
Brussels Environmental Authority

A study of the potential for heating and cooling efficiency in the Brussels-Capital Region



FINAL REPORT – TASKS 1 TO 6

December 2015

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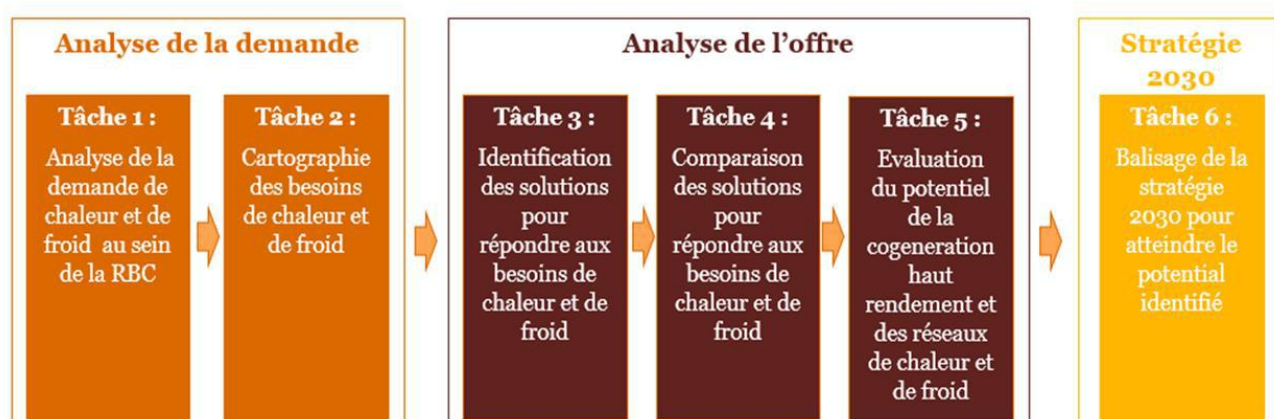
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Document structure

This report has been prepared in connection with the transposition of Article 14 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency. Notably, Article 14.1 of the Directive provides that Member States should carry out a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, containing the information set out in Annex VIII, and notify it to the Commission no later than 31 December 2015. For the purpose of the assessment referred to in paragraph 1 of Article 14, Member States should carry out a cost-benefit analysis covering the whole of their territory based on climate conditions, economic feasibility and technical suitability in accordance with Part 1 of Annex IV.

This report contains the findings from the six phases of the study which the *Institut Bruxellois pour la Gestion de l'Environnement* (IBGE, the Brussels Environmental Authority) commissioned the PwC–ULG (LEMA)–Bureau Ph. Deplasse consortium to carry out. Each phase is covered by a separate chapter which includes a bibliography and relevant annexes.



Overview of the six stages of the project, ‘Study of the potential for heating and cooling efficiency in the Brussels-Capital Region (BCR)’

Analyse de la demande	Analysis of demand
Tâche 1 : Analyse de la demande de chaleur et de froid au sein de la RBC	Task 1: Analysis of demand for heating and cooling in the BCR
Tâche 2 : Cartographie des besoins de chaleur et de froid	Task 2: Mapping of heating and cooling needs
Analyse de l'offre	Analysis of supply
Tâche 3 : Identification des solutions pour répondre aux besoins de chaleur et de froid	Task 3: Identification of solutions to meet heating and cooling needs
Tâche 4 : Comparaison des solutions pour répondre aux besoins de chaleur et de froid	Task 4: Comparison of solutions to meet heating and cooling needs
Tâche 5 : Evaluation du potentiel de la cogénération haut rendement et des réseaux de chaleur et de froid	Task 5: Evaluation of the potential for high-efficiency cogeneration and district heating and cooling
Stratégie 2030	Strategy for 2030
Tâche : Balisage de la stratégie 2030 pour atteindre le potentiel identifié	Task: Charting the strategy for 2030 to achieve the potential identified

Chapter 1 – Estimated heating and cooling needs

INTRODUCTION

Purpose and methodology

This first chapter presents the heating and cooling needs for the BCR for 2012 in aggregated form, based on data from the report on energy consumption, and forecasts the change through to 2030.

The **methodology** adopted includes the following two steps:

Phase 1.1: **estimated heating and cooling needs in 2012**

- Phase 1.2: **estimated change in heating and cooling needs to 2030**

The first section outlines the heating needs in the Brussels-Capital Region in 2012 along with the change in these needs through to 2030. The second section outlines the cooling needs in the Brussels-Capital Region in 2012 along with the change in these needs through to 2030.

I. ESTIMATED HEATING NEEDS

I.1 ESTIMATED HEATING NEEDS IN 2012

Heating needs in the Brussels-Capital Region were estimated in light of the consumption of the different energy carriers used to meet heating needs, on the basis of information taken from the report on energy consumption in Brussels in 2012 by the *Institut de Conseil et d'Etudes en Développement Durable* (Institute for Consultancy and Studies in Sustainable Development, ICEDD, 2014). Estimates were produced for the residential, service and industrial sectors.

According to the European Commission, the estimate of heating needs should be based on data taken from measured and verified national and European energy statistics as well as from energy reviews. Furthermore, sector-specific estimates should be produced from information for the industrial, service, residential and agricultural¹ sectors (European Commission, 2013).

I.1.1 Heating needs in the residential sector

I.1.1.1 Methodology

Heating needs in the residential sector were estimated using data from the 2012 report on energy consumption in the BCR, considering heating consumption by type of dwelling and by energy carrier. For residential buildings, heating needs cover the main source of heating (central or localised), domestic hot water, supplementary heating and cooking.

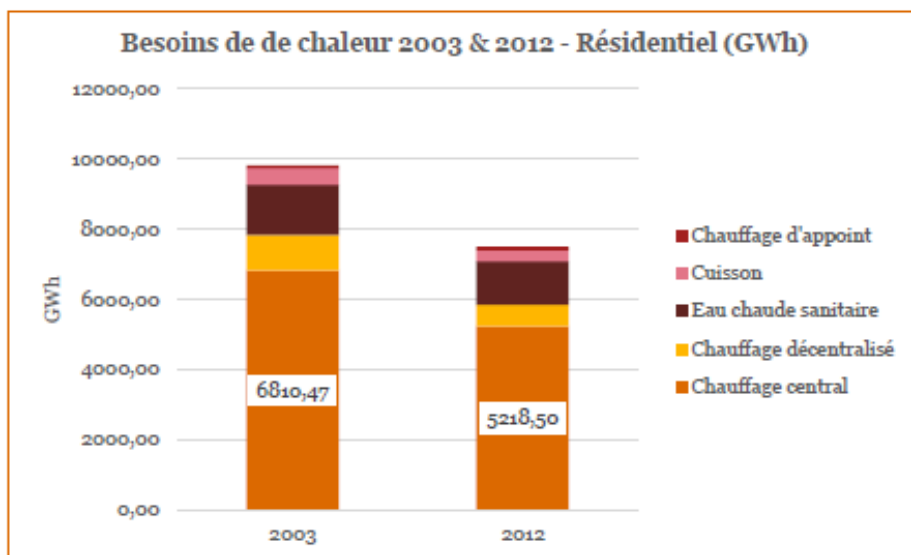
I.1.1.2 Results

Residential heating needs in the BCR were 7 491.4 GWh in 2012 compared with 9 818.6 GWh in 2003, a fall of 24 % over the period under review. They accounted for 89 % of energy use in the residential sector in 2012, compared with 91 % in 2003.

Heating needs in the residential sector are broken down in more detail below, based on use:

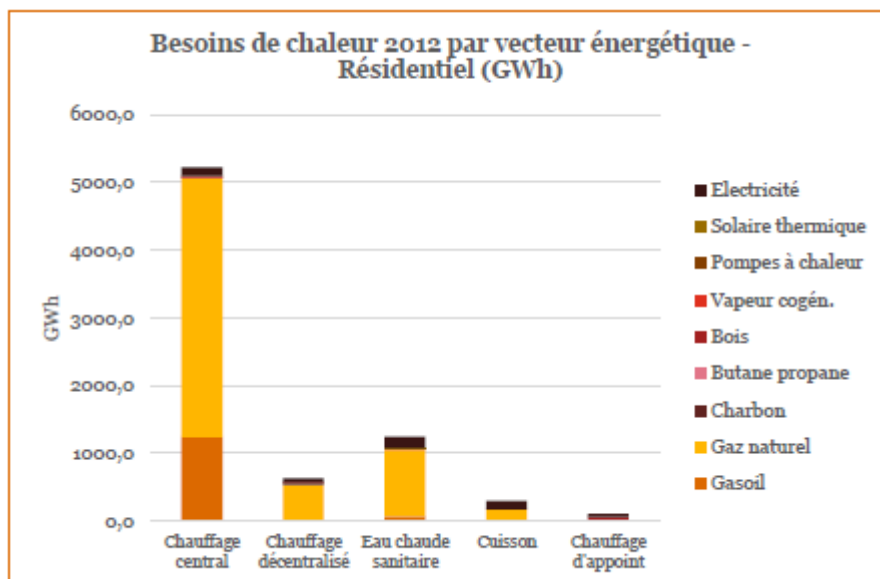
- 5 218.5 GWh for *central heating* compared with 6 810.5 GWh in 2003 (a fall of 23 %)
- 630.6 GWh for *localised heating* compared with 1 022.1 GWh in 2003 (a fall of 38 %)
- 1 239.1 GWh for *domestic hot water* compared with 1 438.4 GWh in 2003 (a fall of 14 %)
- 298.1 GWh for *cooking* compared with 474.4 GWh in 2003 (a fall of 37 %)
- 105.1 GWh for *supplementary heating* compared with 73.3 GWh in 2003 (a fall of 43 %).

¹ Not applicable for the Brussels-Capital Region



Besoins de chaleur 2003 & 2012 – Résidentiel (GWh)	Heating needs in 2003 & 2012 - Residential sector (GWh)
Chauffage d'appoint	Supplementary heating
Cuisson	Cooking
Eau chaude sanitaire	Domestic hot water
Chauffage décentralisé	Localised heating
Chauffage central	Central heating

The energy carrier used most commonly to meet the heating needs of the residential sector is natural gas (5 510.4 GWh, addressing 74 % of residential sector heating needs). It provides 3 831.6 GWh of power for central heating systems, 989.6 GWh for domestic hot water supply systems, 522 GWh for individual homes and 167.2 GWh for cooking equipment. The second most commonly used carrier is gas oil (1 314.7 GWh, addressing 18 % of residential sector heating needs), which is used for central heating (1 237.6 GWh), domestic hot water (65.5 GWh) and localised heating (11.6 GWh).



Besoins de chaleur 2012 par vecteur énergétique – Résidentiel (GWh)	Heating needs in 2012 by energy carrier – Residential sector (GWh)

Electricité	Electricity
Solaire thermique	Thermal solar
Pompes à chaleur	Heat pumps
Vapeur cogén	Steam cogen.
Bois	Wood
Butane propane	Butane propane
Charbon	Coal
Gaz naturel	Natural gas
Gasoil	Gas oil
Chauffage central	Central heating
Chauffage décentralisé	Localised heating
Eau chaude sanitaire	Domestic hot water
Cuisson	Cooking
Chauffage d'appoint	Supplementary heating

I.1.2 Heating needs in the service sector

I.1.2.1 Methodology

Heating needs in the service sector were estimated from data in the 2012 report on energy consumption in the Brussels-Capital Region, which break down energy consumption by segment (retail, transport, banking, administrative services, education, etc.). To gain an insight into energy use to meet heating needs, percentage shares were assigned to the heating fuel consumption recorded in 2012 for the service sector in the Brussels-Capital Region. The percentage values were taken from the report on energy consumption and derive mainly from a study by the University of Antwerp entitled 'Bouw en ontwikkeling van SAVER-LEAP als tool voor scenario-analyses van energiegebruik en emissies' [Construction and development of the tool SAVER-LEAP for scenario analysis of energy use and emissions]

	Percentage of fuel consumption meeting heating needs
Retail	91 %
Transport and communications	86 %
Banking, insurance, business services	92 %
Education	94 %
Healthcare	63 %
Culture and sport	86 %
Other services	86 %
Administrative services	92 %
Power and water	86 %

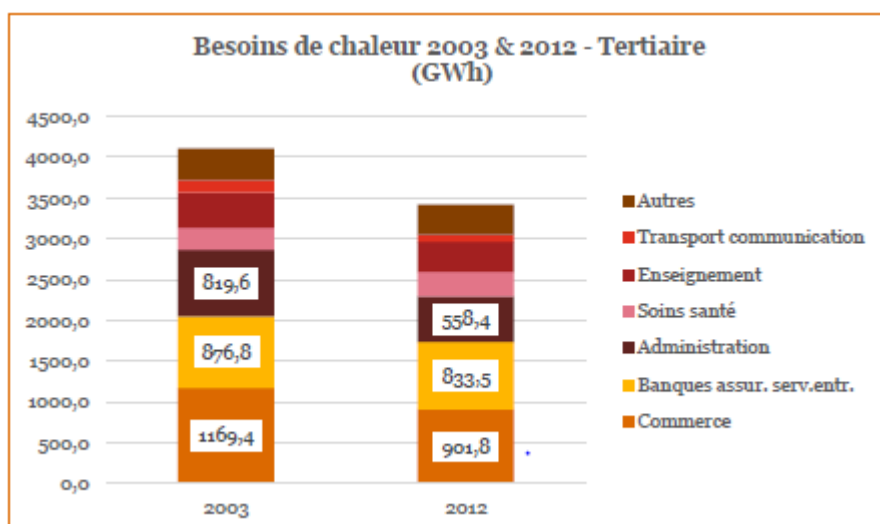
Source: ICEDD (2014)

I.1.2.2 Results

Heating needs in the service sector in the BCR were **3 416.6 GWh in 2012** compared with 4 106.7 GWh in 2003, a fall of 17 % over the period under review. They accounted for 88 % of service sector energy use in 2012, compared with 93 % in 2003.

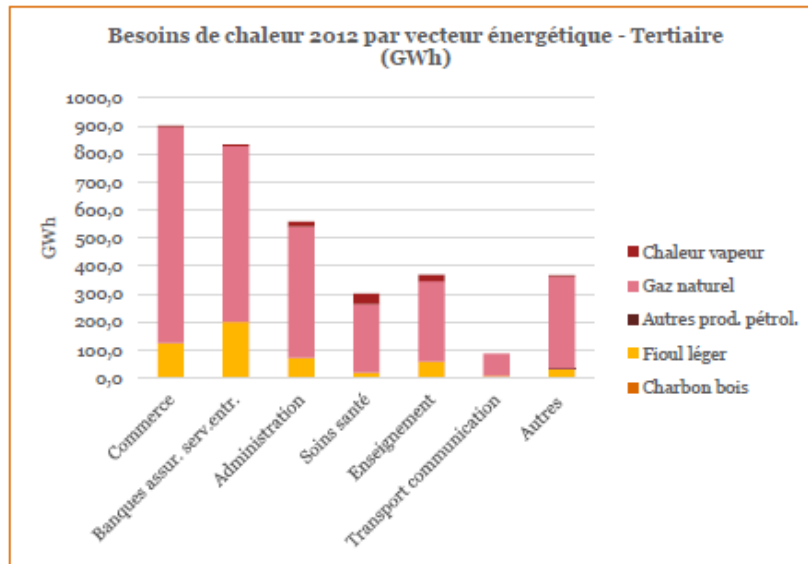
The heating needs of each of the service sector segments in Brussels are shown in more detail below:

- 901.8 GWh for retail compared with 1 169.4 GWh in 2003 (a fall of 23 %)
- 833.5 GWh for banking, insurance and business services compared with 876.8 GWh in 2003 (a fall of 5 %)
- 558.4 GWh for administrative services compared with 819.6 GWh in 2003 (a fall of 32 %)
- 301.1 GWh for healthcare compared with 268.4 GWh in 2003 (a rise of 12 %)
- 368.5 GWh for education compared with 434.3 GWh in 2003 (a fall of 15 %)
- 86 GWh for transport and communications compared with 151.4 GWh in 2003 (a fall of 43 %)
- 367.2 GWh for other service sector segments compared with 387 GWh in 2003 (a fall of 5 %).



Besoins de chaleur 2003 & 2012 – Tertiaire (GWh)	Heating needs in 2003 & 2012 - Service sector (GWh)
Autres	Other
Transport communication	Transport and communications
Enseignement	Education
Soins santé	Healthcare
Administration	Admin. services
Banques assur. serv. Entr.	Banking, insurance, business services
Commerce	Retail

The energy carrier used most commonly to meet the heating needs of the service sector is natural gas (2 809 GWh, addressing 82 % of service sector heating needs). The chart below shows that this trend is replicated across all service sector segments. The second most commonly used carrier is light fuel oil (501.6 GWh, addressing 15 % of service sector heating needs).



Besoins de chaleur 2012 par vecteur énergétique – Tertiaire (GWh)	Heating needs in 2012 by energy carrier – Service sector (GWh)
Chaleur vapeur	Heat-to-steam
Gaz naturel	Natural gas
Autres prod. Pétrol.	Other petroleum products
Fioul léger	Light fuel oil
Charbon bois	Wood charcoal
Commerce	Retail
Banques assur. Serv. Entr.	Banking, insurance, business services
Administration	Admin. services
Soins santé	Healthcare
Enseignement	Education
Transport communication	Transport and communications
Autres	Other

I.1.3 Heating needs in the industrial sector

I.1.3.1 Methodology

The heating needs of industry were estimated on the basis of data from the report on energy consumption in the BCR in 2012 which break down energy use by sector and by energy carrier. However, the report does not specify the proportion of energy use that meets heating needs.

The percentage shares shown in the table below were assigned in order to ascertain the figure for heating alone as a proportion of industrial energy use.²

	Light fuel oil	Heavy fuel oil	Butane-propane	Gas	Wood charcoal
Heating as a proportion of energy use	0.9	0.9	1	0.9	1

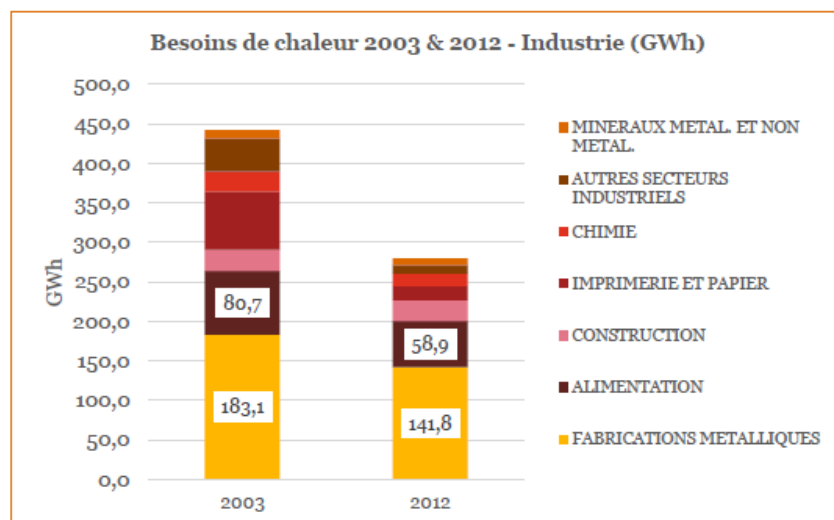
Source: IGBE (*Institut Bruxellois pour la Gestion de l'Environnement*, the Brussels Environmental Authority) (2001), *Les données de base pour le plan* (Basic data for the plan)

I.1.3.2 Results

Heating needs for Brussels-based industry were 279.7 GWh in 2012 compared with 441.7 GWh in 2003, a fall of 37 % over the period under review. They accounted for 45 % of energy use by Brussels-based industry in 2012, compared with 47 % in 2003.

The heating needs of each of the industry segments in Brussels are shown in more detail below:

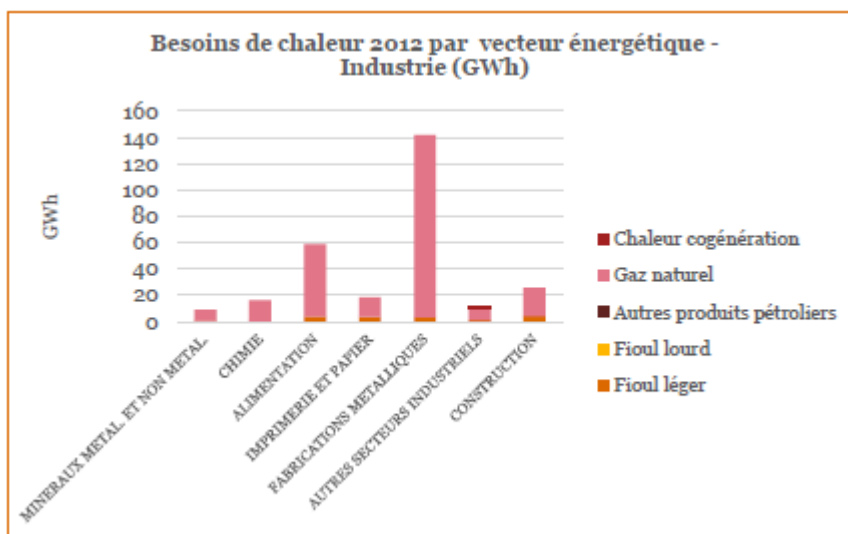
- 141.8 GWh for metalworking compared with 183.1 GWh in 2003 (a fall of 23 %)
- 58.9 GWh for food compared with 80.7 GWh in 2003 (a fall of 27 %)
- 25.6 GWh for building and construction compared with 26.2 GWh in 2003 (a fall of 2 %)
- 18.4 GWh for printing and paper compared with 74.3 GWh in 2003 (a fall of 75 %)
- 15.9 GWh for chemicals compared with 25.1 GWh in 2003 (a fall of 37 %)
- 8.8 GWh for metallic and non-metallic minerals compared with 10.5 GWh in 2003 (a fall of 16 %)
- 10.5 GWh for other industry segments compared with 41.9 GWh in 2003.



² Electricity consumption was not included in the estimate of heating needs for industry as it mainly meets needs other than heating (lighting, motive power, etc.).

Heating needs in 2003 & 2012 - Industry (GWh)	Besoins de chaleur 2003 & 2012 – Industrie (GWh)
METALLIC AND NON-METALLIC MINERALS	MINERAUX METAL. ET NON METAL.
OTHER INDUSTRY SEGMENTS	AUTRES SECTEURS INDUSTRIELS
CHEMICALS	CHIMIE
PAPER AND PRINTING	IMPRIMERIE ET PAPIER
BUILDING AND CONSTRUCTION	CONSTRUCTION
FOOD	ALIMENTATION
METALWORKING	FABRICATIONS METALLIQUES

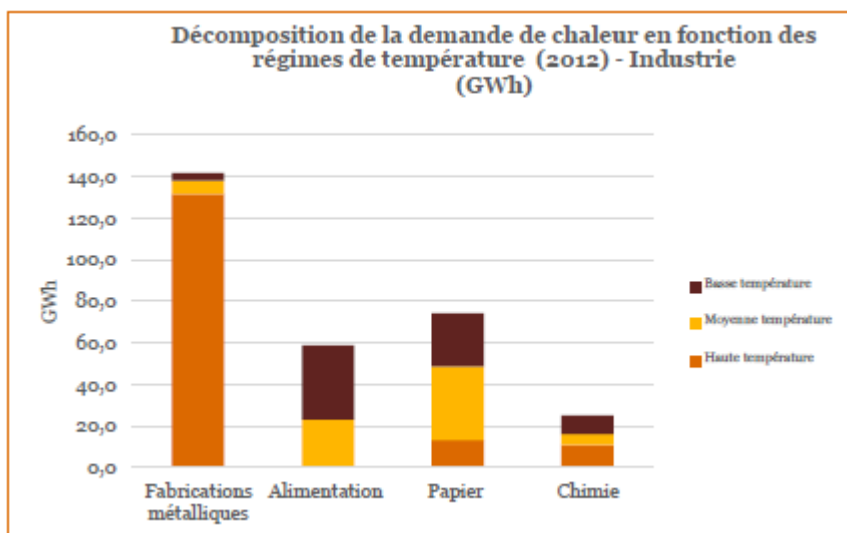
The energy carrier used most commonly to meet the heating needs of Brussels-based industry is natural gas (263 GWh, addressing 94 % of the heating needs of Brussels-based industry). The chart below shows that this trend is replicated across all segments of Brussels-based industry. The second most commonly used carrier is light fuel oil (16.6 GWh, addressing 6 % of the heating needs of Brussels-based industry).



Heating needs in 2012 by energy carrier – Industry (GWh)	Besoins de chaleur 2012 par vecteur énergétique – Industrie (GWh)
Heat from cogeneration	Chaleur cogénération
Natural gas	Gaz naturel
Other oil products	Autres produits pétroliers
Heavy fuel oil	Fioul lourd
Light fuel oil	Fioul léger
METALLIC AND NON-METALLIC MINERALS	MINERAUX METAL. ET NON METAL.
CHEMICALS	CHIMIE
FOOD	ALIMENTATION

PAPER AND PRINTING	IMPRIMERIE ET PAPIER
METALWORKING	FABRICATIONS METTALLIQUES
OTHER INDUSTRY SEGMENTS	AUTRES SECTEURS INDUSTRIELS
BUILDING AND CONSTRUCTION	CONSTRUCTIONS

The chart below breaks down the heat demand of four major industry sectors in the Brussels-Capital Region on the basis of temperature ratings (high, medium and low temperature). The analysis was based on the data available for Belgian industry in a study conducted by the Joint Research Center (2012).

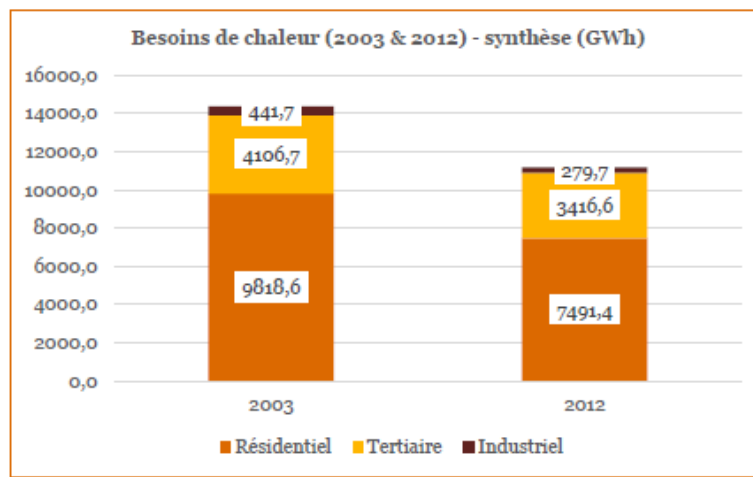


Breakdown of heat demand by temperature rating (2012) - Industry (GWh)	Décomposition de la demande de chaleur en fonction des régimes de température (2012) – Industrie (GWh)
Low temperature	Basse température
Medium temperature	Moyenne température
High temperature	Haute température
Metalworking	Fabrications métalliques
Food	Alimentation
Paper	Papier
Chemicals	Chimie

The energy consumption of Brussels-based industry was analysed in more detail on a sector-specific basis using data extracted from the 'Baden' database. While the analysis was based on a relatively heterogeneous dataset, it broadly confirms the aggregate data used above. In particular, it highlights the significance of the 'transport equipment' sub-segment (primarily automotive) which alone accounts for nearly half of the energy consumption of the Brussels Region.

I.1.4 Summary

Heating needs in the BCR were 11 187.7 GWh in 2012 compared with 14 367.1 GWh in 2003, a fall of 22 % over the period under review. They fell by 24 % in the residential sector, 17 % in the service sector and 37 % in Brussels-based industry. **In 2012, the residential sector was responsible for 67 % of heating needs, the service sector was responsible for 31 % and industry for 3 %.**



Besoins de chaleur (2003 & 2012) – synthèse (GWh)	Heating needs (2003 & 2012) - overview (GWh)
Résidentiel	Residential
Tertiaire	Services
Industriel	Industrial

I.2 ESTIMATED CHANGE IN HEATING NEEDS TO 2030

PwC has developed an approach for each of the sectors (**residential, services and industry**) with a view to discerning the change in heating needs in the BCR to 2030. The forecasts are based on the evaluation of heating needs in 2012 and take into consideration the forward-looking assessment by the *Bureau fédéral du Plan* (Belgian Federal Planning Bureau) of a variety of key parameters; otherwise, they are based on the historical assessment of particular parameters.

According to the European Commission, forecasts should factor in the trends observed in key sectors of the economy (EC, 2013):

- This analysis should take account of the likely change in heat demand in **industrial sectors**, as well as considering long-term structural changes (deindustrialisation, reindustrialisation, improved energy efficiency and the impact of new production technologies) and short-term cyclical changes.
- The change in heat demand in **buildings** should include the impact of energy efficiency improvements as calculated using the method laid down by Article 3 of Directive 2010/31/EU

I.2.1 Change in heating needs in the residential sector

I.2.1.1 Methodology

Residential sector heating needs to 2030 were estimated on the basis of the projected annual change in heating needs in the residential sector in 2012 (denoted by 'g' in Equation 1).

Equation 1 : Projection du taux de croissance des besoins de chaleur du secteur résidentiel

$$BC_{t2}^R = BC_{t1}^R * (1 + g) \rightarrow g = \frac{BC_{t2}^R}{BC_{t1}^R} - 1$$

Avec $BC = \frac{BC}{Log} * Log$:

$$g = \frac{\left(\frac{BC_{t2}}{Log_{t2}}\right)^{Log_{t2}} - 1}{\left(\frac{BC_{t1}}{Log_{t1}}\right)^{Log_{t1}}} = \left\{ \frac{\left[\left(\frac{BC_{t1}}{Log_{t1}}\right)^{1+\Delta \frac{BC}{Log}}\right] * \frac{[(Log_{t1})^{1+\Delta Log}]}{Log_{t1}}}{\left(\frac{BC_{t1}}{Log_{t1}}\right)^{Log_{t1}}} \right\} - 1 = \{(1 + \Delta \frac{BC}{Log}) * (1 + \Delta Log)\} - 1$$

$$BC_{t2}^R = BC_{t1}^R * (1 + [(1 + \Delta \frac{BC}{Log}) * (1 + \Delta Log)] - 1) = BC_{t1}^R * \{(1 + \Delta \frac{BC}{Log}) * (1 + \Delta Log)\}$$

Légende : BC= besoins de chaleur; g = Evolution annuelle des besoins de chaleur ; Log = Logements

Equation 1 : Projection du taux de croissance des besoins de chaleur du secteur résidentiel	Equation 1: Projected growth rate for residential sector heating needs
Légende : BC = besoins de chaleur ; g = Evolution annuelle des besoins de chaleur ; Log = Logements	Legend: BC = Heating needs (<i>besoins de chaleur</i>); g = Annual change in heating needs; Log = Homes (<i>logements</i>)
Avec	Where

On the basis of Equation 1, it emerges that the change in heating needs in the residential sector is dependent on the change in heating needs per dwelling and on the change in the number of dwellings. Accordingly, for the purpose of estimating heating needs to 2030, there is a need to estimate the year-on-year change in the heating needs of each dwelling and the change in the number of dwellings to 2030.

1. Estimated change in heating needs per dwelling:

The starting-point assumption is that there are two parameters which contribute to the change in heating needs per dwelling, namely degree-days and improved building energy performance³ (see Equation 2):

³ Ascertained from the trend in energy consumption to fulfil heating needs per square metre.

Equation 2 : Estimation de l'évolution des besoins de chaleur par logement

$$\Delta \frac{BC}{Log} = \alpha \Delta dj + \beta \Delta EE$$

Légende :

- BC = besoins de chaleur
- Log = logements
- dj = degrés-jours
- EE = Performances énergétiques du bâtiment (besoins de chaleur/m²)
- $\alpha = \frac{\text{contribution } dj / \Delta dj}{\text{contribution } dj / \Delta dj} = 0,04\% \text{ (Estimation du Bureau fédéral du Plan)}$
- $\beta = \frac{\text{contribution } EE / \Delta EE}{\text{contribution } EE / \Delta EE} = 1 - \alpha$

Equation 2 : Estimation de l'évolution des besoins de chaleur par logement	Equation 2: Estimated change in heating needs per dwelling
Légende :	Key:
BC = besoins de chaleur	BC = heating needs (<i>besoins de chaleur</i>)
Log = logements	Log = dwellings (<i>logements</i>)
dj = degrés-jours	dj = degree-days (<i>degrés-jours</i>)
EE = Performances énergétiques du bâtiment (besoins de chaleur/m ²)	EE = building energy performance (heating needs/m ²)
$\alpha = \text{contribution } dj / \Delta dj = 0,04\% \text{ (Estimation du Bureau fédéral du Plan)}$	$\alpha = \text{contribution of } dj / \Delta dj = 0.04 \% \text{ (estimate by the Belgian Federal Planning Bureau)}$
$\beta = \text{Contribution } EE / \Delta EE = 1 \cdot \alpha$	$\beta = \text{contribution of } EE / \Delta EE = 1 \cdot \alpha$

- The Belgian Federal Planning Bureau (2014 bis) makes a basic assumption **with regard to the change in degree-days to 2030** that degree-days are expected to remain constant at the level seen in 2005. Based on this assumption and the estimate of degree-days taken from the report on energy consumption in the Brussels Region (ICEDD, 2014) for 2005, an estimated degree-day figure of 1 828 is assigned to each year to 2030.⁴ Given that degree-days are maintained at a constant level to 2030, they will make a zero contribution to the change in heating needs per dwelling. *It should be understood that the line of argument set out above relates to the contribution of the change in degree-days to the change in heating needs and not to the contribution of degree-days for one year to heating fuel consumption for that same year.* In this particular case, assuming a figure of 1 828 degree-days for every year to 2030, the contribution of the change in degree-days to the change in heat demand is clearly zero.

Estimates by the Belgian Federal Planning Bureau have determined the factor as 0.04 %. In other words, an increase of one degree-day would have an impact of 0.4 % in heating needs. The corollary of the definition of α is that factor β has a value of 0.96.

- The starting point **with regard to the change in building energy performance to 2030** is:
 - o Standardised heating fuel consumption per square metre (kWh/m²) in the residential sector in 2012. By standardising heating fuel consumption, the impact of changes in degree-days on the change in heating fuel consumption can be disregarded. On this basis, standardised heating fuel consumption in 2012 was 140 kWh/m² (see Table 1 for more information).

⁴ It should also be pointed out that this assumption has the effect of smoothing out the significant degree-day fluctuations seen in recent years. The figures were 2 309 in 2010, 1 515 in 2001 and 1 915 in 2012.

Table 1: Estimated heating fuel consumption per square metre

	2001	2012	2001-2012 (average annual growth rate*)
Heating fuel consumption (GWh) Source: Report on energy consumption in 2012	8 947 GWh	6 969 GWh	-2.25 %
Number of dwellings in the BCR Source: BISA (Brussels Institute for Statistics and Analysis, Institut Bruxellois de Statistique et d'Analyse)	462 893	505 545	0.80 %
Average floor area of dwellings in the BCR (m ²) Source: Socio-economic survey 2001 & IBGE data (2015)	74.4	94	2.15 %
Fuel consumption/square metre (kWh/m ²)	259.8 kWh/m ²	146.7 kWh/m ²	-5.07 %
Degree-days Source: Report on energy consumption in 2012	1 929	1 915	1 834.7**
Standardised average consumption (fuel consumption/m²)	246.2 kWh/m² (=259.8 *1 828/1 929)	140.0 kWh/m² (=146.7 *1 828/1 915)	-5.00 %

* Average annual growth rate

** Average degree-days over the period of observation. The standardised value is 1 828 degree-days.

- The entry into force of Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters. The Regulation provides for raising the seasonal efficiency of the majority of equipment to 86 % (higher heating value).
- The present situation, where average annual (seasonal) production efficiency is no more than 70 % (higher heating value).
- The continued exception to Regulation No 813/2013 relating to 20 % of individual boiler capacity in collective housing.

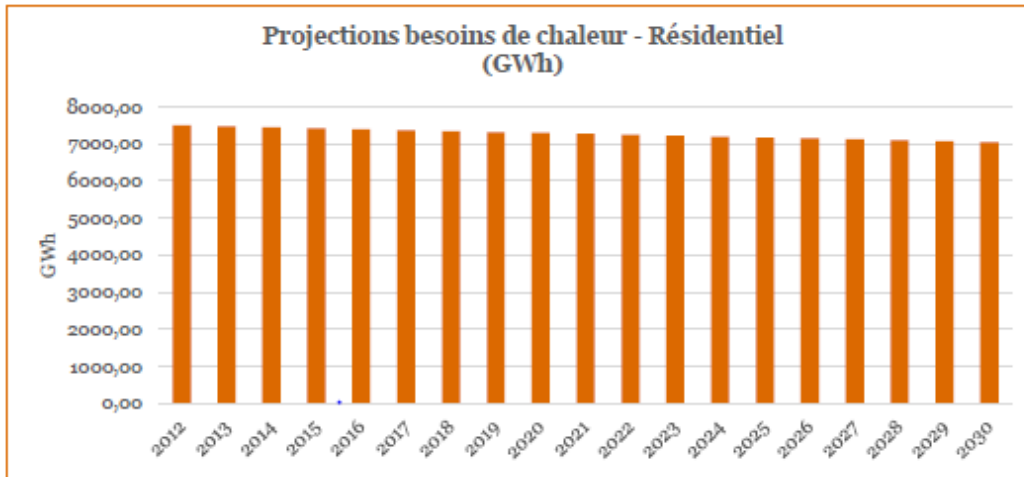
On the basis of this information, it seems reasonable to assume that by 2030, 80 % of boilers will have achieved seasonal efficiency of 86 % Hs, with the remaining 20 % unchanged from 2012. *As a result, fuel consumption per square metre is expected to be 119.15 kWh/m² in 2030* (equating to an annual fall of 0.89 % in fuel consumption per m²).

2. Estimated change in the number of dwellings:

To estimate the change in the number of dwellings, the report uses the projections from the Belgian Federal Planning Bureau (Belgian Federal Planning Bureau, 2014) to factor in the change in the number of households in the Brussels Region to 2030. The Bureau believes that the number of Brussels-based households will increase by 9.2 % between 2013 and 2030, from 542 040 in 2013 to 591 965 (an average annual increase of 0.52 %).

I.2.1.2 Results

Overall, heating needs in the residential sector will fall by an average of 0.34 % per year, from 7 491.4 GWh in 2012 to 7 045.3 in 2030. This change results primarily from the improvement in energy efficiency (heating needs/m²) in dwellings in Brussels. The average annual increase in the number of dwellings (+0.52 %/year) is below the level of improvement in energy efficiency in dwellings (-0.89 %/year).



Projections besoins de chaleur – Résidentiel (GWh)	Projected heating needs - Residential sector (GWh)
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I.2.2 Change in heating needs in the service sector

I.2.2.1 Methodology

Service sector heating needs to 2030 were estimated on the basis of the projected annual change in heating needs in the service sector in 2012 (denoted by 'g' in Equation 3).

Equation 3 : Projection du taux de croissance des besoins de chaleur du secteur tertiaire

$$BC_{t2}^T = BC_{t1}^T * (1 + g) \rightarrow g = \frac{BC_{t2}^T}{BC_{t1}^T} - 1$$

Avec $BC = \frac{BC}{VA} * VA$:

$$g = \frac{\left(\frac{BC_{t2}}{VA_{t2}}\right) * VA_{t2} - 1}{\left(\frac{BC_{t1}}{VA_{t1}}\right) * VA_{t1}} = \frac{\left[\left(\frac{BC_{t1}}{VA_{t1}}\right) * \left(1 + \frac{\Delta BC}{VA}\right)\right] * \left[VA_{t1} * (1 + \Delta VA)\right] - 1}{\left(\frac{BC_{t1}}{VA_{t1}}\right) * VA_{t1}} = \{(1 + \Delta \frac{BC}{VA}) * (1 + \Delta VA)\} - 1$$

$$BC_{t2}^T = BC_{t1}^T * (1 + [\{(1 + \Delta \frac{BC}{VA}) * (1 + \Delta VA)\} - 1]) = BC_{t1}^T * \{(1 + \Delta \frac{BC}{VA}) * (1 + \Delta VA)\}$$

Légende : BC= besoins de chaleur; g = Evolution annuelle des besoins de chaleur ; VA = valeur ajoutée

Equation 3: Projected growth rate for service sector heating needs	Equation 3 : Projection du taux de croissance des besoins de chaleur du secteur tertiaire
Where BC	Avec BC
Legend: BC = heating needs (<i>besoins de chaleur</i>); g = annual change in heating needs; VA = added value (<i>valeur ajoutée</i>)	Légende : BC = besoins de chaleur ; g = Evolution annuelle des besoins de chaleur ; VA = valeur ajoutée

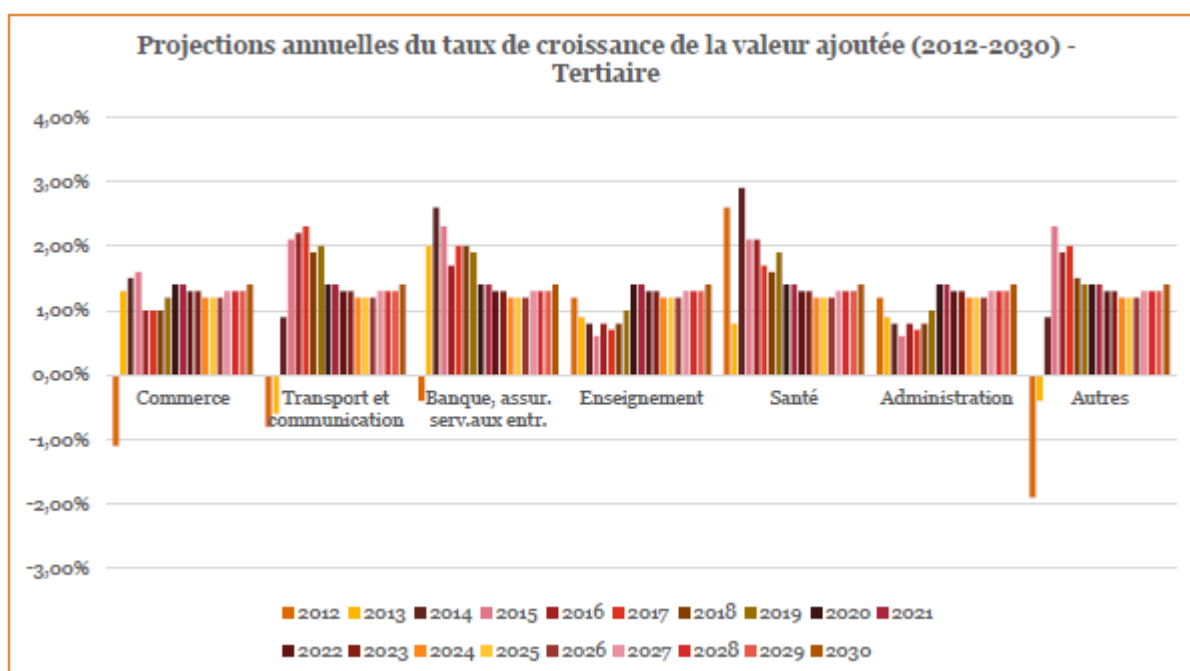
On the basis of Equation 3, it is apparent that the change in service sector heating needs is dependent on the change in heating needs per unit of added value (energy efficiency) and on the change in added value. Accordingly, for the purpose of estimating heating needs to 2030, there is a need to estimate the year-on-year change in heating needs per unit of added value and the change in added value to 2030.

1. Estimated change in heating needs per unit of added value:

The Belgian Federal Planning Bureau’s projections (BFP, 2014 bis) of the change in service sector energy efficiency were used to ascertain the change in service sector heating needs per unit of added value. The Bureau believes that between 2012 and 2020, energy efficiency in the Belgian service sector will improve by 1.9 % per year, with an improvement of 1.6 % per year between 2021 and 2030.

2. Estimated change in added value:

The change in added value in the Brussels service sector was estimated with reference to the Belgian Federal Planning Bureau’s most recent regional projections for each branch of the sector (BFP, 2014 ter). Projections were made to 2019 for each branch (retail, transport and communications, banking, business services, etc.). In the absence of regional projections, national projections were used for 2020 to 2030; these do not distinguish between the different sectors of the economy. They are based on the same methodology as prescribed for the regional projections (BFP, 2014 quater).

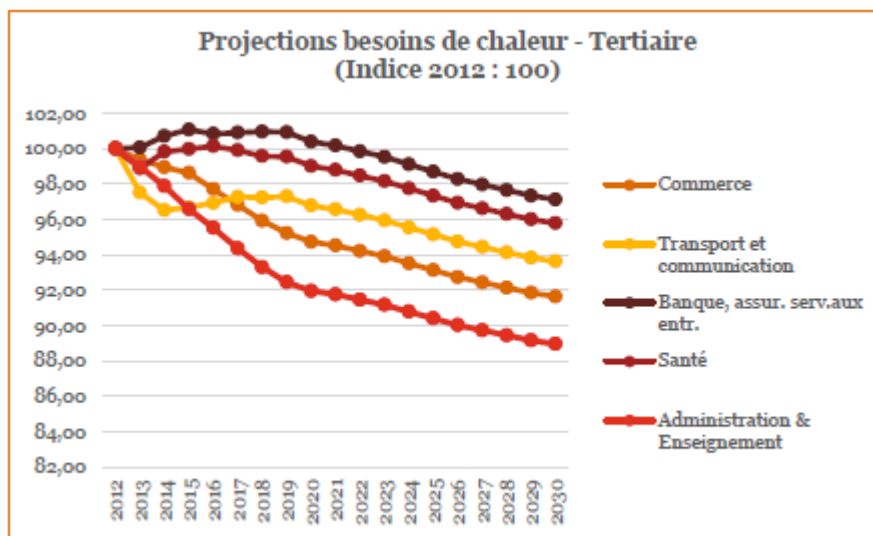
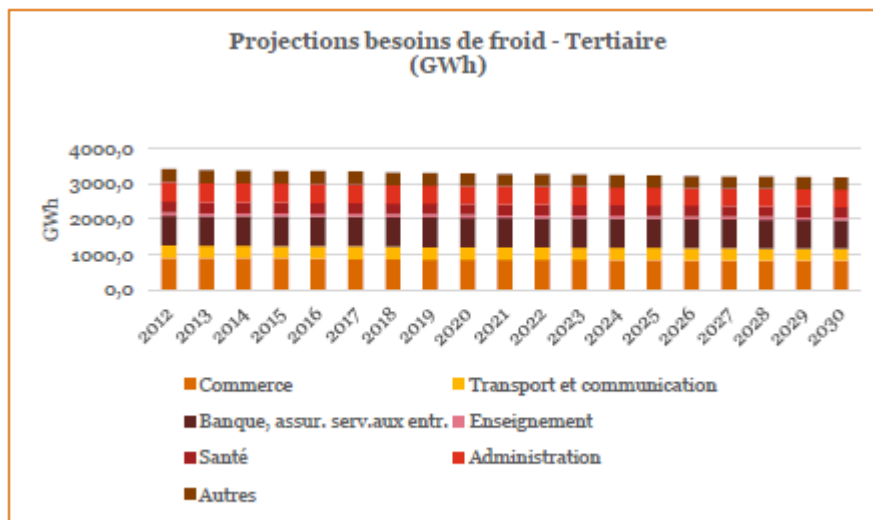


Source: BFP (2014 ter) & BFP (2014 quater)

Projections annuelle du taux de croissance de la valeur ajoutée (2012-2030) - Tertiaire	Projected annual growth rates for added value (2012-2030) - Service sector
Commerce	Retail
Transport et communication	Transport and communications
Banque, assur. Serv. Aux. Entr.	Banking, insurance, business services
Enseignement	Education
Santé	Health
Administration	Admin. services
Autres	Other

I.2.2.2 Results

Overall, service sector heating needs will fall by an average of 0.4 % per year, from 3 416.6 GWh in 2012 to 3 182.6 in 2030. Heating needs will fall *the most* in education and administrative services (-0.65 %) and *the least* in banking, insurance and business services (-0.16 %/year).



Projections besoins de froid – Tertiaire (GWh)	Projected cooling needs - Service sector (GWh)
Commerce	Retail
Banque, assur. Serv. Aux. Entr	Banking, insurance, business services
Santé	Health
Autres	Other
Transport et communication	Transport and communications
Enseignement	Education
Administration	Admin. services

Projections besoins de chaleur – Tertiaire	Projected heating needs - Service sector (Base
--	--

(Indice 2012 : 100)	100: 2012)
Commerce	Retail
Transport et communication	Transport and communications
Banque, assur. Serv. Aux. Entr.	Banking, insurance, business services
Santé	Health
Administration & Enseignement	Admin. services and education

I.2.3 Change in heating needs in the industrial sector

I.2.3.1 Methodology

Heating needs to 2030 in Brussels-based industry were estimated on the basis of the projected annual change in heating needs in the service sector in 2012 (denoted as 'g' in equation 4).

Equation 4 : Projection du taux de croissance des besoins de chaleur de l'industrie

$$BC_{t2}^I = BC_{t1}^I * (1 + g) \rightarrow g = \frac{BC_{t2}^I}{BC_{t1}^I} - 1$$

$$\text{Avec } BC = \frac{BC}{VA} * VA:$$

$$g = \frac{\left(\frac{BC_{t2}}{VA_{t2}}\right) * VA_{t2}}{\left(\frac{BC_{t1}}{VA_{t1}}\right) * VA_{t1}} - 1 = \frac{\left[\left(\frac{BC_{t1}}{VA_{t1}}\right) * (1 + \Delta \frac{BC}{VA})\right] * [(VA_{t1}) * (1 + \Delta VA)]}{\left(\frac{BC_{t1}}{VA_{t1}}\right) * VA_{t1}} - 1 = \{(1 + \Delta \frac{BC}{VA}) * (1 + \Delta VA)\} - 1$$

$$BC_{t2}^I = BC_{t1}^I * (1 + [\{(1 + \Delta \frac{BC}{VA}) * (1 + \Delta VA)\} - 1]) = BC_{t1}^I * \{(1 + \Delta \frac{BC}{VA}) * (1 + \Delta VA)\}$$

Légende : BC= besoins de chaleur; g = Evolution annuelle des besoins de chaleur ; VA = valeur ajoutée

Equation 4 : Projection du taux de croissance des besoins de chaleur de l'insudutrie	Equation 4: Projected growth rate for heating needs in industry
Avec BC	Where HN
Légende : BC = besoins de chaleur ; g = Evolution annuelle des besoins de chaleur ; VA = valeur ajoutée	Legend: BC = Heating needs (<i>besoins de chaleur</i>); g = Annual change in heating needs; VA = Added value (<i>valeur ajoutée</i>)

On the basis of Equation 4, it is apparent that the change in industrial heating needs is dependent on the change in heating needs per unit of added value (energy efficiency) and on the change in added value. Accordingly, for the purpose of estimating heating needs to 2030, there is a need to estimate the year-on-year change in heating needs per unit of added value and the change in added value to 2030.

1. Estimated change in heating needs per unit of added value

The Belgian Federal Planning Bureau's projections (BFP, 2014 bis) of the change in industrial sector energy efficiency were used to ascertain the change in heating needs per unit of added value in industry.

Table 2: Projected change in energy efficiency in Brussels-based industry

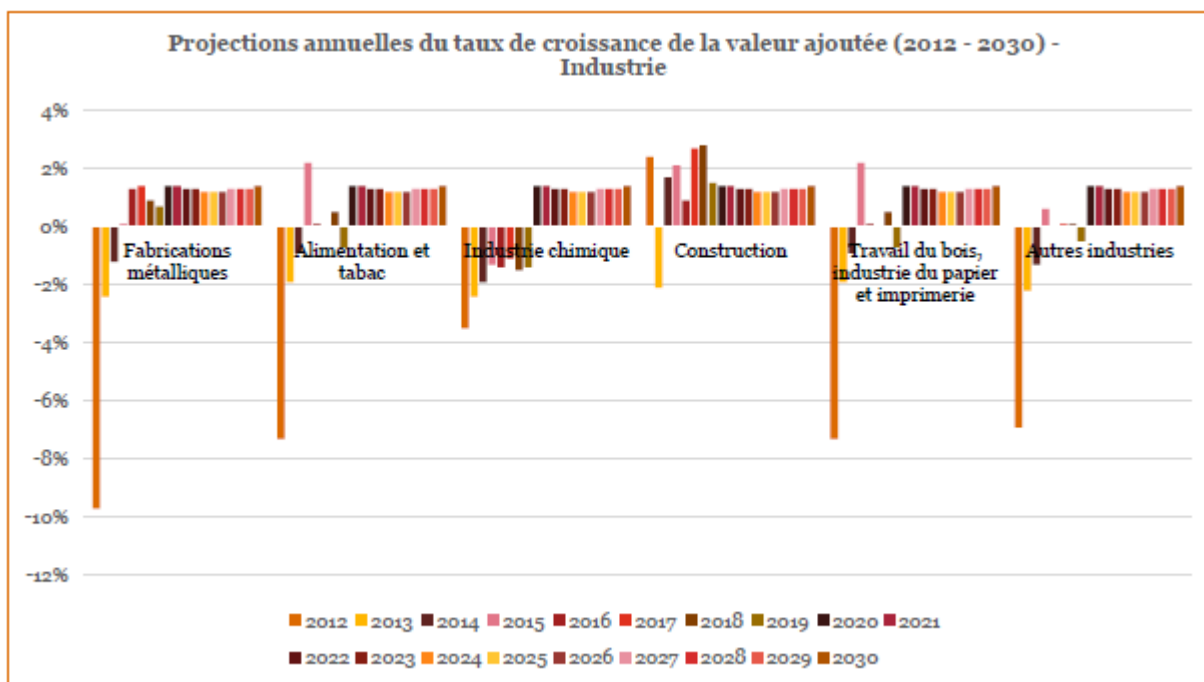
Industry sectors	2010-2020	2021-2030
Metalworking	-1.8 %	-0.50 %
Food and tobacco	-1.2 %	-1.00 %
Chemical industry	-2.2 %	-1.90 %
Building and construction*	-1.3 %	-1.10 %

Woodworking, paper and printing	-1.8 %	-1.50 %
Other industry	-1.3 %	-1.10 %

*In the absence of available statistics for the building and construction sector, the estimates for 'Other industry' were used.
Source: BFP (2014 bis)

2. Estimated change in added value

The change in added value was estimated with reference to the Federal Planning Bureau's latest regional projections for each industry sector (BFP, 2014 ter). These sector-specific estimates were produced through to 2019. In the absence of regional projections, national projections were used for 2020 to 2030; these do not distinguish between the different sectors of the economy. However, they are based on the same methodology as prescribed for the regional projections (BFP, 2014 quater).



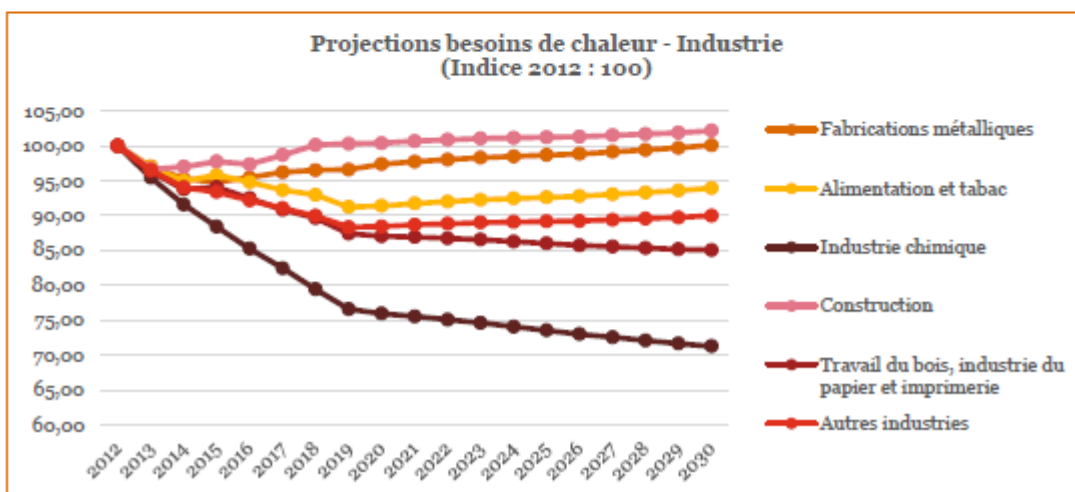
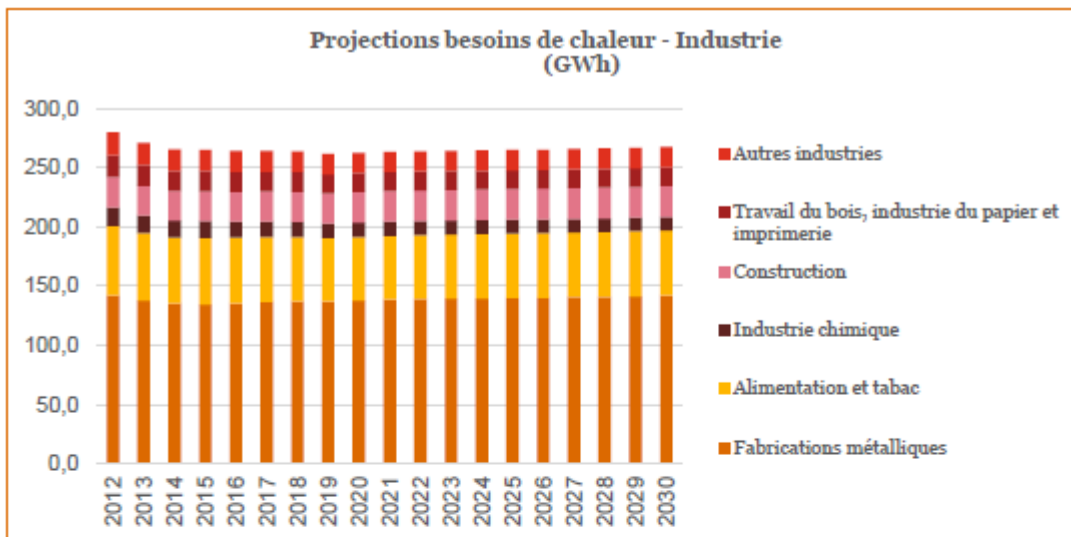
Projections annuelles du taux de croissance de la valeur ajoutée (2012 – 2030) – Industrie	Projected annual growth rates for added value (2012-2030) - Industry
Fabrications métalliques	Metalworking
Alimentation et tabac	Food and tobacco
Industrie chimique	Chemical industry
Construction	Building and construction
Travail du bois, industrie du papier et imprimerie	Woodworking, paper and printing
Autres industries	Other industry

It should be noted that the manufacture of transport equipment falls within the metalworking segment, and contributed 58 % of added value in 2013 (BNB, Banque Nationale de Belgique, National bank of Belgium, 2014). As a result, the forthcoming changes at Audi's Brussels plant will have substantial implications for changes in added value in the metalworking segment in the Brussels Region.⁵

⁵ For information, reports in the press indicate that staff at Audi Brussels will manufacture a successor to the A1, for which the contract comes to an end in 2016. More information is available here: <http://studioweb.lesoir.be/mini04/article/audi-brussels%C2%A0-%E2%80%99a1-aura-bien-un-successeur>

I.2.3.2 Results

Overall, industrial heating needs will fall by an average of 0.25 % per year, from 279.7 GWh in 2012 to 267.6 GWh in 2030. Heating needs will fall *the most* in the chemicals industry (-1.9 %/year). Conversely, the building and construction sector will see its needs increase (+0.12 %/year).



