Future business model for district heating based on renewables in Ile-de-France

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ABSTRACT

District heating is an efficient way to integrate renewable energies in the energy mix. In the French region Ile-de-France, district heating and renewables have known strong developments for several years, and they are expected to grow much more in the future. The expansion of renewable energies depends partly on their competitiveness compared to fossil fuels, which is related to public subsidies, and on the spread of district heating networks in the region. Thus, it could be assess what is the future business model for district heating based on renewables in Ile-de-France.

The data at the disposal of ADEME, the French agency for environment and renewable energies, show that district heating systems based on biomass could soon become more competitive than fossil fuels, whereas systems based on geothermal heat have fairly high costs. Yet, geothermal heat is more developed than biomass, and is expected to reach the targets set by the regional action plan for 2020, on the contrary to biomass. Though the increasing competitiveness of renewables will cut the necessity of public subsidies, the difficulty to reach some regional targets might mean that further actions should be implemented. From the energy operators’ point of view, the sector of district heating will surely grow considerably and therefore represent a large potential of development for those companies.
ACKNOWLEDGEMENT

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I acknowledge Mrs. Joëlle Colosio, director of ADEME Ile-de-France, for welcoming me warmly. I am also grateful to Mr. Guillaume Perrin and Mr. Romain Donat, my supervisors and colleagues at ADEME, for their care, their patience and their ability to pass on their knowledge.
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1. INTRODUCTION

1.1. Background

**France and Europe: targets for 2020**

In 2008, the European Union set 3 objectives that should be reached before 2020, called the “20-20-20 targets” (SRCAE, 2012):

- 20% reduction of greenhouse gases emissions compared to 1990 levels
- 20% of renewable energies in the total energy use
- 20% augmentation in the European energy efficiency (European Commission, 2012)

In France, a first national debate around energy transition called “Grenelle de l’environnement” occurred in 2007 and led to several decisions, and was a clear step forward. France has of course adopted European goals and has even chosen to set a higher target: 23% of renewables by 2020. By 2050, France wishes also to reach a 75% reduction of GHG emissions compared to 1990. This division by 4 of the emissions is called “factor 4” (SRCAE, 2012).

The national objective of 23% renewables by 2020 has been divided spatially and into several categories. Regional goals have been set in each of the 22 French regions. Those goals concern every fields of the energy and environment sector (every renewable energy, every kind of pollutants) and are built taking into consideration the regional contexts (economy, resources). Together, if all those single targets are individually met, it would allow France to meet its main goals.

In each region, a document called Regional Plans for Climate, Air and Energy (in French: Schéma Régional Climat Air Energie: “SRCAE”) was written and published in 2012.

**District heating in France**

Heat - space heating and sanitary hot water - represents around 77% of the energy use of a building (CETE de l’Ouest, 2011). In Ile-de-France, 10% of the heat is injected in district heating networks.
Heat networks should be installed wherever it is possible because they make the most of any heat source: the biggest boilers offer the highest efficiencies and the large installations are worth to invest in reliable filters to avoid air pollution.

So it seems there are obvious reasons to focus on the challenge of heat production and utilization in general; and on heat distribution through district heating networks in particular. The utility of district heating is clear; this is why its potential should be more exploited. Therefore, the aspects of energy mix and future development can be studied.

**District heating in Ile-de-France**

Ile-de-France is one of the 22 French regions. There are 11 786 000 inhabitants in Ile-de-France (Insee, 2010), which represents 18% of the total population of France. The main city of the region is Paris, and the region is divided into 8 districts.
Ile-de-France is a highly populated area with very dense cities, like Paris of course, but there are also many uninhabited places, in Seine-et-Marne for instance. High-density districts suit well for district heating because it reduces investment costs (less pipes, less trenches). This proximity between residential buildings is also to be found between residential and industrial areas, therefore heat recovery from waste incinerators or factories becomes possible. It explains why the first district heating system was implemented in Paris in 1927 (CPCU, 2013).

A second reason why district heating is developed in Ile-de-France is deep geothermal energy (between 1 000 and 2 000 meters deep): the region has indeed one of the highest potential for geothermal energy in France (BRGM & ADEME, 2010). Geothermal energy provides large quantities of heat, and mainly for financial reasons it is advised to extract large amounts of this energy: investment costs are indeed high so a lot of energy should be extracted and sold in order to pay back the investments; besides there is a technical limit: the water extraction flow cannot decrease more than a minimum flow, and this phenomenon requires a minimum heat demand (around 40 000 MWh/year) to balance the heat production (BRGM & ADEME, 2010). Thus, the easiest way to reach enough demand to make the geothermal solution possible and cost-effective is to add the heating needs of several

Figure 2: Map of the region Ile-de-France and its 8 districts
buildings. Heat produced by a central geothermal facility is transported to different buildings by a pipe network: this is the basic concept of district heating. The two first implementations of geothermal energy in France were conducted in Ile-de-France in 1964 and 1969. Today, 80% of the deep geothermal facilities in France are situated in Ile-de-France. 75% of the deep geothermal energy is injected in district heating networks and the rest goes to industrial sites and large buildings like hospitals and malls (BRGM & ADEME, 2010). Most of the projects are done in the geological layer called Dogger (at least 1 500 meters deep), corresponding to the Jurassic era. There, temperatures lay between 60 and 100°C, so direct electricity generation is inefficient, but the temperature is high enough for efficient space and sanitary water heating (BRGM & ADEME, 2010).

Figure 3: Deep geothermal energy potential in France - blue=high potential (BRGM)
Biomass development since 2008 is another explanation for the recent district heating proliferation. Biomass could be seen as a compromise: a plant is less expensive and more easily built than for geothermal energy, and it is more powerful than solar or heat pumps. Besides, Île-de-France, and France in general, have many forests and therefore a high potential for biomass energy.

<table>
<thead>
<tr>
<th>Forests area</th>
<th>Occupation rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ile-de-France</td>
<td>2 787 km²</td>
</tr>
<tr>
<td>France</td>
<td>175 459 km²</td>
</tr>
</tbody>
</table>

Table 1: Forests area in France (DRIAAF, 2012)

Today, 26% (114 among 458 systems) of the French district heating networks are situated in Île-de-France (SNCU, 2013). In the region, district heating represents 5% of the final energy
use whereas it is 2% (21,800 GWh/year) at the national level. In the country, heating corresponds to around 50% total energy use (CETE de l’Ouest, 2011). So in total, 10% of the generated heat is transported by district heating networks in Ile-de-France.

The energy mix used for district heating has a key role for the energy transition in Ile-de-France. Today, only 30% of the primary energy injected in heat networks does not come from a fossil fuel (SRCAE, 2012).

SRCAE is the regional action plan written in 2012 by several public organizations, including ADEME. This document gives objectives for every renewable energy. The goal set by the SRCAE for district heating is an energy mix of 50% of fossil fuel and 50% of renewables or heat recovery by 2020, which consists in almost doubling the share of renewables. In total, there would be an 8% increase of district heating utilization.
<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Situation in 2009</th>
<th>Targets for 2020</th>
<th>Expected Evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal energy</td>
<td>1 163</td>
<td>2 326</td>
<td>100%</td>
</tr>
<tr>
<td>Biomass</td>
<td>88</td>
<td>2 398</td>
<td>2 625%</td>
</tr>
<tr>
<td>Waste incineration</td>
<td>3 405</td>
<td>4 086</td>
<td>20%</td>
</tr>
<tr>
<td>Cogeneration in gas power plants</td>
<td>4 699</td>
<td>4 999</td>
<td>6%</td>
</tr>
<tr>
<td>Individual gas boilers</td>
<td>3 073</td>
<td>2 046</td>
<td>-33%</td>
</tr>
<tr>
<td>Coal</td>
<td>1 930</td>
<td>965</td>
<td>-50%</td>
</tr>
<tr>
<td>Oil</td>
<td>1 457</td>
<td>364</td>
<td>-75%</td>
</tr>
<tr>
<td>Other projects of heat recovery</td>
<td>-</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>85</td>
<td>-</td>
<td>-100%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15 900</strong></td>
<td><strong>17 234</strong></td>
<td><strong>8%</strong></td>
</tr>
</tbody>
</table>

Table 2: Energy mix targets for district heating in Ile-de-France by 2020 (SRCAE, 2012)

One of the major tools to reach these objectives is called “Fonds Chaleur”. In English: Heat Fund. The Fonds Chaleur corresponds to a fund of 1.2 billion euros managed by ADEME for a period of 5 years: 2009-2013. The budget has been divided between the different regional ADEME agencies, and used to subsidize projects of renewable heat (district heating, biomass, geothermal heat, biogas, solar heat, heat pumps). For instance, ADEME in region Ile-de-France got 15.1 million euros in 2012. For year 2014, the same amount as 2013 has been renewed, without any certainty for the years after.
1.2. Research question

Considering the limited fossil fuel resources on Earth, it seems obvious that renewables represent the future for energy supply in the very long term. Still, the speed and the way renewables will replace fossil fuels remain an uncertainty in the medium term. The stakes and actors are numerous: how governments, companies and citizens are going to meet all the ecological, economic, technical, and political challenges? This global question could be asked for the specific case of district heating in the French region Ile-de-France:

What is the future business model for district heating based on renewables?

This question could be answered in two parts. Firstly, from an economic point of view: the cost for the user is a key information because it has a direct influence on the energy operator revenue, and on the medium term it has an impact on the ability of the company to develop its activities because its competitiveness may seduce new clients, or may push the users away to another provider. Besides, the price of heat reflects indirectly the production costs for the companies and thus their possibility to raise their competitiveness compared to less sustainable energy suppliers. Therefore, the first part is titled: Heat pricing analysis and future competitiveness of district heating based on renewables.

The second part treats general development of the sector in terms of facilities and clients. The future development of renewables assesses how many users, and thus citizens could be involved in this growth. On the other side, it gives an idea of how companies could expand their businesses. From the political point of view, assessing the future development of district heating is a way to check if the targets set by the regional government in the regional action plan could be met. Therefore, the second part is titled: Development of district heating and place of renewables in the future regional energy mix.
1.3. Methodology

The goal is to treat the two parts separately and then to discuss and link their results.

Heat pricing analysis and future competitiveness of district heating based on renewables: for this part, the statute of public organization of ADEME is helpful. ADEME has access to many “public service delegation contracts”, which permits a municipality to task an energy operator to develop a district heating network and/or to produce and supply heat to the users who are connected to this system. In such contracts is explained the way the price of heat is decided (indexation formulas). These data are used to assess the future price for district heating based on renewables, and are completed by economic assumptions discussed with the economy service at ADEME. The competitiveness is estimated using the data gathered by ADEME about the cost of heat in the case of fossil fuel solutions, considered as “reference” solutions.

Development of district heating and place of renewables in the future regional energy mix: there are two levels of thinking: the development of each energy source (renewables and also non renewables) and the global development of the sector. Thus, both global and micro approaches are needed. The global approach is done thanks to regional and national statistics coming from surveys conducted by the interprofessional union “SNCU” that gather together district heating professionals. The micro approach is realized with ADEME data, which give energy mix evolutions for all the projects that asked for subsidies since 2008. Those data are used to define tendencies and therefore assume the future evolutions. The future 2020 situation is evaluated using a year-by-year approach, for each energy source and for the total amount of energy.
1.4. Assumptions and limitations

Heat pricing analysis and future competitiveness of district heating based on renewables: to complete the study it is needed to assume the evolution of some main economic parameters like the price of primary energies, or the inflation rate. Those assumptions have a strong impact on the results, mainly from the quantitative point of view.

The study is based on a fixed range of initial technical parameters: the energy mixes of the hypothetic district heating systems, though they are average values calculated from the collected data and therefore represent the actual situation, have an impact on the final results. But as the economic data depend on the technical background, it would not be relevant to change the hypothetic energy mixes and keep the same economic model for the study. Thus, the results are limited to a specific technical background.

Development of district heating and place of renewables in the future regional energy mix: Statistics from SNCU come from yearly studies based on the data given by district heating systems operators. It is assumed that what the operators claim is reliable. It is also assumed that every district heating network that has introduced green energies in its energy mix since 2009 has asked for ADEME subsidies and thus is present in ADEME data.

Strategic action plans cannot actually be used, though it would have been useful to know precisely how the developments are planned in the future. But most of the district heating systems do not have yet realized or published those plans. Among the 8 available plans (there are 114 district heating networks in region Ile-de-France), only 4 have enough details to be studied (clear timeframe, clear targets for the development of every energy source, extension plans that are not completed after the first range of works but later on). Too little information can be taken from the published strategic action plans and it would not be relevant or representative to use them.
2. LITERATURE STUDY

Background

District heating can be approach like the electricity or the natural gas sectors. They all are grid-based energies, meaning that energy has to be transported through a network that has required large investments. The dependency of the users towards the provider, who decides the price and could potentially stop the delivery at any time, is balanced by the dependency of the provider to its clients because the energy can only be sold to customers connected to the grid and switching to other customers who are not connected would be impossible.

District heating is close to electricity because of the similar approach in the necessity to balance demand and supply of heat or electricity (H. Lund, 2010). The supply should be constantly modified to match exactly the demand and keep the delivery stable. Yet, the time scales are not comparable: it is on the micro second scale for electricity whereas minute scale approach is sufficient for heat distribution.

