use of biomass, but the era was coming to an end, leaving the companies facing the unknown...*

<b>Stakeholder</b>	<b>View on the future energy mix and heating market</b>	<b>View on the future heating system organization</b>
CTR	“there’s a huge political wish that we should change again to more electricity kind of heat. That will probably be heat pumps, and power to X [...], surplus heat from carbon capture, and surplus heat from the industries around Copenhagen. We are still	“if we no longer have the big main heating plants, but more or less the whole heating system in a very distribution level, I’m not sure whether there will be a need for transmission.” “I think it [contracts and governance] <i>will change.</i> ”

	<p>hoping to have a breakthrough in geothermal heat, so there's a lot of possibilities ahead."</p> <p>"I guess we will have a lot of storage around the city [...] the market that's ahead of us will be more difficult to foresee than the market we had before."</p>	
<p>VEKS</p>	<p>"In the future we will have a lot of distributed technologies, with heat pumps, there will be heat pumps, geothermal, heat storage (we are building heat storage at the moment), industrial surplus [...] and there will be the power to X, the power to... carbon capture and then..."</p>	<p>"We need to find the... an established... in our project department, planning department, design department... to find expertise. And right now, we have... It's difficult to hire, so we... [...] consultants there, and his seating here two days a week, to go through our heat pumps projects. Eventually, hopefully, we're successful at acquiring an expertise of our own. And also, when you come to the daily operation and maintenance of these plants, our guys are used to maintaining electrical pumps, heat exchangers, boilers, traditional heat technologies, so heat pumps it is a little bit new to them. So, today we have to increase our competencies, our knowledge. And that is part of our strategy but it's difficult. But we need to build this expertise."</p>

<p><i>HOFOR</i></p>	<p>“we have used a lot of efforts to be CO2 neutral, but now some people claim that biomass is not CO2 neutral. So, now we can start all over again, from the very beginning.”</p> <p>“When we have to renew something then we’ll use other technology than biomass. Electricity for example.”</p> <p>+ storage, geothermal, Power-to-X</p>	<p>“It’s going to be easy. I mean we use communication between the plants. We can operate the plants remote control and whatsoever.”</p> <p><i>The interviewee also thinks that electricity will play a greater role at a more local level compared with the current plants.</i></p> <p><i>For storage and power-to-X, there are some discussions on the investments sharing and the ownership, with the same idea: “Those who are having benefits from the storage are also members of the investors”</i></p>
<p><i>Varmelast</i></p>	<p>“I think we will have the waste incineration. I think we will have the heat pumps. I think we’ll get some heat from a data center or 2, maybe some power 2X production, and even more maybe some geothermal heat.”</p>	<p>“I mean, we’re sort of... doing a few things very well, we have to run these 3 power plants, 4 power plants very well. And optimize... have a small organization that can keep costs balanced. And suddenly we are asked to find out what’s the future is going to be like, and we’re not at all ready for it.”</p>

Table 23 Different vision of Greater Copenhagen district heating system's future

*From what Mrs. G. saw, the different interviewees were having different concerns with the future, from the fear that they would no longer be relevant, to the difficult in building new expertise. Some seemed to find the phasing out of biomass bothering but not threatening their way of working. All agreed that co-creation and building the future together was key to success...*

*“Greater Copenhagen is really interesting when it comes to collaboration”, exclaimed Mrs. G. “So much could be learnt from there: Did you see how the actors interact to manage the network, how they share the risks?”*

- *“The collaboration is impressive, but bear in mind two things: the regulatory setting in Denmark which is very distinctive; and the fact that we do not know how resilient this collaboration is.”*
- *“For the distinctiveness I know, but maybe some lessons can still be learnt. But what do you mean about resilience?”*
- *“I mean that the context is changing: more decentralized heat sources, the need to mitigate the demand, new actors to work with... They do not know how to handle that. Especially as they try to phase out of biomass: What is the next step? When the biomass plant is at the end of its lifespan, what happens?”*
- *“Yes, the management of the unknown is still... unknown.”*
- *“All this collaboration and these co-creation habits were designed in a specific setting; we do not know if they will survive the turbulent times ahead.”*

Despite the unknown future, some lessons can be drawn from the Greater Copenhagen case on the sharing of risks and the co-creation processes ahead of any decision impacting the network.

### ***What could be learned from historical collaborations?***

In Greater Copenhagen case, suppliers of all kinds and public operators have been working together to design a collaborative network governance. Their partnerships are shaped by different instruments (*Table 24*).

<b>Instrument</b>	<b>Role</b>	<b>Comments</b>
<i>Regulatory and legal framework (not-for-profit heat, public companies, etc.)</i>	Frames the actors’ actions and the basic rules for their interactions	The framework facilitates openness and cooperation as it partly extracts heat from conflicting economic interests.
<i>Long-term contracts</i>	Explicit and secure the partnership, heat prices, and the sharing	A lot of contracts and partnerships shape the network of stakeholders in Greater Copenhagen, to



	mechanisms (for responsibilities, risks, etc.)	cover the heat and the power deliveries at all steps of the supply chain.
<i>Heat dispatch process</i>	Varmelast optimizes the power and heat production for all the major stakeholders	This process is separate from the contractual heat delivery, it is real-time optimization where all the stakeholders play together to get the best system possible.

Table 24 Instruments shaping Greater Copenhagen district heating

Collaboration is facilitated in Denmark by the national policies and regulations framing district heating. In Greater Copenhagen, this collaboration relies on various long-term contracts securing the interests of each stakeholder. The major stakeholders are stabilized, meaning that they have grown used to working together. They build on this partnership for each new project, which will last for the duration of the technical infrastructure set up, but the partnership for heat delivery does not have an end date. Each decision is discussed openly between all the stakeholders, to find the right setup based on the risks and benefits for each actor and for the network. Co-creation is implemented at different levels: at the transmission level through long-term contracts securing the partnerships with the producers and distributions companies; and at the distribution level with the companies conducting collaborative projects with local actors like industrial firms. The habit of working together has been historically built and is facilitated by the regulatory context (in particular the heat being non-profit, which facilitates the sharing of data).

In this case, instrumenting the co-creation is not an added layer on an existing setting, but the way the network has been implemented from the start. The management dispositive is designed to support and facilitate this co-creation. Co-creation is seen as a basic need for a successful project, and is thus valued by all the stakeholders, making it perform. Here again, by instrumenting co-creation and performing co-creation practices, a specific

collaborative valuation of district heating is constructed based on the different actors. Historical expertise has been built up around co-creation, and the knowledge around the technical system continues to grow and feed this collaborative expertise.

However, this historical setting also questions the resilience of co-creation: facing an uncertain future—in particular with Denmark phasing out biomass and the network becoming more decentralized—can such a collaboration last? The network's decentralization questions the very relevance of the transmission companies. The phasing out of biomass requires the construction of thermal storage, which is outside the classical boundaries of district heating networks. Actors are beginning to wonder who will be paying for and operating such infrastructures. New settings need to be found and it is not clear whether all the actors will be a part of this future. The collective expertise has to be adapted: There will be new settings, new instruments, new roles, and new knowledge. Most of the actors are already starting to build their knowledge and collaboratively sketch out the new partnerships and their settings.

*“Greater Copenhagen is impressive by the number of stakeholders that were gathered together through collaborative contracts”, highlighted Mrs. G. “Several suppliers, two transmission companies and tens of distribution companies. Not to mention the municipalities, which are also part of many discussions!”*

- *“It is impressive, I agree. Long-term contracts, with a sharing of risks between all the suppliers. It is really different from the French Public Service Delegation where the private partner bears all the risks. And at least up to now, it appears to be quite flexible.”*
- *“You mean flexible in which way?”*
- *“They adapt to the integration of new producers for instance. Varmelast is learning about heat pumps and how to optimize them. And this is very important: as the technical systems change quickly, they need to adapt.”*
- *“For now, they have succeeded... But the last change—the phasing out of biomass—may reshuffle the cards and be a difficult challenge to overcome.”*
- *“Maybe... Or an opportunity for the network of actors to seize. Let's look at the management plan in our Canadian case, okay?”*

## Ottawa—ambitious collaboration in a PPP frame

When Mrs. G. arrived at Engie at the beginning of her PhD, one project was taking the center stage. At the beginning of the year, Engie had succeeded in winning a bidding process in Canada. It will be responsible for the Ottawa district heating and cooling system for the next 35 years. Olivier, who was part of the team working on the project, was delighted. In his opinion, this contract was a first step towards the future. The decarbonization ambitions, the all-inclusive contract, the good relationship established with the client, all were characteristics he was pushing for in his everyday work. He was very keen on Mrs. G investigating this project, and maybe finding some best experiences to be replicated in other projects.

### *Data collection*

Mrs. G. thus started to work on the project, first through generic presentation documents. She then gained access to project documents: kick-off presentations, the request for proposals, the answer to this request, and then the final contract. She had the opportunity to discuss these documents with two actors of the Ottawa project: one Engie employee who managed the team working on Engie’s answer to the request for proposals, and the person actually responsible for the district heating system’s operation. *Table 25* gives an overview of the data she could access.

<b>Type of data</b>	<b>Short description</b>
Internal communication document on the project “Highlight Ottawa”. June 2019 (Engie, 2019k)	Presentation of the project and its interest for Engie
Presentation of the project by the Public Services and Procurement Canada “Introduction to Energy Services Acquisition Program (ESAP)”. September 2017 (Public Services and Procurement Canada, 2017)	Presentation of the future bidding process for interested contestants

Presentation of the project to an internal Engie committee “CSIT <sup>43</sup> presentation ESAP project District Heating and Cooling Network in Ottawa – Canada”. December 2018 (Engie, 2018a)	Presentation of the project to an Engie internal committee, focus on the financial aspects
Presentation of the project by the Public Services and Procurement Canada “Modernizing the DES in Canada’s Capital Region. February 2020 (Public Services and Procurement Canada, 2020)	Public presentation of the project with a focus on the decarbonization ambition
Request for Proposals. February, 2018 (Government of Canada, 2018)	143-page document describing the project and its requirements
INNOVATE ENERGY answer to the request for proposals. January, 2019	All the work folders on the project
Project Agreement. May, 2019 (Government of Canada, 2019)	1217-page agreement on the ESAP project
Semi-directive interview with two internal actors of the Ottawa project (call on 09-11-2020)	Presentation of the project and its specificities
Semi-directive interview with two internal actors of the Ottawa project (call on 02-23-2021)	Focus on the payments of the private operator and contract indicators
Informal discussion with an internal actor of the Ottawa project	Debrief on the data collected and insights on the projects

Table 25 List of the data accessed for the Ottawa case study

<sup>43</sup> Strategy, Investments and Technologies Committee (Comité de la Stratégie, des Investissements et des Technologies)

### ***Mrs. G.'s transatlantic investigation***

Let me now describe this project, through a narration of Mrs. G.'s investigation.

*Olivier was so excited about this project, that Mrs. G. was sure it would be a lot of fun to work on. She would soon realize how optimistic she had been...*

*Ottawa was the first planned case study for Mrs. G. She had high expectations, dreaming of a field trip to Canada and multiple interviews. But before going there, she had to find some information on the case. Data were not as easy to collect as she had thought and she had trouble putting the pieces of the puzzle together. She was still very inexperienced both as regards district heating and research... Olivier gave her some first outlines on the project, with a mix of communication elements and data on the project temporality. She understood that it had been a big project, with a lot of time invested in the bidding process: The process was long, the client had a lot of expertise, it was an innovative project. Olivier even stated that it had been the first co-creation project, and that they have a very good relationship with the government.*

*She complemented this first glimpse of the project by rummaging through Engie's online documents. She managed to find some communication documents on the project. Olivier also sent her some files. She eagerly went through these documents, searching for some outstanding elements.*

*The first file she went through was a two-page internal communication paper. It quickly sketched the project outlines before going into the advantages for Engie: "This new Federal DES (District Energy System) Performance Based contract is a major Project reference providing an unprecedented response to the challenges of Ottawa's DHC network while anchoring the Group's international strategy." (Engie, 2019k). Mrs. G. took notes, trying to understand the project. The document went through a lot of information. Engie was part of a consortium, named Innovate Energy. The consortium was composed of Engie and three local partners, seemingly working on construction and architecture. The contract was a 35-year-old PPP contract. Then there were some specifications on the number of plants (four, both in Ontario and Quebec), the power, the number of buildings, etc. Mrs. G. scrupulously wrote down the information, not quite sure what they meant. Then there was a mention of a two-phase program, and the estimated cost of the first one.*

*Finally, Mrs. G. saw some mentions of strategic goals—which spoke a lot more to her—especially the objectives of reducing carbon emissions, improving resilience, reliability, and efficiency. To do so, Engie put forward some tools to trace carbon emissions, blockchain technology and other digital tools.*

*The following week, she started reading another document sent by Olivier. It was a presentation entitled “Introduction to Energy Services Acquisition Program (ESAP) – Energy Service Modernization, P3 Contract, Information session” (Public Services and Procurement Canada, 2017). This information session had been held in September 2017 by the Government of Canada, as Mrs. G. noted from the presentation date. It was quite detailed, showing the expectations of the Government. Again, Mrs. G. took some notes, this time trying to better understand the project structure, what the key requirements were, and how they were evaluated. She then moved on to another internal document, showing how Engie evaluated the project (Engie, 2018a). It was a presentation from December 2018, quickly presenting the project' and then demonstrating the project's alignment with Engie's strategy as well as some financial indicators. Once she had read the document, and tried to decipher the financial calculation, she felt a bit lost. What was the next step, how was she supposed to move forward in this case study?*

*Before moving on with Mrs. G. and her Canadian investigation, let me do a short recap of what she had found so far.*

In 2017, the Government of Canada—more precisely Public Services and Procurement Canada (PSCP)—launched the Energy Services Acquisition Program (ESAP). This Program aims at modernizing the District Energy System (DES) of the National Capital Region (NCR). More than technical or economic requirements (safety and reliability of supply, improved efficiency of the system, reduced costs), the Government claimed other objectives: supporting the Government's environmental priorities and commitments, improving public-private expertise, using the program to create an education platform, and making one of the plants an architectural landmark. These objectives stood out from the classical technical-economic objectives, showing a will to go for more integration of the DES in its environment. For each of these objectives, criteria were put forward by the Government: e.g., a 60% reduction in greenhouse gas emissions by 2025 compared with 2005, and a 90% reduction by 2030. The current DES runs on steam but is to be converted into an

interconnected low-temperature network during the project's lifespan (Figure 30). The DES covers for now only federal buildings: 80 for heating and 67 for cooling but the network is expected to expand during the contract's lifespan.

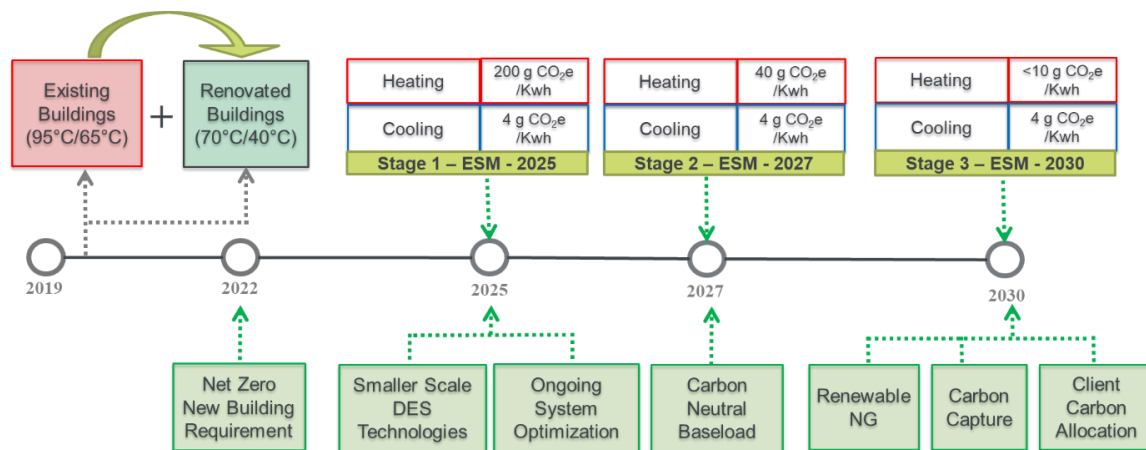


Figure 30 Expected timeline of the network decarbonization (PSPC, 2020)

ESAP is based on a PPP contract divided into different phases. First the procurement process, with the request for qualifications in fall 2017 and the announcement in January 2018 of the selected competitors. Then, the request for proposals running from February 2018 to February 2019. Once this process was completed, the contract was in three phases: a transition phase, then a construction phase (from 2020 to 2025) and finally the operation and maintenance phase (from 2020 to 2055). The Government of Canada had set up a huge team with a lot of expertise (procurement authority, legal advisor, technical team, project management, financial advisor and HR advisor) to handle the project and conduct discussions with the private partner. The scope of the contract, from the physical perimeter of the DES, and the sharing of responsibilities to the value of the contract was decided prior to the procurement process by the Government. Similarly, the Government of Canada decided on evaluation criteria and a basic contractual structure. One key point is that all parts of the project are addressed under the same contract. Nonetheless, they stated in their presentation that the Project Agreement was to be adapted during the Request for Proposals to address potential innovation and discuss the allocation of risks. On the Private Partner side, Engie was part of the winning consortium INNOVATE ENERGY, where they will be the only shareholder for the operation and maintenance phase. The other members of the consortium are local partners, bringing expertise in architecture,

civil engineering, and construction. On their presentation to the CSIT<sup>44</sup>, the project team pointed out three benefits of the contract for their group strategy and the alignment of financial aspects with the group's criteria (risks, profitability, etc.).

*All this information was interesting but not very exciting. Mrs. G. hoped that a discussion with real humans involved in the projects could help her understand what was happening. She contacted Olivier and gained access to a whole folder of documents on the Ottawa project: the request for proposals, INNOVATE ENERGY's answer and the final contracts. The folder's classification was hard to understand, as were the various documents. Mrs. G. started a tedious reading, all the things she had uncovered before were there, detailed, but with a formalized vocabulary hard to grasp.*

*In February, a couple of months after her first research, Mrs. G. presented her work during a committee at Engie. Olivier insisted again on the innovative aspect of Ottawa, how the project was ambitious, how the project went further in the environmental specifications, how the relationship set up was a partnership and not a mere "client-supplier" relationship, how the valuations were different than in any other district heating projects. He highlighted the relationship built up with the Government, the dialogs, the long-term construction of the request for proposals. One point he found ahead of its time was the NPV (Net Present Value) which included several criteria like esthetics and carbon savings. Usually, this NPV is mainly financial and technical, and this project succeeded in quantifying several specifications to include them in the calculation. Olivier also pointed out that the contract, unlike the usual ones, encouraged innovation. But this limited responsibility encouraging innovation came from a legal dispensation of Canadian law.*

*"This NVP idea was so impenetrable for me", sighed Mrs. G. "Franck and Anne were saying it was normal stuff in such projects, Olivier was claiming it was utterly innovative. I was lost. And I knew very little on the economic side of such projects. I spent so much time trying to understand the different financial sheets, payment, profitability, and so on..."*

- "Still, this NPV was an interesting instrument. The specifications, the quantifications were part of this valuation process, and Olivier specifically

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<sup>44</sup> Strategy, Investments and Technologies Committee (Comité de la Stratégie, des Investissements et des Technologies)



highlighted the co-construction aspects. It clearly shows the social dimension of this valuation process and makes an interesting link between valuation and co-creation! Through the instrumentation of this partnership, valuations are co-created and integrated into the instrumentation!”

- “Yes, but what I wanted to see was more action and not only the final documents...”

*Mrs. G. was getting more and more lost in the Ottawa case study. Through the documents given, she was unable to reconstruct the innovative processes briefly mentioned by Olivier. She made several attempts to contact people from the Ottawa project, but COVID elongated all the timelines, and shut down all hope of heading out into the field. She finally succeeded reaching the Canadians in September 2020, almost one year after she first heard of the project. Her two contact people were very friendly, but had little time. They were open to the idea of welcoming her to Ottawa and also gave her some fuzzy information about the contract. Most of what they said was already known by Mrs. G., but their highlights were a bit different than Olivier’s. They explained that the basic principle of performance-based contracts was to agree on performances and to leave the responsibility for reaching these objectives to the project partner. Engie was free to see how to make all the technical stuff, and how to make it in a cost-efficient way. They also pointed out the uniqueness of mixing environmental, financial, and technical objectives in one contract, and to have a lifecycle vision rather than a short-term one. The final point they raised was the huge team necessary and the short-term finance to leave room for future evolutions, without being restrained by long-term investments. The call ended with a glimmer of hope: She was to send them documents on her work, with a timeline on what she wanted to do in Ottawa, and they suggested she start to organize the field trip for February!*

*She got down to what they had asked for. One huge task was making a list of all the documents she had and all the questions she wanted to be answered. With this sent, she waited for an answer but nothing came from their side. In February, they had another call, this time focusing on the payment schedule and how it is linked to specific performances. The call was even shorter and more difficult to focus than the last one. Still, Mrs. G. got some interesting information on the partnership between the Government and Engie. Each month, the operator (Engie) has to produce a report showing how they performed,*

demonstrating the KPIs (Key Performance Indicators). Around these reports, a lot of informal discussions take place to agree on the possible financial penalties and try to collectively solve the problems. Once again, the call ended on the future steps, especially finally discussing the project with other actors of the Canadian contract. They asked her to send them the questions she wanted to ask. She did so soon after the call and waited for the green light.

“That’s a sad ending to the story”, I noted.

- “Yes, but I think the timeframe was not good to really get into this project. Between COVID, the internal reorganization... It was hard to sustain an exchange.”
- “Don’t feel frustrated. With your investigation you still discovered interesting things, and it was also a window onto Engie’s organization and strategy”

### ***Instrumenting collaboration in a conventional setting...***

The co-creation setting in Ottawa is interesting from several angles. I have already mentioned the surprising extent of co-creation efforts in such a conventional PPP setting. These co-creation practices are instrumented through the contractual process, from the bidding documents to the final contract and its requirements. The contract is integrated, encompassing all project aspects including design, building, and operation. The instrumentation set up was first to support collaborative dialogs and co-design the performances and risk sharing. From there, these created aspects were stabilized in the contract. *Table 26* summarizes the main differences between a conventional PPP contractual process and the one studied in the Ottawa project.

<b>Dimensions</b>	<b>Conventional PPP</b>	<b>Ottawa project</b>	<b>Comments</b>
<i>Preparation of the PPP</i>	A couple of years	More than 10 years	This preparation phase was used to carefully design the bidding documents and

			process while starting to create a relationship with potential competitors
<i>Bidding process dialogs</i>	Maintain a client / supplier relationship	Importance given to the building of a relationship	The bidding process was long and dense. It was used as a phase to co-construct solutions and a future partnership
<i>Performance indicators</i>	Pre-determined indicators, usually complying with national regulations	Co-creation of a value for carbon emissions to reach ambitious objectives	The indicators were not entirely stabilized; their value could be discussed and co-created.
<i>Value</i>	Mostly technical and economic	Integration of environmental and esthetic criteria into the NPV	A more holistic approach of value was taken
<i>Openness of the contract</i>	Limited willingness for risks and uncertainty	Phase 2 still to be constructed hand-in-hand with the partner	The partnership is secured, with ambitious objectives but means that are still to be co-created

<i>Reporting process</i>	Assess the achievement of objectives	the of	Mediation tool to engage in collective problem-solving	The monthly reports are thought of as opportunities to improve the project
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Table 176 Main differences between the Ottawa project and a conventional PPP

Through this process, valuations were co-created: e.g., the value given to esthetic considerations, the value given to carbon emissions. During the operation, the reaching of performances is the responsibility of the private partner, but collective problemsolving is encouraged through monthly contracts. This instrument is used as a mediation tool by the actors to discuss performance. The importance given to collective problem-solving shows that co-creation itself is valued as an important dimension of the project. Collaborative expertise is being developed: Work routines are set up, tools developed and knowledge shared. Finally, one major interesting angle of the case study is the collaborative management of the future. The contract sets up broad objectives but the means to reach them are still unknown. The different actors are committed to co-creating future valuations and solutions for them to perform. The contract frames the partnership by setting up objectives and basic rules for the collaboration.

*“The conventional setting is here a means to secure and foster a type of co-creation”, appreciated Mrs. G. “Same thing as ever, by instrumenting co-creation the actors also value co-creation as a necessary dimension of the project.”*

- *“It was already highlighted by Olivier. He said that it was not possible to continue doing PPPs the same way and that more co-creation was needed.”*
- *“Yes, in particular for the sharing of responsibilities. I remember him regretting the old way of setting up PPPs, where the private partner has to bear all the risks.”*
- *“He thought it was no longer possible in such an uncertain world, where the technologies change so fast. The private partner cannot be alone anymore.”*
- *“This Canadian project was truly an example for Engie”, noted Mrs. G. thoughtfully.*

- “Projects perform the group strategy; without projects the strategy is just a story. And they are also an opportunity to create expertise! Let’s see that before going onto the last project, a first sight of a possible future.”

### **... and participating in Engie’s expertise building**

In the Ottawa case study, both the public authority and the private partners were experimenting things that they had never done before. The public authority chose this opportunity to explore new ways of doing PPPs. For Engie, it was one of the first projects where the team could design a sustainable district heating system, and put its strategy into action. Engie saw this project as a huge opportunity for the group, and was a major actor in the co-creation processes with the Government of Canada. Through this project, they have developed their own internal expertise and started to perform a vision of sustainable district heating. Internal discussions showed a will to push in that direction and start instrumenting the project teams, building and spreading collective expertise. More than in the internal project teams, Engie’s valuations can have a global reach through their many projects worldwide and their lobbying role at the policy level. Projects such as Ottawa participated in the global instrumentation process (*Box 6*) set up by Engie to make its sustainable valuations perform.

