AN INDUSTRIAL ECOLOGY PERSPECTIVE ON SUSTAINABLE BUSINESS MODELS: THE CASE OF SUSTAINABLE DISTRICT HEATING

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Abstract

The district heating (DH) market is undergoing a change with the emergence of Sustainable District Heating (SDH), based on renewable locale resources, as a building block for a local ecological transition. However, research on DH tends to focus on technological solutions to support this transition. Business models, especially innovative and sustainable business models (SBM) are overlooked although management scholars have stressed they played a key role in ecological transitions. SDH have a strong local anchorage with the integration of multiple stakeholders to the BM since resources at stake may be varied and require strong coordination and the setting of governance mechanisms to build durable networks. The complexity of such networks is well described on the industrial ecology literature. To what extent the industrial ecology framework may help to design another perspective on SBM for DH at a local scale? To answer this question we analyze two French DH case studies that were pioneers in the integration of renewable heat to their energy mix. We stress how the introduction of a *new value proposition*, based on sustainable concerns, can change the set of *resources and competences* and *organization* (both internal and external), which according to Demil and Lecocq (2010) represent the three pillars in dynamic interaction of a BM. We also study this change through the industrial ecology framework (Brullot, 2009), especially focusing on the *design of a shared imaginary* and *governance* as two aspects ensuring the durability of the SBM.

Keywords: industrial ecology – sustainable business models – district heating

1. Introduction

District heating (DH) refers to a heat production unit and its distribution network. It comprises a great variety of technologies and network typologies. In this communication we focus on DH as a public infrastructure, owned by a public body and operated by a private company on behalf of this public body. This private company is chosen through a call for tenders and the delegation contract can last for decades, during which the private company will manage the production facilities and the heat transport towards Energy Transfer Stations that feed the buildings and final clients.

DH systems have undergone a first evolution in the 2000s, with the raise of environmental concerns. To answer this concern, solutions were initially found in technology, with the implementation of "greener" sources for heat production (biomass, solar panels, geothermal energy, waste, etc.). The actual definition for "sustainable district heating" (SDH) in France is a DH with more than 50 % of renewable and recovery sources in their energy mix (SNCU, 2020). In international energy studies, DH is beginning to be seen as an essential building block of the ecological transition (UNEP, 2020). But the solutions studied focus on the technical aspects of this transition: new green and local sources, low-temperature DH, thermal storage, etc. (Shaffer et al., 2018 ; Schmidt, 2018). This technical approach encountered some limitations and difficulties to lower at the expected pace the share of fossil fuels.

However, different voices have expressed the idea that an ecological transition requires more than technical solutions (Lygnerud, 2018; Lygnerud et al., 2019). As long as heating performance is measured in terms of cost and continuity of supply, there are very few chances for sustainable solutions to be selected. To encourage SDH, changes are required at least two

levels: changing performance criteria in call for tenders, by giving real importance to environmental and social criteria; changing business models (BM) by modeling how environmental and social value are created and captured among different stakeholders.

In this perspective, an interesting evolution is taking place in the heating market at the local level. More and more clients (cities, universities, etc.) have adopted strong environmental strategies with ambitious targets, like being carbon neutral. In this context, DH is seen as an important lever to achieve such targets. For these new contracts, clients include ambitious environmental and social targets in call for tenders, including penalties in case these targets are not met. However, if several works have been conducted on the social and environmental criteria to be taken into account for a "green" transition, very few can be found on a systemic and effective integration of these criteria in the operation process (Maas et al, 2016) and the conditions according to which economic, environmental and social value can be created and shared among stakeholders.

Value is at the heart of another literature, the one on BM. Coming from the managers and first formalized by strategic management literature, the BM is usually understood as the way a company does business, creates and capture value (Osterwalder and Pigneur, 2010; Teece, 2010; Zott et al., 2011). Thus, the company is the focal point of attention in most research. A recent body of literature on sustainability business models (SBM) has developed a more systemic view, paying more attention to environmental and social value creation (Bocken and al., 2014). Another stream of literature has recently emerged around circular business models, by paying special attention to the material and energy flows in circular loops (Geissdoerfer, 2020). However, this literature does not really analyze how different stakeholders are engaged and collaborate in the design of such SBM.

In SDH, we argue that a more systemic and interactive view is required since resources and capabilities are distributed among a large set of actors that need to be coordinated and integrated to design and implement a coherent SBM on the long term.

In this perspective, we propose to draw upon the industrial ecology framework (Erkman, 2004; Neves et al., 2020, Vahidzadeh, 2021) as a frame to rethink the renewal of sustainable BM for public infrastructures facing the ecological transition. Industrial ecology is based on synergies and collaboration within an area between various stakeholders (Erkman, 2004; Beaurain and Brullot, 2011; Brullot et al., 2014 ; Baldassarre et al., 2019), going further than studying flow exchanges. Four pillars are put forward by Brullot (2009) to analyze the maturity of industrial ecology: trust between stakeholders, shared imaginary comprising rules and coming from a collaborative process, governance and density of relationships between stakeholders. In this communication we focus on the shared imaginary and the governance, even if the other aspects were encountered during the case studies, and are mentioned in the following development. The four pillars, with their emerging conditions, dynamic and benefits are well investigated by literature. It also formalizes governance principles to support such synergies as well as collaborative processes to create a shared imaginary.
We use these different aspects of industrial ecology to shed light on the local and systemic aspects of a SBM.

The research question that we want to address in the communication is thus the following: to what extent the industrial ecology framework may help to design another perspective on SBM for DH at a local scale?

We base our study on two French DH networks. They were pioneers in a technical-driven approach of DH, with the early implementation of a great share of renewable and recovery sources in their energy mix. We study these historical examples, understanding the dynamic of their evolution and the potential levers and obstacles to draw conclusions for the ongoing transition. The two DH had a similar objective of having a decarbonized heat for their territory and used a similar systemic and local approach. In both cases, they used contracts as a tool to formalize the BM. We will then analyze its importance for the success of an ecological transition.