District heating is also close to natural gas because of the number of competitor resources available. In the big global geopolitical game, Russian gas could be replaced in Europe by gas from other countries, shale gas or oil. In the same way, district heating can be replaced by several kinds of individual boilers or heat pumps. On the contrary, electricity has no equivalent competitors and our dependency for this energy is very strong.

On the geopolitical point of view, district heating could decrease the dependency of a country to its energy providers because this solution enables the use of local and national resources: heat recovery, renewable energies. Consequently, it reduces the import needs and improves energy security (H. Lund et al, 2009).

Comparison with other countries

Like many other technologies in the world, district heating is far from being developed in the same way in each country. There are economic reasons of course, because district heating is a heating solution that requires high investments as well as advanced technologies for heat production and transmission. There are also climatic reasons: as a highly successful solution for heating, district heating has firstly interested countries with large heating needs.
This is why, today, north Europe is a leading region for district heating (J. Goop, 2012). Whereas many countries simply do not have any district heating installation and others are developing this concept, Northern countries are already considering future issues such as competitiveness for district heating in the case of low-energy buildings (U. Persson & S. Werner, 2010).

In Denmark, district heating is believed to represent between 53% and 63% of the total heating towards 2020 (B. Vad Mathiesen et al, 2010). District heating has a key role to reach the official objective of 100% renewable energy, which should be done by 2060 (H. Lund et al, 2009). Renewables and heat recovery constitutes around 90% of the Danish energy mix for district heating. In Sweden, more than 75% is reached (J. Goop, 2012).

On the contrary in France, only around 4% of the total heat use comes from district heating. In Ile-de-France, the result is more encouraging (10%) but remain far from the results in Northern European countries. The same kind of gap can be noticed for the energy mix: barely 30% of the heat injected in heat networks in Ile-de-France does not come directly from fossil fuels (SRCAE, 2012).

Using European regulations as targets and Northern countries as examples, France wishes to develop district heating in order to reach 23% of renewables in 2020 and decrease by 75% its energy use by 2050 (SRCAE, 2012). Among those 23% of renewable energies, half is renewable heat.

**District heating and heat recovery**

District heating is an efficient way to recover large amounts of unavoidable heat produced when industrial processes, electricity generation or waste incineration are performed (ADEME, 2012). This could even be considered that “the fundamental idea of district heating is the recycling of heat that otherwise would be wasted” (U. Persson & S. Werner, 2010). Consequently, heat recovery can also be seen as an opportunity of low cost energy production because no more fuel is needed: unavoidable heat has already been generated and there is just one more thing to do: recover it (Nordic Energy Perspectives, 2010). Thanks to this cheap energy, high distribution costs are more easily accepted: this is how district heating is economically viable (U. Persson & S. Werner, 2010).
In Ile-de-France, several actions are possible. Heat recovery is already implemented in 11 of the 19 waste incineration factories, but the situation can still be improved: the 8 remaining facilities can be connected to district heating networks, the efficiency of heat recovery can be increased, and electricity generation in waste-to-energy plants can be slowed down and replaced by more heat recovery. Anyway, no more incineration facility will be built as a reduction of waste production is encouraged (SRCAE, 2012). But if this process of waste reduction is well performed and waste quantities drop drastically, we are actually also on the path to the closing of some waste incineration factories. So on the long term it is maybe not on this resource that we should rely.

Data centers are also great heat sources because they need to be constantly cooled down and their number is increasing with the development of the computer industry. The service sector is very developed in Ile-de-France, what justifies the creation of many data centers around the business districts. Though only one heat recovery facility is in project in the region, the potential of this system seems interesting (SRCAE, 2012).

It is also possible to recover heat from waste water. It is basically the hot water used for the shower or to do the dishes that can be used before it becomes lost in the sewage system. Then thanks to heat pumps, the same Joules used for domestic hot water can be recovered and injected in radiators for space heating. As well as for CHP, the efficiency of the process is strongly increased (SRCAE, 2012).

**A scenario with 100% of CHP**

Regarding the role of CHP, it is interesting to consider a scenario of 100% of CHP, when all the “waste heat” (unavoidable heat from electricity generation processes) would be recovered and injected into district heating networks. “Waste heat”, or “unavoidable heat”, corresponds to the energy that cannot be transformed into electricity by the power plant, as it is explained by the second law of thermodynamics.
On the one hand, in the French thermal power plants in 2012, 111.6 Mtoe\(^1\) of primary energy was used to produce 42.73 Mtoe of electricity, so with an average efficiency of 38% (SOeS, 2012). The remaining 62% represents 68.87 Mtoe of heat. Then, considering technical limitation of heat recovery and heat transmission losses, at least 20% of losses can be assumed (this figure can be discussed a long time because power plants are far from the cities, especially in France where nuclear is used; here it is more a theoretic scenario to have in mind some ideas of the CHP potential), there are 55 Mtoe left.

On the other hand, 52% of the final energy use is heat (CETE de l'Ouest, 2011). It represented around 81 Mtoe in 2012 - we get the same result is we consider that heat corresponds to 80% of buildings energy use and that the building sector represent 2/3 of the heating needs.

If all the heat from electricity production in thermal power plants is recovered, a simple calculation (55 Mtoe divided by 81 Mtoe) shows that 68% of the heat demand could be covered. Today, this energy is almost entirely lost whereas it could theoretically strongly reduce the energy bill.

District heating and renewable energy

Interest for district heating has increased because of the growing concern for energy questions. District heating can indeed be seen as a good solution to “heat buildings without heating the world” (Svensk Fjärrvärme, 2009). Heat from renewable energies such as biomass and geothermal energy can be supplied in large quantities to heat networks. Renewable energies and district heating are totally related: between 2009 and 2012 in Ile-de-France, 70% of the renewable heat is transported by such networks (ADEME, 2012).

Both heat recovery and renewables are supported by subsidies. On a district heating network with more than 50% of heat from renewables or heat recovery, the customer pays only 5.5% of value added tax (VAT) instead of 19.6%. It means that the heat provider earns more money, or that the user saves money. This tax system could be modified between 2020 and 2030.

\(^1\) Mtoe=1 000 000 toe (tonnes of oil equivalent). And 1 toe represents the amount of energy released by burning one tonne of crude oil. 1 toe corresponds to 11.63 MWh (megawatt hours), or 42 GJ (giga Joule).
2030 and the threshold could rise from 50% to 75% of renewables or heat recovery (ADEME, 2012).

Nevertheless, the use of renewable energy for district heating should be organized. Waste heat should be prioritized and the maximum should be recovered (SRCAE, 2012). This heat would indeed be lost if nothing is done. Then comes geothermal energy, which cannot be transported - on the contrary to biomass - but which is actually stocked underground as long as the exploitation has not begun. Finally, biomass should be the last solution because it is the one that can be the more easily controlled.

In this context, and considering that many municipalities plan to build biomass power plants when there are heat recovery possibilities or geothermal potentials, a pedagogical decision tool called “tree of choices” has been created to assist municipalities and contractors in their decisions (ADEME Ile-de-France, 2013).

This document is to be published in the region Ile-de-France, to explain the stakes of the renewable heat sector (first choice: heat recovery, second choice: geothermal energy, third choice: biomass), so that decision makers do not forget the potentials of every renewable heat source and eventually chose the best solution considering the local context.
Unfortunately, it is nowadays unthinkable to reach 100% of renewables or heat recovery for every heat network. In winter, there are needs for an extra heating source and a solution based on fossil fuels is the cheapest solution. 100% renewable solutions would augment the investment costs and disturb district heating development (ADEME, 2012).

**Case studies: some operations in Ile-de-France**

As explained in the “tree of choices”, there are basically three energy sources that can be used for renewable district heating: heat recovery, geothermal energy and biomass. For each of them, different technical solutions are used in Ile-de-France.

<table>
<thead>
<tr>
<th>Energy resources</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat recovery</td>
<td>From electricity power plant (CHP)</td>
</tr>
<tr>
<td></td>
<td>From waste incinerators</td>
</tr>
<tr>
<td></td>
<td>From data centers</td>
</tr>
<tr>
<td>Geothermal energy</td>
<td>Deep geothermal energy, in the geological</td>
</tr>
</tbody>
</table>
layer called “Dogger aquifer”, around 1700 – 1900 meters deep, 65°C - 80°C.

Intermediate geothermal energy, in geological layers called “Albian aquifer” and “Neocomian aquifer”, around 700 – 900 meters deep, 25°C – 35°C.

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Woodchip : forest residue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wood industry waste</td>
</tr>
<tr>
<td></td>
<td>End-of-life wood (pallets, crates…)</td>
</tr>
</tbody>
</table>

Table 3: Resources and technologies for renewable district heating systems in Ile-de-France (EDP Sciences & ADEME, 2007; BRGM & ADEME, 2010)

There are three main scenarios for the setting up of renewable energy installations and district heating systems. It is possible to illustrate each of them through a case study.

<table>
<thead>
<tr>
<th>Creation of a district heating network + renewable heat production</th>
<th>Extension of an existing district heating network + fossil fuel replaced by renewable energies</th>
<th>Extension of an existing district heating network + restoration of a renewable heat plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case study: Cities of Arcueil and Gentilly (geothermal energy)</td>
<td>Case study: City of Les Mureaux (biomass)</td>
<td>Case study: City of Chelles (geothermal energy)</td>
</tr>
</tbody>
</table>

Table 4: Examples of recent district heating operations in Ile-de-France

Arcueil and Gentilly

The two bordering cities South of Paris have planned renovations and reconstructions of buildings. This is the appropriate occasion to create a district heating network, as anyway digging operations have to be done. They could have chosen to create two separated network with gas heat plants. But considering, one the one hand the environmental consequences of this decision, and on the other hand the high geothermal potential under the two cities, the geothermal solution has been selected. Then, considering that in each city the district heating demand is not high enough to justify two separated geothermal operations, it was decided to create a common district heating network with a shared
geothermal facility. Besides, in order to increase the efficiency of geothermal energy, a heat pump is used.

<table>
<thead>
<tr>
<th>District heating network size</th>
<th>11 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needs for domestic hot water</td>
<td>12 678 MWh /year</td>
</tr>
<tr>
<td>Needs for space heating</td>
<td>66 270 MWh /year</td>
</tr>
<tr>
<td>Total needs</td>
<td>78 948 MWh /year</td>
</tr>
<tr>
<td>Geothermal energy</td>
<td>47 354 MWh /year</td>
</tr>
<tr>
<td>Heat pump production</td>
<td>10 132 MWh /year</td>
</tr>
<tr>
<td>Extra heating</td>
<td>Gas</td>
</tr>
<tr>
<td>Renewable production</td>
<td>72.8%</td>
</tr>
<tr>
<td>Wells deepness</td>
<td>1 470 meters</td>
</tr>
<tr>
<td>Resource temperature</td>
<td>64 °C</td>
</tr>
<tr>
<td>Total investments (district heating and geothermal energy)</td>
<td>32 200 000 €</td>
</tr>
<tr>
<td>Subsidies from ADEME (state subsidies)</td>
<td>4 040 000 € (15.5%)</td>
</tr>
<tr>
<td>Subsidies from regional government</td>
<td>3 320 000 € (10.3%)</td>
</tr>
</tbody>
</table>

Table 5: Main parameters of the district heating system in Arcueil Gentilly

Les Mureaux

Two district heating networks were created in the 1970s, with an energy mix of 100% fossil fuels. But the networks had become old, and the dependency to fossil energy had become an increasing issue. For economic and environmental reasons, it was decided to renovate the existing networks, to connect together the two networks, to develop the network to new districts and new customers, and to build a biomass heat plant.

One of the main reasons why the network was extended is to increase the number of connected customers, and thus to increase the network revenue, in order to payback the investments done for the biomass heat plant.

<table>
<thead>
<tr>
<th>District heating network size</th>
<th>Extension : 6.6 km – Existing : 3.6 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total heating needs</td>
<td>45 576 MWh /year</td>
</tr>
<tr>
<td>Biomass power</td>
<td>5.8 MW</td>
</tr>
<tr>
<td>Energy from biomass</td>
<td>32 888 MWh/year</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Extra heating</td>
<td>Gas, oil</td>
</tr>
<tr>
<td>Renewable production</td>
<td>72.16%</td>
</tr>
<tr>
<td>Renewable fuels</td>
<td>Woodchips, end-of-life wood</td>
</tr>
<tr>
<td>Total investments (district heating and geothermal energy)</td>
<td>7 682 685 €</td>
</tr>
<tr>
<td>Subsidies from ADEME (state subsidies)</td>
<td>1 399 203 € (18.2%)</td>
</tr>
<tr>
<td>Subsidies from regional government</td>
<td>680 211 € (8.9%)</td>
</tr>
<tr>
<td>Subsidies from EU</td>
<td>250 000 € (3.3%)</td>
</tr>
</tbody>
</table>

**Table 6**: Main parameters of the district heating system in Les Mureaux

**Chelles**

The city of Chelles has used geothermal energy and district heating since 1987. District heating has been continuously developed since, and as geothermal energy was used at its maximum level, several fossil fuel heat plants were created to cover the growing demand. The geothermal plant got old and less powerful, which was expected and quite normal, so the situation had to be resolved.