#### **Box 6: A four-stage cyclic process in the framing and instrumenting of sustainable valuations**

Thanks to her data collection within Engie (see Chapter 3), Mrs. G. could make a first list of all the instruments being made inside Engie. She discussed this list with Anne during a one-hour meeting in November 2021. Anne gave her an overview of the different initiatives launched by Engie to instrument their sustainability ambitions, helping Mrs. G. to better understand the context in which instruments were created. After this meeting, Mrs. G. added to the list. She realized that there were 1) different types of instruments, some developed by Engie, some external and just used by Engie; and 2) interrelations between the instruments, some leading to the development of other instruments, some used to develop instruments, etc. I thus proposed to organize the instruments in a table, stating for each instrument who the stakeholders involved in its design were, which initiative it was part of, and what the aim of the instrument was (see *Table 27*).

Instrument	Description	Initiative / strategy	stakeholders	Expected outcome

Table 27 Structuring the data collection–attempt 1

When Mrs. G. tried to fill in the table with her data, something was wrong. Some important information was getting lost in the process, especially as different instruments were created around the same initiative but with different outcomes. We thus decided to restructure the table, starting from the global management dispositive that was to be designed and going down to the different instruments composing it. These management dispositives are set up to make the strategy perform, and consisted–among other things like narratives and objectives–of several instruments. *Table 28* gives an overview of the new structuration of data collection, with one example of a management dispositive.

Management dispositive	Description	Expected outcome	Stages of the process	Supporting instrument	Created instruments	Stakeholders	Expected outcome of each stage
KPI emissions reporting	Reporting of BUs' direct emissions based on the GHG protocol	Reporting	Indicator design	GHG protocol			Building internal expertise / framing the scope of the reporting
			Communication on the indicators		Internal guidelines		Building the actors' capabilities
			Implementation of the			CSR officer of the GBU	Reporting

			indicators in the GBU				
			Aggregation of the reported indicators and communication		Integrated report	CSR department	Reporting, assessing, and communicating
			Building complementary expertise		Database of emission factors	R&I department	Building internal expertise

Table 188 Structuring the data collection

The first three columns are about the management dispositive as a whole. The setting up process (from design to use) for the management dispositive is separated over several lines. Each line corresponds to the integration of a new element: a newly designed or used instrument, or a new stakeholder now involved. For each stage of this process, the external tool used, internal tools developed, and involved stakeholders are stated, as well as the expected outcome of the stage.

Unfortunately, due to the data available, not all the lines could be entirely filled. Moreover, many instruments were designed at decentralized levels to answer a specific project concern and could not be included in the study as 1) accessing them is difficult, 2) they are not part of any global management dispositive. Similarly, research teams sometimes play ahead of the game, designing tools to quantify upcoming concerns that are not yet part of the strategic focus. Some mapping of all available instruments is attempted by project teams before creating new instruments, in order to integrate them into the design.

“This data collection was tricky”, recalled Mrs. G. “There was a lot of information, but still many missing pieces.”

- “Yes, we had to have many discussions to find the right way to structure the data to be able to analyze them.”
- “But what did you do with the missing pieces?”
- “They are part of the analysis, don’t worry!”

With this table filled, I tried to see if a pattern emerged out of the instrumenting process. I found out that Engie’s instrumenting and expertise building was based on a four-step process.

Along with the framing of its strategy, Engie has worked on its instrumentation to make it perform. This instrumentation was made through the setting up of several management dispositives. This setting-up process can be divided into four steps: framing; translating; implementing; assessing and communicating (Figure 31).

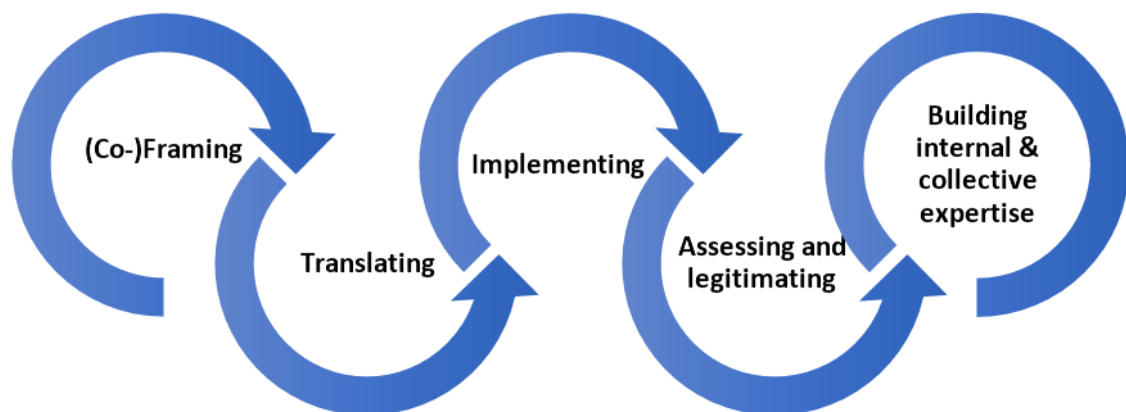


Figure 31 A four-step process to build collective expertise

Depending on the global maturity level of Engie’s objectives, the management dispositive can be based on available instruments or requires the development of innovative ones. In the first case, the group needs to find the right external instrument—with enough legitimacy—to fulfill the strategic objective. In the second case, the group will develop or co-develop instruments (like indicators) to perform and assess its objectives. To do so, it can build on existing internal good practices and external initiatives. For instance, the client decarbonization guidelines were developed with other companies. Similarly, Engie



is part of several global initiatives where instruments are designed and experimented. Through this choice, it frames the scope of its objective and the means to reach it.

Then, it translates this instrument into internal knowledge by e.g., writing down guidelines, setting up training programs, communicating on the new instrument and finding the right management department.

After, it can start implementing the instrument down to the operational level. During this stage, the group sets up a specific organization, with representatives in the different units ensuring the right implementation of the instrument. These representatives will also be responsible for reporting back to the department level.

Finally, in the last step the group assesses and communicates around the outcome of the management dispositive. This communication can be both internal—to set up new objectives, monitor achievement of the strategy—and external, to account for the group's ambitions and activities. If the instruments used are not widely recognized, communicating does not only aim at legitimating Engie's strategy and action. There is also a stake in legitimating the instruments designed and in making them part of collective sectoral expertise. Without a globally acknowledged method, the reporting made by Engie would not have any legitimacy and recognition. Also, some changes in regulations may lead to the mandatory use of some instruments. To avoid having to change all its processes, Engie works on the recognition of its own instruments as sound ones to be expanded, or at least as compatible with upcoming regulations.

Two practices are worth mentioning in this case. This four-step process is not necessarily supported by existing entities, but new entities can be created for it. For instance, in 2019, Engie Impact was created to work on client decarbonization. Their objective was to support the clients in their decarbonization, but they first set up some guidelines and accounting processes for this decarbonization. This creation participates in the structuration of internal expertise. To complement these four steps, some complementary instruments can be designed internally, to support the operational teams in the implementation of the process e.g., database, simplified calculation and reporting tools. Usually, these instruments will be based on external tools like indicators. A framing process will be set up to decide on which indicator to be used. For emission factors, several external databases exist, and Engie has created its own based on what they have

framed as the most relevant figures for their activities. Also, the research departments may be asked to participate in external initiatives and develop internal instruments on sustainability dimensions that were not previously valued inside the company. This internal knowledge may then be re-integrated in the setting up of a management dispositive once these dimensions are deemed strategic. Similarly, some local instruments may be developed to answer specific concerns at an entity or even project level. They are not primarily part of any global management dispositive, only of local expertise. However, they can be integrated into a global management dispositive if they are taken up during the framing step of one. They will then participate into the global expertise building inside the company.

In both cases, the process participated in building Engie's internal expertise: setting up of new reporting processes, development of competencies, creation of entities, etc. When Engie developed new instruments, the external legitimation and building of collective global expertise became an essential challenge.

*"Interesting how you have analyzed the data to come up with these four-step processes",* said Mrs. G. appreciatively.

- *"Thanks! And you see, it also accounts for the "orphan" instruments."*
- *"Yes, it is because some are not yet part of a management dispositive, but they may be integrated later on. Global actors can really shape the global and national valuations, we almost go back to chapter four here. Through the making of instruments, they stabilize their valuations of sustainable infrastructure and it will influence not only the projects, but also the regulations if they have good lobbyists."*
- *"And also, these instruments can be developed through co-creation processes, at the local or global levels! In short, the national valuations are partly co-created with and by global actors, because these actors participate in the design of the instruments. And then these instruments influence the national valuations..."*
- *"All of this participates in the making of collective expertise around sustainable infrastructure."*
- *"Yes and no. It is hard for the local valuations and co-creation processes to become global if they are not supported by a global actor, or by some kind of platform. Otherwise, what was local may remain local."*
- *"Yes, scaling-up is really an issue for valuation and co-creation processes. Global actors are just the start of an answer. The processes you have analyzed do not necessarily give much place to local initiatives."*
- *"Giving place is one step, legitimating the initiatives so that they participate in collective expertise building is another."*

In the Ottawa case, Engie participated in a co-creation process to build new instruments and indicators, leading to an unusual PPP contract. This experience was used to build up internal expertise, having people from different teams participating in the project and then spreading the expertise within the Engie Group. At the more global level, it also influenced the global expertise-building process, with experts working on how the process set-up for Ottawa and its resulting instrumentation could be translated into new Group practices.

## AnergieUrban Lighthouse—an experimentation in Vienna

Mrs. G.'s investigation in Vienna was quite sporadic. She discovered the project thanks to Gregor, chair of the "Geothermal DHC" COST-Action network. He was involved in a research project with the city of Vienna and other partners. She started investigating the project in parallel with her other activities within the COST-Action group. I will now narrate Mrs. G.'s investigation into the project, stating the data collected while describing the project.

*The global context was quite clear: Austria's ambition is to decarbonize the heating and cooling sector by 2040, which is for now heavily dependent on gas. The aim of the project studied is to demonstrate how fifth-generation district heating implemented in urban areas could complement conventional district heating systems. Through the COST-Action network, Mrs. G. had an easy access to Gregor, who introduced her to Gerhard, deeply committed to and involved in the project. He gave her a short presentation of the project, known under the sweet name of "AnergieUrban Leuchttürme". AnergieUrban is the follow-up of the pioneer demonstration project "Smart Block Geblergasse". During this first project, several partners—including the city of Vienna, expert groups, and universities—worked together to set up a shallow geothermal network in a retrofitted Viennese building block. The result was quite impressive on the presentation pictures... The geothermal system is entirely underground and does not take up any place on the surface (see Picture 11).*

## Smart block Geblergasse – a true pioneer project, which needs to be upscaled



Operating drilling rigs in the inner yard of the building, source: ÖGUT

**Left:** during the construction

**Right:** after the renovation



Inner yard after accomplishment of drillings,  
Source: © Lisi Zeininger

Picture 12 Screenshot of the Viennese demonstration project's presentation

Gerhard explained that based on this implementation, several studies were completed to prove the technical feasibility of connecting several such systems. Gregor and Gerhard then came to the core ambition of the second part of the project: to push this idea of connecting several blocks into real life. To do so, the project will identify the right stakeholders and business model; but also work on the incentives to support the introduction of fifth-generation district heating networks. One last ambition is to find ways of connecting conventional networks with fifth-generation ones. This matters particularly to Gregor, who real promise in the interactions between networks. Mrs. G. found the project very interesting, but did not really know how to tackle it: it was not a demonstration one, and the German language was a large barrier. Also, she did not quite understand how the different partners were working together. Fortunately, Gregor and Gerhard were helpful. She made a list of questions that they discussed together and forwarded to several stakeholders (see Annex 6). In the end, she managed to speak with the district heating operator, and received written answers from the architect company.

*She was interested to see that the version of events changed quite a lot from one stakeholder to the other...*

*The district heating operator had a very business-oriented vision: all that could help him sell more systems was interesting. Mrs. G. was shocked to see how little he was interested in establishing partnerships or trying to reach the consumers. However, the interviewee recognized the advantages of making connections with the existing district heating networks “to create win-win situations even if it is competition”. Despite Mrs. G.’s questions, he had not really thought these partnerships through thoroughly, nor did he imagine using them for the near future. Similarly, he saw his role as a private energy supplier to bear all the risks and the investments and foresaw no alternative except public financing for green innovations. On the contrary, the architect seemed more enthusiastic about the opportunities offered by fifth-generation district heating and cooling and exploring them through research projects: “This needs new instruments of information and communication to learn about the benefit of CO2 neutral energy harvesting and how to finance and handle the costs for the tenants. We explored this in a multi professional science team.” More than the technical part, he saw the challenge to “convince partners [...] developing the project”.*

For her focused investigation on this experimentation, Mrs. G. used several types of data, e.g., informal discussions with the COST-Action members, a project presentation, semi-directive interviews (Table 29).

Type of data	Description
Informal discussions with COST-Action members working on the project	Short presentation, co-design of the grid of questions, debriefing on the interviews
Slides of the project description “AnergieUrban Leuchttürme”	Short description of the project (context, first phase and its results, objectives)
Oral presentation of the project (video call) from 2 researchers working on the project (March 2021)	Presentation of the project based on the slides previously sent

Semi-directive interview with the district heating operator of the project and a researcher from the project (09-13-2021)	Focused on the organization (e.g., sharing of risks, pricing, planning, performance indicators)
Written questions on the project by the architect (09-25-2021)	Same grid of questions on the project organization

Table 29 Data collected for the Vienna case study

*Annex 6* contains the grid of questions used for the interviews. Mrs. G. took notes during the presentation and the interview with the district heating operator. For the second interview, no time slot could be found with the interviewee—who did not speak fluent English anyway—so the grid of questions was sent to the interviewee and he wrote down than returned his detailed answers to each question. Just like Greater Copenhagen, the limited amount of time and access to the stakeholders drove Mrs. G. to only study specific aspects. The interview guide focused on two aspects: “contractual and financial aspects” and “governance and local engagement”, which were a main point of interest of Mrs. G in order to understand the instrumentation of collaboration—an innovation proposed by the project. At the end, an open question tackled the future direction and governance of the project.

### *Dreaming up new collaborative settings*

In this project, the actors have begun dreaming about new roles, but their common acceptance is not yet assured. One ambitious objective of the project is to find synergies between conventional district heating (understood here as a centralized high temperature network) and fifth-generation district heating. To do so, the project partners highlight a need to co-create new partnerships, with a new sharing of risks and investments, but also new planning and new roles for the different actors. They identify the contract as an instrument to stabilize these new settings and frame these roles. In such projects, co-creation is an objective valued by the project leaders, but that still needs to be performed through a contractual process.

However, Mrs. G.’s interviews show that the interests of the different actors have not converged yet, and that no common vision of the future is sketched out even by the project partners, let alone other stakeholders from district heating.

*“Instrumentation would not only be a way to stabilize co-creation, but also to perform it here”, summarized Mrs. G. “It may even be an answer to some of the challenges from the Copenhagen or Ottawa cases.”*

- *“For Copenhagen, the challenge was to find a resilient form of co-creation facing the sustainability challenge. The role distributions shaped by this Viennese project may be a track to follow. For Ottawa, going for an interacting mix of conventional and latest-generation district heating could be a solution for reaching their decarbonization objectives. They may find a way to co-create this solution before Vienna!”*
- *“And maybe it will become the new ‘conventional’. It would be a very different way of organizing the network of stakeholders, and a very different way of interacting...”*



## **In a nutshell: Making new valuations through the instrumentation**

In the previous chapter I showed that co-creation practices were integrated—to various extents—into district heating projects. Co-creation itself was becoming a valued dimension of sustainable district heating. However, co-creation processes remained limited and based on interpersonal relationships. To overcome these barriers, actors are attempting to instrument (explicitly or not) co-creation. In this chapter, I analyzed four cases where co-creation practices were instrumented to answer the following question: *How is co-creation instrumented in district heating projects and how is this instrumentation impacting the framing of sustainable district heating valuations?*

### ***Four cases of co-creation instrumentation***

In the four cases investigated, instrumentation is a way of performing and stabilizing co-creation processes. In all the cases, actors tried to adapt or build instruments to mediate their relationships and stabilize their partnerships. One main instrument that stood out in all the projects as a pillar to stabilize co-creation processes is the contractual process. It is an arena where different actors frame their partnership, set up structuring processes (such as reporting) and co-create valuations implemented through indicators and objectives.

However, this instrument is integrated in current instruments (like public market law, or other regulations) which may limit the extent of co-creation to only dominant actors, and focus the process on specific values (e.g., technical and economic ones). More globally, the instrumentation created is embedded in existing expertise that may support (as in the case of Greater Copenhagen), or hinder (as in the case of wood-energy in Bourgogne Franche-Comté) the co-creation processes.

When looking at the type of instruments created, the first step in the wood-energy and Ottawa cases was to co-create indicators and technical calculation tools. It was the basis for a common language. Both these cases also took a step further, designing or adapting management tools (especially contracts) to secure the partnership. However, this second step was not entirely adapted to co-creation practices as it remained embedded in pre-existing frames and instruments. Thus, the co-creation process could lack resilience to future turbulence. On the contrary, the instrumentation securing collaboration in the

Greater Copenhagen case is much more holistic, as both policy instruments and management instruments were designed to support collaboration. Nonetheless, they were all created in a specific context and perform specific frames of collaboration, which can question their resilience to major reframing processes. Finally, the Viennese case did not succeed in co-creating instruments to stabilize its collaborative project. The possibilities of replicating the project, and even to operate it in the long-term thus appear compromised. *Table 30* summarizes the type of instrumentation co-created in each of the four cases studied in this chapter, along with their effects.

	<b>Wood-energy sector in Bourgogne Franche-Comté</b>	<b>Greater Copenhagen</b>	<b>Ottawa</b>	<b>AnergieUrban Lighthouse in Vienna</b>
<b>Types of instruments co-created</b>	Calculation tools and holistic management tools	Policy instruments, management tools and calculation tools	Calculation tools and management tools	None so far
<b>Effects on the co-creation process</b>	Partial securing of the collaborative network governance	Strong resilience of the co-creation process	Securing of a partial co-creation process (integrating few actors)	Questionable future of the project

*Table 190 Instrumentation in the four cases studied*

Entering the instrumentation process also requires a lot of effort. The Ottawa project explicitly underlined the huge resources needed to design and perform the bidding process. Similarly, the Viennese case showed that entering an instrumentation process required co-creation activities to have already been set up, like designing an interest that is common to a network of stakeholders. The existence of a global culture and expertise on collaboration, like in Denmark, can facilitate the setting up of such processes.

### *Instrumenting co-creation and its impact on valuations*

By instrumenting co-creation, the actors also collaboratively instrument their valuations. Reciprocally, the co-creation is valued through the instruments. One major arena framing these processes is the contractual process (from the bidding process to the operation of the contract). This management dispositive relies on, and is embedded in, a multiplicity of instruments from indicators to regulations. In all the cases studied, the instrumentation process is undergone through existing frames (except the case of Greater Copenhagen, where co-creation appeared to be part of the frame from the beginning): it is more about integrating new concerns into the frame than about finding a completely new, stable frame. Building on the available expertise, and on the knowledge under construction, the actors collaboratively integrate new valuations into existing instruments. They also co-design the valuations for the specific project, for instance by creating criteria or indicators to be evaluated during the project. With this process they create and perform their local valuation of sustainable district heating. More than technical or environmental criteria, the contractual process is also the opportunity for the actors to value co-creation and decide on the collaborative management of the infrastructure: How can they share the risks, responsibilities, and manage the uncertainty? The increasing use of long-term contracts is also a way to instrument the value given to stable partnerships. The actors construct the rules for the partnerships, designing complementary instruments to be integrated into the management dispositive. Finally, this instrumentation also impacts the expertise network, giving new roles to the partners compared with conventional settings with limited co-creation practices.

*“Instrumenting really makes a link between co-creation and valuation processes!” exclaimed Mrs. G., delighted. “It shows how interlinked these processes are. I mean, valuating for a project is always co-creating as you need to have some kind of consensus around the valuations, don’t you think?”*

- *“An actor can impose his valuation. With the sustainability challenge, the process seems to be becoming more open, more co-created. But what I found missing is always the final consumer... They are more and more seen as a challenge by the district heating stakeholders, but are still not integrated in any co-creation or valuation process...”*
- *“They are still outside the frame. Even if for sustainable district heating the notion of prosumers make them more central to the network, they are for now*

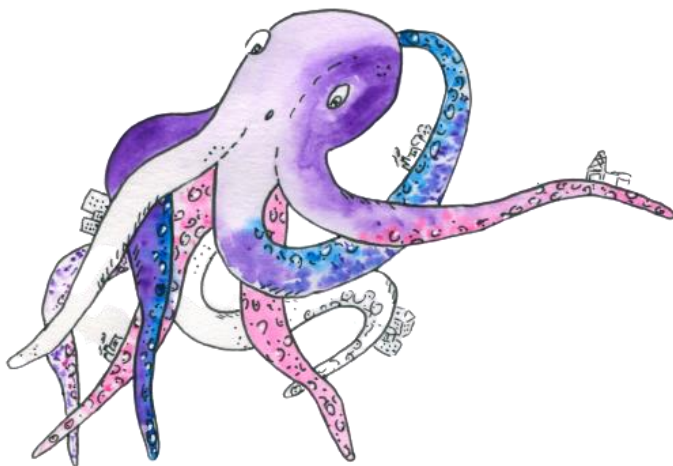
*still outside it. In the regulations, the district heating network stops before them. They are imagined to be “final users” and there is no direct link to them.”*

- *“Yes, they are not even the “client” or “consumer” seen at the scale of district heating operators. They only interact with the building owners. Except in Denmark, these final consumers are a blind spot.”*
- *“It is funny, because when you look at co-creation in the conception literature, it is about integrating the consumer or final user into the very conception of the product or service.”*
- *“Even in public sector co-creation, Mrs. G., many scholars are interested in the role of citizens, and the links between co-creation and democracy.”*
- *“But for now, I guess that these citizens are represented through the building owners or the public authority in the district heating world... Maybe consumer associations sometimes, but I have not heard about them that much. I guess there are still some parts of this huge octopus that remain to be investigated.”*





**Conclusion – Valuation and co-creation processes for sustainable infrastructures**





Coming to a conclusion in a PhD manuscript is no easy task. In this last part, I will first summarize the investigation, then I will highlight the contributions of this manuscript and discuss them, and finally I will suggest some possible research avenues to move the subject forward.

## Wrapping up the investigation

This PhD was anchored in a comprehensive approach, with a pragmatic investigation process. The main research question was constructed during the investigation process, through iterative back-and-forth between the empirical field and the academic literature. To account for this process, I introduced Mrs. G., a character embodying my detective self, working in the field and employed by Engie during her PhD.

This investigation process, materialized in the manuscript's structure, allowed me to tackle a complex object of study: sustainable infrastructures.

In the past decades, a push towards sustainability has been witnessed in many sectors. Infrastructures are part of this dynamic, but they come with many challenges. They usually gather multiple actors (public, private and other actors) in the long term. The infrastructures are materialized by and embedded in multiple institutions, networks, and other infrastructures. Thus, defining a sustainable infrastructure is not easy and requires multiple actors agreeing on a valuation of sustainability. This PhD investigated *How are actors co-creating sustainable valuations for infrastructure projects?* through the example of district heating. To tackle this research problem, I have used a framework of analysis composed of three mediating activities: framing, instrumenting, and building expertise. The main research problem was thus divided into two research questions: 1) *How do actors frame and instrument sustainable valuations?* and 2) *How do actors frame and instrument co-creation for sustainable infrastructures?*



I have investigated these research questions through three embedded streams:

- 1) The framing and instrumentation of national valuations of sustainable infrastructures;
- 2) The framing of co-creation at the project level;
- 3) The instrumentation of co-creation and sustainable valuations from the local to global levels.

The manuscript was divided into two parts, the first one explaining the backbone of the investigation—context, theoretical framework, research questions and method—and the second one following the investigation, from data collection to its analysis bearing in mind three empirical questions (*Table 31*).

<b>Problematic</b>	<b>How are actors co-creating sustainable valuations for infrastructure projects?</b>	
Research questions  Research level	How do actors frame and instrument sustainable valuations?	How do actors frame and instrument co-creation for sustainable infrastructures
Global	<i>How is the frame of sustainable district heating constructed through instruments at the national level and translated at the more local levels?</i>	
Local		<i>How are co-creation practices framed in projects?</i>
Local	<i>How is co-creation instrumented in district heating projects and how is this instrumentation impacting the framing of sustainable district heating valuations?</i>	

*Table 20 Empirical questions and their link to the research questions*

The example of district heating highlighted that the challenge is not to find a global value or even some generic valuation methods for sustainable infrastructures, but to gain expertise on the co-framing and co-instrumentation of these valuations so that they can be performed and adapted to local situations.

In France and Denmark, district heating has experienced various phases of national valuations, the latest one being district heating as a vector for sustainable heat. This phase has different characteristics in the two countries: a transition from one heat production method to the other in Denmark; and an aggregation of various heat production methods in France. The French national frame and instrumentation of sustainable valuations are strongly related to international ones and other national instrumentations. It focuses on decarbonization with the introduction of renewable energies and heat recovery, incentivized through various market instruments. However, I have shown that this frame is not stable and continues to be reshaped, particularly through local alternative framing processes.

