Unstandardized standards: the making of demand in district-heating projects in France

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DRAFT Paper

Abstract

Thanks to their efficiency, their capacity to exploit local energy sources and the adaptability of their energy mix, district-heating solutions are nowadays amongst the preferred options to supply heat to urban areas in Europe (1.1). As for all grid-based systems, estimating future consumption is an important issue for the development of heating networks (1.2). In French district heating projects, however, the numerous demand assessments that are produced at various stages of the design process comply with divergent calculation standards (1.3).

Drawing on an extensive empirical work on energy design in urban development projects, this paper therefore explores the following questions:

- What does explain both the diversity and the divergence of calculation standards for future heating demand? (2.1 & 2.2)
- What are the consequences of this dissonance between standards for district-heating systems and projects? (2.3)
- Why do these standards remain unquestioned? (3.1, 3.2, 3.3)

Unstandardized standards: the making of demand in district-heating projects in France

Guilhem BLANCHARD[1]

District-heating networks are sociotechnical systems designed to supply heat to buildings, especially in high-density urban environments. Thanks to their efficiency, their capacity to exploit local energy sources and the adaptability of their energy mix, district-heating solutions are nowadays amongst the preferred options for the provision of heat when planning and developing eco-districts in Europe (Gabillet 2015). As for all grid-based systems, estimating future consumption is an important issue for the development of heating networks (Summerton, 1992; Guy and Karvonen, 2016). Heating demand assessments, however, are fraught with uncertainty: little is known about actual thermal performance of buildings, user behaviours are far from being understood, and knowledge is even weaker when it comes to the evolution of energy demand in the next decades.

In this context, methods for estimating future consumption are crucial. Yet, in French district heating projects, the numerous demand assessments that are produced comply with divergent calculation standards, which produces dissonances within these systems' design process. Drawing on an extensive empirical work on energy design in urban development projects[2], this paper therefore explores the following questions: What does explain both the diversity and the divergence of calculation standards for future heating demand? What are the consequences of this dissonance between standards for district-heating systems and projects? Why do these standards remain unquestioned except for a few restricted arenas?

1. <u>The making of demand in district-heating projects: a significant issue</u>

1.1. District-heating projects and urban climate-energy policies in France

The development of district heating and/or cooling systems has been considered lately amongst the most effective ways to decarbonise the energy supply of urban areas and to increase the share of non-fossil sources in their energy mix (Bowitz and Dang Trong, 2001; Gustavsson and Karlsson, 2003; Holmgren, 2006; Lund et al., 2014; Rocher, 2014; Guy and Karvonen, 2016). In fact, district heating (DH) networks enable the large-scale distribution of decarbonised heat to dense areas, providing efficiency gains compared to decentralised systems, and allowing recovery from capital-intensive waste and renewable energy sources (Fig. 1). Thanks to their features, and despite their complicated interaction with energy savings (Gabillet, 2015; Späth and Rohracher, 2015), DH systems therefore provide interesting solutions for an "hyperlinked", "post-networked" urbanism (Barles et al., 2016).

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Unless indicated otherwise, all figures and tables are made by the author.

[2] The empirical work has been done for a PhD research on energy design in urban development projects. It brings together 40+ interviews, observations and a significant body of technical and institutional documentation.

	District heating networks	Decentralised systems
Pace of transition	“Fast” (re-)structuration of entire neighbourhoods’ heating supply	Slow-pace dissemination through urban areas
Systems optimisation	Improved overall efficacy and efficiency thanks to mutualised, high-performance infrastructure	(Hyper-)local optima, sometimes counterproductive
Energy sources	Only way to recover and distribute waste heat (from waste incineration, power plants, industries, data centers,…) and capital-intensive renewable sources (deep geothermal energy, biomass plants with top-performance particle filters,…)	Adapted to more extensive renewable and waste energy (solar heat and power, near-surface geothermal energy, waste water,…)
Flexibility	Pipes need to be sized for decades to come, but new fuel and energy sources can be introduced “easily” by adding or replacing heat plants	Dependency on buildings’ design
Land-use and aesthetics	Almost neutral	Space-intensive, visual impact
Socio-economics	Allow cost-sharing of infrastructure investment and price adjustments	Less investment needed, but no sharing

Figure 1. According to their promoters, DH systems have attractive features for urban energy transitions.

In France[3], few DH systems have been set up since the massive construction of large housing projects in the 1960s and 1970s (Rocher, 2014). In a context of highly-centralised, subsidised electricity and gas provision, individual heating has been preferred to collective systems. Since mid-2000s, however, DH has been regaining ground (Fig. 2). The rise of climate and energy issues in the political agendas, as well as the reconfiguration of multilevel energy governance towards more decentralisation, have led to a renewal of interest in district heating (Rocher, *op. cit.*). New rules and incentives, such as compulsory feasibility studies for renewable energy supply of new buildings and districts, subsidies from a national “renewable heat fund” or reduced VAT rates, have been introduced into the national regulatory framework. Going along with emerging urban strategies aimed at developing local, low-carbon energy supplies, these new regulations supported DH development, especially in metropolitan cities such as Paris, Lyon or Bordeaux.

Nowadays, district heating can therefore be seen as a growing segment in the energy sector, with three complementary trends: the creation of new systems, the extension and interconnection of existing networks, and the “greening” of their energy mix[4]. From now on, we will focus on the development of new district-heating infrastructures in the context of urban development projects. Nevertheless, the conclusions we draw remain largely valid for other cases.

[3] A similar process is occurring in the UK (Hawkey, 2012; Hawkey et al., 2013; Webb, 2015)

[4] That means more recovery from renewable and waste energy, and less use of coal and oil. Gas remains trendy as a complementary source to renewable and waste energy.