In the cases of end-of-life geothermal plants, three choices are possible:

- New pipes can be fitted in the two existing wells, but then the water flow goes down (the pipes are narrower).
- A third well can be drilled, for extraction purposes (so there are two extraction wells).
- A new “two-well” installation can be drilled. Costs, performances and sustainability are higher than for the two other solutions.

The last solution has been selected. Though it has the highest investments, on the long term it requires less maintenance and thus it is the most sustainable (economically and environmentally). Besides, in order to increase the total efficiency, a heat pump is used. With this system, the extracted water becomes hotter (exchange of energy with water at the output of the district heating system).
District heating network size | Extension : 5.2 km – Existing : 7.5 km
---|---
Needs for domestic hot water | 19 438 MWh /year
Needs for space heating | 60 086 MWh /year
Total needs | 79 524 MWh /year
Geothermal energy | 45 070 MWh /year
Heat pump production | 10 132 MWh /year
Extra heating | Gas, oil
Renewable production | 56%
Wells deepness | 1 700 meters
Resource temperature | 69 °C
Total investments (district heating and geothermal energy) | 17 700 000 €
Subsidies from ADEME (state subsidies) | 1 467 463 € (8.3%)
Subsidies from regional government | 1 578 000 € (8.9%)

Table 7: Main parameters of the district heating system in Chelles

The case of low-energy buildings

Heat prices are always composed of two parts:

- A variable share, proportional to the energy deliveries, called R1 (€/MWh)
- A fixed share, the subscription, called R2 (€/kW)

Two buildings differently isolated but requiring the same power, and thus paying the same subscription, can be compared. The poorly isolated building will use less energy than the well isolated one because it has more heat losses. Thus, when comparing the average price of one single MWh, the subscription R2 is more attenuated in the poorly isolated building than in the well isolated one.

Moreover for freshly developed systems, district heating providers have to support high investment costs that are recovered through customer’s subscription (S. Tirado Herrero and D. Ürge-Vorsatz, 2011). Consequently, the fixed share gets higher right after a system has been modified and made greener, which attenuates the impact of the decrease of pure energy costs (pure biomass and geothermal prices are lower than gas prices).
A decrease of the heating needs

In the case of low-energy buildings with district heating, the fixed share remains proportionally very high compared to the variable share, due to the low heating demand. From the user point of view, district heating will become less competitive compared to individual solutions like solar thermal panels (H. Lund et al, 2009) or heat pumps (Nordic Energy Perspectives, 2010) that can provide enough energy to cover 100% of the heating demand in a low-energy building. So it is less interesting for the users to connect low-energy buildings than classical buildings to a district heating network. Besides, it is also less interesting to renovate poorly isolated buildings and turn them into low-energy buildings if they are already connected to a district heating network, because energy use decrease would not lead to a proportional reduction of bills – because of the fixed share that would not go down. The pay-back time related to the investments for renovation would be very long and it those cases it is actually more cost-efficient to disconnect from the network, or not to do any renovation (S. Tirado Herrero and D. Ürge-Vorsatz, 2011).

From the provider point of view, low-energy buildings could be less profitable. High investments are still required to build a district heating network. But less heat will be used and thus less money will be earned. The payback periods related to the network creation, already long today, will grow longer and decrease district heating’s attractiveness (Nordic Energy Perspective, 2009).

District heating and renovation

It is also possible to consider the situation from the other side: district heating is today a sector more developed than low-energy buildings. So in some cases, no to threat the investments done for district heating facilities, or because it is forbidden to disconnect from the network, it will be chosen not to invest in buildings renovation and in low-energy buildings. From this point of view, it can be considered that district heating is also a threat for low-energy buildings (S. Tirado Herrero and D. Ürge-Vorsatz, 2011). Furthermore, if a renovation is undertaken, it should not been realized moderately but deeply, with the best technologies available, otherwise another renovation would be needed later and all in all it would be more expensive (S. Tirado Herrero and D. Ürge-Vorsatz, 2011). In many cases, it
is a clear choice that has to be done between a renovation to improve the building isolation, and the connection to a district heating network.

The question of the choice between renovation and connection to district heating will be discussed in many cases during the coming decades (H. Lund et al, 2009). A rough approximation of the lifetime of a building is 100 years (H. Håtvun & P. Bohdanowicz, 2011), whereas a district heating network is paid back after approximately 10 years and has a lifetime of around 20 years (ADEME Ile-de-France, 2013). So actually, low-energy buildings growth and district heating development are anyway compatible.

New business model for district heating systems connected to low-energy buildings

Regarding the construction of low-energy buildings, “DH can become uneconomic, especially due to the fixed costs that derive from capital-intensive investments” (A. Dalla Rosa & J.E. Christensen, 2011). Actually, “the economic viability […] needs to be answered on a case-by-case basis” (S. Tirado Herrero and D. Ürge-Vorsatz, 2011). Several parameters will be taken into consideration: the future fossil fuel prices and the competition on the heat market; the current use of district heating and the opportunities of network extensions, which limit the investments compared to a complete network creation; the city shapes in the future and especially their density (U. Persson & S. Werner, 2010).

Optimizing the demand side

In high heat density districts, district heating is expected to remain competitive because investments costs decrease with density (U. Persson & S. Werner, 2010). This idea of prioritizing dense areas is part of a larger plan of cost-optimization. The highest possible heat demand density should be reached on the network, considering those two contradictory statements: the more buildings are connected, the more heat is sold; the more buildings are connected, the higher are the total investments.

The users’ behavior should also be considered and included in energy simulations. For instance, a non-environment-friendly behavior could intensify heat demand by 50% (A. Dalla Rosa & J.E. Christensen, 2011).
Heat losses are also to be considered because they represent money that the provider will never earn. Therefore, heat losses should be cut, which is also possible thanks to dense areas because heat losses decrease with linear heat density (energy yearly delivered by one meter of pipes, MWh/year/m). Thus, “the linear heat density can be used as the representative value for feasibility studies of district heating networks” (A. Dalla Rosa & J.E. Christensen, 2011).

Optimizing the network design

The network should be designed to limit heat losses. For instance, twin plastic pipes can be used instead of steel pipes to both cut investments costs and heat losses. Furthermore, “traditionally-designed networks often have sub-optimal energy performance, because of over-dimensioned design and unnecessarily high operational temperatures”, whereas it is known that “low supply and return temperatures increases the final energy efficiency of the systems and decreases the distribution heat losses” (A. Dalla Rosa & J.E. Christensen, 2011). On this matter, low heating demand could be seen as an opportunity: if high temperature could be still needed for domestic hot water, the low space heating demand can be covered by the remaining heat from domestic hot water heating in a kind of two-steps heating process, leading to low temperatures in the return part of the geothermic loop and thus reducing heat losses in this part of the network (AMORCE, 2011). Investment costs could also be cut by an optimization of the construction processes, for instance by digging just once for the sewage and district heating networks.

Other optimizations

A lower heat demand is also the opportunity to cover a higher share of the demand with heat recovery or renewable sources such as solar thermal, heat pumps, and thus reduce the cost of fossil fuel for extra heating. A less expensive heat resource can be chosen: for example, a geothermal facility extracting heat from 1 500 meters deep could be replaced by an 800 meters deep installation in the case of low-energy buildings requiring less energy (BRGM & ADEME, 2010).

Solutions do reduce district heating costs and therefore keep the technology profitable have been discussed. Nevertheless, district heating competitiveness does not only depend on the
price of the heat. For the heat producer, the flexibility for the production mix enables him to modify his mix depending on the evolution of fossil fuel prices. From the user point of view, district heating is carefree, on the contrary to individual boilers. Furthermore, the absence of boiler can create some additional and valuable space in the accommodation.

**New trends in district heating optimization**

**Smoothing heating load profiles**

A smart district heating management can consists of trying to smooth the aggregated heat load curve, in order to increase the base loads and cut the peak loads. Indeed, the peak loads are covered by fossil fuel for reactivity reasons, whereas renewables are suitable for base load. The solution is to combine buildings with complementary energy needs, for instance multifamily and office buildings. This district heating management can become more efficient with coordinated heating and ventilation scheduling. Yet, building refurbishment trends to distort the aggregated heat load because annual heat demand decreases more than peak loads (O. Greslou et al, 2013).

**Smart district heating systems**

Smart regulation consists in monitoring and controlling the power delivered at each substation, using sensors and communications tools to send data from every substation to a monitoring center, basically situated in the heat plant (B.tib, 2013). In this case, the classical regulation system is completed by other sensors monitoring input and output temperatures.

**Limitations for district heating systems**

Though district heating has many advantages, there are some situations where it cannot be implemented. A huge issue, not only for district heating but also for building renovation, is the case of shared-ownership buildings, which often are multifamily buildings. An agreement between all the owners is required for any change in the building, which could be considered as a generic “barrier to energy efficiency investments” (S. Tirado Herrero & D. Ürge-Vorsatz, 2011) because they are not always considered as necessary and have a long payback period. Besides, disagreements among neighbours and the different financial situations among the owners can make the situation worse and slow down the decision process.
The overall district heating efficiency varies from country to country. In Poland for example, coal is a cheap national resource, so district heating are run with coal and the environmental performances are bad. Additionally, in Poland, distribution systems are in average old, which reduces the network efficiency and intensifies coal use (S. Tirado Herrero & D. Ürge-Vorsatz, 2011).

For the clients, district heating can also become a real trap. People with low incomes might prefer to have less heating and wear thicker clothes to compensate, which may be less comfortable but clearly less expensive. Besides, it is sometimes not possible to regulate the heating power in the flats as the regulation is only performed at the building scale, which limits users’ freedom and could become a real issue if flats are heated up though there is nobody inside (S. Tirado Herrero & D. Ürge-Vorsatz, 2011).

**Literature study conclusion**

District heating systems allow heat distribution, from one or several heat plants to many buildings and users situated in the neighborhood of the plant. District heating is well developed in Northern Europe where heating issues have been thought for a long time. District heating is not only a collective and effective way to heat buildings, but also a good system to use massively renewable energies such as biomass, geothermal heat and heat recovery. Thus, district heating is part of the French energy action plan towards 2020 and the sector is expected to grow during the next decade. France should follow the examples of Sweden and Denmark, where advanced challenges like the case of low-energy buildings are already discussed. In France, Ile-de-France is a leading region where 26% of the district heating systems are situated. More than 120 systems are already built, yet the share of renewables in the energy mix was only 30% in 2012. This figure should increase to 50% by 2020, according to the regional action plan.
3. HEAT PRICING ANALYSIS AND FUTURE COMPETITIVENESS OF DISTRICT HEATING BASED ON RENEWABLES

3.1. Data analysis

In most of the cases, district heating systems are built and exploited by private companies (Dalkia, Cofely, Idex, Coriance are the leaders) on the request from municipalities. “Public service delegation contracts” are signed, in which the initial heat price is given, and formulas explain how the heat price should evolve over the time.

It has been possible to study 11 contracts for district heating based on biomass and 8 for district heating based on geothermal heat:

<table>
<thead>
<tr>
<th>Renewable energy</th>
<th>Reference date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>June 2008</td>
</tr>
<tr>
<td>Biomass</td>
<td>Oct 2009</td>
</tr>
<tr>
<td>Biomass</td>
<td>March 2010</td>
</tr>
<tr>
<td>Biomass</td>
<td>Sept 2010</td>
</tr>
<tr>
<td>Biomass</td>
<td>Dec 2010</td>
</tr>
<tr>
<td>Biomass</td>
<td>Dec 2010</td>
</tr>
<tr>
<td>Biomass</td>
<td>Jan 2011</td>
</tr>
<tr>
<td>Biomass</td>
<td>Jan 2011</td>
</tr>
<tr>
<td>Biomass</td>
<td>April 2011</td>
</tr>
<tr>
<td>Biomass</td>
<td>Sept 2011</td>
</tr>
<tr>
<td>Biomass</td>
<td>Jan 2012</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>Jan 2009</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>April 2010</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>June 2010</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>July 2011</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>Aug 2011</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>Sept 2011</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>Dec 2011</td>
</tr>
<tr>
<td>Geothermal heat</td>
<td>Sept 2012</td>
</tr>
</tbody>
</table>

Table 8: List of the files provided by ADEME
Formulas construction and average formulas

It appears that whatever the contract, formulas are constructed in very similar ways. In each contract, the price is divided in two parts:

- The energy use, called $R1$ (€/MWh), determined by an energy meter.
- The power subscribed, called $R2$ (€/kW). It corresponds to the maximum power that the user has the right to use and to claim, according to the contract. Physically, the power subscribed is limited by the size of the heat exchanger and the system properties (temperature, water flow).

Each subscriber has to pay:

$$R = R1 \times \text{energy used} + R2 \times \text{power subscribed}$$

R1 is related to the energy mix and the energy prices

The heat provider pays to buy primary energy, and then he sells transformed energy as heat to its subscribers. Therefore a part of the heat price is related to the primary energy used to produce heat.

There are always at least two energy sources in an energy mix: a renewable energy (biomass or geothermal heat) and natural gas. Natural gas is a “clean” fossil fuel, less expensive than oil. It is used to handle peak power demands, whereas the renewable energy is used as base load energy. There is sometimes a third or even a fourth energy source: cogeneration, heat recovery from waste incineration, oil.