At the local level, sustainable infrastructures are implemented through negotiation processes between several stakeholders. While they engage in co-creation processes, they mostly value co-creation at the early stages to set up trustworthy relationships between some dominant actors. However, I have uncovered some attempts to instrument co-creation in all cases. One major way of instrumenting co-creation was by integrating it into existing contractual processes. Through this process, the actors both value co-creation as a useful approach to sustainable infrastructures, and co-create sustainable valuations. These processes can then come and feed global actors in their instrumentation of sustainable valuations. Engie engages in a four-step process to instrument its purpose and builds on external and internal local expertise to instrument global group expertise on sustainable infrastructures.

## Highlighting and discussing the contributions

Through the investigation, I have contributed both to the empirical knowledge on sustainable infrastructures and to the theoretical discussions of valuation studies and public sector co-creation literature. *Table 32* summarizes the main theoretical and empirical contributions of each chapter, and I will discuss each one of them in this section.

	<b>Theoretical contribution</b>	<b>Empirical contribution</b>
<b>Chapter 2</b>	Bridging the study of valuation and co-creation for sustainable infrastructures.	
<b>Chapter 3</b>	Proposing an analysis framework for valuation and co-creation processes based on framing, instrumenting, and building expertise.	
<b>Chapter 4</b>	Valuations are embodied by instruments but can only perform thanks to collective expertise. They are constantly being challenged and reshaped.	Analysis of the public policies around sustainable district heating and the gaps in its expertise.
<b>Chapter 5</b>	Assessment framework to analyze the characteristics of public sector co-creation in infrastructure projects.	Keys to design instruments supporting co-creation processes for the implementation of
<b>Chapter 6</b>	Existing instrumentation is an arena of co-creation.	sustainable infrastructures.

*Table 32 Summary of the PhD's theoretical and empirical contributions*

### *Theoretical contributions*

First, one major contribution of this PhD is to study valuation and co-creation processes through the lens of three mediating activities: framing, instrumenting and building expertise. Through various examples, I have demonstrated that these three mediating activities are cornerstones of both processes, and that only their interrelations can produce balanced and resilient processes. For instance, the lack of collective expertise building highlighted in chapter 4 on French national district heating and in chapter 6 on the wood-energy sector in Bourgogne Franche-Comté resulted in partial successes. The frames and instruments created could not perform all their expected effects—e.g., in France some policy instruments pushed for the integration of more electrical heating at the expense of district heating despite the policy instruments in favor of district heating—and the durability of the sustainable solutions set up could be questioned—e.g., in Bourgogne Franche-Comté, some external crises threatened the development of wood-energy and the stability of collaborations. Similarly, in local experimentations such as Hornsyld and Vienna, teams had not succeeded in instrumenting their frames, thus threatening the future of the co-creation processes set up and the co-created valuations. On the other hand, historical district heating systems such as Dunkirk or Copenhagen, have had a more holistic approach, with local expertise, instrumentation, and frames supporting local valuations and co-creation processes. However, as energy systems are facing more and more crises, the resilience of the frames co-created—and the linked instrumentation and expertise—can be questioned. A last example of a holistic approach under development is in Ottawa, where a focus has been put from the beginning on creating local expertise—with, for example, the setting up of reporting processes, stable instruments, and expert entities with cross-cutting capabilities—and not only local frames and instruments, even though the co-creation process remained limited to a small number of stakeholders. While some scholars of valuation studies have already linked valuation to instrumentation, expertise, and frames (Muniesa, 2011; Doganova et al., 2014; Boholm and Corvellec, 2016), public sector co-creation literature has for now approached these activities only from very specific angles, such as leadership or roles (Torfing et al. 2019; van Gestel et al., 2019). Moreover, even in the literature on valuation

studies, the three mediating activities have not been explicitly analyzed in their interaction as adding to the valuation processes.

Second, I highlighted in this PhD the strong interrelation between valuation and co-creation for sustainable public infrastructure. In such projects, both processes are used together by the actors to define and create sustainable values out of local resources. To do so, they need to co-create a collective frame of sustainability, and the right instrumentation and expertise to make it perform. Through co-creation and valuation processes—based on the three mediating activities—actors can engage in local collective action and perform the sustainability of infrastructures. I have shown that co-creation processes can lead to the design of new valuations, like in Ottawa where carbon emissions and esthetical criteria became valued though co-created indicators, and that reciprocally co-creation becomes a valued process in the implementation of sustainable infrastructures, which is what also happened in Ottawa, where engaged actors claimed to have succeeded in co-creating a new type of partnership for sustainable district heating. Public sector co-creation and valuation studies literature has up to now remained in separate communities, though some links could already be spotted in this literature: scholars of valuation studies highlighted the collective aspect of valuation processes (Kjellberg et al., 2013), while public sector co-creation is defined through the creation of collective public value (Torfing et al., 2019). I argue that linking both processes through the three mediating activities can bring out both theoretical and empirical contributions. For instance, the instrumentation of co-creation through contracts—to frame and secure long-term partnerships—gives a frame for the valuation processes to be collectively set up. Contracts become an arena where values are instrumented through co-created indicators. This instrumentation can also become a basis for building collective local expertise that can grow into global expertise if the instrument is replicated.

Finally, when it comes to each process, I have various results based on the analysis framework that add to each process's literature. For valuation studies, I have analyzed the process of valuing sustainability for infrastructures, which is an underdiscussed object of study (Kjellberg et al., 2013). I have highlighted that the valuation process is strongly embedded in existing frames but also that, just like framing, it is constantly challenged

and readapted (Callon, 1998). I have shown that valuations become stable and visible when they are integrated into instrumentation, but that this instrumentation—like any instrument, e.g., a management dispositive—cannot perform without the building of collective expertise (Aggeri, 2017). For public sector co-creation, I have characterized co-creation processes for public infrastructures, contributing to the literature operationalizing the concept of co-creation for research design (Sørensen and Torfing, 2020; Sillak et al., 2021). This analysis allowed me to add to the understanding of co-creation processes and how public infrastructures may become an arena for co-creation (Torfing et al., 2019). I have highlighted the challenges of co-creation in a constrained environment like that of infrastructures, regulated by multiple rules and institutions. Due to this historical expertise, co-creation expertise develops within the current context: most co-creation processes rely on informal activities and are then integrated into instruments that have already been set up. The contractual process plays a big part both in the instrumentation of co-creation and the design of alternative valuations.

Coming back to the research questions and main research problem, the purpose of this investigation was to understand *How are actors co-creating sustainable valuations for infrastructure projects?* To do so, I investigated two sub-questions: 1) *How do actors frame and instrument sustainable valuations?* and 2) *How do actors frame and instrument co-creation for sustainable infrastructures?*

For the first research question, I have shown that sustainable valuations are dependent on the expertise available. For sustainable infrastructures, the dominant frame is a technical-economic one, which still influences what is valued and the design of instruments stabilizing these valuations. However, local actors gathered around a project also co-create alternative valuations which they integrate into existing instrumentation like contractual processes. Global actors involved both at the local and national levels can build up expertise based on this renewed instrumentation, and by doing so, challenge the dominant frame and its valuations.

Concerning co-creation, the assessment framework I have used revealed that actors do indeed engage in co-creation practices, even in constrained environments like Public-Private Partnerships. Despite valuing e.g., trusted relationships, collective problem-solving and the creation of a collaborative network, they do not explicitly and consciously

relate to co-creation activities. Thus, co-creation framing is usually limited to the setting up of a collaborative network. Nonetheless, I have spotted attempts to stabilize collaborative practices by integrating them into current instruments like the contractual process.

All in all, instrumentation appears to be an arena where actors co-create valuations and value co-creation for sustainable infrastructures. The existing instrumentation is embedded in historical frames and stabilized expertise. By integrating new processes into the instrumentation, actors challenge the frames and participate in the building of alternative expertise. They make the sustainable infrastructure perform. I argue that to co-create sustainable valuation for infrastructure projects, the actors engage in a reframing process. They collectively re-adapt the instrumentation and build locally-anchored expertise to make it perform. This local-anchored expertise may become global by being supported by global actors.

### *Empirical contributions*

On the empirical side, I can outline several contributions. All of them relate to Engie's activities: the operation of projects, national and international lobbying activities and the internal strategic organization.

For project actors, I have shown the importance of co-creation in setting up sustainable infrastructures, offered an analysis framework for co-creation, and shed light on some of its instrumenting processes. In particular, I have shown that contracts and the way they are set up are arenas of co-creation, where innovative valuations can be negotiated and stabilized. This work can be used to rethink contractual processes, purposefully integrating all three co-creation activities (setting up a collaborative network, defining a collaborative governance, and assessing and learning from project outcomes) and this throughout the lifespan of infrastructures. Also, using co-creation as a method throughout a project may facilitate innovation in sustainable infrastructures. The three co-creation activities cover aspects of framing, instrumenting, and building expertise, ensuring a resilient innovation process.

For policy-makers and French national actors of district heating, I have analyzed some gaps in the expertise around district heating that could be helpful when updating policy instruments. One major gap is the invisibility of district heating as a policy object, leading to the design of conflicting instruments. I have also pointed out the emergence of alternative frames at the local level that could usefully be integrated into the national agenda and participate in the co-design of national instruments supporting sustainable district heating.

Finally, for Engie specifically, I have emphasized the local anchorage of sustainable infrastructures and their related processes. I have shown that the challenge lies not in creating global instrumentation on sustainable infrastructures, but more in creating collective expertise with external stakeholders. The group already has some processes in place to build up global expertise, but they are mostly focused on decarbonization and are anchored in a technical vision of sustainability. The PhD work can be used to design methods facilitating co-creation and collective valuations at the project level: instead of arriving with internal indicators, Engie could design instruments supporting co-creation and local valuations processes, such as collaborative methods to integrate local valuation into contracts. These could be, for example, project design workshops with final users or municipalities for the purpose of innovating. Through the same process used to build its technical expertise on sustainability, Engie could build global expertise on co-creation and local valuation processes. I have already started to work on a co-creation proposition for Engie projects, which could become a stabilized instrumentation for future projects, to be used from the project identification phase to its operation. To develop and spread this global expertise, Engie would need to rethink its own frame of sustainability and energy transition. Instead of focusing only on decarbonization, the group could strengthen its relation with stakeholders to innovate at the project level. Local valuations would become the basis and core of the project, not some peripheral concerns to be integrated at the margin. The group would also have to anchor even more research and innovation with operational units, so that local expertise can be developed more easily and grow into global expertise. Finally, the spectrum of skills needed to develop a sustainable infrastructure project should become even wider, ranging from technical, legal, and economic competencies to sociological and organizational knowledge, in order to engage



all the stakeholders, mediate the co-creation activities and build a collaborative governance of collective action.

## Research limitations

This research obviously has several limitations.

First, the validity of results when doing some comprehensive research is always questionable (Dumez, 2016): due to time, accessibility, and contextual reasons some actors could not be interviewed (e.g., partners of the Ottawa case study) and some controversy arenas (e.g., the process of answering a request for proposals) could not be analyzed directly. To address with these limitations, I used secondary sources to gain access to some other stakeholders and conducted interviews ex-post on specific arenas I could not witness.

Also, process studies require a huge amount of data that could not always be collected (Langley et al., 2013). For instance, the history of the Besançon and Dunkirk cases was only accessed through semi-directive interviews, but no archives could be found to complement these aspects. As the study focused on the valuation of sustainability—a more recent valuation—the lack of access to archives had a limited impact but impeded the long-term study of the shifts in valuations. They could only be accessed thanks to some interviewees' recollections. When it comes to co-creation processes, only a part of the actors participating in these processes when the project began could be interviewed giving only a partial view of it.

Another limitation comes from the data analysis, which was done only by me. I have tried to limit the biases by extracting myself from the field during the analysis and discussing the results. However, a double-coding process combined with a multi-researcher investigation would certainly have improved the impartiality of the results.

Second, as I focused during this PhD on district heating systems, it is legitimate to question the scalability and perimeter of the results. The contributions stemmed from empirical work and are thus partly dependent on the case studies chosen. The multiplicity of the case studies chosen and the theoretical hindsight gained partly address this issue, but some complementary comparative analysis could be conducted to better qualify the global results from the more local ones. However, district heating systems are public infrastructures and most of their characteristics (that could be spotted in all case studies)

are shared with other infrastructures (Star, 1999). Thus, the theoretical contributions could probably apply to most infrastructures, providing that they are operated in similar settings. Similar studies have been—and are currently—being conducted for other infrastructures. For instance, the instrumentation of new valuations for water management was studied by Beduneau-Wang (2017). He analyzed the changes in the performance indicators for water management contracts around Paris between 1853 and 2017.

The research design, and particularly the analysis framework, could provide useful insights in similar situations. Going even further than infrastructures, some similar challenges can be identified for several systems under pressure of grand challenges. The forestry sector, for instance, needs to work collaboratively to change forest management to adapt to climate change. Here again, similar concerns arise and the framework of analysis developed in this PhD could be relevant for conducting research on such subjects.

When it comes to the empirical results, they are more closely linked to the object of study, i.e., district heating, but some global lessons could nonetheless be applied to other sectors. For instance, the design of instruments supporting co-creation and local valuation processes could probably be translated to other types of projects gathering multiple stakeholders.

Finally, the theoretical framework chosen—namely valuation studies and public sector co-creation—was one possible angle for approaching sustainable infrastructures. I am aware that even within the world of values and collaboration many other literature streams could have been discussed and could have provided relevant results (e.g., public value co-creation, industrial ecology). The PhD is also a matter of personal choices, and the investigation process, the data collection, and its analysis led me towards these two literature streams at the expense of others.

## Research prospects

I want to point out two avenues of research that could continue the investigation started in this PhD.

First, studying valuation and public sector co-creation processes in infrastructure emphasizes the temporal aspect of such processes. Throughout a project's long lifespan, both processes may evolve. It could thus be interesting to conduct a longitudinal study of a project, to understand how both processes change with respect to objectives and means through the infrastructure's different stages. It also questions the durability of processes over time, and their resilience to turbulence (changes in organization, people, etc.). These questions were of great interest in the public sector co-creation community, especially when it comes to co-creation in a time crisis time: How do the co-creation practices set-up to answer a crisis evolve when the actors get out of the crisis situation?<sup>45</sup> I argue that the same concern can apply to co-creation around long-term projects like sustainable infrastructures.

Second, I have highlighted that sustainable infrastructures are for now performed at the local level. Even when valuation and co-creation processes are stabilized in suitable instrumentation, the latter is usually locally-anchored (for instance, adaptation is only possible thanks to specific resources available for the project, or due to regulatory exceptions). One challenge remains the replicability or scaling-up of such processes. How is it possible to move from locally-anchored expertise to global expertise? Pfothenauer et al. (2021) have analyzed how scaling has become valued as an end in innovation. I believe that innovating through co-creation challenges this imperative of scaling-up technical innovations but also questions the replicability of methods and the building of global expertise. I have outlined a first avenue when formalizing Engie's instrumentation process. Another lead to explore could be the role of platforms in the spreading of local expertise. This is a major challenge for sustainable infrastructures, and loops back to Engie's concern about business models. One characteristic of business models is their

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<sup>45</sup> These concerns were mentioned during both conferences I have attended in 2022 with the public sector co-creation community. Several presentations during these conferences studied the COVID-19 crisis and its impact on co-creation practices.

replicability from one project to the other, a replicability that valuation and co-creation processes for sustainable infrastructures still lack.

## Postface

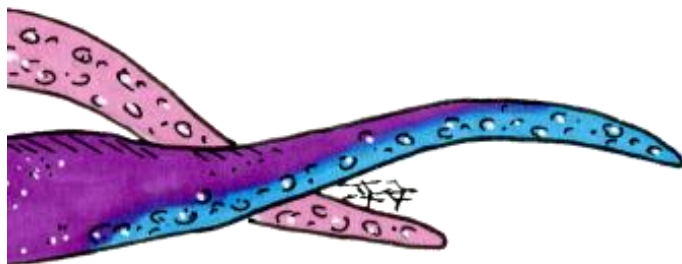
Hey! It is me again. Yes, postface is a bit like post-generic scenes in Marvel movies. You think it is over, but you have a little something left in the end. Although, to be completely honest, I should have put it after the References and the Annex if it was to be a true post-generic scene. But let's go down to business.

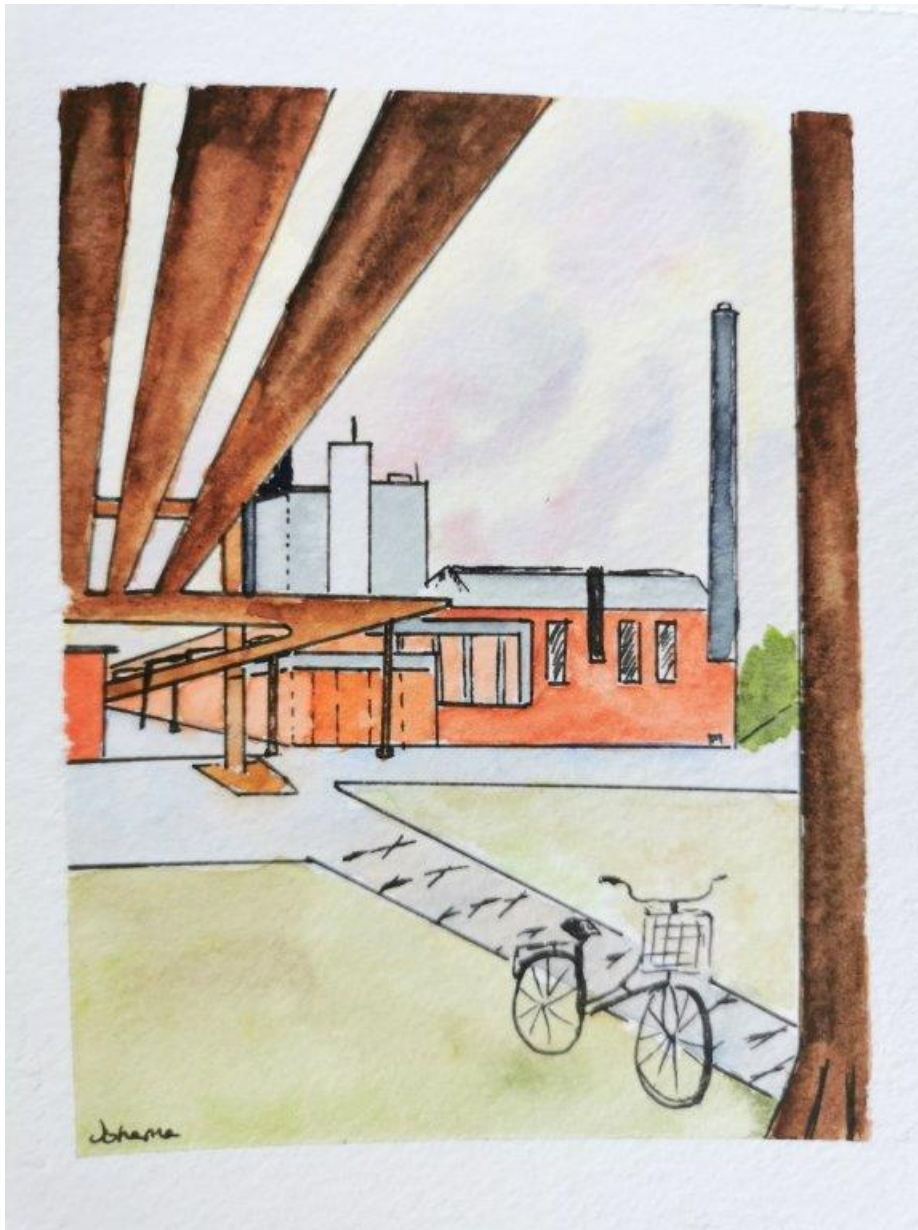
So, this is the end of the story. The end of the junior's detective first investigation, the end of her imaginary dialogs with Mrs. G. The end of my first investigation actually. Congratulations and thank you to those who have made it that far. Yes, even you who just flipped through the page, and you – smart pal – who just went straight for the postface. As you might have felt during your reading, the process was... a process. Intricate, full of doubts, full of discoveries. At times I felt really lost and just kept on following the flood, trusting the process, with the hope that I will land somewhere at some point. Still, it was a very nice experience, and I can't wait to meet again with Mrs. G. for new adventures. – If you still had doubts, Mrs. G. is me, and I am Mrs. G. But I am not schizophrenic – Maybe I will keep you posted with our next adventure...

In the meantime, thank you, goodbye, see you soon, stay safe, and stay curious!

*"It was great sharing this process with you", said Mrs. G. "We were going for the monster, but I think we found out way more on our way."*

- "Yes, I am not so sure we have succeeded in casting light on this complex, hiding and friendly monster. But I know for sure that we have learnt a lot on the way, and not only about district heating!"





*Pipes and boilers, the materiality of district heating systems (artist's view of the Ørsted CHP plant in Copenhagen, own creation)*

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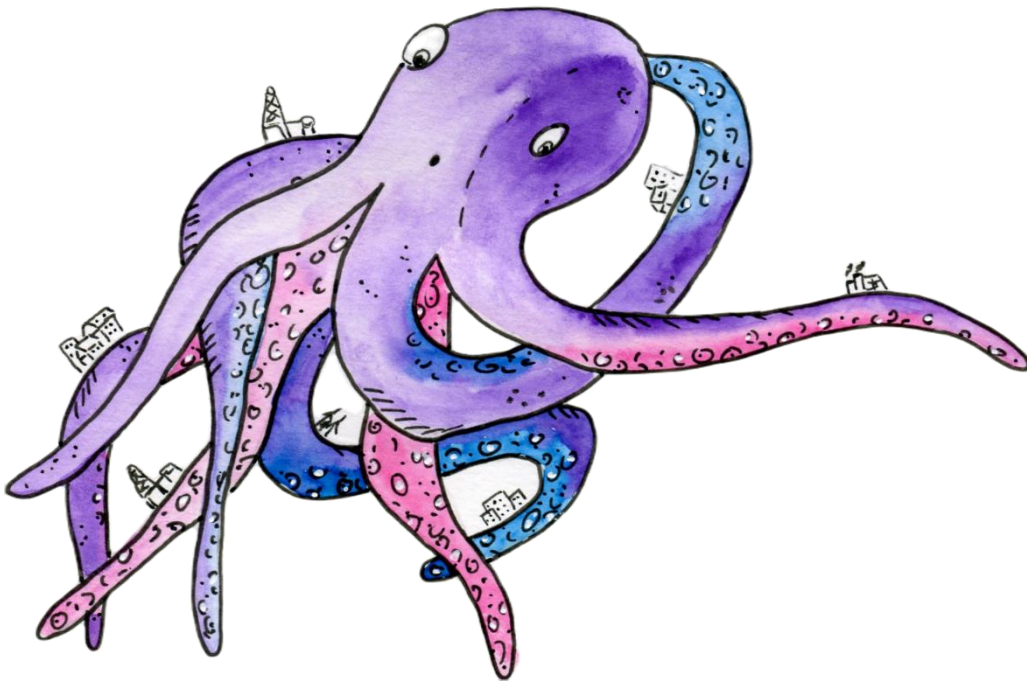
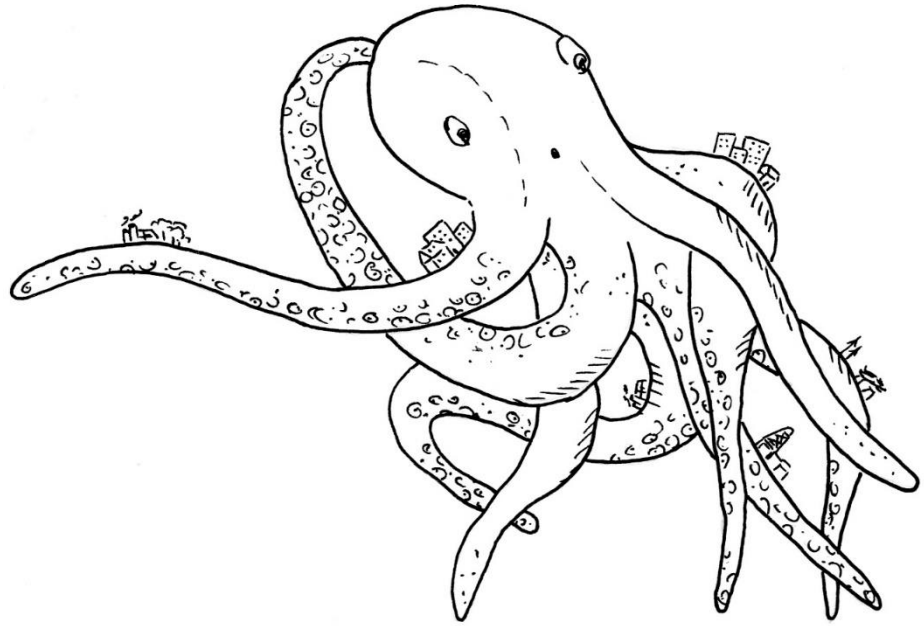
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## Annexes







## ANNEX 1: List of semi-directive interviews for case studies

### *Besançon & wood-energy in Bourgogne Franche-Comté*

Organization	Role of the interviewee	Date of the interview
ADEME–regional office	Renewable and waste energy mission	June 19 <sup>th</sup> , 2020
GBM–energy department	Management of the PSD contract	June 18 <sup>th</sup> , 2020
GBM–environmental department	In charge of the PCAET	June 22 <sup>nd</sup> , 2020
Celsius	Operation of the boilers	June 18 <sup>th</sup> , 2020
Celsius–management	Head of the DH operator	June 18 <sup>th</sup> , 2020
SOVEN	Purchasing agency for Celsius	July 2 <sup>nd</sup> , 2020
Albea	Cit’ergie auditor and advisor for Besançon	June 26 <sup>th</sup> , 2020
ONF-E–regional office	East agency supervisor	June 29 <sup>th</sup> , 2020
Fibois	Wood-energy supervisor	June 30 <sup>th</sup> , 2020
PEFC	Technical manager (France)–responsible of certification (Franche-Comté)	July 7 <sup>th</sup> , 2020

### *Dunkirk*

Organization	Role of the interviewee	Date of the interview
ADEME	Participated in the setting up of the Dunkirk DH	June 10 <sup>th</sup> , 2020
ADEME–regional office	Coordinator of the energy business center	May 29 <sup>th</sup> , 2020
Historical CUD	Former CUD energy director	June 9 <sup>th</sup> , 2020

CUD	Manager of the energy transition departments–energy networks project officer	May 28 <sup>th</sup> , 2020
Grande-Synthe municipality	Energy transition department manager	June 4 <sup>th</sup> , 2020
	Former city mayor	June 10 <sup>th</sup> , 2020
ArcelorMittal	Energy operation support	June 19 <sup>th</sup> , 2020
Engie	Responsible for the Grande-Synthe's DH operation	June 25 <sup>th</sup> , 2020
Cerema–regional office	Renewable and waste energy office on heating networks	June 3 <sup>rd</sup> , 2020
Intermezzo	Cit'ergie auditor and advisor	June 25 <sup>th</sup> , 2020

### *Hornslyd*

<b>Organization</b>	<b>Role of the interviewee</b>	<b>Date of the interview</b>
Hedensted waste water company	Responsible for the waste water management	September 30 <sup>th</sup> , 2021
NCC	Contractor–road construction	October 4 <sup>th</sup> , 2021
Hedensted municipality	Part of the Thermoroad core team	October 6 <sup>th</sup> , 2021
Land&Plan	Consultant for the Thermoroad project	October 9 <sup>th</sup> , 2021
Geodrilling	Responsible for the geothermal system	October 1 <sup>st</sup> , 2021

### *Greater Copenhagen*

<b>Organization</b>	<b>Role of the interviewee</b>	<b>Date of the interview</b>
CTR	Heat transmission company	October 6 <sup>th</sup> , 2021
VEKS	Heat transmission company	October 19 <sup>th</sup> , 2021
Hofor	Heat distribution company	October 19 <sup>th</sup> , 2021
Varmelast	Energy dispatch center	October 20 <sup>th</sup> , 2021



## **ANNEX 2: Grid of questions for the Danish heating market organizations**

Is the zoning between gas and DH still relevant? How is the integration of individual heat pumps in the market managed?