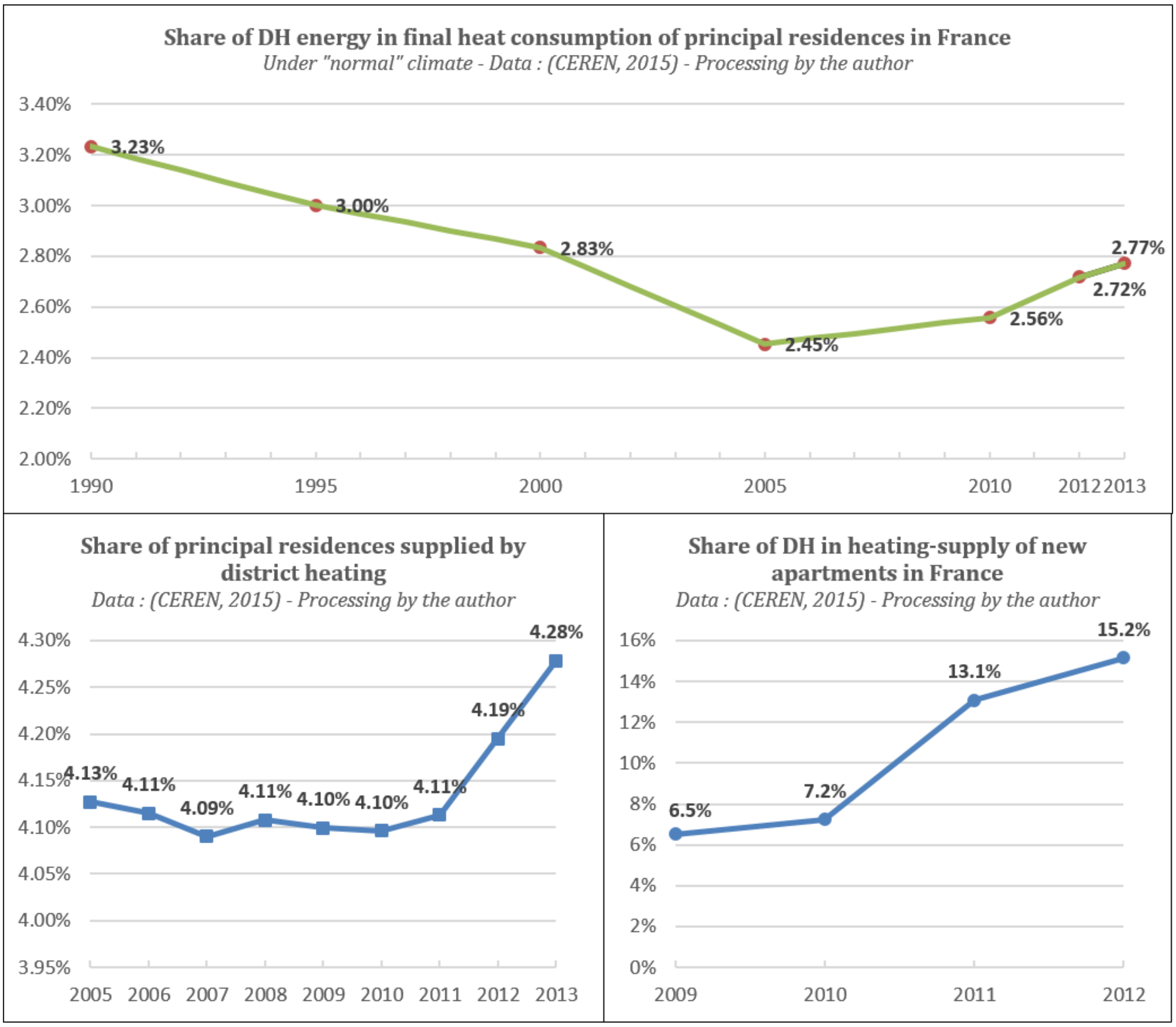

Figure 2. There has been a renewed interested in DH supply in France since the mid-2000s.

1.2. Estimating future demand: a key issue for district-heating projects

> *"[T]he decision to invest in a grid-based energy system is often made under considerable uncertainty with regard to subscriber behaviour. These uncertainties include whether or not prospective subscribers will decide to join the system and whether they will actually come 'on-line' at system-builders' planned pace [...] Another uncertainty concerns what subscribers' actual level of consumption will be and whether or not these consumption levels will change significantly over time: grid-based energy systems place high demands on the coordination of supply and demand within the system. Reductions in energy demand can lead to non-utilized capacity and economic loss unless new subscribers are contracted, while unforeseen increases in demand can cause problems in matching increases in demand with new instalments of capacity"* (Summerton, 1992, p. 77)

The making of energy demand, or more precisely the estimation of future heat demand, is crucial for district-heating projects. Energy demand estimates are indeed key parameters in both the financial and technical design of DH systems, thus impacting their socioeconomic and environmental features:

- As for many Large Technical Systems, the deployment of DH infrastructures requires high investment capacity, with long cost-recovery periods[5]. To recover sunk costs, DH developers rely on long-term financial models based on above-marginal-cost charges applied to heat provision. In this context, heating demand assessments are crucial: they determine the basis upon which developers hope to get their return on investment and, consequently, the price of heat for future consumers. Since future demand is a factor of vital importance for the budget balance of the project, forecasting miscalculations may lead to significant financial risks, especially until break-even is reached.
- From a more technical point of view, demand estimates are key assumptions in the sizing of the infrastructure (pipes diameters, pressure and temperature of the fluid, boilers capacities,…) and the choice of heat sources to make up its energy mix. Underestimating future demand can then lead to failures in heat provision during very cold periods. On the opposite, overrating load curves may affect the overall performance of the system, since technical devices are designed for optimal functioning within given ranges of use. Of course, technical and financial aspects are closely intertwined since the infrastructure design determines the level of needed initial investment in the project.

At this point, it is important to make clear that both the magnitude and the distribution of future demand are key parameters for the financial and technical design of DH systems (Fig. 3). In fact, power demand affects the infrastructure design since systems are sized in order to prevent failures in heat provision while energy consumptions determine energy offtake from heat sources. Combining power demand and energy consumptions, the load curve impacts overall efficiency: basically, the smoother the load curve, the most efficient the heat provision system. Eventually, the structure of heat pricing reflects the structure of energy demand: a variable share (called "R1") is indexed on energy consumptions (in kWh), and a fixed share ("R2") is indexed on contracted power (in kW).