2. Methodology

2.1. Literature review

Literature on business models (BM) mainly comes from strategic management. It is usually defined as the process of value creation and capture by a private company (Teece, 2010 ; Zott et al., 2011 ; Bocken et al., 2014 ; Hamelink and Opdenakker, 2019). It is centered on a specific company and mainly looks at the interactions with its clients and suppliers (Osterwalder and Pigneur, 2010). There is only a partial taking into account of other relevant stakeholders.

As we have argued earlier, this company-centric approach does not fit with the issue of sustainable district heating (SDH). The latter is based on local resources, has a strong local anchorage and rallies many different stakeholders that are more than subcontractors. Looking at this system from a single stakeholder means losing the key idea that any development is based on strong interdependencies, synergies and collaborations. Having a systemic approach also questions the system's boundaries. In the traditional mindset of the private main contractor, DH perimeter is clearly described on the contract, and it defines the relevant stakeholders (supplier, client and final client). Based on fossil resources (gas, oil, coal, etc.)

coming from all over the world, traditional DH have limited local adherence. In sustainable DH, the situation is radically different: local renewable resources are privileged, meaning that the main contractor has to collaborate with local actors that are not substitutable for one another. When looking at the global system, the SDH has an impact on a broader territory: from the forest worker to the prosumer, not forgetting all the public entities committed to the local development and transition. Moreover, the value taken into consideration in BM is mainly economic value, which is not compatible with the objective of an ecological transition.

To tackle all these aspects, a literature on innovative BM and especially sustainable BM is gaining momentum in the last decade (Bocken et al., 2014 ; Hamelink and Opdenakker, 2019). It tackles a broader vision of value, with the integration of environmental and social criteria (Clauss, 2017). It also tries to take into account more stakeholders with the development of collaborative BM (de Man and Luvison, 2019). However this literature remains theoretical and is usually centered on one stakeholder. Moreover, it does not put emphasis on how an effective transition is conducted and the notion of contract - which is predominant in the field study - is not really developed. A specific and recent literature deals with circular BM (Geissdoerfer et al., 2020) that translates the concept of circularity to the field of BM and questions various pillars of the BM like the value proposition but also the resources needed. Nevertheless, this literature, even if it has a systemic view, does not necessarily questions the outcomes of circularity for a sustainable transition and is more focused on the flows of materials, energy, money and knowledge rather than on stakeholders. To conclude, literature on BM is diversified but is historically based on financial value creation for a private company. Even if the latest development of sustainable and circular BM promote a more systemic approach, they lack local and field anchorage with a view on stakeholders linked to an infrastructure.

To fill this gap, we propose to draw upon the literature on industrial ecology (Erkman, 2004; Neves et al., 2020, Vahidzadeh, 2021) as a framework to reconceptualize sustainable BM for public infrastructures as part of a local ecological transition. “Industrial ecology is an approach that applies the ecosystem metaphor and model to suggest that industrial systems should be restructured in order to make them compatible with the way natural ecosystems function. It is promoted as an approach to close industrial production loops and reduce waste, thereby making better use of resources and preventing the overuse of raw materials” (McManus, 2009). In industrial ecology is based on a principle of complementarity and interdependence: waste for certain actors are resources for others. As industrial ecology is not a natural phenomenon. It requires a collective design and governance mechanisms to ensure the minimizing of environmental impacts and a correct sharing of value between stakeholders. Industrial ecology can be seen at two levels: a dynamic collective action and individual strategies (Beaurain and Brullot, 2011). To analyze the maturity of industrial ecology, four pillars are put forward by Brullot (2009): trust between stakeholders, shared imaginary comprising rules and coming from a collaborative process, governance and density of relationships between stakeholders. Literature on industrial ecology formalizes governance strategies (Brullot et al., 2014; Bahers et al., 2020) and questions the public and private interest on going to such collaboration and the impacts for the committed area (Baldassarre et al., 2019; Bahers et al. 2020). Such collaboration may then be used for local development (Beaurain and Brullot, 2011; Cerceau et al., 2018), a clear objective of DH ecological transition. In this communication we focus on two pillars of industrial ecology: the construction of a shared imaginary and the governance, analyzing how they were implemented in our two case studies and in which way they support the path towards SBM for local DH.

We argue that mediating instruments (Miller and Power, 2013) to embody the link between BM and industrial ecology are the contracts put in place to formalize mutual commitments, targets and risk sharing between the different stakeholders. They formalize the links between various stakeholders (Decouzon et al., 2015) but also determine the criteria on which the collaboration is based.

2.2. Field work

To consider the whole picture, we conducted a longitudinal qualitative study with the main stakeholders in the DH with a focus on their long-term strategies. Longitudinal analysis is well adapted for case studies as it enables to explore "the contexts, content, and process of change together with their interconnections through time" (Pettigrew, 1990).

In order to better understand the ongoing transition toward sustainable DH and the role of sustainable BM, we have first conducted a study of the French DH market. It has been done through 5 semi-directive interviews with major stakeholders - e.g. representative of the French government, representatives of the private operators and of the local authorities –, the reading of recent reports on the market and the attendance to several conferences on this issue. It gave us a global vision of the will of clients to integrate DH to roadmaps towards carbon neutrality and ecological transition and the new demands associated. Then, we have made several semi-directive interviews within ENGIE, a major private DH operator, to gain understanding about its strategy on sustainable DH and the process of call for tenders.

After these preliminary studies, we conducted two case studies (Dumez, 2016 ; Yin, 2018) (Dunkirk and Besancon) to get a comprehensive understanding of how SDH emerged, the problems encountered, and the issues at stake in terms of governance and sustainable business modelling.

Both are historical and innovative sustainable DH, at least on technical issues, which allow to have some insights about their evolution. The study aims at analyzing the dynamic of the first environmental transition of DH systems. This study was done through semi-directive interviews (10 interviews for Dunkirk and 9 for Besancon, see the list in annex). We used an interview guide that helped us to collect a coherent set of data in order to facilitate the case study comparison. The categories used in the guide were the following: local history and context, network history, related stakeholders, contractual aspects (including contract renewal process), technical aspects, financial aspects, environmental and social criteria, political organization related to the network. To analyze SBM, we drew upon Demil and Lecocq (2010) framework for BM. This framework considers BM as the dynamic interaction between three pillars: value proposition, resources and competences, organization (internal and external).