How is the energy plan made? What place for the regions?

Are there ongoing discussions to go for a heat market liberalization?

What is the final user's place in the heating systems?

What are the performance indicators monitored during district heating systems operations?

How is the socioeconomic calculation designed and used?

How are the contracts managed (for the supply side and also for the consumers)?

What is the future of district heating networks (use of biomass, electrification, geothermal energy)?



## ANNEX 3: Memo on the ADEME interview

### *Présentation du Fonds*

Créé en 2009 suite aux Grenelle de l'environnement (2007-2008). L'idée était de faire pour la chaleur renouvelable quelque chose de semblable aux aides pour l'électricité renouvelable. La différence c'est que **pour l'électricité il y avait un monopole d'EDF** qui permettait de fixer le tarif d'achat. Avec la chaleur c'est différent car il y a **plusieurs opérateurs**, personne ne s'engage (à plafonner ses prix) **donc on est obligé de revenir sur une aide sur investissement**. Avant ce fonds il y avait déjà un peu d'aide sur le bois-énergie (entre 1995 et 2010) mais rien sur les autres filières. **Ce fonds a connu croissance forte et assez rapide : environ 20M € en 2007-2008 et on passe à 180M € en 2009 (tout devait être dépensé en un an)**. Un certain nombre de projets a été sorti des cartons : l'équipe a pu recontacter collectivités et industriels. Au sein du Fonds Chaleur, il y a un programme, le **BCIAT (Biomasse Énergie et Entreprises)**, (sous forme d'un appel à projets annuel) qui vise à soutenir fortement les industriels (dont parfois Engie) recourant à la biomasse. Le but est de booster la filière bois énergie. Ce fonds s'adresse aux gros projets, au-dessus de 1000tep.

#### → Un contexte initial particulièrement favorable...qui a changé

Si le fonds a pu démarrer aussi vite et aussi fort, il faut bien comprendre que c'est dans contexte qui était assez favorable à l'époque : **on pronostiquait le doublement du prix du baril à court terme (60\$ → 120\$), mais ça a été désavoué à partir de 2013-2014** ce qui a mis le doute dans la tête des penseurs de projets. **La compétitivité de ces nouveaux systèmes a été remise en question par cette diminution inattendue du prix des énergies fossiles (mauvaises prévisions qui font aussi douter sur les modèles)**.

#### → Le parti pris français : financer les réseaux pour soutenir la chaleur renouvelable

Les réseaux de chaleur relèvent d'une question assez spécifique : **il ne s'agit pas de production d'énergie, mais de vecteur**. Cette spécificité fut d'ailleurs **un problème**, car « *en notifiant à Bruxelles le Fonds Chaleur en tant qu'aide gouvernementale, il a fallu justifier que les aides n'allaient pas être déloyales sur le marché européen* » ! Prévoir un financement aussi conséquent sur des tuyaux n'allait pas de soi pour la Commission Européenne. La commission française a ainsi dû « **batailler** » pendant **1 an avec la commission européenne, arguant qu'il n'y aurait pas de développement de la chaleur renouvelable – ou seulement de manière marginale – sans installation de réseaux de chaleur**. Et que ça n'allait pas se faire au détriment des travailleurs



européens. Sachant que faire une subvention sur les réseaux de chaleur faisait partie du deal de base, pour lequel les parties prenantes avaient déjà bataillé au niveau national.

**Point de départ (original) de la France :** Il faut mettre en place une aide massive pour les réseaux de chaleur, sans quoi la chaleur renouvelable ne décollera pas. Et cette « *aide aux réseaux* » consistera bien en une « *aide aux tuyaux* » ! (50 % du Fonds Chaleur alloué aux réseaux, hors unité de production...).

Le Fonds Chaleur s'est intensifié et diversifié depuis, mais en 2019 le montant des aides accordées pour les travaux d'installation de canalisation ("réseaux") représentait 103M € sur le budget total de 275M €. Cette subvention sur les réseaux n'est quasiment plus remise en cause ces dernières années, et est rentrée dans les mentalités.

#### → Le Fonds : l'essentiel de la politique nationale envers les réseaux de chaleur !

Quasiment aucun développement des réseaux de chaleur hors Fonds Chaleur, et avant le Fonds Chaleur.

Le bilan n'est pas mauvais : **entre 250 et 350km/an de canalisations supplémentaires, contre quelques km à peine en 2008** (avant la mise en place des aides nationales). 316km l'année dernière. Certaines années plus hautes que les autres quand il y a des gros projets (de quelques dizaines de km).

De plus, **la chaleur délivrée par les réseaux est en général très compétitive** (grâce aux aides du Fonds : l'objectif c'est un prix de la chaleur 5% moins cher qu'avec une installation fossile).

NB : Le RdC permet de mutualiser les investissements, pour avoir à l'arrivée un prix de la chaleur plus bas. C'est un aspect essentiel de la politique des réseaux, notamment parce que les clients les plus nombreux sont les bailleurs sociaux (ou la santé), qui ont tout intérêt à bénéficier de tarifs avantageux.

### *Quelles dynamiques pour les réseaux ?*

#### → Évolution des énergies récupérées

Au début des années 2010 la majorité des réseaux utilisaient des chaufferies bois (**bois énergie**) ou de la **géothermie profonde** (notamment en Île de France, fort potentiel bassin parisien). Les réseaux de géothermie profonde avaient notamment été mis en place dans les années 80 (avec un contexte de hausse du prix du pétrole) mais ont rapidement été confrontés à des difficultés financières (et un peu technique) avec le contre-coup des choc pétroliers et la chute des prix des énergies fossiles. Comme la géothermie profonde demande des gros investissements, avec des

temps de retours longs, l'une des premières mesures prises par les Fonds Chaleur a été de revitaliser ces réseaux en difficultés. Les quelques réseaux existants autres avaient été mis en place dans des ZUP : par exemple, une usine d'incinération était créée et on tirait un réseau de chaleur pour les logements sociaux autour.

On a petit à petit assisté à une diversification avec la montée en puissance d'autres EnR&R que le bois énergie + incinérateurs...

- ...à commencer par la **chaleur fatale** industrielle (gros gisements dans les Hauts de France, avec une possibilité de développement local) + de CVE. Très vite, organisation d'un recensement macro au niveau national pour repérer les gisements et planifier leur valorisation.

Dans les années 60 : construction de nombreux incinérateurs dont la chaleur a été d'emblée récupérée pour chauffer des quartiers. Sur ces réseaux-là, le Fonds visait surtout à financer des extensions ou des rénovations, pour atteindre de meilleurs rendements (>25%).

Aujourd'hui : sur **120 CVE en France, seuls une trentaine valorisent mal leur chaleur (car isolés, souvent)**. Le Fonds chaleur a donc eu un rôle important pour équiper complètement 30 à 40 UVE et pour étendre des réseaux existants. Il y a encore quelques dossiers tous les ans sur ce type de réseaux.

- Ou encore la géothermie de surface / géothermie sur nappe phréatique. Ces réseaux sont parfois assez courts (400/500m, par exemple pour chauffer un centre hospitalier), mais constituent tout de même une manne.

**NB : Tous les réseaux ne sont pas longs de plusieurs km ! S'il s'agit parfois d'acheminer de la chaleur depuis une grosse source un peu distante des infrastructures, il peut également être intéressant de tirer parti d'une (ou de plusieurs) source(s) moindre mais plus proche, pour un usage + individualisé.**

→ **Des évolutions locales (et technologiques ?) en parallèle, insufflées par le potentiel fort de certains territoires**

Certaines régions bénéficiaient de la présence de gisements importants (Nord-Pas-De-Calais, Hauts-de-France, Bassin parisien). Il apparaissait clairement qu'il fallait pousser plus loin : quantifier, qualifier, développer la valorisation au niveau local était même avantageux sur le plan économique ! D'où des dynamiques régionales fortes et relativement indépendantes de la politique nationale. -> *mais a-t-on un exemple en-dehors de Dunkerque ?*

## → Évolution de la réglementation

Tous les signaux réglementaires sont au vert (prise de conscience au niveau de l'État).

Facturation : L'abaissement de la TVA à 5,5 % fut une grande victoire, fruit d'un combat de 20ans commencé dans les années 90. Cette transition a permis un saut de compétitivité de l'ordre de 15 points pour la chaleur renouvelable, pour « à peine quelques dizaines de millions perdus par l'État ».

Planification : La loi relative à la transition énergétique pour la croissance verte (LTECV) du 17 août 2015 a marqué un grand pas. A l'échelle nationale, elle a introduit un plan stratégique de développement de la chaleur et du froid renouvelables dans la PPE. A l'échelle des collectivités, **elle a fait ajouter la création et l'exploitation des RdC à la liste des compétences relatives aux EPCI** (communes ou intercommunalités). → les réseaux de chaleur entrent dans les documents d'urbanisme (la mesure est pour le moment majoritairement incitative mais permet d'entamer un changement de culture, même politique).

Aussi, la réalisation d'un **schéma directeur du réseau** a été rendue obligatoire pour les collectivités propriétaires d'un RdC en service au 1er janvier 2009, à l'échéance du 31 décembre 2015. C'est un **nouvel élément à ajouter au PCAET**. L'ADEME impose cette démarche (pensée en partenariat avec AMORCE après consultation de plusieurs projets déjà réalisés), et peut aider à la mener. En contrepartie, ce schéma sera **exigé par l'ADEME pour toute demande d'aide à l'investissement sur un réseau de chaleur existant**.

Objectif du schéma directeur : aider chaque maître d'ouvrage d'un réseau de chaleur existant à réaliser un exercice de projection sur le devenir de son réseau à 15 ans\* et à lui fournir différents scénarii qui lui permettront de décider d'une programmation de travaux à entreprendre durant cette période, laquelle pourra ensuite être subventionnée

\* en prenant en compte les sources potentielles avoisinantes, l'évolution à venir de la consommation énergétique des bâtiments raccordés, etc. En accord avec SRCAE et PCAET.

EN BREF : Le schéma prévoit différents scénarios, la collectivité en choisit un, et l'ADEME accepte alors de financer ce plan.

## → Les critères d'attribution ont-ils changé ?

Oui. Au début, les aides étaient au pourcentage de l'investissement. Mais l'ADEME s'est vite aperçue qu'il y avait des disparités énormes entre les coûts annoncés des projets, avec des variations de prix du simple au triple, à longueur et technologie équivalentes.

En effet, **les coûts étaient évalués par les collectivités/investisseurs/locaux avec leurs propres moyens**, leurs propres marges de sécurité, sans réelle mutualisation des connaissances ou des retours d'expérience. Pour pallier à cela, l'ADEME a cherché à construire une réglementation systématique avec le concours de la SNCU en analysant de nombreux projets en 2012-2013, afin de spécifier les pourcentages d'aides vis-à-vis de spécificités techniques. Il s'agissait de *rationaliser* et de *régulariser* les aides à l'échelle nationale. **(Sans toutefois écarter la possibilité de coûts spécifiques)**

Très concrètement, ils ont établi une grille des plafonds d'aides accordées par unité de longueur en fonction du diamètre des canalisations. Les subventions sont ensuite accordées en pourcentages par rapport à cette grille.

#### → Comment définir ces pourcentages d'aide ? Quelle logique ?

Notre interlocuteur a énoncé ce qu'il appelait « *le théorème du fonds chaleur* », mais qui aurait tout aussi bien pu s'appeler « *le théorème des aides publiques* » : apporter « *juste ce qu'il faut* » pour que les projet deviennent rentables et se fassent.

Cependant, cette question de compétitivité de la chaleur renouvelable vis-à-vis des énergies fossiles est à actualiser régulièrement, du fait de l'évolution du coût des énergies fossiles.

Quand celles-ci deviennent moins chères, c'est plus compliqué, et le niveau d'aide augmente...

#### → Toutes les technologies (EnR&R) sont-elles financées de la même manière ?

La base était au départ que les réseaux aient au moins 50% d'EnR&R pour être subventionnés. Maintenant le critère de base est à 65% (il y avait déjà eu une hausse à 55%). L'idée est d'anticiper les nouveaux critères pour la TVA à 5.5% (le critère va sûrement bouger à 55-60%) pour éviter qu'il y ait une soudaine hausse des prix pour le consommateur (typiquement sur les réseaux à 50% pile). Par contre, l'aide "aux tuyaux" est la même quelle que soit l'EnR&R considérée, pourvu que le taux minimum de chaleur renouvelable soit atteint. En revanche, le Fonds différencie les critères selon les filières : elles seront  $\pm$  importantes selon la maturité des technologies engagées et les coûts qui doivent l'être. Par exemple, les installations avec production de chaleur via du solaire thermique\* bénéficieront d'aides plus conséquentes que les chaufferies collectives au bois (aide plus importante rapportée au MWh produit car le coût d'investissement est plus élevé).

\*2-3 réseaux de chaleur avec grosse exploitation solaire sont actuellement financés (il y a en déjà pas mal au Danemark, donc confiant sur leur viabilité)

L'un des freins principaux au développement de la chaleur renouvelable est que les **opérateurs ne jouent généralement pas le jeu**, et il y a une crainte que dans le contexte actuel du COVID-19, avec la chute des prix du pétrole et du gaz, ils ne tiennent pas leurs engagements environnementaux...

→ **Quels dispositifs/certifications/contraintes/engagements supplémentaires au niveau des acteurs ??**

Dans les autres aides sur la chaleur renouvelable, il y a par exemple les **Contrats de Performance Énergétique (CPE)**, où les opérateurs s'engagent sur une certaine performance. Du côté des usagers, on retrouve les CEE (Certificats d'Économie d'Énergie). Depuis le GT WARGON (nouveau 2020, c'est une des propositions qui est déjà mise en application), il est **possible de coupler les CEE au Fonds Chaleur**, c'est-à-dire de faire une demande de CEE même si le réseau a bénéficié des Fonds Chaleur. C'est un changement non négligeable puisque ça peut être le coup de pouce qui fera qu'un usager se raccorde ou non.

### *Retour sur la place particulière de la France*

→ **Par rapport à nos voisins : une volonté nationale, qui peine à se territorialiser**

Une grosse différence entre la France et d'autres pays où les réseaux de chaleur sont très développés (comme les pays Scandinaves, l'Allemagne, l'Autriche ou encore la Suisse sur certains aspects) est une **différence de culture**.

Pour initier le changement de culture, **il faudrait notamment que plus de publicité se fasse autour des réseaux de chaleur** (par exemple par les grands opérateurs) car ceux-ci restent méconnus (on en parle pas assez). **Il y a déjà un changement de culture qui s'est opéré au niveau des ministères** (dans les années 80, les réseaux de chaleur étaient complètement méconnus, et ne bénéficiaient d'aucune aide, et « les EnR était l'apanage des rêveurs et fous furieux »).

→ **Pourquoi cette différence de culture ?**

On peut comprendre en partie cette différence de culture en comparant les choix faits par l'Allemagne et la France après la 2<sup>de</sup> Guerre Mondiale. **En France on a reconstruit via des grandes entreprises nationales fortement subventionnées, tandis qu'en Allemagne il y avait eu une perte de confiance de la gestion centralisée** (qui les a menés à une guerre) et beaucoup de responsabilités ont été déléguées aux Länders, notamment le développement de l'énergie sur leur territoire. **En Allemagne, le développement a ainsi pu se faire en fonction des besoins** et des

ressources spécifiques à l'échelle locale, ce qui a **favorisé l'émergence de réseaux de chaleur en cogénération**. Inversement, en France, des entreprises comme EDF ou Gaz de France ont été missionnées par l'État pour assurer un développement du gaz et de l'électricité sur tout le territoire français (« subventionné à 90 ou 100% pour l'électricité par exemple »). Il y a donc eu une planification à l'échelle nationale, sans réelle prise en compte des contextes locaux. Deux effets pervers de ce développement :

- **Surdimensionnement des réseaux** ! Certaines villes ont un réseau de chaleur, un de gaz et un d'électricité, qui recouvrent les mêmes besoins. Certains ont été dimensionnés pour 100% de la consommation et doivent finalement se partager les usagers avec les deux autres réseaux... Ce qui peut engendrer des problèmes d'équilibre financier.
- **Défaut d'information et de responsabilisation à l'échelle locale** ("Problème de mentalités") : comme l'État a eu un rôle très important et qu'il y a eu des monopoles pendant très longtemps, **les collectivités (et usagers) ne se rendent pas toujours compte de leur rôle et de leur pouvoir** (ce sont elles les délégataires et c'est à elles qu'appartiennent les réseaux, elles ont le pouvoir de mettre des critères contraignants pour les opérateurs). On entend souvent "le réseau EDF" ou "le réseau Engie" ou alors "ce n'est pas du ressort de la ville", alors que les réseaux appartiennent soit aux villes, soit à l'État, et que dans tous les cas les opérateurs ne sont que des concessionnaires !

### *Qui peut, qui va mener la transition dans les années à venir ?*

→ **Du côté institutionnel : un vrai moteur ?**

Par rapport au GT WARGON et aux 25 propositions, **il y a plein de bonnes idées, mais le problème c'est de voir ce qui va être fait concrètement et quels moyens vont être mis.**

Exemple de politique forte qui n'a pas été mise en application : en 2009 (?) il y avait eu une politique européenne avec le paquet du 3\*20. L'UE devait avoir 20% d'ENR, réaliser 20% d'économie d'énergie et baisser de 20% son gaz (consommation ?) d'ici à 2020. La France c'était engagée pour 23% au global (en partant de 13%), et devrait à peine atteindre les 17% à échéance.

**La PPE est donc un bon ensemble d'indications, mais ne donne pas les moyens et le chemin pour chaque acteurs (reste très global).** On peut donc se demander ce qui va effectivement être fait !

Par exemple actuellement **certaines RDC repassent aux énergies fossiles** (volonté des opérateurs via les délégations de services publiques) et rien n'est fait... Alors que ces réseaux ont bénéficié d'aides publiques.

→ **Peut-on compter sur les opérateurs pour appuyer la transition ?**

De son point de vue (cela fait 40 ans qu'il travaille dans la chaleur), la culture des opérateurs n'a pas concrètement changé, et c'est d'ailleurs ce qu'on retrouve dans les dossiers. **Les dossiers proposés par les opérateurs sont optimisés pour avoir la subvention, mais pas pour l'utilisation d'EnR&R.** Certains proposent même des dossiers où la chaleur de récupération n'est pas utilisée à son plein potentiel (sous couvert de problèmes techniques pour la récupérer), pour augmenter la part de chaleur d'appoint fournir par le gaz, puisque la plupart des maisons mères des opérateurs vend du gaz... Lorsque la procédure n'est pas respectée par les collectivités, et que les dossiers sont uniquement portés par les opérateurs ont peut voir du « grand n'importe quoi », puisque les intérêts des opérateurs sont différents des intérêts de la collectivité. **Les entreprises sont juges et partie** (parfois ce sont même des filiales à l'étranger qui remportent l'appel d'offre, plutôt que la filiale locale)... Et généralement **les politiques les protègent, car il y a des liens forts entre les ministères et les gros opérateurs** (et donc aucune action marquante n'est prise pour s'assurer de la mise en œuvre des politiques). Les opérateurs seront d'ailleurs les derniers à bouger, quand il y aura trop de pression et qu'ils ne pourront plus faire autrement (contrairement à ce que dit le greenwashing, les opérateurs ne seront pas chefs de file de la transition).

→ **De leur côté, les collectivités ne sont pas assez au fait sur le sujet...**

**Les acteurs de terrain, une fois sensibilisés, sont au top** (régions, collectivités, municipalités) et sont prêts pour une transition. Le problème c'est que généralement les sphères de direction (ministères et opérateurs) ne suivent pas. Par exemple, le cas de Dunkerque est intéressant parce que c'est un dossier qui vient du terrain, appuyé par une démarche territoriale.

→ **Le plus gros est-il déjà fait, ou reste-t-il à venir ?**

Depuis deux ans, le Fonds Chaleur aide le développement du réseau de froid. **Les aides s'adressent uniquement au froid renouvelable et aux usages prioritaires (comme la santé).** Mais il y a une pression montante, notamment dans le Sud, suite au changement climatique et aux grosses canicules.

Concernant l'évolution future du marché, il y a encore un potentiel énorme des RDC. **On entend parfois des acteurs dire que toutes les villes ont leur réseau de chaleur et que le marché est à bout de souffle, que tout est déjà fait. Mais dans la plupart des villes il y a seulement un ou deux quartiers de reliés (dans les 15% de la ville).** Et les EnR ne couvrent pour le moment que 15% des besoins de chaleur. Donc même en enlevant les besoins des zones pavillonnaires (environ 30% qui sont trop peu denses pour être reliées via un RDC), il reste dans les 55% de potentiel de développement.

→ **Quelles actions de l'ADEME devant cette triste constatation ? Un accompagnement, en parallèle du Fonds chaleur**

**L'ADEME essaie d'aller voir des collectivités pour les sensibiliser, mais elle a peu de moyens.**

L'ADEME présente les RDC comme un vecteur d'emploi local, qui favorise l'économie locale, un projet dynamique (contrairement au rond-point).

Ce que l'ADEME propose c'est une procédure (et une assistance) dès les premières réflexions sur le projet, sans penser à l'opérateur. Il s'agit d'**identifier dans l'ordre 1) les besoins, 2) les sources potentielles de chaleur fatale**, et ensuite **3) la possibilité de production d'EnR, tout en regardant le coût** (chaleur la moins chère possible) **et les retombées pour l'économie régionale**. Il leur faut faire preuve de **beaucoup de pédagogie, les communautés sont réceptives mais manquent parfois d'expertise**. C'est pour cela que l'ADEME met à disposition des modèles de procédures. Il y a également de la documentation mise à disposition, ainsi que des bureaux d'études et des fonds. **Le cadre existe déjà, les communes doivent se remettre à jour et reprendre en main l'énergie.**

Dans certains cas\*, il y a eu la mise en place de comité de pilotage avec toutes les parties prenantes (dont les abonnés). Cette transparence pour expliquer le projet et se concerter est **INDISPENSABLE** pour la bonne compréhension et l'acceptabilité du réseau (que les abonnés acceptent de se raccorder) → changement de paradigme. Dans ce cas, les usagers peuvent choisir d'entamer cette démarche de faire des économies d'énergie, et de vouloir baisser leur consommation. **Le réseau (via la ville ?) peut d'ailleurs mettre en place un système de bonification pour les usagers qui font des économies d'énergie.**

<p>*Exemples de villes intéressantes avec des démarches de concertation (avec parfois des acteurs comme l'armée, des hôpitaux, etc. qui ont des intérêts particuliers mais qui peuvent travailler tous ensemble quand ils ont été sensibilisés) : <b>Besançon, Dijon, Brest.</b></p>
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→ **Pour guider les collectivités dans leurs manœuvres/démarches**

**Les bureaux d'étude sont plutôt au point pour aider les collectivités.** Par exemple *Inddigo* (les autres noms ne lui sont pas revenus). Il y a également des bureaux plus spécialisés sur un filiale à la fois (géothermie, biomasse ou autre) et qui peuvent aider quand le projet est un peu plus défini. Pour aider les collectivités, **il y a également des logiciels d'optimisation** qui viennent notamment de pays scandinaves, et qui commencent à être développés et utilisés en France.