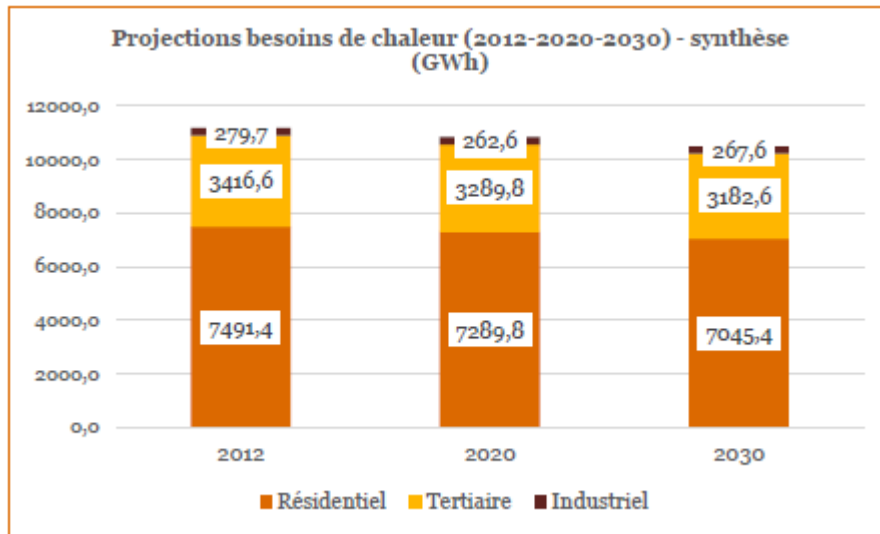
Projections besoins de chaleur – Industrie (GWh)	Projected heating needs - Industry (GWh)
Autres industries	Other industry
Travail du bois, industrie du papier et imprimerie	Woodworking, paper and printing
Construction	Building and construction
Industrie chimique	Chemical industry
Alimentation et tabac	Food and tobacco
Fabrications métalliques	Metalworking

Projections besoins de chaleur – Industrie (Indice 2012 : 100)	Projected heating needs - Industry (Base 100: 2012)
Fabrications métalliques	Metalworking
Alimentation et tabac	Food and tobacco
Industrie chimique	Chemical industry

Construction	Building and construction
Travail du bois, industrie du papier et imprimerie	Woodworking, paper and printing
Autres industries	Other industry

I.2.4 Summary

Overall, heating needs in the Brussels Region will fall between now and 2030, from 11 187.7 GWh in 2012 to 10 495.6 GWh in 2030. The service sector will see the most significant fall in heating needs, from 3 416.6 GWh in 2012 to 3 182.6 GWh in 2030, a fall of 7 %. In the residential sector, heating needs will fall by 6 %, from 7 491.4 GWh in 2012 to 7 054.4 GWh in 2030. Heating needs in Brussels-based industry will fall by 4 %, from 279.7 GWh in 2012 to 267.6 GWh in 2030.



Projections besoins de chaleur (2012-2020-2030) – synthèse (GWh)	Projected heating needs (2012-2020-2030) - summary (GWh)
Résidentiel	Residential
Tertiaire	Services
Industriel	Industrial

II. ESTIMATED COOLING NEEDS

II.1 ESTIMATED COOLING NEEDS IN 2012

Generally speaking, the statistics relating to cooling needs are incomplete and imprecise, although the situation varies by sector and is as much dependent on conditions of use as it is on technical requirements. As such, for example, conditions of use in the *residential sector* are fairly uniform, at least to the extent that it is possible to gather accurate data on market penetration rates for air conditioning systems and the conditions in which such equipment is used.

Conversely, in the *industrial sector*, the reality is more complex. Energy needs for cooling are largely dependent on the line of business and on the associated production conditions. In the building and construction sector, for example, cooling needs may feature in the development of major structures such as dams, which involve mass poured concrete. Refrigeration is required in this case to remove the heat resulting from the process of cement hydration. Another area of application is the development of underground structures, such as tunnels. Under certain site conditions, such as for granular soils in a water table, ground freezing is used to ensure stability during excavation. Load conditions can clearly be quite different depending on the nature of the project.

The same is true for the *service sector*, although to a lesser degree. For example, in the distribution sector, cooling needs are directly impacted by the proportion of business operations relating to cold chain products. Elsewhere, cooling at slightly higher temperatures has a role to play in the preservation of fresh produce, such as fruit and vegetables, cheese, cold meats, etc. It is also used for air handling in air conditioning systems.

II.1.1 Cooling needs in the residential sector

II.1.1.1 Methodology

Residential sector cooling needs are not evaluated in the report on energy consumption in the BCR (2012).

To arrive at an initial estimate of these needs, two complementary assumptions were formulated:

- i. Firstly, it was assumed that only certified dwellings exceeding the 50 % air conditioning threshold would be taken into account.
- ii. In addition, the average consumption of a refrigerated appliance was estimated.

With information on the floor area of dwellings in the BCR, it is possible to make at least an approximation of electricity consumption to fulfil cooling needs in the residential sector (see results of task 2).

II.1.1.2 Results

The findings relating to the two working assumptions are as follows:

- i. 1 % of certified dwellings have a level of air conditioning of over 50 %;
- ii. air conditioning equipment in the residential sector consumes an average of 14.4 KWh of electricity per m² in one year.

As an average dwelling has a floor area of 94 m² and the number of registered dwellings in the BCR is 505 545 units (see above), the annual electricity consumption that would be required to meet cooling needs can be deduced as close to 6 843 MWh. This is clearly a modest figure when set against heating needs. However, it is important to emphasise that this is a low-end evaluation, because of the 50 % minimum threshold for air-conditioning factored into the working assumptions. For the time being, it is not possible to establish any links between these results and the impact of climatic factors.

II.1.2 Cooling needs in the service sector

II.1.2.1 Methodology

Service sector cooling needs were estimated on the basis of data from the report on energy consumption in the BCR (2012) which break down energy use according to the major sectors of the regional economy.

Percentage shares were assigned to the electricity use recorded for the service sector, so that the energy used to meet cooling needs (air conditioning, ventilation and cold) could be estimated. The percentage values were taken from the report on energy consumption and derive primarily from a study by the University of Anvers entitled '*Bouw en ontwikkeling van SAVER-LEAP als tool voor scenario-analyses van energiegebruik en emissies*' [Construction and development of the tool SAVER-LEAP for scenario analysis of energy use and emissions]. The results of this study are set out below.

	Percentage of electricity consumption meeting cooling needs
Retail	13 %
Transport and communications	7 %
Banking, insurance, business services	7 %
Education	7 %
Healthcare	10 %
Culture and sport	8 %
Other services	8 %
Administrative services	7 %
Power and water	0 %

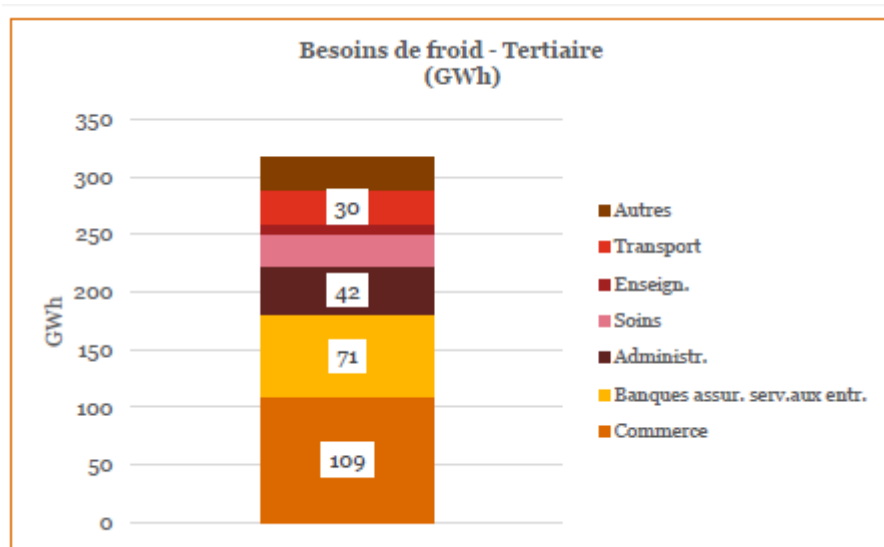
Source: ICEDD (2014)

II.1.2.2 Results

In 2012, consumption for cooling accounted for some 9 % of the electricity consumption of the Brussels-based service sector, or **316.2 GWh**. The cooling needs of each of the branches of the Brussels service sector are shown in detail below:

- 109 GWh in *retail* (35 % of service sector cooling needs)
- 71 GWh for *banking, insurance and business services* (23 % of service sector cooling needs)
- 42 GWh for *administrative services* (13 % of service sector cooling needs)
- 28 GWh for *healthcare* (9 % of service sector cooling needs)
- 8 GWh for *education* (3 % of service sector cooling needs)
- 30 GWh for *transport* (9 % of service sector cooling needs)
- 27 GWh for *other branches* (9 % of service sector cooling needs).

At 35 %, retail accounts for the largest share of the Brussels service sector’s cooling needs, followed by banking, insurance and business services (23 %), and administrative services (13 %).



Besoins de froid – Tertiaire (GWh)	Cooling needs - Service sector (GWh)
Autres	Other
Transport	Transport
Enseign.	Education
Soins	Healthcare
Administr.	Admin. services
Banques assur. Serv. Aux. Entr.	Banking, insurance business services.
Commerce	Retail

II.1.3 Cooling needs in the industrial sector

II.1.3.1 Methodology

As indicated previously, there are fewer statistics available on the consumption of cooling in Brussels-based industry than there are on heating needs. This results in particular from the fact that business operations with manufacturing processes that make use of cooling do not generally convert primary energy (such as natural gas) directly, other than in absorption cycles (their use remains limited for technical reasons).

Additionally, the electricity demand for standard (compression-based) cooling production cycles is combined with other demands (such as lighting, heating, motive power, etc.). It is not appropriate to take a top-down approach in the first instance, therefore.

II.1.3.2 Results

Overall, the main sectors that make use of cooling are:

- *The food processing industry.* Here, cooling plays an important role in preserving produce, controlling the processes of wine- and beer-making and concentrating juices, as well as in dehydration.

- Processing industries such as plastics processing, rubber, mechanical industries, materials processing, surface treatments and the dehumidification of compressed air.
- The production and liquefaction of industrial gases, and the liquefaction and purification of hydrocarbon gases.
- Waste processing (gaseous, liquid and solid waste), such as the collection of VOC⁶ vapours (using low temperature adsorption) and the purification of liquid effluents (via freezing and crystallisation).
- Civil engineering, to stabilise soils (for underground structures) and refrigerate large concrete structures (dams, etc.).
- Leisure, for ice rinks and the production of artificial snow.

Given the sectors which make use of energy for cooling, there is limited demand for it in Brussels-based industry. Aligning the available sector-based segmentation with the industrial demands for cooling described above suggests the following:

- Building and construction plays an important role in overall industrial activity in the BCR since it creates nearly half of the region's added value. However, the construction sector activities that require cooling are niche areas that remain limited to major civil engineering works for specific applications.
- The metalworking sector ranks second in terms of value creation. In theory, it offers potential, but the range of possible applications is broad and conditions of use may differ significantly. Lastly, the figures available are not sufficiently detailed to allow for quantification of the possible implications. An evaluation based on more granular data would be desirable.
- The food processing industry is ranked third. The specific circumstances of the BCR (a very high level of urbanisation and few agricultural resources/areas) suggests that the business activities in question are concentrated downstream in the segment rather than upstream and may relate to processing (intermediary segment), and especially distribution (final segment).
- The leisure industry is also a niche area for cooling applications. These include ice rinks, which are generally found in limited numbers in very large conurbations and are therefore a very small niche, and artificial snow, for which the need is even more restricted in the BCR. Air handling for swimming pools (to control humidity) can also be included, along with air conditioning operations for some sports centres. There is generally a seasonal aspect to the load profile in the instances mentioned.

Whatever the case, taking into consideration (i) the European Commission's request for heating/cooling needs to be assessed on the basis of measured and verified statistics and (ii) the limited extent of industrial activity in the BCR, it is not possible to provide an estimate of cooling needs for the Brussels-based industrial sector as part of this study. However, such estimates could be included in forthcoming energy reviews for the Brussels region.

⁶ Volatile organic compounds.

II.2 ESTIMATED CHANGE IN COOLING NEEDS TO 2030

II.2.1 Change in cooling needs in the residential sector

II.2.1.1 Methodology

Given the inadequate nature of the data on the demand for cold in the BCR residential sector, it is not possible to estimate the change in cooling needs to 2030.

II.2.1.2 Results

As set out in the study by Belgium's Federal Public Department for the Environment, ('Scenarios for a low carbon transition'), it can, however, be assumed for the residential sector that the proportion of households fitted with air conditioning systems will remain similar to the figure for 2014, at 1 %.

This is supported by a number of practical observations:

1. The low renewal rate that is characteristic of the housing stock does not particularly encourage the large-scale installation of efficient refrigeration, depending on the limited energy performance of old buildings and the investment obligations associated with the refurbishment of such buildings with regard to refrigeration.
2. Climate factors which reduce cooling needs accordingly. Belgium has a temperate climate and experiences few extremes of temperature. When such extremes do occur, they are generally time-limited.
3. In the event of a temporary rise in temperatures, old buildings, in which heating performance is generally limited, offer the advantage of significant thermal inertia. All other things being equal, this is conducive to the passive use of 'free/night cooling' (see Task 3).
4. Lastly, the scope of coverage does not really meet the objectives of this study. The use of cogeneration or trigeneration units to produce cold implies simultaneous hot/cold thermal loads, unless use of an absorption cycle is possible to consume all the heat from co-generation during the period of refrigeration. Although possible in theory, issues of sizing arise in practice as a result of seasonal differences in heating and cooling needs.

For all of these reasons, it is necessary to adopt a cautious approach to the change in demand for cold in the BCR.

II.2.2 Change in cooling needs in the service sector

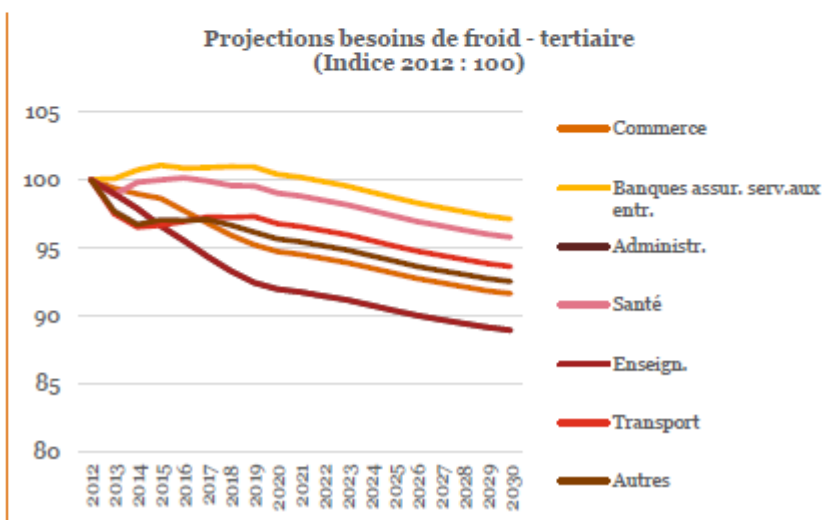
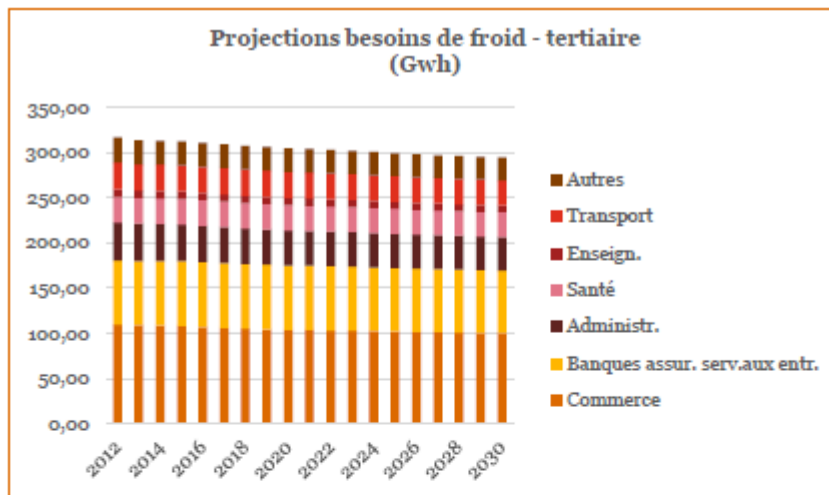
II.2.2.1 Methodology

The same approach is used as for estimating the change in heating needs above.

II.2.2.2 Results

Cooling needs in the service sector in the BCR are expected to fall slightly through to 2030, from 316.2 GWh in 2012 to 294.3 GWh in 2030, making an average annual reduction of 0.4 %.

The following chart illustrates this trend along with the relative shares for the sectors in question.



Projections besoins de froid – tertiaire (GWh)	Projected cooling needs - Service sector (GWh)
Autres	Other
Transports	Transport
Enseign.	Education
Santé	Health
Administr.	Admin. svcs
Banques assur. Serv. Aux. Entr.	Banking, insurance, business services.
Commerce	Retail

Projections besoins de froid – tertiaire (Indice 2012 : 100)	Projected cooling needs - Service sector (Base 100: 2012)
Commerce	Retail
Banques assur. Serv. Aux. Entr.	Banking, insurance, business services.
Administr.	Admin. services
Santé	Health
Enseign	Education
Transport	Transport
Autres	Other

II.2.3 Change in cooling needs in the industrial sector

Given the lack of data on cooling needs in the industrial sector in the Brussels Region, it was not possible to estimate the change in these needs to 2030. If an estimate of cooling needs were to be included in the report on energy consumption in the Brussels Region, this would make it possible to estimate the change in cooling needs for the Brussels Region's industrial sector through to 2030.

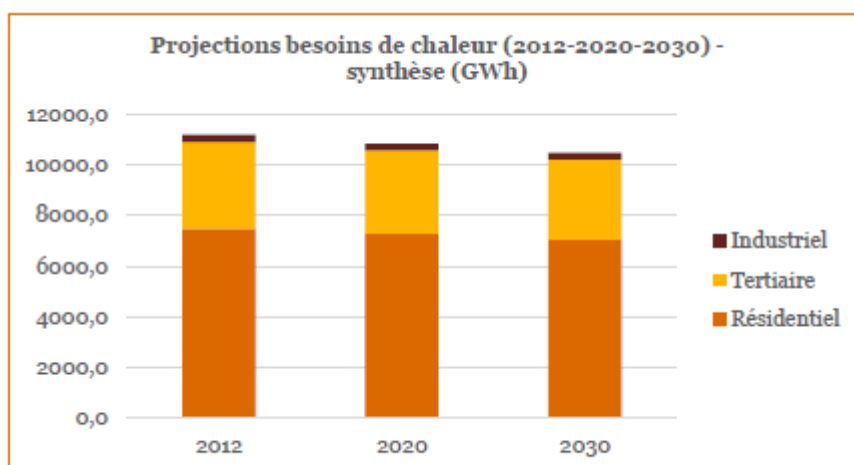
III. CONCLUSION

This report sets out an estimate of the heating and cooling needs recorded for 2012 for the residential, services and industrial sectors in the Brussels Region, and estimates the change in these needs to 2030.

Estimated heating needs

Broadly speaking, heating needs were estimated from the statistics in the 2012 report on energy consumption in the Brussels Region. Heating needs in the Brussels Region equated to 11 187.7 GWh, with 67 % of this total attributable to the residential sector, 31 % to the service sector and 3 % to industry. The energy carrier that was used most often to meet heating needs in these different sectors was natural gas (meeting 74 % of heating needs in the residential sector, 82 % of heating needs in the service sector and 94 % of heating needs in the industrial sector).

Overall, heating needs in the Brussels Region will fall between now and 2030, from 11 187.7 GWh in 2012 to 10 495.6 GWh in 2030. The service sector will see the most significant fall in heating needs, from 3 416.6 GWh in 2012 to 3 182.6 GWh in 2030, a fall of 7 %. Heating needs in the residential sector will fall by 6 %, from 7 491.4 GWh in 2012 to 7 054.4 GWh in 2030. In Brussels-based industry, heating needs will fall by 4 %, from 279.7 GWh in 2012 to 267.6 GWh in 2030.



Projections besoins de chaleur (2012-2020-2030) – synthèse (GWh)	Projected heating needs (2012-2020-2030) - summary (GWh)
Industriel	Industrial
Tertiaire	Services
Résidentiel	Residential

Estimated cooling needs

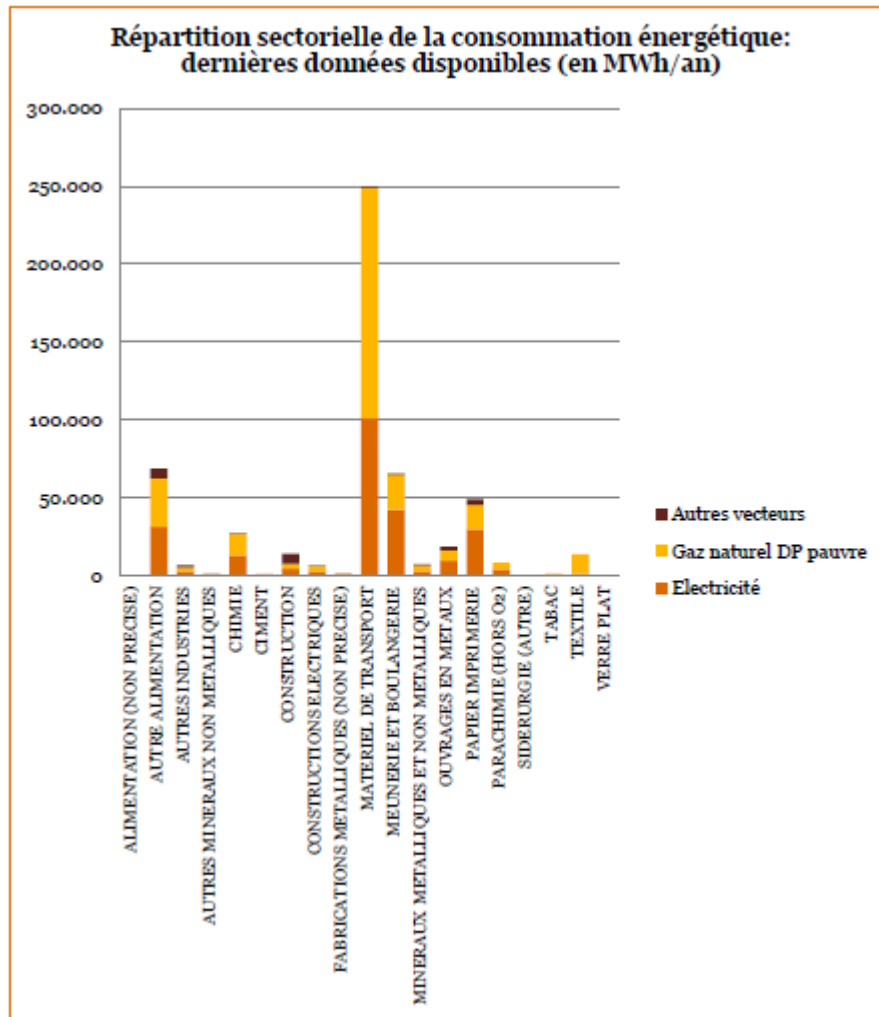
Initial estimates of cooling needs in 2012 were made for the residential and service sectors. Since an average dwelling has a floor area of 94 m² and the number of registered dwellings in the BCR is 505 545 units, the annual electricity consumption required to meet cooling needs in the residential sector would be close to 6 843 MWh. Service sector cooling needs were estimated from the data in the 2012 report on energy consumption in the BCR. In 2012, cooling consumption accounted for some 9 % of the electricity use of the Brussels-based service sector, or 316.2 GWh. Furthermore, taking into consideration (i) the European Commission’s request for heating/cooling needs to be assessed on the basis of measured, verified statistics and (ii) the limited extent of industrial activity in

the BCR, industrial sector cooling needs were not estimated as part of this study.

IV. ANNEXES TO CHAPTER 1

IV.1 HEATING NEEDS IN THE INDUSTRIAL SECTOR

To supplement the results of the assessments of heating needs in the Brussels-based industrial sector shown above, a further analysis was performed using an additional source of statistics with a more granular segmentation (BADEN). The following chart provides an outline of the results.



Source: Baden Bxl, IBGE

Répartition sectorielle de la consommation énergétique : dernières données disponibles (en MWh/an)	Breakdown of energy use by sector: latest available data (in MWh/year)
Autres vecteurs	Other carriers
Gaz naturel DP pauvre	Lean natural gas
Electricité	Electricity
ALIMENTATION (NON PRECISE)	FOOD (NON-SPECIFIC)
AUTRE ALIMENTATION	OTHER FOOD
AUTRES INDUSTRIES	OTHER INDUSTRY
AUTRES MINERAUX NON METALLIQUES	OTHER NON-METALLIC MINERALS

CHIMIE	CHEMICALS
CIMENT	CEMENT
CONSTRUCTION	BUILDING AND CONSTRUCTION
CONSTRUCTIONS ELECTRIQUES	ELECTRICAL ENGINEERING
FABRICATIONS METALLIQUES (NON PRECISE)	METALWORKING (NON-SPECIFIC)
MATERIAL ET BOULANGERIE	MILLS AND BAKERIES
MINERAUX METALLIQUES ET NON METALLIQUES	METALLIC AND NON-METALLIC MINERALS
OUVRAGES EN METAUX	FABRICATED METAL PRODUCTS
PAPIER IMPIMERIE	PAPER AND PRINTING
PARACHIMIE (HORS O2)	SPECIALITY CHEMICALS (EXCLUDING O2)
SIDERURGIE (AUTRE)	STEELMAKING (OTHER)
TABAC	TOBACCO
TEXTILE	TEXTILES
VERREPLAT	FLAT GLASS

However, results which directly aggregate the consumption data received from businesses located within the Brussels Region must be treated with caution, because:

- the 'Baden' database used does not provide uniform coverage with regard to input years. For some businesses, the latest or indeed the only data available date from 2005 or the years immediately following. In other cases data is available up to 2013;
- the database is not always consistent with regard to energy carriers, either;
- the figures do not always relate to heating needs as certain energy carriers are sometimes used as 'feedstock'. In addition, industrial heating needs are at least partly covered by electricity.

The underlying assumptions for the analyses described above were as follows:

- 1) The latest available data would be used as a matter of course (earliest 2005 – latest 2013).
- 2) Use would be made of the most detailed segmentation by carrier for the most recent year for which data is available.

Energy carriers were, however, grouped as follows:

- a) high voltage and low voltage electricity were aggregated;
- b) light fuel oil, heavy fuel oil, diesel for heating and propane were aggregated as 'other carriers'.

The natural gas in question is low heating value gas delivered via the BCR network (from the Netherlands).

In addition to the fact that natural gas is predominant, the significant concentration in the 'transport equipment' branch of industry in the BCR should be highlighted, as it accounts for 46.3 % of the sector's energy use in the Brussels Region. This is a clear reflection of the importance of the local automotive industry. It is followed by the 'other food' segment, at 12.7 %, then 'mills and bakeries', at 12.2 %, and lastly, the 'paper and printing' branch, with 9.1 %. The respective weights of the other sub-sectors are not significant.

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Chapter 2 – Mapping of heating and cooling needs

INTRODUCTION

Purpose and methodology

The purpose of this second chapter is to create a mapping of the Brussels-Capital Region, showing the points of demand for heat and cold, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points.

The **methodology** adopted involves the following three phases:

- Phase 2.1: **spatial mapping of heating and cooling needs** by commune and statistical area.
- Phase 2.2: **spatial mapping of supplementary data**: points of high demand for heat and cold, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points.
- Phase 2.3: **developing an interactive electronic map** that can be viewed on the Brussels Environmental Authority's website.

This second phase of the project included an in-depth spatial analysis of heating and cooling needs in the Brussels Region. The first section describes the **methodology** used for the spatial mapping of heating and cooling needs, points of high demand for heat and cold, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points.

The second section presents the **interactive map** developed to provide a spatial presentation of the data on heating and cooling needs in the Brussels Capital Region area for individual communes and statistical areas. The map is in electronic form and can be viewed on the Brussels Environment Authority's website. Users can zoom in on the map and choose from different options for viewing the results.

I. METHODOLOGY

This chapter describes the **methodology** used for the spatial mapping of heating and cooling needs, points of high demand for heat and cold, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points. This methodology is based on an in-depth analysis of heating and cooling needs in the Brussels Region and the use of a geographic information system.

Further to a request from the Brussels Environment Authority's mapping department (meeting held on 19 May 2015), a free software application, **QGIS**, was selected as the geographic information system for this task, despite the fact that the ArcGIS software had been the system that was proposed when the project was submitted. This use of a different geographic information system will allow the interactive map to be more closely integrated with the body of maps produced and used by the Brussels Environmental Authority, as well as ensuring enhanced monitoring.

I.1 SPATIAL MAPPING METHODOLOGY FOR HEATING NEEDS

This phase consisted in estimating and preparing a spatial mapping of heating needs throughout the region. The heating needs of different buildings were estimated on the basis of land registry data (from the Cadmap 2010 land book) and data from the 2012 report on energy consumption on the Brussels Region (ICEDD, 2014), as well as the analysis already completed in Task 1. For each type of building, heating needs were aggregated at two different levels: **statistical area and commune**. For the record, the 'statistical area is the basic territorial unit that results from the subdivision by Statistics Belgium of the area covered by communes and former communes to disseminate its statistics at a more granular level. It was created for Belgium's 1970 population and housing census and redesigned for the 1981 census on the basis of structural social, economic, urban and morphological characteristics. It was adjusted for the 2001 socio-economic survey in order to take into account the changes in communal boundaries and to incorporate the major changes in land use.' (Statbel 2011)

Task 1 produced an overall estimate of heating needs for the residential, service and industrial sectors throughout the whole of the Brussels Region. The assessment was made with reference to the consumption of the various energy carriers meeting heating needs for different types of building, based on information taken from the **2012 report on energy consumption in Brussels (ICEDD, 2014)**. These overall values for the region will be used in Task 2; however, more precise data are required for a spatial mapping of heating needs by commune and statistical area. This need was met with the use of **land registry data (from the Cadmap 2010 land book)**, with building and plot divisions are provided by digitised land registry maps. Land books assign a large amount of information to buildings constructed on the plots, including the most recent assigned use for the asset and its floor area. This information can then form the basis for a breakdown of the features of each communal territory and each statistical area. The file used as the land book in this study is `donnees_cadastre_bruxelles_traitees_lemma`. It includes the land registry data from Cadmap 2010 which were formatted as part of a previous research project to make them easier to use for cartographical purposes. Based on this global data file, preliminary processing is required on the land registry data.

The **processing carried out on the land registry database** consists of extracting and preparing the data required for the mapping. This includes using the shared CaPaKey to create a data join between B_CaPa and the land book, by making an attribute join between the file that includes the plot information and the `Données_Cadastre_Bruxelles_traitées_LEMA` layer using the CaPaKey field. To place an immediate limit on the number of items to be processed, only those plots with an entry in the land book (plots with at least one building) are selected to be retained. For this purpose, it is important that when the first join is made, the 'keep only matching record' option is ticked, as this allows only those plots with at least one building to be retained.

Next, a spatial join is made between the buildings layer in the land register and the selected plots. This involves creating a spatial join ('join based on location') between B_CaBu (the buildings layer in the land register) and the file created. The process is very time-consuming and must be run using Arcgis. Performing this operation with Qgis creates duplicates unless the spatial join method is modified in Python. A second pass selection excludes buildings that are not closed (closed buildings are selected using `Cabuty = 'CL'`) and those with a

function that does not generate any energy use (electrical substations, garages, sheds, etc.).

The **full list of functions extracted** is as follows: TAUDIS, CABINE, GAR.DEPOT, REMISE, GARAGE, HANGAR, B.ANIMAUX, TR.IMMONDI, STATION, SOUTERRAIN, SERRE, B.PARCAGE, ECURIE, ENTREPOT, LEGATION, MONUMENT, PAVILLON, , CAB.GAZ, LAVATORY, MOUL.VENT, ABRI TRANS, GAZOMETRE, , KIOSQUE, , MARCH.COUV, POINT VUE, GASCABINE, GAZOMETER, PUIN (debris in Dutch), BERGPLAATS (warehouse in Dutch), WACHTHUIS (checkpoint), BAT.FUNNER. , BAT.RURAL, DUIVENTIL (dovecote), ELEK.CABIN, FERME, GAR.STELPL (warehouse), HOEVE (farm in Dutch), K.VEETEELT (livestock farm), KIOSK, KROTWONING (slum), LANDGEBOUW (building land), ONDERGR.R. (ondergrond=underground), PAARDESTAL, PARKEERGEB, PART.COMM., PAVILJOEN (pavilion), PIGEONNIER, PT.ELEVAGE, RUINES, WINDMOLEN (windmill), SUP.& P.C., SUP.BAT.A, GAR.ATEL. , GAR.WERKPL, O, BARAQUEM, , GEB.ERED. INST.FRIGO, EXPL.IND#, KOELINR., RESERVOIR, MAT.&OUT, AFVALVERW., GERECHTSH.(court), SCHRIJNW. (shrine), ABRIS , AFDAK, AFVALVERW. , CAB.ELECT. , CAB.TEL.

Lastly, using the Qgis software to search for the different functions present in the data fields provides a count of the number of m² associated with each building type, by statistical area and by commune. For built-up areas, the count uses the 'built floor area' field to obtain the number of m² per storey. The total floor area of a building is then calculated by multiplying the built floor area value by the number of storeys in the building. Note that the *donnees_cadastre_bruxelles_lemma* file does not give the number of built storeys in a building, but only the number of floors above ground level. The ground floor must therefore be added to the number of floors shown to obtain the total number of storeys. The greater the number of buildings to be taken into account, the longer it takes to process the data. A significant period of time is therefore required to process the data for the Brussels-Capital Region.

Over a hundred different functions are indexed in the land register. The data in the report on energy consumption are not sufficiently granular to allow for an energy classification to be devised on the basis of such a large number of different functions. The different types of building selected for this mapping are consistent with the assigned uses examined in Task 1 on the basis of the report on energy consumption in the BCR in 2012. The table below shows the **building classification** used for the mapping in Task 2 and the associated land registry references.

Sector	Types of buildings	
Residential	Single family residential (house)	MAISON, MAISON#, HUIS (house in Dutch), HUIS#, HAB.VACAN.,
	Multifamily residential (apartment)	BUILDING, P.IM.AP.#, P.P.IM.AP. , BEB.OPP.A, M.D.AP.GEB, G.D.AP.GEB, M.D.AP.GEB, D.AP.GEB.#, D.AP.GEB.#, OPP.&G.D., HAND/HUIS (only the upper floors of the shop building), M.COMMERCE (upper floors only)
Services	Retail	GD.MAGASIN, M.COMMERCE (only the ground floor of shop buildings), MAGAZIJN, CAFE, DRANKHUIS (bar), HAND/HUIS (only the ground floor of shop buildings), ETAB.BAINS, GR.WARENH. , RESTAURANT, SERV.STAT. , SERVICE STATION , HOTEL, CASINO
	Transport – communications	TELECOM/G. , B.TELECOM. ,
	Banking, insurance and business services	BANK, BANQUE, BOURSE, BEDRIJFSC# (bedrijfs=business), KANTOORGEB (=office), BAT.BUREAU,
	Education	B.SCOLAIRE, SCHOOLGEB, UNIVERSIT. , C.RECHER., UNIVERSITE
	Healthcare	BAT.HOSPIT, KINDERBEW (orphanage, classified under Zorg (care) in the Dutch land registry), BESCHER/W (=protection in Dutch, classified under Zorg (care) in the Dutch land registry), CRECHE, RUSTHUIS (nursing home), MAIS.REPOS, MAIS.JEUN, VERPL/INR. (classified under Zorg (care) in the Dutch land registry), WELZIJNSG (classified under Zorg (care) in

		the Dutch land registry), GEZANTSCH, ORPHELINAT, ETAB.CURE
	Administrative services	M.COMMUN., BAT.JUSTIC, BAT.MILIT., BAT.PENIT., ILIT.GEB, BAT.ADMIN., B.AIDE SOC, ADMIN.GEB., GENDARMER., NOODWONING, GOUVER/GEB, GERECHTSH. (Court),
	Culture, sport and other branches of the service sector	LAVOIR, LIJKENHUIS (mortuary), WASSERIJ (laundry), WATERTOREN WATERWINN., CAPTAG.EAU, INS.EPURAT, CENTR.ELEC, ELEK.CENTR, USINE GAZ, BIBLIOTH. , BAT.CULTE, CENTR.CULT, FEESTZAAL (community centre), KULT.CENTRE, S.EXPOSIT. ,S.FETES, S.SPECTACL, TOONZAAL (exhibition hall), SPEKT.ZAAL (performance venue), SPORTGEB, MUSEE, MUSEUM, THEATRE, THEATER, INST.SPORT, CHAPELLE, EGLISE, TEMPLE, MOSQUEE, PRESBYTERE, CHATEAU, COUVENT, BAT.HISTOR, SYNAGOGUE, TEMPEL, BIOSCOOP (cinema), CINEMA, K.PALEIS (palace), KAPEL, KASTEEL, KERK, MOSKEE, PASTORIE (presbytery), KLOOSTER (convent), TEMPEL
Industrial	Metalworking	ELEK.MAT.F, F.MAT.ELEC, BAT.INDUST, NIJV/GEB (industrial building)
	Food	BOULANGER. , F.PR.ALIM. , F.BOISSONS, CHARCUTER. , BAKKERIJ (bakery), F.ALIM.BET, F.PR.ALIM, SLACHTERIJ (butcher), VLEESW/FAB (=meat), ABATTOIR, SLACHTERIJ (=abattoir), MEUNERIE, VOEDINGS/F (=nutrition)
	Building and construction	CEMENTFAB. (Cement factory), BOUWMAT/F (buildingmaterials), F.MAT.CONS, CONSTR/WPL, MENUISERIE, SCIERIE, VERRERIE, ZAGERIJ (sawmill). , BUILDING WORKSHOP
	Printing and paper	DRUKKERIJ (Printing), IMPRIMERIE, PAPETERIE, PAPIER.FAB.
	Chemicals	CHEMIC/FAB, U.CHIMIQUE
	Metallic and non-metallic minerals	METALLURG. , METAALNIJV
	Other industrial sectors	F.HABILLEM, F.ART.CUIR, F.COULEURS. , F.HABILLEME, F.PLASTIQ, TEXTIELFAB, ATELIER, AT.PROTEGE, WERKPLAATS (workshop), F.MEUBLES, F.A.USUELS, F.JOUETS, MEUBELFAB.,

Lastly, heating needs are calculated for each type of building, aggregated by commune and statistical area, using the formulae set out in the following three points below:

- heating needs in the residential sector
- heating needs in the service sector
- heating needs in the industrial sector.

For the record, as part of Task 1, it was shown that in the Brussels-Capital Region in 2012, some 67 % of heating needs were attributable to the residential sector, 31 % to the service sector and 3 % to industry.

I.1.1 Heating needs in the residential sector

In Task 1, region-wide residential sector heating needs were estimated using data from the report on energy consumption in the BCR in 2012 (ICEDD, 2014), looking at heating consumption by type of dwelling and by energy carrier. For residential buildings, heating needs cover the main source of heating (central or localised), domestic hot water, supplementary heating and cooking. **Heating needs in the BCR-wide residential sector were 7 491.4 GWh in 2012 and** accounted for 89 % of residential sector energy consumption in 2012.

Based on the data from the report on energy consumption in 2012 (ICEDD, 2014), this value can be specified more precisely in GWh LHV, as follows: the proportion of specific consumption for all housing that is associated with single-family residential buildings (houses) is 2 403.1 GWh; the proportion of consumption specifically for heating associated with multi-family residential buildings (apartments) is 3 441.7 GWh; and overall consumption specifically for domestic hot water, space heating and cooking for all dwellings is 1 646.6 GWh. The tables and formulae below show the calculation of heating needs for residential sector buildings in each commune and statistical area.

Heating needs	Specific consumption by dwellings (GWh LHV)
Total heating needs of houses in the BCR	3 441.7
Total heating needs of apartments in the BCR	2 403.1
Total heating need associated with domestic hot water + supplementary heating + cooking in all dwellings (houses and apartments) in the BCR	1 646.6

Consumption specifically for heating purposes in the houses in each commune is calculated according to the following formula:

$$\begin{aligned} \text{BCM1} &= \text{Heating needed for the houses in a commune} \\ &= \frac{\text{Number of m}^2 \text{ of houses in a commune}}{\text{Total number of m}^2 \text{ of houses in the BCR}} \times \text{Total heating needs of houses in the BCR} \end{aligned}$$

Consumption specifically for heating purposes in the houses in each statistical area is calculated according to the following formula:

$$\begin{aligned} \text{BCM2} &= \text{Heating needed for the houses in a statistical area} \\ &= \frac{\text{Number of m}^2 \text{ of houses in a statistical area}}{\text{Total number of m}^2 \text{ of houses in the BCR}} \times \text{Total heating needs of houses in the BCR} \end{aligned}$$

Consumption specifically for heating purposes in the apartments in each commune is calculated according to the following formula:

$$\begin{aligned} \text{BCA1} &= \text{Heating needed for the apartments in a commune} \\ &= \frac{\text{Number of m}^2 \text{ of apartments in a commune}}{\text{Total number of m}^2 \text{ of apartments in the BCR}} \times \text{Total heating needs of apartments in the BCR} \end{aligned}$$

Consumption specifically for heating purposes in the apartments in each statistical area is calculated according to the following formula:

$$\begin{aligned} \text{BCA2} &= \text{Heating needed for the apartments in a statistical area} \\ &= \frac{\text{Number of m}^2 \text{ of apartments in a statistical area}}{\text{Total number of m}^2 \text{ of apartments in the BCR}} \times \text{Total heating needs of apartments in the BCR} \end{aligned}$$

Heating consumed specifically for domestic hot water, supplementary heating and cooking in all dwellings (houses and apartments) in each municipality is calculated using the following formula:

$$\begin{aligned} \text{BEL1} &= \text{Heating needs for domestic hot water + supplementary heating + cooking for a commune} \\ &= \frac{\text{Number of residential m}^2 \text{ in a commune}}{\text{Total number of residential m}^2 \text{ in the BCR}} \times \text{Heating needs for DHW, SH + C in the BCR} \end{aligned}$$

Heating consumed specifically for domestic hot water, supplementary heating and cooking in all dwellings (houses and apartments) in each statistical area is calculated using the following formula:

$$BEL2 = \text{Heating needs for domestic hot water} + \text{supplementary heating} + \text{cooking for a statistical area} \\ = \frac{\text{Number of residential m}^2 \text{ of in a statistical area}}{\text{Total number of residential m}^2 \text{ in the BCR}} \times \text{Heating needs for DHW, SH + C in the BCR}$$

The overall heating needs for the residential sector in each commune are calculated according to the following formula:

$$\text{Heating needs for a commune} = BCM1 + BCA1 + BEL1$$

The overall heating needs for the residential sector in each statistical area are calculated according to the following formula:

$$\text{Heating needs for a statistical area} = BCM2 + BCA2 + BEL2$$

An analysis was also performed to assess the possible merits of using the **building energy performance database** or other supplementary information to refine the spatial breakdown of estimated heating needs for residential buildings between the different communes or statistical areas. The Brussels Environmental Authority was unable to supply the building energy performance database. In addition, as building energy performance certificates are often drawn up when a dwelling is sold, before the residents make any energy efficiency improvements, it does not appear that the database can provide a properly accurate representation of the current energy performance of the built stock.

Another option that was considered was to work with the data on **energy premiums in the BCR**: the Brussels Environmental Authority provided information on the number of ongoing construction projects (in receipt of subsidies) compared with the number of dwellings in each commune, excluding subsidies for domestic electrical appliances (see Figure 1). This is a very general piece of data and, as such, it is not possible to ascertain the precise energy performance of the buildings in each commune; it does, however, provide information on the breakdown of energy efficiency improvements undertaken in the different municipalities.

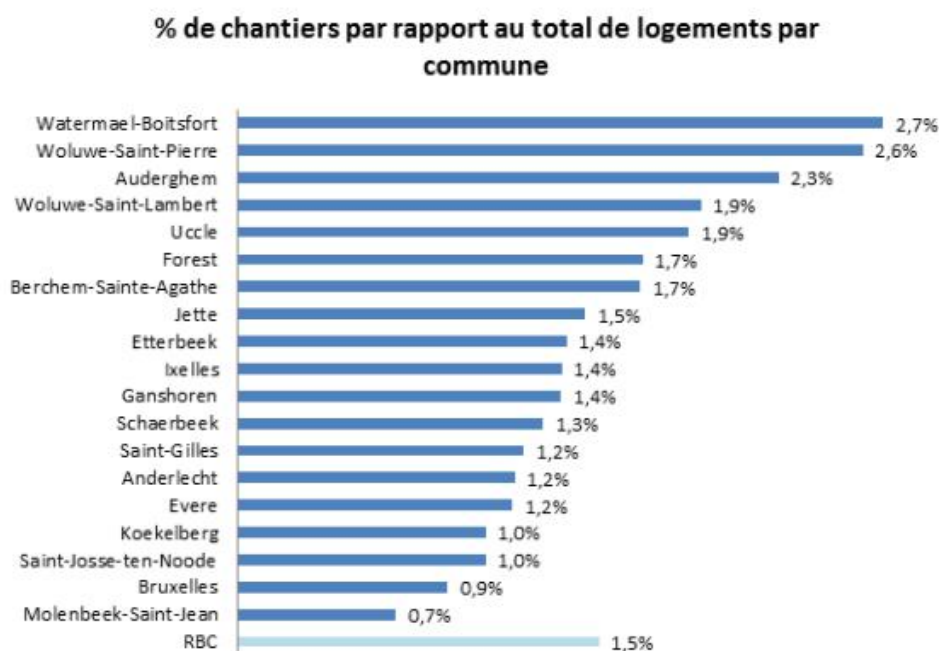


Figure 1: Breakdown by commune of construction sites in the BCR in receipt of energy subsidies in relation to the total number of dwellings per commune (excluding F)

% de chantiers par rapport au total de logements par commune	% of construction sites in relation to the total number of dwellings per commune
Watermael-boitsfort	Watermael-Boitsfort
Woluwe-Saint-Lambert	Woluwe-Saint-Lambert
Uccle	Uccle

Forest	Forest
Berchem-Sainte-Agathe	Berchem-Sainte-Agathe
Jette	Jette
Etterbeek	Etterbeek
Ixelles	Ixelles
Ganshoren	Ganshoren
Schaerbeek	Schaerbeek
Saint-Gilles	Saint-Gilles
Anderlecht	Anderlecht
Evere	Evere
Koekelberg	Koekelberg
Saint-Josse-ten-Noode	Saint-Josse-ten-Noode
Bruxelles	Brussels
Molenbeek-Saint-Jean	Molenbeek-Saint-Jean
RBC	BCR

Figure 1 illustrates that, as a proportion of the number of dwellings located within the area of the commune, there are more construction sites for dwellings in receipt of energy subsidies in the communes of the outer suburbs. However, the difference between the commune that receives the largest number of premiums and the commune receiving the least is slight, at around 2 %. The **regional average is highly representative**, with just five out of 19 communes deviating from the mean value by more than 0.5 % and two of the 19 deviating from the mean by more than 0.8 % (with differences of 1.1 % and 1.2 % respectively). Furthermore, some improvements may have been made to the built stock without the use of energy subsidies and it is not clear whether the level of post-construction requests for subsidies is the same in all communes.

Given the uncertainty about the actual number of energy efficiency improvements undertaken in each commune and their impact on dwellings' energy performance, and the percentage value for the regional mean number of energy subsidies that will be taken to represent the number of subsidies in the vast majority of municipalities, heating needs in the BCR will be mapped solely on the basis of the regional values available in the report on energy consumption in 2012 and the number of m² for each type of dwelling by commune and by statistical area. Lastly, it should be noted that use of the regional mean average values will facilitate future updates to the interactive map.

1.1.2 Heating needs in the service sector

As part of **Task 1**, the region-level heating needs of the service sector were estimated on the basis of data from the report on energy consumption in 2012 in the Brussels Region (ICEDD, 2014), which break down energy use in the service sector by service sector building type (retail, transport, banking, administrative services, education, etc.). To ascertain the level of energy use to meet heating needs, percentage shares were assigned to the heating fuel consumption recorded in 2012 for the service sector in the Brussels-Capital Region. The percentage values were taken from the report on energy consumption. The values for service sector heating needs by service sector building type defined in Task 1 will be used in mapping the heating needs in the Brussels-Capital area.

Service sector heating needs in the BCR were 3 416.6 GWh in 2012 and accounted for 88 % of service sector energy use in 2012. The tables and formulae below show the calculation of heating needs for service sector buildings in each commune and statistical area.

Types of service sector building	Total heating need for each type of building in the BCR (GWh LHV)
Retail	901.8

Transport and communications	- 86
Banking, insurance and business services	833.5
Education	368.5
Healthcare	301.1
Administrative services	558.4
Culture, sport and other service sector branches	367.3

The heating needs for each type of service sector building in each commune are calculated according to the following formula:

$$\begin{aligned} \text{BCT1-type } x &= \text{Heating needs of service sector buildings of type } x \text{ in a commune} = \\ &= \frac{\text{Number of m}^2 \text{ of buildings of type } x \text{ in a commune}}{\text{Total number of buildings of type } x \text{ in the BCR}} \times \text{Total heating needs of buildings of type } x \text{ in the BCR} \end{aligned}$$

The heating needs for each type of service sector building in each statistical area are calculated according to the following formula:

$$\begin{aligned} \text{BCT2-type } x &= \text{Heating needs of service sector buildings of type } x \text{ in each statistical area} = \\ &= \frac{\text{Number of m}^2 \text{ of buildings of type } x \text{ in a statistical area}}{\text{Total number of buildings of type } x \text{ in the BCR}} \times \text{Total heating needs of buildings of type } x \text{ in the BCR} \end{aligned}$$

The overall heating needs for all service sector buildings by commune are calculated according to the following formula: **Heating needs for service sector buildings in a commune** = BCT1-type1+ BCT1-type2+ BCT1-type3+ BCT1-type4 + BCT1-type5 + BCT1-type6 + BCT1-type7

The overall heating needs for all service sector buildings by statistical area are calculated according to the following formula: **Heating needs for service sector buildings in an area** = BCT2-type1+ BCT2-type2+ BCT2-type3+ BCT2-type4 + BCT2-type5 + BCT2-type6 + BCT2-type7

1.1.3 Heating needs in the industrial sector

In **Task 1**, the region-level heating needs of the industrial sector were estimated on the basis of data from the report on energy consumption in the Brussels Region in 2012 (ICEDD, 2014), which break down energy use by industry type (metalworking, food, building and construction, etc.). To ascertain the level of energy use to meet heating needs, percentage shares were assigned to the heating fuel consumption recorded in 2012 for industry in the Brussels-Capital Region. The values for industrial sector heating needs by building type defined in Task 1 will be used in mapping the heating needs in the Brussels-Capital area.

Heating needs in the industrial sector in the BCR were **279.7 GWh in 2012** and accounted for 45 % of energy use by Brussels-based industry in 2012. The tables and formulae below show the calculation of heating needs for industrial buildings in each commune and statistical area.

Types of industrial building	Total heating need for each type of building in the BCR (GWh LHV)
Metalworking	141.8

Food	58.9
Building and construction	25.6
Printing and paper	18.4
Chemicals	15.9
Metallic and non-metallic minerals	8.8
Other industrial sectors	10.3

The overall heating needs for each type of industrial building in each commune are calculated according to the following formula:

$$\text{BCT1-type } x = \text{Heating needs of industrial buildings of type } x \text{ in a commune} =$$

$$= \frac{\text{Number of m}^2 \text{ of buildings of type } x \text{ in a commune}}{\text{Number of m}^2 \text{ of industrial buildings of type } x \text{ in the BCR}} \times \text{Total heating needs of buildings of type } x \text{ in the BCR}$$

The overall heating needs for each type of industrial building in each statistical area are calculated according to the following formula:

$$\text{BCT2-type } x = \text{Heating needs of industrial buildings of type } x \text{ in each statistical area} =$$

$$= \frac{\text{Number of m}^2 \text{ of buildings of type } x \text{ in a statistical area}}{\text{Total number of m}^2 \text{ of buildings of type } x \text{ in the BCR}} \times \text{Total heating needs of buildings of type } x \text{ in the BCR}$$

The overall heating needs for all industrial buildings by commune are calculated according to the following formula: **Heating needs for industrial buildings in a municipality** = BCT1-type1+ BCT1-type2+ BCT1-type3+ BCT1-type4 + BCT1-type5 + BCT1-type6 + BCT1-type7

The overall heating needs for all service sector buildings by statistical area are calculated according to the following formula: **Heating needs for service sector buildings in an area** = BCI2-type1+ BCI2-type2+ BCI2-type3+ BCI2-type4 + BCI2-type5 + BCI2-type6 + BCI2-type7

I.2 SPATIAL MAPPING METHODOLOGY FOR COOLING NEEDS

This phase consists of estimating and preparing a spatial mapping of cooling needs throughout the region. It is important to note at the outset that the **data relating to cooling needs are incomplete and imprecise**, although the situation varies by sector.

Task 1 made an overall estimate of cooling needs for the residential, service and industrial sectors within the whole of the Brussels Region, based on information taken from the **report on energy consumption in Brussels in 2012 (ICEDD, 2014)**. These overall values for the region will be used in Task 2, but more precise data is required for a spatial mapping of cooling needs by commune and statistical area. **Land registry data (from the Cadmap 2010 land book)** can be used for this. The **data processing carried out on the land registry database** and the **building classification** devised for mapping heating needs by commune and statistical area in point 1.1 of this report can be reused for mapping cooling needs at these same levels.

Justifications for the assumptions to be used for calculating the cooling needs for each type of building, aggregated by commune and statistical area, are given under the three points below:

- cooling needs in the residential sector
- cooling needs in the service sector
- cooling needs in the industrial sector.

I.2.1 Cooling needs in the residential sector

Residential sector cooling needs are not evaluated in the report on energy consumption in (ICEDD, 2014), which considers them to be **negligible**. This same assumption will inform the mapping of cooling needs in the BCR. Furthermore, the decision to take the view that cooling needs in the BCR residential sector are negligible was submitted to and approved by the Project Support Committee on 26 June 2015.

I.2.2 Cooling needs in the service sector

Task 1 estimated the region-level cooling needs of the service sector on the basis of data from the report on energy consumption in the Brussels Region in 2012 (ICEDD, 2014), which break down energy use in the service sector by service sector building type (retail, transport, banking, administrative services, education, etc.). Percentage shares were assigned to the electricity use recorded for the service sector, so that the energy used to meet cooling needs (air conditioning, ventilation and cold) could be estimated. The percentage values were taken from the report on energy consumption and derive primarily from a study by the University of Anvers entitled '*Bouw en ontwikkeling van SAVER-LEAP als tool voor scenario-analyses van energiegebruik en emissies*' [Construction and development of the tool SAVER-LEAP for scenario analysis of energy use and emissions]. The cooling needs values by service sector building type defined in Task 1 will be used in mapping the cooling needs in the Brussels-Capital area.

In 2012, consumption for cooling accounted for some 9 % of the electricity consumption of the Brussels-based service sector, or **316.2 GWh**. At 35 %, retail accounts for the largest share of the Brussels service sector's cooling needs, followed by banking, insurance and business services (23 %), and administrative services (13 %). The tables and formulae below show the calculation of cooling needs for service sector buildings in each commune and statistical area.