For instance, the formula could look like this:

$$R1 = R1_{biomass} \times \%biomass + R1_{gas} \times \%gas + R1_{otherEnergy} \times \%otherEnergy$$

$\%biomass$, $\%gas$, $\%otherEnergy$ are the share of each energy in the global energy mix.

Average formula for systems mainly based on geothermal heat (based on the studied public service delegation contracts):

If it is considered that every project has the same influence (regular average), the result is:

$$R1 = 0.58 \times R1_{geothermal} + 0.29 \times R1_{gas} + 0.09 \times R1_{cogeneration} + 0.04 \times R1_{heatRecovery}$$

In the case of a weighted average (weighting with the total energy use of each project):

$$R1 = 0.54 \times R1_{geothermal} + 0.28 \times R1_{gas} + 0.14 \times R1_{cogeneration} + 0.04 \times R1_{heatRecovery}$$
For systems mainly based on biomass heat:

If it is considered that every project has the same influence (regular average), the result is:

$$ R1 = 0,47 \times R_{1\text{biomass}} + 0,25 \times R_{1\text{gas}} + 0,05 \times R_{1\text{cogeneration}} + 0,17 \times R_{1\text{heatRecovery}} + 0,06 \times R_{1\text{geothermal}} $$

In the case of a weighted average (weighting with the total energy use of each project):

$$ R1 = 0,44 \times R_{1\text{biomass}} + 0,32 \times R_{1\text{gas}} + 0,03 \times R_{1\text{cogeneration}} + 0,21 \times R_{1\text{heatRecovery}} $$

In the four previous formulas, oil has been neglected (always less than 0.2% and it tends to disappear). In the first biomass formula, $R_{1\text{geothermal}}$ does not correspond to deep geothermal heat, but to surface geothermal heat (less than 100 meters deep) and therefore when the average is weighted in the second biomass formula, $R_{1\text{geothermal}}$ becomes negligible because surface geothermal energy produces much less energy than deep geothermal energy, biomass and gas.

Though they have a large share in the energy mix of some contracts, heat recovery and cogeneration are not present in many project. On the contrary, geothermal heat (or biomass in the other case) and gas that are both always represented in the energy mix, with high shares. It could be concluded that for the considered projects, the base load is typically covered by the renewable energy (biomass or geothermal heat) and the peak load by natural gas.

Figure 8: Yearly heat production for a system with biomass (green, 58% in the mix) and gas (ADEME Ile-de-France, 2013)
Energy prices such as R1biomass, R1geothermal, and R1gas...evolve over the time depending on parameters like gas price, electricity prices, and economic indexes.

Here are the average formulas:

\[
R_{1\text{biomass}} = R_{1\text{biomass}0} \times (0.06 + 0.34 \times \frac{Tr}{Tr0} + 0.34 \times \frac{Prod}{Prod0} + 0.26 \times \frac{WF}{WF0})
\]

\[
R_{1\text{geothermal}} = R_{1\text{geothermal}0} \times (0.86 \times \frac{El}{El0} + 0.08 \times \frac{Ser}{Ser0} + 0.03 \times \frac{WF}{WF0} + 0.03 \times \frac{Prod}{Prod0})
\]

\[
R_{1\text{gas}} = R_{1\text{gas}0} \times \left(\frac{G}{G0}\right)
\]

R1biomass0, R1geothermal0 and R1gas0 correspond to the initial prices of the energies.

The way they are calculated is not explained in the contracts, but it basically depends on the prices offered by biomass, electricity and gas suppliers.

The other parameters are indexes that are related to the economic conditions of the moment.

They are evaluated by monitoring organizations and the access to most of them is charged:

- WF: general work force cost
- Tr: general transport cost
- Prod: national industrial production cost
- El: general electricity cost
- Ser: diverse services cost
- G: general gas cost

WF0, Tr0...correspond to initial values, determined at the reference date of the contract.

For biomass and geothermal heat, the indexation depends on several parameters, on the contrary to gas. A specific parameter for biomass has been recently created but it is yet not used nor trusted, because of the difficulty to represent clearly the economic and social situation of a sector using only one figure.

It is possible to classify the parameters in two categories:

- Fixed parameters, which do not change during all the contracting period. Their values have an influence on the heat price during all the contracting period: R1biomass0, R1geothermal0, and R1gas0.
- Variable parameters, which are recalculated in average 4 times every year and depend on the economic context.
This classification shows that forecasting initial heat prices in the case of contracts starting between 2014 and 2025 can be done only by forecasting $R1_{biomass}$, $R1_{geothermal}$, and $R1_{gas}$.

**R2 is related to maintenance and investments costs**

A subscriber does not only pay for the heat, but also for the related infrastructures that are used for heat generation and transportation. There are pure “running costs” linked to everyday operations:

- $R21$: electricity used to operate the primary network (basically: pumps)
- $R22$: maintenance

There are also amortization charges:

- $R23$: "big" maintenance-related replacements
- $R24$: investments

$R25$ is a negative term corresponding to the subsidies. The global formula for $R2$ is a sum:

$$R2 = R21 + R22 + R23 + R24 + R25$$

$R21$, $R22$ and $R23$ are indexed on parameters. On the contrary, $R24$ and $R25$ are determined at the beginning of the contracting period and do not evolve after.

**For district heating based on biomass:**

$$R21 = R21_0 \times \left( \frac{E_l}{E_l_0} \right)$$

$$R22 = R22_0 \times (0,13 + 0,47 \times \frac{Ser}{Ser_0} + 0,40 \times \frac{WF}{WF_0})$$

$$R23 = R23_0 \times (0,13 + 0,68 \times \frac{Heat}{Heat_0} + 0,19 \times \frac{WF}{WF_0})$$

With "Heat": intervention cost related to companies specialized in central heating systems.

**For district heating based on geothermal heat:**

$$R21 = R21_0 \times (0,1 + 0,9 \times \frac{E_l}{E_l_0})$$

$$R22 = R22_0 \times (0,16 + 0,50 \times \frac{WF}{WF_0} + 0,25 \times \frac{Ser}{Ser_0} + 0,05 \times \frac{Heat}{Heat_0} + 0,04 \times \frac{Prod}{Prod_0})$$

$$R23 = R23_0 \times (0,18 + 0,70 \times \frac{Heat}{Heat_0} + 0,07 \times \frac{WF}{WF_0} + 0,03 \times \frac{Ser}{Ser_0} + 0,02 \times \frac{Prod}{Prod_0})$$
**Parameters evolution between 2009 and 2013**

In order to build representative forecasts, the current tendencies should be assessed.

\[ R1_{gas_0} \]

\( R1_{gas_0} \), in the case of biomass projects, evolves in the same way as the regular STS price. \( R1_{gas_0} \) does not exactly follow STS curve because for each project the gas price could have been negotiated, depending on the amount of gas and the possibility to supply different project though one delivery contract.

![Figure 9: R1gas0 and Gas price STS versus Time (biomass projects)](image)

In average, the margins realized for the sale of gas are 26% for biomass projects and 28% for geothermal projects.

\[ R1_{biomass_0} \]

\( R1_{biomass_0} \) tends to increase slowly over the time: 5.5% / year net of inflation.
$R_{1\text{geothermal}_0}$

$R_{1\text{geothermal}_0}$ does not have a uniform evolution. It varies between 6.18 €/MWh and 13.21 €/MWh (€ 2013, net of inflation). But the part related to electricity in the total $R_{1\text{geothermal}_0}$ increases strongly by 21% / year.

**Figure 10: $R_{1\text{biomass}_0}$ versus Time**

![Graph](image)

**Figure 11: Electricity share in $R_{1\text{geothermal}_0}$ versus Time**

Besides, the electricity share is very close to 100% in the $R_{1\text{geothermal}_0}$ formula (86% in average), and it has increased with the time. Therefore it is possible to assume that
R1geothermal will be 100%-indexed on electricity in the future, thus that its variations will be the same as electricity price.

R2

There is no time dependency for $R2$, whether it is $R24$ (investments) or the sum $R21 + R22 + R23$ (maintenance cost) that is considered.
Still, there is a link between the fixed costs $R^2$ and the size of the project (power subscribed). This is remarkable on the chart *Maintenance cost vs. subscriptions* and even more obvious on the chart *Investments (R240) vs. subscriptions*. The bigger is the project, the larger are the economies of scale.

**Figure 14:** Maintenance cost versus Subscriptions

**Figure 15:** Investments (R240) versus Subscriptions
For geothermal heat, the relation between subscriptions and $R^2$ is less obvious, but it still exists. Consequently, the coming forecasting study should take into consideration the size of the project when estimating the $R^2$ part.

**Sensitivity analysis**

Public service delegation contracts for systems based on biomass can be used as examples to assess the impact of each parameter on the heat price.

**Impact of the fixed parameters**

As it has been discussed before, there are fixed parameters (ex: $R1_{biomass_0}$, $R2_{20}$) that are determined at the beginning of the contracting period and that have an impact all along the period. It is interesting to assess the possible impact of these parameters on the total price. The sensitivity analysis has been done in the case of a similar 100%-increase of each parameter: it leads of course to a 100%-increase of the total initial heat price. The result explains how each parameter impacts on the total price.

![Pie chart showing the impact of each fixed parameter on a heat price increase](image)

**Figure 16:** Impact of each fixed parameter on a heat price increase

This sensitivity analysis shows that $R2_{40}$ plays the largest role in the price determination; $R2_{20}$, $R1_{gas_0}$ and $R1_{biomass_0}$ have also a large impact on the total price. On the contrary, $R2_{10}$ and $R2_{30}$ do not impact much.
Impact of the variable parameters

Though they will not be discussed in the forecasting study, the impacts of the variable parameters lead to price variation during all the contracting period and thus their study is interesting.

![Figure 17: Impact of each variable parameter on a heat price increase]

It is noticeable that in the case of a similar increase of each parameter, the one with the largest influence is the $\frac{G}{G_0}$ index. It has indeed a direct and strong influence on the $R1$ part: $R1 = R1_{biomass} \times \%biomass + R1_{gas0} \times \frac{G}{G_0} \times \%gas$.

Case study

The Eriva project has started in June 2008. Since then, the variable parameters have evolved:

<table>
<thead>
<tr>
<th></th>
<th>WF</th>
<th>Tr</th>
<th>Ser</th>
<th>Prod</th>
<th>Heat</th>
<th>El</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>12%</td>
<td>9%</td>
<td>9%</td>
<td>6%</td>
<td>12%</td>
<td>35%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Table 9: Actual evolution of the variable parameter from 2008 to 2013

During this period, all the parameters have increased particularly Electricity and Gas. Then, it is possible to assess the impact of these actual variations on the total heat price.
It seems that the *Work Force* index affects a lot the total heat price. The reason why gas has just a small influence is that it represents only 0.3% of the energy mix. There is indeed a huge heat recovery process from a waste incineration plant and the specificity of the project is that natural gas is almost not used.
3.2. Modeling

The goal is to compare the heat price by 2025 for district heating systems based on different kinds of energy sources (biomass, geothermal heat, gas). Today, the systems based on renewables are more expensive than the reference solutions with 100%-gas. It could change in the future, mainly if gas price continues to grow.

The basic idea is to use the conclusions (values, current tendencies) of the previous study about current public service delegation contracts in order to create a fictive but representative project for each kind of energy.

Technical assumptions

3 different projects are compared. The heat demand is assumed to be the same in the 3 projects: same power subscriptions and same quantities of energy sold. The difference thus lies in the heat generation methods and the energy mix:

- **A biomass project**: biomass as base load energy and gas as the peak load energy. Heat is distributed by a district heating system.
- **A geothermal project**: geothermal as base load energy and gas as the peak load energy. Heat is distributed by a district heating system.
- **An all-gas project**: 100% of the demand is covered by gas. This is a “reference situation”. There is no district heating network in the “all-gas project” simulation, as it would increase the total heat price and is not necessary in the case of gas because gas can be easily supplied to every building already connected to the distribution gas system. There is no need to centralized the gas supply and then distribute the final energy (heat). Thus, one gas boiler replaces each district heating substation planed in the biomass and geothermal projects.

In this case, \( R2 \) (investments and maintenance) is determined by average formulas from a national study (CIBE, 2011). \( R1 \) could came from either the STS price (more than 5 000 MWh/year) or the B2S price (between 350 and 5 000 MWh/year). Actually, if gas is bought independently for each individual gas boiler (1 060 MWh/year) B2S pricing should be applied. Yet, several gas boilers (or substations in the case of district heating) could be related to one single subscriber who can consequently pay
the STS price. This is mainly possible in the case of social housing offices (in average 51% of the users according to the data study).

The total power subscriptions and the energy produced are proportionally related. Consequently, once the number of subscribers is determined, the energy use is determined too. The proportionality coefficient is not the same for biomass (1.95) and geothermal projects (2.09). Nevertheless, as the aim of the study is to draw an economic comparison of different energies, the projects should be based on similar input data. Therefore, an average proportional coefficient should be used.

**Figure 19:** Biomass project sizes

**Figure 20:** Geothermal project sizes
Economic assumptions

Forecasts about $R_1$ are based on the study of all the public service delegation contracts, whatever the energy mix of these projects.