Dunkirk and Besancon are recognized in France as pioneers in the implementation of renewable and recovery sources to their energy mix. Dunkirk chose to set up heat recovery from a nearby large steel facility (today called Arcelor-Mittal) in 1986. The local public authority was trying to get rid of fossil fuels and their price variations, to ensure affordable heat supply in Dunkirk. Arcelor was producing great amounts of heat that were lost, and had a reputation of polluter. Its commitment to the DH network gave roots to industrial ecology within the territory, with the ambition of becoming more resilient to crisis (e.g. environmental threats, international competition, etc.). The DH is locally well integrated, with a systemic approach mobilizing various stakeholders. Indeed, in Dunkirk the DH owner is the Urban Community of Dunkirk (CUD), who delegates the management of the network to a private operator (here Dalkia). For the heat supply, the industrial Arcelor-Mittal is committed, along with other industrials and the waste incinerator. The heat is then distributed to the users, who

can be individual, social housing managers, public institutions, etc. However the DH has faced financial problems since 1986 and industrial heat is still an uncertain resource.

Besancon is an old DH, dating from 1968. It was one of the first French DH to set up large scale biomass boilers in 2006. The choice of biomass is strongly linked to the local resources and has strengthened local employment in the forest industry. Here again, various stakeholders are committed, like the public client (the metropolis of Besancon), the private company (ENGIE), the wood industry stakeholders (wood suppliers, wood workers, forest owners, etc.), the waste incinerator and the diverse final clients. Nonetheless, the DH has not developed during the last decade due to a lack of commitment of some important stakeholders. These two fields are utterly interesting because they represent two very different network typologies with the same will of integrating renewable and recovery energy for heat production.

In both cases, contracts appear as crystallizers of stakeholders collaborations and objectives, making them capstones for the sustainable BM implementation.

3. **Results**

3.1. Historical DH concessions

3.1.1. Contracts

The public authority in charge of the DH can choose between different types of contract with the private company, depending on risk sharing, responsibilities, investments, and services. As the communication focuses on public-private partnership for a public service delegation contract, other contracts will not be discussed here. The most common contract is the *concession*. Here, all the risks and investments are borne by the private company. The public authority is only involved as a controller while the private company has a great deal of autonomy on its management of the DH. The other classical type of delegation contract in

France is the *leasing*, where the public authority is in charge of the investments. Here, the role of the private company is more tightly framed by the public authority (figure 1).

Figure 1

The use of other types of contracts allowing a stronger commitment of the public authority and limiting its risks is gaining momentum. For instance, SEMOP and SAS EnR allows the public authority to have shares and play a part in the network management by being part of the private project society in charge of the network management.

Each contract defines the partnership that will last for the concession duration. It also states the evaluation criteria for the performance: financial, technical, but also environmental.

3.1.2. The traditional Public Service Delegation process

Traditional DH is based on several routines when it comes to its contractual frame or its operation. A call for tenders is launched by the public authority, with the help of consulting firms, after a feasibility study and preliminary discussions with stakeholders to state the evaluation criteria for the proposals and the technical frame of the call. The support of consulting firms provides a service but may also prevent the public authority in gaining competences about its network - like technical or managerial aspects - when it relies too much on them. Due to the competitive context and the demanding aspect of negotiations, little official discussions are engaged with future competitors. Usual criteria for the decision-process are technical and financial ones, e.g. service continuity, cheap energy and little price variation for the final users (individuals or companies). The regulatory framework and the subsidies criteria are also an important component, with for instance some emission thresholds and mandatory renewable and recovery energy share, but only a few public authorities try to go beyond. Usually, the delegation lasts for 20 to 30 years as a concession, with the same private company bearing the investments. The commitment of the public

authority in the DH is highly variable and often hindered by the lack of awareness and technical competences. The BM here is centered on the public-private partnership and the predominant value is the financial one. However, this model is now being challenged, as it is not compatible with an ecological transition at the local scale, due to its rigid frame, pre-designed competitive selection process and lack of attention to environmental issues.

To understand how new exploratory partnerships may be built around toward sustainable objectives, in order to produce local positive externalities, the concept of industrial ecology is an interesting framework to consider.

3.2. Co-construction of a shared imaginary and the attached performance

For an ecological transition to happen, new environmental and social criteria are gaining importance in addition to the historical ones. Heat supply is now only a prerequisite of the DH and not its main purpose. The innovation in the BM will thus come from the adoption of a new value proposition, more comprehensive and sustainable. The DH value will not only be the supply of affordable heat but also the supply of low-carbon heat, using local resources and participating in the local ecological transition.

To perform this innovation, a key issue is to mobilize a broader set of stakeholders and make them collaborate for a common purpose (Brullot, 2009). In both case studies, this shift has occurred: a common purpose of doing more than just heat supply has emerged. In Dunkirk, the driver was the integration of industrial ecology with stronger interrelations and complementarities between stakeholders, and in Besancon the use of wood as a local resource linked to a local industry. However, in both cases, this vision was not shared by all

stakeholders, or at least it did not have the same importance for all, which weakened the DH project.

To create this shared vision, industrial ecology may be an interesting concept for the co-construction with various stakeholders, to discuss the building of a collective value and how to share it (Beaurain and Brullot, 2011). This process was not formalized in the two case studies, which sticked with the public authority defining criteria with the consulting firms.

One predominant stakeholder for promoting SDH as an essential building block of an ecological transition are the local representatives, as they are at the crossroads of different interests. They can support SDH so that it is discussed in the political sphere, manage the network of stakeholders to discuss the value and maintain partnerships over time. Representatives envision the territory of the future and embed the DH in a global roadmap towards an ecological / neutral / energy positive area. Creating and maintaining partnerships is at the heart of industrial ecology (Erkman, 2004). However, if the value is not fairly shared and formalized through a contract, the DH can be under threat or some stakeholders may lose interest in it.