Types of service sector building	Total cooling need for each type of building in the BCR (GWh LHV)
Retail	109
Transport and -communications	30
Banking, insurance and business services	71
Education	8
Healthcare	28
Administrative services	42
Culture, sport and other service sector branches	28.2

The overall cooling needs for each type of service sector building in each commune are calculated according to the following formula:

BFT1-type x= Cooling needs of service sector buildings of type x in a commune =

$$= \frac{\text{Number of m}^2 \text{ of buildings of type x in a commune}}{\text{Number of m}^2 \text{ of service buildings of type x in the BCR}} \times \text{Total cooling needs of buildings of type x in the BCR}$$

The overall cooling needs for each type of service sector building in each statistical area are calculated according to the following formula:

BFT2-type x= Cooling needs of service sector buildings of type x in each statistical sector =

$$= \frac{\text{Number of m}^2 \text{ of buildings of type x in a statistical sector}}{\text{Total number of m}^2 \text{ of buildings of type x in the BCR}} \times \text{Total cooling needs of buildings of type x in the BCR}$$

The overall cooling needs for all service sector buildings by commune are calculated according to the following formula: **Cooling needs for service sector buildings in a commune** = BFT1-type1+ BFT1-type2+ BFT1-type3+ BFT1-type4 + BFT1-type5 + BFT1-type6 + BFT1-type7

The overall cooling needs for all service sector buildings by statistical area are calculated according to the following formula: **Cooling needs for service sector buildings in an area** = BFT2-type1+ BFT2-type2+ BFT2-type3+ BFT2-type4 + BFT2-type5 + BFT2-type6 + BFT2-type7

1.2.3 Cooling needs in the industrial sector

As indicated in Task 1, in light of the industrial sectors present in the BCR area, there is **limited demand for cooling** in Brussels-based industry. In addition, there are fewer statistics available on the consumption of cooling in Brussels-based industry than there are on heating needs. This results in particular from the fact that business operations with manufacturing processes that make use of cooling do not generally convert primary energy (such as natural gas) directly, other than in absorption cycles (their use remains limited for technical reasons). Additionally, the electricity demand for standard (compression-based) cold production cycles is combined with other demands (such as lighting, motive power, etc.). It is not appropriate to take a top-down approach in the first instance, therefore.

As such, taking into consideration (i) the European Commission's request for heating/cooling needs to be assessed on the basis of measured, verified statistics and (ii) the limited extent of industrial activity in the BCR, it was decided during Task 1 that cooling needs for Brussels-based industry would not be estimated as part of this study, and that **these cooling needs would be treated as negligible**. This same assumption will inform the mapping of cooling needs in the BCR. Furthermore, the decision to take the view that cooling needs in the BCR industrial sector are negligible was submitted to and approved by the Project Support Committee on 26 June 2015.

It should be noted that more precise estimates could nonetheless be included in future reports on energy consumption in the Brussels Region, which would then allow the interactive map to be updated if necessary.

I.3 SPATIAL MAPPING METHODOLOGY FOR SUPPLEMENTARY DATA

As stated in the specifications, the following items will be mapped for the area of the Brussels-Capital Region by commune and by statistical area:

- **Points of high demand for heating and cooling**, including:
 - zones with an open space ratio of at least 0.3;
 - industrial zones with a total annual heating and cooling consumption of more than 20 GWh.
- **Existing and planned district heating and cooling infrastructure.**
- **Potential heating and cooling supply points**, including:
 - electricity generation facilities with a total annual electricity production of more than 20 GWh;
 - waste incineration plants;
 - existing and planned co-generation facilities.

I.3.1 *Points of high heat and cooling demand*

This part of the task involves mapping zones with an open space ratio of at least 0.3, as well as industrial zones where total annual heating and cooling consumption exceeds 20 GWh.

Thanks to the work carried out using the land registry data and digitised land registry maps during the spatial mapping of heating needs, the open space ratio for each statistical area can be calculated by dividing the total number of built m² (residential + services + industrial, already calculated previously) by the land surface area of each statistical area.

The industrial zones with total annual heating and cooling consumption in excess of 20 GWh are deduced from the statistical area mapping of industrial sector heating needs.

I.3.2 *Existing and planned heating and cooling infrastructure*

Prior to Task 2 being carried out, it was agreed at the meeting that took place on 19 May 2015 that the Brussels Environmental Authority would supply the list and addresses of existing and planned heating and cooling facilities. The list of section 40B operating locations was received, i.e. the environmental permit numbers for boilers exceeding 1 MW, plus the corresponding addresses. There are 2 860 operating locations of this kind in the Brussels Capital Region and it is unlikely that there are as many district heating networks as this. In light of the large number of operating locations falling within this category and the lack of contact email addresses for the majority of them, it is impossible to check, case by case, whether there is a district heating network associated with each address.

Existing and planned district heating and cooling facilities must therefore be selected from this list based on more specific criteria. International mapping of district heating is based on a preliminary investigation of the existing networks, generally at national or regional level.

Unfortunately, no investigation of this type has yet been undertaken in Belgium.

However, there are two factors that can help to clarify which facilities should be mapped:

- the chosen definition for district heating and cooling implies an urban network connecting a number of buildings. It is therefore possible to filter the list of facilities exceeding 1 MW to extract those that are connected to an address covering at least two building numbers, and those for which the address corresponds to just one building.
- Based on the limit chosen by the *Syndicat National du Chauffage Urbain et de la Climatisation*

urbaine (SNCU, the French national union of urban heating and air conditioning), which conducts the annual survey on district heating and cooling networks in France, the threshold capacity for filtering can be increased to 3 MW. The SNCU's national survey in France ignores low-capacity district heating and cooling, unless the operator has seen fit to identify themselves and respond voluntarily to the survey. However, it is impossible to know how many low-capacity networks this methodology overlooks.

Given that the information available for the items selected on the basis of these assumptions consists solely of an address, they provide a very specific snapshot only. The mapping excludes data such as permit number, boiler capacity and any contact addresses.

1.3.3 Potential heating and cooling supply points

This part of the task involves mapping the potential heating and cooling supply points:

- The only power generation facility that was identified as having total annual electricity production of over 20 GWh was the thermal power station and incinerator for household and similar waste at Neder-over-Heembeek (= Electrabel de Schaerbeek thermal power station), which produces 240 to 300 GWh/year and generated 262.5 GWh in 2012.
- There is just one waste incineration plant in the Brussels Capital Region, at 8, Quai Léon Monnoyer in Neder-over-Heembeek.

Regarding existing and planned cogeneration facilities, the Brussels Environment Authority supplied a list with the addresses of all cogeneration units, except for 1 kW domestic micro-generation facilities which were excluded from the study on the grounds that they generate insufficient power. The list does not include decommissioned facilities. Certain facilities are in the process of being certified by BRUGEL and do not yet have a full entry in the list; they were therefore excluded. Each cogeneration unit will be plotted on the interactive map, based on the list of addresses received.

II. THE INTERACTIVE MAP

The spatial data mapped according to the methodology described above are all included in an interactive map that meets the requirements laid down in the specifications document:

- It is produced in electronic format so that it can be made available to the public on the website of the Brussels Environmental Authority.
- Users can zoom in on the map and choose to view the results at different levels (statistical areas and communes).
- Data is always aggregated, to protect commercially sensitive data.

The primary deliverable of this second task is therefore an **interactive electronic map** of the BCR showing heating and cooling needs, points of high heat and cooling demand, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points.

The **size of the items to be mapped** informs the definition of the minimum scale for representing the results (calculations are made by adding up the inputs for each building in the zone to be mapped). As such, the size of the mapping elements is determined by the way in which the map is used and also by the desired level of visibility. In this case, the data must be aggregated by statistical area or by commune, to **protect commercially sensitive data**.

Heating and cooling needs across the region are therefore estimated and a spatial representation provided at **two levels**, as follows:

- commune;
- statistical area.

Commune-level mappings provide an overall interpretation of results for the whole of the region, while at statistical area level they provide a detailed interpretation of particular zones.

The mapping was performed using QGIS, a free geographic information system application. In line with the Brussels Environmental Authority's request, all the layers of the map were produced according to the coordinate system (SCR), **using the Belgian Lambert 72 system code 31370: EPSG**.

For each variable to be mapped, it is important to select the **display gradation for the data**. The use of **Jenks natural breaks** to create separations in the interactive map defines the data classes in a way that minimises the standard deviation within each class.

The screenshots below show the results for the **different layers** of the interactive map.

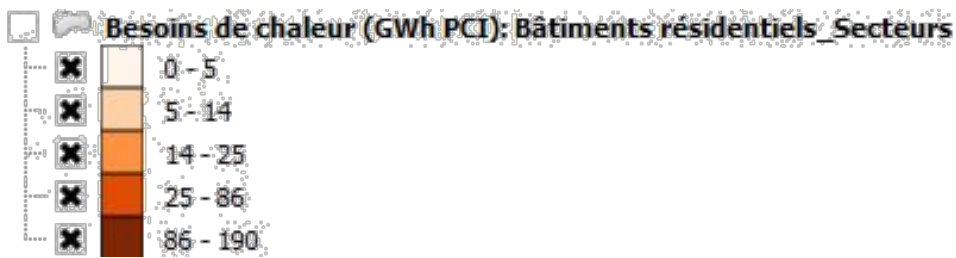
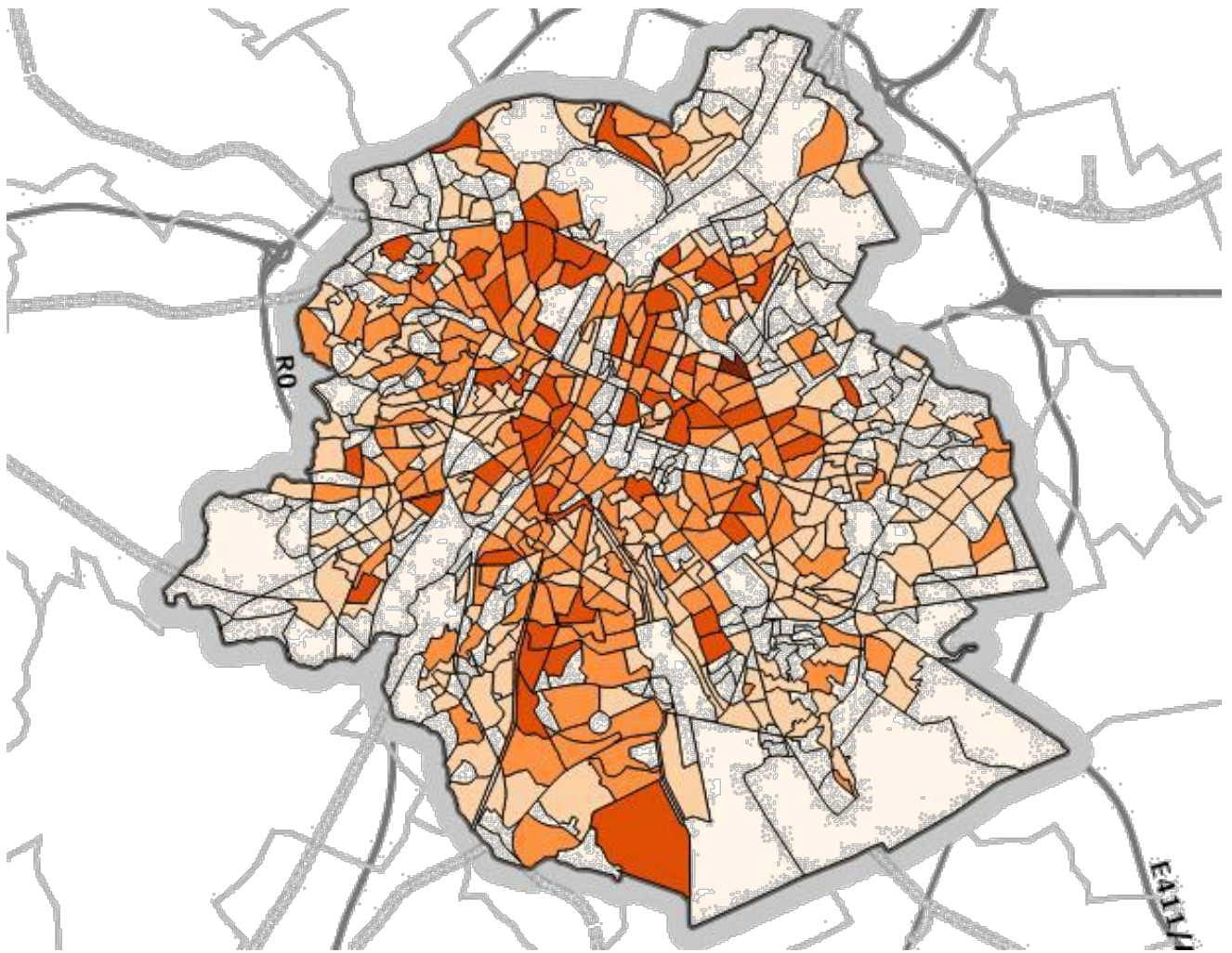


Figure 2: Heating needs: Residential buildings by statistical area (GWh LHV)

Besoins de chaleur (GWh PCI) : Bâtiments résidentiels_Secteurs	Heating needs (GWh LHV): Residential buildings_Areas
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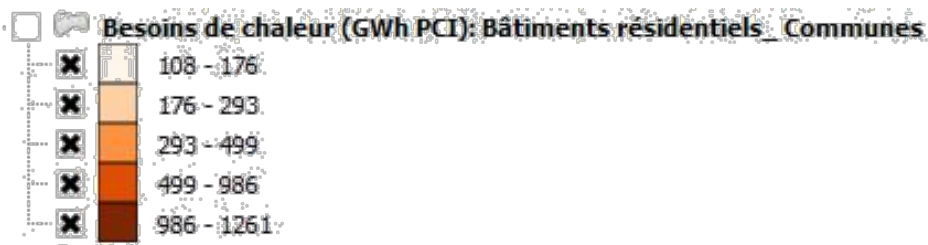
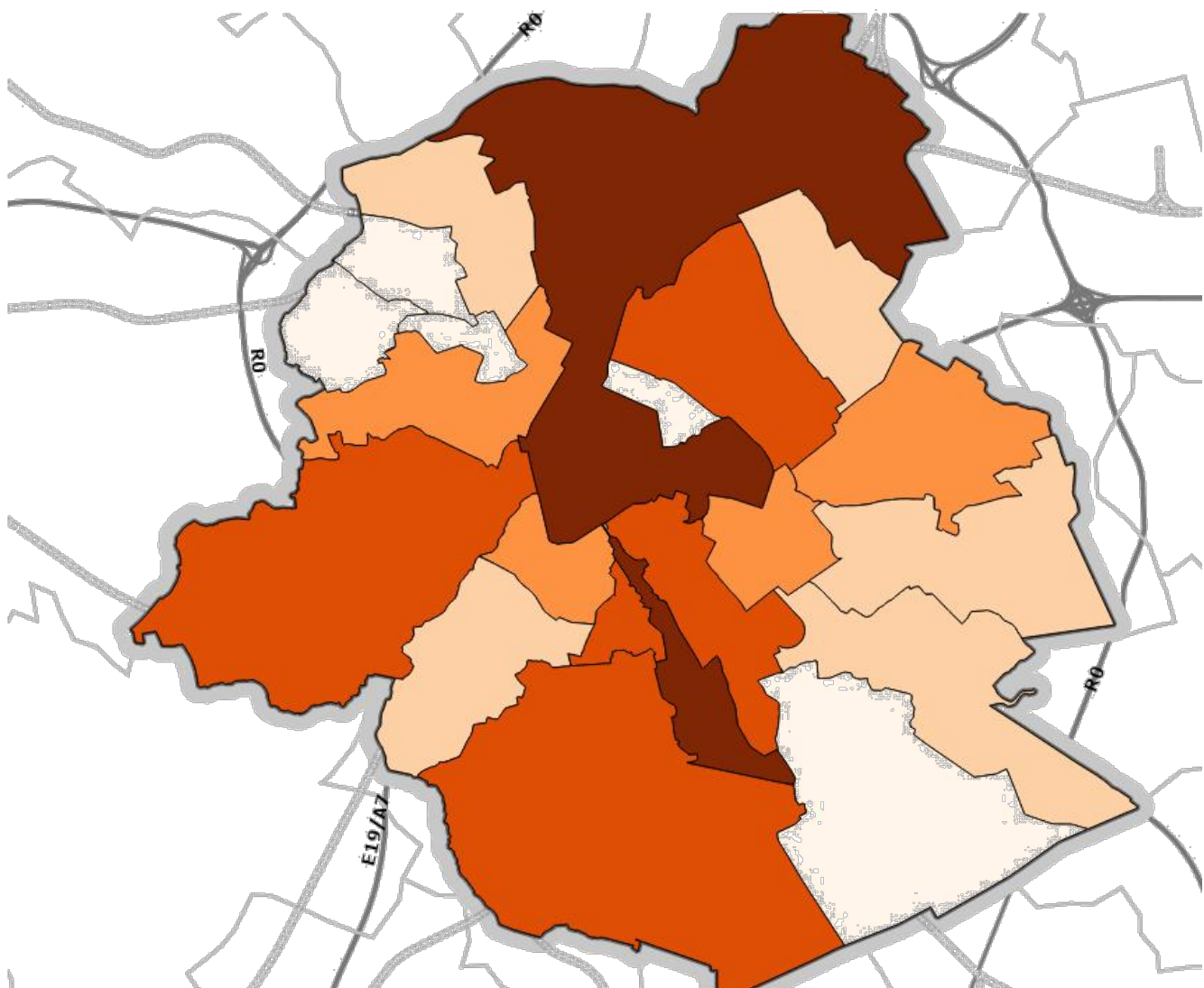


Figure 3: Heating needs: Residential buildings by commune (GWh LHV)

Besoins de chaleur (GWh PCI) : Bâtiments résidentiels_ Communes	Heating needs (GWh LHV): Residential buildings_ Communes
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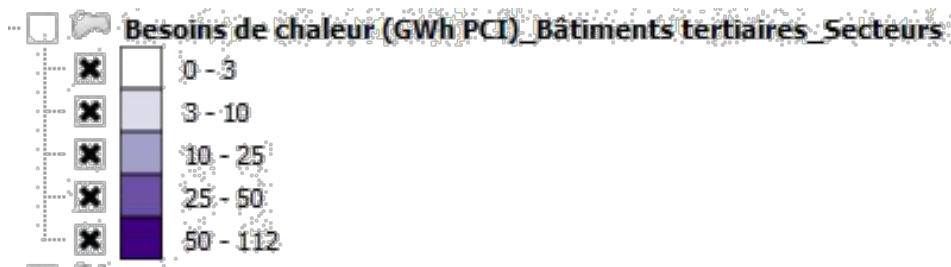


Figure 4: Heating needs: Service sector buildings by statistical area (GWh LHV)

Besoins de chaleur (GWh PCI)_Bâtiments tertiaires_Secteurs	Heating needs (GWh LHV)_Service sector buildings_Areas
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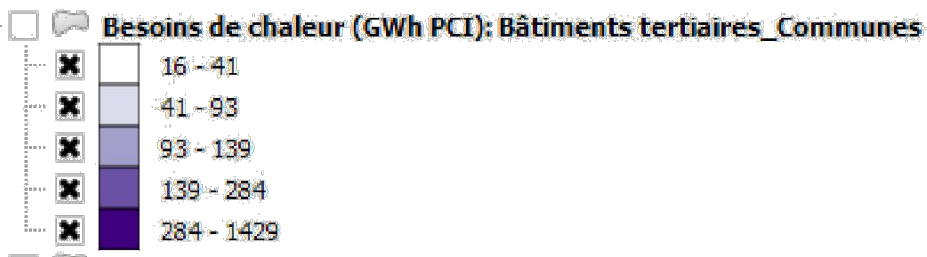
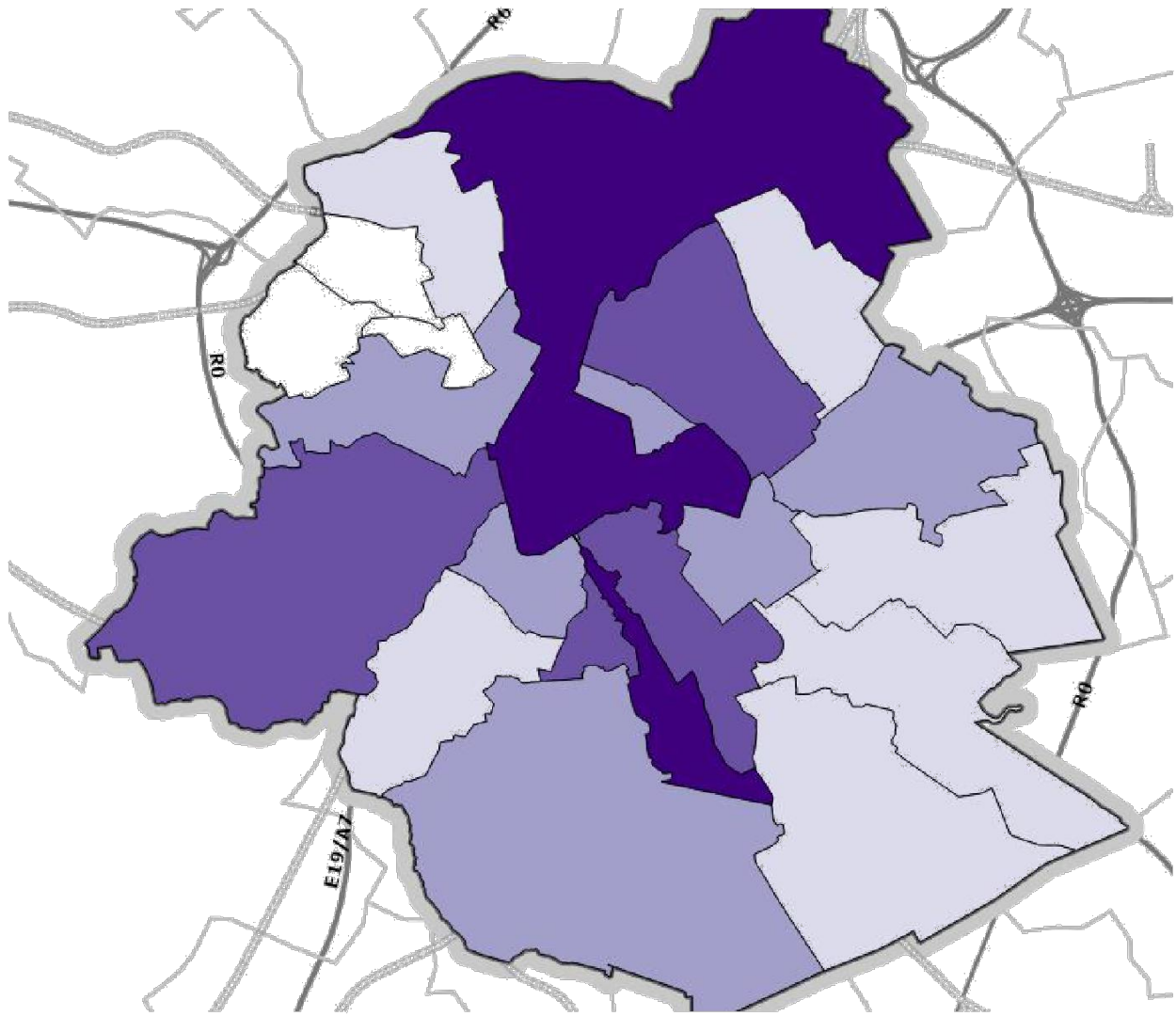


Figure 5: Heating needs: Service sector buildings by commune (GWh LHV)

Besoins de chaleur (GWh PCI)_Bâtiments tertiaires_Communes	Heating needs (GWh LHV)_Service sector buildings_Communes
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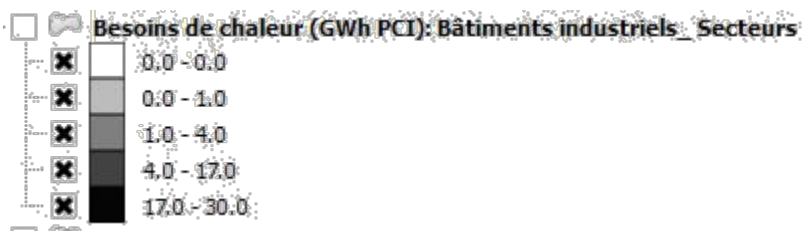


Figure 5: Heating needs: Industrial buildings by statistical area (GWh LHV)

Besoins de chaleur (GWh PCI)_Bâtiments industriels_Secteurs	Heating needs (GWh LHV)_Industrial buildings_Areas
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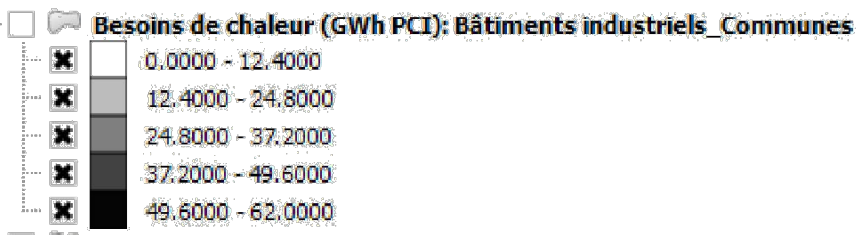


Figure 6: Heating needs: Industrial buildings by commune (GWh LHV)

Besoins de chaleur (GWh PCI)_Bâtiments industriels_communes	Heating needs (GWh LHV)_Industrial buildings_Communes
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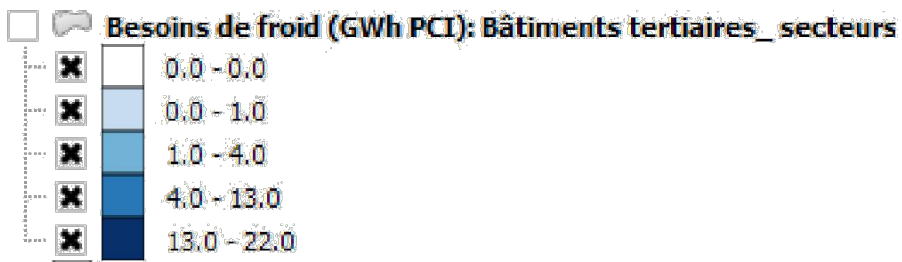
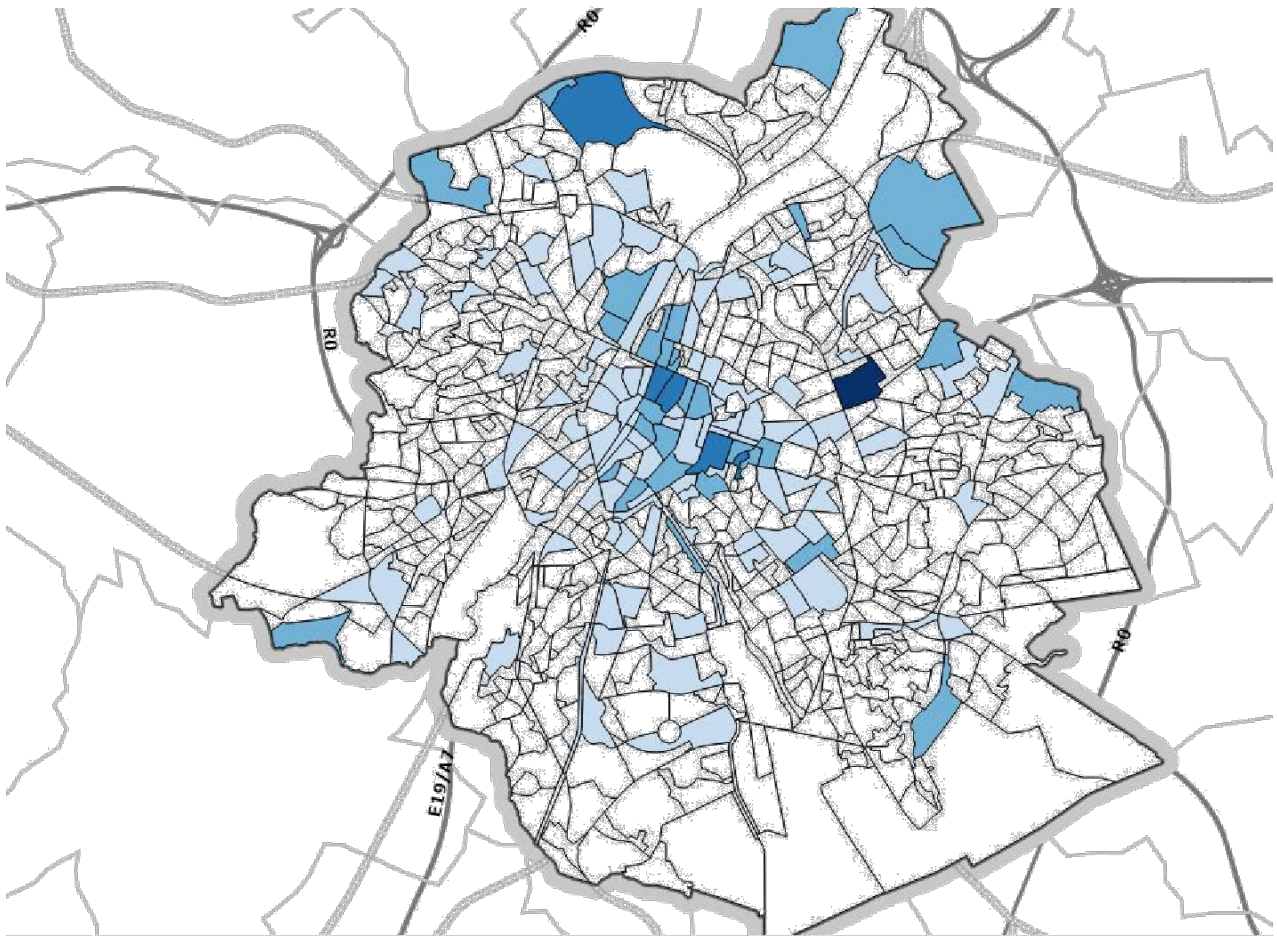


Figure 7: Cooling needs: Service sector buildings by statistical area (GWh LHV)

Besoins de froid (GWh PCI)_Bâtiments tertiaires_secteurs	Cooling needs (GWh LHV)_Service sector buildings_Areas
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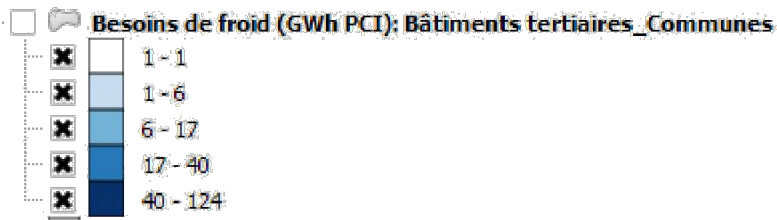
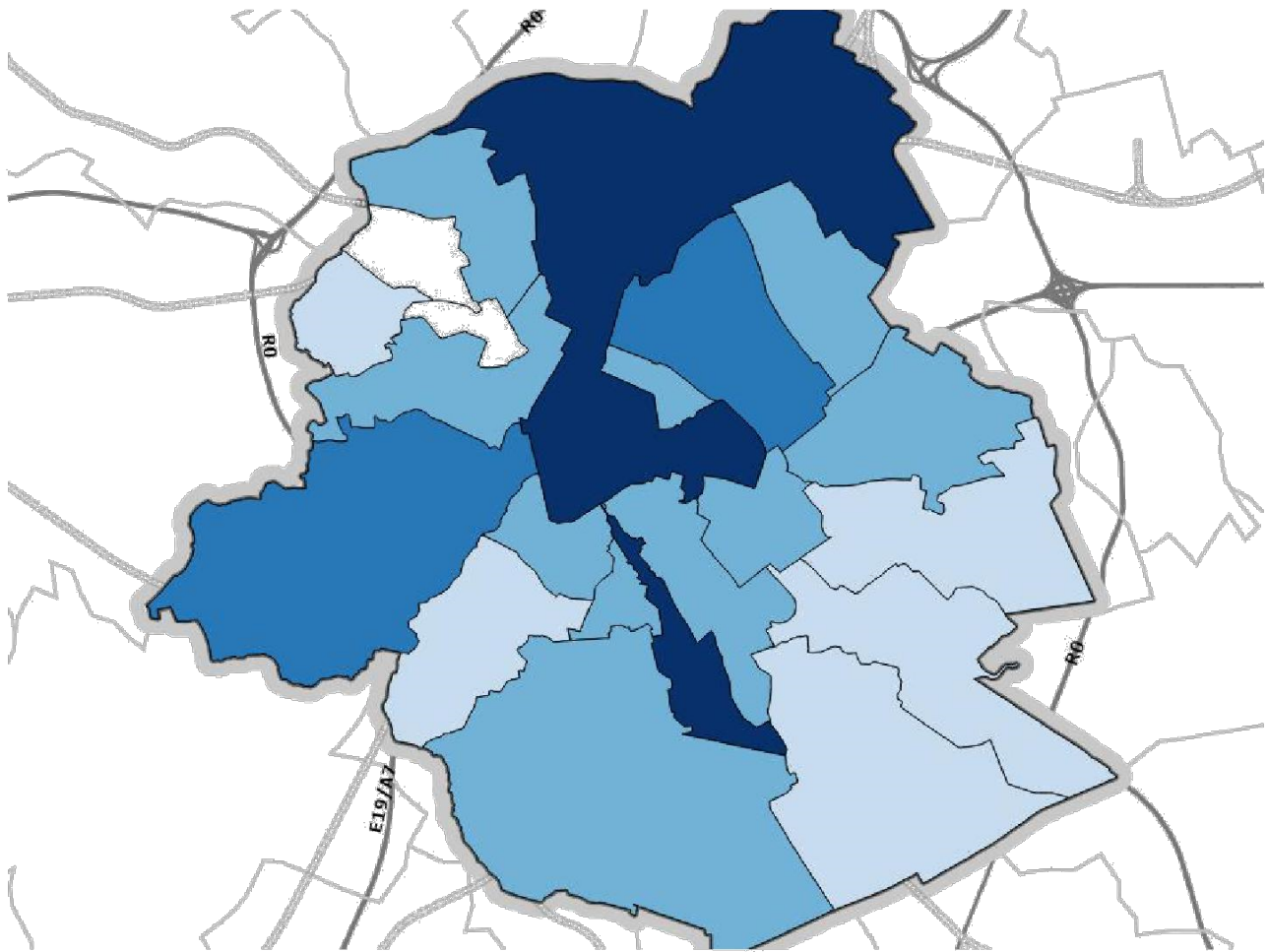


Figure 8: Cooling needs: Service sector buildings by commune (GWh LHV)

Besoins de froid (GWh PCI)_Bâtiments tertiaires_Communes	Cooling needs (GWh LHV)_Service sector buildings_Communes
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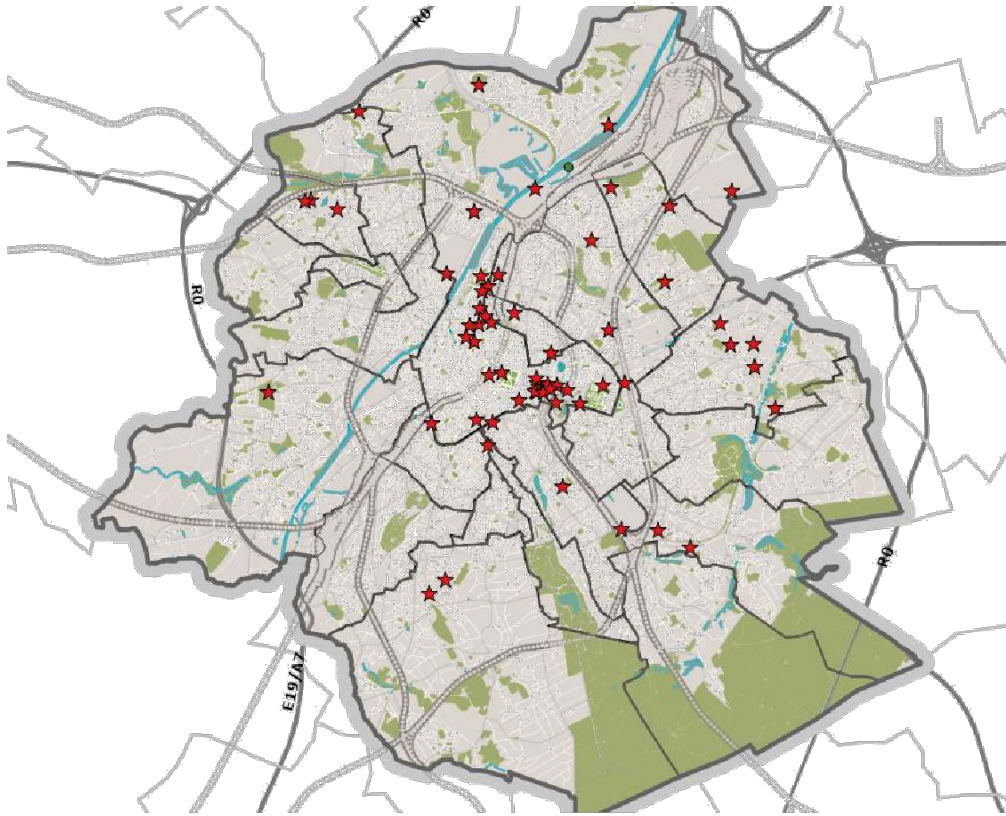


Figure 9: District heating (> 3 MW)

★ Réseaux de chaleur > 3MW



● Usine d'incinération de déchets

Figure 10: Household waste incineration plant

Réseaux_de_chaleur > 3MW	District heating networks > 3MW
Usine d'incinération de déchets	Waste incineration plant

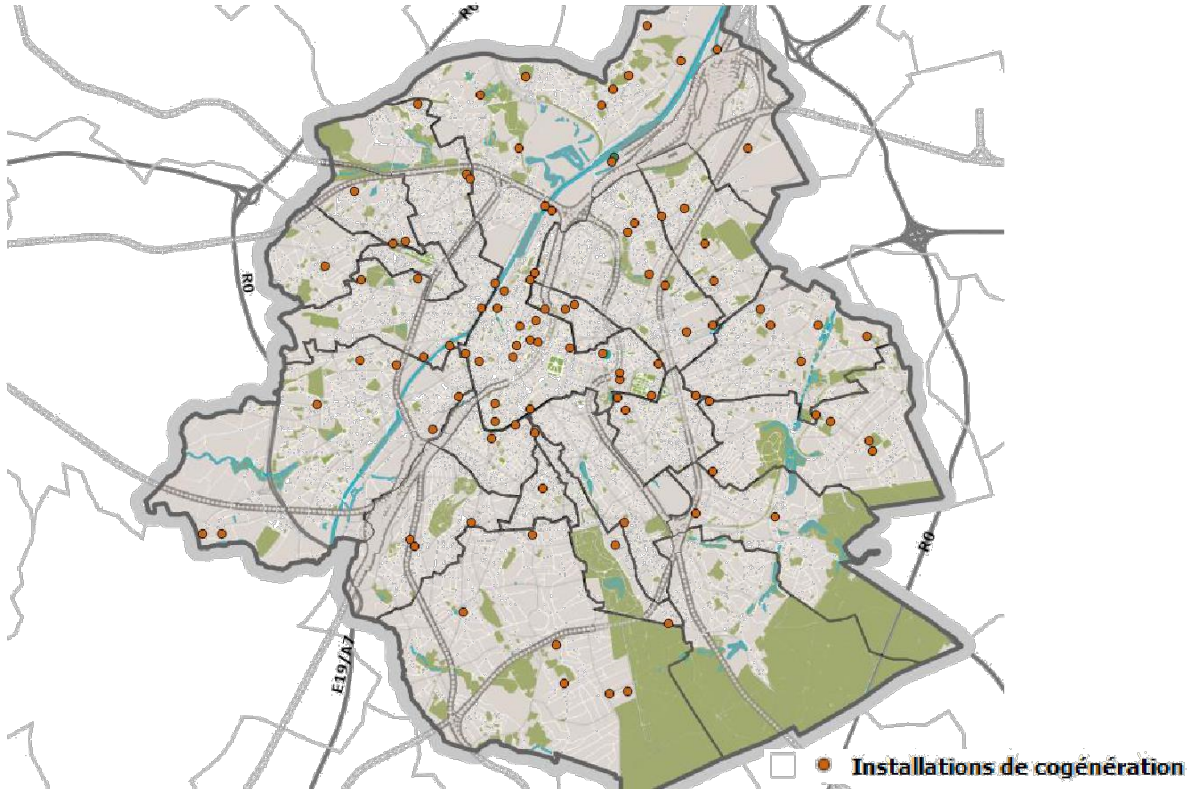


Figure 11: Co-generation facilities

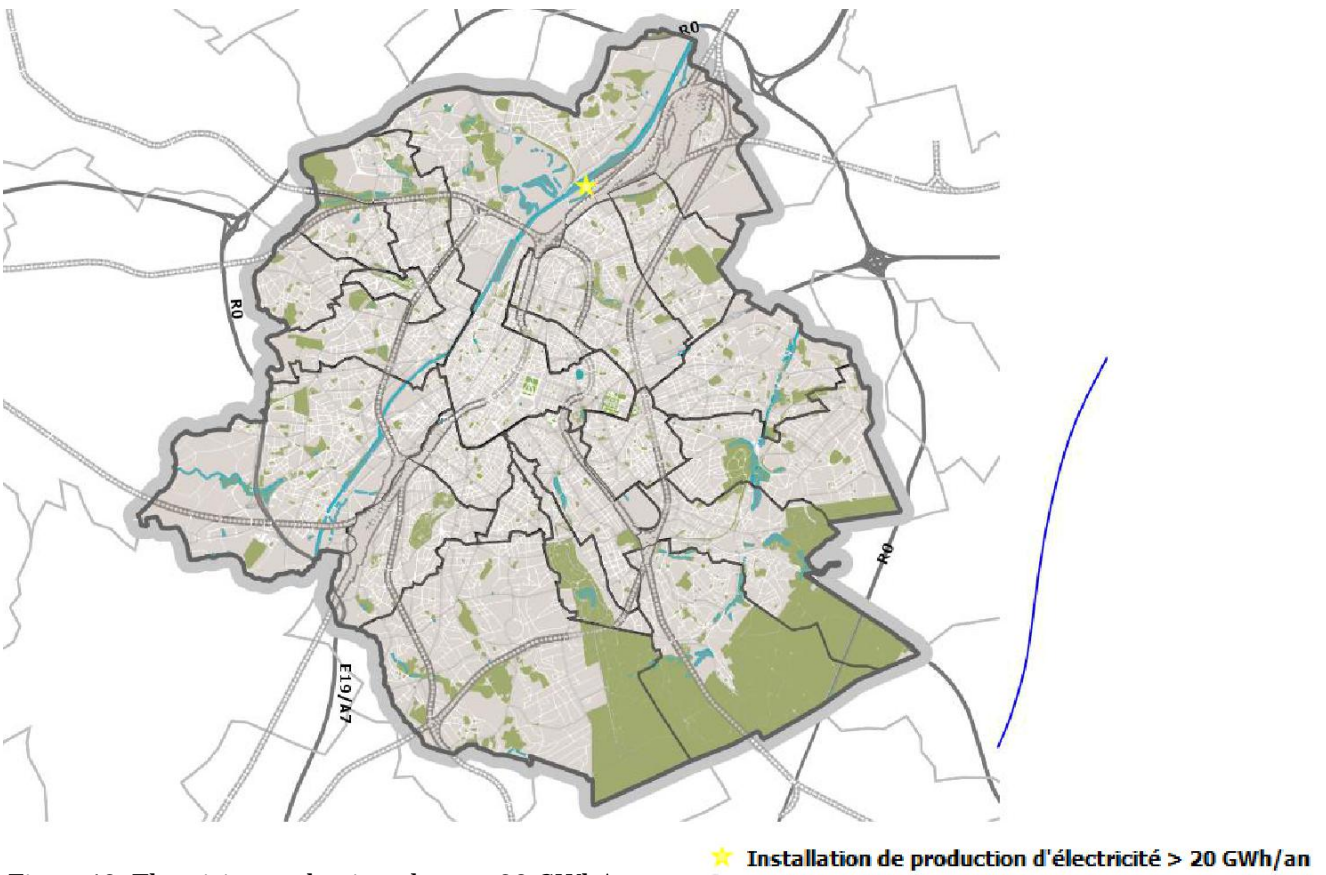


Figure 12: Electricity production plants > 20 GWh/year

Installations de cogénération	Cogeneration facilities
Installation de production d'électricité > 20 GWh/an	Electricity production plants > 20 GWh/year



Figure 13: Industrial zone with heating needs > 20 GWh/year

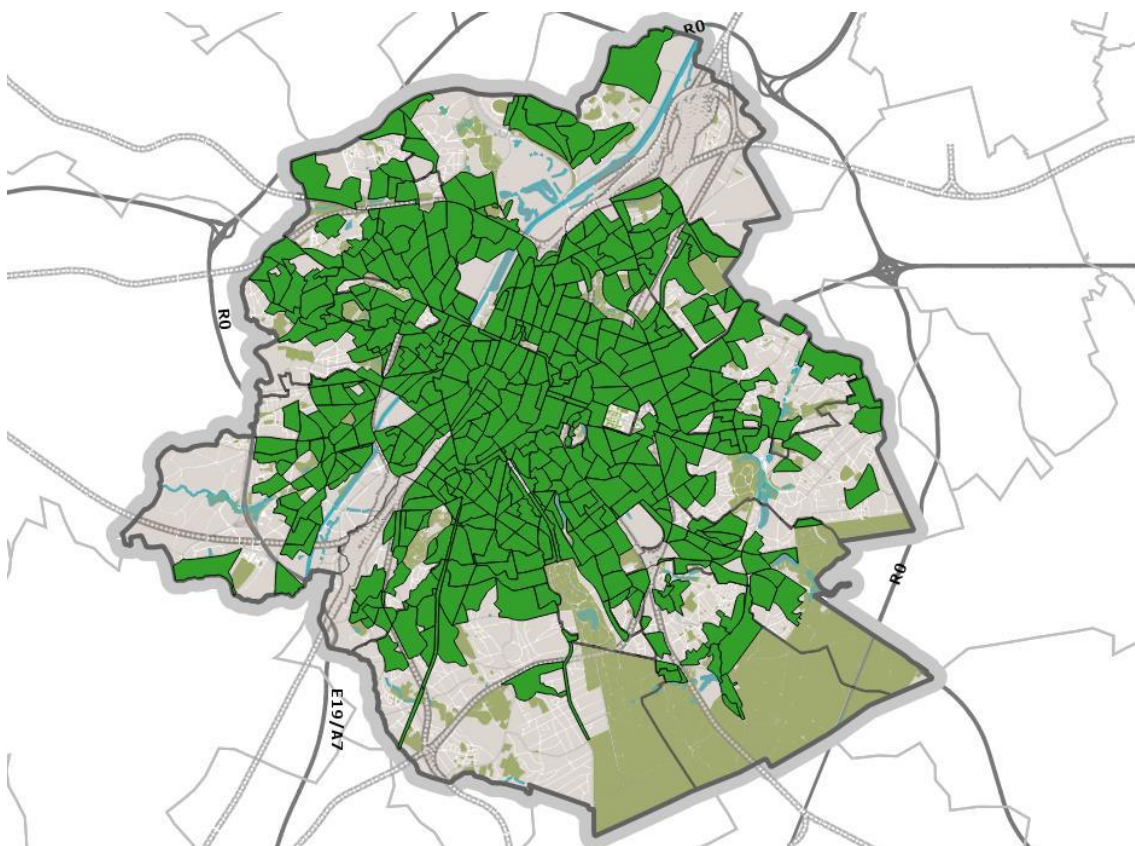


Figure 14: Statistical areas with an open space ratio of > 0.3 for the area.

II. BIBLIOGRAPHY FOR CHAPTER 2

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ICEDD 2014, *Bilan énergétique de la Région de Bruxelles-Capitale 2012*. Final Report. IBGE, 179p.

Chapter 3 – Identification of solutions to meet heating and cooling needs

INTRODUCTION

Context, purpose and methodology

The purpose of this third chapter is to list the potential solutions for meeting heating and cooling needs, drawing a distinction between standard solutions (for the baseline scenarios) and alternative solutions. The **methodology** adopted includes the following two steps:

- Phase 3.1: **assessing the available technologies** as regards standard solutions and potential alternatives for meeting heating and cooling needs
- Phase 3.2: **selecting a baseline scenario and alternative scenarios** to meet heating and cooling needs in the Brussels-Capital Region (BCR).

This third phase of the project included a detailed analysis of the scientific and industrial literature. The first section describes the various technologies in existence that meet heating and cooling needs, considering centralised solutions (cogeneration, district heating and cooling networks, etc.) and localised solutions (such as individual condensing boilers and micro-cogeneration). Technologies which cannot be applied in the BCR for technical, financial or legal reasons were quickly excluded from the scope of the analysis, further to debate.

The second section is based on the assessment of the available technologies set out in the first chapter and includes technology-needs matrices specific to the BCR (incorporating technical, financial and legal considerations), to show the potential benefit of each solution in the BCR for different types of projects with distinct heating and cooling needs. All the technology-needs pairings with a positive matrix-based evaluation for the BCR through these matrices are scenarios with potential for the BCR. A smaller selection of the scenarios offering the greatest potential benefit for the BCR will then be put forward, to form the basis for the work to be addressed by subsequent tasks. The process of selecting these scenarios will be based on the analysis of heating and cooling consumption undertaken in the first chapter.

I. TECHNOLOGY ANALYSIS

Based on a detailed analysis of the scientific and industrial literature, this chapter looks first at the various existing technologies for meeting heating needs and then at the existing technologies for meeting cooling needs. It addresses both with centralised and localised solutions for meeting heating and cooling needs. Technologies which cannot be applied in the BCR for technical, financial or legal reasons were quickly excluded from the scope of the analysis, further to debate.

I.1 TECHNOLOGIES TO MEET HEATING NEEDS

The following technologies will be discussed:

- condensing boiler
- high-efficiency cogeneration
- heat pump
- electric heating
- thermal solar panels
- industrial solutions
- district heating.

For each technology, the following aspects will be described:

- definition and characteristics
- constraints
- choice of heating fuel or energy source
- potential value and relevance in the BCR.

It is important to note that the efficiency figures given in this report are always based on the lower heating value of the heating fuel. It is also important to stress that there is always a difference between the theoretical figures published by builders and the actual figures measured on the ground.

I.1.1 Condensing boiler

I.1.1.1 Definition and characteristics

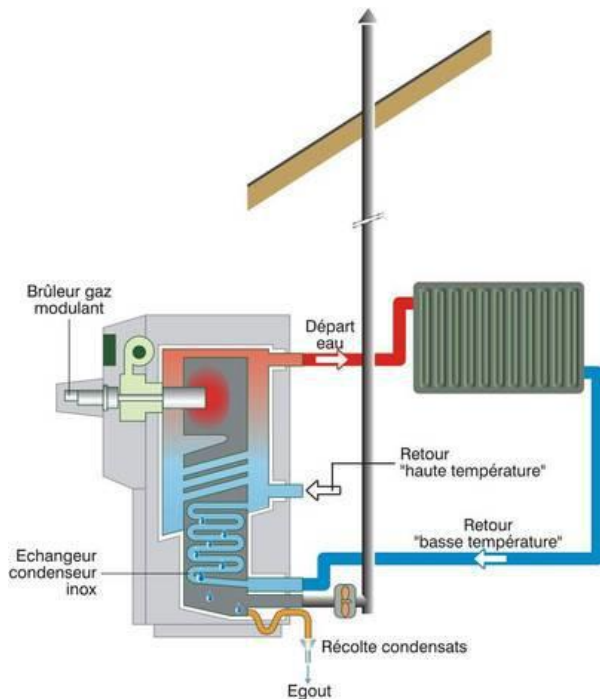


Figure 1: Condensing boiler (Source: www.energiepluslesite.be)

Brûleur gaz modulant	Modulating gas burner
Départ eau	Water to radiators
Retour "haute température"	'High temperature' return
Retour "basse température"	'Low temperature' return
Echangeur condenseur inox	Stainless steel condensing heat exchanger
Récolte condensats	Condensate trap
Egout	Drain

As with all boilers, condensing boilers continuously transfer thermal energy to a heat-carrying fluid (generally water), to provide space heating or domestic hot water. However, condensing boilers are specifically designed so that a significant proportion of the energy contained in the steam that is released with the flue gases is recovered through condensation, **consuming much less fuel with fewer emissions**. Furthermore, it should be remembered that, even in the absence of condensation, condensing boilers are still more efficient than conventional boilers, thanks to a larger heat exchanger surface area.

Condensing boilers can be **distinguished by the type of heating fuel** that they use (gas, oil or pellets). The **standardised efficiency** (ratio of energy supplied by the boiler to the hot water circuit to the heat emitted during combustion) of a **gas condensing boiler** can reach 110 % of LHV; for an oil condensing boiler, 104 % of LHV; and for a wood pellet condensing boiler, 102 %. In contrast, the standardised efficiency of low temperature gas and wood boilers carrying the Belgian HR+ label fluctuates between 93 % and 96 %. **Gas condensing boilers** therefore offer a **better efficiency gain** than oil or pellet boilers.

Condensing boilers can be used to cover a **variety of heating needs**. They can be applied to almost any type of heating or domestic hot water equipment or a combination of the two and are available in a wide range of power capacities for use in residential, service sector and industrial settings.

Depending on how well they are maintained, condensing boilers have a **lifespan of 20 to 30 years** and offer a **relatively inexpensive** solution.

I.1.1.2 Constraints

Condensing boilers work best at **low temperature** (with a return water temperature of 55 °C or less), equating to a 70/50 °C flow/return temperature for radiators, a 55/40 °C flow/return temperature for convection heaters, underfloor heating sized for a flow/return temperature of 40/30° C, heating for a swimming pool, producing domestic hot water sized for a 70/40 °C flow/return temperature and hot water coils sized for a 70°/40° flow/return. They therefore offer better performance when supplying **oversized heat emitters** (underfloor heating and oversized radiators).

However, condensing boilers still perform well even with **old radiators** (sized for a flow/return temperature of 90/70 °C) if the temperature regulation control is set so that the flow temperature is dependent on the external temperature (climate- controlled). In this instance, the return temperature will be 70 °C only during the coldest periods of the year and condensation will occur the rest of the time. In practice, a boiler sized for a 90/70 °C flow/return temperature with appropriate temperature regulation will produce condensate 75 % of the heating time in the case of a gas condensing boiler and 40 % of the heating time in the case of an oil condensing boiler. In contrast, the corresponding proportions for a system sized for a 70/50 °C flow/return temperature are 100 % of heating time for a gas condensing boiler and 93 % for the oil-fired variant.

In addition, as the combustion products from a condensing boiler are saturated with water vapour, using a standard masonry flue for discharging the flue gases could cause serious damage to the building. Therefore, either a **moisture-proof flue** (in stainless steel or a synthetic material) must be installed, or an **existing flue must be lined** so that a condensing boiler can be connected to it.

There is no need to neutralise the condensate from gas condensing boilers, nor from oil condensing boilers using low-sulphur (< 50 ppm) gas oil, but neutralisation is required for oil condensing boilers using standard gas oil. However, for large systems where the scale of domestic hot water production results in significant amounts of condensate, it may be prudent to treat the condensate from all condensing boilers before it is discharged. The need for a system for neutralising condensate from oil condensing boilers using standard gas oil is an additional constraint compared with gas, but it can be avoided by choosing a high-quality oil.

I.1.1.3 Choice of heating fuel

The conclusions drawn from the comparison of condensing boilers using gas, oil and wood pellets are set out below.

The factors in favour of **gas condensing boilers** are as follows:

- **Gas condensing boilers are more efficient** than condensing boilers using other fuels.
- Currently, gas is the heating fuel with **the least impact on the local environment**. Both oil and wood emit NO_x, SO₂ and fine particles, with a larger proportion of SO₂ for oil and a larger proportion of fine particles for wood, while gas does not emit any of these three pollutants. Of the systems that operate with fossil fuels, gas combustion emits less CO₂ than oil. Wood pellet condensing boilers reduce CO₂ emissions still further, provided that the pellets are sourced from close by. The balance of opinion is that wood brought in from more than 50 km away loses much of its environmental value as a result of CO₂ transport emissions, making its use debatable (Filloux 2010). In any case, wood combustion generates a higher level of pollutant emissions that affect air quality in the immediate environment of the boiler than gas does.
- A gas boiler occupies **minimal floor space** as there is no need for energy storage, while an oil boiler must include a fuel tank (underground, in a cellar or outdoors) and a pellet boiler requires even more space in order to store the pellets.
- Gas supply **is independent of any action by users**.
- It **costs less to install** a gas condensing boiler than an oil condensing boiler which, in turn, costs two to three times less than a pellet condensing boiler. In addition, installing an oil boiler also incurs the cost of a storage tank (around EUR 2 300 for a 2 500 l underground tank), which is significantly more than the cost of a connection to the gas supply. The maintenance cost for a wood boiler is no more than the cost for oil-fired solutions and slightly higher than for gas systems.

- Gas boilers make it easiest for a building's occupants or managers to **monitor its energy use**.
- Gas condensing boilers with the Belgian **HR TOP label** guarantee a level of performance that goes beyond the standards, ensuring a minimum efficiency (according to Council Directive 92/42/EEC of 21 May 1992 on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels) at rated power (in kW) of 95 % or more (at an average water temperature in the boiler of 70 °C) and a minimum efficiency under partial load conditions (0.3 x rated power in kW) of 107 % or more (water temperature on entry into the boiler = return temperature of 30 °C). The label also ensures compliance with CO and NOx emissions limits in combustion products deprived of air (0 % O₂) and moisture, measured according to the applicable European standard: CO: 110 mg/kWh max and NOx: 70 mg/kWh max. However, the HR TOP label will no longer exist after 26 September 2015, once the Eco-design regulation is implemented.

There are two significant drawbacks associated with gas, however. The first is that it is a **fossil energy source** that results in **dependence on foreign energy imports**. The second is that it has to be possible to connect a gas condensing boiler to the **gas network**. It should be noted that in 2010, 80 % of Brussels' inhabitants were already connected to the gas network (MATRIciel 2010) and that a recent survey by the ARGB (*Association Royale des Gaziers de Belgique*, the royal association of Belgian gas) suggested that 95 % of Belgian homes are now connected to the gas network. In the absence of a gas connection, **an oil condensing boiler** is a useful option in a large number of cases.