As explained previously, $R_2$ depends on the size of the project (total power subscribed) and on the energy mix because more maintenance and investments are needed if there are three energy sources or more than if there are only two (biomass and gas or geothermal heat and gas). Forecasts about $R_2$ are therefore based on existing projects with energy mixes similar to the one of the fictive projects. Those representative projects are: Mantes-la-Jolie, Sevran, Colombes, Bagnolet for the fictive biomass project and Neuilly-sur-Marne, Villejuif, Arcueil Gentilly for the fictive geothermal project.

The case of Villejuif is an exception: cogeneration is also present in the energy mix, yet a third representative project was necessary to adjust the $R_2$ values in the case of the geothermal fictive project. Besides, charges related to geothermal energy are high so the impact of a third heat generation facility on $R_2$ becomes negligible, mainly if this is a cogeneration plant because a part of the charges are also paid by the electricity provider.

It is assumed that the $R_{24}$ value for the representative projects take into account investments amortization for both heat generation facilities (basically the boilers) and district heating systems (basically the pipes), though in some cases the most recent investments are only about heat generation facilities. Previous investments for the heat distribution network have indeed been realized and still have to be amortized.

The inflation rate is expected to be 2% / year according to the French strategic analysis center (Centre d’analyse stratégique, 2011) and ADEME economists.

Economic background

Past inflation rates should be taken into account when analyzing data from the previous years.
<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual inflation rate</td>
<td>2.82%</td>
<td>0.09%</td>
<td>1.53%</td>
<td>2.12%</td>
<td>1.96%</td>
<td>0.94%</td>
</tr>
</tbody>
</table>

*Table 10: Inflation rate from 2008 to 2013 (Triami Media BV, 2013)*

The value added tax should not be forgotten because the forecasts are about heat price from the user point of view. The rate depends on the share of renewables in the energy mix:

<table>
<thead>
<tr>
<th>Share of renewables</th>
<th>VAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 50%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Less than 50%</td>
<td>19.6%</td>
</tr>
</tbody>
</table>

*Table 11: Different VAT values*

**Timeframe**

In order to have significant results, a rather long period of time should be studied. Nevertheless, a too long period could lead to large mistakes because of the uncertainties. 5 years (the data collected are mainly from 2009-2013) is too short, but 20 years (average length of a public service delegation contract) may be too long considering the economic, political and technological fluctuations. Thus, a period of 12 years (2013-2025) seems relevant.

Besides, considering the 12-year forecasting period and the strong energy price evolution of the 5 past years, the tendencies should be taken from the 10 last years rather than form the 5 last. This is possible for electricity and gas, but not for biomass because there is no data at all. Still, biomass increase between 2009 and 2013 does not seem consistent compared to the evolution of the other energy sources.

**Values and tendencies determination**

The following table summarizes how the parameters that have an impact on the initial heat price have been calculated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Tendency</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1biomass0</td>
<td>Determined from the tendency observed in the public service delegation contracts (35.30 €/MWh in</td>
<td>The contracts show a clear tendency (+ 5.5% / year net of inflation)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
<td>Tendency</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>R1geothermal0</td>
<td>Average value observed in the public service delegation contracts (10.08 €/MWh in 2014)</td>
<td>No clear tendency for R1geothermal0 between 2009 and 2012. Yet, the weight of electricity in the R1geothermal0 calculations increases up to 100%. Therefore R1geothermal0 could increase like the electricity price in the future (+ 3.6% / year net of inflation between 2003 and 2013).</td>
</tr>
<tr>
<td>R1gas0</td>
<td>For the renewables projects: R1gas0 is determined with a margin (in average 26% for biomass projects and 28% for geothermal projects) compared to the market gas price STS. For the fictive all-gas project: it is assumed that the subscriber buy directly the gas from the provider so there is no margin.</td>
<td>STS pricing has increased by 6.2% / year (net of inflation) B2S pricing has increased by 5.1% / year (net of inflation) between 2003 and 2013.</td>
</tr>
<tr>
<td>R2biomasse0</td>
<td>R2 depends on the energy mix (this is why the reference projects used have an energy mix close to the fictive projects) and on the size of the project.</td>
<td>No tendency noticed in the public service delegation contracts.</td>
</tr>
<tr>
<td>R2géothermie0</td>
<td>R2 depends on the energy mix (this is why the reference projects used have an energy mix close to the fictive projects) and on the size of the project.</td>
<td>No tendency noticed in the public service delegation contracts.</td>
</tr>
<tr>
<td>R2gaz0</td>
<td>The costs are estimated according to a study of the CIBE (used for the ADEME subsidies calculation and attribution).</td>
<td>No tendency noticed (sector with a strong competitiveness already).</td>
</tr>
</tbody>
</table>

*Table 12: Values and tendencies for the initial parameters*
3.3. Results

Scenario 1: Business as usual

This first scenario is based on the tendencies noticed in the data study. Assumptions have been discussed with several experts at ADEME. Some assumptions come from previous studies. This is a forecasting scenario: the goal is to see how heat prices evolve when they are submitted to a certain set of assumptions.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation expectations</td>
<td>2% / year</td>
<td>- French strategic analysis center</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discussions with the economy department at ADEME</td>
</tr>
<tr>
<td>Gas prices increase (2003 – 2013)</td>
<td>STS: 6.2% / yr net of inflation</td>
<td>- Gas prices analysis</td>
</tr>
<tr>
<td></td>
<td>B2S: 5.1% / yr net of inflation</td>
<td>- Discussions with the economy department at ADEME</td>
</tr>
<tr>
<td>Electricity price increase (2003 – 2013)</td>
<td>3.6% / yr net of inflation</td>
<td>- Electricity prices analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discussions with the economy department at ADEME</td>
</tr>
<tr>
<td>Biomass price increase (2009 – 2013)</td>
<td>5.5% / yr net of inflation</td>
<td>- Data analysis</td>
</tr>
<tr>
<td>Trade margins on gas sales</td>
<td>Biomass DH: 26%</td>
<td>- Data analysis</td>
</tr>
<tr>
<td></td>
<td>Geothermal DH: 28%</td>
<td>- Insee (French statistics organism)</td>
</tr>
</tbody>
</table>

Table 13: Economic assumptions
Figure 21: Business as usual // Heat price at the beginning of a contract

In this chart, the 2013 values are close to those noticed in the real contracts. It confirms the reliability of the model used for the heat prices calculations.

The proximity of the biomass system with all-gas solutions reflects the reality of the previous years. Biomass would become competitive (same cost as the solution based on fossil fuels) in 2017. Geothermal heat would become competitive in 2022. These results are encouraging and besides they seem realistic.
This chart explains the reason why the all-gas solution becomes less competitive: 86% of the price is due to gas, a more and more expensive fossil fuel. On the contrary it does not cost much to extract geothermal heat: only 8% of the total price. Actually, the higher the demand is, the more geothermal heat becomes competitive because the high investments (here 29% of the price) are spread thanks to the low-cost geothermal energy.

**Secondary business as usual scenario**

A *secondary business as usual* scenario could be helpful to understand the results given by the *business as usual* approach because it could assess some margins of error. The assumptions are similar but more conservative than those from the *business as usual* case. Basically, energy prices are considered to have a 1%-lower increase and inflation a 0.5%-lower increase:
The most interesting in this secondary scenario are not the heat prices but the variations of those prices compared to the classical business as usual scenario. It is possible to change just one parameter each time, or all in the same time:

<table>
<thead>
<tr>
<th><strong>Yearly increases</strong></th>
<th><strong>Business as usual</strong></th>
<th><strong>Secondary business as usual</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation</td>
<td>2.0%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Electricity</td>
<td>3.6%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Gas STS</td>
<td>6.2%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Gas B2S</td>
<td>5.1%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Biomass</td>
<td>5.5%</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

*Table 14: Yearly increases of energy prices*

<table>
<thead>
<tr>
<th><strong>Price variations compared to the BAU scenario</strong></th>
<th><strong>Biomass system</strong></th>
<th><strong>Geothermal system</strong></th>
<th><strong>All-gas solution</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU except electricity</td>
<td>0%</td>
<td>-0.97%</td>
<td>0%</td>
</tr>
<tr>
<td>BAU except gas</td>
<td>-3.83%</td>
<td>-3.95%</td>
<td>-9.60%</td>
</tr>
<tr>
<td>BAU except biomass</td>
<td>-4.14%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>BAU except inflation</td>
<td>-5.73%</td>
<td>-5.73%</td>
<td>-5.73%</td>
</tr>
<tr>
<td>Secondary BAU</td>
<td>-13.24%</td>
<td>-10.36%</td>
<td>-14.83%</td>
</tr>
</tbody>
</table>

*Table 15: Comparison between Business as usual and Secondary business as usual*

After 12 years (between 2013 and 2025), a 1%-variation of the gas price has an almost 10-time larger impact on the all-gas solution (-9.60%) whereas the impact on the geothermal solution is low (-0.97%). The secondary business as usual scenario corresponds to a feasible situation, and thus the results (up to -14.83% for the all-gas solution) give an idea of the margin of error and characterize the sensitivity of the forecasting study. Gas is the single parameter with the highest impact on the prices (in average -5.79%) but actually inflation has an average impact of -5.74% when it is cut only by -0.5%, so inflation seems to have the highest influence. Comparing the projects, the all-gas solution is the most sensitive because of gas role, whereas the geothermal solution is the less sensible, thanks to the huge role of electricity.
The chart is similar, yet the competitiveness is reached later because of the smoother increases.

**Scenarios 2 and 3: backcasting approaches**

It would be interesting to build complementary scenario about the possibility of stronger development of renewable energies, or about specific gas price augmentations.

But according to ADEME experts, no reduction is soon expected for investments and maintenance costs of Renewables projects. Reductions could come from either a technological novelties or a stronger competition in the sector (linked to an increase of the number of projects: the more cities want to create district heating systems, the more companies try to become positioned on the market). If there are diminutions, it will not occur before at least 3 or 4 years because no new technologies are currently developed by searchers, and regarding the number of projects, ADEME is well positioned to have an overview of the projects in preparation for the coming years, and it seems this figure will not grow soon.
Regarding gas price, it is a very important parameter because gas is involved in every district heating projects, either as secondary fuel or as unique fuel. It is also a parameter with many dependencies (geopolitics, economy).

Furthermore, one of the ADEME’s goals is to give subsidies so that technologies based on renewables have a price 5% lower than classical systems based on fossil fuels. Then, in which cases subsidies will not be necessary anymore?

A backcasting approach could answer this question. The two main uncertainties are the gas price evolution and the investments costs evolution for renewables projects. Therefore it could be assessed how those two parameters should evolve so that renewables become fully competitive with fossil fuels.

Scenario 2: backcasting approach for gas prices evolution

In this section, the yearly gas price increase is the unknown and the assumptions are the years when the different renewable energies could become competitive.

The notion of “high competitiveness” could be introduced. It corresponds to the moment when the price of heat from renewable become 5% cheaper than heat from fossil fuel. This 5% limitation is the official method used every year by ADEME engineers to determine the subsidies amounts.
According to these results, every target except the two for geothermal heat by 2020 is reached in the business as usual scenario. If the 2009-2013 tendency appears to be actually followed (7.54%), then the 2020 competitiveness (6.52% needed) becomes reachable for geothermal heat, and the 2020 high competitiveness (7.94% needed) is not so far.

**Scenario 3: backcasting approach**

In this section, the possibility of a decrease of the initial investments is analyzed. All the assumptions from the *Business as usual scenario* are kept. The unknown value is the percentage of yearly decrease of the investments, both for biomass and geothermal projects. The decrease cannot occur too soon, according to experts. Yet, the possibility of such a decrease starting from 2017 is worth considering.
<table>
<thead>
<tr>
<th>Targets</th>
<th>Results if the target concerns biomass district heating (yearly decrease of initial investments for Renewables, from 2017)</th>
<th>Results if the target concerns geothermal district heating (yearly decrease of initial investments for Renewables, from 2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competitiveness reached in 2020</td>
<td>No needs</td>
<td>2.16%</td>
</tr>
<tr>
<td>Competitiveness reached in 2025</td>
<td>No needs</td>
<td>No needs</td>
</tr>
<tr>
<td>High competitiveness reached in 2020</td>
<td>1.13%</td>
<td>7.18%</td>
</tr>
<tr>
<td>High competitiveness reached in 2025</td>
<td>No needs</td>
<td>No needs</td>
</tr>
</tbody>
</table>

Table 17: Results for scenario 3

It appears that no cost decrease is needed to reach competitiveness and even high competitiveness by 2025. If a yearly reduction of 7.18% seems difficult to reach, reductions of 1% or 2% per year are entirely possible. The following chart gives heat prices in the case where geothermal systems become competitive by 2020:

![Chart showing heat prices](image)

**Figure 24**: Backcasting // Decrease of initial investments for renewables by 2.16% / year
3.4. Discussion

The study relies on a large set of assumptions, which could be discussed.

The increase of the gas prices is actually an asset for renewables because though it raises the prices of renewable systems, because it affects more the all-gas solution and thus contributes to the renewables competitiveness. Therefore, the yearly gas price variations can be discussed, as it has been done in the scenario 2.