In Dunkirk, even if Arcelor-Mittal was committed to supply the network with heat, it did not want to share a long-term contract with the other stakeholders, stating clearly that the industrial process was always coming first and that it could not take risks and responsibilities to ensure heat supply. This threat was counterbalanced by the informal network of interpersonal confidence and long history of industrial collaboration with public authority. However, when a new stakeholder tries to integrate the territory, he cannot rely on a formal contract and must find its place into this informal network. The public authority is then a facilitator and a mediator between the parties.

In Besancon, the representatives were not fully committed to the network. Even if most stakeholders shared a common vision for the DH and were aware of its benefits for the territory (affordable heat for social housing, integration of the wood industry to heat supply, local jobs, etc.) the lack of interest from the representatives severely hindered the network development during the last decade.

We see here that the commitment of all stakeholders to a common vision and value process is necessary for the good integration and development of the DH network. This commitment can go through a contractual process, with a cascade of long-term contracts interlinking all stakeholders and ensuring the territory resilience. Nevertheless, the formal aspects are also supported by an informal network of collaboration and confidence. This first point shows that to implement a new value proposition, there is a need for a new organization of stakeholder relationships, supported by new competences (like the one needed for co-construction). The new role of the DH implies innovation in the associated BM, as all three pillars (Demil and Lecocq, 2010) are changing simultaneously and recursively to reach a new equilibrium.

3.3. New governance principles

The emergence of a network of stakeholders sharing the same vision questions the place of the main private operator. In the historical delegation frame, the relationship between the public authority and the private company was the only one that mattered, with the private company usually having a large autonomy thanks to its financial and technical investments. Nowadays, a strong interest for innovative frames, giving more room to the public authority, are gaining momentum, questioning and changing the historical organization of DH BM. This interest can be linked with the specificity of long-term partnerships. They require a careful sharing of the risks and investments from the beginning to avoid free-riding and opportunistic behaviors. In Dunkirk for example, the public authority has an important role - even if the

historical contract is a concession - as the industrial Arcelor-Mittal has recently chosen to set up its supply contract with the public authority instead of the private operator in charge of the DH (figure 2).

Figure 2

All stakeholders have to be interlinked, they all have to bear part of the risks and to find a counterpart in the project (Brullot et al., 2014; Bahers et al., 2020). Here again, the competences and place of the public authority are important. Being more committed to the DH and its management helps to design new governance schemes and control over its development process. This thinking and design is mainly done upstream and then formalized in the contract.

The interlinking between the stakeholders ensure the resilience and positive impact of the network, its integration to the territory and the integration of a wider pool of stakeholders (Beaurain and Brullot, 2011; Cerceau et al., 2018).

This stakeholder network is dynamic and needs careful governance over the lifetime of the network. This governance is facilitated by the greater role taken by the public authority, committed to all local stakeholders and with a knowledge of the territory, over the private company. From the beginning, the risks and opportunities have to be carefully shared among this network to identify interdependencies and ensure the DH resilience and embeddedness to the local context. As the perimeter of the DH is widened by the new sustainable value proposition, new stakeholders need to be integrated to the BM. The organization has once again to be redesigned, which requires new competences especially for the public authority.

3.4. Renewal of the contractual process

All the aspects mentioned above are bricks to a new sustainable business model: a new value proposition requires a new organization of stakeholders and new resources and competences (Demil & Lecocq, 2010). To formalize these aspects and articulate them in a coherent setting, the contractual process needs to be adapted.

3.4.1. Transforming social and environmental value into performance criteria

One first step towards a renewal of main contract is the transformation of the new value proposition, including social end environmental values, into different indicators and criteria so that it can be part of the evaluation process, both for the call for tenders and for other contracts.

This evolution of the contractual process can be seen in Besancon since the last renewal of the call for tenders: new commitments were mentioned in the contracts (like the fixed energy mix determined at the beginning of each year) and sanctioned with financial penalties if they are not kept by the end of the contract duration.

This process takes place on an international dynamics, with clients being more and more demanding and putting some efforts on the call for tenders and the contract design. To better understand these international dynamics, we are also studying at the moment two ambitious and innovative SDH in Ottawa (Canada) and Helsinki (Finland).

Regarding the evolution of the contractual process in Ottawa, during the call for tender set up by the Government of Canada, a price was given to carbon in order to reward ambitious commitments, but also to give financial penalties if the chosen competitor did not respect its commitments. Aesthetics criteria, aiming at integrating the new boilers to the city, were also added.

When the objectives are ambitious and require disruptive innovations and a shift toward innovative SBM, the difficult for the client is to design an appropriate call tenders. Thus, the municipality of Helsinki launched an open call for ideas to decarbonize the energy system, looking for guidelines to design the future call for tenders they intend to launch.

New indicators taken into account in the contractual process can be co-designed with the various stakeholders, to make sure the thresholds are ambitious enough but remain reachable. For instance in Ottawa the carbon price was discussed between the client and the competitor, and based on a comprehensive and systematic research of best practices all over the world. Designing such criteria and the associated penalties also mean the construction of calculation tools and methodologies. They act as mediating instruments (Miller and Power, 2013), creating a common language and structuring the discussions between the stakeholders during the contractual process. This design step may be long and demanding (financially but also when it comes to the competences at stake) since the valuation and monitoring process needs to be carefully organized with the mobilization of various resources and competences from different stakeholders. The issue is to find a way of integrating what was considered as externalities (carbon emissions, pollutions, aesthetics, refurbishment, etc.) into the evaluation process that makes sense for all stakeholders. Penalties can be powerful tool to incentivize actors but it requires counterparts: the client shall secure investments and competence building on the long term.

3.4.2. A stream of contracts

To ensure the equilibrium between different stakeholders, one interesting tool is to implement a stream of contracts (Decouzon et al. 2015). Instead of defining the partnerships only through the public-private main contract, the governance can be formalized through a stream of long-term contracts. It allows the interlinking and interdependencies between stakeholders

mentioned above in the long term. For instance in Besancon, the long-term supply contract for wood is reverberated along the whole wood process until the forest worker. It gives the wood sector more stability and a better anchorage in the local economy (figure 3).