The major advantage of **wood energy** is that it is a renewable source of energy, provided that its use as a biomass fuel does not outstrip the regeneration of the resource. There are no logging operations for wood energy in the BCR, however. Biomass is the leading source of renewable energy in Belgium. It is not a solution with general application, though, as there is insufficient biomass for this type of heating to be used throughout the region. Biomass today accounts for 93 % of renewable energy production in Wallonia, with wood energy alone covering 65 %. Most of the fuel wood used in Wallonia is imported, though, and, according to the update to the *Plan pour la Maîtrise Durable de l'Énergie* (PMDE, Sustainable control of energy plan) (ICEDD, ECONOTEC, IBAM, 2009), the Walloon resource is already being exploited to full capacity, at slightly less than 3 500 GWh of primary energy.

Pellets are made from sawdust or very small particles of wood, dried and compressed to produce a dense, cohesive material. The sawdust used to manufacture pellets is sourced from wood processing companies such as sawmills. As such, it is not the case that trees are felled to produce pellets, but that the by-products of normal, sustainable forestry operations are recovered.

Wood energy requires significantly more storage space than oil and an increased frequency of delivery, which limits the large-scale benefit in dense urban settings. The calorific load for a storage volume of 1 m³ (1000 l) of oil is 10 000 kWh, while for 1 m³ of pellets, it is just 3 200 kWh (Hegger et al., 2011). Of the different sorts of wood energy, in an urban setting preference will be given to pellets as they require less storage space than wood chips or logs and offer better heating efficiency. Even for the use of pellets, though, there is a need for adequate storage space which can be accessed by a blower truck and is appropriate for requirements (30 m³ for a 60 kW boiler or 7 to 8 m³ for a detached house).

In addition, wood combustion generates more local pollution than gas, through the emission of NOx, SO₂ and small particles (PM₁₀) that are harmful to health, something which is also to be avoided in highly urban settings as it could have a considerable impact on air quality in towns and cities. The presence of the flue and emissions close to housing can be a source of significant discomfort. Filters are available for cleaning flue gases before they escape into the atmosphere, but they are relatively expensive, putting them beyond the reach of all but the largest industrial facilities (Crehay & Marchal, 2004). Such filters are warranted from an environmental perspective despite the fact that they are not 100 % effective. The level of discomfort is also reduced when the boiler facility serves a district or a group of buildings since there is just one flue, which can be sited in the least detrimental location. The boiler room for a wood boiler will also be a source of pollution for those living nearby because of the noise that it produces. The benefit of centralisation is that it reduces pollution as a result of distance from housing, but the built density of the urban setting means that it cannot be eliminated completely.

It is therefore difficult to envisage that wood-fired heating has a place in a dense urban setting. However, there is one exception, which consists of exploiting wood energy where it is possible to take advantage of the waste from a timber industry facility nearby. An example is a carpenter's son Rue Faes in Brussels, where the waste is sufficient to cover much of the heating for the carpenter's premises and the neighbouring apartment. Depending on the nature of the business activity, this type of set-up could be extended to produce heat for a number of homes or even a district.

I.1.1.4 Potential benefit and relevance in the BCR

Condensation boilers have already achieved significant **penetration in the Brussels market**, with figures of 85 % for gas and 33 % for oil in 2012 (ICEDD, 2014).

They can be used to cover heating needs for **projects on all scales**, from individual dwellings to urban district heating.

Condensation boilers are always an excellent choice for a **new building** or when installing a new central heating system, as in these cases the heat emitters can be oversized to ensure optimum performance of the condensation boiler. When **significant energy efficiency improvements** are carried out in an existing building, the existing heat emitters become oversized, which also provides the right conditions for installing a condensing boiler.

For an **existing building**, where only the boiler needs to be replaced, a condensing boiler remains the best choice from the point of view of energy consumption, although certain constraints emerge. If the building does not have a lined flue, then either an existing flue must be lined, or an outlet must be created via an air vent in the outside wall (subject to compliance with standard NBN D 51-003), which incurs additional cost (EUR 110 to EUR 150/m of flue to be lined). The installation of condensing boilers in multi-family housing fitted with standard localised boilers and a **shunt flue** therefore presents the disadvantage that simultaneous investment is required in all dwellings, to line flues or to increase the number of air vents, which may be problematic from an urban planning perspective. Where the **emitters** associated with an existing heating installation cannot operate at a low temperature, they must either be replaced, incurring significant additional cost, or it must be accepted that the condensing boiler will be less efficient as a result. In the latter instance, a gas condensing boiler will be the preferred choice. There is thus no assurance that installing a condensing boiler in an existing building will generate a financial return within a reasonable timescale compared with a standard boiler, because of the higher investment cost associated with the condensing boiler. However, as the gas condensing boiler reduces the environmental impact and local pollutant emissions compared with a standard boiler, it nonetheless seems preferable to recommend the condensing boiler in the majority of cases. Furthermore, in many cases, existing radiators were oversized at the time of initial installation. Lastly, even a partial energy retrofit (adding roof insulation to an existing building, replacing windows, etc.) provides the opportunity to oversize existing emitters to allow an existing heating system (initially sized for a 90 °C/70 °C flow/return temperature) to be used at a flow/return temperature of 70°/50° with no loss of comfort, at the same time as encouraging condensation.

As regards the **choice of heating fuel**, preference should be given in the Brussels-Capital Region to **gas condensing boilers**. Where there is no gas network, an oil condensing boiler remains an attractive solution that is cheaper than a pellet condensing boiler. It should be remembered, however, that the gas network in the Brussels-Capital Region covers virtually the whole of the region and any extension that is required, for example to provide supply to a new development, is added as a matter of course. A pellet condensing boiler may be considered in conjunction with district heating for projects encompassing a group of buildings or a district located close to sites that offer a supply of biomass fuel, particularly where there is opportunity to take advantage of the waste from a timber industry facility (such as a sawmill).

I.1.2 High-efficiency cogeneration

I.1.2.1 Definition and characteristics

Cogeneration is a technology process providing simultaneous thermal and electrical energy from a single source of primary energy. This combined heat and electricity generation technology offers **higher levels of energy efficiency compared with the equivalent separate generation of heat and electricity**.

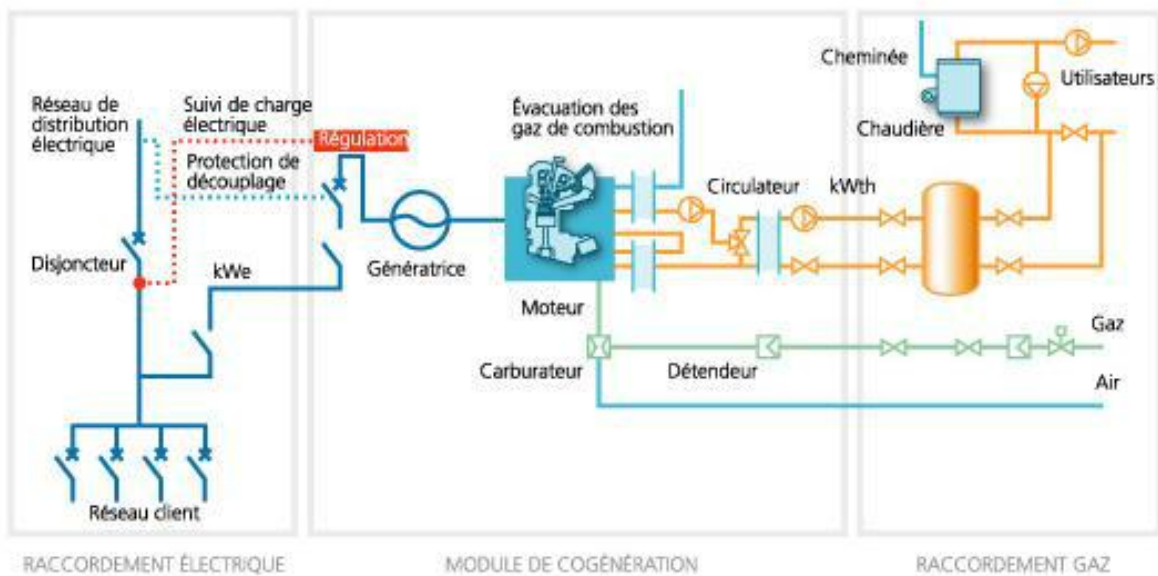


Figure 2: Simplified diagram of a gas cogeneration system (Source: ICEDD)

Réseau de distribution électrique	Electricity distribution network
Suivi de charge électrique	Electrical load monitoring
Protection de découplage	Isolation unit
Disjoncteur	Circuit-breaker
kWe	kWe
Réseau client	Customer network
RACCORDEMENT ELECTRIQUE	ELECTRICITY NETWORK CONNECTION
Régulation	Regulation
Génératrice	Generator
Évacuation des gaz de combustion	Combustion gas vent
Moteur	Engine
Carburateur	Carburettor
Circulateur	Circulator
Detendeur	Expansion valve
kWth	kWth
MODULE DE COGENERATION	COGENERATION MODULE
Cheminée	Flue
Chaudière	Boiler
Utilisateurs	Users
Gaz	Gas
Air	Air
RACCORDEMENT GAZ	GAS CONNECTION

Cogeneration is generally described in terms of **installed electrical power (EP) and thermal power (HP) capacity** and according to **electrical efficiency ($E\eta$), the heat efficiency ($H\eta$) and/or combined overall heat and electrical efficiency ($CHP\eta = E\eta + H\eta$)**. A cogeneration unit can also be characterised in terms of its PES (Primary Energy Saving), which expresses the primary energy savings achieved in comparison with a standard off-site power generation system. Technically, the various manufacturers routinely provide information on the heating fuel source used, the type of engine, the generator, the size of the unit and even the noise that it makes.

According to **Directive 2012/27/EU**, electricity from a facility producing simultaneous heat and electricity is considered to have been cogenerated provided that the overall efficiency exceeds 75 to 80 %. Below these efficiency thresholds, only a proportion of the electricity which is dependent on the amount of heat actually used is deemed to have been cogenerated. For example, in the case of a 400 MW combined-cycle gas and steam power generation facility from which the equivalent of 3 MW of heat is recovered through steam extraction, the Directive considers that this facility is equivalent to a cogeneration unit with an electrical power capacity of $3 \text{ MW} \cdot 0.95 = 2.85 \text{ MW}$. The coefficient of 0.95 was determined on the basis of the various technologies and is the default value given in the annexes to the Directive. (ICEDD, 2014)

The Directive also defines the concept of **high-efficiency cogeneration** as cogeneration with a **primary**

energy saving (PES) of over 10 % compared with separate generation, where the benchmark efficiency levels vary according to the technologies and heating fuels used and even the years in which the cogeneration units were manufactured. Take, for example, a natural gas-fired cogeneration unit with a gas engine and an alternator with an estimated thermal efficiency of 53 % and a combined electrical efficiency of 35 %. That is to say, 1 000 kWh of primary energy (from natural gas) simultaneously generates 530 kWh of heat and 350 kWh of electric energy. There is thus a primary energy loss of 12 %. Now take separate generation comprising a generation station with 55 % efficiency and a boiler with 90 % efficiency, both fired by natural gas; to produce the same quantities of thermal and electrical energy, 589 kWh of primary energy will be needed to generate the 530 thermal kWh and 636 kWh of primary energy will be needed for the 350 electrical kWh. The combined losses are therefore 345 kWh on a total primary energy consumption of 1 225 kWh, or 28 %. The diagram below illustrates this.

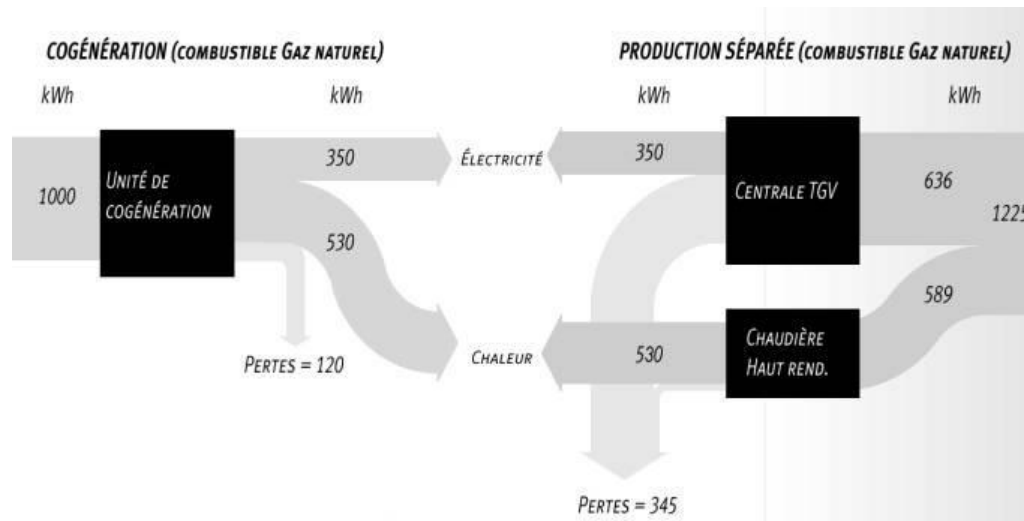


Figure 3: Illustration of the energy efficiency of cogeneration (Source: ICEDD)

COGENERATION (COMBUSTIBLE GAZ NATUREL)	COGENERATION (NATURAL GAS HEATING FUEL)
UNITE DE COGENERATION	COGENERATION UNIT
PERTES = 120	LOSSES = 120
ELECTRICITE	ELECTRICITY
CHALEUR	HEAT
PERTES = 345	LOSSES = 345
PRODUCTION SEPARÉE (COMBUSTIBLE GAZ NATUREL)	SEPARATE PRODUCTION (NATURAL GAS HEATING FUEL)
CENTRALE TGV	GAS/STEAM TURBINE POWER PLANT
CHAUDIÈRE HAUT REND.	HIGH-EFFICIENCY BOILER

Use of the energy generated by a cogeneration system reduces primary energy consumption and therefore reduces CO₂ emissions. The energy savings associated with the use of high-efficiency cogeneration are generally estimated at **15 to 25 %**.

Financially, the price of gas being lower than the price of electricity, it is important to emphasise that generating electricity from a natural gas-fired cogeneration system is cheaper than purchasing it from the grid. For it to be profitable, though, the difference in price between electricity and gas has to be quite large. To make a saving, the required ratio of electricity to gas is 2.5. Cogeneration systems are also eligible for subsidies and green certificates from the Brussels-Capital Region.

Cogeneration facilities can be **differentiated on the basis of their capacity**. Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 specifies that:

- the term ‘cogeneration’ applies in cases where electrical capacity exceeds 1 000 kW;
- ‘small-scale cogeneration’ describes a capacity of more than 50 kW and less than 1 000 kW of electrical power;
- ‘micro-cogeneration’ applies to an installed capacity of 50 kW of electrical power or less.

The **operating principle** of a co-generation facility is as follows:

1. The fuel drives the engine. Different techniques may be used:
 - a steam turbine
 - a gas turbine
 - an internal combustion engine

- a Stirling engine
 - and in the long term, there will certainly be fuel cells, too.
2. In turn, the engine drives an alternator, which generates electricity.
 3. The motion of the alternator generates heat.
 4. A heat exchanger recovers this heat and uses it to produce hot water for heating or sanitation.
 5. The heat deriving from the combustion gases can also be recovered through condensation and used to produce hot water.

The alternator can be driven by a **gas or steam turbine, or by an internal or external combustion engine**:

- *External combustion engines* are most appropriate for very small power capacities, as in the case of domestic micro-cogeneration. The electrical capacities of external combustion engines are generally equivalent to 1 kWe in domestic settings and are less than 10 kWe in all cases. Their available thermal power capacity is less than 50 kWth and for a domestic micro-cogeneration unit, the installed thermal power capacity will always depend on the user's needs, varying between 5 and 25 kWth in most cases. It generates less noise and vibration than internal combustion engines. The Stirling engine has an electrical efficiency of just 10 to 20 % but a thermal efficiency of 80 to 90 %. It should also be noted that an electricity-generating boiler is available for single-family homes, consisting of a boiler combined with a cogeneration engine within the system itself. As such, it is therefore a boiler that produces electricity. These systems are not at all cost-effective, however, and they have yet to achieve the same level of efficiency as units used for larger power capacities. Purchase and maintenance costs are high and preclude any return on this kind of investment. These systems will therefore be disregarded in subsequent scenarios.
- The *internal combustion engine* is equivalent to the engines found in motor vehicles: a combustion engine combined with an alternator. This is the type of engine that is used most frequently, and it covers the full range of small power capacities (from 3 kWe to 1 or 2 MWe). This type of engine is generally fired by natural gas or by oil. Subject to a few adjustments, it is also compatible with vegetable oil. The overall electrical efficiency of internal combustion engines is quite good, at 30 to 40 %, and their thermal efficiency ranges from 45 to 60 %.
- Larger power capacities (up to 100 MWe) make use of *gas turbines* (these are derived from aircraft reactors). The fuel (generally natural gas) burns in a combustion chamber and the gases produced are used to drive the turbine. At smaller power capacities, it is less electrically efficient than an engine, with an electrical efficiency of 25 to 40 % depending on capacity. The maintenance overhead for gas turbines is smaller than for cogeneration engines. This kind of equipment is less appropriate in situations where the level of demand varies, which is generally the case for heating needs in buildings. However, these turbines produce ultra-high temperature steam, which can be used in industry, or in the context of a combined generation cycle. As afterburning can be used independently of the operation of the turbine, it ensures that the turbine can operate at maximum electrical power output, with afterburning adjusted according to the user's heating needs.
- *Steam turbines* are fired by high pressure steam generated by the combustion of any heating fuel in a standard boiler. Their particular feature is that they produce more steam than electricity, and are only of benefit for very large power capacities (in excess of 1 MWe). The associated investment cost is also very high. They are not recommended in situations where heating needs are low, or in case of smaller power capacities, as electrical efficiency will be low, making it difficult to justify in financial terms. This kind of equipment is also less appropriate in situations where the level of demand varies, which is generally the case for heating needs in buildings. They are mainly used in industry, in large power capacity applications where more heat than electricity is required. The maintenance overhead for steam turbines is smaller than for cogeneration engines. Steam turbine cogeneration allows for the use of a range of primary energy sources, including various sources of energy recovered from industrial waste, such as wood waste from sawmills, or plant waste from agriculture. Any heating fuel can be used.
- Steam turbines and gas turbines can also be combined. Since gas turbines can produce steam, this steam can also drive a steam turbine instead of being used directly, thereby producing additional electricity. Heat can be produced from the outlet steam from the turbine. This kind of configuration provides high electrical efficiency, which is then reflected in lower thermal efficiency.

I.1.2.2 Constraints

The **cost of investment** for cogeneration units is higher than for standard boilers. Some cogeneration facilities have a cost of EUR 3 000 per installed kWe, but the investment varies significantly according to the type of fuel, the chosen make, the technology and the installed electrical power capacity. As such, for gas engine technology, the 'all in' cost requires an investment in the region of EUR 1 800/kWe for a power capacity of 240 kWe, falling to around EUR 1 000/kWe for a power capacity of 3 000 kWe. It should be remembered that energy bills are reduced as a result of on-site production, that less energy has to be purchased and that furthermore, the surplus can be sold back to the grid. There is also the possibility of subsidies and green certificates from the Region.

Cogeneration units have a **limited lifespan** (for example, internal combustion engines generally have a lifespan of between 50 000 and 60 000 hours) and have to be serviced regularly, increasing the associated maintenance costs. It is therefore important to secure a good maintenance contract and to ensure that a spare parts line item is included when cost planning.

To make a return on cogeneration, **all the heat and electricity produced must be recovered**. Optimum efficiency requires that electrical and thermal needs are simultaneous. If electricity generation outstrips need, it will be sold back to the grid (which is less cost-effective). It is more difficult to do for surplus heat, though, and this is the reason that cogeneration is sized for a building's thermal needs. The primary objective is for cogeneration to cover as much of the heating needs (calculated as power capacity x operating time) as possible. During times of low heating demand, cogeneration is of less benefit, therefore. The sizing of the cogeneration system will thus depend on the net heating needs, as well as on the operating hours, when all the heat that is generated can be recovered. Electricity needs are factored into the economic optimisation of system size, by determining how much of the power is used by the owner and how much is sold back. The more electricity is used by the owner, the better the return on the project will be. This is because the electricity used directly on site is valued at the purchase price from the supplier while surplus electricity will be fed back into the distribution grid and valued at the sale price, which is lower than the purchase price. It may be difficult to value cogenerated electricity in some types of projects, and this is the case in particular for multi-family housing projects.

The higher the **cogeneration power capacity** and the **longer the operating period**, the better the energy and financial return. The aim is to install the largest possible power capacity, on condition that all the heat and electricity generated can be recovered. Cogeneration is therefore suitable for projects where **heating needs, and especially domestic hot water needs, are significant**. In practice, cogeneration is considered to be useful for projects where heating needs exceed around **100 000 litres of oil or m³ of gas per year** (EnergiePlus). It is therefore suitable for use in hospitals, hotels, retirement homes, multi-family housing, swimming pools, industry, district heating networks, etc.

Note that **cogeneration** is an additional investment that **does not generally replace a standard boiler, but provides a useful complement to it**. The fact is that the heating system must always be able to meet all energy needs in the event of the cogeneration unit being out of order or being serviced.

In addition, one of the constraints of cogeneration is that it **needs to operate as regularly as possible** to ensure that it remains efficient. It cannot therefore cover peaks in thermal needs, and most of the time it will need to be combined with another means of heat generation to ensure that additional heating needs can be met beyond what is cost-effective with the cogeneration unit. To ensure that a cogeneration unit is efficient and cost-effective, it is vital that it operates **at a constant load** for as long as possible, so as to **minimise shutdowns and start-ups**, which not only result in a reduction in the overall efficiency of the system, but also shorten the lifespan of the generator set engine quite substantially.

This is where the addition of **thermal storage** can sometimes be of benefit. As such, in case of surplus heat, one alternative is to store the surplus for redistribution at a later date according to need, by means of **hydro-accumulation**, for example. As part of a project to develop an old people's home in Brussels, a 230 kWth and 150 kWe natural gas cogeneration unit was evaluated as being an economically attractive option when combined with 10 m³ of heat storage.

In practice, cogeneration requires an estimated **minimum operating time of 4 500 hours** per year to make it cost-effective. The true cost-effectiveness of the cogeneration unit will need to be examined on a case-by-case basis. The appropriateness of the cogeneration unit is evaluated using the COGENcalc software, available from the IBGE-BIM website (www.ibgebim.be). This is a streamlined tool that provides an order of magnitude of the power capacities required and evaluates the project's cost-effectiveness before work commences on a feasibility study. The software calculates the financial return on the basis of the initial investment and the various savings from cogeneration, compared with the same situation without cogeneration. However, care must be taken with the

parameters used to examine the cost-effectiveness of a cogeneration system, taking into consideration the guaranteed values at 0 % margin.

In addition, it is important that the building has the **necessary space** for a cogeneration unit, and easy access to it. The space requirement for a micro-generation system is limited, and similar to that required for installing a standard boiler.

Cogeneration systems are quite **noisy** and can cause vibrations. Good acoustic insulation is therefore required in and around the appliance, and the system must be installed such that it is separate from the structure of the building. The noise pollution caused by a cogeneration system – resulting from the engines, the ventilators and the pressure regulator – should not be overlooked when undertaking the feasibility study. A micro-cogeneration unit with an internal combustion engine generates a constant noise level. Depending on the make and the technologies used, it varies from 45 to 60 dB, which is around equivalent to the noise level of a washing machine during the wash part of the cycle.

There are a few **additional points to consider**, too: the footprint (for the cogeneration unit and the storage tank, if applicable), confirmation that the pressure and the gas flow are adequate, the water quality (there is a risk of deposits accumulating on the exchangers), the exhaust ducting (flue lining), and how the balance between the boiler(s) and the cogeneration unit is adjusted (to ensure that cogeneration takes precedence).

I.1.2.3 Choice of heating fuel

Cogeneration units with internal combustion engines cover a range of power capacities from 30 kWe to 1 or 2 MWe and are the systems most commonly used for individual buildings (hospitals, retirement homes, etc.) and for small urban district heating networks extending over, for example, a block or an eco-district. Three types of fuel can be used in this type of co-generation:

- natural gas;
- oil;
- biomass. In this instance, the oil is vegetable (primarily rapeseed) oil, which is typically recommended for micro-cogeneration. The high price of biogas means that is not a viable option, and wood is only used for the smallest power capacities (1 to 2 kWe), with a Stirling engine, for which there is a very limited market.

As is the case with condensing boilers, **natural gas** has the advantage that it is less polluting for the local environment than oil. However, cogenerated electricity can only be treated as renewable if renewable fuel (biomass) is used.

Biomass cogeneration offers a combination of energy savings and a renewable energy resource. Regrettably, the price of rapeseed oil has risen considerably over the last few years, to the point that it is no longer cost-effective. Furthermore, the maintenance costs associated with vegetable oil cogeneration equipment are higher than for gas. There are also frequent issues relating to the quality of the oil. Given the current market, this type of fuel is therefore to be avoided.

For large-scale urban district heating (over 2 MWe), **gas turbines** are worthy of consideration. In certain specific, high-power industrial applications where there is more demand for heat than electricity, **steam turbines** are to be recommended. Steam turbine cogeneration is most common where the primary energy source is **biomass**.

I.1.2.4 Potential benefit and relevance in the BCR

The current cogeneration facilities in the BCR are all combustion engine systems (Lebbe 2014), installed mainly in large multi-family housing estates and in the service sector (in hospitals and healthcare facilities, hotels, offices or swimming pools), sometimes in conjunction with urban district heating. According to the calculations by the ICEDD (2014), over **92 % of cogeneration in the Brussels region** was categorised as **high efficiency** in 2012. Furthermore, based on the rules for calculation and the values specified in the Directive, the percentage **PES of cogeneration facilities in Brussels** was **22.2 %** in 2012, equivalent to an absolute PES of 72.0 GWh.

It should also be noted that Brussels has seen a significant expansion in cogeneration over the last few years, with the number of cogeneration systems listed in the BCR increasing from 3 in 1991 to 88 in 2012. BRUGEL, the Brussels regulator, lists 104 operational cogeneration facilities with a total power capacity of 30.2 MW in 2012, and

no large power capacity facilities (< 3 MWe). Of these, **82 facilities, totalling 88 cogeneration units (engines)**, declared an output. The gross total installed electrical power capacity of these 82 facilities is **28.4 MWe**, the net output obtained is 28.0 MWe and the thermal power capacity is 36 MWth. These results demonstrate the technical efficiency of the cogeneration fleet: 2.73 kWh of primary energy is needed to provide 1 kWh of electric power via cogeneration, bearing in mind, too, that 1.25 kWh of heat is also recovered. The overall efficiency of gross electricity generation per cogeneration unit is 36.7 % and thermal efficiency is 45.9 %, giving an overall efficiency of 82.7 % for 2012. Systems were in operation for an average of 3 530 hours/year on an equivalent full power year basis. (ICEDD, 2014)

In 2005, the Brussels-Capital Region tasked the ICEDD with carrying out a study of the potential for expanding cogeneration in the region (www.icedd.be). The results show that in industry, it would be cost-effective for one business in five to install a cogeneration system (with a time to return on investment of less than three years), while in the service sector, one business in two would find it cost-effective to install a cogeneration unit (recouping their investment in less than five years). The study also confirms that the economic potential for generating electricity via cogeneration is 77 % in the service sector (with 33 % in public and private sector office buildings), 17 % in industry and 6 % in the residential sector.

In the BCR, cogeneration will be planned into all **development projects with significant and reasonably constant heating needs**, such as hospitals, care homes, swimming pools, large apartment buildings, large office buildings, manufacturing plants, district heating, etc. Its potential profitability is enhanced by the **Green Certificates** that are issued for high-quality cogeneration facilities in the Brussels-Capital Region. Micro-cogeneration units (generating < 50 kWe) will be explored for multi-family housing, offices and sports complexes, and small cogeneration facilities for hospitals, swimming pools and saunas, as well as small urban district heating networks. Given the significant built density of the Brussels area, there is potential in the BCR for cogeneration to be applied to blocks or groups of buildings via district heating, on the condition that, based on the needs of the area in question, both the cogeneration unit and the district heating resulting from centralisation are cost-effective.

The use of cogeneration within a district heating network helps to stabilise the heat demand profile, therefore allowing for optimal operation of the cogeneration unit. Cogeneration is **of value in collective settings** firstly because the shared heating system means that all the technologies are centralised, making it easier to monitor and maintain them, and it reduces the space requirement for such facilities within each building and/or home. It also allows for the heating fuel to be purchased in bulk, thereby securing more competitive prices from suppliers. Furthermore, larger cogeneration units offer better electrical efficiency: electricity generation is significant in this case, and so are the energy and economic gains. Lastly, it is easier to generate heat uniformly over time and the unit may reduce the number of shutdowns/restarts during the year.

I.1.3 Heat pump

I.1.3.1 Definition and characteristics

Heat is naturally available in the environment, in the air, the water and the ground. A heat pump is a machine which takes the heat that is present in the environment and transfers it to a building, reducing energy use. It can be used to heat a building, produce domestic hot water or both at the same time (with a combined heat pump). So-called 'reverse cycle' heat pumps can also be used to cool a building, by reversing their operation.

Using a liquid refrigerant, the heat pump extracts heat from a so-called 'cold' source (underground water, the ground or the air) via an evaporator, raises its temperature using a compressor and carries it to a 'warm' source via a condenser. Furthermore, although the compressor requires energy to operate, a heat pump recovers much more energy than it uses.

Provided that it has a good Seasonal Performance Factor (SPF) and therefore provided that it is used in ideal operating conditions, heating using a heat pump may provide a better CO₂ emissions balance and primary energy consumption than a gas condensing boiler.

There are many potential sources of heat (cold sources) and heat emission systems (warm sources), resulting in a large number of possible combinations. In addition, heat pumps are often classified on the basis of their cold source/warm source, as follows: water-to-water, air-to-water, brine-to-water, air-to-air, water-to-air, ground-to-water, etc.

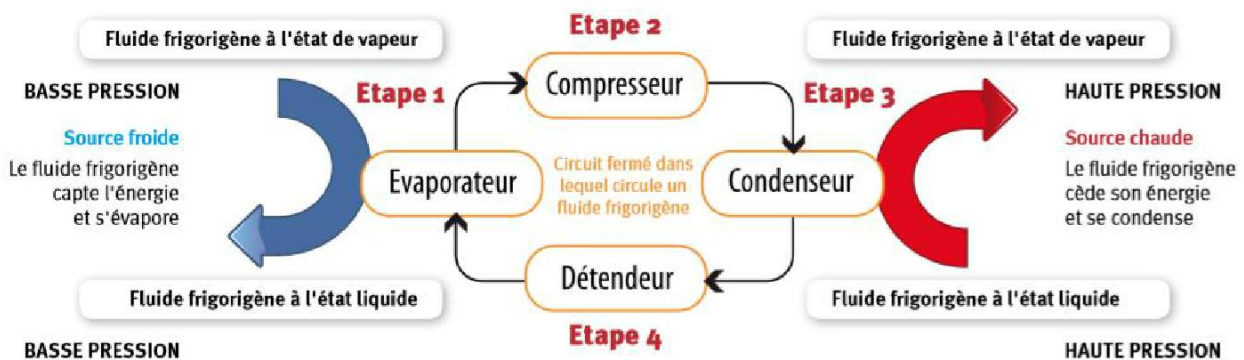
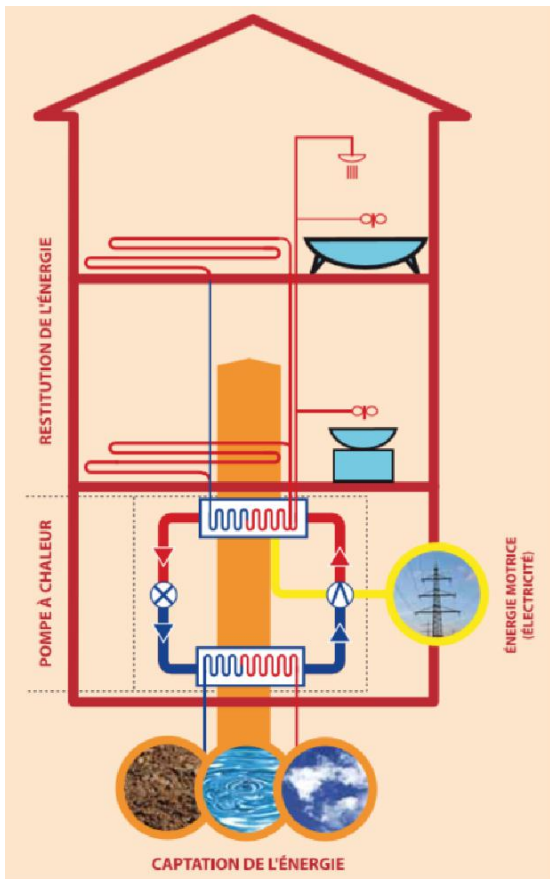


Figure 4: Operating principles of a heat pump (Sources: ODE Vlaanderen and SPW)

POMPE A CHALEUR	HEAT PUMP
RESTITUTION DE L'ENERGIE	ENERGY DELIVERED
ENERGIE MOTRICE (ELECTRICITE)	INPUT POWER (ELECTRICITY)
CAPTATION DE L'ENERGIE	ENERGY CAPTURED

Fluide frigorigène à l'état de vapeur	Liquid refrigerant in gaseous state
BASSE PRESSION	LOW PRESSURE
Source Froide	Cold source
Le fluide frigorigène capte l'énergie et s'évapore	The liquid refrigerant captures energy and evaporates
Fluide frigorigène à l'état liquide	Liquid refrigerant in liquid state
BASSE PRESSION	LOW PRESSURE
Etape 1	Phase 1
Evaporateur	Evaporator
Etape 2	Phase 2
Compresseur	Compressor
Etape 3	Phase 3
Condenseur	Condenser
Etape 4	Phase 4
Détendeur	Pressure reducer
Circuit fermé dans lequel circule un fluide frigorigène.	Closed-loop circuit with liquid refrigerant
Fluide frigorigène à l'état de vapeur	Liquid refrigerant in gaseous state
HAUTE PRESSION	HIGH PRESSURE

Source chaude	Warm source
Le fluide frigorigène cède son énergie et se condense	The liquid refrigerant releases its energy and condenses
Fluide frigorigène à l'état liquide	Liquid refrigerant in liquid state
HAUTE PRESSION	HIGH PRESSURE

There are three key factors that determine and constrain the CO₂ emissions from a heat pump compared with a conventional heating system:

- The performance coefficient for the heat pump. This represents the efficiency of the heat pump: the higher the coefficient, the less electricity will be consumed. The performance coefficient is defined as the ratio of the amount of energy provided to the building by the heat pump and the amount of energy required to make this transfer. As such, a heat pump that provides 3 kWh of heat to a building using just 1 kWh of electricity will have a performance coefficient of 3.
- The type of fuel used to generate the energy required to operate the heat pump and the pump's generation and distribution efficiency. For example, electricity can be generated by photovoltaic solar panels, which would make it a fully energy efficient, entirely renewable system. In the case of a heat pump intended to heat a premises, drawing electricity from the grid, 70 % of the energy is renewable and for a heat pump intended to produce domestic hot water, drawing electricity from the grid, 60 % of the energy is renewable (Cuvellier & De Herde 2015). Note that when using solar energy to produce domestic hot water, it is more efficient to use thermal solar panels than photovoltaic panels with a heat pump. Lastly, the potential benefit of gas heat pumps should not be overlooked.
- The type of liquid refrigerant used: some liquids are harmful to the environment (contributing to depletion of the ozone layer, for example) and release CO₂.

Compared with conventional heating, two factors may work to the advantage of the heat pump in the primary energy balance: an environment that is particularly conducive to its use (with a high-quality cold source) or an area of use in which it will work particularly efficiently (as a result in particular of its capacity for producing heat and cold). The table below compares a number of heating pumps (taking an average level of power plant efficiency of 38 %) with a gas condensing boiler for net energy needs of 25 000 kWh/year, an average distribution, control and emission efficiency of 88 % (to identify the production efficiency of the heating production system) and low temperature heating (IBGE, 2015).

Comparison with gas condensing boiler	Seasonal production efficiency LHV or SPF	Emissions gain/loss (kgCO ₂ /year)	Consumption gain/loss (primary kWh/year)
Air heat pump	2.7	-70 %	+6 %
Ground heat pump (vertical)	4.2	-10 %	+40 %
Water heat pump (underground)	5	+8 %	+49 %
Gas condensing boiler	1.01	-	-

Heat pumps offer effective heating systems with a lifespan in excess of 15 years. They do not require a flue, sweeping out, or heating control; nor do they release any odour or present any risk of explosion.

I.1.3.2 Constraints

Nonetheless, a heat pump requires the **temperature of the cold source** to be sufficiently high. The average ground temperature of 12 to 13 °C is generally sufficient, and is relatively constant. In the case of hydrothermal energy, surface water temperature varies considerably in response to solar energy. The nature of Belgian summers means that water becomes too warm to be viable for use in meeting any demands for cooling; in winter, the reverse is true and the water is too cold to provide heat. Hydrothermal energy from surface waters is not a practicable solution in Belgium, therefore (Penders, 2013).

The performance of the heat pump depends on the **return/flow temperature of the emitter (the warm source)**. Heat pumps perform more efficiently if they are supplying **low-temperature heat emitters**, as is the case with underfloor heating (at a flow/return temperature of 30/45 °C). For this reason, heat pump systems

should only be used in low energy, very low energy or passive buildings, or in service sector or industrial buildings with minimal heating needs. This is also the reason that heat pumps are less suitable for use in producing domestic hot water. To heat domestic hot water to 60 °C (the required temperature since Legionella control measures were introduced), tanks must be placed in series so that the heat pump can pre-heat the water to 45 °C with the use of an additional electric heater. This of course adds to the cost at installation stage (EnergiePlus). Efficient heat pumps are not suitable for existing buildings, other than in case of major energy efficiency improvements.

The **investment cost** for a heat pump is around two to three times the price of a gas condensing boiler (excluding flue, gas connection, etc.), and the cost of any requirement for geothermal drilling must also be factored in (at a rate in the region of EUR 50/m or EUR 750/kW). While heat pumps do create energy savings, they run on electricity, at a EUR/kWh cost some two to five times greater than that of fuels such as natural gas, oil or wood. As such, despite the system's performance, its annual **cost of use** places it in the same bracket as more conventional systems such as boilers and stoves. Likewise, the investment cost is some three to five times more than for a traditional heat-generating appliance. As a result, it is not always easy to recoup the extra investment in the pump over the lifespan of the equipment. Outcomes may differ depending on whether the pump is replacing an existing system or is a brand new installation.

The **simple payback period** for a heat pump is negative since the cost of acquisition and use is higher than for a gas condensing boiler. Vertical geothermal heat pumps are only a practical option for major projects where there is scope to generate a return on the investment in drilling over the long-term.

Heat pumps generate **noise** which may prove to be a nuisance for the external or internal environment. However, there are rules for siting and design that can be applied to provide protection from such nuisance; these include consideration of the location, position, support bracket, network and pipework for the pump (see AFPAC 2013a and 2013b [*Association Française pour les Pompes à Chaleur*, French association for heat pumps]). This is an essential requirement for air-source heat pumps.

I.1.3.3 Choice of energy source

Air-source heat pumps

Air-air or air-water (air-source) heat pumps are the most widely used in residential buildings, given their lower cost and the advantage that they can easily capture heat from the cold source, which is available everywhere. This type of heat pump is the easiest to use in energy retrofitting. They can be adapted to work with existing heating distribution networks when replacing a boiler. The cold source is the outside air or air extracted from the building (by means of controlled heat recovery ventilation). This is then combined inside the building with mechanical ventilation in the case of an air-to-air pump, or with underfloor heating or radiators where an air-to-water pump is used. Their seasonal performance coefficient is relatively low, however, at +/- 2.5 - 3.5. When the cold source is outside air, the external temperature has a major influence on the performance of the heat pump: as the temperature approaches 0 °C, efficiency wanes and energy use increases proportionally. In addition, this type of pump does not receive a subsidy from the BCR, in contrast to other types of air-source (air-to-water) heat pumps. Lastly, the evaporator is located externally and may cause noise pollution, which is all the more of an annoyance in a dense built environment.

Horizontal geothermal heat pumps

These ground-to-air or ground-to-water heat pumps are more efficient than air-source heat pumps and have a seasonal performance coefficient of +/- 3 to 4.5. They are also more costly, however (de Meester & De Herde 2012). An external connection is required to horizontal ground loops running through the garden at a depth of +/-1.5 m. It must therefore be ensured that there is sufficient land available for installing layers of sunken ground loops. The surface area requirement for a well-insulated property is around 1.5 to 2 times the area to be heated. This is why it is not easy to incorporate horizontal geothermal heat pumps as part of a retrofit, particularly in urban settings.

Vertical geothermal heat pumps (to +/-100 m)

The benefit of this system is that it takes advantage of a heat source with a near-constant year-round temperature. However, the requirement to drill down demands a minimum amount of space and good access for the drilling equipment. The capital cost of drilling (which is dependent on the soil type and ease of access to the site) is significant and in many cases undermines the cost efficiency of this type of solution. The thermal potential of the

ground may vary from 25 W/m to 80 W/m (according to the VDI 4640 guideline) and will need to be quantified by a specialist firm to enable accurate sizing of the loops. Furthermore, if the geothermal heat pump is used with a vertical heat exchanger (geothermal ground loops), there is a risk of pumping excessive energy out of the ground, making the ground unfit for this purpose. In a passive design, heating needs are reduced and this should not occur. Conversely, in developments with more significant heating needs, these needs may outstrip the rate of ground heat regeneration (MATRIciel, 2010). Large developments (multi-family housing, office buildings, districts, etc.) in a position to make larger investments than individuals may also consider ground-to-water heat pumps with drilling to greater depth to obtain increased power capacity.

Water-source heat pumps

For heating, a water-to-water heat pump is the most attractive from an environmental perspective. Provided that the system is properly adjusted, it is also still a more attractive option than a condensing boiler. However, this technique is not yet economically viable (IBGE, 2010). This type of heat pump demands that groundwater or sufficient surface water is available in the locality. Where surface water is to be used, it must provide an adequate flow rate that is maintained over time.

As such, where groundwater is present, water-water heat pumps, which offer better performance and less restricted power capacity, will be preferred. This type of heat pump works by extracting thermal units from underground water, removing the thermal units by means of open loop systems and reinjecting the flow of water into the aquifer. This offers the advantage of an inexhaustible, permanently available cold source at a constant temperature, something which is not necessarily the case with vertical ground loop systems. Accordingly, these open loop systems have a better seasonal performance factor (SPF) than closed loop systems, although they still require an in-depth hydrogeological and geochemical survey. The risks associated with the use of an open loop system must be examined on a case-by-case basis and require a permit to be obtained.

The **comparison table** below shows the seasonal performance coefficient for different types of heat pump, in new-build and retrofit settings (source: OFEN).

Comparison with gas condensing boilers	New build	Renovation
Air-to-water heat pumps	2.7-3.5	2.5-3.0
(Vertical) ground-to-water heat pump	3.5 to 4.5	3.2 to 4.0
(Underground) water-to-water heat pump	3.8-5	3.5-4.5

The following **table** sets out the main **benefits and constraints** of the different **potential sources of cold in the natural environment**. (énergie.Wallonie)

Type of cold source	Benefits	Constraints
'Static' air	No noise (compared with 'dynamic' air)	Change in air temperature Size of the exchanger
'Dynamic' air	Reduced size	Change in air temperature Noise of the fan
Water (groundwater)	Constant, raised water temperature (7 to 12 °C)	Cost of drilling Water quality requires checking Quantity of water required Water pumping (maintenance of and consumption by the pump)
'Static' water (surface water)	Relatively constant water temperature	Water quality requires checking Quantity of water required

'Dynamic' (surface) water	Relatively constant water temperature	Water quality requires checking Quantity of water required Water pumping (maintenance of and consumption by the pump)
Ground (direct evaporation horizontal)	Relatively constant ground t°	Land area required Significant quantity of liquid refrigerant required
Ground (glycoled water - horizontal)	Relatively constant ground t°	Land area required
Ground (glycoled water - vertical)	Relatively constant, raised ground temperature (10 °C at 20 m) Reduced size	Cost of drilling

Other cold sources may also be used. Many businesses waste large amounts of energy in **extracting air** (to cool down a computer room, etc.) or gas. Very often, the volume of air extracted and the fluid temperature are near constant, which makes it easier to install the system. A buffer tank will be fitted to the evaporator if there is any significant change in these parameters. The same applies to the condenser in case of any variation in thermal load.

Buildings where considerable **moisture** is produced and where humidity will therefore be controlled to prevent condensation forming on the walls (swimming pools, laundries, industrial kitchens, etc.) are an ideal environment for using a heat pump: all the energy from the condensation of the water vapour can be reused in the form of high temperature heating (to heat the air or domestic hot water). As such, swimming pools are an example of a specific implementation of heat pumps.

Specific, highly cost-effective applications are sometimes possible for shops and are particularly suitable for supermarkets with a frozen foods aisle where, for example, the heat extracted from the **freezers** can be used to heat the shop or the warm air curtain at the entrance to the store. In summer, a valve will discharge the heat outside.

Gas absorption heat pump

This is a leading-edge variation on the standard heat pump. It differs from the thermodynamic system of a hot water gas boiler in that it is an ammonia solution (NH₄OH) that is heated, rather than pure water in a closed circuit. In addition, ammonia (NH₃) is used in a secondary refrigeration cycle that allows the heat to be pumped from a cold source (at the evaporator) to be recovered by the warm source (at the condenser). It should be noted that gas heat pumps offer excellent energy and environmental performance.

With regard to the total primary energy consumption, there is genuine equivalence between electric heat pumps and gas heat pumps, as shown in the diagram below (EnergiePlus). However, gas heat pumps differ significantly from electric heat pumps with regard to the sizing of the cold source, which allows for the use of a smaller evaporator. This is a very interesting feature! If the cold source is outside air, the evaporator and fans will be smaller, reducing the investment required for the evaporator part of the system. It follows that energy use by auxiliary equipment will also be reduced. If the cold source is water, and more specifically, geothermal energy, the size of the geothermal system is reduced by nearly two-thirds. On this basis, use of a gas heat pump represents a significant improvement, particularly when set against the **design and operation of a geothermal energy system**, where the significant upfront investment required to cover a large number of ground loops, excavation to a significant depth, etc., is a major constraint.

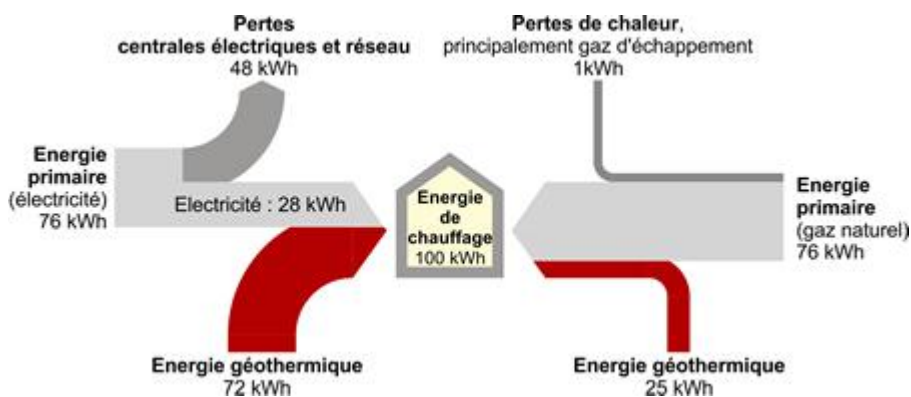


Figure 5: Comparison between electric heat pump and gas heat pump (EnergiePlus)

Pertes centrales électriques et réseau	Power plant and network losses
Pertes de chaleur	Heat losses,
Principalement gaz d'échappement	primarily exhaust gases
Energie primaire (électricité)	Primary energy (electricity)
Electricité	Electricity
Energie géothermique	Geothermal energy
Energie de chauffage	Heating energy
Energie primaire (gaz naturel)	Primary energy (natural gas)
Energie géothermique	Geothermal energy

I.1.3.4 Potential benefit and relevance in the BCR

Heat pumps can be used both in residential settings and the service sector (to heat a swimming pool, for example), and for specific applications in industry. However, it is **cost-effective** only in very specific situations, primarily for **service sector and industrial buildings** that meet one of the criteria below:

-If particular premises generate large internal gains during the winter: computer room, premises with equipment generating significant heat such as an X-ray room, printing plant, industrial processes with heat discharges, etc., the heat from these premises may be extracted via a heat pump and delivered to other premises where there is demand for heat.

-If a premises' needs fluctuate significantly over time (for example, a series of small shops in a shopping centre, with, in winter, premises that require heating while their neighbours overheat under spotlights).

-If the building is fitted with a hygienic air handling unit which requires heating in the winter and cooling in the winter: since the heat pump is reversible, it kills these two birds with one stone.

-If the building includes warm, damp areas (a swimming pool or a laundry room, for example).

A heat pump is a practicable solution for **thermally efficient buildings** (classified as low energy at least) or **buildings with negligible heating needs**, where in both cases it becomes possible to use the free heat that is present in the environment.

In an energy retrofit, if heating capacity has been reduced by means of good insulation, the old radiators can operate with water at 50 °C under external temperature conditions of -10 °C, making them usable with the heat pump, which can also be combined with underfloor heating.

Ease of access to the cold source differs between urban and suburban and rural settings. In dense urban settings, **geothermal heat pumps with vertical ground loops** and air-source heat pumps are most suitable, as they take up very ground space. In towns and cities, though, there is a risk that air-source heat pumps could be a major nuisance if their use becomes widespread. The Inspectorate of the Brussels Environmental Authority (IBGE) has to deal on a regular basis with complaints about noise from HVAC equipment, and a proportion of these complaints relate to air-source heat pumps.

Soil conditions may determine whether ground loops can in fact be placed, however: a recent study by VITO, a Flanders-based research organisation, showed that regrettably, this type of heat pump cannot be installed in all

locations throughout the Brussels-Capital Region (source: Vito). It is therefore imperative to engage specialist firms to carry out soil testing. In addition, it should always be ensured that the ability of the soil to regenerate its heat is not exceeded. As such, the energy that can be drawn from the ground must be restricted, to ensure that it is regenerated. If it is likely that the geothermal energy project will pump out too much energy, there is a risk that in the medium term, the soil will become too cold and therefore unusable. This pitfall can be avoided by giving preference to the use of a reverse-cycle heat pump that returns heat to the soil in summer to generate cold for service sector buildings, combining residential and retail or office developments for district-scale projects, or reducing the heating needs of residential buildings with passive design.

Ground-source heat pumps with horizontal ground loops require sufficient unobstructed ground space. Water-source heat pumps exploit a source of energy that is not universally available. In the Brussels region, only the Brussels and Paleocene aquifer systems might have the required characteristics, in principle. Additionally, highly detailed preliminary studies are required for these systems, meaning that they are only of interest for large development projects with more or less equivalent heating and cooling needs.

I.1.4 Electric heating

I.1.4.1 Definition and characteristics



Figure 6: Electric heating coil (Source: Helios)

In the best case, a gas/steam turbine power plant generates power with 55 % efficiency. In contrast, the production efficiency of a gas boiler is over 90 %; for a gas condensing boiler, it is 100 %. The **energy balance** of electric heating connected to the electricity grid is always **negative**, therefore, and electricity should not generally be used for space heating. It is only with the use of a heat pump that electrical energy can be used efficiently in some cases and thereby make up for poor power station efficiency.

There are **two types of electric heating**: direct electric heating and electric accumulation heating.

In the case of **direct electric heating**, heat is produced and emitted at the place and time of demand. The **cost of installation** for direct electric heating is of course very low, which is attractive, but it should be remembered that the **cost of use** per kWh of electricity used in the daytime (inclusive of peak demand) is around double that of a gas- or oil-generated thermal kWh. From an economic perspective, this type of heating is therefore only practicable for use as **supplementary heating** or for **buildings with minimal or intermittent heating needs** (passive buildings, buildings or premises with an occasional demand for heat, etc.). In addition, electric radiators have a very short response time, so are well-suited to situations of low heating need. Lastly, temperature control is very accurate and, compared with other systems examined, it is an approach that saves space in the building.

Electric accumulation heating is based on drawing current during off-peak hours so as to produce heat at a lower cost than direct electric heating, storing it in an accumulator. The accumulated heat is then delivered on demand. The cost of use of this type of heating is lower, but it does have a number of disadvantages (EnergiePlus):

- system inertia has a **significant adverse impact** on control and therefore on **efficiency**;
- the **investment is significantly higher** than for direct heating;
- high capacity accumulators are very **heavy**, and this should be factored in right from the project design stage.

I.1.4.2 Constraints

The major constraint associated with electric heating connected to the Belgian grid is its **impact on the environment**. For buildings with high thermal efficiency that are designed for minimum heating consumption (passive buildings), direct electric heating may initially appear to have potential value. However, given the Belgian energy mix, this does not apply in Belgium. Here, **the conversion factor for converting final energy to primary energy** is **2.5** for the consumption of electrical energy from the Belgian grid. This means that for a passive building with net heating energy needs of $15 \text{ kWh}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$, total primary energy consumption for direct electric heating will be:

- $14.7 \text{ kWh}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$ with a condensing boiler (with a seasonal efficiency evaluated at 102 %);
- $37.5 \text{ kWh}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$ at the power plant.

The EnergiePlus site illustrates this principle by showing that, for an individual residential passive building with 20 cm of wall insulation, the use of electric heating takes its primary energy consumption to the same level as that of a building which has just 8 cm of wall insulation but is also fitted with a gas condensing boiler.

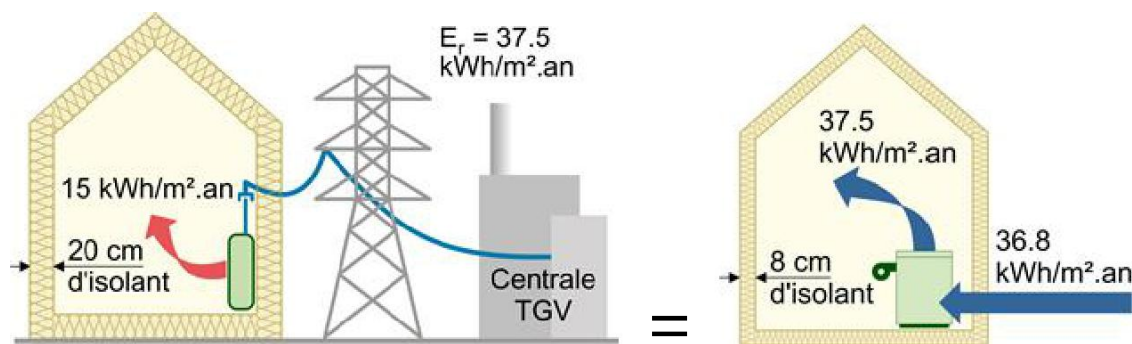


Figure 7: Comparison of the insulation requirement with electric heating and with a gas condensing boiler for the same level of primary energy consumption (source: EnergiePlus)

D'isolant	of insulation
Centrale TGV	Gas/steam turbine power plant
D'isolant	of insulation

I.1.4.3 Choice of energy source

The previous paragraphs have explained why electric heating **connected to the Belgian grid** can only be used for **supplementary heating**. For example, it can be used as an **add-on to thermal solar panels** to heat domestic hot water. This supplementary need could also be met by a condensing boiler, though (although it takes up more space).

Direct electric heating can be powered by a **renewable source of energy** (photovoltaic solar panels or wind turbines), which makes it a form of renewable energy heating. However, it is essential not to overlook the fact that the use of photovoltaic solar energy to power a source of heating also conflicts with its potential for covering a building's other energy needs (for lighting, computing, running an electric vehicle, etc.).

In regard to wind turbines, the efficiency of small turbines designed for urban settings is currently too low and their noise emissions are troublesome. There is also a frequent risk of breakage (CERAA et al., 2009). For these reasons, they will be disregarded in the remainder of the report.

A more detailed analysis shows that photovoltaic solar energy cannot currently meet all the direct electric heating needs of Brussels' passive residential buildings given that, on average, buildings are more than two storeys high (ground floor + first floor). Conversely, it would cover the needs of a heat pump with a seasonal performance factor (SPF) of at least 3, and the needs of dwellings with low heating energy requirements as a minimum. The difficulty of combining a heat pump with photovoltaic energy resides in the capital cost, however, which can be extremely high.

Although in most cases a photovoltaic installation will not yet cover electric heating needs in their entirety, it is

worth noting that the principle of tradable green certificates makes it a good investment (in Brussels, the payback for an individual is around seven years; with larger, more cost-effective installations it is better and may be achieved in as little as five years). In addition, the energy efficiency and/or the financial return associated with photovoltaic solar panels are likely to improve in the future. In spite of this, taking a holistic approach to the building, it seems more prudent, environmentally speaking, to use the green electricity generated by photovoltaic solar panels primarily for uses that can only be covered by electricity, such as lighting and office equipment, and to opt for another, more efficient source of heat energy for heating buildings.

I.1.4.4 Potential benefit and relevance in the BCR

As it stands, the potential value of electric heating lies in its ability to **provide additional energy on an ad hoc basis**, without losses, given an electrical efficiency in use of close to 100 %. They are therefore useful for heating small spaces that require heating at different times from the rest of the building (for example, a security room that is in use throughout the night) or for buildings that are occupied only intermittently (holiday rental properties, etc.). Electric heating is currently very detrimental from an environmental perspective, but this **could change in the future** with the development of new, more efficient types of photovoltaic solar panels or an improvement in the Belgian energy mix for electricity generation.

I.1.5 Thermal solar panels

I.1.5.1 Definition and characteristics

There are two types of technology for harnessing solar energy directly: thermal solar technology and photovoltaic solar technology. Thermal solar technology uses solar collectors to convert solar energy into heat, while photovoltaic technology converts solar energy into electrical energy.