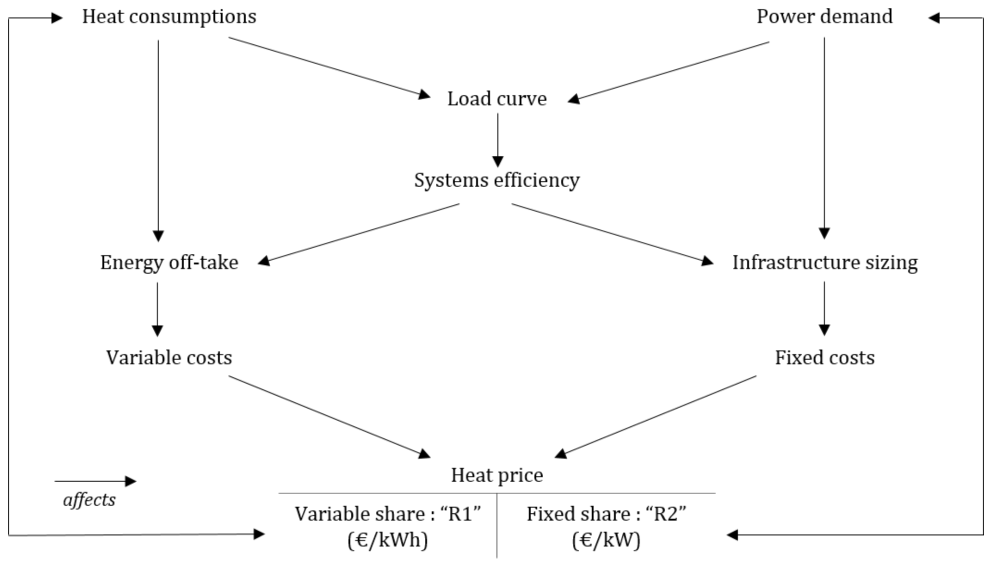

Figure 3. Both heat consumptions and power demand affect the whole financial and technical structuration of DH systems.

[5] For example, in recent proposals for a small-scale DHC network based on geothermal energy, initial investment represents about 15% of the overall costs in a 25-years period, and the share of fixed costs in the price construction is between 45 and 65%.

1.3. *Entering the design & development process of a DH system: a dissonance between various demand assessments*

As we have seen, estimating future demand is a key parameter for the design of DH systems. In this section, we follow heat demand assessments through the design process of a DH network in the context of an urban development project in France[6]. At every step, a new actor enters the design arena and brings along new estimates, based on his own calculation method.

The first step occurs during the operational planning of the new district. The urban developer (*aménageur*), under the supervision of the local authority (*collectivité locale*), needs to choose between various energy supply solutions so as to provide heat, electricity and sometimes cold to future buildings. Neither the developer nor the urban authority staff members have the proper skills to carry out this choice alone: they usually contract with an urban energy consultant, who undertakes a comparative study of available solutions to support decision making. In order to assess the feasibility and interest of mutualised energy provision, the consultant needs to estimate the density of energy demand within various areas of the future neighbourhood. To do so, he has his own calculation tool, which usually uses surface power and consumption ratios based on both current and anticipated national regulations for thermal performance of new buildings. This estimate provides the first basis upon which a DH project is launched.

In the second phase, the local authority and the urban developer have to find an energy operator to design, build and manage the DH system. In fact, French DH networks are mostly owned by municipalities, but initial investments and infrastructure management is delegated to private companies through long-term (e.g. 25 years) public contracts (*délégations de service public*). To ensure fair competition, invitations to tender are first made public by the responsible authority and negotiations are conducted with a few candidates. Tender files include demand assessments, which are based on feedbacks from other DH networks managed by the same operator in similar urban contexts[7], and on anticipations of building performance evolutions during the next decade. Most of the time, these new figures are higher than the energy consultant's previous estimates (Fig. 4, Fig. 5): here is our first dissonance.

In the third phase, the DH infrastructure is being built by the operator: the divergence between demand assessments has been "resolved" by using the winner's estimates, since he is the one actor to assume the major part of the financial risk associated with the DH project[8]. In parallel to the network's construction, property developers are negotiating the features of their building projects with the urban developer. Energy performance is included among the various issues addressed during this commercialisation process: the environmental engineer of the building's designing team has to convince the urban developer and his own consultant that planned building design complies with legal regulations and possible additional requirements. To do so, the engineer usually calculates future energy demand according to legal assumptions given by the national framework for buildings' thermal performance (the Th-BCE standard). Since these conventional assumptions are considered as quite distant from observed reality (see section 2.1), he may also provide complementary estimates by using dynamic thermal simulation software. It is interesting to notice that such estimates do not converge with any of the previous figures for heat demand (Fig. 4, Fig. 5): here is the second dissonance.

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[6] Even though our analysis is based on an extensive empirical study of one urban development project in Bordeaux, the major part of it remains valid for other urban development contexts in France.

[7] In this case, similar urban context means comparable climate and real estate products.

[8] Of course, our narrative is oversimplified. In reality, local authorities bear part of the financial risk, and most of the political risk associated with failures in providing the public service of heat. Anyway, energy operators are considered the most skilled structures when it comes to system design.

In our fourth (and last) phase, the DH system is becoming operational and new buildings are being built. In order to ensure the provision of heat to their products, property developers need first to have heat distribution networks (that is pipes and radiators) set up within the buildings, and second to contract heat supply with the DH operator. New "fluids" technicians (*bureaux d'études fluides*) are in charge of sizing the "secondary" distribution system and the contract power. The calculation method for this sizing is given by a national standard (the NF EN 12831 standard) issued by professionals from the sector. The assumptions of this last standard differ from both national thermal regulations and dynamic thermal simulations (STD). Moreover, they lead to very high contract power, quite different from what has been anticipated by DH operators. Here are our third and fourth dissonances (Fig. 4, Fig. 5).