Figure 3

However, when thinking about long-term stream of contracts, the duration of the contracts needs to be tackled. Not all sectors have the same need and constraints and can commit for the same duration. If all the contracts have the same duration, the SDH may lack flexibility but if all the contracts do not have a similar duration, it can question the commitment of some stakeholders. The stream of contract is a powerful tool to ensure that positive externalities are integrated to the DH BM as it formalizes the governance principles and interlinks various stakeholders. However, like any management tools, it has to be carefully designed to fulfill its objective.

A specificity of the ecological transition and its impact on DH is that it is strongly linked to the local context. The value and expected performance depends on the stakeholders and on the local resources and opportunities found in the territory. Contracts and technological solutions "on the shelf" cannot be directly transposed in a specific context, but have to be adapted and parameters has to be set with all stakeholders. Taking into account the local complexity is key for its resilience and legitimacy. This complexity also means new competencies to manage the DH and the related contracts.

4. Conclusion and discussion

This communication, based on two French case studies, gives a comprehensive understanding of the innovative aspects of Sustainable Business Models (SBM) for Sustainable District Heating (SDH) which has become a pillar for ecological transition at the local scale. We drew

upon the industrial ecology framework to stress how another perspective on SBM for DH at a local scale could be designed.

Our first contribution is empirical. We have analyzed the challenges and conditions under which traditional technical-driven DH can change towards sustainability-driven DH. The first and main difference between DH and SDH is the sources of energy at stake: traditional DH rely on fossil energy (coal, gas, oil) whereas SDH rely as much as possible on all sustainable sources of energy that can be found on the territory (geothermal energy, solar energy, wood energy, etc.), eventually trying to structure new local industries for that purpose.

Indeed, with the strong local anchorage of such infrastructures, the historical framework for DH had to be renewed as well as its BM. The historical DH framework is based on a public-private partnership for the public service delegation. First, value proposition are focused on technical performance (delivering heat), price and continuity of service. Second, resources and competences are mainly technical and focused on the focal company (the main operator) in charge of operating the DH. Third, the organization and governance are quite simple and structured around the main contract between the client and the main operator. Therefore, evaluation criteria are mainly financial and technical, and the public authority is not necessarily committed to its DH.

These three pillars of BM (value proposition, resources and competences, organization and governance) need to be changed when looking for ambitious and innovative sustainability objectives (Clauss, 2017).

First, the design of a new value proposition, including environmental and social dimensions, is at the heart of the SBM and co-constructed with all stakeholders impacted by the DH. Second, new resources and competences are necessary, not only to run a SDH but also to design an open call for tenders, encouraging innovations and stimulating cooperation between

stakeholders. Third, new governance and organization processes have to be designed. In this perspective, we showed the importance of contractual processes, with a cascade of contracts formalizing the organization.

To encourage the formation of this network of competences, resources and stakeholders, the industrial ecology framework may be interesting. Indeed, this change towards a more systemic and sustainability-oriented approach can be linked to the industrial ecology, with stronger interdependencies between stakeholders of a territory, assembled around a common purpose associated to a collective and shared value proposition (Beaurain and Brullot, 2011 ; Brullot et al., 2014). In this communication, we paid particular attention to two pillars of the industrial ecology: construction of a shared imaginary and governance (Brullot, 2009). The creation of a new value proposition and the commitment of all stakeholders to this proposition depends on the creation of a shared imaginary. To implement the collective value proposition, this network of stakeholders have to redefine the governance principles and the organizations surrounding the DH, in particular how risks and values are shared as well as investments and opportunities (Brullot et al., 2014; Bahers et al. 2020). All these aspects are formalized in a stream of contracts (Decouzon et al. 2015), insuring a fair sharing and anchoring the governance principles for the main contract duration. The implementation of industrial ecology principles may also contributes to the local development and dynamic of the territory (Beaurain and Brullot, 2011; Cerceau et al., 2018), with a better integration of the DH and its positive impacts.

In the two case studied, parts of this global dynamic could be observed but the collective intelligence was limited. The major part of the efforts were put on the technological solutions for the integration of more renewable and recovery sources. On the contrary, the BM and contractual arrangements did not change as much as they could be, explaining probably most of the difficulties encountered in the field. On the contrary, new contractual arrangements

implemented in Ottawa and Helsinki show that it is possible to design on a completely new basis the governance process for SDH. But such an approach requires important preliminary explorations to acquire the necessary competences and legitimacy to build an ambitious, coherent framework that can stimulate innovation and cooperation.

Our theoretical contribution is twofold: first, we proposed a first conceptualization of potential synergies between industrial ecology and SBM, showing how the first can enrich the latter, by putting emphasis on interdependencies and complementarities between resources and actors and the key role of cooperation and governance in the emergence of a SDH anchored in the territory. Second, we stressed the specific and key role of contracts in the governance process, showing how these contracts act as mediating instruments (Miller and Power, 2013), encouraging cooperation and innovation between stakeholders.

However, the question of the BM perimeter still needs further research. In the communication, we chose to consider a BM centered on the DH, and the stakeholders impacted by this infrastructure defined the perimeter at stake. But since values need to be shared between all stakeholders, where does the perimeter of interdependencies end? How to take into account peripheric stakeholders that may be far from the core infrastructure however important in its legitimacy and operation?

Moreover, we have considered that the contract embodies a simplified vision of the BM. However, not all externalities and partnerships can be integrated in the main contract from the beginning. Further research shall be conducted on the conceptualization of SBM as the dynamic interplay between contractual and non-contractual aspects, thus including temporal aspects and learning issues. In the same line, a better analysis of temporalities (temporality of

the contract, of the infrastructure, of investments in sustainable industries, of stakeholder perceptions) shall be studied.

Lastly, further research needs to be conducted on the study of SDH in different contexts. Many cities and universities around the world are taking commitments towards carbon neutrality and plan in using DH as a tool for this roadmap. If this dynamic can be observed all around the world, differences in terms of technical options, governance, business models, collaborations and historical trajectories remain and shall be further analyzed.