Thermal solar panels can be installed on both new builds and existing buildings. In Belgium, they provide a renewable means of addressing a significant proportion of buildings' domestic hot water production needs, with the advantage that they use renewable solar energy. While solar panels themselves do not emit greenhouse gases when in operation, these gases are emitted as part of the manufacturing process for the panels. In addition, the use of thermal solar potential is non-polluting, although consideration must also be given to the electricity consumption of the auxiliary equipment required for installation (which should be minimised) and to the energy consumption of the add-on system required to produce domestic hot water.

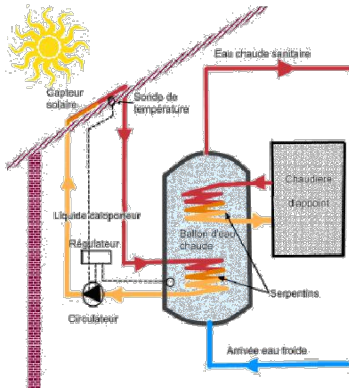


Figure 8: Operating principle of thermal solar panels (source: www.notre-planete.info)

Capteur solaire	Solar collector
Sonde de température	Temperature sensor
Eau chaude sanitaire	Domestic hot water
Liquide caloporteur	Heat transfer liquid
Régulateur	Controller
Circulateur	Circulator
Ballon d'eau chaude	Hot water tank
Chaudière d'appoint	Supplementary boiler
Serpentins	Ground loops
Arrivée eau froide	Cold water inlet

There are several types of collector, as described in the table below (source: Hegger et al., 2011). The most commonly used are flat plate collectors, and these are the focus of attention in this report. Opinion is divided on the efficiency of tube collectors, and under ideal solar exposure conditions, the additional cost is not necessarily justified.

Types of collector	Operating temperature	Application
<i>Bare absorber plates</i> No insulating container, no glass cover	30-40 °C Efficient only at low temperature as losses are significant	Swimming pool heating
<i>Flat plate collectors</i> The absorber plate is in an insulating container and protected by a special glass cover	60-90 °C Losses are limited by the container and the glass cover	Production of domestic hot water and heating
<i>Air collectors</i> Same as for flat plate collectors, except that air takes the place of the heat transfer fluid	40-50 °C	Warm air space heating
<i>Vacuum tube collectors</i> The absorber plate is placed in a vacuum glass tube	70-130 °C Convection losses in the collector are almost completely eliminated	Production of domestic hot water and heating (residential or industrial)

The efficiency of a thermal solar collector depends primarily on:

- the solar fraction (or solar coverage rate);

- the amount of solar energy received, which in turn is dependent on the siting of the collectors (orientation and tilt) and the time of day and year;
- the efficiency of the many heat transfers;
- the desired water temperature (as low as possible);
- storage (sizing and losses).

They have a lifespan of at least 25 years and offer a kWh price that remains stable throughout the life of the system.

I.1.5.2 Constraints

The harnessing of solar potential is highly dependent on the built context into which it is incorporated. For a solar water-heater to be efficient, installation of the panels must adhere to particular requirements in terms of roof area and orientation and must consider neighbouring buildings that create shade. This is even more of a constraint in energy retrofits of existing buildings and districts (Penders et al., 2015). A specific survey of **solar potential** is required in all cases, to evaluate the actual potential in relation to the orientation of the building, the type of roof and its tilt, shade from the surroundings, etc.

The solar energy provided varies with the seasons and input will differ considerably between winter and summer. This technology is therefore appropriate where there is **regular demand for hot water in summer**. It should also be noted that some systems may need to be flushed out in the winter.

In the case of individual domestic systems, the **economic optimum** for the system is that it should cover 50 % to 70 % of annual domestic hot water needs. In larger systems, such as for multi-family housing, the economic optimum is often between 20 % and 40 % (de Meester & de Herde, 2012). This means that additional energy is required not just for heating, but also for the proportion of domestic hot water production that is not covered by the solar panels.

One of the principal constraints is that the **economic return** on thermal solar panels continues to depend on investment subsidies. The payback period on fixed energy costs (for gas and electricity) for the solar collector is around 20 years for a newly installed system, 15 years if the water heater alone needs replacing and over 10 years if subsidies are taken into account (IBGE 2015).

Lastly, in systems that require warm water to be stored, the conditions for the **development of legionella**, a bacterium which is hazardous to health, are created when the water temperature stagnates between 25 and 45 °C. The solutions to this are to increase the temperature of the stored water periodically in order to kill the bacteria, to use a system that prevents the water from stagnating, or to store the water at a sufficiently high temperature (De Herde & Massart, 2010). In the latter case, however, the result is reduced collector performance.

I.1.5.3 Thermal or photovoltaic solar energy?

Since roof surface area is finite, it should be noted, when looking at solar renewable energy, that thermal and photovoltaic energies are in **competition**. In Brussels:

- Thermal solar energy satisfies heating use needs (domestic hot water) in the region of 350 to 500 thermal kWh/(m².year).
- Photovoltaic solar energy covers around 120 to 160 electric kWh/(m².year).

Thermal solar energy is not an attractive option for heating in Belgium as the majority of heat production occurs outside the heating season. In contrast, photovoltaic energy could be considered for this type of application as an add-on to a heat pump.

On the other hand, though, thermal solar panels are still more efficient for domestic hot water production than photovoltaic panels in terms of energy produced per m².

I.1.5.4 Potential benefit and relevance in the BCR

Thermal solar panels are a **useful technology** for the BCR for renewable domestic hot water production, primarily for thermally efficient buildings (low energy or better), but also for service sector buildings which have significant hot water needs in summer, such as dry cleaners, swimming pools, hotels, restaurants and hospitals.

I.1.6 Industrial solutions

I.1.6.1 Definition and characteristics

Four heating solutions are available for industry: **centralised systems with a boiler and emitters, recovery of unavoidable energy, infrared radiation heating and hot air heating.**

This report has already covered two efficient solutions providing centralised systems with a boiler and emitters that can be configured for use in certain types of industry: **condensing boilers** and **high-efficiency cogeneration**. This section looks at the other three types of solution for meeting industrial heating needs: **recovery of unavoidable energy, infrared radiation heating and hot air heating**, which are more specific to industry.

Recovery of unavoidable energy

The most environmentally friendly, cheapest kind of energy is energy that is not wasted. Many industries generate waste heat from industrial processes, engines (via dissipation or exhaust gases), heat-power couples or any other equipment that generates heat. This is known as **waste heat**, defined as the **heat produced by a process that is not specifically intended to produce this heat** and which, as a result, is not necessarily recovered. Waste heat recovered for use is deemed to be a **non-CO2** energy source in that it consists of the use of a resource that is produced and released in any case. The **recovery of waste heat** therefore offers **very significant potential** for energy and environmental improvements in industry.

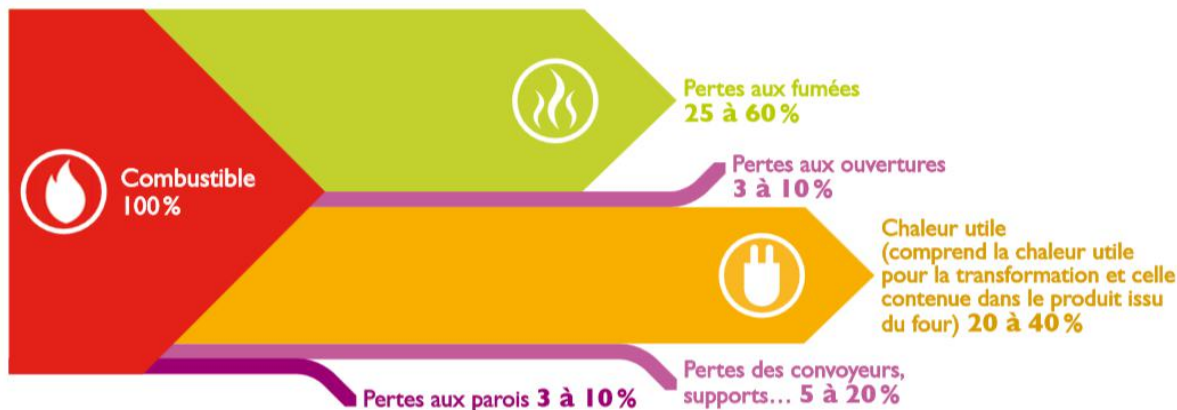


Figure 9: Operating principle of a heating fuel-fired furnace and unavoidable energy produced (source: ADEME)

Combustible 100 %	Heating fuel 100 %
Pertes aux fumées 25 à 60 %	Losses through flue gases 25 to 60 %
Pertes aux ouvertures 3 à 10 %	Losses through apertures 3 to 10 %
Chaleur utile (comprend la chaleur utile pour la transformation et celle contenue dans le produit issu du four) 20 à 40 %	Useful heat (includes useful heat for conversion and the heat contained in the product coming out of the furnace) 20 to 40 %
Pertes des convoyeurs, supports... 5 à 20 %	Losses from furnace conveyor belts, mounts, etc. 5 to 20 %
Pertes aux parois 3 à 10 %	Losses through furnace walls 3 to 10 %

An obvious example of waste heat is the heat released from waste incineration (a process whereby the primary purpose is to destroy waste rather than producing energy) in household waste incineration plants. In France, for example, waste incineration today provides 21 % of all the energy distributed by the country's district heating networks, far ahead of biomass and geothermal energy. However, large quantities of heat are also produced by the steel-making, chemicals, cement, food-processing and glass industries, as well as by power plants, refineries and certain service sector buildings such as hospitals and data centres, and this is often lost into the atmosphere. The temperatures of the heat recovered can range from 30 °C (for waste water) to 500 °C (for combustion gases, etc.). According to statistics for French industry published by ADEME, the French Environment and Energy Management Agency, around 17 % of industrial fuel consumption is lost as waste heat above a level of 100 °C (the minimum temperature considered to be most efficient as regards energy recovery).

There are **two complementary approaches to the use for heating** of recovered waste heat: **internal use**, to meet the business' own heating needs, and **external use**, to meet the heating needs of other businesses or an area (encompassing residential and service sector buildings) via a district heating network. The unavoidable energy is transferred to the network for the building or to an urban district heating network via a **heat exchanger**. In this way, industrial processes may act as a source of heat supply for an area of industrial, service sector or residential activity.

In addition to use for heating, the waste heat can be used to **generate electricity**, which can then be used in situ or sold back to and fed into the electricity grid. However, while direct use for heating is possible (if there is a significant heating need close to the site), the latter solution is a better fit with regard to energy efficiency.

The most promising technology for generating electricity from unavoidable energy with a temperature of more than 150 °C and less than 350 °C is offered by Organic Rankine Cycle (ORC) machines. The benefits of converting waste heat into electricity are the low environmental cost of producing electricity in this way, better use of the energy from the fuels that are the source of the unavoidable energy and an approach to implementation that is independent of geographical conditions and local context, since electrical energy is very easy to transport, even over long distances, which is not the case for heat.

The differing temperature levels for use in the form of heat and use for electricity generation mean that these two forms of use are coherent and complementary. Once the recovered heat reaches a certain temperature (around 150-200 °C), it becomes possible to produce electricity. In contrast, the recovery of heat for district heating does not necessarily require such high temperature levels. For lower temperatures, **heat pumps** provide a means to use sources of waste heat; these have already been described in this report. **Cogeneration** also allows both forms of use to be combined, thereby taking advantage of their respective benefits.

Radiation heating

A particular feature of industrial sites is that they often have **very high ceilings** and therefore **large spaces to heat**. This results in very poor efficiency for conventional central heating systems where the aim is to disperse heat right throughout the building, often with very high associated energy costs. More often, though, the intention is to **create comfortable conditions for the occupants** in this kind of setting rather than heating the premises as a whole. **Radiation heating** (using dark tubes or infrared radiation) offers a particularly appropriate way of addressing this issue. It has the particular feature of transferring heat to the liquids and solids that it encounters, without heating the ambient air. This type of heating is ideal for heating open spaces or enclosed buildings with an elevated ceiling height. The technique makes use of collectors, a liquid and emitters (radiant heating panels, single-unit low-temperature radiant tubes and modular low-temperature radiant tubes).

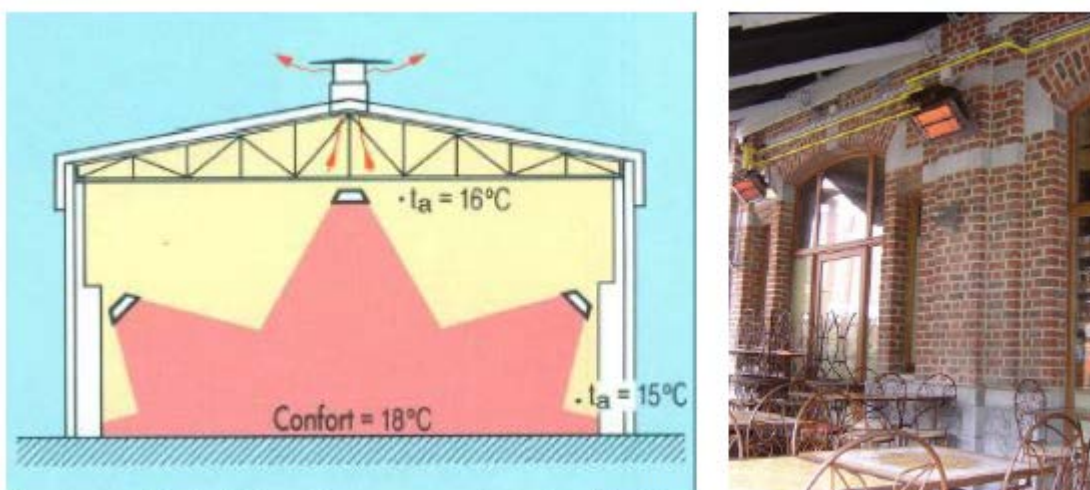


Figure 10: Operating principle and photo of infrared radiant heating. (Source: www.thermico.be)

Confort	Comfortable
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Radiant heating technology makes use of equipment placed at a height of 3 to 20 m above ground, suspended from the roof structure or affixed to the wall. These devices have instantaneous start-up, making them

economical and easy to use. Even distribution of units is required to ensure uniform coverage at ground level. The thermal efficiency of the units used is in excess of 90 % and they eliminate the inherent losses of distribution systems for centralised solutions. They are also easy to install and maintain. For **buildings with poor insulation and an elevated ceiling height**, they reduce the heat lost through the walls and through air exchange by around 15 %, providing energy savings that generally exceed 30 % and may reach 70 %. An example is the main lobby at the ARGB laboratory in Brussels, which has a floor area of 500 m² and a height of 8.4 m and is not thermally insulated. When its heating system, based on six 70 kW hot water heaters, was replaced with six dark radiant tubes of 30 kW each, placed at a height of 6 m, the energy saving over one year was 58 %.

Hot air heating: direct-fired makeup air unit

Industrial activity often generates pollutant emissions (noxious fumes, smoke, dust, etc.) inside buildings, hence the need to replenish with new air continuously during occupancy periods at elevated rates of air exchange (> 2).

The makeup air unit provides a cost-effective means of heating the outside air introduced into the premises. It is a simple design providing 100 % efficiency at LHV with direct combustion of gas in the air stream drawn in by a centrifugal fan. It offers significant flexibility of operation and does not require a boiler room, machine room or flue. Direct-fired makeup air units **running on gas** are designed primarily for industrial premises.

Their use is called for in certain types of industry: surface treatments, galvanisation, scouring, foundries, paint shops, body shops, and indeed any premises where there is a need to deliver air at a high rate of air exchange to offset the extraction of exhaust air ('complete outside air' operation).

I.1.6.2 Constraints

The main constraint associated with the thermal recovery of waste heat, other than the existence of usable waste heat potential, is the need to align the energy generated from the recovered waste heat with the heating needs of the industry in question and its surrounding area of industrial, service sector and residential activity.

Furthermore, if the waste heat recovered has to be reused externally for urban district heating, the overall constraints of this kind of infrastructure (as detailed in the section on district heating) will also have to be considered.

The limitations on the conversion of waste heat into electricity are a minimum temperature level of 150 °C for the recovered heat and a significant capital cost relative to the expected saving from the self-consumption of electricity.

Radiant heating requires an adequate ceiling height of at least 5 m. It cannot be recommended if the rate of air exchange is greater than 2 and is therefore unsuitable for premises requiring significant air exchange. In this scenario, the cost of radiant heating and an air exchange system is greater than if the heating system were built directly into the air exchange system.

Lastly, direct-fired makeup air units require the presence of pollutant emissions with a significant rate of air exchange (in excess of 2). They also present the disadvantage of being slow to start up.

I.1.6.3 Choice of technology

There are three characteristics of industrial buildings that will influence the use of these different techniques: the **potential waste heat produced**, the **ceiling height of the premises**, the **rate of air exchange for the premises** and the **level of insulation in the walls of the building**.

If there is potential for waste heat, priority should be given to carrying out a specific technical and economic study on the potential benefit of recovery. If this solution is ruled out, centralised systems with a boiler and emitters will be preferred in thermally efficient buildings with no particular pollutant emissions. Energy-hungry buildings with elevated ceiling heights (> 5 m) will be installed with radiant heating. Lastly, buildings with sources of pollutant emissions which therefore require substantial rates of air exchange (> 2) will be installed with warm air heating, which includes proven technologies such as direct-fired makeup air units.

I.1.6.4 Potential benefit and relevance in the BCR

Of the four heating solutions for industry (centralised systems with a boiler and emitters, the recovery of waste

heat, radiation heating and warm air heating), the best solution varies according to the unavoidable energy available and the type of premises to be heated. In all cases, though, **analysis of the potential for recovery of unavoidable energy** is always advisable. A **specific study** of the potential for recovery of unavoidable energy in the BCR area **should be considered**.

I.1.7 District heating

I.1.7.1 Definition and characteristics

Directive 2010/31/EU defines ‘district heating’ or ‘district cooling’ as ‘the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling’. In the case of urban district heating, heat recovered from a waste heat source or produced by one or more power generation plants, is distributed in the form of steam or hot water throughout a group of buildings via a network of underground pipelines. A heat exchanger then needs to be installed in every building connected to the network. Substations should be provided for large-scale networks.

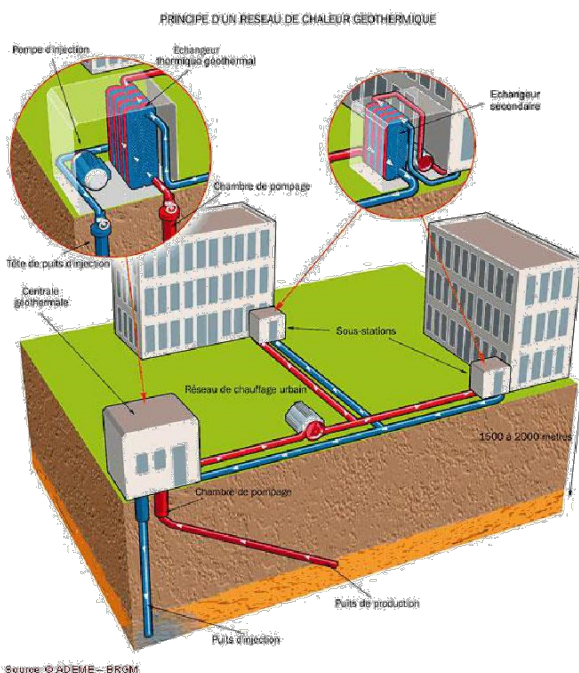


Figure 11: Operating principle of a geothermal heating network (source: ADEME-BRGM)

PRINCIPE D'UN RESEAU DE CHALEUR GEOTHERMIQUE	OPERATING PRINCIPLE OF A GEOTHERMAL DISTRICT HEATING NETWORK
Pompe d'injection	Injection pump
Echangeur thermique géothermique	Geothermal heat exchanger
Chambre de pompage	Pumping chamber
Echangeur secondaire	Secondary exchanger
Tête de puits d'injection	Injection well head
Centrale géothermale	Geothermal power plant
Sous-stations	Sub-stations
Réseau de chauffage urbain	Urban district heating network
1500 à 2000 mètres	1 500 to 2 000 metres
Chambre de pompage	Pumping chamber
Puits de production	Production well
Puits d'injection	Injection well

The main advantage of a heating network over decentralised heat generation solutions is the **variety of energy sources** that can be connected to it (including renewable energy sources and waste heat), as well as the **flexibility to make changes** over time in the associated sources of energy that are used. For a given region,

this allows effective objectives to be set in terms of energy independence, security and efficiency, greenhouse gas reduction and the potential for use of renewable energies. This type of system can be used to connect a wide variety of buildings and building uses, such as offices, industrial premises, housing and hospitals. There are other significant advantages to centralisation in this way, too:

- heat production is centralised in powerful industrial boilers that are maintained and monitored by a centralised maintenance function;
- the pollution associated with heat generation is centralised, making it easier to address than when it is produced by individual buildings and dispersed throughout a town or city;
- it makes it easier to use certain renewable energy assets that are difficult to harness in urban areas for individual buildings, such as geothermal energy or the waste heat that originates from industry and from waste incineration plants, as well the most efficient technologies for generating heat, particularly cogeneration.

District heating networks are local systems which **should be adapted for each individual area**. This is a plus in the sense that they can thus take the specific features of the local area into account, but also a drawback to the extent that development projects are more complex to initiate and complete compared with other energy networks with much more uniform countrywide models.

I.1.7.2 Constraints

District heating networks require a significant **initial outlay** which is much higher than for other energy networks (because of the major infrastructure requirement) (Lebbe 2013). The overall cost of a district heating network is EUR 300 to 500/kW excl. tax (Seynhaeve 2012). In addition, the presence of the distribution network results in **heat loss** ranging from 5 % for the most efficient networks to 15-20 % for older networks.

For this type of system to be both economical and energy efficient, **consumption density** must be high. This favours dense urban environments and environments that incorporate buildings given over to uses that require large amounts of energy, such as hospitals and certain types of industry. In fact, the economic return on the network depends primarily on the density of the heating needs that it covers, i.e. the amount of energy provided by the network per unit length of pipe. Obviously, the density is a reflection of heating needs: the number and types of consumers supplied by the network (houses, apartment blocks, service sector, industry, etc.), the harshness of the climate, how well buildings are insulated, and so on. There are slightly differing views on the **lower limit of linear heat load density** (KWh/m):

- According to MATRIciel (2010), the connection density must exceed 1 500 kWh/m and 1.5 kW/m. Therefore, taking as an example buildings separated by an average of 10 m, each building has to reach a threshold of 15 kW. For passive buildings, this translates as a continuous frontage encompassing at least four storeys (ground + three upper floors) and for low-energy buildings, a continuous frontage of at least two storeys (ground floor + one upper floor).
- According to the report by Capgemini Consulting (2010) commissioned by the Walloon Public Service, the linear heat load density should exceed 2 kWh per linear metre of heating network. On this basis, therefore, passive buildings would require a continuous built frontage encompassing at least five storeys (ground + four upper floors), while a continuous frontage of at least three storeys (ground + three upper floors) would be needed for low-energy buildings. Seynhaeve (2012) also describes 2 000 kWh/m as the threshold value beyond which the linear density of the district heating network has little impact on energy costs.
- In the new district heating networks implemented in France over the last few years, particular attention has been paid to reducing heat loss in the network, with the result that their linear density can be as low as 1 000 kWh/m (Le Dû, 2012).

As a safeguard, the lower linear heat load density threshold value chosen here is **2 000 kWh/m**.

It is therefore not impossible to achieve such linear densities in dense, continuous urban settings as in Brussels, in as much as they are much easier to achieve with older, poorly insulated buildings. However, a district heating network should be considered as a long-term facility and as such, buildings may potentially be subject to energy efficiency improvements during the life of the district heating network. It is therefore advisable to check the

economic return on district heating if all buildings achieve low-energy status.

The other kinds of significant constraints relating to the installation of urban district heating are:

- the lengthy feasibility study required;
- the complexity that results from the number of stakeholders involved (to obtain permits, etc.);
- the impact of future building energy efficiency improvements on the consumption density of the group of buildings or district installed with a heating network and therefore on the long-term cost-effectiveness of the associated district heating network;
- the long-term commitment that this system implies;
- urban constraints such as the earthmoving operations and roadworks required to install it;
- the difficulties of contracting when both public and private sector entities are involved;
- lack of awareness amongst users, who are generally not aware of the energy efficiency and environmental benefits of district heating.

Despite all these pressures, the Walloon Union of towns and communes takes the view that, 'An existing built context is not an insuperable obstacle to creating a district heating network, given that this has been the situation in most of the recent district heating projects undertaken in Wallonia.' (*Union des Villes et Communes de Wallonie*, 2009)

I.1.7.3 Choice of energy source

The recovery of unavoidable energy or the use of a renewable source of energy should be preferred as far as possible. However, generating heat by means of cogeneration and/or a gas condensing boiler is a useful alternative.

Network supplied by unavoidable energy

District heating is an excellent means of using waste heat to heat industrial buildings and other buildings close by. The unavoidable energy is transferred to the network via a heat exchanger.

The particular issue that must be overcome in the feasibility study for a district heating network supplied by unavoidable energy is the often considerable distance between the area where the unavoidable energy source is generated (usually an incinerator or an industrial facility) and the areas with a high potential heat demand (generally dense urban environments). It is the case that while the location of the boiler for a network supplied by cogeneration, biomass or by geothermal or hydrothermal energy depends on the area to be supplied with heat, the places where unavoidable energy can be recovered are often sited away from housing or office districts. A further issue is the potential mismatch between the availability of heat from the unavoidable energy source and the needs of the network. Lastly, a final constraint lies in the fact that district heating implies a long-term commitment, which therefore requires that sufficient unavoidable energy will continue to be produced in the long term.

Network supplied by a source of geothermal or hydrothermal energy

In the specific case of geothermal and hydrothermal energy, it is advisable to install a decentralised heat pump network for each building, connected via a shared water loop to the central cold source. It is also worth pointing out that Belgium offers no potential for deep geothermal energy.

Network supplied by a cogeneration system

The use of district heating helps in developing an in-depth understanding of heat demand profiles, therefore providing the means for optimal operation of the cogeneration unit. The higher the cogeneration power capacity and the longer the operating period, the better the energy and financial return on investment. The combination of

cogeneration and urban district heating is thus a useful alternative, since the plethora of different individual heat demand profiles combine to provide the overall heating network with a profile that is generally good. This increases the number of operating hours for the cogeneration unit, thereby making it more cost-effective.

Value of a heat pump for supplementing a network supplied by cogeneration

Using heat pumps to supplement a cogeneration system helps to improve its efficiency (this is how today's much more economical domestic tumble dryers work), while at the same time bringing the heat-carrying fluid up to the desired temperature. The system reuses the residual heat from combustion, condensation of the water vapour contained in flue gases, radiation losses from the thermal system and, in trigeneration mode, additional heat from the environment, typically geothermal, combining them with cogeneration to produce further useful heat. In this scenario, the **total useful energy** produced is **double the amount produced by a condensing boiler**. With the same quantity of gas burned. Assessed in terms of the lower heating value (LHV) of the heating fuel burned, the energy use factor ranges from 1.8 to 2.3 depending on the availability of supplementary energy from the geothermal source or the environment (which may be none). This level of energy efficiency is very similar to that of fuel cells currently in development, but with a lower electricity-to-heat ratio for cogeneration.

Network supplied by thermal solar panels

Some countries, such as Denmark, Italy and Spain, are already using the energy from thermal solar panels in district heating, but it is used far less in other countries, like France, where just one network was making use of this form of energy in 2014. However, ADEME, the French Environment and Energy Management Agency, has produced a guide to designing solar district heating networks for use in ecodistricts. In Germany, the district of Freiburg has opted to centralise the production of domestic hot water with a small local district heating network using solar energy produced by vacuum tube collectors, a set-up which allows more efficient performance to be achieved.

At decentralised level, it has been found that in Belgium, solar input does not coincide with heating demand. At the scale of an urban district network, however, it is possible to store the solar energy produced during the summer, and both medium- and long-term storage systems are available. Conventionally, energy is stored in large volumes of several tens of thousands of cubic metres, the aim being to minimise the ratio of energy stored to heat transfer surface. As such, a storage density of 50 kWh/m³ and a volume of 60 000 m³ allows for the storage of 3 GWh. There are a few sites in Europe where this type of storage has been installed. Other systems that might have greater stored energy densities have also been examined. These include phase-change materials and endothermic and exothermic chemical reaction techniques.

While this type of network exists, the initial outlay is still too high and represents a considerable investment cost that results in higher kWh production costs than for other renewable energies that could be used to supply the same network (biomass, geothermal energy, etc.). Lack of space may also be an obstacle, as thermal solar power stations and storage systems require large areas for installation which are difficult to reconcile with a dense urban environment. It is therefore recommended that for Brussels, preference is given to decentralised thermal solar systems for each building, to meet domestic hot water needs only.

Network supplied by a biomass boiler

It was seen in the section on condensing boilers that biomass boilers are only recommended for Brussels where waste from a local industry can be reused (wood waste from a sawmill, for example). If this is the type of heat production selected, care should be taken to choose a wood or pellet boiler (or boilers) with a nominal efficiency of around 92 %. As with district heating networks supplied by unavoidable energy, a final constraint lies in the fact that district heating implies a long-term commitment, which therefore requires that sufficient local biomass will continue to be produced in the long term.

I.1.7.4 Potential value and relevance in the BCR

There are numerous reasons why this approach might be suitable in Brussels: consumer density and diversity (in terms of extent, needs and profile), the presence of numerous housing and other development projects and the production of waste heat (from incinerators, industrial facilities, etc.). However, the constraints of district heating networks, particularly those associated with the urban context, are significant and therefore warrant careful consideration.

It should also be emphasised that there is little experience of district heating in Brussels, which does not make

implementing this kind of project any easier. There are number of active district heating networks in Brussels, though, on major university sites or associated with hospitals: the ULB (*Université Libre de Bruxelles*, Free University of Brussels) Solbosch campus, the ULB/VUB (*Vrije Universiteit Brussel*) La Plaine campus, Saint-Luc university hospital, the Brugmann hospital's Horta site and AZ-VUB Laarbeek university hospital [now UZ Brussel Hospital]. A recent example of a district heating network in Brussels is the new Bervoets sustainable district in Forest, on a Brussels Regional Development Agency (SDRB) site with 239 homes (houses, duplexes and other apartments) and 12 shops and workshops connected to a central boiler and a district heating network. However, there is a need to make a full inventory of all existing district heating networks in the BCR and examine the potential for extending them to neighbouring apartment blocks or buildings.

To conclude, district heating offers real long-term potential for specific groups of buildings and districts in Brussels, allowing heat to be recovered and renewable energies to be used simultaneously. The minimum linear heat load density threshold to ensure financial viability could be taken as 2 000 kWh/m in the first instance, but it is crucial to carry out a feasibility study, since the decision on whether to invest needs to be made on a case-by-case basis.

According to the Brussels Enterprise Agency (BEA), the success factors for an urban district heating project are (BEA, 2010):

- a strong project owner (sponsor, municipal authority, incinerator, etc.);
- captive long-term consumers (public authorities, housing developments, etc.);
- an adequate consumption density;
- commitment from local authorities;
- adequate generation (renewable if possible);
- an enabling regulatory environment (building energy performance, green certificates, etc.);
- a financial benefit (waste heat, subsidies, etc.).

BEA (2013) strongly advocates small urban district heating projects that connect a small number of buildings with a central boiler and where the producer is also the consumer and the project owner, making it easier to set up the project and generate a return. The Agency also advocates district heating projects for new housing developments when the project owner is the developer and enlists the services of an experienced operator. It seems that district heating should also be investigated (although with additional constraints) in cases where the project owner is a producer of waste or green heat and partnerships can be forged with major industrial or public sector consumers close to the site where the heat is produced. BEA (2013) emphasises the difficulty of securing buy-in from individual consumers in the latter instance.

I.2 TECHNOLOGIES TO MEET COOLING NEEDS

The following technologies will be discussed:

- passive cooling
- renewable cooling
- absorption cooling and trigeneration
- district cooling

For each technology, the following aspects will be described:

- definition and characteristics

- constraints
- choice of energy source or technique
- potential value and relevance in the BCR

I.2.1 Passive cooling

I.2.1.1 Definition and characteristics

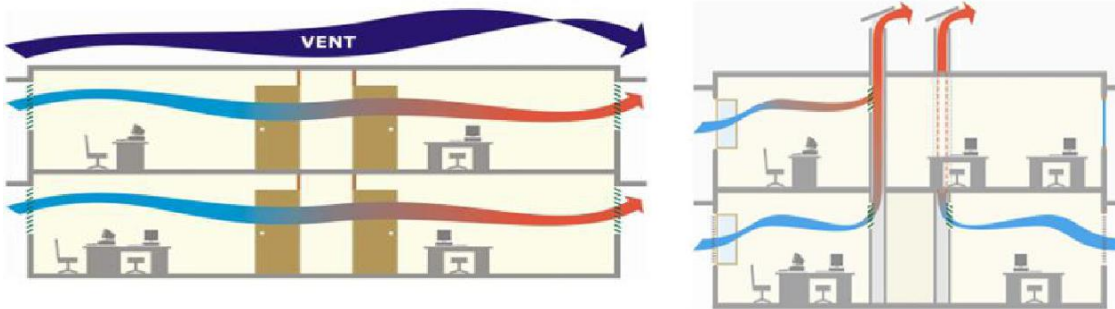


Figure 12: Examples of passive cooling (source: EnergiePlus)

VENT	WIND
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Passive cooling consists of reusing cold from the natural sources of the air and the ground. It is consistent with the concept of passive buildings and lends itself very well to such buildings (building energy performance level 2015 in Brussels), given their minimal need for cooling ($< 15 \text{ kWh/m}^2 \cdot \text{year}$). The use of passive techniques means that the costs associated with energy consumption for cooling are very low and are restricted to the costs incurred by the use of a fan or pump to transport free cooling energy into the building. The use of passive cooling offers the advantages of limited energy consumption, lower pollution levels and a reduction in the use of liquid refrigerants, which have a considerable environmental cost in terms of both their manufacture and use.

The main techniques for passive cooling are:

- free cooling/night cooling;
- ground-coupled heat exchanger;
- indirect adiabatic cooling.

Free cooling/night cooling

Free cooling is the use of outside air to cool the building through intensive ventilation of the premises when the air temperature outside the building is lower than the air temperature inside. Intensive ventilation can be achieved naturally, by mechanical means or with the use of a hybrid system. The use of natural ventilation involves the natural movement of air as a result of differences in pressure and/or temperature in the air around the building. In hybrid ventilation, mechanical assistance (generally an extractor fan fitted to a stack ventilator) is installed to improve the flow of air in adverse weather conditions, but its use is limited. Mechanical ventilation uses fans to induce movement of the air inside the building, necessitating continuous electricity consumption.

The air exchange rate should be no more than four volume changes per hour during periods when the premises are occupied. The maximum rate in a mechanical system will generally be two volume changes per hour to prevent undue oversizing of the ventilation system.

Night cooling is a form of free cooling that operates during the night, taking advantage of lower air temperatures and the building's thermal inertia to keep it cool during the day. For service sector buildings that are generally empty at night, this enables a higher rate of air exchange (up to eight volume changes an hour) than would be acceptable for free cooling during the day since it creates draughts.

The **following conditions** must be met in the provision of a natural **free cooling/night cooling system** (EnergiePlus):

- the building must have sufficient thermal inertia (with an accessible ceiling structure and masonry walls);
- the intensive ventilation must run across the building (opening out onto opposite external walls) or must be assisted by vertical venting;
- the size of the ventilation apertures must be equivalent to a minimum of 2 % of the floor area of the premises;
- in the case of manual ventilation apertures, occupants must be well-versed in how to manage them (by opening doors and windows). Otherwise, apertures must be automatically controlled.
- internal gains are limited to 22–26 W/m² for a building with average thermal inertia and 27–32 W/m² for a building with high thermal inertia. This implies the use of energy efficient equipment (lighting, office equipment, etc.);
- solar gains are restricted by effective (external) solar protection.

Ground-coupled heat exchanger

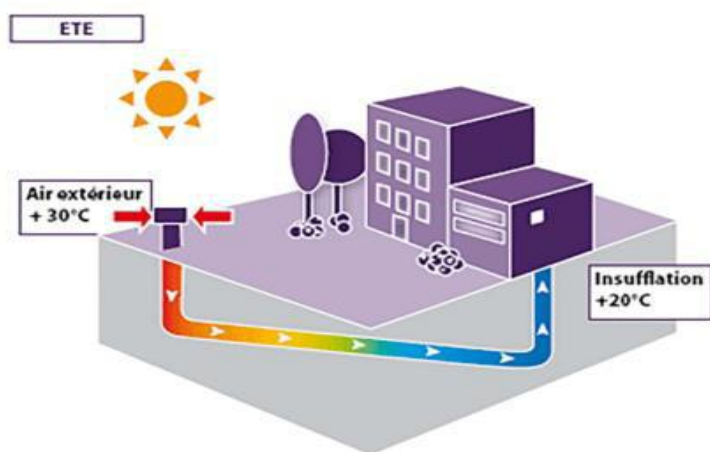


Figure 13: Ground-coupled heat exchanger (source: Xpair)

ETE	SUMMER
Air extérieur	Outside air
Insufflation	Intake

Ground-coupled heat exchangers cool the air in the building by making use of the ground temperature, generally through ventilation pipes laid in the ground. Outside air is drawn into the building via one or more underground pipes (along a length of 20 to 50 m and at a depth of 2 to 4 m) which will cool warm air during the summer and can also preheat incoming fresh air during the winter. The greater the temperature differential between the ground and the outside air, the better the thermal performance of the ground-coupled heat exchanger. Ground-coupled heat exchanger efficiency depends on a number of factors: dimensions (tube length and diameter), the design of the building, the depths of the trenches, the subsoil composition and the route and the material chosen for the tubes.

Second generation ground-coupled heat exchangers consist of tubes containing glycoled water. The same principle applies, but in this instance a ground loop filled with glycoled water runs through the soil and will preheat or cool the incoming air by means of an exchanger.

Indirect adiabatic cooling

Indirect adiabatic cooling takes an initial air flow (generally an outgoing flow) and cools it by humidifying it. The cooled air is then used to cool the air coming into the building by means of a heat exchanger. The advantage of this system is that it cools the air coming into the building with the use of water, without humidifying it. Indirect

adiabatic cooling takes up very little space and can be implemented for all buildings installed with heat recovery ventilation. Direct adiabatic cooling (where incoming air is cooled directly via humidification) is not used in buildings because of the high risk of Legionella.

I.2.1.2 Constraints

Free cooling and night cooling

These systems have **limited cooling capacity** and are not adequate to replace active cooling for service sector and industrial buildings in all cases. Optimal, fully natural operation requires that **buildings are appropriately designed**, which, in retrofitting, may involve significant measures such as enlarging air intake openings, creating a stack ventilator, etc.

Mechanical free cooling only needs ventilation ducts, which present few issues even when retrofitted. In contrast, the degree of efficiency of natural and hybrid free cooling, and night cooling as well (even in mechanical form) depends on the **architectural characteristics of the building** (wall inertia, the possibility of creating air transfers inside the building, etc.). Their potential application in existing buildings or as part of energy efficiency improvements will need to be assessed case by case. One of the most important factors in night cooling is the presence of adequate inertia. However, energy efficiency improvement work does not always allow for thermal mass to be made available within the building. One solution, which is still at the experimental stage, could be to use phase change materials. With careful planning, new buildings can be designed to promote natural free and night cooling.

However, even when passive cooling techniques are not sufficient to allow for the complete removal of a building's active cooling system, they can still be put to good use to **reduce the energy used by active systems**. A dynamic energy simulation presented in EnergiePlus looked at the use of night cooling at a rate of four volume changes per hour (with windows opening automatically when the internal temperature rises above 23 °C and the external temperature is less than 18 °C) as a basic cooling system in a Brussels office building of 3 000 m². The results showed that this approach reduces the energy consumed by the building's air conditioning system by 44 % if the building has significant thermal inertia (concrete floor, ceilings and partition walls) and by 21 % if it has little thermal inertia (false ceiling, false floor and lightweight internal walls). It is clear from this example that it is important to install a system that opens air intake openings automatically in response to temperature conditions both inside and out.

The use of fully mechanical intensive ventilation for free or night cooling can result in considerable **electricity consumption**. This issue can be resolved with the use of natural or hybrid ventilation, provided that the building allows for it. Both natural free and natural night cooling are entirely possible in residential buildings in Brussels. In service sector buildings, even those with a low thermal cooling load, hybrid ventilation is preferable. Whatever the case, the investment required to provide free cooling and night cooling in residential and small service sector buildings is relatively low (for installing air vents, automatic windows, etc.), and they are still more energy efficient than an air conditioning system. In contrast, in service sector buildings with greater cooling needs or industrial buildings, mechanical free cooling/night cooling may lead to nonsensical situations where more energy is used than is consumed by conventional air conditioning during the day. (Ceraa et al. 2015)

With night cooling, it is **difficult to predict the benefits that can be achieved** in terms of comfort without an in-depth analysis based on simulations of temperature distributions and the circulation of air for the building. Night cooling in fact depends on a number of factors such as the method of ventilation, the structure of the building (whether it has an atrium, etc.), the inertia of the internal walls, the size of the apertures, the external/internal temperature differential, etc. However, simple tools are available to provide guidance for designers (AlterClim, for example: www.ibgebim.be/soussites/alter_clim).

It should be noted that air intake openings that remain open throughout the day and night may increase the **risk of break-ins, insects** or small animals **getting in, noise** nuisance and **air pollution**. Screens and grates are available, however, which can be placed over the windows during the night or over the apertures for the intensive ventilation system to prevent break-ins and stop insects from getting in. Intruder alarms can also limit the risk of break-ins.

Inside the building, the free flow of air for cooling may conflict with the approach to **fire partitioning**. This problem can be solved with an appropriate design, though. In addition, fire prevention fittings (smoke and heat vents) may be useful for natural ventilation, by acting as a skylight dome for natural extraction, for example. Lastly, where air intake openings are opened manually, they should also be sufficiently robust to withstand high winds and be watertight in inclement weather.

Note that a distinction must be made between intensive ventilation for passive cooling and the hygienic ventilation required to ensure good air quality inside the building. Opening the windows of a natural free cooling or night cooling system can never replace the system of hygienic ventilation prescribed by building energy performance regulations.

Lastly, it should also be emphasised that, for existing office buildings, there is often also a **sociocultural obstacle** to the use of passive cooling (associated with the desire for false ceilings and floors).

Ground-coupled heat exchanger

Using a ground-coupled heat exchanger still requires the use of a **fan** to offset the pressure differential of the underground pipes. Installing a ground-coupled heat exchanger also **involves the risk of internal condensation** and additional pressure losses in the ventilation system. In winter, the ground-coupled heat exchanger competes with the recovery of heat from the air that is extracted, which is more efficient. In summer, it can supplement other passive systems, but retains a **secondary role**. Furthermore, it is more difficult to implement in towns and cities or as an energy efficiency improvement measure for reasons of lack of space.

Adiabatic cooling

The adiabatic air cooling technique is most effective in hot, dry climates. This is not really the case in Belgium, where it can be used to **complement** another active or passive cooling system, but its cooling power capacity remains limited. Indirect adiabatic cooling requires **mechanical ventilation** and therefore results in energy consumption. However, it uses much less energy than active cooling and has an **EER (Energy Efficiency Ratio) of 20**, or even more in the best designs. (EnergiePlus) Despite this energy advantage, adiabatic cooling involves considerable **water consumption**. It also requires regular maintenance to prevent build-up of limescale deposits in the pipework or issues with Legionella.

I.2.1.3 Choice of technique

Free cooling and especially night cooling systems offer real potential value for passive cooling in all buildings in Belgium. Depending on the thermal load that they have to support, such systems will either be used for full cooling, or on a supplementary basis to reduce energy use in air-conditioned buildings. Where the building allows, preference will be given to natural free, night or hybrid cooling solutions over solutions that make use of intensive mechanical ventilation.

Given the limited power capacity of ground-coupled heat exchangers and the constraints on this solution and on adiabatic cooling resulting from the Belgian climate, both these techniques are secondary solutions that can usefully supplement free or night cooling systems in some cases, but which are not sufficient to provide all the cooling for a building in their own right.

I.2.1.4 Potential value and relevance in the BCR

As long as they can provide the required level of comfort, **free, night and hybrid cooling techniques** should always be preferred over active forms of cooling. Passive residential and service sector buildings should be overheated ($T > 25\text{ °C}$) for no more than 5 % of the time that the premises are occupied. This is a mandatory criterion from 2015 for new build residential and service sector premises in the Brussels Capital Region. It should be noted, however, that in an urban environment, **noise and air pollution** are sometimes major obstacles to the use of natural free and night cooling. Filters can be added to the ventilation ducts in mechanical variants of these techniques.

Used in conjunction with roof insulation and effective external solar protection ($g < 0.5$) for windows with an area in excess of 4 m^2 that may be exposed to sunlight, the passive cooling techniques of free and night cooling (whether natural, mechanical or hybrid) are **sufficient** to provide cooling for **all of the BCR's residential buildings**. These techniques will also be sufficient to provide cooling in the BCR for **small service sector buildings** with non-substantial cooling needs, in conjunction with the use of roof insulation and effective external solar protection ($g < 0.5$) for windows with an area in excess of 1.5 m^2 . This is **dependent**, though, **on an internal thermal load of no more than 26 to 32 W/m²** (based on the building's inertia) and on a building design that specifically encourages intensive natural cooling (with automated apertures, etc.). In terms of **cost**, free and night cooling require little in the way of expenditure for residential and small service sector buildings (offices, shops and schools). More significant investment is generally associated with automation for some of the apertures (EUR 300 to EUR 700/m² for each window). This type of automation is not required for

residential buildings, however.

In **large service sector buildings** with very limited need for cooling, free cooling/night cooling can only be used as the main cooling system if the building's cooling needs are reduced to a minimum (an internal load of $< 32 \text{ W/m}^2$) and investment is made to ensure an entirely suitable building design, something which may generally be difficult to achieve in a retrofit. In addition, the costs can become substantial (involving oversized ventilation ducts, stack ventilators, etc.). In sizeable service sector buildings requiring large-scale intensive ventilation, the use of mechanical free and night-cooling entails a risk of overconsumption associated with the fans. The options are therefore to design a natural or hybrid cooling system requiring significant investment (for stack ventilators, etc.), or to mechanise these passive cooling techniques for judicious use in conjunction with active (preferably renewable) cooling solutions. Free cooling/night cooling will never be sufficient to meet the standard cooling needs of large service sector buildings in full, but it can usefully supplement an active, preferably renewable cooling system.

A ground-coupled heat exchanger provides a complementary solution to free and night cooling but the associated risks are different and it is often difficult to implement in an urban setting or as part of a retrofit. Indirect adiabatic cooling offers very limited cooling capacity in the Belgian climate. There is therefore very limited potential for these two techniques in the BCR. However, they can sometimes act as an add-on to a natural/hybrid free or night cooling system where minimal supplementary chilling is needed to dispense with air conditioning.

In the BCR, even when active cooling is necessary, passive cooling techniques **should always be used at least to supplement** it, so as to keep the use of active cooling to a minimum. Adequate management is essential in this scenario to prevent energy waste.

I.2.2 Renewable cooling

I.2.2.1 Definition and characteristics

While passive cooling techniques are efficient, they are not always sufficient to meet demand for cooling. The ideal when additional cooling is required is to use renewable sources of energy (air, ground and water). Such systems have a high energy efficiency ratio/seasonal energy efficiency ratio (EER/SEER). They are classified here on the basis of the renewable energy source used:

- air-source refrigeration unit with free cooling mode;
- ground-source refrigeration unit with free cooling mode;
- water-source refrigeration unit with free cooling mode;
- reverse cycle water-source heat pump.

First of all, it seems helpful to explain what free cooling is. The specific features of the four technologies listed will then be reviewed.

The principle of free cooling consists of producing chilled water without the use of the refrigeration unit, by taking advantage of cool outdoor temperatures. The water is cooled directly by the external air and the refrigeration unit is switched off, resulting in an energy saving. Clearly, the higher the demand for cooling in the winter, the more cost-effective the system. To take advantage of free cooling, the use of **'high temperature' cold emitters** is recommended. These include cold ceilings (with a flow/return temperature of $15/17 \text{ }^\circ\text{C}$), cold beams or fan coil units which have been oversized to work with a flow/return temperature of $12/17 \text{ }^\circ\text{C}$ or $14/19 \text{ }^\circ\text{C}$. If the system requires low mid-season or winter cooling capacity (in the region of 50 W/m^2), cold ceilings could be made to work at a flow/return temperature of $17/19 \text{ }^\circ\text{C}$, allowing for cooling to make use of the outside air whenever the air temperature is below $14 \text{ }^\circ\text{C}$. There may therefore be an opportunity to modulate the setpoint for the water in the cold ceilings in response to the outside temperature. This situation can be improved further by using a cooling tower, which reduces the temperature of the outside air still further through the partial evaporation of the water in the tower. Furthermore, when the system is working at partial load, the average temperature of the 'chilled' water should best be as high as possible to encourage exchange with the outside air. The variable flow heat exchangers will therefore be controlled to increase the flow/return temperature differential.

Air-source refrigeration unit with free cooling mode

This is a standard refrigeration unit (with an evaporator, compressor, condenser and expansion valve) where the heat produced by the condenser is released into the outside air. The transfer can be made in a number of ways, including by means of a cooling tower or a fan condenser. The efficiency associated with the use of air as a source of cooling is limited. It can be significantly improved, however, with the addition of adiabatic cooling by means of a wet condenser (with a cooling tower). The free cooling mode offers a high level of efficiency and should be used whenever possible.

Under test conditions (high outside temperatures), the EER of this system will be around 3. When the capacity of these refrigeration devices is increased with the addition of adiabatic cooling, though, such as by means of a cooling tower or a hybrid cooler, the EER can double, to achieve a value of 6. (Ceraa et al. 2015). This type of refrigeration system can be **placed into almost any type of building**. Various free cooling systems can be used for cooling: a specific dry air cooler, a combined device, a closed-circuit tower within the system, an air-to-air heat exchanger placed in front of the suction port of a cooling tower or a standard plate heat exchanger.

Ground-source refrigeration unit with free cooling mode

This is a standard refrigeration unit (with an evaporator, compressor, condenser and expansion valve) where the heat produced by the condenser is released into the ground. The transfer can be made using a borehole thermal energy storage field (BTES), to store geothermal energy, for example. The ground is a more efficient source of cold than the air and has a lower temperature during the warmer months. It can therefore operate in free cooling mode for much of the year.

Ground-source refrigeration units will have a higher EER because the ground temperature is usually lower. However, it can also fluctuate, from +5 °C at the start of the summer (the season for cooling) to +15 °C at the end of the summer, and the range can easily be even wider. This is actually an annual, rather than daily, fluctuation. In active cooling mode, the EER for a good system will be less than 4 to 5. The EER may exceed 5, however, if free cooling is an option. Given annual fluctuations, free cooling may be used much more frequently at the start of the heating season. The more that free cooling is used throughout the year, the greater its average annual efficiency. (Ceraa et al., 2015)

Water-source refrigeration unit with free cooling mode

This is a standard refrigeration unit (with an evaporator, compressor, condenser and expansion valve) where the heat produced by the condenser is released into water (a canal, lake, underground water, etc.). As with the ground, water used as a source of cold has a lower temperature than the outside air during the warmer months and this system can therefore operate for long periods in free cooling mode. Its advantages are similar to those associated with use of the ground.

Reverse cycle water-loop heat pump

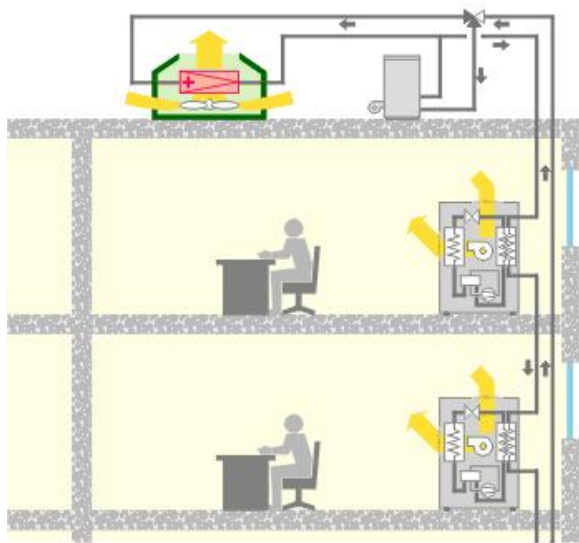


Figure 14: Operating principle of a reverse cycle water-loop heat pump

Several heat pumps are connected to a shared water loop. **In summer**, they operate as a refrigeration unit, with the condenser cooled by the water loop (which in turn is cooled by a roof-mounted cooling tower). **In winter**, they operate as a heat pump, with the water loop forming the 'cold' source (heated in turn by a boiler placed in series on the loop). This system proves its worth **in mid-season and in premises requiring simultaneous**

cooling and heating, where the **loop connecting them allows energy to be transferred between them, with remarkable energy performance**. It should be noted that reverse cycle air conditioning units also exist, but the electricity consumption of such units is high in contrast to reverse cycle heat pumps. Reverse cycle water-source heat pumps can be optimised by connecting them to a system for storing heat and delivering it on demand at a later date.

Ground-to-water heat pumps offer a reverse cycle. In summer, this type of pump acts as a water chiller by discharging the heat from its condenser and thus resetting it. The system therefore **recharges the ground**. **Open systems** are used if the water table is close to the ground's surface, where it may be possible to take water directly from the water table rather than running a heat exchanger and heat-carrying fluid through it. Given the movements in the water table and depending on the distance between the hot and cold zones, the impact of any imbalance between heating and cooling needs is significantly reduced in the case of an open-loop system in comparison with a closed-loop system. Furthermore, it is also possible to **produce heat and cold** in the building **at the same time**. If necessary, the water pumped out of the groundwater can actually be routed towards the heat pump and to the geothermal cooling exchanger or towards a heat exchanger used for both heating and cooling.

This kind of operation offers significant flexibility in the management of heating and cooling needs and can also be provided by a **variable refrigerant volume (VRV) heat recovery air conditioning system**. If different types of walls or partitions are introduced into the same area of the premises, an energy transfer can take place in mid-season, inside the building. This 'energy recovery' alternative is especially relevant if large internal gains are expected during the winter (from a computer room, internal rooms, etc.). The extracted heat may be delivered to adjoining rooms that need it. This system is easy to adapt for renovation as there is no requirement for a machine room (it is roof-mounted) and the pipes have a small footprint. The system can operate simultaneously in hot and cold mode. However, **running a network containing liquid refrigerant throughout a building** raises questions from an environmental perspective and within a few years it may be prohibited or at the very least, much more strictly regulated. For this reason, this system will now be discounted.

I.2.2.2 Constraints

Free cooling is recommended as advantageous in cases where cooling is needed outside of the warmest periods (in winter and mid-season) and requires the use of 'high temperature' cold emitters, such as cold ceilings (with a flow/return temperature of 15/17 °C), cold beams or fan coil units which have been oversized to work with a flow/return temperature of 12/17 °C or 14/19 °C. In addition, sizing the high temperature emitters in this way also reduces the energy used by the system, including by reducing the energy losses in the network.

The ideal emitter for free cooling is the **active slab** (where pipework is incorporated into the floor slabs to circulate cold water through). This technique is reversible (either heat or cold can be emitted) and characteristically, water flow/return temperatures are very high in cooling and very low in heating, making the system highly energy efficient. In addition, the significant thermal mass associated with the active slab is conducive to the night cooling technique. This type of emitter cools the ambient air using high-temperature cold water (at around 20 °C), improving the generation efficiency of the refrigeration units and also making it easier to recover cold from the outside environment (via free cooling, geothermal cooling, etc.). Active slabs are especially suitable for energy efficient buildings (with a low energy level at least). It should be noted, however, that there still sociocultural obstacles to the more widespread adoption of this technique, since it means that neither false ceilings nor carpets can be fitted. In addition, major work is required to fit an active slab and may be too much as part of a renovation. It is only suitable for new buildings or for major refurbishments works, therefore.

Air-source refrigeration unit with free cooling mode

Since air is very inefficient as a source of cold, these units have the **lowest EER/SEER of all the types of renewable cooling system**.

The cost-effectiveness of this system will depend on the **distribution of cooling needs throughout the year**, but it is still a solution worth considering.

A further constraint with regard to air-source cooling is the need for **roof space** to mount the condenser. Where a heavier condenser is used, the load-bearing capacity of the roof must be sufficient to support it.

Lastly, the use of outside air to cool chilled water is associated with the **problem of ice** in the cooling tower. The most common solution is to add glycol, but this is expensive, reduces heat exchange capabilities and increases the density of the liquid, leading to an increase in pump capacity. Furthermore, an additional heat exchanger has to be provided in this scenario, resulting in power consumption associated with its pressure loss and a temperature differential that shortens the operating period for free cooling. It is also possible to lay heating cables (although this raises the question of whether a tower can be fully protected in this way) or to provide for a special heating circuit which is implemented during periods of freezing weather. However, there is a risk that this will offset the energy gains associated with the cooling tower.

Ground-source refrigeration unit with free cooling mode and reverse cycle water-source heat pump

The necessary space should be available for drilling vertically into the ground. This can be difficult in the case of renovation works and/or a dense built environment. In addition, the urban context requires care to be taken with regard to pipelines, tunnels, etc. already in the ground. Drilling necessitates a substantial financial investment.

In addition, air-source geothermal heat pumps in cooling mode and air-source refrigeration units heat the ground. When this heat is not used in winter, the ground will get gradually warmer. Unless it is working on extremely energy efficient (passive) buildings, over a five-year period a geothermal system should always maintain an energy balance (between the heat absorbed and the heat emitted), so as not to disrupt the underground heat balance. Considering a five-year period allows the impact of annual fluctuations in heating and cooling demand in response to weather conditions to be neutralised. The ideal situation for ground-source cooling is to install the technology in buildings where demand for heating and cooling is balanced and asynchronous.