### Points marquants :

- **Ancrage historique de la situation française**, surdimensionnement qui en découle
- **Manque de moyens concrets mis en France en-dehors du Fonds chaleur**, difficulté de mise en œuvre des 25 propositions
- **Changement de mentalité récent au niveau des politiques et des collectivités vis-à-vis de la chaleur renouvelable** : les RdC font maintenant partie du champ des possibles, contrairement à il y a 30 ans
- Historique bois-énergie / chaleur fatale et UVE / géothermie + prospection des gros gisements
- Démarche d'adaptation des critères d'attribution des aides

### Zones d'ombre :

- Rien sur des évolutions contractuelles ou de modèle d'affaires comme vecteurs de changement
- **Cumul CPE, CEE, aides Fonds Chaleur et FEDER...**  
(Se renseigner sur CEE)
- **Fonctionnement précis des aides**

## ANNEX 4: Transcript of the Danish Energy Agency interview

Yeah, well so the Danish. Well, I'll just give a brief introduction to myself. I have a background from... I'm an energy engineer and worked with district heating project as a private consultant, in a private consulting company for 10 years approximately. And then I switch to the Danish Energy Agency almost a year ago and working with DH as well here. So, in Denmark we have, first of all we've started with having DH in a few major cities I think a hundred years ago, where [...] this founding (?) opportunities of using the surplus heat from power production in combined... well in [...] power plants, making them in CHP more. And we'll also do the same with surplus heat from waste incineration. And then that the two major systems. Then I think it really became a big thing around the 70s, after the 70s oil crisis. We... There was a major focus on having this... utilizing heat everywhere, from a power production. So, during the... mainly the 90s I think, we've had maybe more than 200 small DH systems being established based on the same [...] elements: we have natural gas power plant, and natural gas boilers. And then we have this power price system. Before it was made commercial, we had like high-low-medium power prices, very easy to manage power systems so... The idea was simply to say that, well instead of producing all the power in the major cities, perhaps producing so much power that it's not possible to use all the surplus heat, then let's make small power production systems in the smaller cities so we can utilize the surplus heat from power production. You know all these minor cities as well. So, there was about, [...] 250 DH systems being established with the same ground rule that when the power price was high you could use the CHP plant, and when the power price was low, you could use the gas boiler instead. So, that made DH a system really getting out there to minor areas as well. And then at the same time we had of course, I think, established a 100 (?) DH (*district heating*) systems using mainly biomass boilers as heating source. And then of course we also have some medium scale DH systems where we have, well sort of... well medium size CHP (*combined heat and power*) systems. So, we [...] 30-40 systems where we have power production of – I don't know – 30-40-50MW and we have surplus heat from this production too to supply most of the DH system. And approximately 25 DH systems with waste-to-energy asset base load. So, it's all sort of different things, but of course one of the main things is the thought

of using waste heat from different sources: waste incineration, CHP, solar heating, some thoughts (?) as well. But that have been the based, the ground, of the establishment of the systems.

*OK and on what tools did the development relied on? Like what were the incentives or the planning tools, or zoning tools that were used to make it efficient and make it work?*

I think the main management... the main tool when initiating this was that you had quite low costs of heat. So, you would... you would... see the waste heat on CHP plants as actual waste heat. Meaning that heat [...] the heat consumer [...] pay for the marginal cost of the heat production. And in some cases that would be almost 0. Not 0 of course, but still very low [...] systems, I think if you have bypassed this extraction system, then... extraction CHP plants... you will have... if you need to use heat for DH purpose then you will decrease you power production slightly and this would have some cost and you would say that heat could have efficiency of 200 perhaps 300%. So [...] there would be very low amount of fuel consumption for the CHP plant which should actually be sent to the heat consumer. That would make the heat price quite low. Then you have, back in the... before it was commercialized the power system... then you would have this 3-stage-tariffs. So, you would have for each week, each day, all year around, you would have this one tariff perhaps during daytime for week days, and then another tariff meaning that the amount of... whatever you could sell, the electricity to the market... this would have a fix price depending on when during the day and the week you would sell it. So, this would mean that you would have this incentive to produce the heat when the power consumption in Denmark is high. The you would have an incentive to produce heat, and produce heat from CHP plants and then use short term heat storage to store the heat from day to night time for instance. So, you would have some ways of delivering efficient, cost-efficient heat as well in that terms. Then I think it was 2005 – actually not sure – we had a commercialized power system, maybe in 3, I can't remember... But more than 15y ago, the power system was commercialized and that actually meant suddenly you couldn't depend on the power price to be high and low on certain times. It would be more difficult to actually optimize the systems. So the transmission system operator would pay the DH companies some amount of money to have these CHP plants standing stand-by for well emergencies... but of course for any situation where the power market would demand

more power production. Then you would get one fixed amount of money to be able to turn on the CHP plants if needed. Because I think the power price would not be incentive enough to keep all of these power plants. So, it was a way of maintaining the power plants and the systems. And that went out of operation this subsidy... I think it was by the end of 2018 or 2019... It was taken out. So now everyone is going for transition to HP (*heat pumps*) instead.

*So, you mean that CHP plants are closing to create more HP?*

Yeah. Of course, the... the speed of the transition is quite different to tell. But I think during the 2010s, last 10y, there has been a major focus actually on converting the fossil-fuel based DH systems towards... these larger ones... towards biomass-based CHP. So, we have seen both the actual conversion (?) or rebuilding of actual coal-fired plants for instance to biomass plants. But also closing fossil-fuels based power plants and building biomass CHP plants instead. Some of these developments was made interesting by subsidy of power production from biomass-based CHP and also by actually having no tax on biomass for energy production but having quite high tax on fossil fuels. We've been having high tax on fossil fuels for many, many years so but apparently the tax wasn't high enough so instead of increasing the taxes there was this subsidy for power production from biomass. Yeah... but that subsidy scheme was also taken out of the system two years ago. So those who had already received or built a plant based on this subsidy would have some 20y, I think, where they could keep receiving this subsidy and then this subsidy will stop. And for new plants it would not be possible to get this subsidy anymore. So, because of this missing subsidy biomass CHP... will not have... it would not be very feasible to use compared to heat pumps.

*And so, if this subsidy is out, I guess that's because there are other priorities now? The main things you're working on for Danish DH is what? To introduce more HP, large-scale HP?*

Yeah, because parallel with the... this, well... building all these large-scale biomass CHP plants, almost... every second years during the 2010s we actually had a decrease on the power tax if it was used for heating purpose. We've had a quite high – we still have a quite high – tax on power, for households for instance. At some point many years ago... it was

not allowed to use heat... uhm sorry, using power for heat production was not allowed because it was seen as an unfeasible way of using, or not a good way of using the produced power, because it was based on coal mainly. But as we have developed the wind power production in Denmark, now we go more the other way around actually, try to get the DH companies to use HP for heating purpose. And that would... yeah. So, the power tax has been decreased many times during the last ten years and I think it will... it was last year it was decided that it should be lowered to the EU minimum tax, which is almost nothing compared to the other costs of producing heat with HP. So, so, you have this tendency of... [...] the HP but not so much the biomass anymore. I think the reason why they stopped using both these subsidies for power plants, power plant capacity [...] ending this subsidy scheme for power production from biomass CHP was, I think... both of the reasons... mainly EU saying it was not allowed, illegal government support.

*OK and also, I've heard a lot about the socio-economic calculation that you have to do when you do a project for heating. Has it changed in a way to also help the transition and promote HP or stuff like that or are the assumptions still the same?*

Yeah, I've been working also with the socio-economic calculation for... yeah, more than 10y. And I think actually the most significant step towards... actually having a helping hand in the transition towards green energy is that... It was made earlier this year, but decided last year... In general [...] about 15y, the DH companies would make this project proposal for the municipality to approve before they would be able to actually begin the construction of a heat production plant, but also if you want to convert natural gas or oil consumers to DH, or rolling out(?) DH pipe system, then you will need to have the municipal approval. And this project proposal would include all sorts of things, a long list of elements, but the most important thing would be that it was... it should have a proved socio-economic benefit of this scenario. So, if you have... if you wanted to make HP but the socio-economic calculation says that biomass boilers would be better, then you're not allowed to go forward with the HP. Then you would have to go with the other project even though it could be more expensive for the heat consumer. And well, usually it's not have been a pb between HP and biomass boilers, because DH companies would be glad to use either of them. But the pb has been it has been actually a better socio-economic solution to use gas boilers for heat production instead of biomass boilers or HP. And even though

we have high taxation on natural gas, that would not mean anything in the socio-economic calculation analysis, actually it would have a slightly... it would slightly improve the gas scenario, which was even worse. But it would have very little influence. That would mean that almost all the DH companies would want to have a solution which would be both greener and cheaper for the consumer but they would not be allowed to do this because of this socio-economic restriction. Then last year it was decided to remove this restriction, saying that now it should be able for the municipality when receiving this project proposal to say that... you still need to show alternative proposals to what you want to do, but the municipality could say that they do not need to see any alternative using fossil fuel. So, this means that suddenly you could not... if you have natural gas today and you want a HP, you would not need to compare, socio-economically, you don't need to compare the HP scenario with the reference scenario, then you only need to compare the HP scenario with biomass, or other surplus heat production for instance. And this [...] has made a huge change because you could actually get somewhere with the project.

*OK, and how are scenarios decided? I mean it's mandatory to compare to specific scenarios or you could choose?*

Well, we actually have a guidance document saying that is how you do the socio-economic calculation. And it is the guidance. So, of course, you should follow it mainly. But it's also quite easy to bypass some of these things. But I would say that it is... you don't have so many options. You have the option of using HP and of course, you could see if it's... you could see if seawater heat pump, or groundwater HP, or wastewater HP would be better than air-water HP. But, but, you will... it's not everyone who would actually have the possibility of using these sources, and not at all at the scale at which it will often be demanded for minimum large-scale system. So, of course, you would have diff possibilities for biomass. But biomass CHP would not be relevant for all the minor systems. It would be way to expensive. So, it would only be relevant or the top 20-30, say, almost [...] DH systems. Then you only have very few opportunities. We try to highlight... It's important to see if there's any surplus heat opportunities available. You should actually go out and [...] overall mapping of surplus heat possibilities, because that could have some relevance taking them into consideration. So, [...] the only thing that is fixed is that you should always

see HP as an alternative solution. But if your project is a HP, it's quite flexible what you're looking at actually.

*And don't you fear the competition between large-scale HP in DH, or even DH, with individual HP?*

Yes, that's a major focus for the district heating... yeah, we call it the organization of district heating companies in Denmark... and some of the DH systems as well... Yeah that's a major, well, point of interest at least. And I think that we'll have... I believe that within the next few years we will see almost the final conversion projects from individual heating to DH. I believe that when we get 5-7 years ahead, then individual HP will be... will take out... cover a large part of the global city areas, and therefore DH cannot be feasible in these areas anymore. It's not saying that they will cover 60%, but taking 20% of the consumers within a specific area will make it difficult to have a feasible DH project. Because we'll also see a lot of people just not converting right away. So, even though you will still have 80 % that could possibly convert to DH, you can't be certain that they will convert to anything, and then it will be difficult. So, I think that as we see more and more HP coming in city areas, we will see that it will be more and more difficult to get new DH projects.

*OK so you think that in the next years, the DH will kind of stop developing or expanding in Denmark?*

I think at least that we will see, a very... large conversion projects... most of the... all the DH companies within these years will say "it is now that we need to do the project. We don't need to fulfill, we don't need to do the actual conversion within the next 3 years, but within the next 3y, we would need to decide which areas should be our conversion areas". And then it will of course take some years to do the actual roll up of the pipe system and final conversion but... This is also... this could also be seen in the context that the government right now is using a lot of money for the... getting... to provide a subsidy for households to actually put-up individual HP. So as of now we're actually already(?) pushing for more individual HP by giving funds to the households. And I can't remember how many is actually getting... how many will be able to get this fund, but I think it's quite a lot. It's tens of thousands and in Danish that's quite a lot. I think right now we have

almost, between 400 000 and 500 000 individual heat consumers in Denmark (using gas and oil). So, if we could... let's say if only 50 000 of them will get a subsidy... I can't remember how many... but let's say 50 000, then that would be a lot. And then we'll get to the [...] in the next few years so that would of course, yeah...

*And so, for the... you were saying that the DH companies need to do their projects now, so the government doesn't plan to do a zoning like it was done for the gas vs DH in the 70s?*

Uhm, no. Uhm, well, actually, the thing is that the only zoning that's been done right now is that to get, to get the subsidy for the individual HP you need to be placed outside of an area approved for DH. So, this means that first of all you cannot... if there's a DH pipe just outside your door but you don't have DH, you will not be able to get a subsidy. But also, if you... if the local DH company has a project proposal which has been approved, then you'll not be able to get a subsidy for a HP, even though the project is not actually at your doorstep yet. So, so we have this kind of zoning. Then we have another... well not zoning but... which was also taken out of the system [...] until the end of 2019 we had this demand that if... for some areas if you wanted to... then the DH company and the municipality could agree that this new DH area would be with mandatory connection to DH. And that's of course extremely efficient to get an efficient DH system. To say that... within the next 9y you would need to convert to DH no matter if you want it or not. It's not all of the DH systems that actually have this. I think it's about 50% of the consumers where this is a thing. Because it's... from municipality to municipality it's different whether you want it or not. Because of course, even though it can be very cost-efficient for the DH system, it would be great for the consumers as well, because if you have a higher nb of users, you will have more to pay for the fixed costs so... But, of course, it's also taking away some of your... some freedom as a citizen. So, it's not everyone who wants this. And that's probably also why it was taken out as a possibility. So, now we still have those areas where it was approved before 2019... it's still a thing. But for now, you can't use it anymore. Now we have actually a new thing which is under consideration. As I understand it's not at all approved or discussed, it's just a very overall thought, to try to turn this mandatory connection upside down, saying that it could be relevant, instead of having mandatory connection to DH, then, to make it mandatory that you disconnect and convert from individual gas and oil, to individual HP or DH. So, it would not mean that you need to use



DH but it will... if this was to be implemented, then you would have... you would really speed up the transition, to have the individual consumers to figure out what to do from now and up to 2030. So that's quite interesting. But I think it's not something that is discussed much politically, as I understand.

*OK and uh, I had another question about the... because the DH companies are under the supervision of a kind of authority that is ensuring they do things right, and they also look at different KPIs, and I was wondering are there... did the government also wanted to change this KPIs also to push companies for more green solutions, or was it not a tool discussed?*

I don't think with regards to what this authority... the authority of utility something... I don't think it would be... I don't hear it discussed with them at all. What we are looking at is doing some... could we highlight in some way, and also get the DH companies to highlight, the climate footprint for their system, to show... to make it easier for the user, the consumers, to see whether this is actually green or not. And hopefully this will... could be... could help to speed up the transition as well. Then I... Yeah, no... I think that's probably the main thing. But uh, I don't think it would be any KPIs. But for now, actually, I would say that after the disappearance of the tax on power for heat production, then it's not really feasible to use fossil fuel for heat production in DH at least. And therefore, it's mostly a matter of actually doing it. It's a matter of being comfortable with new technologies, and perhaps waiting a few years until you would have paid off the debt for your current technology, making them be [...] takes the time to purchase a new production. And I think the same would be or individual HP, especially individual HP would see the... this is quite new, we don't have very much experience on what is the noise of these small HPs going 1-2-3-5 years in the future, what will the COP be within a few years... And just managing this... And also, the individual HP will be much more expensive than the gas boiler in the CAPEX, and this will also be some barrier for actually go along with the purchasing of these green technologies. So, I think overall we have all these(?) feasible green alternative for the heat solution. So, it's just a matter of being comfortable using it and actually have the funds(?) of going into a new market.

*OK and for the HP, do you think that groundwater source HP have a future in Denmark?*

Uhm, no. Not really actually. I think we have one, maybe two HPs... just heat production. I think also we have some groundwater heat storage where it's both heat and cooling, but that's for process propose so it's different. I think we only have one or two very small groundwater HP. And I think that probably it would be one of the issues... I'm not saying it's not feasible and that it's not a good idea, it could easily be the case. I don't know much about groundwater HP, but I think, as I understand, you will... the... what I [...] been working within this area, I just understand that you will have some limitation of how much... how large groundwater system you can do with one drilling, and you would need... you would often need to have many holes. And suddenly you will have this huge network of groundwater moving from miles outside of the city to some... some point where you will have the HP system. And it just seems quite expensive and comprehensive to do this way. If you could do a small groundwater system for a small DH system that could probably be relevant. But I think it would have this limitation of actually have enough heat capacity locally from groundwater. But I'm not sure, it's just my understanding.

*OK. I don't know much about either, it's just that I've heard about this type of DH and I was wondering [...] Uh I have only two more questions. Like the first one is the future of cooling. Do you think there will be more heating and cooling in the future?*

Yeah, I think so. Uh, I can't really grasp how much it will be but I think we will - also of course with the climate change - see it more relevant to have... actually more feasible to actually have more district cooling but in Denmark DC is not really... or cooling anything is not always necessary... but, but I think [...] more focus on district cooling from the district heating companies now.... I think now... than we have seen before. And, so, therefore I'm saying yes, that will probably be more. It's... It also has some, you'll also have some... some synergies the DH and DC systems, because you will have... When you have the DH system, you will be able... for instance you could use, during the summer, you could use the surplus heat from the DC production for DH purpose. So, therefore, you could actually have a synergy where you produce heat and cooling at the same time. Not with the same compressing unit but still with using surplus heat from cooling production and therefore have... So, I think they will be relevant, mainly I think in the major cities where it's not really wanted... nobody wants to have these individual cooling systems on top of rooftops

or on the side of the buildings ruining the way we present the city, and so on. So, I think... we could have more focus on having DC.

*And for that do you plan to have them under the same rules as DH which are non-profit and stuff like that?*

Uhm no, I don't think so. I think I actually... If we should talk of a tendency, I think there is a tendency of removing regulation... or loosening a bit regulation on the DH area. Not saying that it will be commercialized but saying that as we saw when we remove the mandatory connection, well at least remove the possibility of using this mandatory connection. We removed what was called the CHP demand in large cities, which actually said that you could only, almost only product CHP plants in the major cities. We removed fuel restrictions in the gas-based DH systems, saying that they could actually also used biomass now. We have softened up on many scales. So, but I don't think... I think the tendency will be more liberalization, less regulation in the DH and not more regulation in the DC. Of course, it's not easy to say, but I think it's...

*OK, and so if you could just wrap up your vision of heating in Denmark in 10 years, that would be what?*

Well, I think we would... I think we'll see most of the... most of the minor and medium size gas CHP plants or maybe all the gas CHP plants, we'll be taken off operations and instead we will put up HP. I think we will also see less heat production based on biomass, both in CHP, but also in biomass boilers, using HP instead. We will see more electric boilers, also trying to get some electric boilers to cover some of the peak load production instead of gas and oil. And we have – I just forgot about that – there's a focus right now also within waste handling to do more fractioning and using death waste for incineration, and I think the target was, within 2030 decrease the waste incineration by 30% at least. And waste incineration actually supplies 20% of the heat production. So, there'll be also be a decrease here. So, I think that would be most of the... the most important things. Hopefully we also see some low-temperature DHS but it's very difficult to manage this conversion. And it's done very slow also because heat pipes have a life time, lifespan of 40 to 50 years, so it's quite expensive to dig up a functional pipe to put up a new one. But hopefully we'll see some low-temp DHS as well. But I will say, except if we do some things

right of course, we will still have a lot of heat being produced from biomass CHP, we will still have heat produced from biomass boiler, and of course still from waste incineration. We will not have anything from coal CHP, and not from oil CHP. And we will probably have some from gas CHP but it will probably be mainly for peak load in the power system. And of course, if it's used for power production, we will find a way to use the surplus heat as well. And then I think it will be a lot of, a lot of HP.

*OK, thank you for sharing this vision of 2030 in Denmark.*



## ANNEX 5: Workshop summary

### *Low-temperature DHCSs–socioeconomic boundary conditions*

*Online workshop. October 14<sup>th</sup>, 2021*

*Organizer: Johanna AYRAULT. Technical support: Farah DOUMIT*

*Participants to the workshop: Gerhard BAYER, Isabel Fernandez, Theis Raaschou Andersen, Altin Maraj, Soren Erbs Poulsen, Jessica Maria Chicco, Zsuzsa Hargitainé Molnar, Gregor Götzl, Vasilike Gemeni, Peter Jurik, Morten Hofmeister, Tobias Steen, Valentin Gavan, Chloé Duchayne, Dimitri Aymard, Jerjes Porlles Hurtado.*

*Participants to the online PESTLE/SWOT survey: Gregor Götzl, Valentin Gavan, Isabel Fernandez, Gerhard Bayer, Tobias Steen, Arzu Frat Ersoy, Aleksandrs Zajacs, Jessica Maria Chicco, Theis Raaschou Andersen, Morten Hofmeister*

### Genesis of the workshop

The idea of the workshop comes from discussions with Gregor Götzl, chairman of the COST-Action Geothermal-DHC. As I made a presentation of my PhD to him, he offered several case studies coming from his network, that I may use. After some discussions, we chose 3 cases: one in Vienna, a research project on the introduction of a small low-temperature DHCSs (district heating and cooling systems) in an existing district; one in Denmark with Thermonet, a network supporting the development of low-temperature DHCSs; one in Spain with the setting up of a district heating in a mountain area. The three cases are innovative, each one in its own way. The one in Vienna tackles the setting up of a low-temperature DHCSs in an existing district of a densely settled urban area. Thermonet offers several cases of the latest generation of low-temperature DHCSs. Val d'Aran (in Spain), has the ambition to implement a state-of-the-art DH, based on local resources (like local biomass from the Pyrenees). Stakeholders from the three cases were invited to discussions, and due to the difference of schedule and implementation objectives, the idea of creating a common workshop was raised. The objective of the workshop was twofold: 1) gathering data for my PhD and getting to know more about the projects, 2) sharing experiences between a variety of stakeholders.

During a few months, we discussed the content of the workshop and its timeframe. Several ideas were considered, e.g., a single workshop, a series of three workshop concluding by a creative one, and finally the one chosen: one online survey followed by two workshops. The date chosen for the first workshop was postponed from September to October give more time for the preparation of the workshop (as the summer break was not relevant for doing preparation meetings). The series of workshop was designed as followed:

- A PESTLE/SWOT analysis on low-temperature DHCSs, to get a first idea on the representation of DHCSs by the participants
- A first workshop to give basis on low-temperature DHCSs (through presentations) and to discuss the barriers and enablers for its implementation.
- A second and last workshop, on the future of DHCSs. This last workshop will be a creative one. The content of the workshop was clearly defined after the first one, based on its outcomes.

The design of the workshops was also inspired by a training on moderation, given by Geothermal-DHC.

### Stakeholders

The workshop was first to focus on the stakeholders of the case studies. Several types of stakeholders were identified during a first step (*Table 1: Identified stakeholders*).

Geographical level	Stakeholder role*			
	<i>Decision maker</i>	<i>Adapter</i>	<i>Multiplier</i>	<i>Expert</i>
<i>International</i>	--	DHC operator in SUI	International interest group?	Crowdthermal EU project
<i>Regional</i>	<b>Local authorities, communities</b>  National authorities and funding agencies	<b>Energy suppliers &amp; DHC operators (public and private)</b>  <b>Real estate developer</b>  Service providers (planners, building constructors, architects)	Regional / national interest groups  NGOs  <b>Sectoral Agencies</b>	<b>R&amp;D</b>

\*Bold target groups were considered having a high relevance for the workshop

However, as the goal of the workshop was a quite global brainstorming, it felt more relevant to open the workshop to more participants than just the one directly concerned by the case. Moreover, some of the target groups (like municipalities) were thought too specific and hard to reach for this type of exploratory workshop (as low-temperature DHCSs are not well-known, they would have needed a longer acclimatation period to participate in discussions). Engie was also integrated to the loop. In the process, the Spain case study was left behind, as the COVID crisis caused a lot of delay to the project and they did not feel relevant for presenting their project or inviting stakeholders.

Close to the workshop, the invitation (with the registration link, and the PESTLE/SWOT survey) was extended to the whole Geothermal-DHC network. In the end, there was a bias towards geoscientists in the participants, but a great variety of countries were represented.

### Summary of the PESTLE/SWOT analysis and following discussions

The following categories are adapted from a PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis. Participants to the workshop were asked to fill a survey before the workshop. For the survey, the political and legal aspects were merged to facilitate the understanding of the participants (which background was mostly technical). The order of the categories was also changed: first the technological part to comfort the participants, then the political and legal ones which are usually seen as having a great impact on the development, then the economic aspects, the social ones and the environmental ones. The technological part was taken out of the summary as the focus here is on the non-technical aspects impacting the development of low-temperature DHCSs. The result categories were renamed depending on their key focus. For instance, the social one became “social context: multi-stakeholder integration and social acceptance” as the two main concerns for the development of the systems are: 1) the integration of a variety of stakeholders into a collaborative action, 2) the social acceptance by the consumers and local stakeholders of such systems. The final categories are the following:

- **Legal and political issues**
- **Social context: multi-stakeholder integration and social acceptance**
- **Economic aspects: pricing and business model**



### - **Environmental impact**

The survey took the form of a SWOT analysis, but after studying the answers, it seemed that the boundaries of the system are mainly thought in technical terms. For the other categories, it was mainly the external context that was presented as having a huge impact on the system's development. Thus, the results do not follow the SWOT classification. In light green you can find the future opportunities that low-temperature DHCSs offer. In dark green the existing facilitators. In orange are the important points to bear in mind, which can be turned into a threat or an opportunity. In red are the existing barriers to the development.