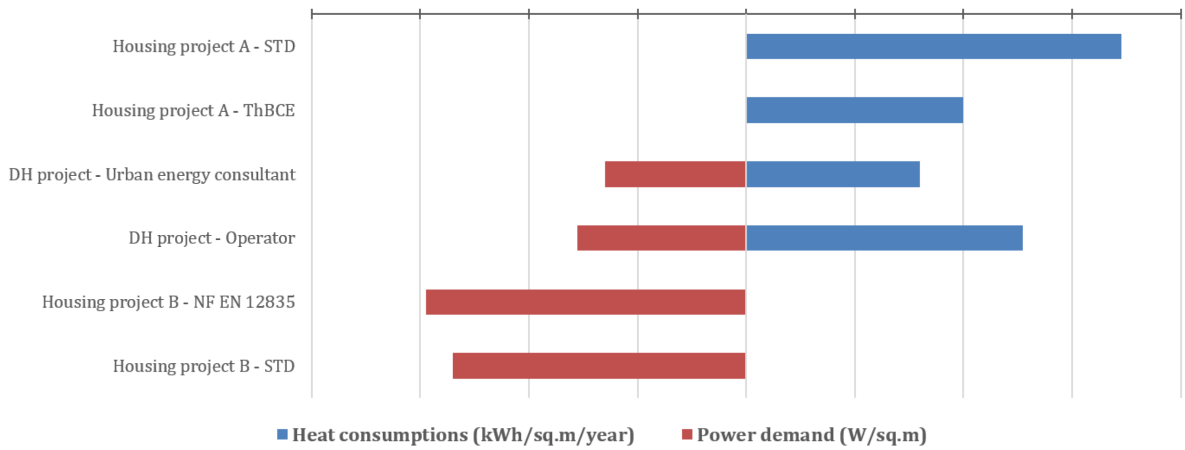

Figure 4. Dissonances between heat demand estimates during one urban development project in Bordeaux.

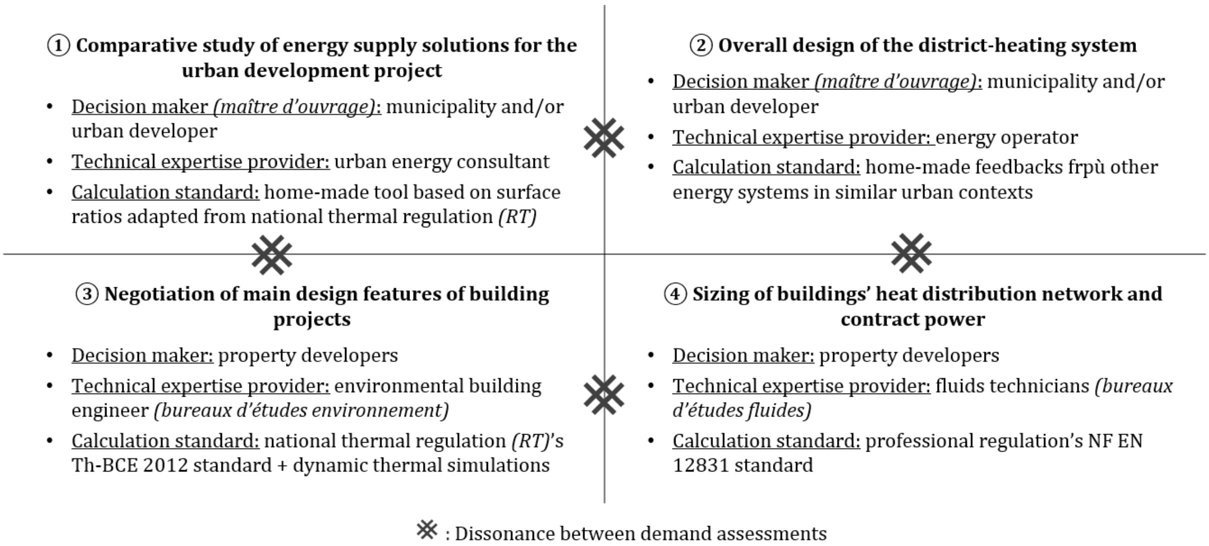

Figure 5. At each of the four steps in the DH design process, heat demand is estimated by a different actor using a new calculation standard, which leads to dissonances between the various demand assessments.

Finally, we sliced the design process of DH systems into four pieces (Fig. 5). At each step of the process, new actors enter the scene and bring along new estimates for future heat demand. Every estimate is based on a different calculation method, which leads to divergent demand assessments. In the following sections, we will see why demand estimates can differ that much (2.1), why the DH design process is punctuated by so many divergent assessments (2.2) and how it affects the overall performance of the heating supply (2.3).

2. <u>How much heat shall we foresee? A tricky and ambiguous question</u>

2.1. Demand estimates are fraught with uncertainty

Heat demand assessments for future buildings are fraught with uncertainties. To understand these uncertainties, we need to follow the methodological steps of heat demand assessments. Each of these steps provides a new estimate, which is supposed to be more accurate (that is closer to future measured reality) than the previous ones. Every new step, however, introduces new assumptions together with their uncertainties; uncertainties add up, therefore producing estimates with wide scopes for error (Fig. 6, Fig. 7).

- The first step is to determine which standard(s) (legal thermal regulation [RT], high environmental quality [HQE], low-consumption building [BBC], positive energy building [BEPOS]…) building projects with comply with. Each of these standards come with its own limitation for conventional, annual energy consumption, which provides a first heat demand estimate, though nothing is said about the consumptions pattern (power demand, load curve). This first step is associated with two uncertainties: first, no one knows exactly which will be the chosen standards for the various building projects to come; second, since urban development projects last for a decade (at least), standards' (fast) evolution has to be anticipated.
- The second step is to derive a theoretical heat demand from the conventional annual energy consumption of the building standard. To do so, one needs to presume a consumption pattern, using updated climate data and information on future users' profiles. Once again, such an operation is complex: future users are not known and their energy use is far from being understood, and even future climate is uncertain in a context of rapid climate change.
- The third step is to move from the theoretical project to the actual building. It is well-known that buildings' construction process impact their energy performance (see Fischer and Guy, 2009): compared to the project, alternative options may be chosen during the construction work, and implementation failures (e.g. in insulation attachment) affect the overall building design and performance.
- Fourth step, intrinsic building performance doesn't say all about actual heat demand: in fact, one has to take into account the in-use performance of technical devices (radiators, venting systems, control equipment,…) as well as the inhabitants' domestic practices (lifestyles, use of devices,…) and their evolution.

The methodology for demand assessments explains why estimates can diverge that much: first, even *measured* heat demands can be very different between housings with similar design (Fig. 7), with high dependence upon domestic practices and household lifestyles; second, uncertainties add up at every step of the estimation process, thus producing a wide scope for error in intrinsic building performance's assessment. This does not tell us, however, why heat demand is estimated in different ways by different actors during the design process of a district heating system.