At present, there is no specific legislation governing geothermal energy in the BCR. Nonetheless, geothermal systems are almost always classified installations that are subject to environmental declaration or an environmental permit.

Water-source refrigeration unit with free cooling mode and open-loop system heat pump

Firstly, the distance between the building and the water source must not be too great. Then, there are costs for installing the means of transmitting the heat to the surrounding water (pipes, pumps, filters, etc.) with the result that the system necessitates a significant financial investment.

In the case of open-loop geothermal systems, the underground water collectors are class 2 or class 1B (section 62) installations and are therefore subject to the requirement for an environmental permit. Additionally, open-loop geothermal systems require pumping authorisation from IBGE for 'standard' water collection.

I.2.2.3 Choice of energy source

As well as requiring a substantial financial investment, there are numerous constraints associated with the installation of a ground-source refrigeration unit with free cooling mode and a reverse cycle water-source geothermal heat pump in a dense urban setting; for a water-source refrigeration unit with free cooling mode and an open-loop heat pump, a nearby water source is required. These two techniques should therefore be preferred for very large buildings or projects which concern a group of buildings, or even a whole district. In contrast, **air-source refrigeration units with free cooling mode** are suitable for nearly all types of buildings and built environments. They also have much less of an environmental cost, making this an ideal cooling technology for use in individual buildings.

I.2.2.4 Potential value and relevance in the BCR

Air-source refrigeration units with free cooling mode can be used both in the service sector and for certain industrial applications. Its potential for use in the BCR extends to the majority of buildings currently fitted with an air conditioning system. However, it is more appropriate for use on the scale of an individual service sector building than on the scale of a district.

Conversely, the cost of the **other four technologies considered** is too high, and the constraints on their integration into the urban setting are too great for their use to be widespread in the BCR at the scale of individual

buildings. On the other hand, there is value in using these techniques in connection with large-scale projects (for hospitals, factories, etc.) or small urban district cooling networks, since the constraints can more easily be managed and the efficiency gain is genuinely useful. In particular, reverse cycle heat pumps allow for the management of simultaneous cold and heat production.

1.2.3 Absorption cooling and trigeneration

1.2.3.1 Definition and characteristics

Absorption cooling uses a standard refrigeration unit (with an evaporator, compressor, condenser and expansion valve) where the heat from the condenser is released into a source (water or air), with the difference that the pressure increase is not induced by a standard compressor, but by the combination of residual heat and a saline solution. This heat can be produced by incineration plants, industrial processes, overproduction by solar collectors, etc., and therefore provides a way of taking advantage of a **waste heat** source. Moreover, the heat used must be classified as 'waste', otherwise all the economic and environmental value of absorption cooling compared with a standard refrigeration unit is lost. An absorption cooling system generally has an EER of between 0.5 and 1.2.

It is possible to connect solar collectors (specially designed for absorption cooling) to the system, but this set-up cannot achieve a financial return in Belgium.

If the heat used in the compressor of an absorption device is produced by cogeneration units, this unit becomes a **trigeneration** unit (producing electric power, heat and cold). The potential value of trigeneration relates to its use for buildings with simultaneous heating and cooling needs (slaughterhouses, pharmaceutical companies and the food industry, for example, which use cooling for storage and heating for working areas) and buildings which see spikes at different times in their demand for heating (in winter, for example) and cooling (in summer, for example). Trigeneration allows for the use of cogeneration for more of the year.

1.2.3.2 Constraints

For absorption cooling, the **cooling demand** should preferably be **as constant as possible**. In addition, absorption cooling is only an option **in conjunction with a waste heat source**, so either for industrial buildings, or via an urban cooling network supplied by a waste heat source (an incinerator, industrial plant, etc.) Furthermore, the waste heat must be at a temperature of at least **80 to 95 °C** for it to be able to generate absorption cooling (Ceraa et al. 2015).

The fundamental issue with trigeneration derives from the balance of heating and cooling needs in relation to their respective production: this type of demand matches just a few specific types of building (hospitals and industrial facilities). Additionally, trigeneration is less energy-efficient on average than cogeneration.

Absorption cooling and trigeneration techniques are **very costly** and **most of the time they are uneconomic** in buildings that only need cooling for a few months of the year. Trigeneration is more cost-effective in operation than cogeneration, but not sufficiently so to offset the difference in investment between the two systems (Daoud 2006).

1.2.2.3 Choice of technology

Other than in very specific situations, neither of these two technologies can be recommended from a technical or economic perspective.

1.2.3.4 Potential value and relevance in the BCR

Given the constraints of these two technologies, their potential in the BCR is minimal.

1.2.4 District cooling

1.2.4.1 Definition and characteristics

There are district cooling networks in existence that adopt the same model as district heating networks to cool a group of buildings or a district through the centralised production of chilled water (at 5-6 °C) and its distribution

across an urban district network. A power plant, often the same plant as is used to generate heat, produces cold water either by extracting it directly from a lake or a water table, or with the use of a heating pump. The cold water (at around 6 °C) is then routed to the customer via a network of insulated pipes, passing through a client-side heat exchanger so that cold is supplied to the air conditioning system for the building.

Most of the benefits of district heating also apply to district cooling. As with district heating networks, where cooling needs are significant, district cooling networks offer greater energy efficiency and are therefore greener than individual cooling systems. District cooling networks are therefore an attractively energy-efficient alternative to decentralised systems. They make use of cold from the natural environment (from water courses, etc.) in order to extract the cold and feed it into the network. A further advantage of district cooling lies in the economies of scale that it offers. The hydrothermal system may be closed-loop (with one or more loops and with a single heat exchanger, an array or none at all) or open-loop (where the water that is expelled is used for irrigation, to fill up bodies of water or to water green open spaces). The network can be managed by the municipality (under its control) or by a private sector service provider.

I.2.4.2 Constraints

Most of the constraints of district heating also apply to district cooling. District cooling networks need significant upfront investment, representing an economic risk that must therefore be considered in the long-term.

In Belgium, the major constraint for district cooling is the localised nature of urban heating demand and the limited number of months of the year to which it applies. It was seen in Task 1 that there is minimal residential demand for cooling in the BCR and that there is insufficient documented information on industrial demand, which is in all likelihood also very low. Only in the case of groups of service sector buildings using active cooling systems could there be value in connecting them up to use a district cooling network, provided that they are located sufficiently close to one another.

In addition, users are generally not aware of the energy performance and environmental benefits of district cooling, making it more difficult to convince some partners.

I.2.4.3 Choice of energy source

District cooling networks use several methods to cool the water:

- Refrigeration units can be cooled by cold water from a water course, lake or groundwater. Then, if needed, the water is brought to temperature by a cooling facility (powered by electricity, gas, etc.).
- The waste heat produced by a variety of buildings (incineration plants, cogeneration facilities, etc.) can be reused to run absorption refrigerators, but as seen, their upfront cost is substantial.

Clearly, district cooling networks should best be supplied by a hydrothermal source of cold that can also be used for producing heat in the winter. It should be noted that better energy efficiency and economic returns are seen with district cooling networks when they employ systems that are used both for heating (in the winter months) and for cooling (in summer).

I.2.4.4 Potential value and relevance in the BCR

It should be emphasised that there is no experience of district cooling in Brussels, which does not make implementing this kind of project any easier.

The potential value of a district cooling network in the BCR will be quite limited, since ideally it should have the following characteristics:

- there is adequate energy density of cooling needs per linear metre of network, which is the case only in densely built areas where service sector buildings predominate;
- cooling production and cooling needs are aligned;
- easy access to a source of hydrothermal energy;
- a strong project owner (sponsor, municipal authority, etc.);
- long-term captive consumers;

- commitment from local authorities.

There is a clear benefit in being able to pair a district heating with district cooling through the use of a network supplied by a shared hydrothermal source, so as generate a return on the infrastructure costs of these two types of network. However, since there are numerous conditions associated with the use of these two networks, detailed examination is required to determine in depth the actual potential for this type of project.

It thus appears that small district heating and cooling projects are to be strongly recommended in cases where the network connects up a handful of service sector buildings with access to a hydrothermal energy source and adequate heating and cooling needs, and where a strong project owner is present. Given the number of criteria to be met, the potential for this approach in the BCR is, in all likelihood, limited to a small number of specific cases.

II. SCENARIO DEVELOPMENT

Following the assessment of the available technologies set out in the first chapter of this report, technology-needs matrices specific to the BCR were developed (incorporating technical, financial and legal considerations) to show the potential benefit of each solution in the BCR for different types of projects with distinct heating and cooling needs. The methodology used to devise these matrices is first explained and the matrices are then presented in full. Taken together, the technology-needs pairings evaluated as positive for the BCR on the basis of the matrix provide a set of scenarios that offer potential for the BCR. A smaller selection of the most attractive scenarios for the BCR is then put forward, based on an analysis of the heating and cooling needs coming out of Task 1. Those scenarios identified as priorities for the BCR will form the basis for the work to be completed subsequently, in the tasks that follow.

II.1 THE TECHNOLOGY-NEEDS MATRICES

The **methodology used to define the technology-needs matrices** for the BCR is as follows. The matrix has to show the potential value for the BCR of using the various energy efficient technologies/solutions that were examined, based on the different types of heating and cooling needs encountered in different types of projects.

It was therefore necessary to define the different **types of projects** to be examined. The **distinction was drawn** according to:

- their **heating needs** and their **cooling needs**;
- their **energy performance, assessed according to three levels**: new building projects (with a Brussels-specific level of PEB 2015, equivalent to a passive level), renovation projects (low energy), and existing buildings (refurbishment of the heating/cooling system).

A matrix was then prepared for each type of project to evaluate every technology on the basis of the **scale of intervention and the assigned use**: a district (or a group of buildings), a multi-family housing block (with centralised heating), an individual home (house or apartment with its own individual heating), offices and shops, a hospital, swimming pool or an industrial facility.

The **three matrices describing heating needs** are set out below:

Heat technologies (heating and domestic hot water) for new builds (passive level)												
	Gas	Oil	Pellet	Gas	Ground	Water	Air-to-	Direct	Thermal	Recovery	District	District
Heat technologies (heating and domestic hot water) for renovation projects (low energy)												
	Gas condensing boiler in each building	Oil condensing boiler in each building	Pellet condensing boiler in each building	Gas cogen in each building	Ground-to-water heat pump	Water-to-water heat pump	Air-to-water or air-to-air heat pump	Direct electrical	Thermal solar panels + boiler	Recovery of waste heat	District heating: waste heat, geothermal or hydrothermal energy	District heating with cogen
District, block, group of buildings	++	-	-	-	-	-	-	-	+	-	++	++
Multi-family housing: centralised heating	++	+	-	++	-	-	-	-	+	-	+	+
Individual dwelling	++	+	-	-	-	-	+	-	+	-	-	-
Offices, shops	++	+	-	+	+	+	-	-	+	+	+	+
Hospital	+	+	-	++	+	+	-	-	++	+	+	+
Swimming pool	+	+	-	++	+	++	++	-	+	-	-	-
Industrial facility	+	+	+	++	+	++	-	-	+	++	+	+

Heat technologies (heating and domestic hot water) for existing built stock (refurbishment of heating system)												
	Gas condensing boiler in each building	Oil condensing boiler in each building	Pellet condensing boiler in each building	Gas cogen in each building	Ground-to-water heat pump	Water-to-water heat pump	Air-to-water or air-to-air heat pump	Direct electrical	Thermal solar panels + boiler	Recovery of waste heat	District heating: waste heat, geothermal or hydrothermal energy	District heating with cogen
District, block, group of buildings	++	-	-	-	-	-	-	-	+	-	++	++
Multi-family housing: centralised heating	++	-	-	++	-	-	-	-	+	-	+	+
Individual dwelling	++	-	-	-	-	-	-	-	+	-	-	-
Offices, shops	++	-	-	++	-	-	-	-	+	+	+	+
Hospital	+	-	-	++	-	-	-	-	++	+	+	+
Swimming pool	+	-	-	++	-	-	+	-	+	-	-	-
Industrial facility	++	-	+	++	-	-	-	-	+	++	+	+

++ = Very positive

+ = Positive under certain conditions

- = Negative

The **three matrices describing cooling needs** are set out below:

Cold technologies (cooling) for new passive construction projects					
	Free cooling/night cooling	Refrigeration unit with elevated EER operating for as long as possible in free cooling mode and high temperature emitters	Reverse cycle geothermal heat pump with a water loop	Trigeneration	District cooling supplied by an open-loop system
District, block, group of buildings	-	++	-	+	++
Multi-family housing: centralised heating	++	-	-	-	-
Individual dwelling	++	-	-	-	-
Offices, shops	++	++	+	-	+
Hospital	-	+	-	+	++
Swimming pool	-	-	++	-	-
Industrial facility	-	++	++	+	++

Cold technologies (cooling) for low energy renovation projects					
	Free cooling/night cooling	Refrigeration unit with elevated EER operating for as long as possible in free cooling mode and high temperature emitters	Reverse cycle geothermal heat pump with a water loop	Trigeneration	District cooling supplied by an open-loop system
District, block, group of buildings	-	++	-	+	++
Multi-family housing: centralised heating	++	-	-	-	-
Individual dwelling	++	-	-	-	-
Offices, shops	+	++	+	-	+
Hospital	-	+	-	+	++
Swimming pool	-	-	++	-	-
Industrial facility	-	++	++	+	++

Cold technologies (cooling) for existing built stock					
	Free cooling/night cooling	Refrigeration unit with elevated EER operating for as long as possible in free cooling mode and high temperature emitters	Reverse cycle geothermal heat pump with a water loop	Trigeneration	District cooling supplied by an open-loop system
District, block, group of buildings	-	++	-	+	++
Multi-family housing: centralised heating	++	-	-	-	-
Individual dwelling	++	-	-	-	-
Offices, shops	+	++	+	-	+
Hospital	-	++	-	+	++
Swimming pool	-	-	++	-	-
Industrial facility	-	++	++	+	++

++ = **Very positive**

+ = **Positive under certain conditions**

- = **Negative**

II.2 MOST ATTRACTIVE SCENARIOS FOR BCR

Based on the observations from the European Commission (in the Guidance note on Directive 2012/27/EU), the scenarios to be devised should have the following characteristics:

Baseline scenario:

- ‘The baseline scenario should describe the existing situation and its likely evolution in the selected timeframe, if no parameters of the existing situation are changed.’

Alternative scenarios:

- They must consider relevant solutions for making heating and cooling more efficient.
- They must examine cogeneration and urban district heating and cooling first.
- Only realistic scenarios need to be examined.

- Scenarios can be excluded if they are not feasible due to technical reasons, financial reasons or time constraints.

Generally speaking, the scenarios to be examined are selected on the basis of **preliminary filtering**. In this case, the filtering was based on findings in relation to the specific features of the Brussels Region:

- **Specific technical features:** some solutions have been ruled out on the grounds that, in Belgium, the scale required for certain energy resources is difficult to achieve. This is the case for biomass, for example. Similarly, geothermal energy offers a usable source of heat but suffers from a number of limitations.
- **Specific town planning-related features:** the residential sector in the BCR includes many old buildings. The rate of renewal for the housing stock is low, and a significant proportion of new building takes place in the peripheral ring around the urban area. The situation is mixed in the administrative and commercial sectors and districts that have been developed are frequently concentrated.
- **Specific economic features:** the city of Brussels is primarily focused on the residential and service sectors. Industrial added value amounts to around 5 % of all wealth creation and is falling. Additionally, the industrial segment is highly concentrated, with the construction sector alone generating half of this added value.

The diagram below, taken from the report on energy consumption in the BCR (ICEDD, 2014), shows the breakdown of final energy consumption in the BCR by sector and by type of need, in GWh.

The following conclusions can be drawn from this diagram:

1/ The **residential sector** uses 38.7 % (8 375 GWh) of the total, including 85.6 % (7 173 GWh) for heating and domestic hot water.

2/ The **service sector** uses 34.8 % (7 5295 GWh) of the total, including 51.5 % (3 882 GWh) for heating and domestic hot water and 3.9 % (290 GWh) for air conditioning.

3/ The **industrial sector** uses 2.9 % (623 GWh) of the total.

The industrial sector can therefore be considered **negligible** for the purpose of identifying **strategic scenarios** for the BCR.

Heating consumption also seems to **predominate** over cooling consumption and **should therefore be prioritised in developing the detailed scenarios**. The diagram below does not show clearly the full extent of cooling needs, but Task 1 evaluated all cooling needs for the BCR service sector at 471.5 GWh, equating to just **2.8 % of the total**. **Cooling needs** in the **BCR** really **are minor**, therefore.

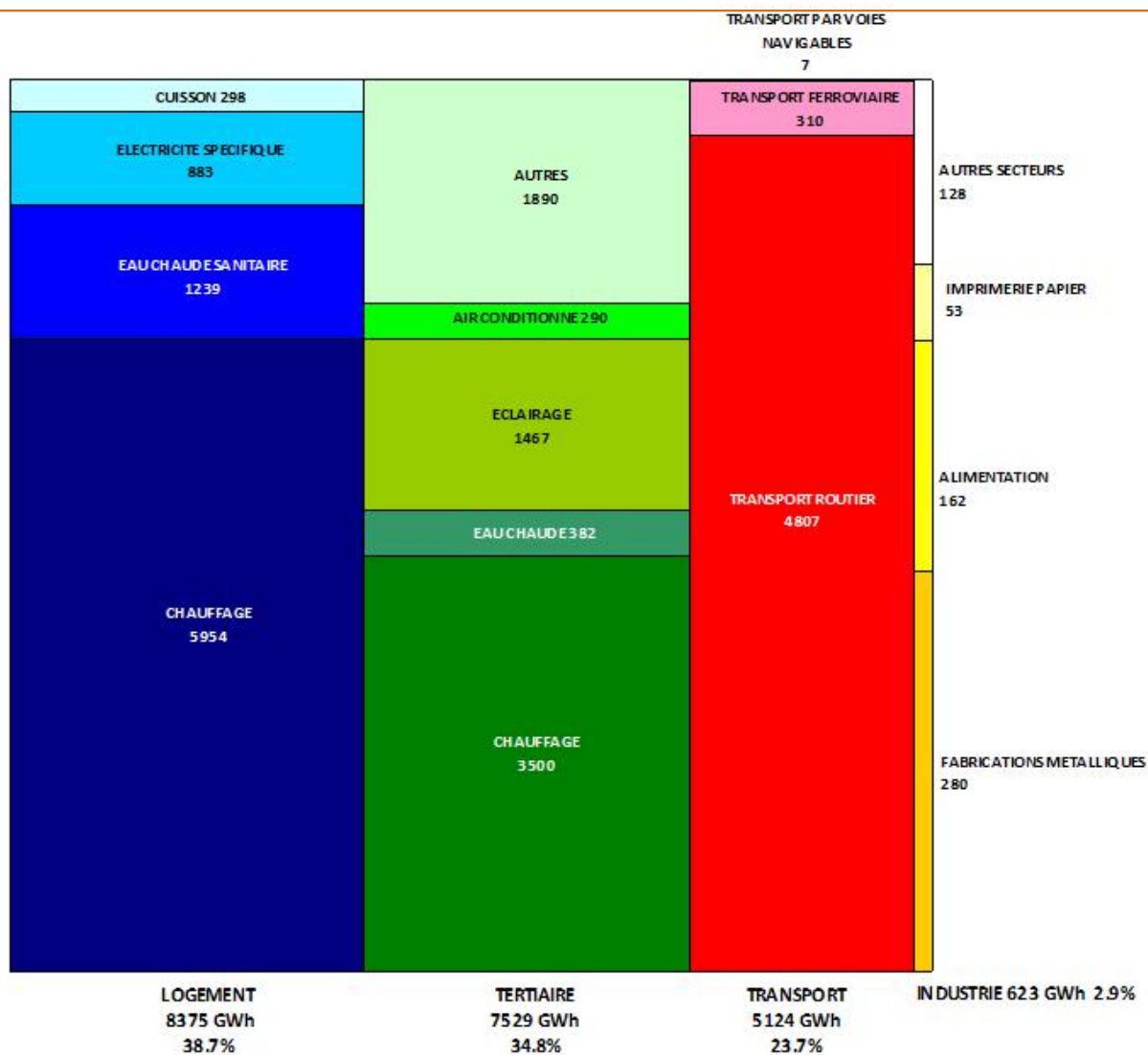


Figure 15: Final energy consumption in the BCR by sector and type of need (ICEDD 2014)

TRANSPORT PAR VOIES NAVIGABLES	INLAND WATERWAY TRANSPORT
CUISSON	COOKING
ELECTRICITE SPECIFIQUE	SPECIFIC ELECTRICITY CONSUMPTION
EAU CHAUDE SANITAIRE	DOMESTIC HOT WATER
CHAUFFAGE	HEATING
LOGEMENT	HOUSING
AUTRES	OTHER
AIR CONDITIONNE	AIR CONDITIONING
ECLAIRAGE	LIGHTING
EAU CHAUDE	HOT WATER
CHAUFFAGE	HEATING
TERTIAIRE	TERTIARY
TRANSPORT FERROVIAIRE	RAIL TRANSPORT
TRANSPORT ROUTIER	ROAD TRANSPORT
TRANSPORT	TRANSPORT
AUTRES SECTEURS	OTHER INDUSTRY
IMPRIMERIE PAPIER	PRINTING AND PAPER
ALIMENTATION	FOOD
FABRICATIONS METALLIQUES	METALWORKING
INDUSTRIE	INDUSTRY

It is therefore proposed to focus the scenarios specifically on heating needs, examining both centralised district-level solutions and localised solutions for individual buildings.

The chart below derives from Task 1 and looks in more detail at the statistics for overall heating needs in the BCR in 2003 and 2012 on the basis of the report on energy consumption in the BCR (ICEDD, 2014).

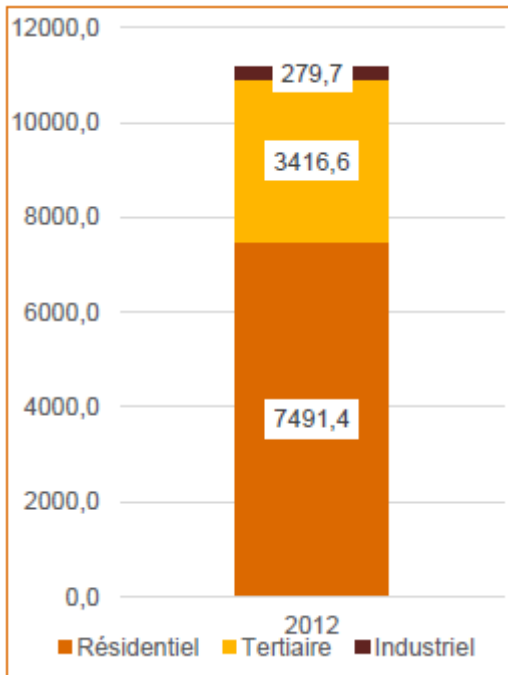


Figure 16: Consumption associated with heating needs by sector in the BCR in 2012 (source: ICEDD 2014)

Résidentiel	Residential
Tertiaire	Services
Industriel	Industrial

Heating needs in the residential sector account for around **67 %** of the total, with heating needs in the **service sector** accounting for **30.5 %**. It is therefore very important to consider both these sectors in the heating needs scenarios, but the residential sector should be looked at more closely.

It can be seen that heating needs in the **industrial sector** accounted for just **2.5 %** of the total in 2012, having already fallen sharply between 2003 and 2012. This confirms that they can be disregarded.

According to the report on energy consumption in the BCR (ICEDD, 2014), 53 % of the total number of occupied homes are within an apartment block and 23 % of apartments are in houses and shop buildings. Just 24 % of homes are single-family houses, and 20 % are terraced houses. As such, **77 % of homes are apartments in multi-family buildings**. This is the structure that will therefore be adopted for the preferred scenarios for Brussels.

The following diagram shows the detail of **heating needs in the service sector** in the BCR, as evaluated in Task 1 on the basis of the report on energy consumption in the BCR (ICEDD, 2014). From this, it can be concluded that:

- **office buildings** (government + banks, insurance and business services) account for **41 %** of these heating needs;
- shops are responsible for **26 %** of these heating needs;
- the proportion of consumption in the BCR for all other uses combined is very low.

The focus of the preferred scenarios for the BCR will be to explore the technologies that meet the heating needs of **office buildings and shops**.

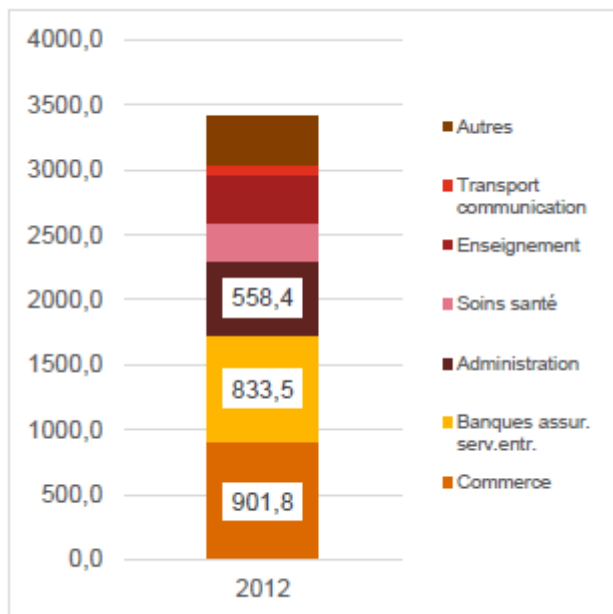


Figure 17: Consumption associated with service sector heating needs by assigned use in the BCR in 2012 (source: ICEDD, 2014)

Autres	Other
Transport communication	Transport and communications
Enseignement	Education
Soins santé	Healthcare
Administration	Government
Banques assur. Serv. Entr	Banking, insurance, business services
Commerce	Retail

Cooling needs in the Brussels **residential sector** are sufficiently **low** that they were not assessed in the report on energy consumption in the BCR (ICEDD, 2012). Task 1 assessed the proportion of PEB-certified buildings for which the probability that air conditioning is installed is over 50 %, arriving at a figure of 1 % of the certified homes in the BCR. Cooling needs in the residential sector can therefore be **disregarded** in the most attractive scenarios for the BCR.

With regard to cooling needs in the Brussels service sector, the report on energy consumption in the BCR (ICEDD, 2012) indicates that in 2012, cooling consumption accounted for 9 % of electricity consumption by the Brussels service sector, i.e. 316.2 GWh, including:

- 109 GWh or 35 % for retail;
- 113 GWh or 36 % for government, banking, insurance and business services;
- 28 GWh or 9 % for healthcare;
- 8 GWh or 3.9 % for education;
- 30 GWh or 9 % for transport;
- 27 GWh or 9 % for other uses.

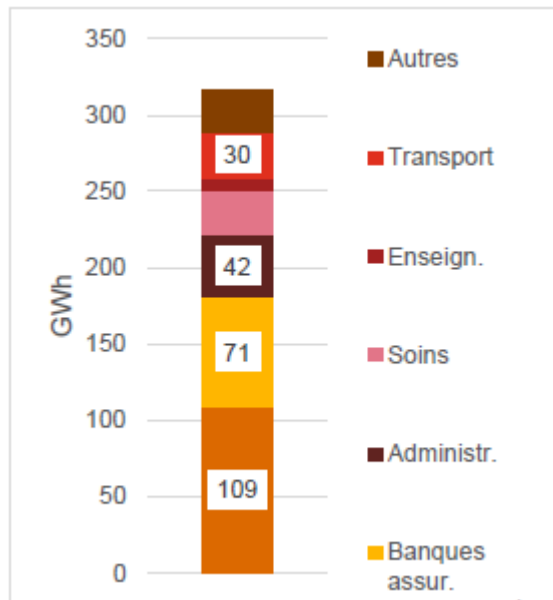


Figure 18: Consumption associated with service sector cooling needs by assigned use in the BCR in 2012 (source: ICEDD, 2014)

Autres	Other
Transport	Transport
Enseign.	Education
Soins	Healthcare
Administr.	Admin. services
Banques assur.	Banking, insurance

The focus in the preferred scenarios for the BCR is therefore on exploring the technologies that meet cooling needs in **office buildings**, which account for 36 % of overall service sector cooling demand in the BCR, **and shops**, which are responsible for 35 % of overall cooling demand in the service sector in the BCR. It should be remembered, however, that consumption associated with these cooling needs for offices and shops in the BCR is very low compared with overall energy consumption in the BCR.

Given the lack of measured, verified statistics on the demand for cooling in Brussels-based industry, and the narrow focus of industrial activity in the BCR, the **estimated cooling needs for the industrial sector** and the change in these needs were **considered to be negligible in Task 1**. The same assumption will be made here in relation to the preferred scenarios for the BCR.

Scenario selection criteria for the BCR

A number of criteria for defining preferred scenarios for the BCR can be deduced from this analysis of heating and cooling needs:

- Scenarios are needed to examine the potential for meeting **district-level heating needs**.
- Scenarios are needed to optimise **heating needs in apartment blocks**.
- Scenarios are needed to optimise **heating needs in office and retail buildings**.
- Scenarios are needed to optimise **cooling needs in office and retail buildings**.

Four areas have therefore been identified as having the greatest interest in relation to the review of the detailed scenarios for the BCR; these are shown in Figure 19.

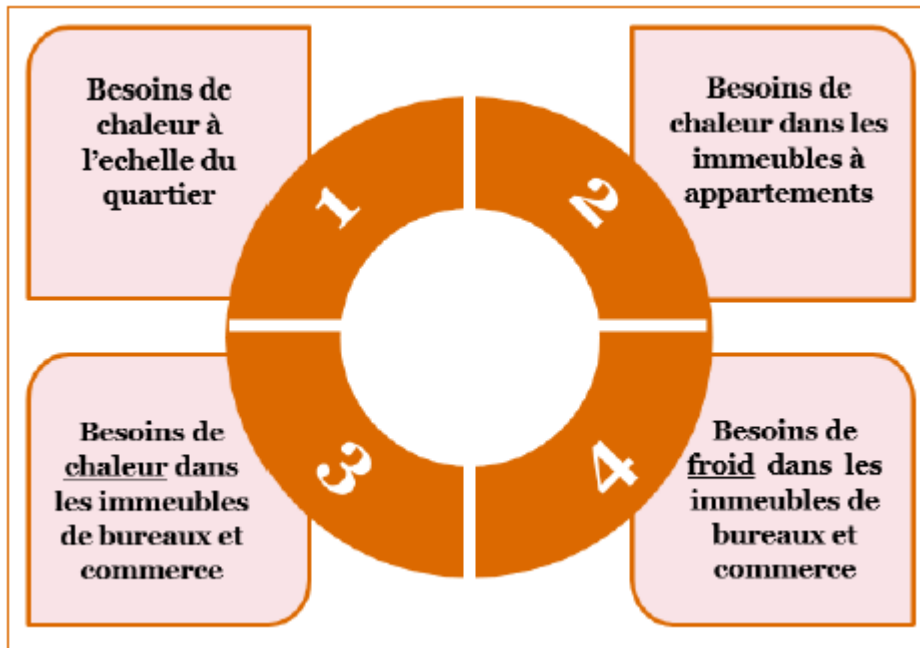


Figure 19: Priority areas for scenario definition for the BCR

Besoins de chaleur à l'échelle du quartier	District-level heating needs
Besoins de chaleur dans les immeubles à appartements	Heating needs in apartment buildings
Besoins de <u>chaleur</u> dans les immeubles de bureaux et commerce	<u>Heating</u> needs in office and retail buildings
Besoins de <u>froid</u> dans les immeubles de bureaux et commerce	<u>Cooling</u> needs in office and retail buildings

The next phase will examine a baseline scenario and alternative scenarios for each of these areas. **The baseline scenario** looks at a standard heating and cooling production technology (such as, for heating, a localised gas condensing boiler). **The alternative scenarios** are based on standard solutions as well as on non-standard solutions that are nonetheless likely to provide an efficient, appropriate response to the demand for energy in the BCR.

In addition, since the **built stock in Brussels** is already largely built, consideration will be given more specifically to those **technologies that are very positive (+ +)** in the current situation as well as in the context of **low energy renovations**.

Most attractive scenarios for the BCR

Following this methodology, the **scenarios** for meeting heating and cooling needs in the BCR **to be examined as a priority** will be:

1/ District-level heating needs:

Baseline scenario = localised gas condensing boilers in each building

Alternative scenario 1.1 = district heating network supplied by a high-efficiency gas cogeneration unit and supplementary heating

Alternative scenario 1.2 = district heating network with gas cogen. unit + heat pumps for supplementary heating

2/ For heating needs in apartment buildings:

Baseline scenario 2 = collective gas condensing boiler

Alternative scenario 2.1 = high-efficiency gas cogeneration+ collective gas condensing boilers

Alternative scenario 2.2 = individual gas condensing boilers in each apartment.

3/ For heating needs in office and retail buildings:

Baseline scenario 3 = collective gas condensing boiler

Alternative scenario 3.1 = absorption heat pumps

Alternative scenario 3.2 = compression heat pumps

4/ For cooling needs in office and retail buildings:

Baseline scenario 4= standard refrigeration unit

Alternative scenario 4.1 = high-efficiency gas cogeneration (absorption cycles)

Alternative scenario 4.2 = chiller (standard machine for producing chilled water) on a distribution network

II.3 TECHNICAL POTENTIAL

The table below provides an estimate of the technical potential for each of the technologies considered in the scenarios, reflecting the contribution made by a technology or a resource to meeting the heating needs of a particular sector.

			Consumption (2012, MW)	Localised gas condensing boiler in each building	District heating network supplied by high-efficiency gas cogeneration and supplementary heating	District heating with gas cogen + heat pumps for supplementary heating	Collective gas condensing boiler	Collective gas cogen + gas condensing boilers	Individual gas condensing boiler in each apartment	Collective gas condensing boiler	Absorption heat pumps	Compression engine heat pumps	Conventional refrigeration unit	Gas cogen	Chiller on distribution network		
Residential	Houses		2 404.9	65 %	15 %	15 %											
	Apartments	Heating	3 444.2				75 %	60 %	100 %								
Services	Retail	Heating	901.81							90 %	50 %	30 %					
		Cooling	109.33										100 %	10 %	20 %		
	Office buildings	Heating	1 391.6							80 %	60 %	50 %					
		Cooling	112.98											100 %	80 %	30 %	

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Chapter 4 – Cost-benefit analysis

INTRODUCTION

Purpose and methodology

The purpose of this fourth chapter is to compare the baseline and alternative scenarios selected in the previous task on the basis of a cost-benefit analysis. In other words, the aim of Task 4 as a whole is to produce a comparative cost-benefit analysis of the potential offered by the various production technologies that may meet the heating and cooling needs of the BCR.

The **methodology** adopted includes the following two steps:

- Phase 4.1: **technical analysis**
- Phase 4.2: **economic valuation**

The first section provides a recap of the different scenarios that were defined as part of Task 3 of the assignment.

The second section looks at the technical and economic analysis of the various scenarios considered.

I. RECAP OF THE SCENARIOS DEFINED IN SECTION III

The baseline scenarios describe the existing situation and how it is likely to develop. The alternative scenarios are based on standard solutions as well as on non-standard solutions that are nonetheless likely to provide an efficient, appropriate response to the demand for energy in the BCR. The choice of alternative, less conventional (or non-conventional) methods of production is justified by market developments as well as, more fundamentally, the situation in the BCR. In particular, channels producing cold by means of compression cycles are appropriate for covering air conditioning needs in office buildings, hospitals and similar buildings.

1/ District-level heating needs:

Baseline scenario = localised gas condensing boilers in each building

Alternative scenario 1.1a = district heating network supplied by a high-efficiency gas cogeneration unit and supplementary heating

Alternative scenario 1.1b = district heating network with gas cogen. unit + heat pumps for supplementary heating.

2/ For heating needs in apartment buildings:

Baseline scenario 2 = collective gas condensing boiler

Alternative scenario 2.1 = gas cogen + collective gas condensing boilers

Alternative scenario 2.2 = individual gas condensing boilers in each apartment.

3/ For heating needs in office and retail buildings:

Baseline scenario 3 = collective gas condensing boiler

Alternative scenario 3.1a = absorption heat pumps

Alternative scenario 3.1b = compression heat pumps.

4/ For cooling needs in office buildings and shops:

Baseline scenario 4 = conventional refrigeration unit

Alternative scenario 4.1 = gas cogen. (absorption cycles)

Alternative scenario 4.2 = small cooling network supplied by a shared chiller.

II. TECHNICAL AND ECONOMIC SCENARIO ANALYSIS

This chapter looks at the different scenarios identified above and provides a technical and economic analysis of the technology solutions being considered for an effective response to heating and cooling needs in the Brussels Region

II.1 DESCRIPTION OF TECHNICAL OPTIONS RELATING TO SCENARIO DEVELOPMENT

II.1.1 Scenarios for district-level heating needs

Architecture:

Scenario 1 new	Scenario 1 renovation
Group of 20 houses (terraced or equivalent), three heated floors, along a linear street	
external wall 7 m x depth 9 m = 63 m ² floor area	
Heated area = 3 780 m ²	
Heat recovery ventilation	Natural ventilation
Level of insulation compliant with Cobrace <i>(Code Bruxellois de l'air, du climat et de la maîtrise de l'énergie, Brussels Code of Air, Climate and Energy Management)</i>	Insulation: external walls insulated with 4 cm closed-cell insulation equivalent Roof insulation: 20 cm layer of mineral wool or equivalent New window frames with an overall U-value of 1.1 W/m ² K.

Energy use:

	Scenario 1 new	Scenario 1 renovation
Est. heating needs	15 kWh/m ² yr	74 kWh/m ² yr
Nominal heating capacity	34.2 kW	152 kW
Q heat (annual)	56 700 useful kWh	279 720 useful kWh
Q domestic hot water ⁷	20 x 900 kWh ⁸ = 18 000 kWh	
Q electricity ⁹	20 x 2 100 kWh = 42 000 kWh	

⁷ 20 m³/year at 50 °C cold water temperature 12 °C based on measurements from 1 000 homes (production on demand).

⁸ 20 m³/year domestic hot water (from 15 °C to 55 °C) for a four-person apartment.

⁹ 60 % of existing published average consumption figures (technology development)

Technologies applied

N.B. 'new' shown in italics on the left-hand side of the cell
 'renovated' shown in upright text on the right-hand side of the cell
 information common to both is shown in the middle

BS 1	AS 1.1a	AS 1.1b
Individual heating	Gas cogen with network	Gas cogen with network
	<i>16.8 kWth</i> GC 40 kWth $\eta_{th} = 53\% \eta_e = 25\%$	<i>16.8 kWth</i> GC 40 kWth $\eta_{th} = 53\% \eta_e = 25\%$
Boiler with modulating burner NG +100 l boiler	+ supplement same as for BS1	+ supplement air-to-water heat pump + 200 l reservoir
20 x 24 kW seas $\eta = 90\%$ (Hs)	20 x 24 kW 82% seas η (Hs) 90 %	<i>20 x 1.8 kW</i> 20 x 7 kW Seas. performan ce coefficient 3.7
	Network losses 4 % ¹⁰	Network losses 4 %

N.B.:

- The seasonal efficiency of space heating in new builds is impaired by the domestic hot water service; the same is true for the seasonal performance coefficient for heat pumps operating in the winter.

-As a general rule, boiler power capacity results from the need for instantaneous production of domestic hot water.

II.1.2 Scenarios for heating needs in apartment buildings:

Architecture:

Scenario 2 new	Scenario 2 renovation
12 three-bedroomed apartments over six floors (ground floor + 5)	
external wall 7 m x depth 13 m = 91 m ² floor area/apartment	
Heated area = 1 092 m ²	
<i>Heat recovery ventilation</i>	Natural ventilation
<i>Level of insulation compliant with Cobrace</i>	Insulation: no external wall insulation Roof insulation: 20 cm layer of mineral wool or equivalent New window frames with an overall U-value of 1.2 W/m ² K.

¹⁰ Expressed as a % of useful consumption of a network 2 x 200 m average flow/return temperature 65/35 °C polyurethane pre-insulated dual pipe, placed underground (10 °C) ND 32 (average outside diameter 175 mm).

Energy use:

	Scenario 2 new	Scenario 2 renovation
Est. heating needs	<i>15 kWh/m²yr</i>	62 kWh/m ² yr
Nominal heating capacity	<i>9.83 kW</i>	31 kW
Q heat (annual)	<i>16 380 useful kWh</i>	279 720 useful kWh
Q domestic hot water	12 x 900 kWh = 10 800 kWh	
Q electricity	12 x 2 100 kWh + lift 1 000 kWh/year ¹¹ + communal lighting 720 kWh/year ¹² = 26 920 kWh	

Technologies applied:

N.B. 'new' shown in italics on the left-hand side of the cell
 'renovated' shown in upright text on the right-hand side of the cell
 information common to both is shown in the middle

BS 2	AS 2.1	AS 2.2
Collective heating	Collective heating with cogeneration	Individual heating with collective exhaust
Cond. boiler NG	GC 10 kWth $\eta_{th} = 55\%$ $\eta_e = 22\%$ <i>3 x (28 kWth + 1 kW_e) (1)</i>	NG cond. boiler
315 l boiler with modulating NG burner	Boiler with modulating NG burner + 300 l domestic hot water storage	Boilers with modulating NG burner + 100 boiler
<i>88 kW</i> 32 kW	<i>84 kW</i> 32 kW	12 x 24 kW
<i>92 %</i> η_{th} (Hs) 90 %	$\eta_{th} = 90\%$ (Hs)	82 % η_{th} (Hs) 90 %

N.B.:

-As a general rule, boiler power capacity results from the need for instantaneous production of domestic hot water.

-SA 2.1 Hybrid boiler with Stirling motor, as the only kind of cogeneration technically feasible for low-energy new builds.

¹¹ <http://www.energieplus-lesite.be/index.php?id=11510>

¹² <http://www.energies-solidaires.org/wp-content/uploads/2012/06/Bilan-%C3%A9l%C3%A9ctricit%C3%A9-de-IARC.pdf>

II.1.3 Scenarios for heating needs in office and retail buildings

Architecture:

Scenario 3 new	Scenario 3 renovation
Office building over six floors (GF+5) with adjoining buildings both sides	
external wall 7 m x depth 11 m = 800 m ² floor area	
Heated area = 4 800 m ²	
Heat recovery ventilation	
<i>Level of insulation compliant with Cobrace</i>	Insulation: no external wall insulation (U = 2 W/m ² K) Flat roof: 12 cm of insulation (U = 0.35 W/m ² K). Doubled-glazed windows with an overall U-value of 1.2 W/m ² K. Glazing spanning 50 % of external walls

Energy use:

	Scenario 3 new	Scenario 3 renovation
Est. heating needs	<i>15 kWh/m²yr</i>	75 kWh/m ² yr
Nominal heating capacity	<i>54 kW</i>	240 kW
Q heat (annual)	<i>72 000 useful kWh</i>	360 000 useful kWh
Q electricity ¹³	381 480 kWh	

Technologies applied:

N.B. 'new' shown in italics on the left-hand side of the cell
'renovated' shown in upright text on the right-hand side of the cell
information common to both is shown in the middle

BS 3	AS 3.1a	AS 3.1b
Collective heating		
Condensing boiler with modulating NG burner	2 NG-fired absorption heat pumps (1)	NG engine-driven compression heat pump (GHP)
<i>54.6 kW</i>	175+70 kW th	<i>56 kW</i>
240 kW	Seas. performance coefficient	240 kW
<i>seasη = 92 % (Hs)</i>	<i>1.16</i>	Seas. performance coefficient
	1.3	1.5

¹³ <http://www.energieplus-lesite.be/index.php?id=11501>

35 W/m² x 2 200 hrs = 77 kWh/m²/yr

lighting for 1 500 m² car park 6 hrs/day x

77 x 4 800 m² =

220 days x 6 W/m² x 1 500 m² =

369 600 kWh/yr

11 880 kWh/yr

II.1.4 Scenarios for cooling needs in office and retail buildings

Architecture:

Scenario 4 new	Scenario 4 renovation
Group of six office buildings over two floors (GF +1)	
external wall 28 m x depth 14 m = 400 m ² floor area	
Air conditioned area = 4 800 m ² (int. temp. 24 °C/ext. temp. 30 °C)	
Heat recovery ventilation	
Solar glazing g = 50 %	No solar glazing + internal blinds

Energy use:

	Scenario 4 new	Scenario 4 renovation
Q cold e ¹⁴	7 kWe/m ² yr	8.05 kWh/m ² yr
Total nominal cooling capacity	6 x 40 kW _r = 10 800 kW _r	
Q cold (annual) ¹⁵	6 x 22 400 = 134 400 useful kWh	6 x 25 760 = 154 560 useful kWh
Q electricity ¹⁶	369 600 kWh	

Technologies applied:

N.B. information is common to both new and renovation situations.

BS 4	AS 4.1	AS 4.2
Individual air conditioning in each building		Shared networked chiller
6 single-unit chillers with air-cooled condensers	6 x NG-fired cogenerator units in conjunction with an absorption heat pump ¹⁷	Single-unit air-cooled condensing chillers serving a network to the buildings
6 x 40 kW _r	GC 6 x 50 kW _{th} ¹⁸	1 x 240 kW _r
ESEER = 4.5	Performance coefficient = 0.8	ESEER = 4.5
		Network losses 1 % ¹⁹

¹⁴ <http://www.energieplus-lesite.be/index.php?id=11508>

¹⁵ ESEER based on 4 220 days/year at a rate of 10 hrs/day (interior blinds)

¹⁶ 35 W/m² x 2 200 hrs = 77 kWh/m² year => 77 x 4 800 = 369 600 kWh/year excluding cooling equipment

¹⁷ gross cost of machinery amounts to ± EUR 100 000.00/building

¹⁸ Cogenerator: η_{th} 45 % η_e 25 % (Hs)

¹⁹ As a % of useful consumption Network length = 2 x 210m ND 100 insulated 13 mm polyurethane pipe av water temp +13 °C ground temp 10 °C

II.2 TECHNICAL AND ECONOMIC ASSUMPTIONS FOR THE SCENARIOS

II.2.1 *Technical assumptions*

The model supports the technical assumptions as follows:

- The model identifies three different types of energy load: heating needs, cooling needs and power needs. Needs are annualised and simulations are performed at static capacity (no transitional ranges; see below).
- Two complementary means of energy production are considered in the calculation: on the one hand, the primary source covering basic needs and on the other, the secondary source, where necessary, which supports the supplementary requirement. Different technologies may be used in each case.
- Natural gas is used as heating fuel, since the BCR has access to an extensive distribution network and it involves relatively few restrictions with regard to the environment. In addition, it should be emphasised that, unless supplied by the network, alternative options such as biogas have been ruled out in principle because of the profile of the BCR.
- The evaluation is based on consumer heating and power needs. The primary source and, in general, the additional supply from the supplementary heating should be sufficient to cover the full extent of thermal demand. In the case of electricity demand, a number of specific cases need to be considered, depending on whether:
 - demand for electricity is met by cogeneration (in theory);
 - cogeneration exceeds the demand for electricity: in this case, the surplus is purchased by and fed into the network;
 - cogeneration falls below the demand for electricity: in this case the surplus is sold back to the network;
 - the production system does not include cogeneration and all the customer's energy demands are satisfied by separate withdrawals from the network. This is the case for compression refrigeration cycles. It is also the default situation in the baseline scenarios based on the use of standard boilers.
- The savings made from self-consumption and the energy capability sold to the network are deducted from the costs/cash flows for the applicable scenario (profit).
- The sizing of the facility takes place separately from the estimate of annual energy needs and is derived as a function of peak thermal power for all uses combined (heating and domestic water²⁰). Electrical capacity is dependent on the production system and whether the shortfall/surplus is imported from/exported to the network.

II.2.2 *Economic assumptions*

The model supports the economic assumptions as follows:

- The benefits of the alternative options are determined on the basis of cost. Each option is then compared to the costs for the baseline scenario. The costs considered are the net balances resulting from the cumulative total costs of production on the one hand and, in the case of cogeneration, any deduction of income generated by the sale of the electricity produced on the other (see above)²¹. Any subsidies granted are also deducted from production and operating costs.

²⁰ Included in secondary (supplementary) production unless otherwise indicated

²¹ This assumes that it is possible to meter both ways, which is not currently the case in BCR. This will need to be addressed, however, if the desire is to encourage the use of cogeneration systems that are sufficiently large, or even to allow for flexible incorporation of cogeneration units for use on the basis of potentially divergent electrical and thermal load profiles. It will be seen below that most of the systems considered produce little or no excess power, as they are sized essentially to meet the self-consumption needs of the customer, at least in part.

- Since cogeneration units produce both thermal units and electricity, the bases for comparison include the expression of consumer demand in both forms, valued in currency units (see above).
- The operational life of the equipment equates to the physical depreciation period (time to technical obsolescence). It is parameterised, varies according to the technology used and is common to all the systems (primary and secondary sources). The reason for this is the integration of the two production systems and the resulting period of joint use.
- Since the physical depreciation periods for the equipment vary widely, actual values are not comparable in principle and the comparison is based instead on net present values (NPV). The actuarial calculations are based on monetary data expressed in EUR at current prices, thereby accounting for inflation. Accordingly, the results reflect the speculative impact of price slippage.
- Cost cash flows include both CAPEX and OPEX:
 - CAPEX, or capital expenditure, encompasses the cost of equipment, installation and infrastructure.
 - OPEX, or operating expenditure, covers care and maintenance. Heating fuel expenses are covered separately in the model.
- Disinvestment costs relating to primary and secondary production installations are also accounted for.
- Cash flows are gross of tax. The reason for this is that tax arrangements differ substantially depending on the consumer's status and circumstances. As such, for example, the level of an individual's income affects their opportunity for writing the expenditure off against tax. Different scales apply in respect of commercial and/or industrial use.
- Given the non-uniform nature of the production methods considered, it only really makes sense to express the gains/losses deriving from the adoption of the new technology in kWh. This creates difficulties in respect of methodology: should the gains/losses be offset against the heat or the power that is generated? As a result, they will not be calculated. Conversely, the baseline scenario and the alternatives considered are compared in terms of the contribution of each component, or group of variables, to the final net present value.
- Investment costs differ depending on whether the project relates to a new development or integration into an existing building. In cases where renovation is a realistic option in the context of the BCR, both options are analysed separately. This evaluation focuses on the following considerations:
 - *Technical*: economies of scale, sufficiently reliable availability of materials on the market, efficiency (such as network distribution losses), etc.
 - *Town planning*: concentration/distribution of housing, utilities, disruption resulting from use (noise, civil engineering works, etc.).

II.2.3 Input data

Generally speaking, and for all the scenarios, inputs are categorised as follows:

1. Data relating to the *economic and financial framework*. These data include variables such as interest rates, the tariffs applicable to the sale and purchase of energy to and from the grid, the cost of heating fuel (natural gas), inflation, subsidies, etc.
2. Data relating to consumer (or consumer group) *charges for heating and electricity*. These are considered as net values, i.e. excluding any requisite additional charges for switching on heat- or cold-producing equipment (such as a heat pump).
3. Data describing the solutions considered for *basic production*: the sums required for investment in the equipment (CAPEX), other installation expenses such as assembly costs, fitting flues for condensing boilers (expressed as a percentage of CAPEX), the cost of care and maintenance for the equipment, life spans, the financial resources that can be made available for end-of-life dismantling, thermal efficiency (in the case of boilers and cogeneration systems) and electrical efficiency (for cogeneration systems),

performance coefficients (relating to compression and absorption cycles), annual output and system capacity. Taking the example of an apartment building or an administrative building, basic production can be localised or centralised. Use of the network is optional (see below).

4. Comparable data on *supplementary production*, which relates to needs for both heating and domestic hot water. Supplementary production is localised for each housing unit. It can cover a significant proportion of the consumer's needs in case of primary source limitations to do with the load curve.
5. Data relating to *network transmission*. These mainly include investment expenditure, maintenance costs and losses. The network is the system used to transmit energy between the buildings. Internal networks, such as those used within a single building to transmit heat and cold to supply induction units, are not considered to be part of the network at this stage.

Data on capital and operational expenditure are expressed in terms of the capacity of the system, as physical units. Specific energy consumption is therefore treated separately from OPEX and is dependent on efficiency or on the performance coefficient. The underlying assumption is the absence of any economy of scale. This is acceptable in practice provided that the capacity ranges considered are sufficiently narrow.

In the cases that were looked at, use of a network was considered only in a limited number of cases, two for heating and one for cooling. The cases selected relate in principle to technically advantageous solutions.

The simulations are based on a core set of economic and financial data. These are given below.

Actuarial rate	%/yr	3.50 %
Cost of heating fuel (natural gas)	EUR/kWh	0.05 ²²
Heating fuel inflation (natural gas)	%/yr	1.00 % ²³
Price of LV electricity sold by RDE24	EUR/kWh	0.15
Price of LV electricity purchased by RDE25	EUR/kWh	0.05 ²⁶
Electricity inflation	%/yr	2.00 % ²⁷
CAPEX inflation (equipment)	%/yr	1.00 %
OPEX inflation (operation)	%/yr	1.50 %
CAPEX subsidies (primary source)	EUR	see below
OPEX subsidies (primary source)	EUR/year	see below

The rates used are low side prices for low voltage electricity in the BCR²⁸, to reflect points of comparability with localised systems intended for use by private individuals. However, some solutions qualify for mid-voltage pricing. The working assumption is therefore conservative.

Capital and operating expenses and heating fuel are shown exclusive of VAT²⁹.

²² Excl. VAT.

²³ This figure reflects the assumption that the current downward trend may not be sustainable in the long-term (2030). As such, it is expected that the next decade will see a degree of stabilisation or even a limited recovery taking place. This assumption should therefore be considered as an average over the relevant period.

²⁴ Via the distribution network. Transaction handled by a supplier or a customer. Excl. VAT.

²⁵ As above. Excl. VAT

²⁶ Is above current sell-back tariffs (in the region of EUR 30/kWh). The way is therefore clear for a market conducive to localised feed-in, including from cogeneration.

²⁷ The rate of inflation applied to electricity is based on expectations with regard to the gradual decommissioning of nuclear power plants, sustained growth in the proportion of hitherto subsidised renewable energies and lastly, on the additional investment required to upgrade the transmission and distribution networks in response to the development of intermittent, localised energy sources.

²⁸ Situation in August 2015, BELSIM simulations.

²⁹ Rule applied for all calculations, including pricing, operating and/or capital expenditure.

The common consumer demand data for the four scenarios used are set out below. Data are deduplicated, since new builds are treated separately from renovations. The buildings are similar in both cases, however.

DATA	(scenarios)	BS 1	BS 2	BS 3	BS 4
Energy load (consumer demand)		New builds			
Thermal heat load	kWhth	75 000.00	27 180.00	72 000.00	-
Thermal cooling load	kWhth	-	-	-	134 400.00
Electrical load	kWhe	42 000.00	26 920.00	381 480.00	369 000.00
Energy load (consumer demand)		Renovation			
Thermal heat load	kWhth	298 000.00	78 800.00	360 000.00	-
Thermal cooling load	kWhth	-	-	-	154 560.00
Electrical load	kWhe	42 000.00	26 920.00	381 480.00	369 600.00

There is a significant discrepancy between the thermal loads of new and old (renovated) buildings. The reason is the application of energy performance standards to current buildings, or, at the very least, current regulations on constructing an energy efficient building shell.

For the record, regardless of whether or not the cases in point, and in particular the baseline scenarios, include a centralised primary source, the use of a secondary source is only envisaged in the following instances:

- Alternative scenario AS 1.1a: cogeneration, back-up boiler, district heating network.
- Alternative scenario AS 1.1b: cogeneration, back-up heat pumps, district heating network.
- Alternative scenario AS 2.1a: cogeneration, collective gas boilers.

A distribution network also features in the following alternatives:

- Alternative scenario AS 1.1a: cogeneration, back-up boiler, district heating network.
- Alternative scenario AS 1.1b: cogeneration, heat pump, district heating network.
- Alternative scenario AS 4.2: reverse cycle water-source chiller, small cooling network.

Natural gas is the only heating fuel used, except in the case of compression cooling cycles.

Lastly, the working assumptions with regard to the environmental burden and subsidies can be summarised as follows:

- in order not to skew the results of the economic calculation, there are no plans to consider investment and/or operating subsidies, or at least, not to begin with, since the sensitivity analysis that supplements the results uses the baseline scenario to evaluate the subsidies needed to obtain an equivalent outcome in the event of economic underperformance of the options considered. The balancing subsidies defined on this basis give net amounts and their equivalent under the regulatory framework applicable in the BCR, i.e. green certificates (EUR 80/green certificate under current conditions)³⁰.
- CO₂ emissions are also considered. The CO₂ emissions coefficients considered in the calculation are 395 kg CO₂/MWh for electricity and 217 kg CO₂/MWh for natural gas (at LHV³¹), respectively. One tonne of CO₂ is assigned a value of €10, a high-case assumption in the current market context³².

³⁰ As green certificates are granted over a 10-year period, an adjustment has been made for facilities where the operational life is assumed to be longer (15 years other than for district networks). The adjustment is prorated to the operational life.

³¹ Higher heating value.

³² The current price is close to EUR 5/t.

II.3 RESULTS

The results of the analyses of the scenarios examined are described below.

II.3.1 Results analysis

The results are presented by scenario group (baseline scenario and alternative scenarios) to facilitate direct comparison. The first three scenarios relate to the coverage of heating needs in the residential and service sectors. The fourth scenario, on the other hand, relates to cooling in the service sector. The construction of new buildings and the renovation of old buildings are considered separately for each scenario group. The figures for both are shown side by side for ease of comparison. A summary table is set out at the end of the section which shows the results for each scenario as net present values. It also includes the differential between the various alternative scenarios and the benchmark scenarios.