You can find hereafter a summary of the main point raised by the SWOT/PESTLE survey and discussed during the workshop. All of the categories are strongly linked, barriers or opportunities from some impacting the others. In **light green** you can find the future opportunities that low-temperature DHCS offer. In **dark green** the existing facilitators. In **orange** are the important points to bear in mind, which can be turned into a threat or an opportunity. In **red** are the existing barriers to the development. In **bold** are the interesting practices that could foster the development of low-temperature DHCSs.

### **Legal and political issues**

The use of low-temperature DHCSs can **decrease the dependency on energy imports** and pave the way to energy resiliency and more energy sovereignty. They participate in **reaching European, national and local objectives** like 1) increasing the RES share on the energy mix, 2) using more local energies, 3) phasing out of fossil fuels (oil, coal, and even gas in some specific countries or for specific uses like heating).

Low-temperature DHCSs are also an opportunity to develop **multi-sector integration**, increasing local resilience. Nevertheless, **the logistics (contracts, legal frame, etc.) to support such multi-stakeholders** project is not yet existing (at least, not is a standardized format).

However, **the legal framework is not supportive and clear enough** for now. For the use of geothermal energy for instance, the regulation does not cover clearly the open loops circuits using groundwater. Similarly, some countries lack incentives and clear framework for the use of the underground public space for geothermal energy and the use of waste heat. Some facilitators for getting public work authorizations for innovative low-

temperature DHCSs (especially geothermal drilling) are also needed. Such limitations are partly due to the low visibility of the systems. They suffer from 1) a **lack of awareness** from decision-makers, 2) **prejudged opinions** on their feasibility and the resulting energy affordability, 3) **lack of confidence** in some technologies (e.g., geothermal). One last weakness is that **existing incentives for renewable energy are hugely used for green electricity** at the expense of green heat, and little is specifically designed for sustainable heat. Costs of transaction for adapting the existing frames (e.g., energy communities) to heat are thus non-negligible, all the more as little experiences are made. Heat remains mainly an unthought of the political field and public policies.

Some levers and drivers are already set up. **New EU regulations** (Green Deal, Taxonomy) push forward the investments (financial, human, etc.) on green technologies like low-temperature DHCSs. At the same time, there are more and more **incentives for the energy transition** (national revival plans, European funds for projects, CO2 taxation, etc.). National laws are starting to give **more power to local authorities** on heat planning, who can promote local energies and create energy zoning plans to manage the energy transition.

Despite the EU framework and objectives, there are **strong differences between EU countries**: some are already starting to think about phasing out of gas whereas others are still dependent on coal for their heating system. The legal framework differs strongly also between the countries, making it difficult to design adapted European frames. The implementation feasibility of low-temperature DHCSs will thus depend a lot on the local context and maturity. This diversity is a challenge for succeeding the energy transition in due time, but gives an opportunity for experience sharing and inter-national support.

#### **In short concrete terms**

+ One political practice which seems to enhance the dynamic of innovative heating solutions in some countries (like Denmark or Austria) is a **well-communicated commitment from the government to phase out fossil fuels within a clear deadline**.

- One major actual weakness is the **lack of awareness** of decision makers on the technical possibilities for sustainable heat, leading to misaligned policies and incentives for the development of solutions like low-temperature DHCSs.

### **Social context: Multi-stakeholder integration and social acceptance**

More and more (local) stakeholders have an **interest in sustainable development** and are searching for suitable sustainable solutions using local resources. Low-temperature DHCSs can answer this demand and offer **various co-benefits for the community**: e.g., enhance local attractiveness, the aesthetical benefit of having an underground system, getting rid of the maintenance burden for consumers.

However, the social license to operate (SLO) is not yet won over. Such systems are not widely known, leading to some **mistrust** and to some aspects being seen as **risky** (e.g., the level of affordability considering the substantial investments). Any mistake in the making of a project can threaten the credibility of the system. The **disturbances** due to the work and the drilling also put a damper on citizens' acceptance.

Unknowns remain also on the consumer's side. Indeed, low-temperature DHCSs demand that they **shift from their actual paradigm** and 1) change their consumption habits 2) move from individual to collective solutions. Collective solutions can create win-win situations and allow to share the risks but all stakeholders in the network become dependent and have to be committed. Due to the number of solutions that are developed to answer the challenge of the energy transition, low-temperature DHCSs have to face **competition**. It is not sure that consumers will choose this solution over heat pumps or other individual solutions. If in a neighborhood several consumers chose not to connect to the network, its feasibility can be seriously threatened. Moreover, without incentives or obligation from the government, making the necessary investments to switch from the existing system is not easy, especially in times of crisis. If given a choice for changing their heating system, consumers are likely to avoid risks and high investments.

On the operators and professional sides, **experience is still lacking**. It is difficult for established actors to get away from their "business-as-usual" view. Moreover, they can enter in a **conflict of interest** with the consumers on the optimization of the grid, questioning the boundaries of the systems and the sharing of the responsibilities: if the system relies on cooling for balancing and the consumer does not want it, who is the one in charge?

One tool that can help develop low-temperature DHCSs are the **non-profit organizations** like energy communities or cooperatives. They engage with communities and are part of

the EU toolbox for the energy transition. Even more than such tools, there is a strong need for **success stories**, that can be spread and foster the shift.

One limit of low-temperature DHCSs for their global spread is their **capacity to adapt to existing building**, without major over costs. It can also necessitate lot of underground space (for storage), creating **conflict of interest with other uses of the underground**.

### **Economic aspects: Pricing and business model**

The main barrier to the establishment of the low-temperature DHCSs seems to be the **high investment coupled with high risks**. Indeed, the upfront costs are sizable and for some of the technical solutions (like geothermal) uncertainties on the level of heat the plant can supply remain until the drilling (which is costly by itself). These high investments can mean long payback time if the heat price is to remain affordable. It could also be solved by sharing the investments and risks, but this sharing is a challenge by itself: who would be the relevant partners? What level of risk are they willing to take? What is their expertise? To complicate even more this equation, some **costs** (investments and operational) **are not easily estimated** for now, as few systems are under operation. Their **control and optimization is complex**, introducing a variability on their economic feasibility (the better managed the system is, the better the business case will be). As the system is still not very well-known, **misjudged lifespans** of the different components and of the system as a whole can lead to wrong assumptions on the depreciation times and limiting the competitiveness of the network. Changing these lifespans can be tricky (due to regulations on the assumptions or on the contract duration for instance)

The system will also have to compete in a context of **heat market electrification**, with e.g. incentives for the implementation of individual air-to-water heat pumps. Moreover, these complex systems can be very **sensitive to energy prices volatility**, the latter threatening the economic equilibrium of the system.

However, low-temperature DHCSs are promising at many levels. The technology development may allow **economy of scales**, making the system more competitive. Once in place, it is likely to have **low operation costs and a high stability**, ensuring a long-term economic balance. The **use of surplus heat** allowed by the low supply temperature provides the system with low-cost heat. More than waste heat, low-temperature DHCSs could allow **synergies with other grids** (e.g., electricity grids, conventional DHSs). It can

**act as an energy storage**, giving more flexibility to the energy grid. Moreover, the demand is real, especially in places where conventional district heating cannot spread and where sustainable heating alternatives are demanded. Due to climate change, the cooling demand is also expanding and low-temperature DHCSs can **provide cooling without additional costs**, creating an economy of scope. The concept of low-temperature DHCS makes it easy for new consumers to connect to the network, improving the business case through the system extension. However, these extensions usually have to be through from the system design so that the pipes and other devices are rightly sized.

To reduce the implementation costs, a planning of the work can be done jointly with other utilities (electricity, water, fiber optic, etc.).

To help put in place the networks, there is for now a need for **incentives to secure the business model** and ensure the competitiveness of the solution. However, if the system becomes dependent on incentives and subsidies to be feasible, it may be difficult to expand it (// change in the taxation in Denmark threaten the economic equilibrium of plants and linked heat distribution). As low-temperature DHCSs give opportunities to foster synergies, an **adapted frame for such synergies** (with standardize contracts, clear processes, etc.) would help reach their full potential. Moreover, these systems for now struggle to attract investors, but the new EU taxonomy may help raise their interest if the stakeholders put on the right communication.

As for now, it seems that an adapted business model would depend on the setting up of new economic assumptions and contractual frames helping the stakeholders to think long-term (with longer contract duration aligned with the system lifespan) and balance CAPEX and OPEX (making it feasible to implement systems with high CAPEX and low OPEX).

### **Environmental impact**

The use of low-temperature DHCSs offer various advantages: the system has a **low level of emissions** as it can integrate multiple low-temperature heating sources (waste water, shallow geothermal, surplus heat, etc.), it can provide **environmental-friendly cooling**, it has a **high efficiency with little losses and can encourage a reduced consumption**. Moreover, geothermal-based low-temperature DHCSs can store excess heat in the ground, **mitigating the heat islands** in urban areas and could even be coupled with

rainwater management (with ponds under permeable roads, the water stored being also used as a heat source for the district heating).

However, the low-temperature DHCSs are **dependent on the available local sources**, and the expectations regarding the level of energy available are not always met. Moreover, **low TRL** (Technology Readiness Level) can slow down the development of the systems.

One main issue concerning low-temperature DHCS based on geothermal energy is the **management of groundwater and drinking water**. The excessive use of ground water for heating purposes can lead to conflicts and technical issues: e.g. possible icing of the probe, limited available heat for the neighboring heat pumps, thermal plume. The use of groundwater thermal storage may also impact underground micro-organisms and plants. The implementation of low-temperature DHCSs can have **other environmental impacts**: use of grey energy, air pollution during the work, etc.

Concerning groundwater management, an interesting practice could be introduced: **public interest and integrative urban groundwater management measures**. In Austria the rule for now is “first come, first served”. The technical and legal issues are to create thermal management plans to identify options to use the groundwater and give priority to heat extraction from urban heat islands. Four steps would be necessary 1) gain knowledge about the local groundwater, forecast the demand and the possible consequences of its uses; 2) design a regional management plan; 3) implement the plan and find the right operators; 4) ensure the monitoring of the groundwater use.

Moreover, putting in place a **EU Water Framework Directive with clear thermal thresholds for the groundwater** is another practice that could help the development of low-temperature DHCS.

### Design of the second workshop

The brainstorm of the first workshop did not go as far as expected. Technical issues hindered discussions, and participants took a lot of time to go through the material. It was thus chosen to focus the second workshop on a specific aspect of importance on the implementation of low-temperature DHCSs: the setting up of partnerships and contracts. Indeed, this aspect is of importance to formalize a network of stakeholders and implement innovative solutions. It is also used to secure a business model, with a sharing

of risks, investments and benefits. It was underlined during the first workshop but not tackled as such by the participants.

The idea of the second workshop was thus to create a situation of creativity to design innovative partnerships supporting the development of low-temperature DHCS. The pitch of the workshop is the following.

*“We are in 2025 in a major European city where a conventional district heating supplies the historical center. **The municipality took a commitment to become carbon neutral in 2040.** For the heating sector, the municipality wants to build on **cross-sector integration and develop low-temperature district heating and cooling systems** in the coming building blocks where conventional district heating cannot expand. The districts are **still to be built, and will mix housings, offices, and various shops and supermarkets.** You are experts on low-temperature district heating and cooling systems, invited by the municipality to help develop this ambitious “Heat Neutrality for 2040” plan. Today’s meeting is on **the partnerships and contracts** that would be needed in these new blocks: who will be the needed partners for the construction and operation? what are the important aspects of the partnership to consider?*

*Today’s focus will be on a **small future district, thought as an experimentation area. All regulations can be adapted** to the imagined solutions. The district will be planned with the principle of “15-min district”, meaning that everything like offices, shops, sports infrastructure will be 15min on foot or bicycle from the housing. The exact mix of buildings is still to be decided, and there is a flexibility as the city is planning other districts in the neighborhood for the future. The municipality wants a **heating mix 100% renewable.** They plan on using **large-scale heat pumps and surplus heat from the supermarket** but don’t really know where to begin. They already have in mind some relevant stakeholders: the housings and shops owners, DH operators, the supermarket owner, construction companies, heat pump providers, water management utilities, electricity providers. They now wonder what type of partnerships will be needed between the different stakeholders to make the heating and cooling system real...”*

The workshop was to be held on November, but was finally postponed to January 2022 due to the little number of participants available at the end of 2021. The invitation was sent to the mailing list of the first workshop (participants and interested people).

## *Low-temperature DHCSs—the network of stakeholders and their partnerships*

*Online workshop. January 12<sup>th</sup>, 2022*

*Organizer: Johanna Ayrault. Technical support: Frédéric Bonin*

*Participants to the workshop: Jessica Maria Chicco, Gregor Götzl, Vasiliki Gemeni, Aleksandr Zajacs, Soren Skjold Andersen*

The workshop was the continuation of a PESTLE/SWOT analysis and debriefing around the results of this analysis, held online on the October 14<sup>th</sup>, 2021. The invitation for the workshop was sent to all the participants or interested people of this first analysis. The date of the workshop had to be postponed (from November to January) due to the end-of-year deadlines forcing many people to decline the invitation.

The purpose of the workshop was to dig into one point raised during the first workshop as both an enabler and strength for future projects on low-temperature district heating and cooling systems (DHCSs), and a threat and barrier: partnerships. Indeed, cross-sector integration can be an advantage of low-temperature DHCSs compared to other heating and cooling solutions. Strong partnerships involving local actors (from industries to citizens) can be put in place and participate in local attractivity and resilience. However, these partnerships are not usual in the district heating sector for now, so they are not formalized and demand resources to be put in place.

Building on an imaginary situation, the purpose of the workshop was 1) to define the stakeholders that could be interesting to integrate into the design and operation of a low-temperature DHCSs; 2) create an imaginary possible organization of the stakeholders' network (making explicit their links, roles, responsibilities, etc.).

The given situation was the following:

*“We are in 2025 in a major European city where a conventional district heating supplies the historical center. **The municipality took a commitment to become carbon neutral in 2040.** For the heating sector, the municipality wants to build on **cross-sector integration and develop low-temperature district heating and cooling systems** in the coming building blocks where conventional district heating cannot expand. The districts are **still to be built,***



*and will mix housings, offices, and various shops and supermarkets. You are experts on low-temperature district heating and cooling systems, invited by the municipality to help develop this ambitious “Heat Neutrality for 2040” plan. Today’s meeting is on **the partnerships and contracts** that would be needed in these new blocks: who will be the needed partners for the construction and operation? what are the important aspects of the partnership to consider?*

*Today’s focus will be on a **small future district, thought as an experimentation area. All regulations can be adapted** to the imagined solutions. The district will be planned with the principle of “15-min district”, meaning that everything like offices, shops, sports infrastructure will be 15min on foot or bicycle from the housing. The exact mix of buildings is still to be decided, and there is a flexibility as the city is planning other districts in the neighborhood for the future. The municipality wants a **heating mix 100% renewable**. They plan on using **large-scale heat pumps and surplus heat from the supermarket** but don’t really know where to begin. They already have in mind some relevant stakeholders: the housings and shops owners, DH operators, the supermarket owner, construction companies, heat pump providers, water management utilities, electricity providers. They now wonder what type of partnerships will be needed between the different stakeholders to make the heating and cooling system real...”*

Some main characteristics were pointed out:

- District to be built – mix of housings, shops, offices still to be defined
- 100 % renewable low-temperature DHCS (heat pumps, surplus heat, etc.)
- Cross-sector integration (already a conventional DH nearby)
- Experimentation – no regulatory limits

As a basis, the following stakeholders were already identified as relevant: shop owners, house owners, DH operator, water management utilities, electricity provider, construction company (housing), municipality, supermarket, construction company (heat network), heat pumps provider.

The stakeholders were sticky notes on a Miro board. All the participants had access to the board and could brainstorm on it (add notes, add text, change colors/size/etc., add circles/squares/etc., add arrows and all type of links, etc.).

The following guidelines were given:

Step 1: Brainstorm on the needed partnerships between the stakeholders → Who need to be involved and what for?

Step 2: Dig into some of the partnerships → What type of contracts? What sharing of risks and investments? Etc.

The first step was mostly done individually on the Miro board, each participant adding the stakeholders they found relevant. A first attempt to organize this network launched some conversation to define stakeholders' categories. The final categories were the following: municipality (and all stakeholders responsible for creating the vision and concept), the consumers, the financing institutions, the developers, the building contractors, the energy providers and the service providers. For each role, a color was attributed, helping to visualize the network.

As some stakeholders could be part of several categories, it was decided to leave them white and specify their categories underneath. These categories were mostly roles within the project. The roles defined mainly stuck to usual technical roles within energy projects, and did not go into the details of their interactions, and possible innovations in their involvement. For instance, the citizens were pointed out as an important stakeholder, but weren't integrated into the process of design and operations.

To clarify the process of making the project and the roles, Gregor gave the idea to create altogether a story around the network.

*“The conventional DH operator cannot expand to the new district (due to technical limitations on the capacity and diameter of the pipes). However, it is interested to interact with the low-temperature network to be built, through a cascadic grid (to lower the temperature level of the conventional DH to the one of the future network). The future network would thus get 20% of its heat from the conventional DH and 80% through local resources. The municipality is willing to help in the making of this network and involves researchers and developers in the discussions. They ask for different scenarios, to choose the right technical solution achieving 100% renewable heating and cooling. The new houses and offices will be well insulated and all the users (residents, renters, etc.) want a comfortable home provided with heating and cooling. However, the property developers need to be involved, so that they are aware of what it means (technically, regulatory, etc.)*

*to be connected to a low-temperature network. On the regulation side, for the experimentation to scale-up, some actions to raise policy-makers' awareness were taken (for instance the need of specific regulation for groundwater in the case of shallow geothermal).*

*Once this first design step is made, comes the time for operations. The DH operator of the conventional network decides it would be interesting for him to be also in charge of the low-temperature one. He thus gives the municipality a proposal for the construction of this new network. The solution is of course the result of all the discussions around the scenarios made with all the stakeholders. The municipality of course agrees, and a public tender is launched for the actual construction of the grid. The DH operator would like a one-stop-shop contractor (which will take care of all the digging, contract-making with the energy sources, etc.). In the tender, it is specified that local manufacturers and energy providers are to be selected. However, the business model of the case is not so strong, so it is decided that only the basic infrastructures would be done first, financed by a loan taken by the DH operator (with very low interest as it is a public service). To pay back the loan, the network will be leased out to an energy contractor (in charge of operation and maintenance) for the first years of operation."*

This story showed the difficulties for the different participants to integrate stakeholders other than the most classical ones. The roles given to the stakeholders mainly came from what they had already seen (or hoped for) in projects, and did not get really innovative. The angle taken is strongly technical, and the "involvement" is never specified. If during the discussions it was mentioned that citizens could become investors in the network, their role was finally reduced to consumers (and maybe producers in specific cases).

From the discussions, it came out that 1) biomass was not considered as an interesting resource for urban heating (due to e.g., logistic issues, air pollution and the level of heating required for a biomass boiler to perform well compared to the level of demand of a low-temperature network); 2) the most important part for such projects is to have a clear head of the project creating the right technical solution (vision and concept) and the organization and financing will result from that.

All in all, this workshop allowed to create together a network of all the stakeholders that could be of interest for the design and operation of a low-temperature DHCSs. However, if the global roles of the stakeholders could be clarified, the specifications of their interactions between each other and how they were committing into the process of designing and operating the workshop was not completely tackled. Cross-sector integration also requires some interdisciplinarity, which is far from obvious to achieve. A lot of work is still to be done before having a good integration of low-temperature DHCSs into the heating and cooling market.

One barrier encountered was the small diversity of the stakeholders in the district heating world: all technical ones (researchers, operators, etc.). If they already had difficulties to talk with each other in the technical field, it became even more difficult when getting into non-technical aspects. One thing that came over often was *“once we have the right technical system it will work”* or *“this cannot be defined until we have the technical system”*. We see that the complexity of district heating is mainly seen through the lens of technical issues and solutions, and that organization come afterwards, as a logical consequence of technical aspects. It points out the lack of interdisciplinarity when talking about district heating, and the difficulties of going in the same direction when having different languages and angles.

Moreover, the participants of the workshop encountered difficulties to get creative in a given imaginary situation without all the specifications of the technical system. It would have thus required a specific design of the brainstorming session, and maybe some more preparation of the context with some participants or specialists ahead. The fact that the workshop was held online also made it difficult for the participants to interact and co-construct, each one staying within its comfort zone and building its own solution.



## ANNEX 6: Interview guide—AnergieUrban Lighthouse

### *PhD thesis: Transition towards sustainable district heating systems*

I am entering my third year of PhD in management, working on the transition towards sustainable district heating systems. I look at the instruments use to make this transition at two levels: 1) the project level with the business model and all supporting tools (contracts, indicators, etc.) 2) the market level with the public policies instruments (taxes, incentives, etc.). I study how the instruments are framed (what do they take into account) and how this framing may be challenged by other stakeholders or by the changing context. In particular I analyze how they go hand-in-hand with the valuation and governance processes.

The case study helps me understand the vision of a sustainable district heating, and what it takes to implement it (who needs to be involved, does it fit in the actual vision of sustainable heating, how to govern the stakeholders network created by the project, etc.)

### *Case study Vienna*

#### General information on the discussed case study

Name of the case study:

Number of households supplied:

Cooling offered (yes, no):

Status (in preparation—planned date of operation / in operation—since when):

#### Contractual and financial aspects

What partnerships need to be implemented (what type of flows between the partners, what type of contract, what risks, etc.)?

What type of financing is considered for the DH (are there public incentives, public loans, etc.)?

What type of pricing is considered? How will the economic equilibrium be ensured (obligation to connect, use of other sources, etc.)?

What are the expected and monitored performances? How will they be ensured/measured?

What are the lessons learned so far in your project–what would you do differently?

What would be scale-up?

### Governance and local engagement

How is the interaction with the city thought? (integration to energy planning, contract, authorization of work, etc.)

How is the local engagement thought (communication, authorizations, etc.) ?

How will the DH be governed? (consumers getting a vote, etc.)

To which regulation will the system fall under? (energy planning, urban planning, underground regulation, etc.). Is the system recognized as district heating?

What are the lessons learned so far in your project–what would you do differently?