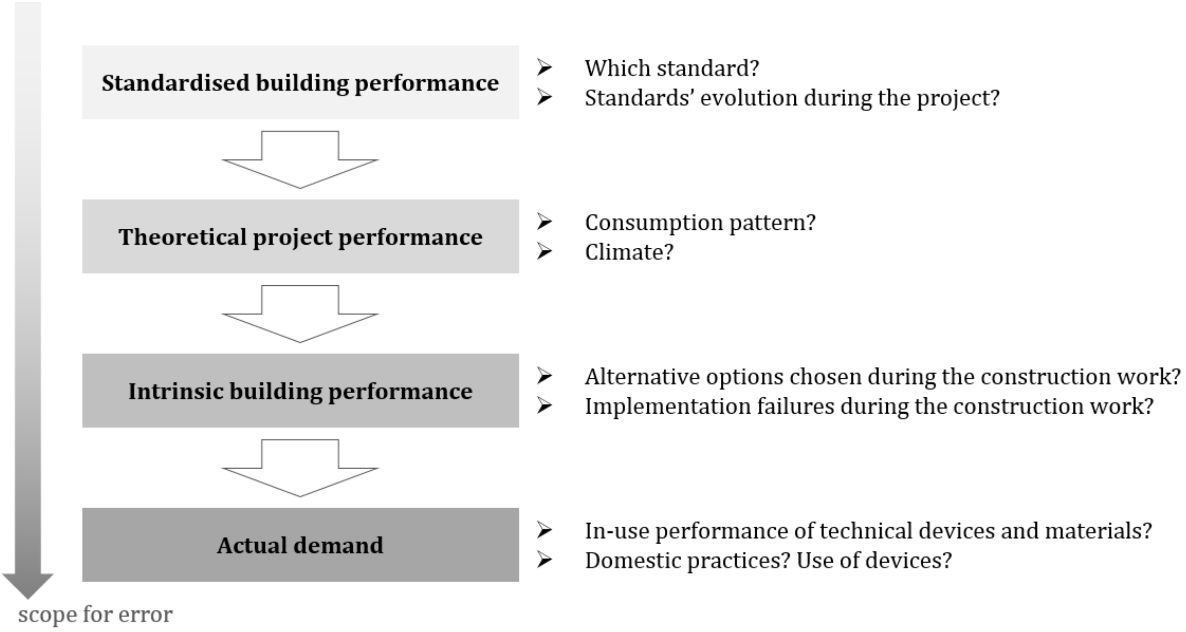

Figure 6. Uncertainties add up during the estimation process of future heat demand.

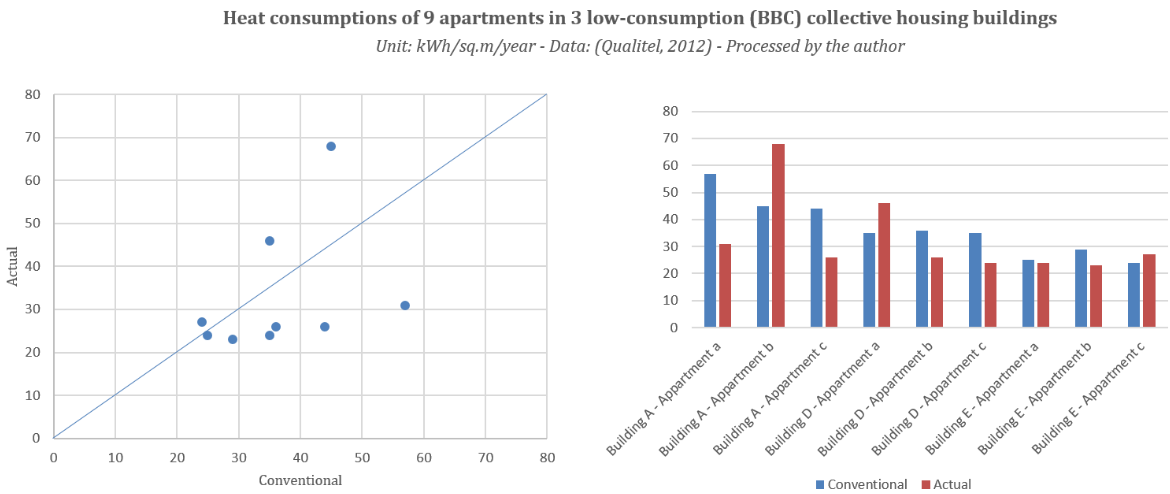

Figure 7. For a same building standard, conventional and actual heat consumptions are highly heterogeneous.

2.2. One physical object looked at through many different lenses

To understand the divergence of demand assessments, one has to analyse the motivations behind those estimates. Let us go back to the four steps of DH design (section 1.3) to see what the main goals of the demand assessment's providers are.

First, the urban energy consultant needs to provide a comparative analysis of energy provision to the future neighbourhood. Because of the numerous uncertainties on the project, it is impossible to build a comparison precise enough to choose "the very best" solution. Therefore, one of the main concerns is to test the technical and economical robustness of various alternatives when urban development differs from what is planned at first. Since grid-based systems are highly dependent on demand intensity (see section 1.2), the consultant usually uses low-demand assumptions to make his estimates.

> *There is antagonism between the district-heating designer and the urban energy consultant. What they asked us [the consultant], was to prove that the network still makes sense if consumption is low […] What the designer is asked, is to size an infrastructure so as to make sure that everybody has heat on a very cold, February 21st day, even if everybody is at home and the urban development has been faster than expected.*
> (Interview with an urban energy consultant, June 2015, personal translation)

As for the DH operator, he is caught between two important concerns. On the one hand, he needs to size a system that is robust enough to get along with a peak in heat demand in order not to be faulted: that's why safety margins are included in the design assumptions. On the other hand, those same assumptions should not be overestimated because the financial model of the DH project is very sensitive to demand changes (see section 1.2). That is why usually, DH operators try to sharpen their estimates and to minimise their safety margins.