References

Bahers, J.-B., Tanguy, A. and S. Pincetl, 2020, "Metabolic relationships between cities and hinterland: a political-industrial ecology of energy metabolism of Saint-Nazaire metropolitan and port area (France)". Ecological Economics, 167

Baldassarre, B., Schepers, M., Bocken, N., Cuppen, E., Korevaar, G. and G. Calabretta, 2019, "Industrial Symbiosis: towards a design process for eco-industrial clusters by integrating Circular Economy and Industrial Ecology perspectives". Journal of Cleaner Production , 216: 446-460

Beaurain, C. and S. Brullot, 2011, « L'écologie industrielle comme processus de développement territorial : une lecture par la proximité ». Revue d'Economie Régionale & Urbaine, 2: 313-340

Bocken, N. M. P., Short, S. W., Rana, P. and S. Evans, 2014, "A literature and practice review to develop sustainable business model archetypes". Journal of Cleaner Production, 65: 42-56

Brullot, S., 2009, « Mise en œuvre de projets territoriaux d'écologie industrielle en France : vers un outil méthodologique d'aide à la décision ». PhD thesis in Sustainable Development, Troyes University of Technology

Brullot, S., Maillefert, M. and J. Joubert, 2014, « Stratégies d'acteurs et gouvernance des démarches d'écologie industrielle et territoriale ». Développement durable et territoires, 5

Clauss, T., 2017, “Measuring business model innovation: conceptualization, scale development, and proof of performance”. R&D Management, 47: 385-403

Decouzon, C., Maillefert, M., Petit, O. and A. Sarran, 2015, « Arrangements institutionnels et écologie industrielle – L’exemple de la gestion des déchets ». Revue d’économie industrielle, 152

Demil, B. and X. Lecocq, 2010, “Business Model Evolution: In Search of Dynamic Consistency”. Long Range Planning, 43: 227-246

Dumez, H., 2016, "Qu'est-ce qu'un cas et qu'attendre d'une étude de cas?". In H. Dumez. Méthodologie de la recherche qualitative. Paris: Magnard-Vuilbert, pp. 203-220

Erkman, S., 2004, « Vers une écologie industrielle ». Paris: Charles Leopold Mayer

Geissdoerfer, M., Pierono, M. P. P., Pigosso, D. C. A. and K. Soufani, 2020, “Circular business models: A review”. Journal of Cleaner Production, 277

Hamelink, M. and R. Opdenakker, 2019, “How business model innovation affects firm performance in the energy storage market”. Renewable Energy, 131: 120-127

Lygnerud, K., 2018, “Challenges for business change in district heating”. Energy, Sustainability and Society, 8-20

Lygnerud, K., Wheatcroft, E. and H. Wynn, 2019, “Contracts, Business Models and Barriers to Investing in Low Temperature District Heating Projects”. Applied Sciences, 9: 31-42

Maas, K., Schaltegger, S. and N. Crutzen, 2016. “Integrating corporate sustainability assessment, management accounting, control, and reporting”. Journal of Cleaner Production, 136: 237-248

McManus, P., 2009, “Ecology”. In Kitchin, R. and N. Thrift (eds), International Encyclopedia of Human Geography. Amsterdam: Elsevier, pp. 294-303

de Man, A.-P. and D. Luvison, 2019, “Collaborative business models : Aligning and operationalizing alliances”. Business Horizons, 62: 473-482

Miller, P. and M. Power, 2013, “Accounting, Organizing, and Economizing: Connecting Accounting Research and Organization Theory”. The Academy of Management Annals, 7: 557-605

Neves, A., Godina, R., Azevedo, S. G. and J. C. O. Matias, 2020, “A comprehensive review of industrial symbiosis”. Journal of Cleaner Production, 247

Osterwalder, A. and Y. Pigneur, 2010. “Busines Model Generation: A Handbook for Visionaries, Game Changers, and Challengers”. Hoboken: John Wiley & Sons, Inc.

Pettigrew, A. M., 1990, “Longitudinal field research on change: theory and practice”. Organization Science, 1: 267-292

Schmidt, D., 2018, “Low Temperature District Heating for Future Energy Systems”. Energy Procedia, 149: 595-604

Shaffer, B., Flores, R., Samuelsen, S., Anderson, M., Mizzi, R. and E. Kuitunen, 2018, “Urban Energy Systems and the Transition to Zero Carbon – Research and Case Studies from the USA and Europe”. Energy Procedia, 149: 25-38

SNCU, « Les réseaux de chaleur et de froid : chiffres clés, analyses et évolution » ; Enquête annuelle sur les réseaux de chaleur et de froid – édition 2019; SNCU-Rapport-Global-2019-Restitution-enquete-réseaux.pdf (fedene.fr); accessed 2021, 05th January

Teece, D. J., 2010, “Business Models, Business Strategy and Innovation”. Long Range Planning, 43: 172-194

UNEP, “District Energy in Cities Initiative”; UN environment programme ; District Energy in Cities Initiative | UNEP - UN Environment Programme; published 2020, 04th February

Vahidzadeh, R., Bertanza, G., Sbaffoni, S. and M. Vaccari, “Regional industrial symbiosis: A review based on social network analysis”. Journal of Cleaner Production, 280

Yin, R. K., 2018, “Case Study Research and Applications: Design and Methods”. Los Angeles: SAGE

Zott, C., Amit, R. and L. Massa, 2011, “The Business Model: Recent Developments and Future Research”. Journal of Management, 37: 1019-1042