A second main discussion point concerns the initial gas price in the all-gas solution ($R1gas0$). Actually this value depends on the context. The purchase of large amount of gas, negotiations, or deregulated gas pricing could limit the costs and thus make the all-gas project far more profitable. These possibilities are difficult to predict and evaluate; besides it would be more feasible to get such reductions in the case of an all-gas district heating, which is not analyzed in this study since the solution of separated gas boiler at the bottom of each building has been selected.

The competitiveness of district heating systems based on renewables could be put into question by individual solutions like heat pumps and solar heat. In 2013, those solutions are not competitive. Solar heat costs around 120 €/MWh all taxes included and heat pumps costs between 100 and 120 €/MWh all taxes included (ADEME, 2013). These individual solutions based on renewables are today more expensive than district heating based on renewables, nevertheless they could improve their competitiveness is the case of low-energy buildings, mainly in eco-districts. If solar is not expected to become very popular in Ile-de-France due to the lack of sun, heat pumps represent a high potential. Their development could also be helped by the energy prices augmentation. All of this could be assess in another study.
3.5. Conclusion

Backcasting and forecasting approaches are complementary. Backcasting approaches are particularly useful to comprehend parameters with high uncertainties and that are difficult to predict. Backcasting scenarios are helpful to assess what should be done to reach “symbolic” goals, whereas a forecasting approach determines results using a large set of assumptions.

In the following table are summarized the main results in the case of the Business as usual scenario:

<table>
<thead>
<tr>
<th></th>
<th>Price 2013 €/MWh all taxes included</th>
<th>Price 2020 €/MWh all taxes included</th>
<th>Price 2025 €/MWh all taxes included</th>
<th>Variation 2013-2025</th>
<th>Variation 2013-2025 net of inflation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass systems</td>
<td>70</td>
<td>103</td>
<td>140</td>
<td>100%</td>
<td>58%</td>
</tr>
<tr>
<td>Geothermal systems</td>
<td>86</td>
<td>113</td>
<td>140</td>
<td>63%</td>
<td>28%</td>
</tr>
<tr>
<td>All-gas solution</td>
<td>68</td>
<td>108</td>
<td>152</td>
<td>124%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Table 18: Main results in the case of the Business as usual scenario

There are high chances that renewables become soon competitive. Biomass systems are expected to become competitive in 2017, and if the gas price increases by 6.52%/year, that is to say more than the 2003-2013 tendency (5.70%) but less than the 2009-2013 tendency (7.54%), geothermal could also become competitive in 2020. The worst case leading to renewables competitiveness in 2025 is a 3.38% yearly increase.

This study is useful for ADEME because it is a tool to forecast how long subsidies will still be necessary. If the subsidies allocation remains based on the same rules (“high competitiveness” target), it would not be necessary to give any more money for biomass district heating projects starting from 2021 and for geothermal district heating projects starting from 2024.

The sensitivity analysis explains that every parameter has a certain impact on the total price, and the secondary business as usual approach shows that a different but still realistic set of
assumptions leads to a delayed competitiveness but a similar evolution anyway, which confirms the chances of district heating based on renewables to become competitive.

The business model for district heating systems based on renewables actually depends much on non-renewable energy, in a direct way with the secondary energy source and in an indirect way with the comparison to a reference all-gas solution. The dependency to fossil fuels of the classical solutions is the key of the renewables’ competitiveness. Comparing the energy mix with the price repartition, it seems that district heating companies should try to optimize and maximize renewables resources use and thus extend the share of renewables in the energy mix. Besides, the comparison of the $R1$ and $R2$ parts, and the $R2$-versus-power subscriptions chart shows that large district heating systems are profitable and that the systems should be developed to connect more and more users in dense-enough areas.
4. DEVELOPMENT OF DISTRICT HEATING AND PLACE OF RENEWABLES IN THE FUTURE REGIONAL ENERGY MIX

4.1. Analysis and modeling

Context

The background of the study is the regional action plan SRCAE, which both describes the energy mix of district heating in Ile-de-France for 2009 and sets goals for 2020.

<table>
<thead>
<tr>
<th>(in GWh of primary energy)</th>
<th>Situation in 2009</th>
<th>Targets for 2020</th>
<th>Expected evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal energy</td>
<td>1 163</td>
<td>2 326</td>
<td>100%</td>
</tr>
<tr>
<td>Biomass</td>
<td>88</td>
<td>2 398</td>
<td>2 625%</td>
</tr>
<tr>
<td>Waste incineration</td>
<td>3 405</td>
<td>4 086</td>
<td>20%</td>
</tr>
<tr>
<td>Gas cogeneration</td>
<td>3 523</td>
<td>3 823</td>
<td>6%</td>
</tr>
<tr>
<td>Gas cogeneration (import)</td>
<td>1 176</td>
<td>1 176</td>
<td>0%</td>
</tr>
<tr>
<td>Individual gas boilers</td>
<td>3 073</td>
<td>2 046</td>
<td>-33%</td>
</tr>
<tr>
<td>Coal</td>
<td>1 930</td>
<td>965</td>
<td>-50%</td>
</tr>
<tr>
<td>Oil</td>
<td>1 457</td>
<td>364</td>
<td>-75%</td>
</tr>
<tr>
<td>Other projects of heat recovery</td>
<td>-</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>85</td>
<td>-</td>
<td>-100%</td>
</tr>
<tr>
<td>Total</td>
<td>15 900</td>
<td>17 234</td>
<td>8%</td>
</tr>
</tbody>
</table>

Table 19: Energy mix targets for district heating in Ile-de-France by 2020, according to SRCAE

Limitations

Import of heat from gas cogeneration plants will not be considered in the study, firstly because this energy is not produced in the region and it would be a hard task to get data, secondly because the SRCAE target (no evolution) shows that regional policies are not expected to have any impact on this.

The categories “other projects of heat recovery” and “other” are not incorporated in the study, considering their order of value and the lack of clarity about their definition both in the regional action plan SRCAE and in few marginal projects subsidized by ADEME.
Analysis

In this study, the future 2020 situation will be evaluated using a year-by-year approach. For each energy source, and for the total amount of energy, the evolution \( \Delta \text{Heat\_deliveries} \) will be estimated between year \( N \) and year \( N+1 \). There are potentially two ways to evaluate \( \Delta \text{Heat\_deliveries} \), from the heat provider’s point of view and from the user’s point of view.

From the provider’s point of view, the variation of heat deliveries may come from the creation of new plants or the shutdown of old plants. But district heating is in total expansion and when an old plant is shut down it is always because a new plant is built, with at least the same amount of heat generated, and often more within the context of district heating development. This variation is thus assumed as always positive: \( \Delta \text{New\_plants} \). New plants do not explain all the variation: it may also come from existing heat plants that modify their production to cover the demand (\( \Delta \text{Existing\_plants} \)).

\[
\Delta \text{Heat\_deliveries} = \Delta \text{Existing\_plants} + \Delta \text{New\_plants}
\]

District heating creations or developments are generally known by ADEME when subsidies are asked. It is assumed that no heat plants are nowadays built without noticing ADEME, because those plants are either run with renewables, or there are run by fossil fuels but as extra heating in the case of a partly-green network. Therefore, \( \Delta \text{New\_plants} \) can be estimated using the description of the projects subsidized by ADEME since 2008. These precise data permit to assess the evolution of each energy source in the total mix. On the contrary, it is not possible to estimate the variation of the production of existing plants. That is why another approach is needed.

From the user’s point of view, the variation of heat deliveries may come from the existing subscribers: they have variable heating needs depending on the climate (\( \Delta \text{Climate} \)) or on their behavior (\( \Delta \text{Behaviour} \)); besides, demand decreases because of the renovation of some buildings (\( \Delta \text{Renovation} \)). The variation of heat deliveries may also come from new subscribers who have recently been connected to the system, in the case of extensions and network development (\( \Delta \text{Extensions} \)).

It is assumed that \( \Delta \text{Behaviour} \) is very small compared to \( \Delta \text{Extensions} \) and \( \Delta \text{Renovation} \), so it can be neglected. Besides, environment-friendly behaviours are counterbalanced by defiant
and careless behaviours. Climate is not taken into consideration because every figure is calculated from year 2009 data and therefore all the figures are expressed in the meteorological base of year 2009, and compared using this background. Besides, when the technical description of a project followed by ADEME expresses the expected annual heat production (these figures are used in the model), the meteorological background is never clarified. It is assumed that the possible differences compensate themselves. Renovation is taken into consideration using the same assumptions as CPCU, which is the company that runs the biggest district heating network in France: the one in Paris. Extensions can be assessed thanks to SNCU data. Consequently, it is possible to assess Heat_deliveries with this method.

\[ \Delta \text{Heat}_{\text{deliveries}} = \Delta \text{Extensions} + \Delta \text{Renovation} \]

**Modeling**

“\( \Delta \text{Extensions} \)”, expressed in GWh, can be developed like this:

\[ \Delta \text{Extensions}(\text{GWh}) = \Delta \text{Extensions}(\text{km}) \times \text{Energy}_{\text{delivered}}_{\text{by substation}} \times \text{Substations}_{\text{by km}} \]

Or also, using the units: \( \Delta \text{GWh} = \Delta \text{km} \times \frac{\text{GWh}}{\text{km}}_{\text{substation}} \times \frac{1}{\text{km}} \)

“\( \Delta \text{Extensions}(\text{km}) \)” and “Substations_{by km}” are accessible thanks to SNCU data. Basically there is very often a 2-year gap in the regional data collection process of SNCU, therefore in 2013 the most recent completed survey describes the situation of 2011.

The chart “Regional district heating systems size versus time” shows a linear evolution, meaning that “\( \Delta \text{Extensions}(\text{km}) \)” is quite stable between 2005 and 2011. Between 2005 and 2011, the average is 45 km/year. During the beginning of the “Fonds Chaleur” period (2009 - 2011), the average is 50 km/year. As many ADEME data concern projects subsidized with the “Fonds Chaleur”, it is justified to use this value of 50 km/year. Besides, the linear evolution during 6 years justifies the choice to take 50 km/year for the Business as usual scenario.
“Substations_by_km”, which can also be seen as district heating density, decreases linearly between 2007 and 2011. The explanation is that existing district heating networks are often based in the most dense parts of a city and thus reach less dense parts when they start to develop; completely new district heating systems are rare and not situated in dense enough areas to counterbalance this clear trend.

Figure 25: Regional district heating systems size versus Time

Figure 26: Substations_by_km versus Time
“Energy_delivered_by_substation” is given directly by SNCU data and indirectly by ADEME data. For the reference year 2009, SNCU gives 1.064 GWh/year/substation, and it gives 1.040 GWh/year/substation in average for the period 2008 – 2011. The study of 13 projects from ADEME data gives the value of 1.060 GWh/year/substation. The fact that three values calculated from two sources, three different time bases and three different climate backgrounds are eventually so close, shows that “Energy_delivered_by_substation” can be considered as constant. 1.064 GWh/year/substation is the value from the reference year 2009 and is based on a complete regional survey (114 networks), therefore this figure is kept for the modeling.

“ΔRenovation” is estimated applying a multiplication factor on the result of the simulation for “ΔExtensions(GWh)“. This coefficient corresponds to a yearly diminution of heat demand, used by the company CPCU in its simulations:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly heat demand decrease</td>
<td>-0.5%</td>
<td>-0.6%</td>
<td>-0.6%</td>
<td>-0.7%</td>
<td>-0.7%</td>
<td>-0.7%</td>
<td>-0.7%</td>
<td>-0.7%</td>
<td>-1.0%</td>
<td>-1.2%</td>
<td>-1.2%</td>
</tr>
</tbody>
</table>

Table 20: Yearly heat demand variation according to CPCU

“ΔNew_plants” is estimated for each energy source using ADEME data from projects subsidized with the “Fonds Chaleur”. The two major kinds of district heating energy sources that are subsidized by ADEME are biomass and geothermal heat. Geothermal heat corresponds actually to deep geothermal heat, at least 800 meters deep, on the contrary to surface geothermal heat and heat pumps, which are rather considered as individual energy sources than as district heating energy sources.

Similarly to SNCU data, there is in average a 2-year gap between the moment the subsidies are asked and the moment the project is completed (new plant put into service and shutdown of the non-renewable plant). Consequently, ADEME data are used in two times: firstly, the projects already subsidized between 2009 and 2013 have been- will soon be put into service, and thus are added in the energy mix modeling. This is usable up to year 2015. Secondly, for
the period 2016 - 2020, a tendency based on the existing data can be estimated. For the two main renewable energies, biomass and geothermal heat, the amount of plants subsidized every year has been growing from 2009 to 2013. According to ADEME experts, this trend will not go on and it is more relevant to consider an average of the two last years as the future yearly value for the period 2016 – 2020.

“ΔExisting_plants” can be deduced from ΔHeat_deliveries and “ΔNew_plants”. Though “ΔNew_plants” gives specific values for every energy source, “ΔExisting_plants” is, at first, calculated without precision about the way the production of the energy corresponding to “ΔExisting_plants” is allocated to the different energy sources. Therefore, it is assumed in first approximation that “ΔExisting_plants” is divided up between every source, renewable and non-renewable, proportionally to their values of the previous year.