> *A building engineer, when he designs his building, he calculates the heat loss, for example 300kW, then he asks for an energy production facility of 350 or 400kW with domestic hot water. As for us, we don't have those parameters, so we do it backwards: we start from maximal consumption ratios from the thermal regulation, then we infer a heat consumption, and finally we estimate a power demand using a weather profile. So if you take low-demand assumptions as a starting point, the heating capacity is too low and, a few years later, people will complain because they're cold. It's a first pitfall, we can't be wrong about this, so usually we take some safety margins […] Then the second problem is a matter of economics, because the financial balance of the network is made with a fixed share and a various share. So if you overestimate or underestimate the demand, your balance is skewed.*
> (Interview with a DH design engineer, September 2015, personal translation)

Third, what environmental building engineers care much about is justifying the design choices for building projects. Since national thermal regulations are based on precise conventional technical assumptions, they have no need to question them when using the Th-BCE standard. When it comes to dynamic thermal simulations, those are made to help optimizing the architectural choices for the project, as well as the selection of technical systems to implement. To do so, engineers use highly contextualised assumptions that aim at providing realistic estimates of energy consumption and power demand.

Nevertheless, dynamic thermal simulations are not considered as baselines for the sizing of buildings' heating systems. Indeed, construction professionals use specific standards – such as the NF EN 12831 standard – to prevent potential claims about the quality of their work. When professional liability is at stake, the court judges whether the work has been done in accordance with standard practice (*dans le respect des règles de l'art*), which usually refers to professional standards such as NF technical norms even when they're not explicitly mandatory. To avoid major trouble, those professional standards are based on high safety-margins. Moreover, the very standard for heating systems' sizing has not been updated since 2004 even though construction techniques and heating systems have since moved on significantly.

Finally, heat demand assessments are framed with different imperatives in mind, which explains why they diverge so much (Fig. 8). Such a dissonance between successive estimates produces what can be considered as an overall sub-optimisation of the district heating system.

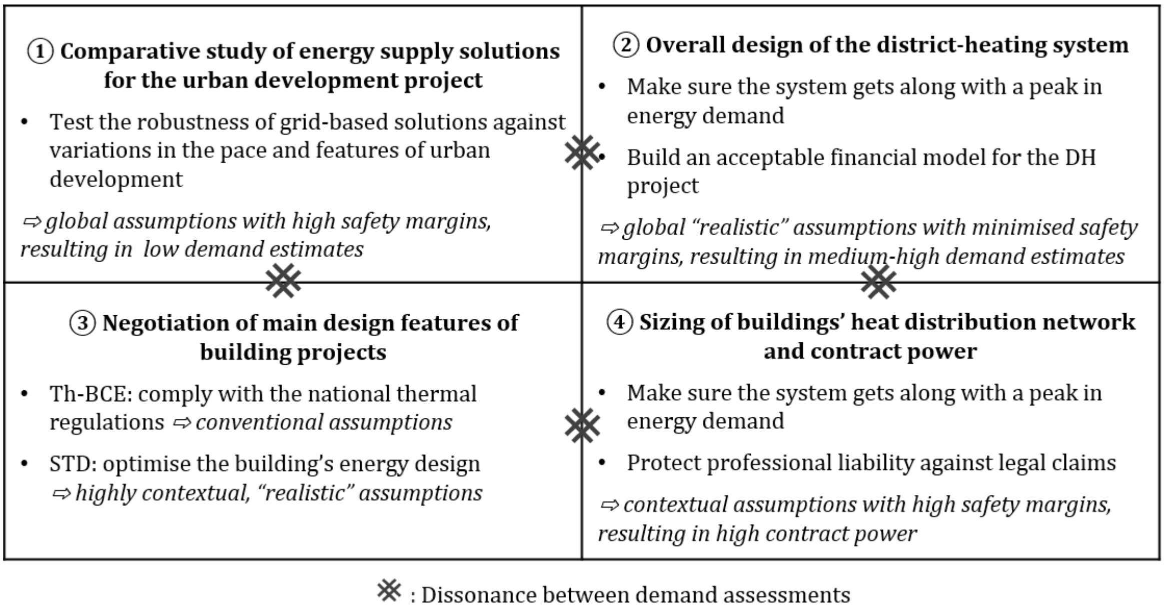

Figure 8. Demand assessments follow different goals, which explains the divergence between estimates.

2.3. Diverging estimates: a sub-optimisation of heat supply in urban development projects?

> *Demand estimates were discussed at length. Working hypotheses are not the same between [the energy consultant] and [the operator] because responsibility is not shared: the one who's committed to provide heat is the operator. That's why he is responsible for the system's sizing. And when you add up high-demand assumptions for the network's sizing and high-demand assumptions for the sizing of power contract, you get to design solutions… I think it raises a major concern.*
> (Interview with an urban developer, January 2015, personal translation)

As we have seen, a district heating design process combines at least four heat-demand assessments that do not follow the same objective, thus providing diverging estimates for future demand. Such dissonances can produce contradictions within the process, thus leading to sub-optimisation of the overall heat-supply design from (at least) two ways:

- First, there is a contradiction between the steps ① and ② of the DH design process (Fig. 9). When the urban energy consultant compares various energy-supply alternatives, he uses low-demand estimates to make sure grid-based systems still make sense if energy demand's development is lower than expected. This position leads him to base his global (that is technical, financial, environmental,…) comparisons on a low-demand scenario while in the meantime, system operators base their design on medium-high demand scenarios. This means that the upstream comparative studies for urban energy provision are "unrealistic" when compared to tenders from network operators, especially when it comes to heat price estimates. Although such a conservative position is understandable from a risk-management point of view, it leads to somehow "distorted" decision making from the local authorities, who may be tempted to launch solution-focused call for tenders that are based on "conservative, unrealistic" assessments. The divergence between upstream estimates and actual financial models is even more important when contract powers' overestimations from step ④ are included in the final pricing.