**+ information on the current governance of Vienna DH system, their plans for the future and their interest in such project**

## ANNEX 7: Data collection–French instrumentation of district heating

Instruments				Framing		Stakeholders			
Name	Type	Description	Date	Intended effect	Underlying assumption	Designer	Quote / comment	Intended user	Quote / comment
Heat Fund	Policy tool	Subsidy to develop sustainable DH created during the Grenelle de l'Environnement roundtable	2009	Allow sustainable DH to be competitive	Sustainability > 50 % renewable or recovery heat  Competition with gas  Market regulation for “natural	ADEME	<i>“to speed up the development of renewable heat, there is a need for massive state aid to district heating”</i>  (head of the Heat Fund,	DH owner	Aid goes through the DH operators



					monopolies ”		own translation) <i>“for the projects to be profitable”</i> (head of the Heat Fund, own translation)		
ADEME subsidies	Policy tool	Multiple subsidies to support the lifecycle of the project (e.g., preliminary studies, feasibility studies)	Depend on the study (1026 for feasibility studies)	Support the capacity of local governments to develop DH	DH as a local concern	ADEME		Municipalities	Can be used by private actors (consulting groups, operators)

ADEME & Cerema guidelines	Calculation tool	Guidelines to help the municipalities (e.g., new regulation, frames for feasibility studies and getting subsidized, best practices)		Support the capacity of local governments to develop DH	DH as a local concern	ADEME & Cerema	Lack some human resource to help all the municipalities	Municipalities	
DH masterplans	Management tool	Ten-year masterplan (in the PCAET) outlining the evolution of DH (different scenario). Mandatory to	2015	Integrate DH into local planning	DH as a local concern	DH owner	Usually made hand-in-hand with the DH operator	DH owner and ADEME	DH owner: for the development of DH ADEME: to get subsidies

		be eligible to Heat Fund							
DH ranking	Policy tool	DH owner can make the connection to sustainable DH mandatory for new buildings or refurbished one in an area.	2012	Ensure the economic balance of the district heating by securing consumers	Sustainable: > 50% of renewable energy	Code de l'énergie	Lots of exemptions, should become automatic in 2022	DH consumers (mandatory connection) / DH owner & operator (help to optimize the network)	
Performance indicators	Management tool	Indicators to assess the DH system (technical, economic, etc.)		Assess the DH performance	Mainly technical and economic	Can come from various laws		DH owner & operator	Leave little room for innovation
Cost-benefit analysis	Calculation tool	Mandatory cost-benefit analysis on the	2014	Encourage the use of	Economic assumptions	Comes from a		DH owners (municipalities)	Does not help mitigate the

for industrial waste heat		integration of waste heat (if the heat is more than 80°C, the plant does not produce electricity and is close enough to the district heating) for district heating with more than 20MW.		industrial waste heat		European directive		es) & private operators	industrial risks for heat delivery. The instrument does not necessarily lead to any action.
Contracts	Management tool	Formalize the partnership (usually between the DH owner and the operator).		Define and secure the DH operation	Markets and competitors to regulate monopolies	Abide by regulations		DH operator & DH owner	Can be a barrier to innovation with other stakeholders

		Mainly Public Service Delegation Contracts							
Legal set-up	Management tool	Type of company created to operate the network (SA, SAS EnR, etc.)		Define the perimeter of the DH operator		Abide by regulations		DH operator	Can be a mix of private companies and public owners
Public market law	Policy tool	Define what is possible when doing a public bid	2006	Frame the actions for DH operators	Market regulation of public monopolies	Can be modified through laws	Not often readapted	DH owner & operators	Constraint the dialogs between the bidder and the competitors
RE2020 (previously RT 2012)	Policy tool	Environmental regulation (sets up obligation)	2020	Set up environment	Focus on decarbonation	Ministry of Ecological		Effect on all stakeholders of DH	Focuses more on improving

		for buildings, emission thresholds, etc.)		tal obligations		and Solidarity Transition			electricity instead of DH
GT Wargon	Policy tool	25 measures to develop the DHC sector. Outcome of a working group to identify and remove the barriers to the development of the sector	2019	Develop DH in France		Ministère de la Transition écologique et de la Cohésion des territoires Ministère de la Transition énergétique	Rely on the main stakeholders (ADEME, Cerema, etc.)	Effect on all stakeholders of DH	Little means to put it in place

SNBC	Policy tool	Gives the roadmap to achieve LTECV	2015 and revised in 2018-2019	Gives milestones to reach carbon neutrality		Ministère de la Transition écologique et de la Cohésion des territoires Ministère de la Transition énergétique		Effect on all stakeholders of DH	
PPE	Policy tool	Sets up intermediary targets before 2030: 1.35 Mtep in 2018, between 1.9	2016	Give milestones for the development of	Sustainable: > 50% of renewable energy	Ministère de la Transition écologique et de la Cohésion		Effect on all stakeholders of DH	

		and 2.3 Mtep by 2023 of renewable and recovery heat in DH		sustainable DH		des territoires Ministère de la Transition énergétique			
National Heat map	Calculation tool	Mapping of the heating and cooling demand, mapping of the heating offer (waste incineration plants, electric power plants, Combined Heat	2015 then 2020	Give quantified information to the DH developers	European assumption s, heat demand models	SETEC then Cerema	"De façon générale, cette cartographie doit être utilisée avec précaution, comme outil d'aide mobilisé très en amont des projets	Local actors (from regions to municipalities)	First version (2015) was not precise enough to be used by local actors



		and Power plants, DHC)					d'infrastructures ou de travaux" (ADEME, 2015)		
SRADDET	Management tool	Mandatory heat mapping and energy planning at the regional scale	2015	Integrate DH into regional energy planning	Sustainable: local interest	Law NOTRe	Law on the decentralization	Municipalities & regions	Hard for regions to do a comprehensive planning
PCAET	Management tool	Planning for energy efficiency and climate change mitigation measure at the scale of municipalities	2016	Integrate DH into local planning	Sustainable: local interest	LTECV		Municipalities	Supposed to be align with the PPE (national) & SRADDET (regional) but not

									always aligned
LTECV	Policy tool	Sets up a target of 39.5 TWh of renewable energy delivered by DH in 2030 (*5 compared to 2012). 3 actions: creation of new DH when it is economically and technically feasible; extension of existing DH; replacement of	2015	Give a target and frame to DH developers for the development of SDH	Sustainability > 50 % renewable or recovery heat  Competition with gas  DH as a local concern	Ministère de la Transition écologique et de la Cohésion des territoires  Ministère de la Transition énergétique		Effect on all stakeholders of DH	

		fossil-fuel by renewable and recovery energy. Give the capacity to municipalities or intercommunities for DH creation and operation. Set up the mandatory DH masterplan for DH owners.							
Tax reduction	Policy tool	Reduced VAT (from 20% to 5.5%) for DH with more than	2018?	Help the DH to be competitive	Sustainability > 50 % renewable	Code général des impôts		DH consumers	

		50% renewable or recovery energy (for the energy bill, not the subscription --> all DH benefit from the 5.5 VAT on the subscription)			or recovery heat  Competition with gas  Market regulation for "natural monopolies"				
CPE	Policy tool	Enhance the energy efficiency of buildings	2009	Incentive for refurbishment	State subsidies to reach energy objectives	Grenelle law 1			Can impact the DH consumers (not necessarily thought alongside with the DH

									developmne t)
CEE	Policy tool	Improve the energy efficiency	2005	Incentive to work on energy efficiency	State subsidies to reach energy objectives	Created with the first PPE			Can now gained when connecting to a DH
MAPTAM law & le NOTRe	Policy tool	Frame the capabilities of municipalities (e.g., perimeter of action when it comes to energy)	2014 - 2015	State the local responsibilities	DH as a local concern				Give more responsibilities with little tools to build capabilities
Agenda 21	Managem ent tool	Planning of municipalities around sustainable development						municipaliti es	One of the first tool where DH could be planned

									alongside with other energy vectso (local planning of the territory)
CO2 quota	Policy tool	Limited right to emit carbon	2009	Give a limited right to emit to various actors to incentivize for decarbonation	Carbon market	EU regulation		DH owners & operators	Not a constraint on DH. Can be distorted (packing quotas so that you don't have to limit your emissions later)

NPRU	Management tool	Subsidies and projects to refurbish and transform some urban areas	2014	Transform the urban areas		Agence Nationale pour la Rénovation Urbaine		Municipalities	Can be an opportunity to develop DH, but not always integrated into the planning
TICGN	Policy tool	Tax on natural gas. Limited for some industrials (cheap gaz)		Keep the industry competitive	State subsidy to support the industry			Industrials	Barrier to the commitment of industrials into DH
Climate and energy law	Policy tool	Give national objectives and action in the context of climate urgency	2019	Frame for the PPE	Renewable energies, energy efficiency and	Ministère de la Transition écologique et de la	Continuation of the LTECV, SNBC. Base for the PE		

		and Paris Accords			regulated gas & electricity markets	Cohésion des territoires Ministère de la Transition énergétique			
SCoT	Management tool	Regional urban planning	2000			Code de l'urbanisme		Regions and municipalities	Could be an opportunity to integrated DH into regional planning (link between urbanism and energy)



PLU	Management tool	Local urban planning	2000			SRU law	Should be compatible with the PLH		Could be an opportunity to integrated DH into local planning (link between urbanism and energy
PLH	Management tool	Local housing planning				Code de la construction et de l'habitation	Should be compatible with the SCoT		Can be a barrier to the development of DH when not thought together (demolished neighborhood

									od --> less DH clients)
Code de l'énergie	Policy tool	Define renewable energy and all the regulation around its production and operation	2011- 2015				Can be modified by different laws		Can be hard to align all the codes around DH (urbanism, housing, public market, etc.)



## ANNEX 8: Data collection collaborative and co-creation activities

### *Besançon*

Case study	Project	Stage of the lifecycle	Summary	Formal / informal	Quote	Stakeholders	Remarks	Data
Besançon	historical DH	procurement	Long-term contracts to secure local biomass supply	formal		suppliers (cooperatives and regional agencies), DH operator		SOVEN
Besançon	historical DH	operation	Strong relationship between the three stakeholders for each action	informal		DH owner, DH operator, national energy agency		SOVEN

Besançon	contract renewal	preparation	consultation of the consumers to have feedbacks before the contract renewal	formal		DH owner, DH operator, consumers, consultancu firms	the DH owner wants to go further than the legal obligation of consultation. Before, the DH operator had to make a survey but it is now mae by the DH owner helped by a consultancy firm	GBM - energy direction
Besançon	historical DH	operation	monthly public meetings to communicate on the DH operations	formal	<i>"all the consumers are invited at least once a year, but on the 100</i>	DH owner, DH operator, consumers		GBM - energy direction

					<i>consumers only about 20 usually come"</i>			
Besançon	contract renewal	preparation	align the urban planning and energy planning	formal		DH owner (urban planning direction & energy direction), DH operator	lack of communication leading to wrong sizing of the DH network	GBM - energy direction
Besançon	historical DH	operation	the DH owner has to create discussions between the stakeholders for problem-solving, even outside the boundaries of the DH network	informal	<i>"when there are troubles on the secondary network, the subscribers tend to call the city hall even if it's not his responsibility. The energy</i>	DH owner, consumers, building owners (?), secondary network operators (?)	doesn't want to extend the energy direction's role outside its boundary	GBM - energy direction

					<i>direction then has to play the referee and make people discuss even if it's not its role"</i>			
Besançon	historical DH	operation	The DH owner forces the DH operator to engage with the consumers through different communication channels	formal	<i>"to communicate with the consumers, there are monthly meetings with the DH operator, visit of the boiler rooms and information on the work"</i>	DH owner, consumers, DH operator	stays to the point of communication, not necessarily creation	GBM - energy direction

Besançon	historical DH	operation	Annual meeting to analyze the performance of the DH network	formal	<i>"reading of the annual report made by the DH operator and a debrief meeting on the results, that can lasts for 2h30-3h (but it lasted for a day before)"</i>	DH owner, DH operator	possible problem-solving and planning	GBM - energy direction
Besançon	contract renewal	preparation	To prepare the contract renewal, the DH owner created the specification bill (based on previous experience and	informal		DH owner, DH operator, consultancy firms		GBM - energy direction



			innovations) and a list of requirement the DH operator will be paid for. This list is made by the DH owner, but based on discussions with the current DH operator and validated by consultancy firms on to give them a legal ground					
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Besançon	historical DH	operation	The yearly results are communicated to the users through different channels: meetings, consultative commission	formal	<i>"once the report is analyzed, the financial commission and the CCSPL (consultative commission for local public services) verify it, and there is a presentation to the subscribers and representatives of the consumers in autumn. Usually, a meeting with the big consumers</i>	DH owner, DH operator, representatives of the consumers, commission, consumers	does not go to co-construction, but a strong attempt to integrate the consumers in the network	GBM - energy direction
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					<i>(social housing and hospital) is made in June."</i>			
Besançon	historical DH	operation	Local problem-solving to adapt national regulations to specific context	informal	<i>"On the indicators, we've negotiated with the DREAL to spend money on the most recent biomass-fired boilers rather than on upgrading the old fuel-fired ones we want to get rid off. We negotiated to</i>	DH owner, regional agency for environment, housing and agriculture		GBM - energy direction

					<p><i>have 2 small fuel boilers registered rather than one big boiler, because the indicators are more demanding on big boilers."</i></p>			
Besançon	historical DH	operation	Continuous dialog between the operator and the owner to solve problems, follow the performance of the network and discuss the	informal	<p><i>"the city is very present alongside us [the DH operator], they exchange about 2 or 3 emails per week, and they closely follow the process. [...]"</i></p>	DH owner, DH operator	very context-dependent (depend on the person responsible in the DH owner side) and the contacts with the other directions	Celsius

			future investments		<i>there are constructive dialogs."</i>		inside the DH owner are not easy	
Besançon	historical DH	operation	In the Public Service Delegation, the DH owner specifies different communication actions the DH operator has to do: website,	formal		DH owner, DH operator, citizens		Celsius - management

			open doors day, communication in high school careers event, stand at the urban raid					
Besançon	extension of the network	identification	co-construction of a DH roadmap, and then a energy roadmap to support the development of the networks and the synergies with other networks	formal		DH owner (energy direction, urbanism direction, environment direction and financial direction), national energy agency		ADEME - regional office

Besançon	historical DH	operation	To align with the ADEME requirements, the DH owner makes some concertation with the CCSPL and committee of users	formal	<i>"Besançon has a habit for concertation with the users, or at least to associate with them but they did not implement all the tools for concertation provided by the ADEME"</i>	DH owner, DH operator, citizens and users		ADEME - regional office
Besançon	historical DH	operation	A strength of Besançon is the strong technical expertise of the DH owner, but it	informal	<i>"the dialog needs to happen at a political level but also at a technical one"</i>	DH owner, DH operator		ADEME - regional office

			is not the case in many cities					
Besançon	extension of the network	identification	The different services of the DH owner try to work together for the local planning (including the energy and DH planning)	formal	<i>"the construction of the PCAET (climate, air, energy, local plan) is very transversal and designed with all the vice presidents that have a direction in the agglomeration: mobility, economy, culture, waste</i>	DH owner		GBM - environmental direction



					<i>management, environment, housing, etc.)"</i>			
Besançon	extension of the network	preparation	The environment service has planned several concertations to integrate the citizens in the design of the local planning	formal	<i>"the CDP (concil for participatory development) has taken the subject and wants to participate in the design of the climate plan"</i>	DH owner		GBM - environmental direction
Besançon	extension of the network	preparation	alignment between the services for the development of the DH network	informal	<i>"when the city wants to develop a DH, it has to be thought and set up with the metropolis"</i>	DH owner		Albea

## Dunkirk

Case study	Project	Stage of the lifecycle	Summary	Formal / informal	Quote	Stakeholders	Remarks	Data
Dunkirk	historical DH	identification	Project identification and first steps bore by a signe stakeholder. Use of a consulting firm to make the preliminary studies.	informal	"A l'époque, Pierre Radanne avait pointé du doigt les possibilités d'exploitation de chaleur fatale avec Usinor [...] la prospective a ensuite été portée principalement par l'AFME qui a engagé des études et	national energy agency, consulting firm	one actor having the idea	historical CUD

					<i>contacté à cet effet un bureau d'études."</i>			
Dunkirk	historical DH	preparation	Creation of a common identity gathering the municipalities around the project.	formal	<i>"Le SICURD a été créé spécialement pour le futur réseau de chaleur"</i>	3 municipalities		historical CUD
Dunkirk	historical DH	preparation	Technical meetings around the feasibility studies with all the technical stakeholders under the supervision of		<i>"Les parties prenantes se réunissaient à l'agence d'urbanisme de Dunkerque, qui était le chef d'orchestre du projet. C'était</i>	energy syndicate (municipalities), DH operator, industrial, national energy agency		ADEME

			the public authority.		<i>notamment des réunions techniques avec Dalkia. Les études de faisabilité ont été lancées, et régulièrement il y avait des réunions techniques à l'Agence Locale d'Urbanisme."</i>			
Dunkirk	historical DH	preparation	Attempt to secure the customers through preliminary discussions around the project.	informal	<i>"Il y a eu des discussions avec les organismes de logements collectifs qui se situaient sur le tracé du réseau."</i>	energy syndicate, DH operator, customers		ADEME

Dunkirk	historical DH	preparation (work)	Communication around the work for the citizens.	formal	<i>"Il y a eu une dimension de pédagogie, d'explications et de communication autour des travaux"</i>	energy syndicate, DH operator, citizens	top-down, not very collaborative	ADEME
Dunkirk	historical DH	preparation	Communication around the network for the customers.	formal	<i>Ils [les bailleurs sociaux] ont mis en place des réunions de quartier et produit des documents pour informer."</i>	social housing landlords, customers	top-down, not very collaborative	ADEME
Dunkirk	historical DH	operation	Collaboration to make the network resilient	informal	<i>"Il y avait une volonté collective de faire résister le</i>	energy syndicate, DH operator, industrial		ADEME

			to issues (financial balance): adaptation of the contract duration.		<i>réseau de chaleur malgré les difficultés économiques."</i>			
Dunkirk	historical DH	operation	Innovative projects proposals by the DH operator within the Public Service Delegation	informal	<i>"Dalkia [...] bougeait beaucoup en proposant des projets de récupération d'énergie."</i>	DH operator, intercommunalities		Engie
Dunkirk	historical DH	operation	Creation of tools to integrate the final users (heat supply cut, consumption, etc.).	formal	<i>"Des outils relation client se mettent en place via les opérateurs et les bailleurs sociaux acceptent</i>	social housing landlords, customers, DH operators, intercommunalities	final users can be "informed" but are not really "involved"	CUD

					<i>d'ouvrir la communication."</i>			
Dunkirk	expansion to Grande-Synthe	identification	Project identification by a single stakeholder integrating the municipality and intercommunality in the early stages.	informal	<i>"c'était un travail transverse, la ville a été associée au projet. Le maire de Grande-Synthe était politiquement initiateur du projet (et faisait partie à la fois de la ville et de la Communauté Urbaine de Dunkerque)."</i>	municipality, intercommunality	one actor having the idea	Grande-Synthe municipality

Dunkirk	expansion to Grande-Synthe	preparation	Coordination of the work by the municipality.	informal	<i>"ils [mairie de Grande-Synthe] sont plus partiellement prenante que la CUD en termes de coordination du chantier. Ce sont eux qui connaissent les voies et qui peuvent influencer les conditions du chantier"</i>	municipality, intercommunality, DH operator, contractors		Grande-Synthe municipality
Dunkirk	expansion to Grande-Synthe	preparation	Technical meetings around the feasibility studies with the			industrial, intercommunality, contracting authority support	studies were made by each stakeholders beforehand	ArcelorMittal



			technical stakeholders.					
Dunkirk	expansion to Grande-Synthe	preparation	Collaboration to make the pricing.	informal	<i>"Il y a d'abord eu des discussions entre la CUD et Arcelor, puis ils ont regardé la possibilité de subventions, avec l'ADEME et la CUD, et l'impact que cela allait avoir sur le prix de vente au consommateur"</i>	intercommunalité, industrial, national energy agency		ArcelorMittal
Dunkirk	expansion to	preparation	formal agreement on heat selling	formal	<i>"Une fois que le protocole de vente et de mise à</i>	industrial, intercommunalité		ArcelorMittal

	Grande-Synthe		procedure and sharing of responsibilities		<i>disposition était validé par tous, ils ont pu discuter de la répartition des respnsabilités de chacun et faire une convention avec la CUD."</i>	y, contracting authority support		
Dunkirk	expansion to Grande-Synthe	preparation	Impact of the expertise repartition on the trust creation.	informal	<i>"L'expertise technique est cette fois-ci chez les deux parties [...] Les premiers échanges ont été compliqués, mais une confiance relative a été retrouvée."</i>	industrial, DH operator		Engie

Dunkirk	expansion to Grande-Synthe	procurement	Set-up of the procurement.	formal	<i>"sur le montage il y avait un AMO et la CUD, ce sont eux qui ont retenu le maître d'ouvrage délégué"</i>	contracting authority support, intercommunality	Not so collaborative	Grande-Synthe municipality
Dunkirk	expansion to Grande-Synthe	procurement	No collaborative discussions for the procurement set-up. Check-in of the feasibility of the procurement set-up with some stakeholders.	formal	<i>"Il n'y a pas eu de discussion en amont de l'appel d'offre : il a été lancé par la collectivité avec son bureau d'études, sans consultation préalable des autres parties prenantes (mis à</i>	Contracting authority, intercommunality, industrial	Limited integration of the stakeholders	Engie

					<i>part entre la CUD et Arcelor pour validation de la source de chaleur et source de secours)"</i>			
Dunkirk	expansion to Grande-Synthe	preparation / operation (commercialization)	Communication made by the DH operator in the direction of the future customers.	formal	<i>"c'est Engie qui s'occupe de la commercialisation, mais avec l'appui de la ville pour identifier et cibler les nouveaux prospects" / "La communication était vraiment ciblée sur les potentiels clients"</i>	municipality, DH operator, customers	Limited "aucune consultation (no consultation)"	Grande-Synthe municipality

Dunkirk	expansion to Grande-Synthe	operation	Collaboration between the DH operator and the private operator for the operation of the network, possible integration of other stakeholders when relevant.	informal	<i>"ils [la CUD] ont réfléchi le projet avec Engie, par exemple sur des questions de recherche sur l'optimisation du réseau et de l'utilisation d'énergie renouvelable et de récupération. Même si en pratique ils [la mairie de Grande-Synthe] sont associés aux discussions, notamment en</i>	intercommunalité, DH operator, municipality		Grande-Synthe municipality
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					<i>cas de problème (ils sont clients à plus de 50 %)"</i>			
Dunkirk	expansion to Grande-Synthe	operation	Lack of expertise as a barrier for a collaborative discussions	formal	<i>"Les élus font face à des délégataires professionnels."</i>	intercommunalité, DH operator, contracting authority support		CUD
Dunkirk	renewal of the historical PSD	preparation	No collaborative discussions to decide the future of the network but decision based on studies involving the DH operator	formal	<i>"Les candidats à la délégation ne seront pas associés au processus de décision sur la forme d'exploitation du réseau."</i>	intercommunalité		CUD

*Ottawa*

Case study	Project	Stage of the lifecycle	Summary	Formal / informal	Quote	Stakeholders	Remarks	Data
Ottawa	PSD	operation	discussion each month based on a report made by the DH operator, for problem-solving	informal	<i>"there is a negotiation each month on the report and payment" "the reports are used to demonstrate the KPIs and discuss with the client. The problems are negotiated upfront during informal</i>	DH operator, DH owner		Engie

					<i>discussions. The meeting minutes can even be redacted together."</i>			
Ottawa	PSD	operation	monthly report on the KPIs resulting from the informal negotiation phase	formal		DH operator, DH owner		internal documents
Ottawa	PSD	preparation	building of relationships on the long-term to allow co-creation through all the project lifecycle	informal	<i>"an advantage is the very good relationship with the government. It's a relationship that was created during years, even before the</i>	DH operator, DH owner		Engie North America



					<i>procurement phase."</i>			
Ottawa	PSD	procurement	take into account inputs from the National Capital Commission on the solution design (2 presentations, and comments on the Draft Project Agreement)	formal	<i>"The PSPC team worked through several iteration of the design, each time responding to input from the staff and the ACPDR."</i>	contestant, DH owner		project website
Ottawa	PSD	procurement	6 confidential meetings with the contestants during the project design	formal	<i>"the purpose of Commercially Confidential Meetings is to provide a process</i>	contestant, DH owner		RFP

					<p><i>that foster open, candid and frank discussions between Canafa and each of the Proponents in order to enable Proponents to develop optimal solutions for the project."</i></p>			
Ottawa	PSD	operation	<p>communication with final users is done through several channels (website, etc.) and reported to the client each month</p>	formal		DH operator, users		internal documents

Ottawa	PSD	identification	long lasting discussions with different possible partners, to best design the bidding process	informal	<p><i>"a team from the Government of Canada came in France to study the opportunities of PPP 10 years ago."</i></p>	DH operators (future contestants and others), DH owner		Engie
					<p><i>"The Energy Service Acquisition Programme (ESAP) was established in 2009 to explore potentials new business models for the provision of energy services"</i></p>			RFP

					<i>in the National Capital Region."</i>			
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## Hornsyld

Case study	Project	Stage of the lifecycle	Summary	Formal / informal	Quote	Stakeholders	Remarks	Data
Hornsyld	Hornsyld	preparation	Integrate the stakeholders buiding the house into the collaborative network	informal	<i>"it will be up ot the contractor of the house to either figure out by himself how he wants to do that, or work in collaboration with us in the project on how to do it."</i>	Core team (VIA College, Geodrilling, Land & Plan, + ?), contractor (house builder)		Geodrilling
Hornsyld	Hornsyld	identification	Frame the expected outcomes of the	informal	<i>"this was the whole idea of the project: to make a shared system</i>	Core team		Geodrilling

			collaborative network		<i>where there was no shared system yet"</i>			
Hornsyld	Hornsyld	preparation	Writing a collaborative agreement on the governance of the network when it will be in operation	formal	<i>"the municipality makes this homeowners association on behalf of the future residents."</i>	Hedensted municipality, Geodrilling		Hedensted municipality
Hornsyld	Hornsyld	preparation	collaborative discussions with all the relevant stakeholders for framing the project and	informal	<i>"we should be able to do this, all the necessary partners are here, so let's just get on with it"</i>	Core team		Geodrilling

			problem-solving					
Hornsyld	Hornsyld	preparation	Geodrilling agreeing to bear most of the risks and costs. Other costs divided as "normal" costs for the partners + funds for research	informal	<i>"they [the municipality] have the impression that whenever there is a risk, there's always someone who's prepare to handle it."</i>	Core team		Geodrilling
Hornsyld	Hornsyld	operation	Lots of monitoring planned for the operation, to	formal		Core team?		Geodrilling

			gain experience					
Hornsyld	Hornsyld	preparation	Discussions to commit the future customers into the collaborative network	informal	<i>"the municipality explaining what is special about this road" "the municipality were very proactive and they understood that they have an important role beause the project is dependent upon these houses being built"</i>	Hedensted municipality, future consumers		Geodrilling
Hornsyld	Hornsyld	identification	Finding all the right partners	formal	<i>"VIA was the main driver for putting</i>	VIA College		Geodrilling



			for the project and integrating them into the project		<i>together the consortium"</i>			
Hornsylt	Hornsylt	identification	Trying to get all the stakeholders to get into the project (first attempt from VIA and then from the municipality)	informal	<i>"we had some conversations and the Hedented municipality wanted to attempt the project [...] could you please attend it because then we have a solution where we take all the supply into the project"</i>	VIA College, Hedensted municipality, water utility		Hedensted waste water company

Hornsyld	Hornsyld	preparation	Discussing with all the partners to really design the project and give life to the pre-identified ideas	informal	<i>"I know that Theis and Soren had some ideas, long before we got together. But how it should be done, wasn't really scheduled at that time. It was more discussions around the table with the municipality, us, NCC, hwich is a contractor."</i>	VIA College, Hedensted municipality, water utility, NCC		Hedensted waste water company
Hornsyld	Hornsyld	preparation	Aligning the interests of all stakeholders (done by the	informal	<i>"All the companies have their own interest [...] put us</i>	VIA College, Hedensted municipality,		Hedensted waste water company

			project leaders, VIA College)		<i>together is hard : how can we come up with something new. That's on their shoulders, that was their job."</i>	water utility, NCC		
Hornsyld	Hornsyld	preparation	Collaborative and exploratory mindset	informal	<i>"all the companies have been very good at saying, 'OK let's do this, we don't know where we will end, we don't know what our end costs will be with the project, but we have to do something</i>	Geodrilling, NCC, Hedensted municipality, water utility		Hedensted waste water company