Annex 1: List of the context interviews

Cerema (*Risks, Environment, Mobility and Layout Study and technical Center*, a public institution)	
Sylvie LEVEAUX	Coordinator/Head of the Heat and Cold District Heating Networks department/service *(called on the 18th of May 2020)*
Cindy MELFORT	Climate responsible of study *(called on the 18th of May 2020)*
Matthias BERRY	Renewable energy and District Heating responsible of study *(called on the 18th of May 2020)*
ADEME (French governmental *Ecological Transition Agency*)	
Michel CAIREY-REMONNAY	*Fonds Chaleur* coordinator *(called on the 20th of May 2020)*
FNCCR (*National Federation of Concessions granting Collectivities*, focused on public services topics such as energy, water and waste treatment)	
Guillaume PERRIN	Assistant/deputy chief of the Energy department ; Chief of District Heating and Cooling service *(called on the 12th of June 2020)*
Hortense FOURNEL	Energy efficiency mission head *(called on the 12th of June 2020)*
FEDENE (*Federation of Energy and Environment services* : pool of 7 professional trade unions, including SNCU (*National District Heating and Air conditioning Syndicate/Trade union*))	
Laura ROSSI	FEDENE Technical and innovation manager *(called on the 15th of June 2020)*

AMORCE (Cities and companies association on public services topics (waste, water and energy))	
Laurène DAGALLIER	Renewable energy and District Heating mission head *(called on the 10th of July 2020)*

Annex 2: List of the Dunkirk case study's interviews

ADEME (Hauts-de-France regional direction)	
Herminie DE FREMINVILLE	Coordinator of the Energy business center *(called on the 29th of May 2020)*
Bruno Frimat	Assistant director *(called on the 10th of June 2020)*
Cerema (Hauts-de-France territorial direction)	
Odile LEFRERE	Renewable and waste energy study on heating networks *(called o n the 3rd of June 2020)*
Urban Community of Dunkirk (CUD) technical services	
Arnaud DUQUENOY	Head of the Energy transition service of the CUD. Direction of environment, territories and energy transition *(called on the 28th of May 2020)*
Jean-Luc TANGHE	Energy networks project officer *(called on the 28th of May 2020)*
Frédéric MABILLE	Former CUD Energy Director *(called on the 9th of June 2020)*
ArcelorMittal (industrial waste heat supplier)	
Pascal RITAINE	Energy operation support, Energy department *(called on the 19th of June 2020)*
City of Grande-Synthe	
Nicolas PIERS	Energy transition service's manager (technical service) *(called on the 4th of June 2020)*
Damien CARÊME	Former city mayor, European deputy *(called on the 10th of June 2020)*

Cit'ergie label	
Laurent GODINEAU	Cit'ergie auditor and advisor for Grande-Synthe *(called on the 25th of June 2020)*
ENGIE Solution (private operator in charge of Grande-Synthe's network)	
Vincent PIBOULEU	Energy production and supplying - North-East Cities and communities *(called on the 25th of June 2020)*

Annex 3: List of the Besancon case study's interviews

ADEME (Bourgogne-Franche-Comté regional direction)	
Louison RISS	ADEME Renewable and waste energy mission head on Besancon Metropolis department *(called on the 19th of June 2020)*
Technical services of the Grand Besancon urban community	
André BATAILLARD	Energy supplying officer on Grand Besancon sector *(met on the 18th of June 2020 in the Grand Besancon Energy management office)*
Céline BOUCHERON	Grand Besancon Environment office *(called on the 22nd of June 2020)*
Celsius (private operator in charge of the DH, ENGIE subsidiary)	
Didier PELLISSIER	Operation leader *(met on the 18th of June 2020)*
Martine GOUVERD	In charge of the heating network management *(met on the 18th of June 2020)*
Coraline GIRARD	In charge of communication (*met on the 18th of June 2020)*
Cit'ergie label	
Marie-Luce SAILLARD	Cit'ergie auditor and advisor for Besancon *(called on 26th of June 2020)*
Wood-energy sector	
Jimmy EQUENOT	ONF East agency manager/supervisor, wood energy branch *(called on the 25th of June 2020, met on the 29th for a visit of a wood storage platform in Besancon and a grinding work site in a forest)*

Laura ROUVELIN	Wood energy mission head for Fibois Bourgogne-Franche-Comté *(met on the 30th of June 2020)*
P-L PICHON	SOVEN representative, wood central purchasing agency for Celsius biomass boilers *(called on the 2nd of July 2020)*
Geoffroy DHIER	Technical manager, PEFC France (wood network certification organization) *(called on the 7th of July 2020)*
Stéphane LEFEVRE	In charge of PEFC certification of wood supplies, region Franche-Comté *(called on the 7th of July 2020)*

Figures

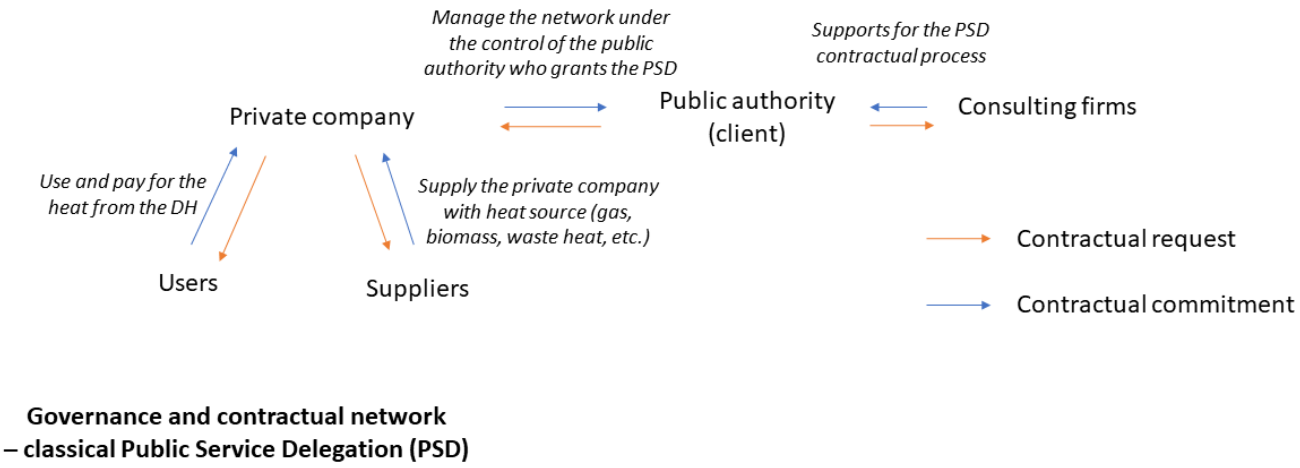

Figure 1 Governance and contractual network of classical Public Service Delegation

Figure 1 shows the contractual network between the major stakeholders of a Public Service Delegation (PSD), with the different commitments and counterparts of each relationship. The PSD is centered on the relationship between the private company and the public authority.