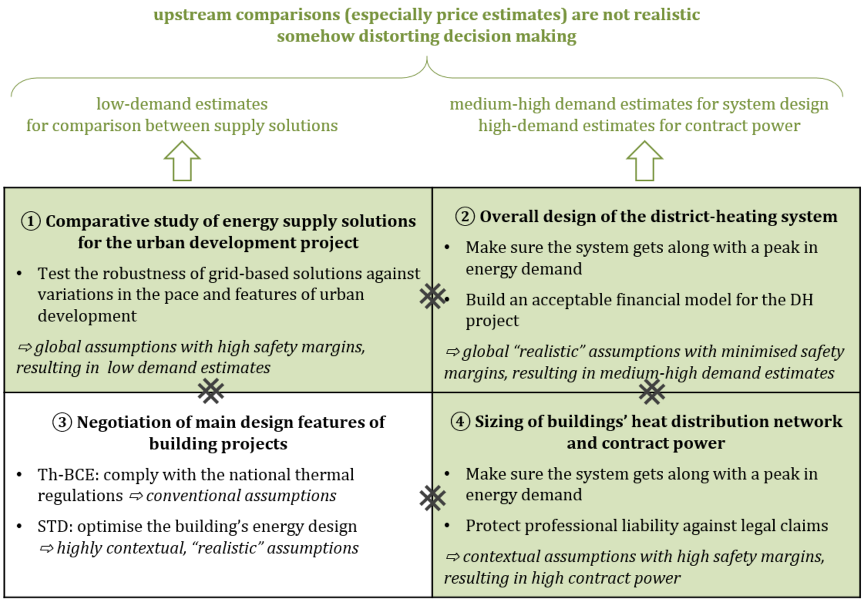

Figure 9. Contradiction between steps ① and ②+④ leads to a first sub-optimisation of the energy-supply design process.

- As it happens, overpricing is due to a second contradiction between the steps ② and ④ (Fig. 10). In fact, the DH operator builds the system's technical and financial model using "realistic", medium-high demand estimates; the heat pricing and the pipes and boilers' sizing, in particular, are based on those estimates. But during the DH commercialisation process, contracts rely on very high estimates for the contract power; since the fixed part ("R2") of the pricing depends on this contract power, property developers and final clients therefore suffer from overpricing due to power overestimations. Furthermore, the operator can't keep commercialising the DH when total contract power exceeds the system's overall capacity, so the network's extension capacity is compromised by contract power overestimations by building projects' "fluids" technicians.

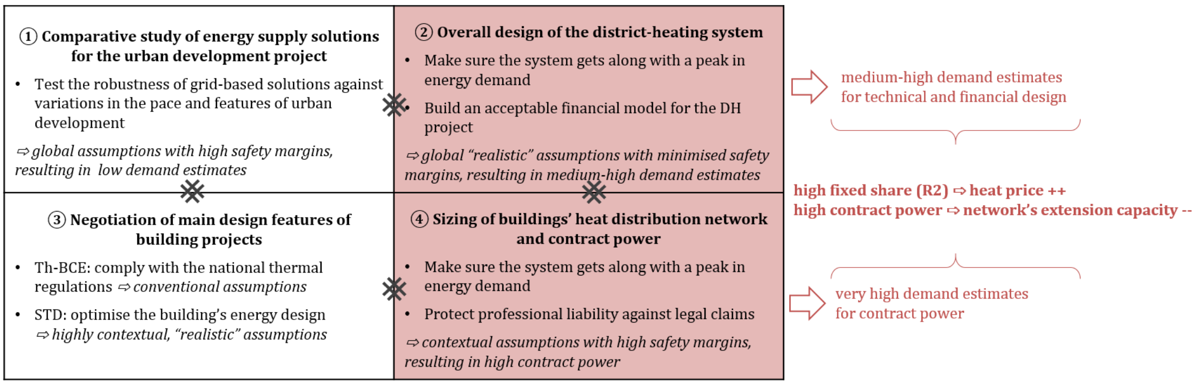

Figure 10. Contradiction between steps ② and ④ leads to a second sub-optimisation.

- Finally, it is ironic that the most "realistic" heat demand estimates respectively made at the scale of the DH system (by the operator) and at the scale of each building project (by the environmental engineer) usually never meet up during the whole design process, thus making impossible any homogenisation between design assumptions (Fig. 11).

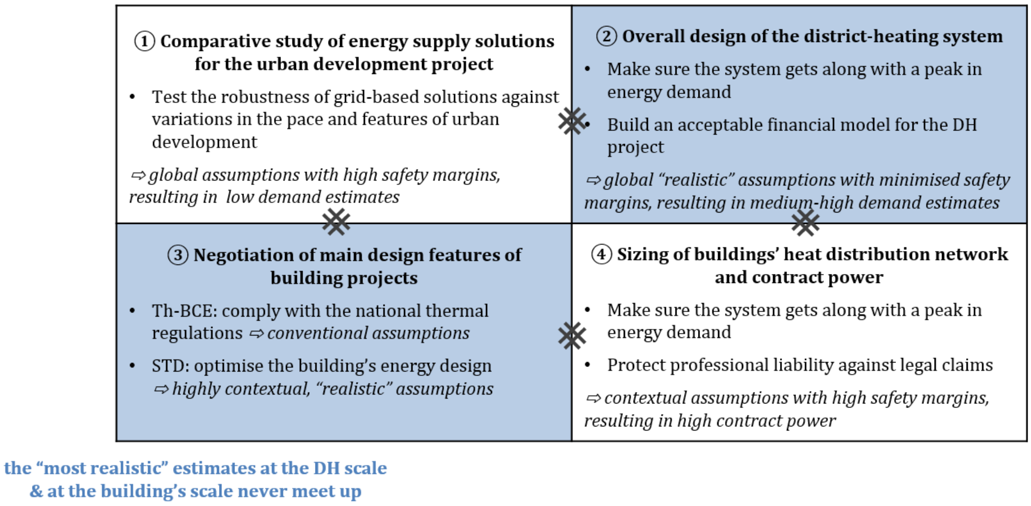

Figure 11. 'Realistic' estimates from steps ② and ③ usually don't meet up during the design process.

3. Unstandardised standards: three interpretative readings

In such a context of apparent overall sub-optimisation of DH systems' design process, what can explain that nothing has been done to make calculation standards consistent so as to align the various demand assessments? In the following, we propose three different, complementary interpretations of this seemingly absurd situation.