**Scenarios definition**

**Scenario 1: Business as usual**

This scenario is based on the assumption and parameters previously explained. The first step is to estimate “ΔHeat_deliveries” using the fact that:

\[
ΔHeat\_deliveries = ΔExtensions + ΔRenovation
\]

Coefficients for ΔRenovation are from CPCU data, which is relevant because CPCU runs the biggest district heating system in France (Paris, 5 300 000 MWh/year), and ΔExtensions is calculated with:

\[
ΔExtensions(GWh) = ΔExtensions(km) \times Energy\_delivered\_by\_substation \times Substations\_by\_km
\]

knowing that “ΔExtensions(km)” and “Energy\_delivered\_by\_substation” are constant and that “Substations\_by\_km” decreases constantly.

The second step is the energy mix evolution from ADEME-subsidized projects and ADEME data.

The last step is to take into account the intensification of heat production in existing plants (“ΔExisting_plants”) using proportionality laws.
Scenario 2: No renovation

In this scenario, the business as usual background is kept, except that “ΔRenovation” is not added and therefore:

\[ Δ\text{Heat\_deliveries} = Δ\text{Extensions}. \]

This scenario is used to assess the impact of renovation plans, which is actually one of the current national energy policies in France. And what if renovation could prevent from achieving regional goals?

Scenario 3: Proactive development

The business as usual situation regarding “ΔExtensions(km)” leads to a yearly increase of 50 km. Considering that in 2012 and 2013 46 km and 43 km of district heating systems have been subsidized in the case of system creations or extensions, it means that only around 5 km of densification (a “densification” is an extension of less than 200 meters) would be realized if the extension rhythm of 45 km/year is kept. This could appear as being too little and thus could ask for one step further, with 60 km/year realized from year 2015.

Scenario 4: Non-renewables put aside

The business as usual modeling is so that “ΔExisting\_plants” has a positive impact on renewables and a negative impact on non-renewable energies. This is totally in agreement with the current trend and with ADEME goals. However, the remaining part “ΔExisting\_plants”, which is calculated this way:

\[ Δ\text{Existing\_plants} = Δ\text{Heat\_deliveries} - Δ\text{New\_plants}, \]

is assumed to have similar consequences on each part of the energy mix, i.e. positive impacts on both renewable and non-renewable energies. This approach is completely true in a certain way, but somehow even if production from fossil fuels plants has to increase to cover a growing demand, most of the operators are likely to prefer increasing the renewable part more than the non-renewable one. Therefore, a scenario where “ΔExisting\_plants” only leads to more renewables in the energy mix is expected to assess the impact that such an
extreme policy could have on the total energy mix. In this scenario, heat generation from fossil fuels is only impacted negatively by “ΔNew_plants”.

<table>
<thead>
<tr>
<th>Scenario 1: Business as usual</th>
<th>Renovation plans</th>
<th>Proactive development of DH systems</th>
<th>Existing fossil fuel plants increase their production if needed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No, standard development</td>
<td>Yes</td>
</tr>
</tbody>
</table>

| Scenario 2: No renovation | No, ΔRenovation = 0 | No, standard development | Yes |

| Scenario 3: Proactive development | Yes | Yes, ΔExtensions(km) = 60 from 2015 | Yes |

| Scenario 4: Non-renewables put aside | Yes | No, standard development | No, “ΔExisting_plants” impacts only on renewables |

Table 21: Summary of the three scenarios
4.2. Results

Main targets

Just as a reminder, SRCAE plans 4 major targets:

- To move from 32% to 54% of renewables in the energy mix.
- To move from 1035 GWh/year to 2070 GWh/year for geothermal heat use.
- To move from 65 GWh/year to 1771 GWh/year for biomass use.
- To move from 12880 GWh/year to 14107 GWh/year for the total district heating use.

Figure 27: Energy mix in 2009: initial situation
Figure 28: Energy mix in 2020: targeted situation
As targeted by SRCAE, the highest augmentation in proportion is for biomass (+ 1900%), because the initial situation was not advantageous at all for biomass energy and because ADEME programs and actions have led to numerous new projects.

The other observation is that fossil fuels (gas cogeneration, gas boiler, coal and oil) situation is stable: + 0.25% of heat generated from 2009 to 2020. The reason for this is the opposite action of “ΔExisting_plants”, which tends to raise fossil fuels use, and “ΔNew_plants”, which tends to cut fossil fuels use.

There is a double consequence to that. Admittedly, the fossil fuels stability whereas the total district heating use rises means that the place of fossil fuels in the global energy mix is cut. But this diminution is not sufficient: the final energy mix is 45% renewables and 55% fossil fuels. It is far from the 53% targeted by the regional action plan.
Figure 30: Business as usual // Share of renewables in the energy mix versus Time
**Scenarios: results and comparisons**

For each scenario, the main part of the result is for the year 2020, because it is the last studied year and because it gives the possibility to compare with SRCAE targets.

The following table gives the main values and the following chart is helpful to compare the scenarios.

<table>
<thead>
<tr>
<th>Final energy (GWh/year)</th>
<th>2009 Initial situation</th>
<th>2020 Business as usual</th>
<th>2020 No renovation</th>
<th>2020 Proactive development</th>
<th>2020 Non-renewables put aside</th>
<th>2020 SRCAE targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal heat</td>
<td>1 035</td>
<td>1 939</td>
<td>2 207</td>
<td>1 985</td>
<td>1 991</td>
<td>2 070</td>
</tr>
<tr>
<td>Biomass</td>
<td>65</td>
<td>1 242</td>
<td>1 367</td>
<td>1 266</td>
<td>1 256</td>
<td>1 771</td>
</tr>
<tr>
<td>Waste incineration</td>
<td>3 030</td>
<td>3 301</td>
<td>3 877</td>
<td>3 397</td>
<td>3 436</td>
<td>3 637</td>
</tr>
<tr>
<td>Gas cogeneration</td>
<td>2 759</td>
<td>2 988</td>
<td>3 511</td>
<td>3 075</td>
<td>3 111</td>
<td>2 994</td>
</tr>
<tr>
<td>Gas cogeneration (imports)</td>
<td>1 047</td>
<td>1 047</td>
<td>1 047</td>
<td>1 047</td>
<td>1 047</td>
<td>1 047</td>
</tr>
<tr>
<td>Gas boiler</td>
<td>2 407</td>
<td>1 886</td>
<td>2 267</td>
<td>1 947</td>
<td>1 985</td>
<td>1 602</td>
</tr>
<tr>
<td>Coal</td>
<td>1 409</td>
<td>1 206</td>
<td>1 445</td>
<td>1 245</td>
<td>972</td>
<td>704</td>
</tr>
<tr>
<td>Oil</td>
<td>1 128</td>
<td>1 053</td>
<td>1 250</td>
<td>1 085</td>
<td>864</td>
<td>282</td>
</tr>
<tr>
<td>TOTAL</td>
<td>12 880</td>
<td>14 663</td>
<td>16 971</td>
<td>15 047</td>
<td>14 663</td>
<td>14 107</td>
</tr>
</tbody>
</table>

*Table 22: Results of the 4 scenarios*
Starting with the comparison between the scenarios and SRCAE goals, the major positive point is that in every scenario the total district heating development target is largely exceeded.

On the contrary, all the scenarios are far away from their oil and coal targets. In order to reach this target, average yearly decreases of 64 GWh for coal and 77 GWh for oil would be
needed, whereas in the most encouraging scenario (scenario “Non-renewables put aside”) coal use is cut in average by 40 GWh/year and oil use by 24 GWh/year.

Gas boilers use is not cut enough, and gas cogeneration use rises, but too much. Yet, the case of gas boilers and gas cogeneration are less worrying, though the objectives are not reached. Gas boilers are indeed kept or even created in the case of district heating based on renewables, because they are helpful as secondary fuel. From the emissions of pollutant point of view (both particles and carbon dioxide), gas is clearly less dangerous than oil and coal, although natural gas is admittedly not a renewable resource. Gas cogeneration is also an interesting compromise, as it’s a way to decrease heat losses linked to electricity generation. This is a way to think globally about energy issues, and not only about district heating. Besides, it should be kept in mind that district heating based, though on gas, is preferable to individual gas solutions because heating demand and heat losses are better managed.

In the case of heat recovery from waste incineration and geothermal heat, the targets are reached except in the business as usual scenario. For geothermal heat, the difference is very small and thus it could be considered as successful.

The case of biomass is specific. In every scenario the increase is very significant in proportion, but the target is never reached. For instance in the business as usual scenario, there is an average augmentation of 107 GWh/year whereas 155 GWh/year would be required, that is to say 45% higher.

Scenario 2 “No renovation” performs the highest deliveries for each kind of energy source, even in comparison with the scenario 3 “Proactive development”. It shows how much renovation has a major role, and that policies encouraging renovation plans are relevant. On the contrary, energy operator would be likely to see a bit less renovation because it has a direct impact on their sales. It seems reasonable that operators take into account this parameter in their development plans.

It is besides the only scenario where not only oil use rises compared to 2009, but also coal use. Consequently, renovation plans seems to be a necessity in the case of pro-renewables policies. Renovation and pro-renewables policies succeed together, or shall not be
conducted at all. From an operator point of view, it could be argued that although the lack of renovation plans offers more sales, it also leads to higher fossil fuels uses and therefore, considering their increasing prices, to higher running costs and economic risks.

Scenario 3 “Proactive development” does not lead to significantly higher results compared to the business as usual situation. There is indeed a 2.5% difference between scenario 1 and 3 for the total heat deliveries, whereas “ΔExtensions(km)” is assumed as moving from 50 km/year to 60 km/year (+20%) between the two scenarios on the middle term, leading to a 10% difference between “ΔExtensions(GWh)_scenario1” and “ΔExtensions(GWh)_scenario3”. It means that the impact of the “Proactive development” is reduced by the presence of the existing district heating systems, and therefore is not as important as expected. Actually, if a backcasting approach is used, it is not 60km/year but 80 km/year between 2015 and 2020 that would be necessary just to reach the same augmentation as scenario 2 (16 971 GWh/year in 2020). A 60%-bigger development is equivalent to a situation without any renovation plan, which again shows that renovation policies are completely relevant on the middle and long term.

Scenario 4 “Non-renewables put aside” has the same total heat deliveries variation as scenario 1 “Business as usual”. The difference lays in the energy mix evolution. Scenario 4 is the only one that reduces oil and coal use, the two “dirty” fossil fuels. It does not impact gas because considering the role of gas, as a necessary secondary fuel and for cogeneration plants, and considering that gas could have a renewable future with biogas and carbon capture and storage (CCS) facilities, the first step of a pro-renewables policy would be to erase completely coal and oil from the energy mix. As it has been noticed previously, the actions suggested by scenario 4, namely the reduction of coal and oil use thanks to “ΔNew_plants” and no intensification due to “ΔExisting_plants”, are far from being sufficient enough to reach the SRCAE targets.

Scenario 4 gives the highest share of renewables: 45.4%, not so far from the worst which is for scenario 2: (43.9%). If very successful actions succeed in shutting down all the coal and oil plants, and transfer their heat generation plans proportionally to all the other energy sources (renewables and gas solutions), even in this case SRCAE goal would not be met: the resulting share of renewables would be 52.6% whereas the objective is 53.0%. Not so far
from a match, but the conclusion of this is that gas plants should not be used like every other renewable solution to counterbalance the loss of coal and oil plants.

**Sensitivity analysis**

Quantitative consequences of renovation programs have high uncertainties because it depends on the governmental ability to convince that renovation is actually an interesting investment, and also the ability of owners to invest money in those renovation works.

The data used for the study come from the private company CPCU. The company uses them for its business plans. Besides, the figures seem pretty realistic according to experts at ADEME (total heat demand reduced by 8.27% between 2009 and 2020). Nevertheless, these assumptions are lower than the objectives that are given in the regional action plan “SRCAE” because these official assumptions correspond to the way to reach the “factor 4” in 2050 (energy demand divided by 4 from 2005 and 2050). Twice-higher yearly diminutions of heat demand would be a set of assumptions very close to the official expectations, though maybe less realistic.

Therefore, in order to assess the impacts of renovation on heat demand, the three sets of assumptions are: no renovation plans, heat demand cut by 8.27% from 2009 to 2020, and heat demand cut by 15.93% from 2009 to 2020.

<table>
<thead>
<tr>
<th>Assumption</th>
<th>2009-2020 heat demand variation</th>
<th>2020 total heat deliveries on regional DH networks (GWh)</th>
<th>Comparison with “no renovation”</th>
</tr>
</thead>
<tbody>
<tr>
<td>No renovation</td>
<td>0%</td>
<td>16 971</td>
<td>-</td>
</tr>
<tr>
<td>Currently used (CPCU assumptions)</td>
<td>-8.27%</td>
<td>15 774</td>
<td>-7.1%</td>
</tr>
<tr>
<td>Factor 4 (official target)</td>
<td>-15.93%</td>
<td>14 663</td>
<td>-13.6%</td>
</tr>
</tbody>
</table>

*Table 23: Results of the sensitivity analysis*

The diminutions related to the scenario “factor 4” give a result for the total heat deliveries that still is higher than SRCAE targets. Thus, renovation is not in contradiction with the regional action plan.
**Economic aspects**

Using the business as usual situation as an example, it is interesting to assess the possible economic situation of 2020 for the district heating sector.