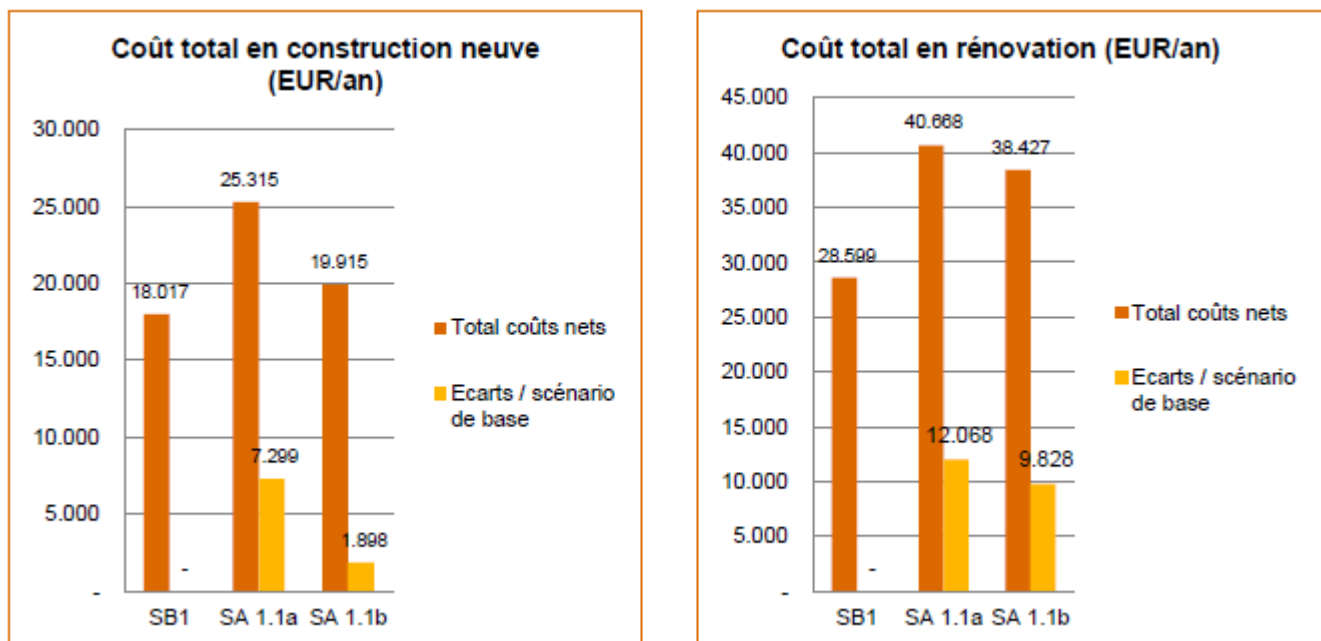
II.3.1.1 Scenario 1: District-level heating needs

In the first case examined, localised collective condensing boilers (BS1) are compared with, respectively:

- a district heating network supplied by a high-efficiency gas cogeneration unit and supplementary heating (AS 1.1a);
- a district heating network with a gas cogeneration unit and heating pumps providing supplementary heating (AS 1.1b)

As the following figures show³³, comparing the baseline scenario with the alternative options indicates that there are additional costs associated with the latter. In the case of **new buildings**, there is an adverse variance for heating networks supplied by cogeneration (SA 1.1a). All other things being equal, the situation is marginally improved if the supplementary heating is provided by the heat pumps (AS 1.1b).

Given the additional costs that they entail in comparison with the baseline scenario, the situation is similar for the alternatives considered for **renovation**, with cogenerated district heating offering the least cost-effective solution. There is less of a disparity between the two alternatives, however.



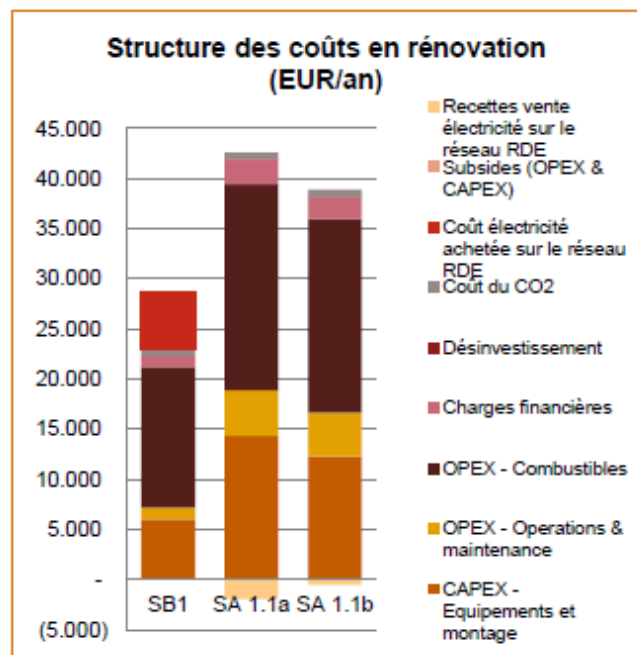
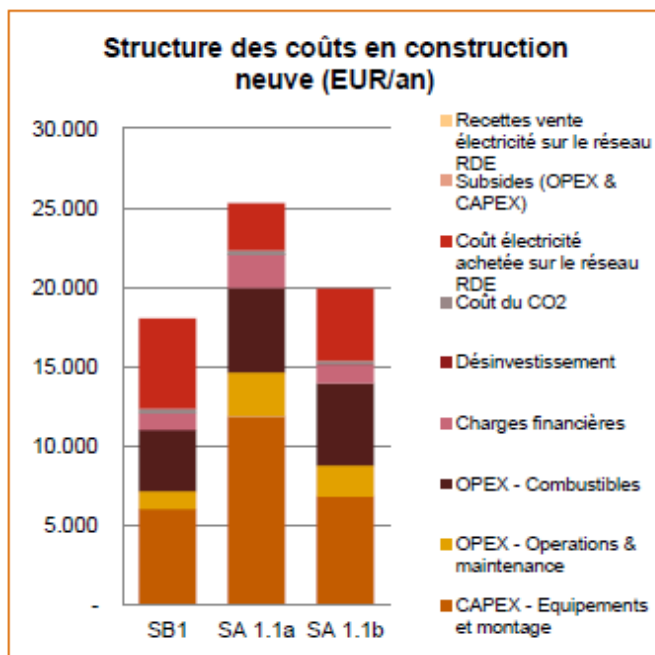
Coût total en construction neuve (EUR/an)	Total cost – new build (EUR/year)
Coût total en rénovation (EUR/an)	Total cost – retrofit (EUR/year)
Total coûts nets	Total net costs
Ecart/scenario de base	Baseline scenario

³³ Net present value of total costs on an equivalent annualised basis.

Structure des coûts en construction neuve (EUR/an)	Cost structure – new build (EUR/year)
Structure des coûts en rénovation (EUR/an)	Cost structure – renovation (EUR/year)
Recettes vente électricité sur le réseau RDE	Income from sale of electricity back to the RDE grid
Subsides (OPEX & CAPEX)	Subsidies (OPEX & CAPEX)
Coût électricité achetée sur le réseau RDE	Cost of electricity purchased from the RDE grid
Coût de CO2	Cost of CO2
Désinvestissement	Disinvestment
Charges financières	Financial expenses
OPEX – Combustibles	OPEX - Heating fuel
OPEX – Operations & maintenance	OPEX – Operations & maintenance
CAPEX – Equipements et montage	CAPEX – Equipment and assembly

It should be remembered that the net costs are calculated after deducting the benefits deriving from the production of electricity, where present, whether the deduction relates to self-consumption or to the sale of the available excess in the case of a net surplus.

As can be seen in the left-hand figure below, which shows the situation for **new builds**, the potential for synergy offered by cogenerated district heating (AS 1.1a) is diminished by the costs associated with installation and the purchase of equipment for supplementary heating. To a lesser extent, this is also true for the second option, which makes use of heat pumps (AS 1.1b).



Cost structure – new build (EUR/year)	Structure des coûts en construction neuve (EUR/an)
Cost structure – renovation (EUR/year)	Structure des coûts en rénovation (EUR/an)
Income from sale of electricity back to the RDE grid	Recettes vente électricité sur le réseau RDE
Subsidies (OPEX & CAPEX)	Subsides (OPEX & CAPEX)
Cost of electricity purchased from the RDE grid	Coût électricité achetée sur le réseau RDE
Cost of CO2	Coût de CO2
Disinvestment	Désinvestissement
Financial expenses	Charges financières
OPEX - Heating fuel	OPEX – Combustibles
OPEX – Operations & maintenance	OPEX – Operations & maintenance
CAPEX – Equipment and assembly	CAPEX – Equipements et montage

The right-hand figure above describes the **renovation** of existing buildings. Financial expenses are comparable in the cost/income structure. The other line items that make a significant contribution to the difference in cost are CAPEX costs, which considerably increase overall expenses in the case of the alternatives covered by AS 1.1a and AS. It should be noted that in the first [sic] alternative (AS 1.1b), the system generates a return through the sale of electricity back to the grid.

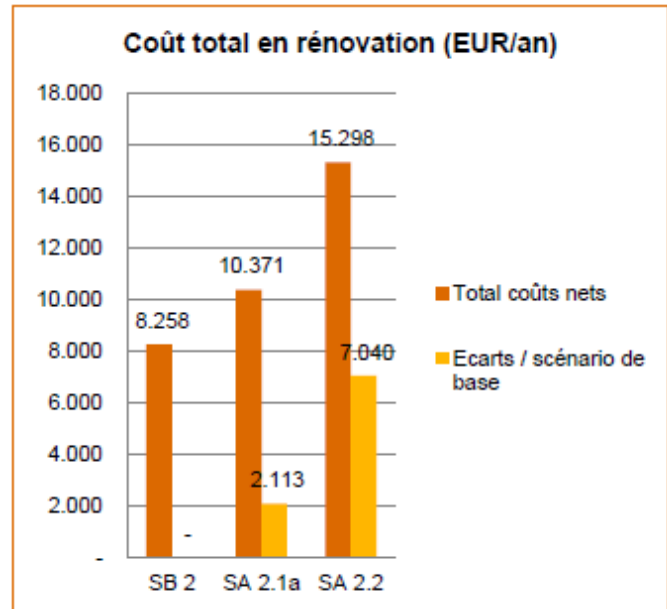
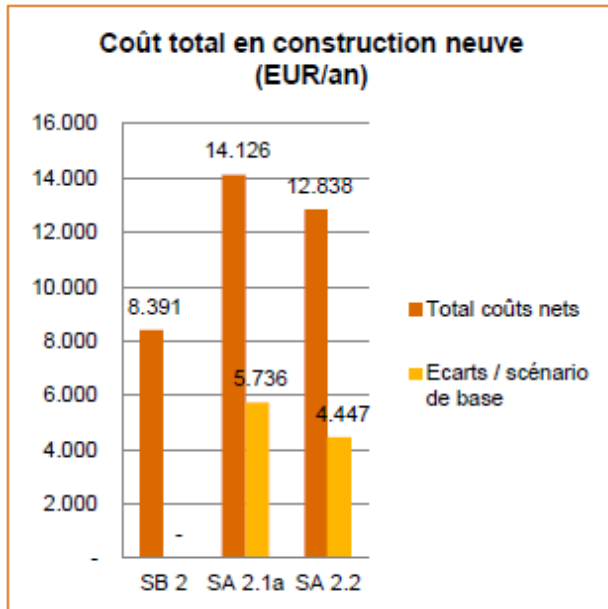
II.3.1.2 Scenario 2: Heating needs in apartment buildings

In the second case examined, collective condensing boilers (BS2) are compared with, respectively:

- cogeneration supplemented by collective condensing boilers (AS 2.1a);
- individual condensing boilers (AS 2.2).

As shown in the left-hand figure³⁴ below, which deals specifically with **new buildings**, cogeneration is a less competitive alternative than the baseline scenario. The second option (individual boilers) is also more costly, although to a lesser degree (BS2).

The baseline scenario is also the most competitive in the case of **renovations**, as outlined in the figure on the right. Cogeneration³⁵ (10 kWth for SA 2.1a) is also much more expensive than individual boilers (AS 2.2), which themselves entail considerable additional cost compared with the baseline scenario (BS 2).



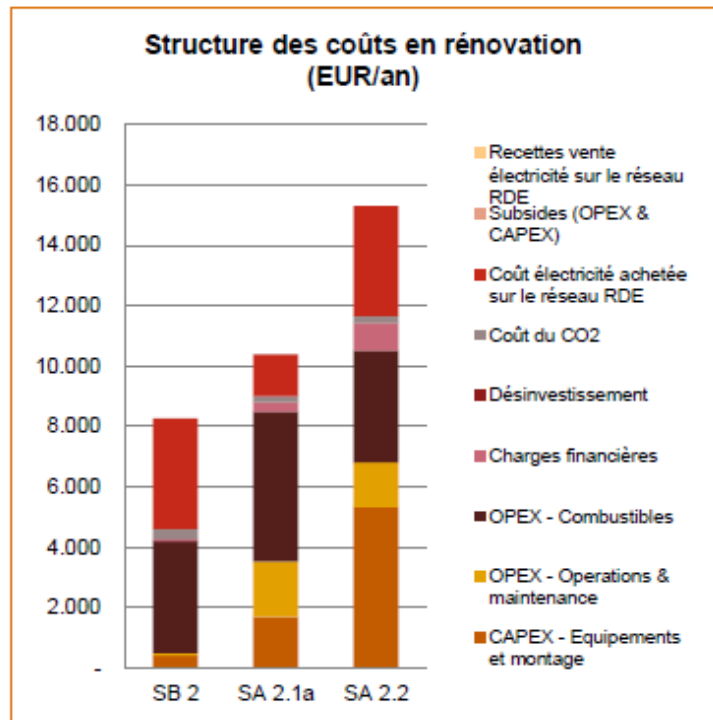
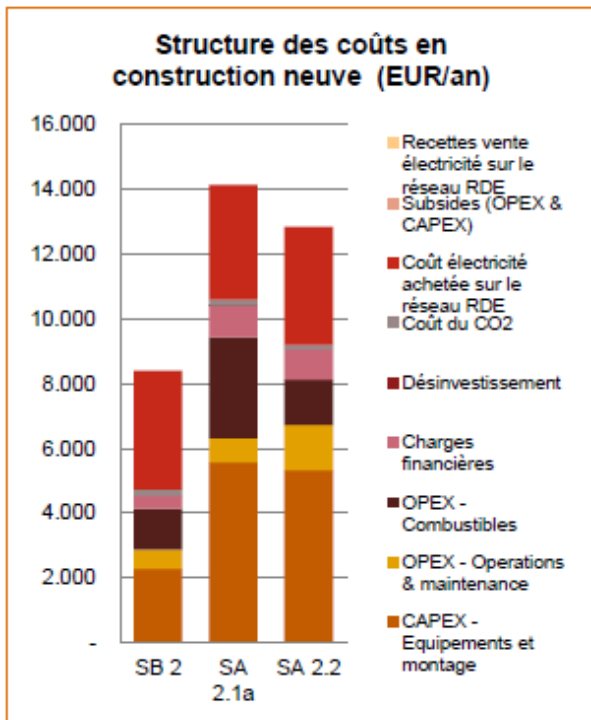
Cout total en construction neuve (EUR/an)	Total cost – new build (EUR/year)
Cout total en rénovation (EUR/an)	Total cost – retrofit (EUR/year)
Total couts nets	Total net costs
Ecart/scenario de base	Baseline scenario

The left-hand figure below shows that, in the case of **new builds**, the main line item responsible for the additional cost associated with the final option (individual boilers, AS 2.2) is ‘other net costs’, such as CAPEX, OPEX and financial expenses.

Capital expenditure (CAPEX) also places a considerable burden on the cost chain for **renovations**, as outlined in the right-hand figure. The second line item responsible for this negative differential encompasses operating expenses and heating fuel costs (this is a combined line item).

³⁴ Net present value of total costs on an equivalent annualised basis.

³⁵ Estimated using Cogencalc.



Structure des coûts en construction neuve (EUR/an)	Cost structure – new build (EUR/year)
Structure des coûts en rénovation (EUR/an)	Cost structure – renovation (EUR/year)
Recettes vente électricité sur le réseau RDE	Income from sale of electricity back to the RDE grid
Subsidés (OPEX & CAPEX)	Subsidies (OPEX & CAPEX)
Coût électricité achetée sur le réseau RDE	Cost of electricity purchased from the RDE grid
Coût de CO2	Cost of CO2
Désinvestissement	Disinvestment
Charges financières	Financial expenses
OPEX – Combustibles	OPEX - Heating fuel
OPEX – Operations & maintenance	OPEX – Operations & maintenance
CAPEX – Equipements et montage	CAPEX – Equipment and assembly

II.3.1.3 Scenario 3: Heating needs in office and retail buildings

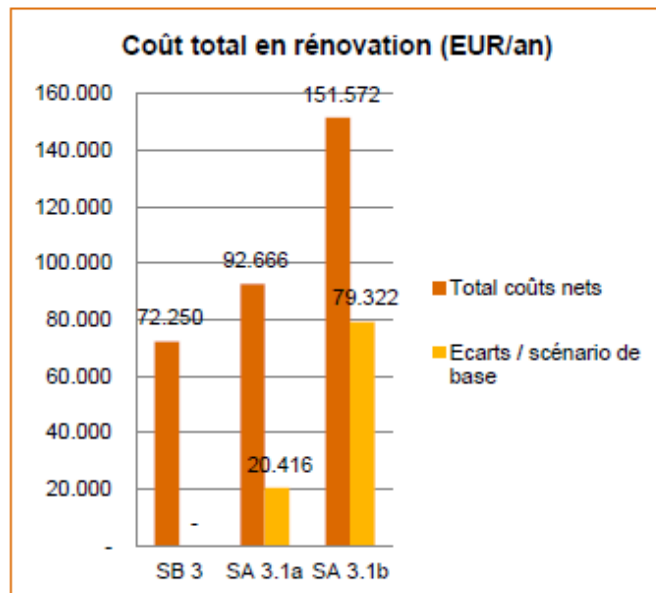
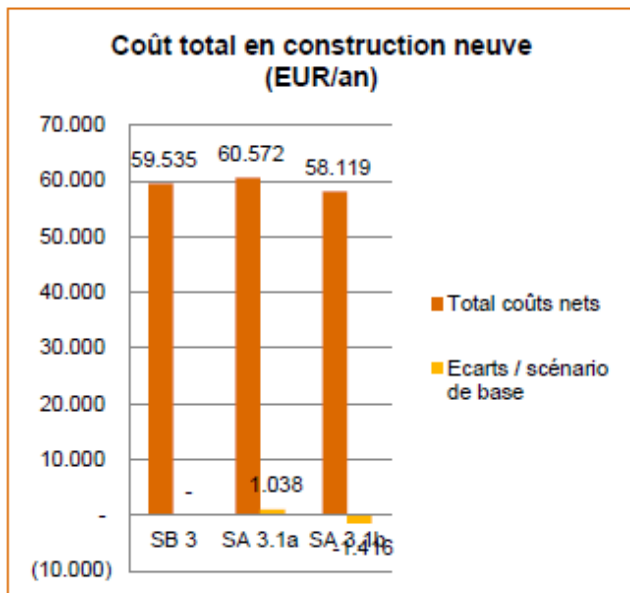
The baseline scenario covers collective boilers (BS 3). The two options examined are, respectively:

- absorption heat pumps (AS 3.1a);
- compression heat pumps (AS 3.1b).

In the case of **new builds** as shown in the figure on the left³⁶, the baseline scenario is comparable to the two alternatives in terms of competitiveness. Absorption heat pumps (AS 3.1a) are very slightly more expensive than collective boilers (BS 3). In contrast, compression heat pumps (AS 3.1b) are a little more affordable.

The baseline scenario is still the most competitive in **renovations**, as shown in the figure on the right. A feature of both options is an appreciable difference in cost compared with the baseline scenario. The option that fares best is the compression cycle (AS 3.1b), which is slightly less competitive than the baseline option. In contrast, compression heat pumps are much more costly (AS 3.1b)

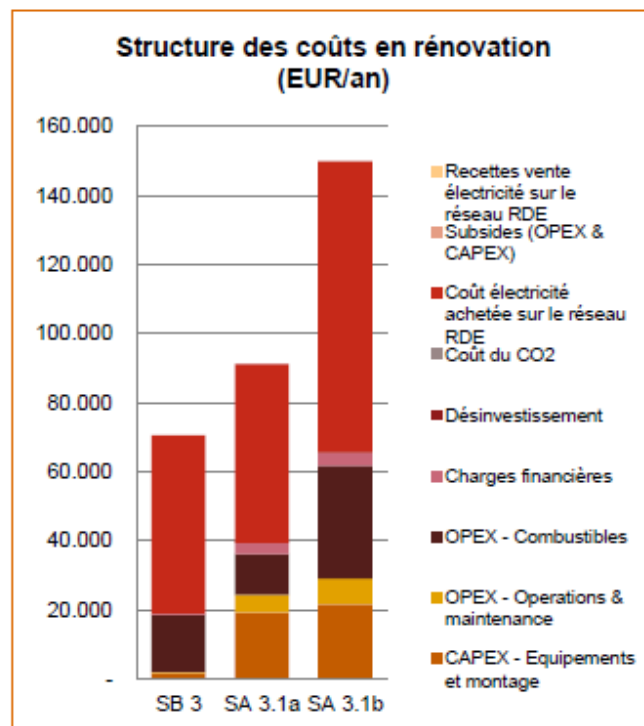
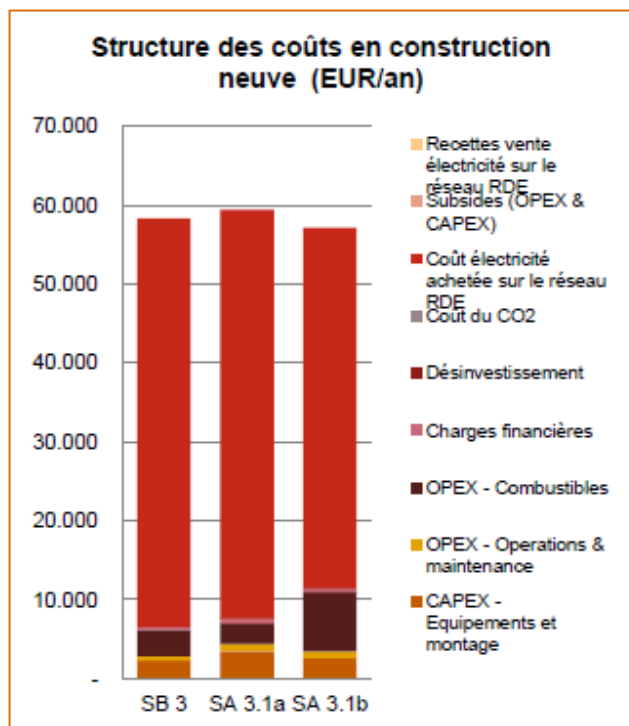
³⁶ Net present value of total costs on an equivalent annualised basis.



Cout total en construction neuve (EUR/an)	Total cost – new build (EUR/year)
Cout total en rénovation (EUR/an)	Total cost – retrofit (EUR/year)
Total couts nets	Total net costs
Ecart/scenario de base	Baseline scenario

The three **new build** scenarios are characterised by a substantial electricity bill, the first element in the cost chain (see the left-hand figure below).

The impact of electricity purchases is also significant in the three **renovation** scenarios considered here, and to a greater extent (see the right-hand figure below).



Structure des coûts en construction neuve (EUR/an)	Cost structure – new build (EUR/year)
Structure des coûts en rénovation (EUR/an)	Cost structure – renovation (EUR/year)
Recettes vente électricité sur le réseau RDE	Income from sale of electricity back to the RDE grid
Subsides (OPEX & CAPEX)	Subsidies (OPEX & CAPEX)
Coût électricité achetée sur le réseau RDE	Cost of electricity purchased from the RDE grid
Coût de CO2	Cost of CO2
Désinvestissement	Disinvestment
Charges financières	Financial expenses
OPEX – Combustibles	OPEX - Heating fuel
OPEX – Operations & maintenance	OPEX – Operations & maintenance
CAPEX – Equipements et montage	CAPEX – Equipment and assembly

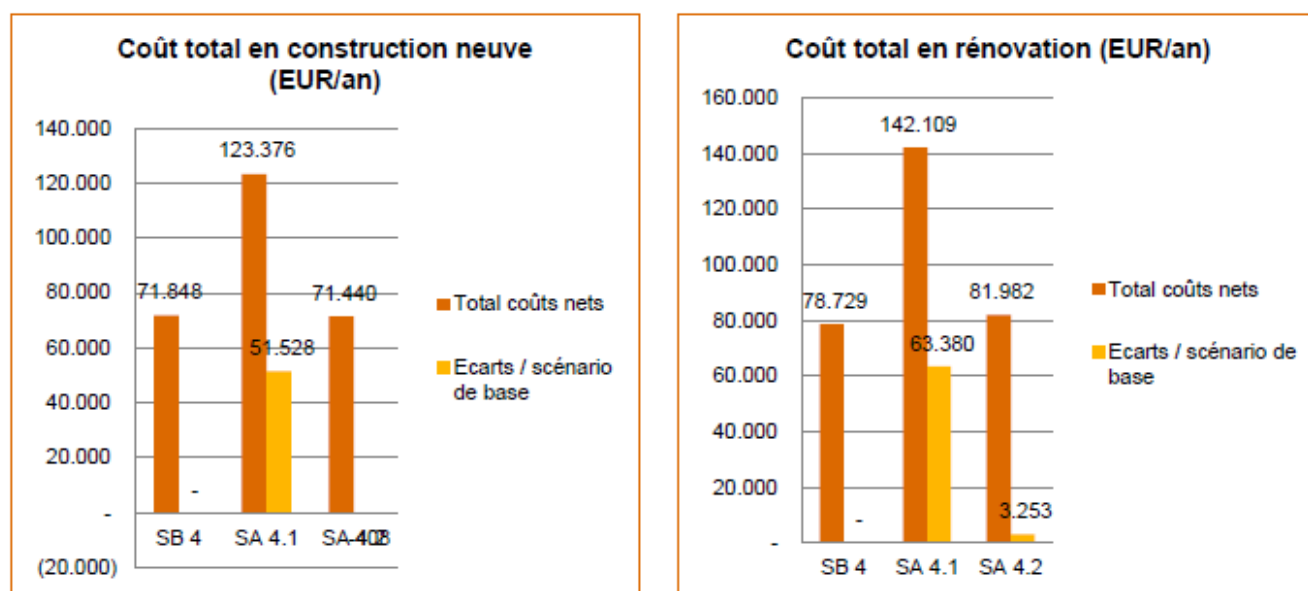
II.3.1.4 Scenario 4: Cooling needs in office and retail buildings:

The final baseline scenario involves the use of conventional refrigeration units for office buildings and shops (BS 4). It covers significant refrigeration needs and is compared with two sub-options:

- i. gas cogeneration supporting an absorption cycle (AS 4.1);
- ii. a small district cooling network supplied by reverse cycle water-source heat pumps (AS 4.2).

The baseline scenario remains competitive for **new buildings** (SB 4). Cogeneration with an absorption cycle is a much more costly option than district cooling in conjunction with heat pumps (see the left-hand figure below³⁷), a scenario which is only slightly less competitive than the baseline.

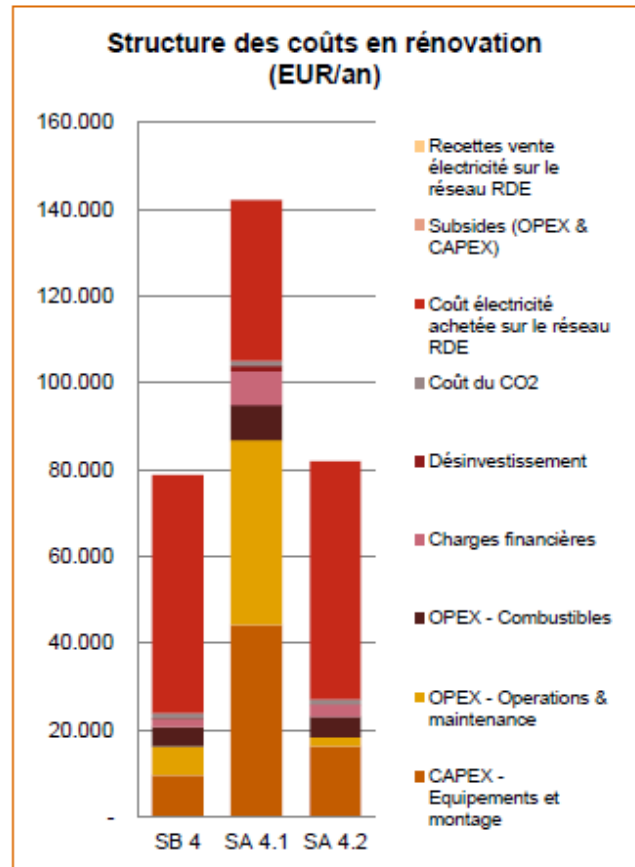
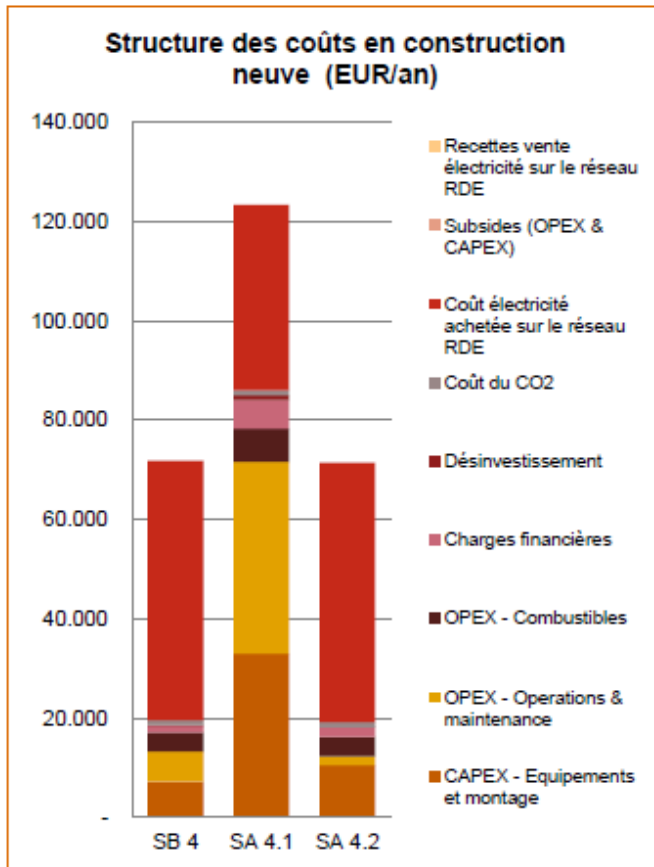
As regards **renovations**, conventional refrigeration units are still the most competitive solution (SB 4). The absorption cycle option is much more expensive, while heat pumps supplying a network are at only a slight competitive disadvantage compared with the baseline option.



Cout total en construction neuve (EUR/an)	Total cost – new build (EUR/year)
Cout total en rénovation (EUR/an)	Total cost – retrofit (EUR/year)
Total couts nets	Total net costs
Ecart/scenario de base	Baseline scenario

The main line item responsible for the additional cost is ‘other net costs’, such as CAPEX, OPEX and financial expenses. As with the previous scenarios, it includes investments. Cogeneration absorption cycles (AS 4.1) generate savings on purchases of electricity, but these cannot offset the ‘other net costs’ comprising the other cost components cited.

³⁷ Net present value of total costs on an equivalent annualised basis.



Structure des coûts en construction neuve (EUR/an)	Cost structure – new build (EUR/year)
Structure des coûts en rénovation (EUR/an)	Cost structure – renovation (EUR/year)
Recettes vente électricité sur le réseau RDE	Income from sale of electricity back to the RDE grid
Subsidies (OPEX & CAPEX)	Subsidies (OPEX & CAPEX)
Coût électricité achetée sur le réseau RDE	Cost of electricity purchased from the RDE grid
Coût de CO2	Cost of CO2
Désinvestissement	Disinvestment
Charges financières	Financial expenses
OPEX – Combustibles	OPEX - Heating fuel
OPEX – Operations & maintenance	OPEX – Operations & maintenance
CAPEX – Equipements et montage	CAPEX – Equipment and assembly

SUMMARY TABLE: Results expressed as net present values on an equivalent annual basis (NPV/year)

New builds		BS 1	AS 1.1a	AS 1.1b	BS 2	AS 2.1a	AS 2.2	BS 3	AS 3.1a	AS 3.1b	BS 4	AS 4.1	AS 4.2
Total net costs	EUR/year (T0)	18 017	25 315	19 915	8 391	14 126	12 838	59 535	60 572	58 119	71 848	123 376	71 440
Variance/baseline scenario	EUR/year (T0)	-	7 299	1 898	-	5 736	4 447	-	1 038	1 416	-	51 528	-408

Renovations		BS 1	AS 1.1a	AS 1.1b	BS 2	AS 2.1a	AS 2.2	BS 3	AS 3.1a	AS 3.1b	BS 4	AS 4.1	AS 4.2
Total net costs	EUR/year (T0)	28 599	40 668	38 427	8 258	10 371	15 298	72 250	92 666	151 572	78 729	142 109	81 982
Variance/baseline scenario	EUR/year (T0)	-	12 068	9 828	-	2 113	7 040	-	20 416	79 322	-	63 380	3 253

II.3.2 Sensitivity analysis

A sensitivity analysis was performed on those main variables where some doubt remains about how they will change in the long term (see below). The results for all the relevant scenarios are set out in the figures below.

The analysis examined the following:

- 1) the rate of inflation for natural gas;
- 2) the rate of inflation for electricity;
- 3) the rate of growth in operating expenses (excluding heating fuel);
- 4) the cost of capital or discount rate.

The underlying assumption is that these variables relate to forecasts that are reasonably likely to change between now and 2030. This is the case in particular for financing conditions and the market for primary energy commodities, both of which are heavily influenced by economic context. It is also true, however, for electricity prices, which are subject to fluctuations in the prices of standard primary sources and changes in the energy mix; ultimately it holds true as well, although to a lesser degree, for operating expenses.

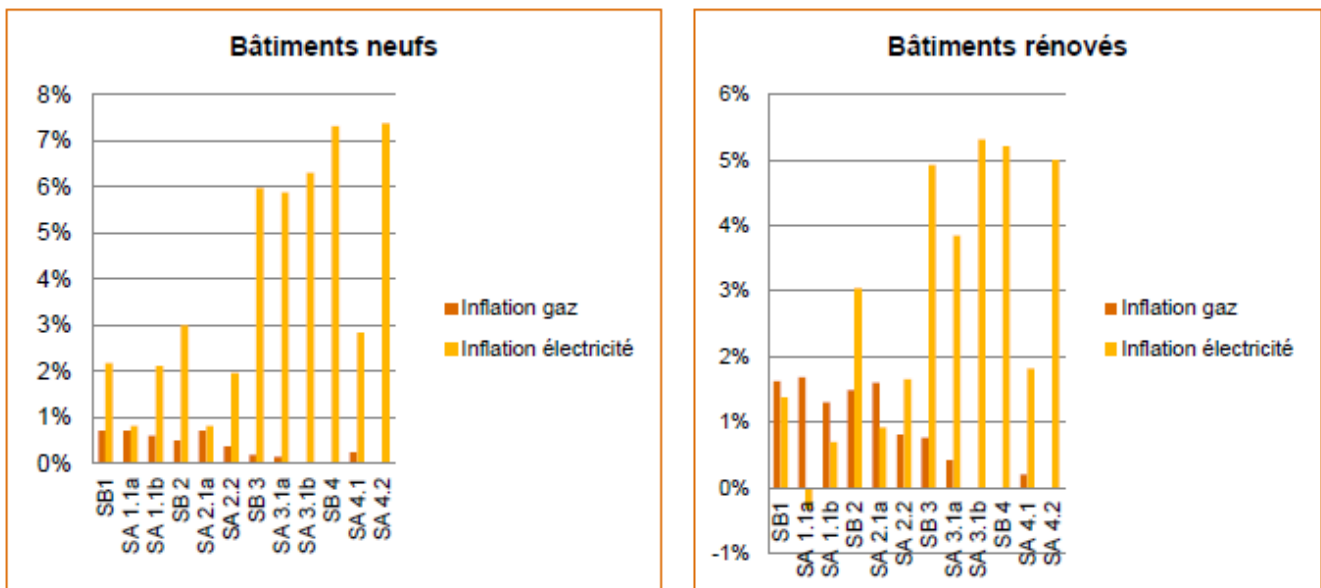
The analyses were all performed with a standard adjustment to the relevant rates to ensure that results were comparable, with a common variance of **+50 %** from the reference rate used for the baseline scenarios.

As previously, the approach considers new and renovated buildings separately.

It will be seen that the profiles and orders of magnitude of the two inflation variables applied to energy products (gas and electricity) are reasonably comparable. This is the case in particular for new buildings where the sensitivity range for the two variables is between 0 % and 7 % (left-hand figure).

However, electricity tariffs are subject to higher inflation than for gas prices, particularly in the commercial (BS3) and cooling (BS4) scenarios, which are characterised by very high electricity demand.

As regards renovations, the sensitivities already observed for new builds are rather lower overall. At first glance, this can be explained by the greater extent of building reconversion work.

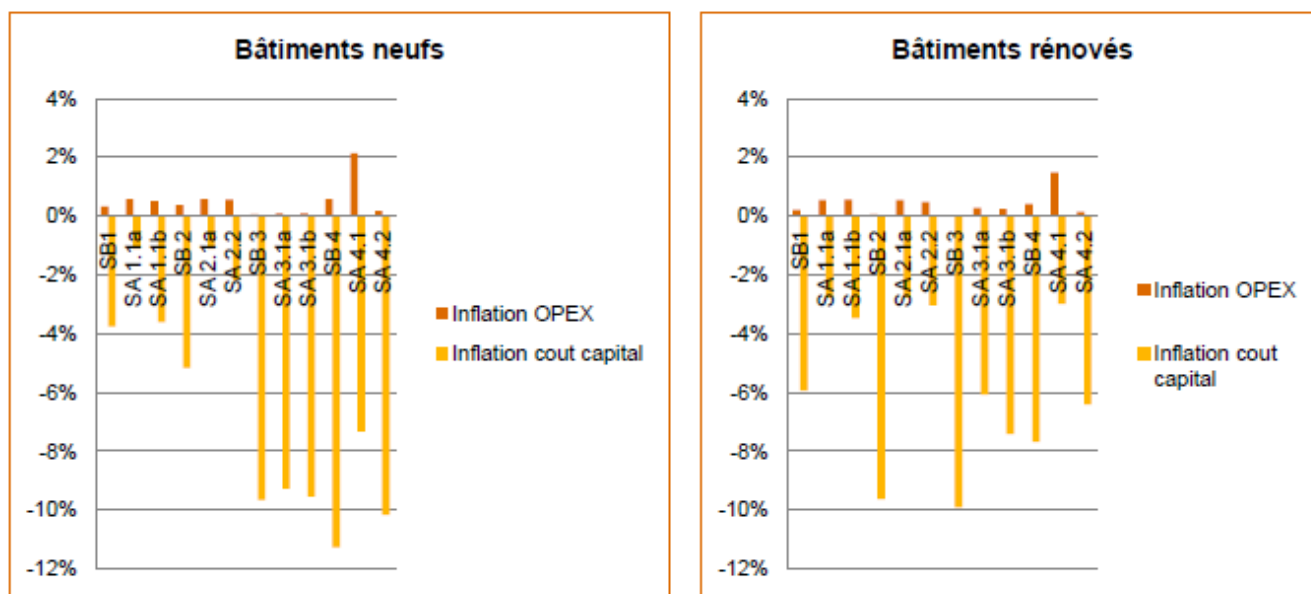


New buildings	Bâtiments neufs
Renovated buildings	Bâtiments rénovés
Gas inflation	Inflation gaz
Electricity inflation	Inflation électricité

The results are also mixed, since inflation can have a negative impact on energy prices in situations where cogeneration offers the opportunity not only for savings on potentially more costly electricity purchases, but especially for exporting a significant surplus to the network (AS 1.1.a, retrofiting). Even in situations that do not go so far, at the very least cogeneration seems to offer a means of moderating rapid growth in the cost of electricity. This factor is speculative, since it is based on longer-term forecasts.

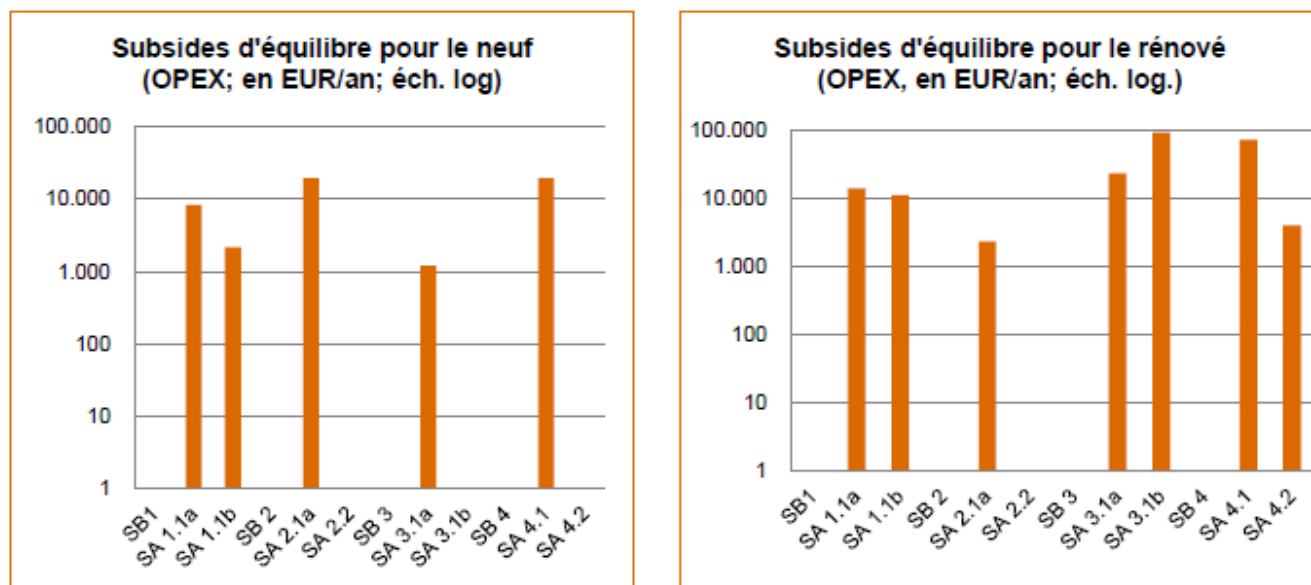
The ranges of price shifts in OPEX and the cost of capital are comparable, but fall either side of zero (see the figures below). Overall, an increase in capital costs tends to reduce future expenditure and therefore costs. The reverse is true for OPEX.

As indicated for new builds, the cost of capital has a bigger impact in the commercial scenarios (SB 3) and the cooling scenarios (SB 4) than for the other new construction segments (BS 1 and BS 2). There is greater variation in sensitivity between the technology scenarios in the case of renovations.



Bâtiments neufs	New buildings
Bâtiments rénovés	Renovated buildings
Inflation OPEX	Inflation in OPEX
Inflation cout capital	Inflation in the cost of capital

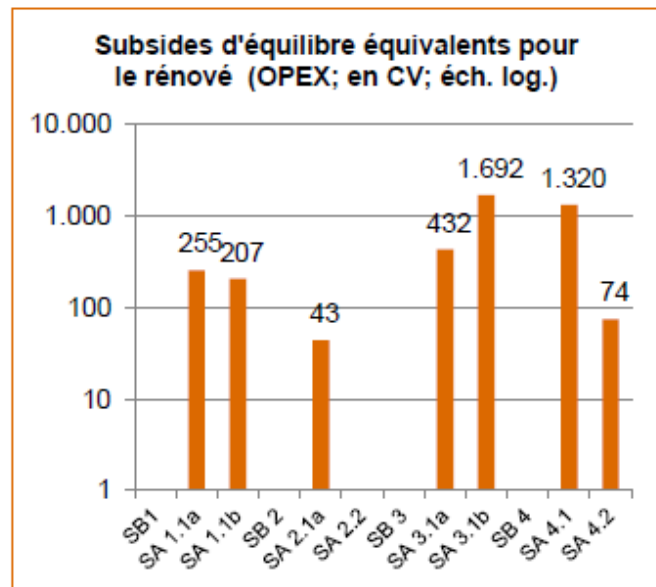
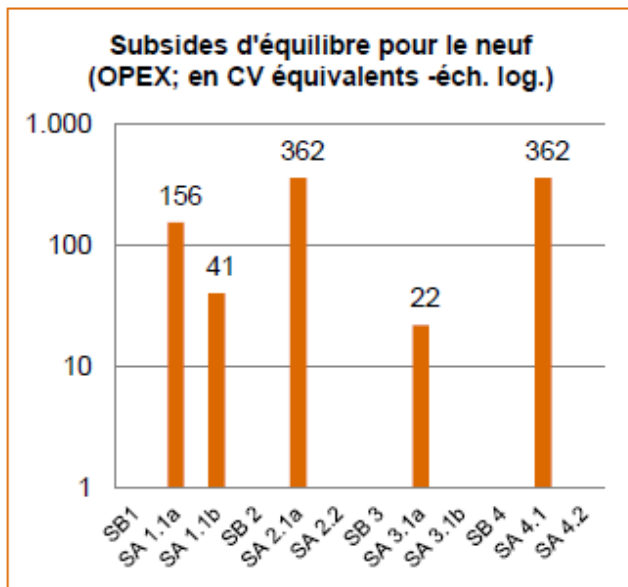
The final stage in the sensitivity analysis involves the need for subsidies which would be required to achieve a competitive balance between the baseline scenario, on the one hand, and the alternatives considered on the other. New builds and renovations will again be addressed separately, as shown in the two figures below.



Subsides d'équilibre pur le neuf (OPEX ; en EUR/an ; éch. Log)	Balancing subsidies for new builds (OPEX; in EUR/year; log. scale)
Subsides d'équilibre pur le rénové (OPEX ; en EUR/an ; éch. Log)	Balancing subsidies for renovations (OPEX; in EUR/year; log. scale)

The subsidy amounts are determined as part of an annual assistance payment that is subject to inflation in the same way as operating expenses (OPEX). These amounts may be significant in some cases.

The results are expressed as green certificates and are as follows.



Subsides d'équilibre pur le neuf (OPEX ; en CV équivalents -éch. Log)	Balancing subsidies for new builds (OPEX; in green certificate equivalent; log. scale)
Subsides d'équilibre pur le rénové (OPEX ; en CV équivalents -éch. Log)	Balancing subsidies for renovations (OPEX; in green certificate equivalent; log. scale)

It should be noted that since green certificates can be granted for a period of 10 years³⁸, the figures reported were converted so as to re-allocate the green certificate credit that could theoretically be generated during the life span of the equipment over the regulatory grant period.

II.3.3 Conclusions

The energy load profiles of the four baseline scenarios examined are quite different and reflect actual situations.

Uniform energy needs ensure that technical comparisons can be made between each baseline scenario and its associated alternatives. At the same time, all the economic analyses are based on net present value results to ensure that amounts occurring at different times can be compared over time, given the operational life of 15 years adopted for the scenarios that were examined. The same cost of capital is applied when discounting the corresponding payment schedules.

Lastly, the results must be evaluated in light of the particular urban context and the specific needs of the BCR. It cannot be inferred that the findings below are valid for other environments, therefore.

Looking at the different simulations, it emerges that the baseline options are generally the most competitive, both for new builds and renovations.

Cogeneration can offset the additional costs incurred by network distribution only partially when the two are used in conjunction. For this reason, no further consideration will be given to district heating in the remainder of the study (Task 5).

The competitiveness of cogeneration is also impacted by the additional cost of the supplementary system, where necessary. This is the case for scenarios AS 1.1a (district heating supplied by a high efficiency cogeneration system and supplementary heating) and AS 1.1b (district heating with gas cogen + supplementary heating supplied by heat pumps).

Independently of the scenarios including cogeneration and/or a district network, the potential value of the conventional option of condensing boilers has been confirmed, especially for collective systems in individual buildings (with no network). This is largely down to their high level of efficiency and, in the latter scope of application, to the economies of scale available to the system.

³⁸ Green certificates can be granted for a period of 10 years. The various scenarios are assessed over a longer period, though, which is 15 years. The amounts of the green certificates required have therefore been re-allocated over a 10-year period, which is shorter than the life span of the equipment.

In other cases, there are sometimes considerable variances between the costs for the baseline scenarios and the alternative options. In general, the 'other net costs' line item is a significant factor in the competitive disadvantage of the alternative scenarios in question. An element with a potentially significant impact is the cost of capital.

It should be assumed that tax (including VAT) is not taken into account in the results.

The results may demonstrate considerable sensitivity to the main external variables, particularly in the case of commercial applications and cooling. The lack of competitiveness of the proposed alternatives could generally be addressed through subsidies in the form of operational assistance, such as green certificates.

Large levels of subsidy would be required to restore the competitiveness of the alternative options that do not stand up against the baseline scenarios for reasons of additional investment costs and often higher operating expenses as well.

Chapter 5 – Economic potential of cogeneration

INTRODUCTION

Purpose and methodology

The purpose of this report on Task 5 is to produce an analysis of the economic potential of cogeneration. The **methodology** adopted includes the following four steps:

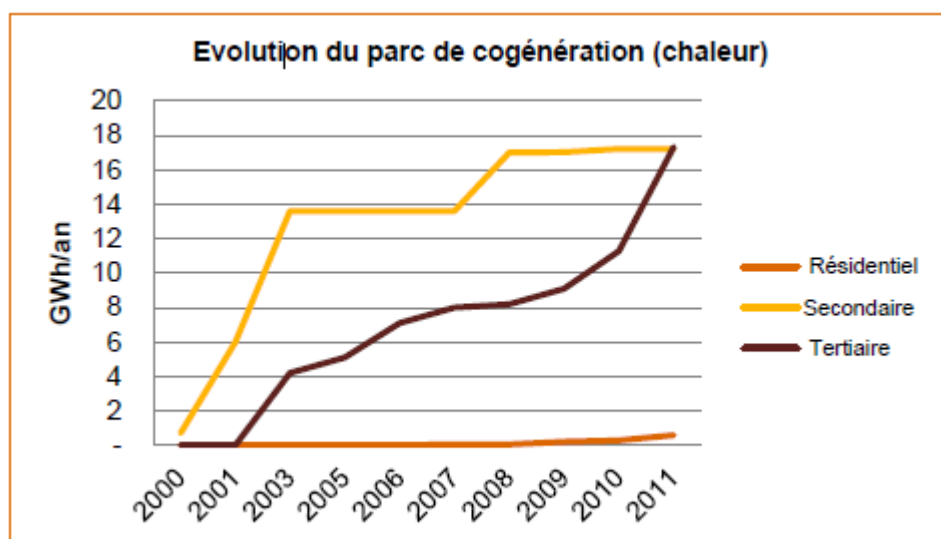
- Phase 5.1: **aligning technologies with current needs**
- Phase 5.2: **maximising current potential**
- Phase 5.3: **incorporating cogeneration into heating needs**
- Phase 5.4: **making projections for the two time horizons under consideration**

I. ALIGNMENT OF TECHNOLOGIES WITH CURRENT NEEDS

I.1 DEVELOPMENT OF COGENERATION IN THE BCR

I.1.1 Change over time

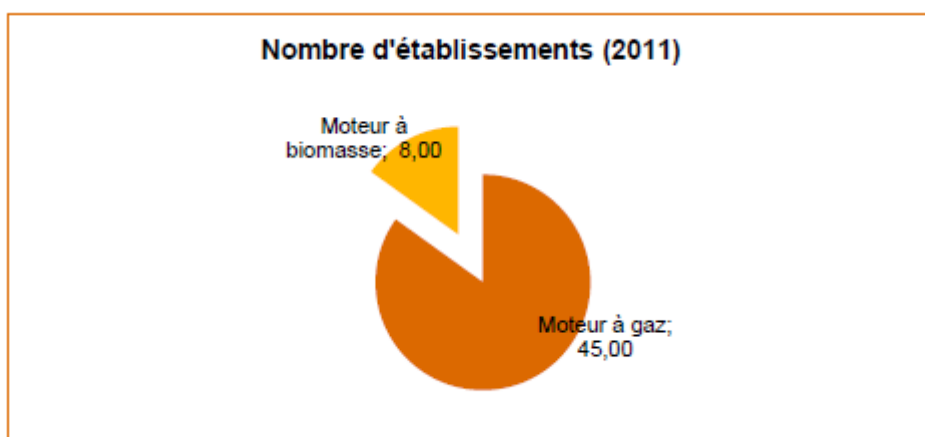
The development paths followed by the sector profiles have been mixed. In 2011³⁹, cogeneration satisfied heat demand of 37.6 GWh a year in the BCR. The same data show that the industrial sector has been declining over the last five years, while housing still accounts for a very small share of the market for cogeneration. In contrast, the service sector has experienced strong growth since 2003.



Evolution du parc de cogénération (chaleur)	Change in cogeneration capacity (heating)
Résidentiel	Residential
Secondaire	Secondary
Tertiaire	Services

I.1.2 Segmentation by fuel

In 2011, cogeneration capacity in Brussels comprised 45 gas engines and eight biomass engines.

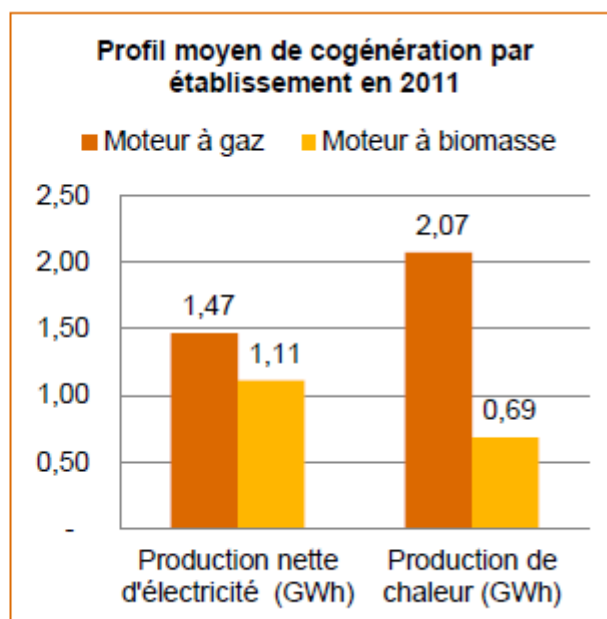
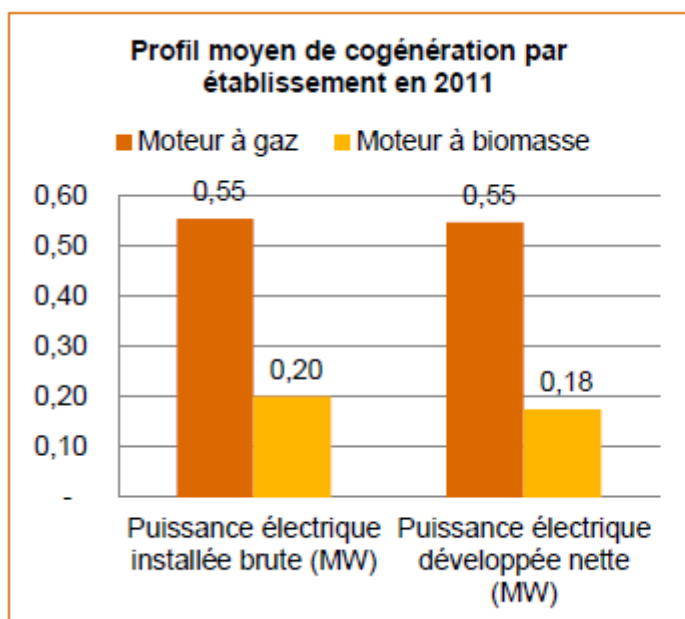


Nombre d'établissements (2011)	Number of facilities (2011)
--------------------------------	-----------------------------

³⁹ Source: Report on energy consumption in the BCR in 2011, PwC calculations.

Moteur a biomasse ; 8,00	Biomass engine; 8.00
Moteur a gaz ; 45,00	Gas engine; 45.00

Gas engines are most numerous in the BCR and they are also larger, as the figures below demonstrate.

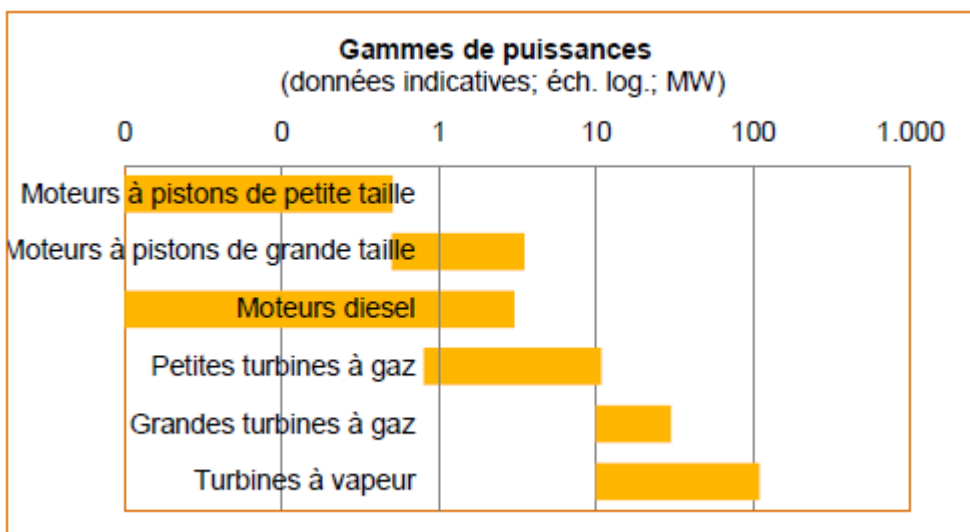


Profil moyen de cogénération par établissement en 2011	Average cogeneration profile by facility in 2011
Moteur à gaz	Gas engine
Moteur a biomasse	Biomass engine
Puissance électrique installée brute (MW)	Gross installed electrical power capacity (MW)
Puissance électrique développée nette (MW)	Net electrical power output (MW)
Production nette d'électricité (GWh)	Net electricity production (GWh)
Production de chaleur (GWh)	Heat production (GWh)

Available technology

The following figure on the available technologies for combined heat and power production units prompts a number of observations:

- Piston engines (and therefore diesel engines) are used at the bottom of the range of power capacities.
- Gas turbines are used in the mid-range.
- Steam cycles are used only for very large-scale facilities.