3.1. A matter of coordination and mutual knowledge

A first interpretative reading relates to design management of energy within urban development. The DH design process we described here refers to a distributed, multi-linear design model where the various components of the urban energy system are designed separately and sequentially (Fig. 12). Project management studies, however, have shown that concurrent engineering (Ben Mahmoud-Jouini and Midler, 1996; Midler, 2004) seems to produce more performant designs, especially when there are high levels of interdependencies between products' components.

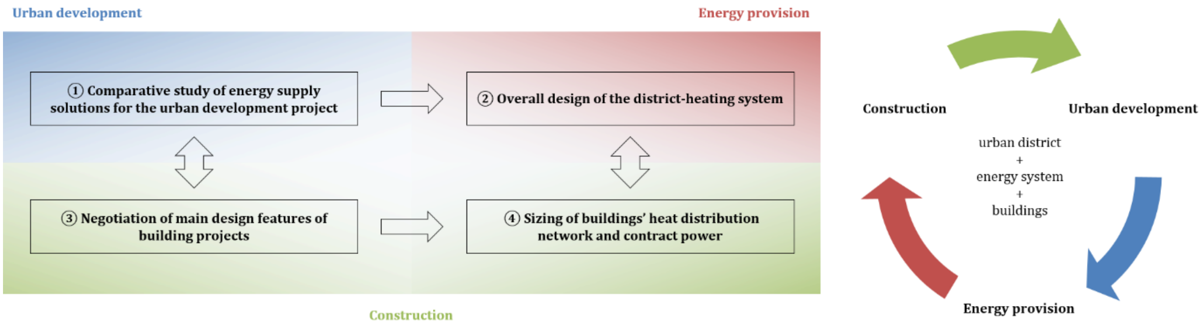

Figure 12. Distributed, multi-linear design shared between three communities of practice *vs.* concurrent engineering.

Another concern, then, is why concurrent engineering has not been implemented to design urban energy systems. In a context of concurrent engineering, integrative actors should be able to coordinate design operations, which includes the alignment of major assumptions so as to work within a shared framework: here, an "integrative actor" seems to be missing.

Municipalities and urban developers, who are central actors following on both energy supply projects, urban development projects and building projects, could play this part. Moreover, they would have important power over each project through public energy-provision contracts and building permits. The problem is, no one among these actors' staff members has enough knowledge to discuss technical issues with urban developers, building engineers and energy operators at the same time. Indeed, urban development and building construction's communities of practice (Wenger, 1998) are not used to work on energy issues. Both urban developers and property developers need to contract with specialised engineers to provide basic energy expertise to their projects. These technical experts come from either the spatial planning community, the construction or the energy sector, but none of them is familiar enough with all of the three communities so as to develop top-level coordination and integration skills.

3.2. A matter of interests

The current situation's *status quo* can also be read as the result of a satisficing compromise[9] between the various technical actors. In fact, even though we highlighted the overall imperfections of the design process, they give some kind of satisfactions to involved actors:

- As for urban energy consultants, the use of a unique, conservative demand assumption allows them to compare energy provision alternatives in only one development context. Multiplying demand assumptions would imply comparing more supply scenarios, which would make decision-making even more complex. Yet, what consultants are asked to, is to help decision-making by providing not-too-complex estimates of various alternatives' pros-and-cons.
- As for district heating operators, their financial model is highly dependent on fixed-share ("R2") incomes. Dependency upon variable-share ("R1") incomes is less important, since they correspond to variable costs (mainly primary energy), which are adjustable depending on actual (final) energy consumptions. When contract power is higher than power demand, it generates complementary R2 incomes that are much more important than losses associated with lower-than-expected consumptions.
- As for "fluids" building technicians, the use of a calculation standard with high security margins prevents them from being sued even if they miscalculate something. Since they usually don't have to justify their sizing during the building's design process, they get no trouble from the unnecessary costs generated by their assumptions.
- As for environmental building engineers, they would not want to use overestimated power demand assumptions to comply with actual sizing, since it would make it harder to justify the energy performance of the building's projected design.

3.3. A matter of collective risk management

These last two readings of heat-demand assessments during a DH design process may be considered critical. In this section, however, we would like to show that observed dissonances can also be analysed as a collective, distributed way to control the risk during an infrastructure project.

Indeed, the various safety margins that add up during the design process match with two different risks related to the DH project:

[9] The compromise we mention here should be understood as the passive result of actors' strategies. It is highly unlikely that the actors involved or their (non-existent) representatives actively combined to bring about the current situation.

- If urban development is too slow, energy demand will be lower than expected, which threatens the DH financial model.
- Nevertheless, if actual demand is higher than expected, the systems may be undersized, which would lead to either failures in heat provision or major expenditures so as to resize the whole infrastructure. This concern relates to the buildings' internal systems design as well.

In mega-projects, upstream feasibility studies are often criticised for being too optimistic (Flyvbjerg et al., 2003). Unlike mega-projects, district heating projects can't rely on the State to compensate for spending overruns, and sunk costs place a significant financial burden on the operator. Using various, divergent estimates to assess the feasibility of a DH project and size the systems, then helps controlling the risks that are associated with major demand-related uncertainties. Put it another way, the dissonances between heat-demand assessments can be seen as a distributed, multi-criteria analysis of a district heating project.

4. Conclusion

Even though future demand assessment is crucial to design a district-heating project, we have seen that these projects bring various, divergent estimates into play, thus creating dissonances within design processes. In fact, each estimate complies with its own calculation standard, which obeys its own rationale.

One could see such a situation as an absurd sub-optimisation of DH systems' design process, due to the lack of coordination and shared knowledge between communities of practice associated with urban development, building construction and energy provision. Nevertheless, it can also be considered as the result of a strategic compromise between the "technical" actors of DH design, as well as a distributed way to control the risks associated with poor estimates for future demand.

Beyond this case study, our study first provides empirical data about the use of standards in the making of energy demand, from a supply-side perspective. By unblackboxing demand assessments within DH design processes, we bring out bring out the controversial nature and the performative power of calculation standards (Akerman and Peltola 2006). Mobilizing standards as indicators of sociotechnical processes involved in the making of demand, we also (partly) unveil the sociotechnical networks and decision-making chains into which district heating systems are inscribed, thereby providing new insights on the organisation and governance of urban energy systems (Summerton 1992; Hawkey et al. 2013).

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