Firstly, as far as **public subsidies** are concerned, they can be divided into two categories: on one side for the network (pipes) itself and on the other side for the heat plants. For the network, it is assumed that the extensions (network development) will be less and less subsidized: the constant subsidy for one meter of new network (248 €/meter in 2013) has been decreasing since 2009.

![Subsidies for district heating networks extensions versus Time](image)

**Figure 32:** Subsidies for district heating networks extensions versus Time

For heat plants creation, according to the previous study (“3.3 Results”), new projects would become competitive in 2016 for biomass and 2022 for geothermal heat. From those moments, no more subsidies would be awarded. Knowing this and the average 2012-2013 subsidies amount (33€ / (renewable MWh yearly expected/year) for biomass, and 91€ / (renewable MWh yearly expected/year) for geothermal heat) the yearly amount of the future subsidies can be estimated. All in all, the amount of yearly public subsidies is expected to decrease and would reach 6.4 million euros in 2020 in Ile-de-France.
Secondly, the heat deliveries have an impact on the operators’ revenues and thus on their ability to develop their activities on the middle term. Future heat prices have been estimated using data of the association AMORCE, which is specialized in district heating, as initial values for 2009 (Amorce, 2010), and then using similar assumptions as in the previous study “3. Heat pricing analysis and future competitiveness of district heating based on renewables”.

Figure 33: Public subsidies versus Time
In the business as usual situation, the revenues are intensified by 92% from 2009 to 2020 whereas the heat deliveries are increased by 22% only. It is noticeable that the revenues related to coal and oil grow between 2009 and 2020 when in the same time the related heat deliveries are cut. Besides, the order of value is interesting: every year, around 1 billion euros are in stake for district heating in Ile-de-France.

As explained in the “Literature study”, renovation plans and low-energy buildings could be a threat for district heating. Thus, the economic comparison of scenarios 1 and 2 can be drawn. Moreover, a complementary scenario “factor 4” should also be taken into account.
The results show that there is a decrease of 7.2% between the “no renovation” situation and the “business as usual”. This diminution would reach 13.9% if the path to the “factor 4” is followed. Thus, non-negligible differences could be created because of renovation programs in only 11 years. Renovation could have a significant impact on revenues and operators’ economic health.
4.3. Discussion

This study gives a largely positive view of the possible developments of renewable energies, and puts forward the high reachability of the regional total target for 2020. The regional action plan SRCAE evaluates the total potentials for biomass and geothermal energies in the region. These potentials are high and will surely not be reached before decades. On the contrary, the maximum potential for heat recovery from waste incineration has not been evaluated. Besides, considering the high amounts of heat already recovered, this upper limit should be taken into consideration. There are possibilities to increase the efficiency of heat recovery on waste incinerators (SRCAE, 2012), but on the other side the quantities of waste are expected to fall.

The sector of biomass is special. It is actually constituted of two levels: biomass supply (forests management, biomass storage, quality checking) and building and operating of heat plants (purchase of biomass and sales of heat). These two industries are very linked and dependent from each other's, yet it appears, according to experts at ADEME, that the supply chain does not develop fast enough compared to the important number of new biomass heat plants. This desynchronization could penalize biomass growth and sustainability. Furthermore, the assumptions used correspond to a linear development of biomass energy, following the yearly average increase of 2012 and 2013. If a more audacious augmentation would have been assumed, the results could have been closer to the regional target.

Whatever the source of energy, another issue could be the operators' capacity to invest continually in new projects. A lot of money has indeed been spent the last years, encouraged by the governmental subsidies (“Fonds chaleur”). This is why a tendency based on similar investments as years 2012 and 2013 is justified according to ADEME. The growing investments noticed between 2009 and 2012 are expected to stabilize in the future and the wish is that they do not decrease.

The evolution of fossil fuels prices is largely uncertain, as it has been elaborated in the previous part (“3. Heat pricing analysis and future competitiveness of district heating based on renewables”). Strong augmentations would benefit to renewables, but it could affect district heating sector as a whole because 100% of the networks have gas in their energy mix (Via Seva, 2012), and 66% of the networks in the region Ile-de-France do not use any
renewable energies (SNCU, 2011). On the contrary, if prices fall, like in the case of shale gas extraction, the development of renewables could be constrained.
4.4. Conclusion

Based on some assumptions and on pretty clear tendencies, this study highlights the constant development of the district heating sector in Ile-de-France. In terms of total heat deliveries, the target set by the regional action plan SRCAE would be exceeded in 2020, according to the study. The objective for geothermal heat would also be met, on the contrary to biomass, whose development, though strong, would not be sufficient.

The most challenging issue is certainly the limitation of fossil fuel use. On that matter, the regional goals are far from being reached. Perhaps these goals are too optimistic, but there might be also a form of lack in the energy policies, because although high rates of renewable energies are always encouraged, anti-fossil fuels policies are maybe not strong enough. The necessity to respect quotas of CO2 is not a sufficient measure because the price of one ton of CO2 is low (around 5€) and thus companies prefer to buy White Certificates, to keep the “right” to pollute, than to invest in new facilities that would reduce their footprint on the environment (L’énergie en questions, 2013). The paradox with district heating is that it is a great way to massively use renewable energies, but the systems require also a very flexible fuel like gas to manage the peak load demand. Thus, promoting district heating without thinking about the role of fossil fuels leads to mitigated consequences. Therefore, more constraining policies would be an interesting complement to pro-renewables measures that are already applied with quite a success.

A direct consequence of the lack of anti-fossil fuel policies is the energy mix variation, which is positive thanks to pro-renewables measures, but not high enough to reach the regional goals for 2020. From a share of 32% of renewables in 2009, the most encouraging scenario reaches 45% of renewables in 2020, whereas the target of SRCAE is 53%.

The last main result concerns the key role of renovation. Without renovation, the heat demand would be 7.6% higher after 11 years. Renovation obviously limits energy demand and thus it limits partly fossil fuel use.
5. GENERAL CONCLUSION

Main results

In order to assess the future business model for district heating based on renewables in Ile-de-France, this thesis has been built in two parts, one about the economy of district heating and the other about the development of district heating.

The first part shows that the price of heat is calculated with several formulas, based on many indexes. Though the structuration of the formulas is similar for every district heating system, the coefficients and initials values differ from one project to another. Quantitatively, district heating will become more expensive in the future because of the increasing fossil fuel prices, which have an influence on the price even in the case of systems based on renewables, but also because investments and maintenance costs are expected to stagnate in the coming years. Qualitatively, district heating based on biomass could have the same price as reference individual systems based only on gas in 2016. This competitiveness would be reached in 2022 for systems using geothermal heat as the main energy source. Besides, this study is characterized by high uncertainties on gas prices and gas prices evolution.

The second part shows that the sector of district heating in Ile-de-France is in a fairly good shape. This development has been encouraged by the public subsidies that are given since 2009 to help the growth of renewable energies. The study indicates that the targets set by the regional action plan for 2020 would be exceeded in the cases of the total heat deliveries and heat deliveries from geothermal heat, but not in the cases of biomass and fossil fuels (44 % of renewables by 2020). Moreover, this work puts forward the impact of renovation on heat demand and therefore indirectly on fossil fuel use.

In the field of district heating, the pro-renewables public policies have been successful. Many systems are now based on renewable energies, and these energies will in the medium term become very competitive. Renewables are fairly well developed (45% of the energy mix by 2020) and it could be time to focus on more drastic policies to limit fossil fuel use.
## SWOT analysis

A SWOT (Strengths, Weaknesses, Opportunities and Threats) is an interesting tool to summarize the conclusions of both the literature study and the two parts of the thesis. It is helpful to step back and express what could be remembered from this work. Two different points of view can be adopted: ADEME’s point of view, whose role is to support the sector as a public organization, and the energy operators’ point of view, whose activities enable the development of the district heating sector.

<table>
<thead>
<tr>
<th>ADEME As a public agency</th>
<th>Helpful (to develop district heating based on renewables)</th>
<th>Harmful (to develop district heating based on renewables)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal origin</strong></td>
<td><strong>Strengths</strong></td>
<td><strong>Weaknesses</strong></td>
</tr>
<tr>
<td></td>
<td>o Strong impact of the fund “Fonds Chaleur” (public subsidies) on the development of renewables.</td>
<td>o ADEME impacts renewables growth, but its tools do not directly act to limit fossil fuels use.</td>
</tr>
<tr>
<td></td>
<td>o Strong impact of renovation plans on heat demand and thus on fossil fuels use.</td>
<td>o The need for public subsidies goes down, thus the possibilities for ADEME to impact on projects will also be cut.</td>
</tr>
<tr>
<td></td>
<td>o ADEME has many data and thus has the possibility to study deeply the sector of district heating.</td>
<td>o If ADEME estimates than a renewable project is competitive enough and does not need any subsidies, the project still can get money from the attribution of White Certificates: ADEME’s message is overstepped.</td>
</tr>
<tr>
<td></td>
<td>o ADEME allocates public subsidies without which projects are difficult, therefore ADEME can ask for some changes in order to improve the project and use the maximum potential of renewables.</td>
<td>o The economic analysis used to estimate the right amount of subsidies is based on assumptions about gas price and thus has a certain part of uncertainties.</td>
</tr>
<tr>
<td><strong>External origin</strong></td>
<td><strong>Opportunities</strong></td>
<td><strong>Threats</strong></td>
</tr>
<tr>
<td></td>
<td>o Biogas and biomethane could be used as a secondary fuel and thus help to reach renewable district heating systems</td>
<td>o The creation of district heating networks implicates new heat plants run with gas. The renewable energy mix evolves slowly.</td>
</tr>
<tr>
<td></td>
<td>o The price of heat is lower when the network is large. Interconnections of networks lead to economies of scale.</td>
<td>o With gas price augmentation, systems based on renewables become more expensive.</td>
</tr>
<tr>
<td></td>
<td>o With a gas price augmentation, renewable energies are more competitive.</td>
<td></td>
</tr>
</tbody>
</table>

Table 24: SWOT analysis of ADEME’s situation
<table>
<thead>
<tr>
<th>Internal origin</th>
<th>Helpful (to develop the operators’ activities in the field of district heating based on renewables)</th>
<th>Harmful (to develop the operators’ activities in the field of district heating based on renewables)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths</td>
<td>District heating is an efficient way to integrate renewables and thus benefit from the related economic and environmental advantages.</td>
<td>Network extensions may decrease heat density and consequently represent less profitable investments.</td>
</tr>
<tr>
<td></td>
<td>The extensions (development) of existing systems are a way to have more clients and reach economies of scale.</td>
<td>Large investments are required to develop district heating. Operators could have problems to invest more in the future, considering the crisis and the huge investments realized since 2008.</td>
</tr>
<tr>
<td></td>
<td>The sector of district heating is currently having a constant and strong development.</td>
<td>No technological breakthrough is expected in the coming years, so prices are not expected to drop.</td>
</tr>
<tr>
<td></td>
<td>Long term contracts (between 15 and 25 years) signed with local governments offer stable incomes and thus the possibility to perform a well-organized development.</td>
<td>The building of new heat plants often requires long administrative procedures and is impacted by the local political life.</td>
</tr>
<tr>
<td>Opportunities</td>
<td>Pro-renewables policies play a huge role. Many subsidies have been awarded, and still will be in the future, in order to carry on the sector’s development.</td>
<td>An increase of fossil fuel prices will decrease the needs of subsidies. It could be seen as an issue if ADEME does not help a project because the project has less credibility and is then considered by the banks as a bad project, whereas it is actually a perfectly independent and self-sufficient project.</td>
</tr>
<tr>
<td></td>
<td>The objectives set by the regional action plan intend to boost the growth, and could be adjusted to match the actual trend.</td>
<td>Renovation plans will lower the heat demand and therefore lower the sales.</td>
</tr>
<tr>
<td></td>
<td>Besides, an emerging procedure called “district heating classification” aims to both protect existing systems by avoiding disconnections, and intensified their growth by making the connection mandatory in specific situations.</td>
<td>The uncertainties about the energy prices evolution complicate long term studies.</td>
</tr>
<tr>
<td></td>
<td>District cooling, though 15 times less developed than district heating (SNCU, 2013), could soon experience an exponential growth in a context of global warming.</td>
<td>If existing district heating systems become much less competitive than individual solutions, users could choose to disconnect and therefore make the situation worse.</td>
</tr>
<tr>
<td></td>
<td>Even if a district heating project does not get any public subsidy, it can still claim for White Certificates and then turn them into money by selling them.</td>
<td></td>
</tr>
</tbody>
</table>

Table 25: SWOT analysis of energy operators’ situation
Those two tables are complementary. The “opportunities” for energy operators show how ADEME and private operators are linked. The role of ADEME is indeed to sustain the development of district heating based on renewables, and therefore to orientate the growth of those operators in the direction expressed by the regional action plan.

The results of this thesis could be used to improve the calculation and attribution of subsidies, but also to discuss and modify the targets set in the regional action plan (the action plan will be modified in 2015), and more generally it will improve the understanding of the sector and support strategic decisions in the future.
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