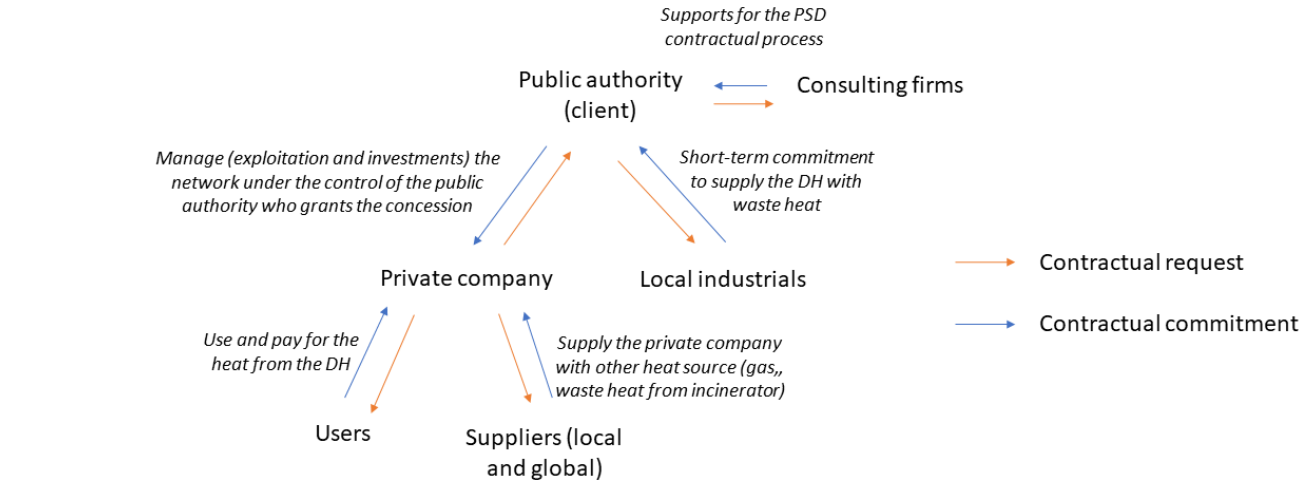

Figure 2 Governance and contractual network of Dunkirk DH

Figure 2 shows the contractual network between the major stakeholders of the Dunkirk's DH, with the different commitments and counterparts of each relationship. We highlight here the predominant position of the public authority in the concession especially for the local integration of the DH.

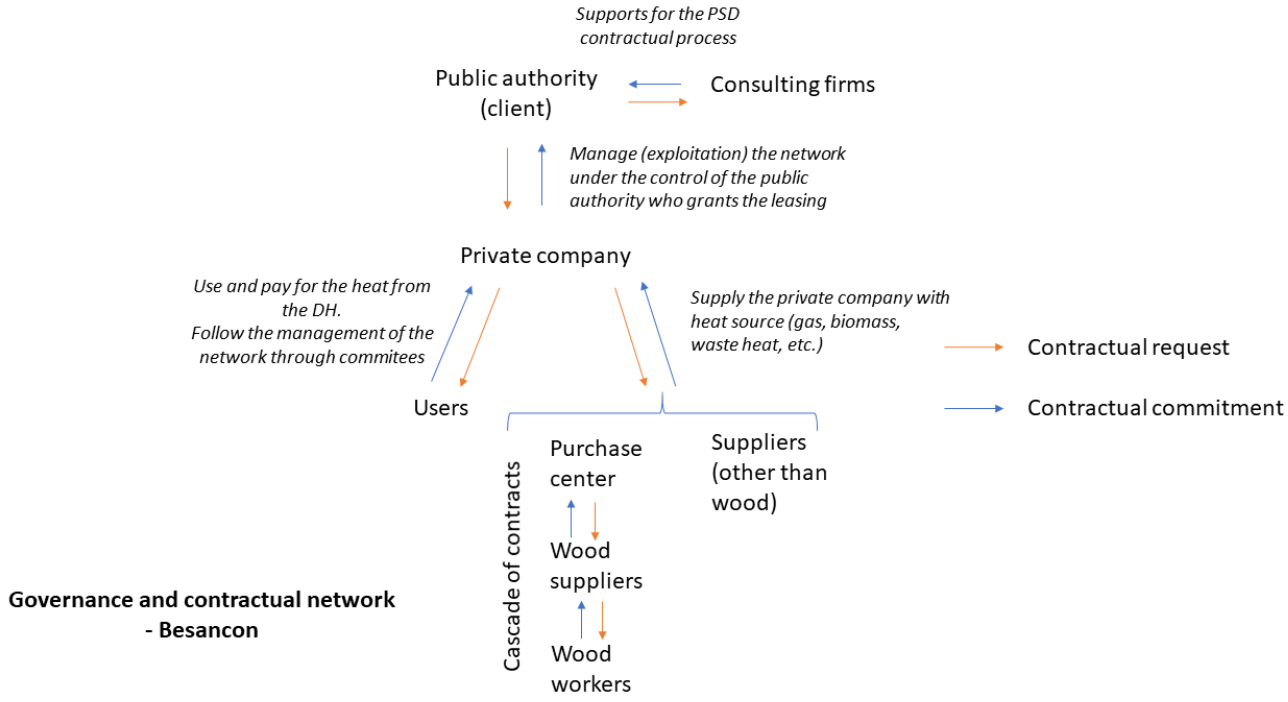

Figure 3 Governance and contractual network of Besancon DH

Figure 3 shows the contractual network between the major stakeholders of the Besancon's DH, with the different commitments and counterparts of each relationship. Here, due to the leasing contract, the public authority has an important management role. One interesting aspect is the cascade of contracts for the whole wood process sector, securing some workers.