					<i>different from today in the future, so let's try it out."</i>			
Hornsyld	Hornsyld	preparation	Good collaborative environment	informal	<i>"the working environment in the group is very very good"</i>	VIA college, Geodrilling, NCC, Hedensted municipality, water utility		Hedensted waste water company
Hornsyld	Hornsyld	preparation	setting and managing collaborative discussions to share the investments	informal	<i>"there were discussions on how to do it and how to share the investments"</i>	VIA college, Geodrilling, NCC, Hedensted municipality, water utility		VIA College University
Hornsyld	scaling-up	identification	internal experience learning for	informal	<i>"I think we'll try to scale it up [...] told him about this"</i>	NCC		NCC

			scaling up and translate it into their partnerships		<i>one, about what we had done together with VIA"</i>			
Hornsylid	Hornsylid	identification	expression of motivation for a collaborative project	informal	<i>"And actually, in Hedensted we were very happy because we found that we would like to make another project as soon as possible. And of course, we said that to VIA and all our others partners and friends. And that's why you know, we sort of together</i>	Hedensted municipality; VIA College; otherS?		Hedenstad municipality

					<i>actually made this new project in a housing area."</i>			
Hornsyld	Hornsyld	preparation	discussions to find the right ownership sharing	formal	<i>"What I've found has been difficult is that we have to find a new way of ownership for a road like this."</i>	VIA college, Geodrilling, NCC, Hedensted municipality, water utility		Hedenstad municipality
Hornsyld	Hornsyld	preparation	collective problem-solving with consultants, contactors and all the stakeholders	informal	<i>"we were lucky to have consultants and constructors that were willing to go into this type of projects ,and also willing to find solutions</i>	VIA college, Geodrilling, NCC, Hedensted municipality, water utility, Land & Plan		Hedenstad municipality

					<p><i>together with us"</i></p> <p><i>"One thing is that we were able to make this in that project because there were some good people together."</i></p>		
Hornsyld	Hornsyld	preparation	calls to build the relationship and commit into the project	informal		Land & Plan, VIA College	Land&Plan
Hornsyld	Hornsyld	preparation	collective discussions to explain and discuss the project	formal		VIA college, Geodrilling, NCC, Hedensted municipality,	Land&Plan

						water utility, Land & Plan		
Hornsyld	Hornsyld	preparation	manage the stakeholders network and identify and commit all the right contractors	informal	<i>"So, they did hire me and I think, when I speak to Soren today, the main part is to make a very very big effort. My success in this was I gave myself time and effort to listen to people, and making understand. "</i>	Land & plan, contractors		Land&Plan



Hornsyld	Hornsyld	procurement	design the tendering process to get contractors who can work collaboraitve	formal	<i>"Yeah everything. I picked them myself because I didn't want to just get someone outside that I didn't know. I needed to know that they are, they have capacity and they have the cooperation."</i>	VIA College, Land & plan, contractors		Land&Plan
Hornsyld	Hornsyld	operation	make all the contractors work in the same direction	informal	<i>"So, I have a different people, with different interest, I need to sew them all together and make them work."</i>	Land & plan, contractors		Land&Plan

					<i>Because if only one resist, and wants to do it his own way and resist, it can damage all the process."</i>			
Hornsyld	Hornsyld	preparation	identify the right contractors	informal	<i>"it's not all about the money, about the technical part, it's also about planning the perfect project and picking out the right people, putting effort in the right places at the right times"</i>	Land & plan, contractors		Land&Plan



## Helsinki

Case study	Project	Stage of the lifecycle	Summary	Formal / informal	Quote	Stakeholders	Remarks	Data
Helsinki	Helsinki Energy Challenge	Preparation	will to encourage transversality to solve the municipality issues (Q&A sessions, webinars showing cooperation projects, etc.)	informal	<i>"HEC webinars and other online events, organised during the application phase, are opportunities to learn more about the Challenge and to network with the others who are interested in the Challenge and to find new</i>	all applicants, HEC team		<a href="#">HEC website</a>

					<i>members to partner with."</i>			
Helsinki	Helsinki Energy Challenge	Preparation	learning process and feedbacks	formal	<i>"This webinar will focus on the lessons learnt though the challenge competition process"</i>	open to all		<a href="#">HEC website</a>
Helsinki	Helsinki Energy Challenge	Preparation	organization of a "co-creation" boot camp with meetings with relevant stakeholders	formal	<i>"Shortlisted teams will work to develop and fine-tune their proposals during the co-creation phase, which includes</i>	3 members of the shortlisted teams (or more but expenses not covered), local industry experts, representatives	no integration of the final users...	<a href="#">HEC website</a>

					<p><i>webinars, teams' individual work and a three-day boot camp in Helsinki. During the boot camp, the teams will have joint sessions with all participants, local industry experts and representatives from the City of Helsinki [...] there will be one-on-one meetings with selected industry experts</i></p>	<p>from the city of Helsinki and the city-owned energy company</p>		
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					<i>and time dedicated to the teams' own work."</i>			
Helsinki	Helsinki Energy Challenge	Preparation	Q&A sessions during all the duration of the challenge, with all answers published on the website	formal		all applicants, HEC team		<a href="#">HEC website</a>

## ANNEX 9: Coded data for collaborative and co-creation activities

Stage of the lifecycle	Case study	Project	Summary	Formal / informal	Stakeholders	Code 1 (co-creation activity)	Code 2 (literature)	Code 3 (main co-creation activity)
identification	Besançon	extension of the network	Co-construction of a DH roadmap, and then a energy roadmap to support the development of the networks and the synergies with other networks	formal	DH owner (energy direction, urbanism direction, environment direction and financial direction), national energy agency	Tool co-construction	Resource acquisition	Defining the collaborative governance



identification	Besaçon	extension of the network	The different services of the DH owner try to work together for the local planning (including the energy and DH planning)	formal	DH owner (different services)	Collaborative tool construction	Resource acquisition	Defining the collaborative governance
preparation	Besaçon	extension of the network	The environment service has planned several concertations to integrate the citizens in the design of the local planning	formal	DH owner	Concertation with citizens	Determining the core values	Setting up a collaborative network
preparation	Besaçon	contract renewal	consultation of the consumers to have feedbacks before	formal	DH owner, DH operator, consumers,	Public consultation	Measuring user	Assessing and learning from

			the contract renewal		consultancy firms	n with final consumers	satisfaction	project outcomes
preparation	Besançon	contract renewal	To prepare the contract renewal, the DH owner created the specification bill (based on previous experience and innovations) and a list of requirements the DH operator will be paid for. This list is made by the DH owner, but based on discussions with	informal	DH owner, DH operator, consultancy firms	creating a list of services and requirements	Defining collaborative value capture	Defining the collaborative governance

			the current DH operator and validated by consultancy firms on to give them a legal ground					
procurement	Besaçon	historical DH	Long-term contracts to secure local biomass supply	formal	suppliers (cooperatives and regional agencies), DH operator	Contracting to secure long-term partnerships	Forging initial agreements	Defining the collaborative governance
operation	Besaçon	historical DH	Strong relationship between the three	informal	DH owner, DH operator, national	Collective problem-solving	Co-creation dialog	Setting up a collaborative network

			stakeholders for each action		energy agency			
operation	Besaçon	historical DH	Continuous dialog between the operator and the owner to solve problems, follow the performance of the network and discuss the future investments	informal	DH owner, DH operator	Discussions for collective problem-solving	Co-creation dialog	Setting up a collaborative network
operation	Besaçon	historical DH	The DH owner has to create discussions between the stakeholders for problem-solving,	informal	DH owner, consumers, building owners (?), secondary	Collaborative problem solving	Co-creation dialog	Setting up a collaborative network

			even outside the boundaries of the DH network		network operators (?)			
operation	Besaçon	historical DH	Monthly public meetings to communicate on the DH operations	formal	DH owner, DH operator, consumers	Communication to final users	Reporting	Assessing and learning from project outcomes
operation	Besaçon	historical DH	The DH owner forces the DH operator to engage with the consumers through different communication channels	formal	DH owner, consumers, DH operator	Communication to final users on the DH network	Distributing information	Setting up a collaborative network

operation	Besaçon	historical DH	To align with the ADEME requirements, the DH owner makes some concertation with the CCSPL and committee of users	formal	DH owner, DH operator, citizens and users	Concertation with final users	Determining the core values	Setting up a collaborative network
operation	Besaçon	historical DH	The yearly results are communicated to the users through different channels: meetings, consultative commission	formal	DH owner, DH operator, representatives of the consumers, commission, consumers	Communication to final users on the DH network performance	Reporting	Assessing and learning from project outcomes
operation	Besaçon	historical DH	Annual meeting to analyze the	formal	DH owner, DH operator	Debriefing on the DH network	Assessment and	Assessing and learning from

			performance of the DH network			performances	evaluation	project outcomes
operation	Besançon	historical DH	Local problem-solving to adapt national regulations to specific context	informal	DH owner, regional agency for environment, housing and agriculture	Negotiations to define local framing	Arbitrating model	Defining the collaborative governance
preparation	Hornsyld	Hornsyld	Integrate the stakeholders building the house into the collaborative network	informal	Core team (VIA College, Geodrilling, Land & Plan, + ?), contractor (house builder)	Building relationships with relevant stakeholders	Aligning partners on shared purpose	Setting up a collaborative network
identification	Hornsyld	Hornsyld	Frame the expected outcomes of the	informal	Core team	Identifying the values	Identify value cocreation	Defining the collaborative governance

			collaborative network				opportunities	
preparation	Hornsyld	Hornsyld	Writing a collaborative agreement on the governance of the network when it will be in operation	formal	Hedensted municipality, Geodrilling	formalizing a collaborative agreement	Forging initial agreements	Defining the collaborative governance
preparation	Hornsyld	Hornsyld	colaborative discussions with all the relevant stakeholders for framing the project and problem-solving	informal	Core team	collaborative problem-solving	Co-creation dialog	Setting up a collaborative network



preparation	Hornsyld	Hornsyld	Geodrilling agreeing to bear most of the risks and costs. Other costs divided as "normal" costs for the partners + funds for research	informal	Core team	sharing of risks	Risk governance	Defining the collaborative governance
operation	Hornsyld	Hornsyld	Lots of monitoring planned for the operation, to gain experience	formal	Core team?	monitoring	Monitoring	Assessing and learning from project outcomes
preparation	Hornsyld	Hornsyld	Discussions to commit the future customers into the collaborative network	informal	Hedensted municipality, future consumers	committing the end customers	Building relationships	Setting up a collaborative network

identification	Hornsyld	Hornsyld	Finding all the right partners for the project and integrating them into the project	formal	VIA College	Find and commit partners	Identifyin g and selecting partners	Setting up a collaborative network
identification	Hornsyld	Hornsyld	Trying to get all the stakeholders to get into the project (first attempt from VIA and then from the municipality)	informal	VIA College, Hedensted municipality, water utility	Find and commit partners	Identifyin g and selecting partners	Setting up a collaborative network
preparation	Hornsyld	Hornsyld	Discussing with all the partners to really design the project and give life to the pre-identified ideas	informal	VIA College, Hedensted municipality, water utility, NCC	discussions from problem solving	Co-creation dialog	Setting up a collaborative network

preparation	Hornsyld	Hornsyld	Aligning the interests of all stakeholders (done by the project leaders, VIA College)	informal	VIA College, Hedensted municipality, water utility, NCC	discussions to align interests	Articulation and alignment of expectations	Setting up a collaborative network
preparation	Hornsyld	Hornsyld	Collaborative and exploratory mindset	informal	Geodrilling, NCC, Hedensted municipality, water utility	commitment into the project	Building trust and personal relationships	Setting up a collaborative network
preparation	Hornsyld	Hornsyld	Good collaborative environment	informal	VIA college, Geodrilling, NCC, Hedensted municipality, water utility	good network culture	Building trust and personal relationships	Setting up a collaborative network

preparation	Hornsyld	Hornsyld	setting and managing collaborative discussions to share the investments	informal	VIA college, Geodrilling, NCC, Hedensted municipality, water utility	sharing the investments	Risk governance	Defining the collaborative governance
identification	Hornsyld	scaling-up	internal experience learning for scaling up and translate it into their partnerships	informal	NCC	internal discussions on potential scaling up	Social learning	Assessing and learning from project outcomes
identification	Hornsyld	Hornsyld	expression of motivation for a collaborative project	informal	Hedensted municipality; VIA College; otherS?	discussions to frame a project	Identifyin g need and articulating intent to collaborate	Setting up a collaborative network

preparation	Hornsyld	Hornsyld	discussions to find the right ownership sharing	formal	VIA college, Geodrilling, NCC, Hedensted municipality, water utility	sharing the ownership	Risk governance	Defining the collaborative governance
preparation	Hornsyld	Hornsyld	collective problem-solving with consultants, contactors and all the stakeholders	informal	VIA college, Geodrilling, NCC, Hedensted municipality, water utility, Land & Plan	collaborative discussions for problem-solving	Co-creation dialog	Setting up a collaborative network
preparation	Hornsyld	Hornsyld	calls to build the relationship and commit into the project	informal	Land & Plan, VIA College	discussion to commit into the project	Building trust and personal relationships	Setting up a collaborative network

preparation	Hornsyld	Hornsyld	collective discussions to explain and discuss the project	formal	VIA college, Geodrilling, NCC, Hedensted municipality, water utility, Land & Plan	collective framing of the project	Co-creation dialog	Setting up a collaborative network
preparation	Hornsyld	Hornsyld	manage the stakeholders network and identify and commit all the right contractors	informal	Land & plan, contractors	identify and commit the right actors	Identifyin g and selecting partners	Setting up a collaborative network
procurement	Hornsyld	Hornsyld	design the tendering process to get contractors who can work collaboraitve	formal	VIA College, Land & plan, contractors	identify and commit the right actors	Identifyin g and selecting partners	Setting up a collaborative network

operation	Hornsyld	Hornsyld	make all the contractors work in the same direction	informal	Land & plan, contractors	align the interest and govern the contractors	Aligning partners on shared purpose	Setting up a collaborative network
preparation	Hornsyld	Hornsyld	identify the right contractors	informal	Land & plan, contractors	identify and commit the right actors	Identifyin g and selecting partners	Setting up a collaborative network
Preparation	Helsinki	Helsinki Energy Challenge	will to encourage transversality to solve the municipality issues (Q&A sessions, webinars showing cooperation projects, etc.) through webinars and online events	informal	all applicants, HEC team	create a network with all participants	Building relationships	Setting up a collaborative network

Preparation	Helsinki	Helsinki Energy Challenge	webinar on learning process and feedbacks	formal	open to all	experience sharing and learning process	Social learning	Assessing and learning from project outcomes
Preparation	Helsinki	Helsinki Energy Challenge	organization of a "co-creation" boot camp with meetings with relevant stakeholders	formal	3 members of the shortlisted teams (or more but expenses not covered), local industry experts, representatives from the city of Helsinki and the city-owned	three-day co-creation boot camp on the proposition	Co-creation dialog	Setting up a collaborative network



					energy company			
Preparation	Helsinki	Helsinki Energy Challenge	Q&A sessions during all the duration of the challenge, with all answers published on the website	formal	all applicants, HEC team	Q&A sessions	Interaction and dialog	Setting up a collaborative network
operation	Ottawa	PSD	discussion each month based on a report made by the DH operator,	informal	DH operator, DH owner	Negotiation for problem-solving	Co-creation dialog	Setting up a collaborative network

			for problem-solving					
operation	Ottawa	PSD	monthly report on the KPIs resulting from the informal negotiation phase	formal	DH operator, DH owner	Reporting on the KPI	Reporting	Assessing and learning from project outcomes
preparation	Ottawa	PSD	building of relationships on the long-term to allow co-creation through all the project lifecycle	informal	DH operator, DH owner	Discussions to build a relationship	Building trust and personal relationships	Setting up a collaborative network
procurement	Ottawa	PSD	take into account inputs from the National Capital Commission on the solution design (2	formal	contestant, DH owner	Dialog on the propositions	Interaction and dialog	Setting up a collaborative network

			presentations, and comments on the Draft Project Agreement)					
procurement	Ottawa	PSD	6 confidential meetings with the contestants during the project design	formal	contestant, DH owner	Dialog to help design the propositions	Interaction and dialog	Setting up a collaborative network
operation	Ottawa	PSD	communication with final users is done through several channels (website, etc.) and reported to the client each month	formal	DH operator, users	Communication and reporting from final users	measuring user satisfaction	Assessing and learning from project outcomes

operation	Ottawa	PSD	communication with final users is done through several channels (website, etc.) and reported to the client each month	formal	DH operator, users	Communication and reporting from final users	Distributing information	Setting up a collaborative network
identification	Ottawa	PSD	long lasting discussions with different possible partners, to best design the bidding process	informal	DH operators (future contestants and others), DH owner	Preliminary discussions	Knowledge and idea sharing	Setting up a collaborative network
identification	Dunkirk	historical DH	Project identification and first steps bore by a single stakeholder. Use of a consulting	informal	national energy agency, consulting firm	Gathering of relevant stakeholders	Identifying need and articulating intent to	Setting up a collaborative network

			firm to make the preliminary studies.				collaborate	
preparation	Dunkirk	historical DH	Creation of a common identity gathering the municipalities around the project.	formal	3 municipalities	Creation of a common entity	Developing structural and procedural governance	Defining the collaborative governance
preparation	Dunkirk	historical DH	Technical meetings around the feasibility studies with all the technical stakeholders under the		energy syndicate (municipalities), DH operator, industrial, national	Stakeholders' meetings to frame the project - collaborative problem-solving	Co-creation dialog	Setting up a collaborative network

			supervision of the public authority.		energy agency			
preparation	Dunkirk	historical DH	Attempt to secure the customers through preliminary discussions around the project.	informal	energy syndicate, DH operator, customers	Discussions to commit customers	Identifyin g and selecting partners	Setting up a collaborative network
preparation (work)	Dunkirk	historical DH	Communication around the work for the citizens.	formal	energy syndicate, DH operator, citizens	Communica tion to citizens	Distributi ng informati on	Setting up a collaborative network
preparation	Dunkirk	historical DH	Communication around the network for the customers.	formal	social housing landlords, customers	Neighborho od meetings to communica	Distributi ng informati on	Setting up a collaborative network

						te on the network		
operation	Dunkirk	historical DH	Collaboration to make the network resilient to issues (financial balance): adaptation of the contract duration.	informal	energy syndicate, DH operator, industrial	Adapting the governance through collaborative problem-solving	Risk governance	Defining the collaborative governance
operation	Dunkirk	historical DH	Innovative projects proposals by the DH operator within the Public Service Delegation	informal	DH operator, intercommunality	Propose innovative projects	Identifyin g need and articulating intent to collaborate	Setting up a collaborative network

operation	Dunkirk	historical DH	Creation of tools to integrate the final users (heat supply cut, consumption, etc.).	formal	social housing landlords, customers, DH operators, intercommunality	involvement of the final users through tools	Managing incentives	Defining the collaborative governance
identification	Dunkirk	expansion to Grande-Synthe	Project identification by a single stakeholder integrating the municipality and intercommunality in the early stages.	informal	municipality, intercommunality	Dialog with stakeholders to create a project	Identifying need and articulating intent to collaborate	Setting up a collaborative network
preparation	Dunkirk	expansion to Grande-Synthe	Coordination of the work by the municipality.	informal	municipality, intercommunality, DH operator, contractors	Coordination of the contractors	Aligning partners on shared purpose	Setting up a collaborative network



preparation	Dunkirk	expansion to Grande-Synthe	Technical meetings around the feasibility studies with the technical stakeholders.		industrial, intercommunality, contracting authority support	Strategic meeting on the project design (technical)	Co-creation dialog	Setting up a collaborative network
preparation	Dunkirk	expansion to Grande-Synthe	Collaboration to make the pricing.	informal	intercommunality, industrial, national energy agency	strategic meeting on the project design (pricing)	Co-creation dialog	Setting up a collaborative network
preparation	Dunkirk	expansion to Grande-Synthe	formal agreement on heat selling procedure and sharing of responsibilities	formal	industrial, intercommunality, contracting authority support	sharing of the responsibilities	Risk governance	Defining the collaborative governance

preparation	Dunkirk	expansion to Grande-Synthe	Impact of the expertise repartition on the trust creation.	informal	industrial, DH operator	creating relationships	Building legitimacy	Setting up a collaborative network
procurement	Dunkirk	expansion to Grande-Synthe	Set-up of the procurement.	formal	contracting authority support, intercommunality	Set-up of the procurement	Forging initial agreements	Defining the collaborative governance
preparation / operation (commercialization)	Dunkirk	expansion to Grande-Synthe	Communication made by the DH operator in the direction of the future customers.	formal	municipality, DH operator, customers	Dialog with customers	Distributing information	Setting up a collaborative network
operation			Collaboration between the DH operator and the private operator for the operation	informal	intercommunality, DH operator, municipality	Strategic discussions for problem-solving	Co-creation dialog	Setting up a collaborative network

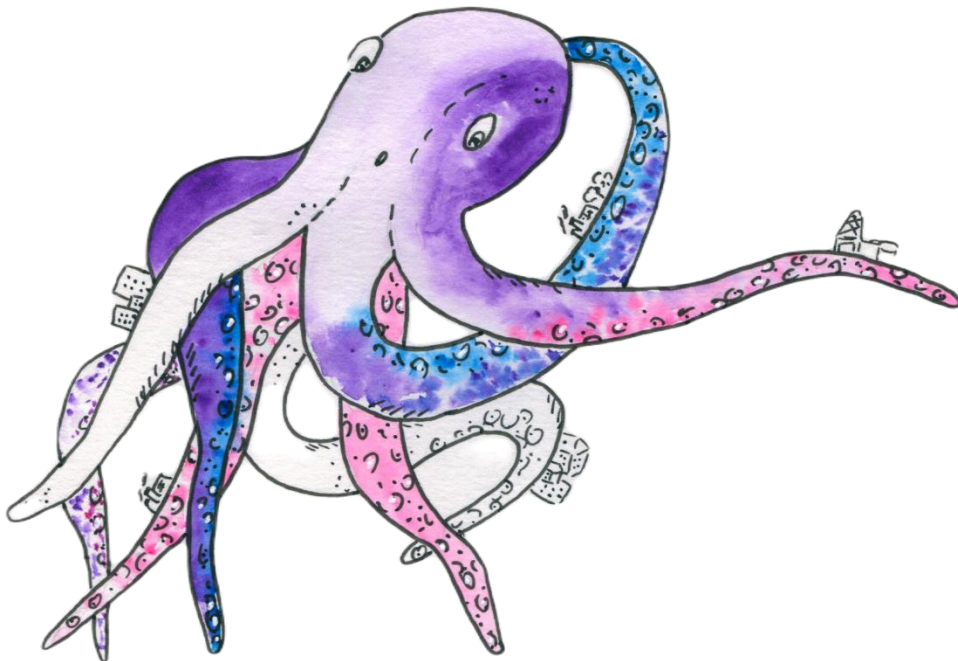
			of the network, possible integration of other stakeholders when relevant.					
preparation			No collaborative discussions to decide the future of the network but decision based on studies involving the DH operator	formal	intercommunality	Strategic discussions on the performance of the network	Assessment and evaluation	Assessing and learning from project outcomes





*“L’ignorance reste la condition sine qua non de l’importance d’un savoir. Puis ce dernier  
deviendra à son tour source d’ignorance... Et la Science chemine sereinement vers  
l’inconnu.” (Hanitra R.)*

*“Ignorance remains the sine qua non condition of a knowledge’s importance. In its turn  
this knowledge will become a source of ignorance... And Sciences moves serenely  
towards the unknown.” (own translation)*



## RÉSUMÉ

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Dans cette thèse, j'étudie la création d'infrastructures durables à travers les réseaux de chaleur. En devenant plus durables, ces systèmes deviennent également plus dépendants des ressources locales - comme la biomasse - et des acteurs locaux - comme des producteurs de chaleur locaux. J'étudie deux processus qui se déroulent autour du chauffage urbain durable. Premièrement, un processus de valuation où les acteurs tentent de définir et de valoriser de nouvelles caractéristiques du système - par exemple l'amélioration de l'attractivité locale. Deuxièmement, un processus de co-création au travers duquel plusieurs acteurs du projet innovent collectivement. Ces deux processus impliquent que les acteurs s'engagent dans trois activités : le cadrage, l'instrumentation et le développement d'expertise. Le cadrage est un moyen de définir le périmètre du chauffage urbain durable. L'instrumentation signifie que les acteurs adaptent et utilisent des instruments pour soutenir leur vision du chauffage urbain durable - par exemple des indicateurs de performance. Enfin, le développement de l'expertise englobe à la fois la création de connaissances et l'adaptation de dispositifs et d'institutions.

## MOTS CLÉS

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Infrastructures durables, valuation, co-création

## ABSTRACT

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In this PhD, I study the making of sustainable infrastructures through the example of district heating. When aiming at sustainability, these collective heating systems become more dependent on local resources such as biomass, and local actors such as like suppliers for local heat production means, or citizens acting on their consumption. I study two processes taking place around sustainable district heating. First, a valuation process where actors try to define and value new characteristics of the system e.g., local anchorage and improved local attractiveness. Second, a co-creation process where several project actors collectively innovate. Both these processes involve the actors engaging in three activities: framing, instrumenting and building expertise. Framing is a way to define the perimeter of sustainable district heating: What is considered sustainable district heating? Instrumenting means that the actors adapt and use instruments such as performance indicators to support their vision of sustainable district heating. Finally, building expertise encompasses both knowledge creation and all the tailoring of devices and institutions to make it perform.

## KEYWORDS

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Sustainable infrastructures, valuation studies, public sector co-creation