Gammes de puissances (données indicatives ; éch. Log. ; MW)	Power capacity ranges (indicative data; log. scale; MW)
Moteurs à pistons de petite taille	Small piston engines
Moteurs à pistons de grande taille	Large piston engines
Moteurs diesel	Diesel engines
Petites turbines à gaz	Small gas turbines
Grandes turbines à gaz	Large gas turbines

The cogeneration facilities currently in existence in the BCR have a power capacity of less than 3.1 MW, with an average of 0.6 MW, suggesting a statistical bias towards very small units.

Gas engines are used in the majority of cases in the BCR. The use of natural gas as a heating fuel is explained by the urban status of the region, which features a significant population density and widespread access to the distribution network.

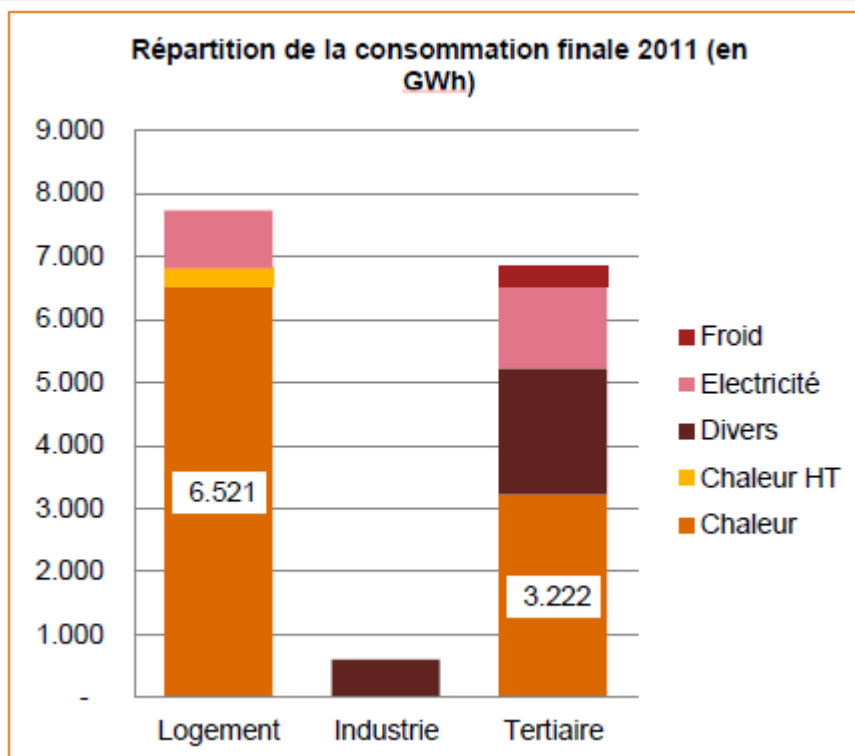
Furthermore, as identified above, the cogeneration units that have been installed are generally small, which is a plus for gas engine manufacturers.

II. ESTABLISHING THE VALUE OF CURRENT POTENTIAL

The analyses and projections that follow are taken from the data available in the report on energy consumption in the Brussels-Capital Region (BCR) in 2011. Calculations were made by PwC.

II.1 STRUCTURE OF DEMAND

The following figure describes the structure of demand in 2011 in the housing, industrial and service sectors.



Répartition de la consommation finale 2011 (en GWh)	Breakdown of final consumption 2011 (in GWh)
Froid	Cooling
Electricité	Electricity
Divers	Other
Chaleur HT	HT heating
Chaleur	Heat
Logement	Housing
Industrie	Industry
Tertiaire	Services

Details of the main findings are set out below:

- Housing and the service sector are responsible for the largest percentage of final demand in BCR.
- Housing has the greatest heating needs, with this sector alone accounting for an aggregate 43 % of total demand across all sectors.
- The service sector is next, with a heating demand that amounts to 21.2 % of the total.
- In contrast, the largest proportion of electricity demand – 4.7 % – is concentrated in the service sector.
- Cooling demand is limited, at 2 %, and is mainly concentrated in the service sector.
- Demand from industry is negligible, something which is a fundamental characteristic of the energy

profile of the BCR⁴⁰.

Focusing now on the two priority sectors, housing and the service sector, it can be seen that they are very different in terms of the ratio of heating demand (Q) on the one hand to electricity demand (E) on the other.

The Q/E ratios given in the following table illustrate that there is much more of an imbalance in the housing sector than in the service sector, in favour of heating demand.

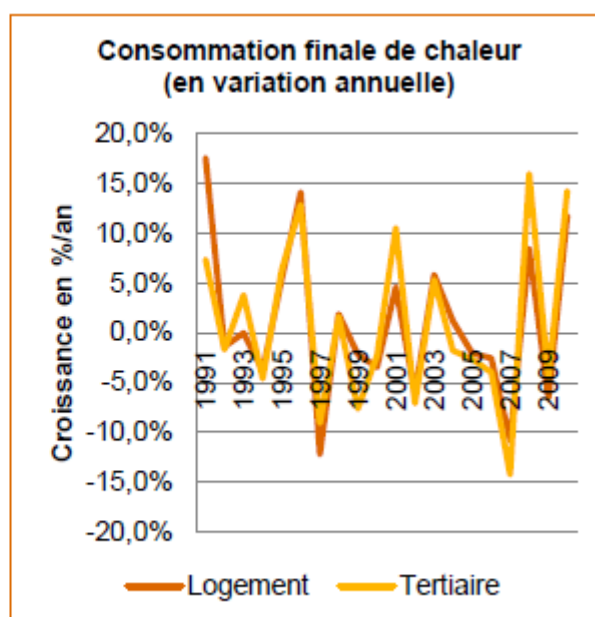
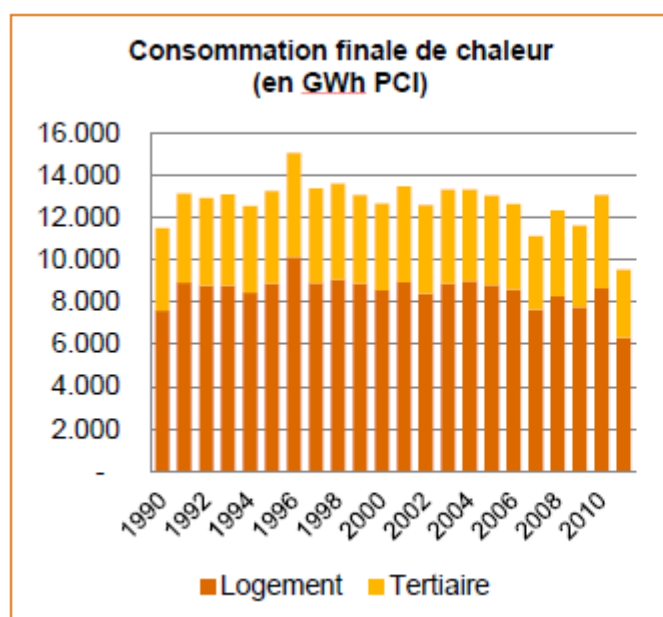
All other things being equal, this would make cogeneration facilities – where the sole aim is self-consumption – a more attractive option for the former sector than the latter. In other words, a large-scale cogeneration facility in the housing sector would tend to be a net exporter of electricity, at least if the hypothesis that all heat demand can be cogenerated is adopted. In practice, this is unrealistic as there are other parameters to be taken into account, such as heating and electricity load curves, which are likely to qualify the finding. This point is further addressed below.

<i>Q/E ratio</i>	
<i>Housing</i>	<i>Services</i>
7.09	2.46

II.2 CHANGE OVER TIME IN HEAT DEMAND

On average, heating demand remained relatively stable between 1993 and 2002, despite significant annual fluctuations. The variations seen can largely be explained by weather conditions (figures below)⁴¹.

More recent developments indicate a break with the trend. While short-term (annual) fluctuations are still significant, the last decade or so reveals a downward trend affecting both the housing and the service sector.

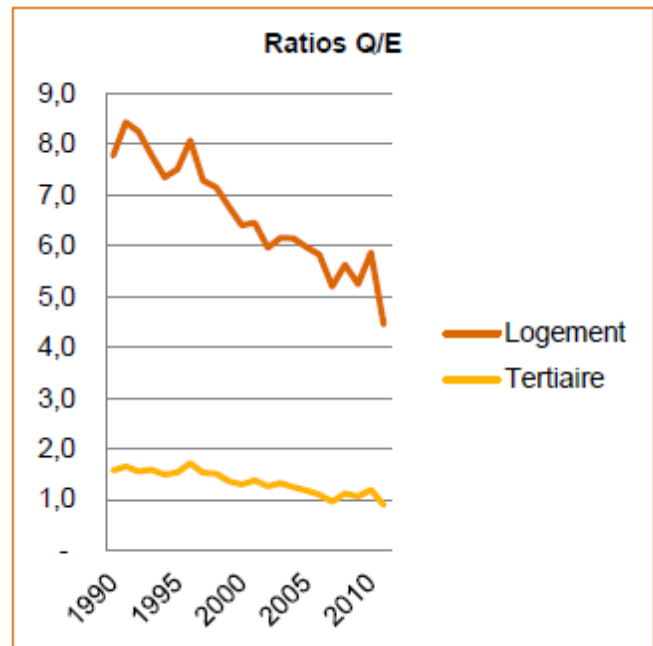
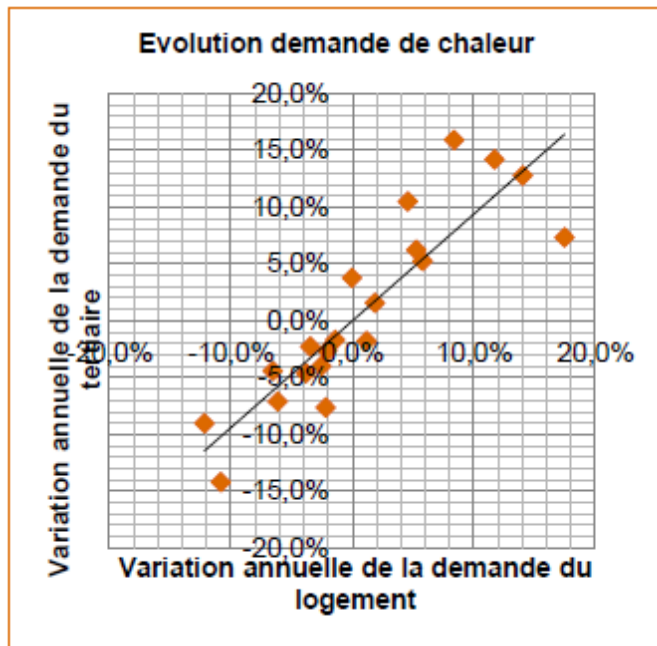


Consommation finale de chaleur (en GWh PCI)	Final heat consumption (in GWh LHV)
Logement	Housing
Tertiaire	Services
Consommation finale de chaleur (en variation annuelle)	Final heat consumption (annual change)
Croissance en %/an	Growth in %/year

⁴⁰ Based on initial analysis, it is not possible to separate out the different elements for the industrial sector using the available data. In addition, it should be remembered that the industrial sector makes a negligible contribution to final energy consumption.

⁴¹ The data used are raw and non-standardised. Annual fluctuations are therefore assumed to be 'smoothed' by the decline.

Closer analysis reveals a correlation between demand for heating in the housing and service sectors (see left-hand figure). As already stated, the situation in the first sector (housing) is not conducive to cogeneration wholly for self-consumption, even where the load is partial, while in the service sector, it is to be anticipated that part of the electricity will be imported from the network, even in cases where heat demand is largely met through cogeneration. This is the case on average, and all other things being equal (see right-hand figure).



Evolution demande de chaleur	Change in heat demand
Variation annuelle de la demande du tertiaire	Annual change in service sector demand
Variation annuelle de la demande du logement	Annual change in housing demand
Ratios Q/E	Q/E ratios
Logement	Housing
Tertiaire	Services

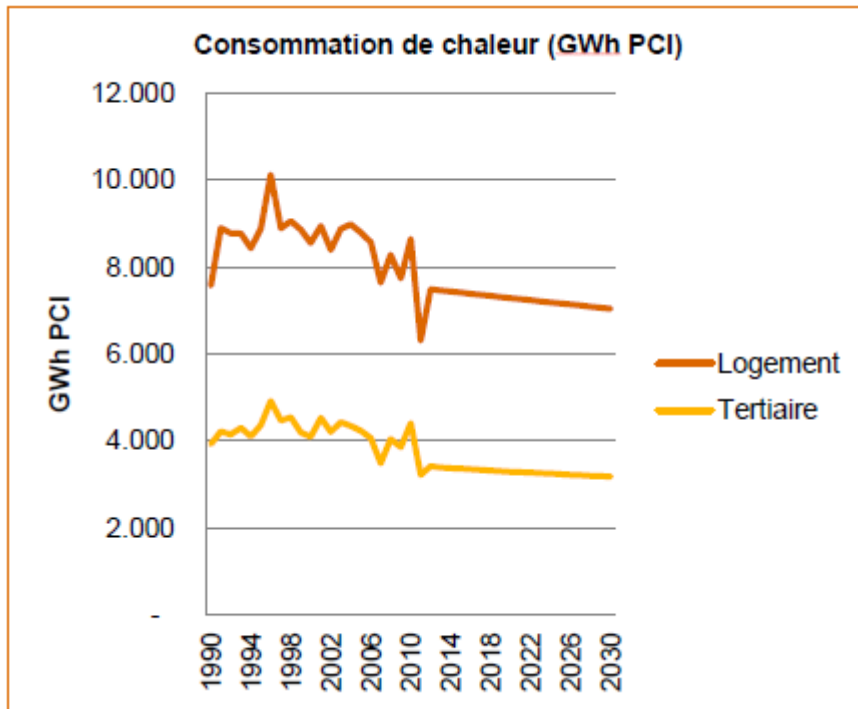
The Q/E ratios have been eroded most rapidly in the housing sector, both in absolute and relative terms (see right-hand figure).

II.3 FORECASTS FOR GROWTH IN HEAT DEMAND TO 2030

The forecasts of heat demand set out below were devised using the results from Task 1. They reflect a variety of forward-looking parameters (energy efficiency, number of homes, added value, etc.). Average rates of change for these projections are as follows:

- For housing (between 2012 and 2030): -0.89 %/year;
- For the service sector (between 2012 and 2030): -0.4 %/year.

The figure below gives the series of historic data on heat consumption in BCR and projected use to 2030.

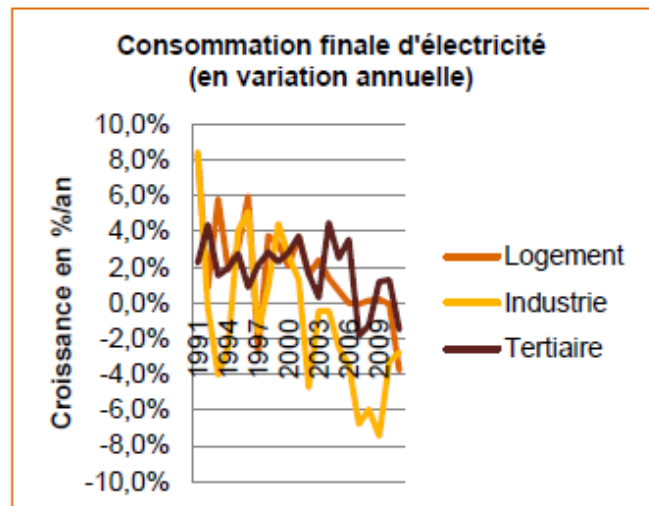
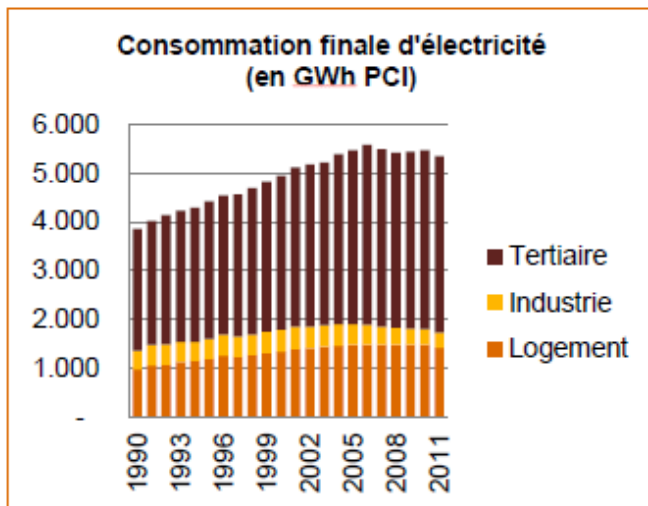


Consommation de chaleur (GWh PCI)	Heat consumption (GWh LHV)
Logement	Housing
Tertiaire	Services

The downward trend is particularly clear for both the housing and service sectors.

II.4 CHANGE OVER TIME IN ELECTRICITY DEMAND

The same approach was taken to projecting electricity demand. The results are shown in the following two figures.



Consommation final d'électricité (en GWh PCI)	Final electricity consumption (in GWh LHV)
Tertiaire	Services
Industrie	Industry
Logement	Housing
Consommation final d'électricité (en variation annuelle)	Final electricity consumption (annual change)

A number of observations emerge from the results shown in the graphs:

- Electricity demand is greatest by far in the *service sector*, and has continued to grow, albeit more slowly, since 2008 in particular. It even contracted slightly after 2010.
- The situation is comparable in the *housing* sector.

- Lastly, in *industry*, the change for electricity mirrors the pattern of change in heat demand. The contraction is significant, with growth rates consistently in negative territory since 2002.

II.5 FORECAST GROWTH IN ELECTRICITY DEMAND TO 2030

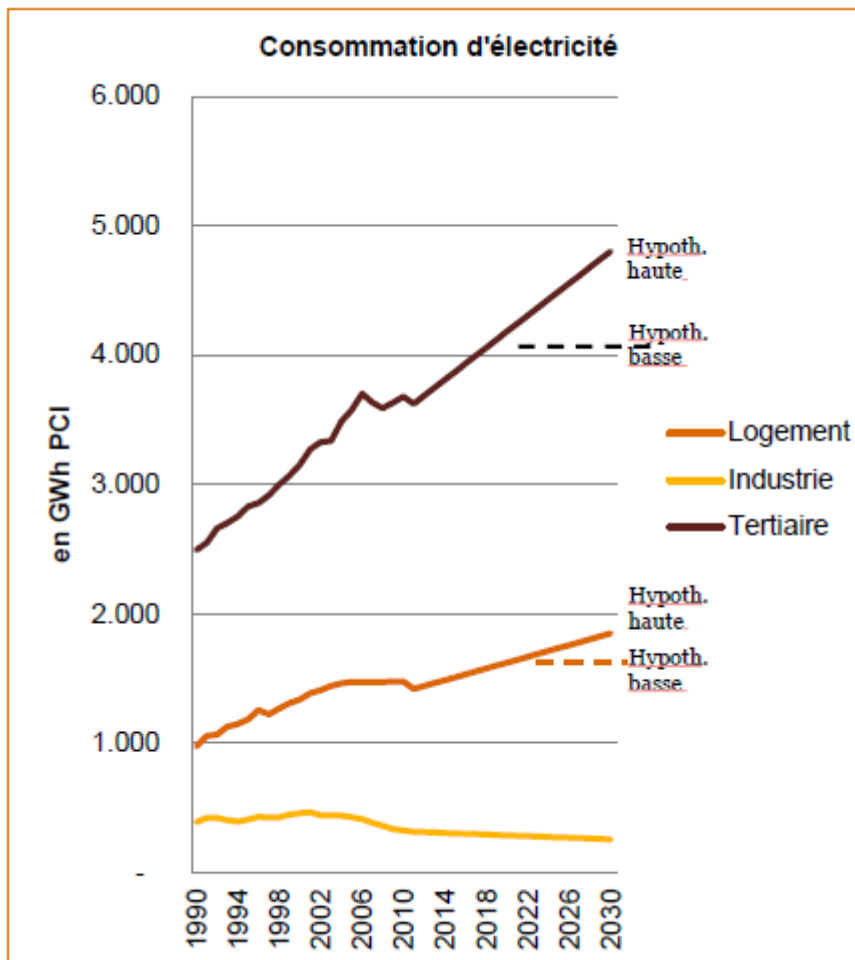
The following figure on electricity demand takes the same approach as for heat.

The working assumption is that the prevailing trend seen over the last two decades will continue. In this connection, the following points are worthy of note:

- There is a clear disparity between the three sectors considered, since the service sector continues to grow quite quickly, in contrast to industry which is expected to contract over the timeframe in question (2030).
- The housing sector continues to expand, but slowly.
- In addition to the downward trend observed, it should be remembered that the weight of the industrial segment is negligible in comparison with the other two sectors. It will not be discussed further.

For electricity, the package of forecasts described serves as a basis for two sub-scenarios, detailed as follows:

- In the best case, or high-case scenario, electricity demand continues to grow in the largest segments (housing and services) at the average pace for the last two decades.
- In contrast, the industrial sector experiences a contraction (this sector is not discussed further).
- In view of the relative stability seen in the first two sectors over the last few years, the low-case scenario assumes that demand will remain flat, as shown in the figure below.



In GWh LHV	En GWh PCI
High-case scenario	Hypoth. Haute
Low-case scenario	Hypoth. Basse
Housing	Logement
Industry	Industrie
Services	Tertiaire

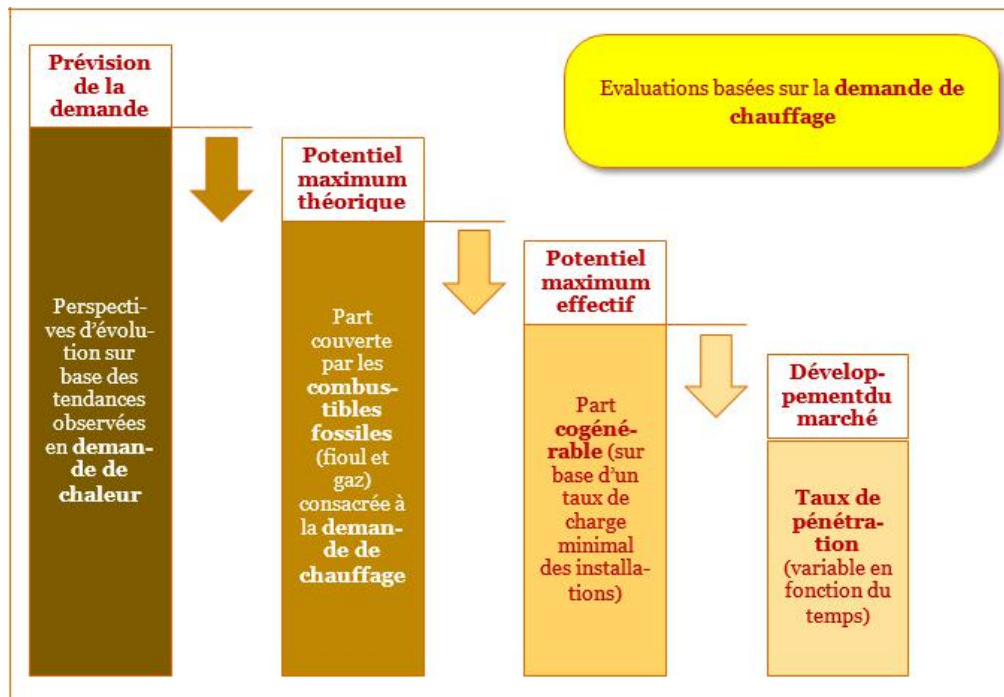
As indicated, the two sub-scenarios relate only to housing and services, as the two sectors selected for analysis. The ranges in values attached to the projections for electricity are somewhat broad.

III. INCORPORATING COGENERATION INTO HEATING NEEDS

III.1 METHODOLOGICAL APPROACH

Heating needs were evaluated using a top-down analytical framework, which is a classic approach to market analysis.

The figure below describes the four main constituent phases.



Evaluations basées sur la demande de chauffage	Evaluations based on heating demand
Prévision de la demande	Forecast demand
Perspectives d'évolution sur base des tendances observées en demande de chaleur	Outlook based on trends observed in heat demand
Potentiel maximum théorique	Theoretical maximum potential
Part couverte par les combustibles fossiles (fioul et gaz) consacrée à la demande de chauffage	Proportion covered by fossil fuels (fuel oil and gas) for heating demand
Potentiel maximum effectif	Actual maximum potential
Part cogéné-rable (sur base d'un taux de charge minimal des installations)	Proportion that can be cogenerated (based on a minimum system load rate)
Développement du marché	Market development
Taux de pénétra-tion (variable en fonction du temps)	Rate of penetration (variable over time)

As stated, the evaluation is based on heat demand, since it is generally representative of the sizing constraint associated with cogeneration systems⁴². The electricity produced by cogeneration will be then be based on average system Q/E ratios.

On a practical level, the starting point is therefore overall heat demand in BCR. A number of reductions deriving from physical incompatibilities are then applied. These include the type of heating fuel used and the desire for a minimum system operating time.

As above, the assumptions relating to the evaluation of the different potential values are taken from available

⁴² It should be noted, however, that cogeneration units in residential settings are sometimes sized on the basis of electricity needs. This takes place under very specific conditions that may, for example, be based on inability to sell the surplus back to the grid. Nonetheless, sizing on the basis of thermal demand is mainly the result of constraints such as the difficulty of using surplus heat (except in the case of district heating; see below), load curves and minimum system usage targets. This is the reason why some scenarios in this study include supplementary boilers. In this sense, a cogeneration unit may, on initial analysis, be seen as a generating unit that offers the possibility of recovering heat. In contrast, the economic approach considers a cogeneration unit to be a heating device that also produces electricity, which cost accounting treats as a co-product (not a by-product). The Q/E ratio also demonstrates that in terms of energy, heat production outweighs electricity production. These factors distinguish cogeneration systems from conventional localised production units from an economic perspective, despite significant technical similarities. It is also the reason that the baseline scenarios only involve conventional heating systems (condensing boilers).

statistical data series (report on energy consumption in the BCR, 2011).

Where there are limitations on available statistical data (as with the maximum market penetration used for forecasting), additional assumptions have been made.

III.2 WORKING ASSUMPTIONS

The following table sets out the main assumptions used:

	Housing	Services
Capacity already installed (GWh; 2011)	0.59	19.63
Central heating (%; 2011)	85.3 %	62.8 %
Fuel oil and gas (%; 2011)	95.8 %	71.1 %
Maximum % possible from cogeneration	60.0 %	60.0 %

To sum up, therefore:

- a) The trend in the market for heating is downwards, as stated above.
- b) The theoretical potential for the housing and service sectors is based only on central heating supplied by fossil fuels (fuel oil and natural gas).
- c) In both cases market penetration is assumed to be 60 % after 2030 (and is asymptotic).
- d) Clearly, this is an ideal scenario. Technical constraints (such as monotonic load curve) are reflected in the latter assumption regarding market penetration but economic constraints are not. This will be discussed below.

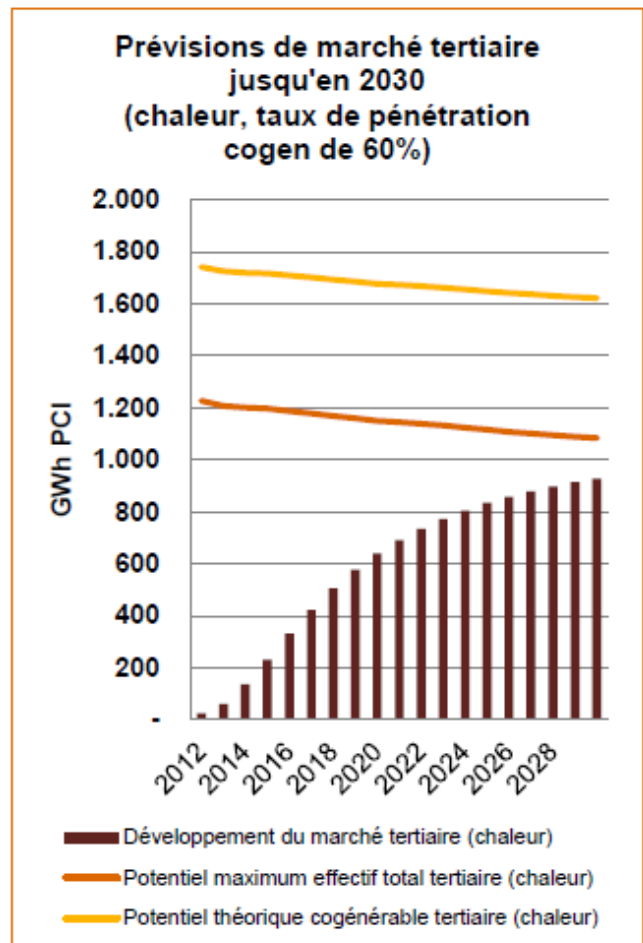
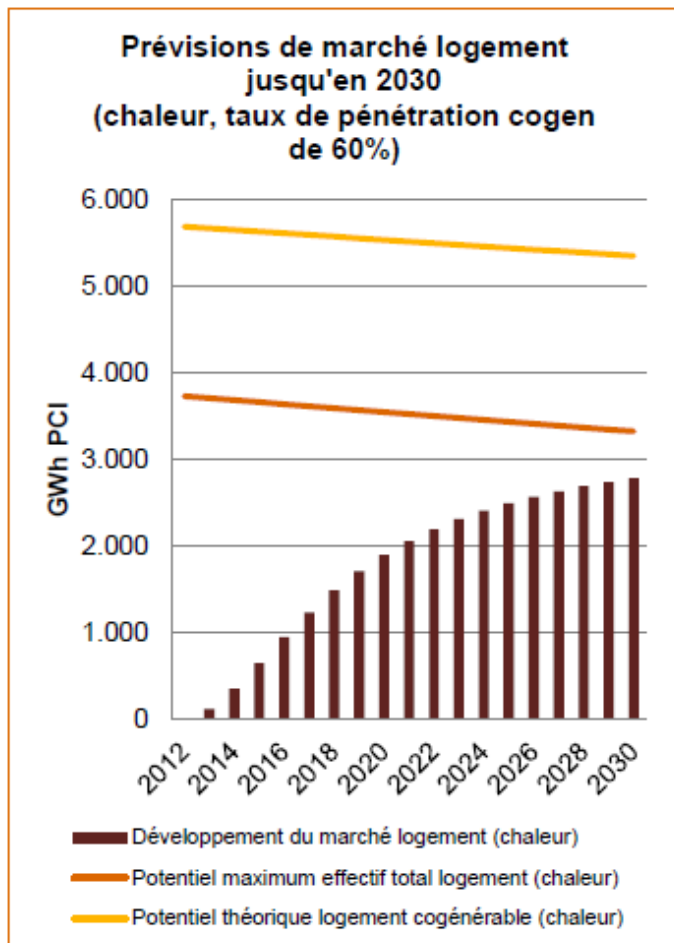
IV. PROJECTED POSITION FOR THE TWO TIME HORIZONS CONSIDERED

IV.1 SEGMENT-BASED ANALYSIS

The figures below show the different components of market potential. The figure on the left describes the situation for housing while the figure on the right relates to the service sector.

As can be seen, the market is in its infancy at the starting point of 2011 compared with the theoretical maximum potential, and with the total actual maximum potential. This holds true for both sectors, housing and services. A phase of more rapid expansion is then assumed, which begins to level off gradually at the end of the next decade (2020-2030).

In theory, forecasts are asymptotic with respect to the maximum actual potential of both sectors. In each case, though, the maximum is expected to be seen shortly after 2030, with a fall then likely as a result of the growing impact of energy savings. The potential market for cogeneration would then diminish accordingly. There would be no further expansion of cogeneration, therefore, and investment would be made solely to replace units operating in the most competitive environments.



Prévisions de marché logement jusqu'en 2030 (chaleur, taux de pénétration cogen de 60%)	Market forecasts for housing to 2030 (heating, 60 % cogen penetration rate)
GWh PCI	GWh LHV
Développement du marché logement (chaleur)	Growth in the housing market (heating)
Potentiel maximum effectif total logement (chaleur)	Total maximum actual potential for housing (heating)
Potentiel théorique logement cogénération (chaleur)	Theoretical potential of cogeneration for housing (heating)
Prévisions de marché tertiaire jusqu'en 2030 (chaleur, taux de pénétration cogen de 60%)	Market forecasts for the service sector to 2030 (heating, 60 % cogen penetration rate)
Développement du marché tertiaire (chaleur)	Growth in the service sector market (heating)
Potentiel maximum effectif total tertiaire (chaleur)	Total maximum actual potential for the service sector (heating)

Potentiel théorique cogénération tertiaire (chaleur)	Theoretical potential of cogeneration for the service sector (heating)
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It should be remembered that the assumptions that underlie the market penetration rate of 60 % adopted for the analysis are essentially technical and relate to the ability to use the systems for enough hours (in practice, between 2 500 and 3 000 hours) to ensure a minimum level of use.

The introduction of cost-efficiency requirements will surely lead to a considerable fall in market penetration. It could even be zero in absolute terms if certain, potentially cost-effective niches and the impact of adequate subsidies for restoring the competitive performance of such projects in comparison to conventional solutions were to be excluded. This was addressed in Task 4.

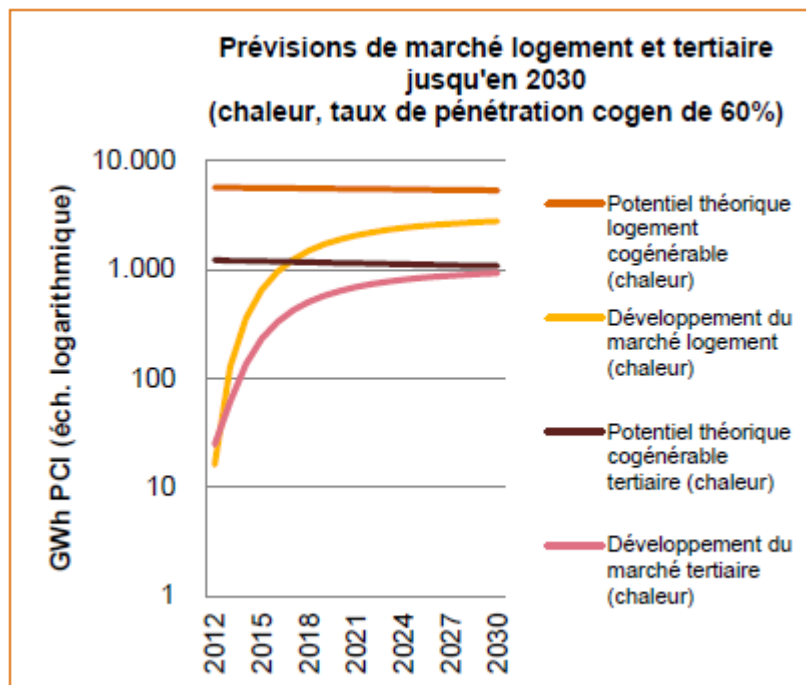
In practice, a cautious estimate of possible penetration would most likely be between 10 % and 20 %, far below the total maximum actual potential but nonetheless ambitious in an area where there is no guarantee that the conditions for generating a return can be met (see Task 4).

IV.2 COMPARISON OF FORECASTS

The figure below combines the projections for both market segments to allow for comparisons to be drawn. The housing sector is of major importance in the BCR because of the urban context already mentioned.

In both cases (housing and services):

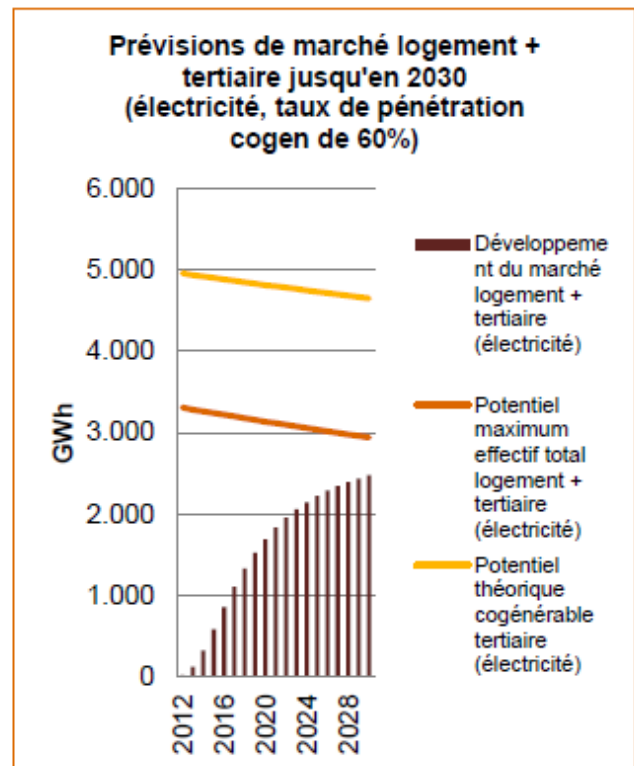
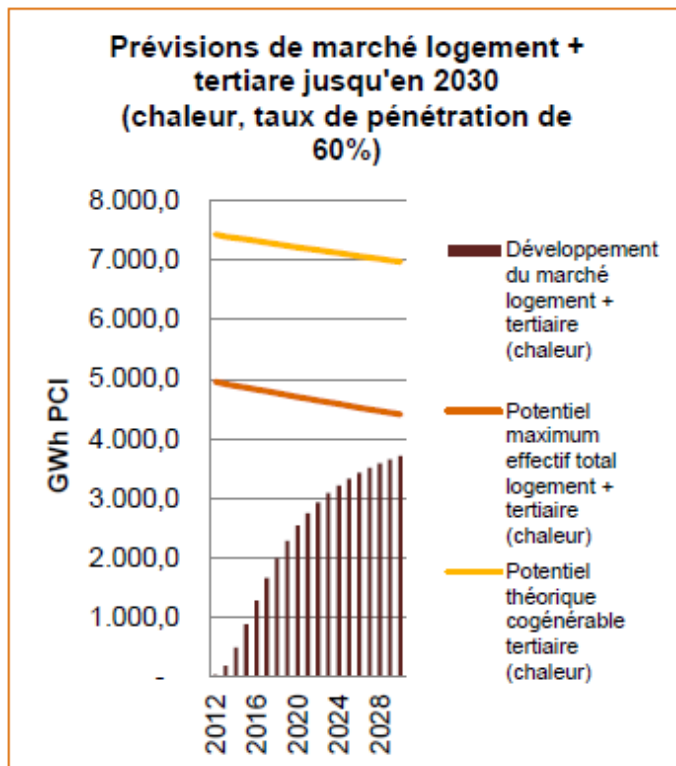
- the development model applied assumes relatively strong growth at the end of the decade, followed by a period of relative stability from 2020 onwards;
- actual market potential leads to a decline that reflects the growing impact of energy savings.



Prévisions de marché logement et tertiaire jusqu'en 2030 (chaleur, taux de pénétration cogen de 60%)	Forecasts for housing and service sector market to 2030 (heating, 60 % cogen penetration rate)
GWh PCI (éch. Logarithmique)	GWh LHV (log. scale)
Potentiel théorique logement cogénération (chaleur)	Theoretical potential of cogeneration for housing (heating)
Développement du marché logement (chaleur)	Growth in the housing market (heating)
Potentiel théorique cogénération tertiaire (chaleur)	Theoretical potential of cogeneration for the service sector (heating)
Développement du marché tertiaire (chaleur)	Growth in the service sector market (heating)

The working assumptions adopted expect that actual maximum potential will be achieved for the service sector market before the housing market.

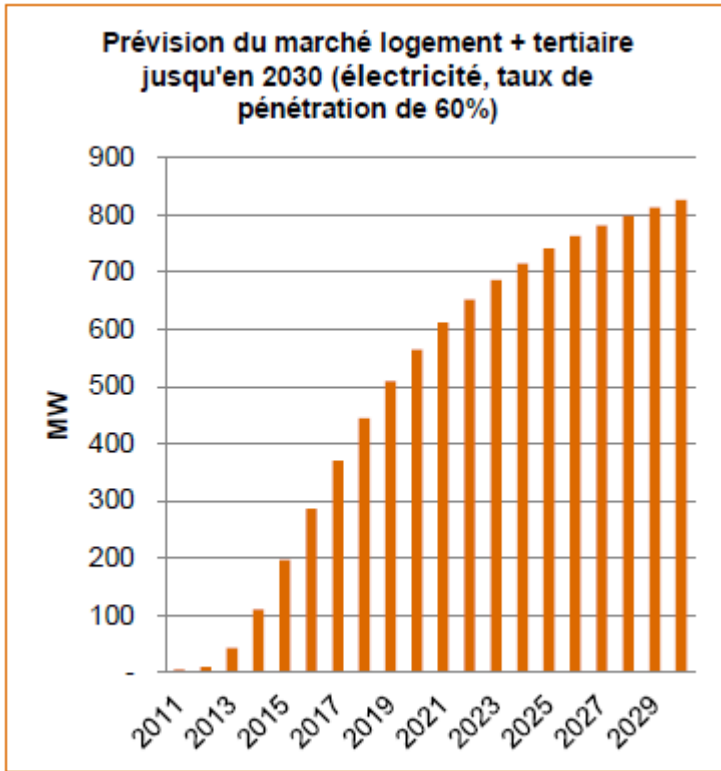
The two figures below compare heating and electricity potential as expressed for both of the segments considered (housing and services). The electricity curves are derived from the coverage of heating needs by applying an average Q/E ratio which is representative of the gas engines used for production. This ratio stands at 1.50.



Prévisions de marche logement + tertiaire jusqu'en 2030 (chaleur, taux de pénétration de 60%)	Market forecasts for housing + service sector to 2030 (heating, 60 % cogen penetration rate)
Développement du marche logement + tertiaire (chaleur)	Growth in the housing + service sector market (heating)
Potentiel maximum effectif total logement + tertiaire (chaleur)	Total maximum actual potential for housing + service sector (heating)
Potentiel theorique cogenerable tertiaire (chaleur)	Theoretical potential of cogeneration for the service sector (heating)
Prévisions de marche logement + tertiaire jusqu'en 2030 (électricité, taux de pénétration cogen de 60%)	Market forecasts for housing + service sector market to 2030 (electricity, 60 % cogen penetration rate)
Développement du marche logement + tertiaire (électricité)	Growth in the housing + service sector market (electricity)
Potentiel maximum effectif total logement + tertiaire (électricité)	Total maximum actual potential for housing + service sector (electricity)
Potentiel theorique cogenerable tertiaire (électricité)	Theoretical potential of cogeneration for the service sector (electricity)

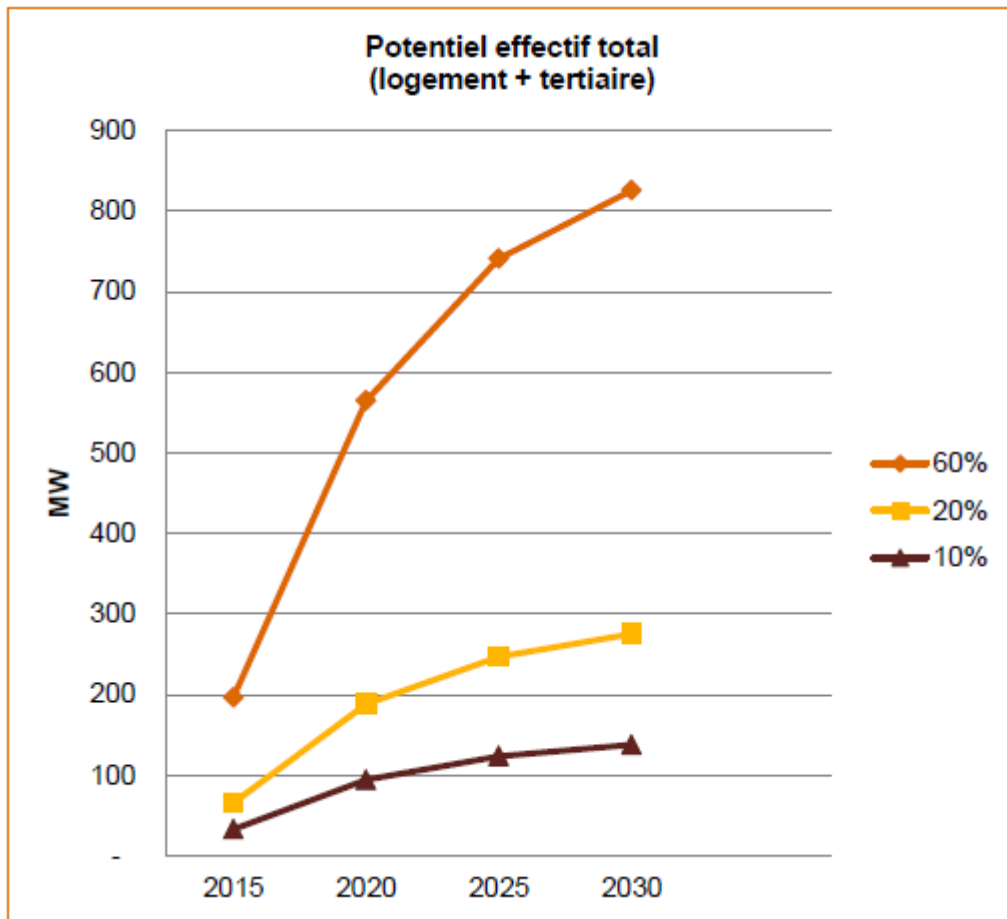
Clearly, the observations relating to the penetration rate for heating are applicable to electricity. As systems are sized on the basis of heat demand, the adjustment variable is electricity production, which can therefore exceed or fall short of customer demand. Accordingly, the adjustment is made by way of exchanges with the network, with an import in the first case and an export in the second.

The relevant electrical capacities can easily be derived on the basis of the figure above, assuming an average but realistic load of 3 000 hours/year. The profile of the theoretical potential for cogeneration assuming 60 % market penetration is described below.



Prévision du marché logement + tertiaire jusqu'en 2030 (électricité, taux de pénétration de 60%)	Market forecasts for housing + service sector market to 2030 (electricity, 60 % penetration rate)
MW	MW

It should be emphasised that the penetration rate of 60 % is very optimistic. As stated, it is a theoretical maximum. In practice, consideration must be given to the specific constraints already mentioned, such as siting restrictions, the difficulty, if not impossibility, of converting apartment buildings with individual boilers to cogeneration, etc. For these reasons, penetration rates within the range from 10 % to 20 % appear more realistic. The graph below provides a summary of these various items of information.



Potentiel effectif total (logement +tertiaire)	Total actual potential (housing + service sector)
MW	MW

This would therefore place electricity potential for the BCR within the range from 100 to 200 MW by 2020. It should be borne in mind that this potential is available on the basis of strictly economic appeal, as indicated in Task 4 (see above).

IV.3 SUMMARY OF FORECASTS

The table below sets out the forecasts for 2015 (base 2011), 2020, 2025 and 2030.

Forecasts for heat are extrapolated from the results for Task 1. Forecasts for electricity are extrapolated from the data for 1990 to 2011. Looking at the long-term trend, these forecasts are optimistic (high-case scenario, see top table opposite). The opposite case assumes that electricity demand is stable from 2015 (low-case scenario, see bottom table opposite).

In both cases (high-case and low-case scenarios), the Q/E ratio stays above 1.50 to 2030. As this ratio evaluates the proportion of electricity that can be cogenerated according to electricity demand, the conclusion is that the market for cogeneration can potentially export electricity through to the end of the forecast period.

Low-case scen.	Heating			Electricity			Q/E ratios
	Forecast of total demand (housing + service sector)	Total theoretical maximum potential (housing + service sector)	Total actual maximum potential (housing + service sector)	Forecast of electricity demand (housing + service sector)	Total theoretical maximum potential (housing + service sector)	Actual maximum potential (housing + service sector)	Forecast service demand (housing + service sector)
GWh							
LHV							

2015	10 744	7 351	4 864	5 380	4 900	3 242	2.00
2020	10 538	7 215	4 701	5 803	4 810	3 134	1.82
2025	10 360	7 093	4 555	6 225	4 729	3 037	1.66
2030	10 189	6 795	4 413	6 648	4 650	2 942	1.53

Low-case scen.		Heating			Electricity		Q/E ratios
GWh LHV	Forecast of service demand (housing + service sector)	Total maximum potential from heating (housing + service sector)	Potential maximum actual potential (housing + service sector)	Forecast of electricity demand (housing + service sector)	Potential maximum potential from heating (housing + service sector)	Potential maximum actual potential (housing + service sector)	Forecast of service demand (housing + service sector)
2015	10 744	7 351	4 864	5 380	4 900	3 242	2.00
2020	10 538	7 215	4 701	5 380	4 810	3 134	1.96
2025	10 360	7 093	4 555	5 380	4 729	3 037	1.93
2030	10 189	6 975	4 413	5 380	4 650	2 942	1.89

MW (3 000 operating hours/year assumed)	Potential maximum actual potential (housing + service sector); 60 %	Potential maximum actual potential (housing + service sector); 20 %	Potential maximum actual potential (housing + service sector); 10 %
2015	196	65	33
2020	565	188	94
2025	741	247	123
2030	826	275	138

V. CONCLUSION

The main points that emerge from the preceding analysis are as follows:

- 1) From a technical viewpoint, the BCR does, in principle, offer several advantages for the development of cogeneration. These include a concentrated settlement pattern, characterised by the presence of clusters of apartment buildings, or a significant level of service sector activity (with offices, shops, etc.).
- 2) Conversely, though, opportunities for opening up the market are impacted by the limited industrial sector, where cogeneration already meets a proportion of energy needs.
- 3) While there are, in theory, substantial short-term opportunities based on demand for heat in the two key sectors (housing and services), the market will increasingly feel the impact of the contraction in demand over the next decade and especially after 2030.
- 4) There is even a suggestion that the theoretical maximum potential will level off shortly after, implying that the market for cogeneration could contract after having reached a peak. This is based on the assumption which establishes the penetration rate on a technical basis (with a minimum of 2 500 to 3 000 operation hours). Other technical constraints could further influence the maximum levels identified; these include site-specific restrictions, constraints to do with adaptation to existing buildings, etc.
- 5) As a result, the true potential will be well below the previous maximum, and this could be reflected in a penetration rate in the region of 10 % (800 GWh) to 20 % (1 600 GWh) – or less – in both sectors.
- 6) Looking at the potential for cogenerating electrical power, the estimated figure for BCR is somewhere between 140 and 280 MW, based solely on technical constraints.
- 7) In practice, it will only be possible to exploit the technical potential if cogeneration is competitive in comparison with conventional technologies. Failing this, its development will be dependent on the ability to implement effective accompanying measures.
- 8) The particular features of the BCR rule out any extrapolation of these conclusions to other regions.

Chapter 6 – Strategy for 2030

INTRODUCTION

Purpose and methodology

The purpose of this sixth chapter is to chart the strategy for 2030 to achieve the potential identified in the previous chapter. The following multi-phase exercise was therefore conducted:

- Phase 6.1: **SWOT analysis of the technical and environmental context of the Brussels region** with a view to identifying the technical and economic factors that support/weigh against the development of cogeneration and district heating within the Brussels Region.
- Phase 6.2: **definition of technical, legal, economic or financial courses of action** that would unlock the economic potential of cogeneration and district heating and cooling.
- Phase 6.3: **mapping out these courses of action along a timeline.**

I. SWOT ANALYSES

This initial section covers the various factors in the technical and economic environment of the Brussels Region that support/weigh against the development of cogeneration (Table 1) and district heating (Table 2).

TABLE 1: SWOT ANALYSIS FOR COGENERATION

STRENGTHS	WEAKNESSES
<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> In principle, the BCR offers a number of advantages for the development of cogeneration associated with its socio-economic context: a concentrated settlement pattern (characterised by the presence of clusters of apartment buildings), and a significant level of service sector activity (offices, shops, etc.) Green certificate scheme: a major support scheme for high-quality cogeneration (5 % CO2 saving). <p><u>Technical dimension:</u></p> <ul style="list-style-type: none"> Localised electricity production: cogeneration facilities are sited/distributed within the transmission/distribution network. As a result, they help to reduce losses and, with proper coordination, they contribute to the reliability of the electricity grid or portions thereof. Extensive coverage/availability of the natural gas network in Brussels. Contribution to autonomy in electricity production. 	<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> CAPEX & OPEX are high Price of micro-cogeneration: while micro-cogeneration is an available technology for meeting the specific needs of the residential sector, its price per KWh is relatively high. Cogeneration requires additional investment compared with a standard boiler as it does not replace it (there is a need for a back-up). It should also be noted that there are many such systems that have been commissioned that are non-operational and non-profitable. As the technology is more complex than for a simple boiler, it requires closer monitoring and the operating costs are higher. Withdrawal of regional subsidies in support of cogeneration with effect from 2016. Issue of selling electricity: there are many administrative and legal complexities surrounding the fact that selling electricity produced to neighbouring buildings requires a series of legal and technical obligations to be fulfilled, such as the requirement to use the distribution network. It should be noted, though, that there is a multiplication coefficient for gas cogeneration systems in multi-family housing. Difficulty of securing buy-in from a district or a local authority for their involvement in the project. In the case of multiple owners/decision-makers, the ‘free rider’ problem, where a decision-maker supports a decision that directly benefits them and blocks a decision that is positive for the community if it has a negative impact on them personally, makes collective decision-making more difficult. <p><u>Technical dimension:</u></p> <ul style="list-style-type: none"> Complexity: for a cogeneration unit to operate under ideal conditions requires careful integration into an existing system. It also needs regular care and maintenance and monitoring on an almost daily basis. <p>There is no ‘control centre’ to drive a cogeneration unit and it must therefore be connected up in accordance with best practice to ensure the safety of equipment and persons.</p> <ul style="list-style-type: none"> Administrative challenges associated with the project: the development of cogeneration is impacted by the complexity of various administrative procedures (permit applications, certification procedures, etc.) and their apparent lack of

	<p>transparency.</p> <ul style="list-style-type: none"> • Installation constraints: need for a boiler room to install the cogeneration unit (but space is limited in the Brussels residential sector in particular, with the majority of homes being apartments). • Renewable heating fuels: rapeseed systems do not work properly at present and no biogas is currently produced in the BCR.
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OPPORTUNITIES	THREATS
<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> • Changes in gas and electricity prices: an increase in energy prices should be a factor that encourages all projects for rational use of energy and energy savings. It should therefore also be conducive to cogeneration, which offers a primary energy saving compared with localised production. It should be remembered, though, that it is the gap between the individual prices of electricity and gas which has the biggest impact on the cost-effectiveness of cogeneration. The greater the difference between these costs, the bigger the economic appeal of cogeneration projects. • Meeting the heating and electricity needs of new districts, multi-family housing, groups of existing buildings or service sector buildings with significant, constant heating and electricity needs, e.g. nursing homes 	<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> • Energy price volatility: investing in a cogeneration system requires a technical and economic feasibility study, and the results of this study will be highly dependent on energy price assumptions for the next 10 years. • Limited development potential and few large-scale projects to make cogeneration desirable within the Brussels Region. Opportunities for opening up the market are impacted in particular by the fact that there is a narrow breadth of industry in Brussels, and its needs are already met in part by cogeneration. The results of Task 5 show that investment will peak in 2030 and that thereafter, there will be no further expansion of cogeneration, and investment will be restricted simply to replacing those units operating in the most competitive contexts. •
<p><u>Presenting heating and electricity needs</u></p>	<ul style="list-style-type: none"> • Change in the prices of green certificates.

STRENGTHS	WEAKNESSES
<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> • Significant investment fund pools for heat production. <p><u>Technical dimension:</u></p> <ul style="list-style-type: none"> • The heating needs of several households and/or businesses can be met from a centralised unit. The consumer is therefore freed from the demands of maintenance and the need to source heating fuel. • Makes it possible to use renewable heating fuels (on a large scale) and to leverage new technologies (cogeneration, heat pumps, etc.) 	<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> • Economic suitability is not clear: additional investment is required. However, the distinction should be drawn between new build and renovation projects. • Withdrawal of subsidies for installing district heating networks encouraging rational energy use, with effect from 2016. • Difficulty securing buy-in from a district or a local authority for their involvement in the project. In the case of multiple owners/decision-makers, the 'free rider' problem, where a decision-maker supports a decision that directly benefits them and blocks a decision that is positive for the community if it has a negative impact on them personally, makes collective decision-making more difficult. • The payback period is quite long when the project's profitability is certain. Investors prefer a reasonably short payback period, particularly when the project is dependent on external variables, such as subsidies, which are not guaranteed to be a long-

term measure.

TABLE 2: SWOT ANALYSIS FOR DISTRICT HEATING NETWORKS

OPPORTUNITIES	THREATS
<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> • There is potential value in developing district heating networks to meet significant heating needs (for new districts, office buildings, etc.), in conjunction with a cogeneration system. A district heating network can be considered when heating needs reach a target figure of 1 MW. • Increased network density offers an improved economic return. To put this in context, a thermal density in the region of 3 000 kWh per year and per linear metre of network is generally used as the key value for evaluating the economic viability of a district heating project. • The development of district heating will be even more beneficial for a group of buildings with a single owner or decision-maker (social housing, office park with an owner, a school with several buildings, etc.). <p><u>Technical dimension:</u></p> <ul style="list-style-type: none"> • In theory, district heating can smooth out heating needs by means of a scale effect. In the case of a building complex with a single assigned use, this smoothing of needs is achieved on a statistical basis, by increasing the number of users. On a site with several assigned uses, this smoothing effect is also enhanced by the variety of needs, the characteristics of each assigned use, etc. (such as housing + offices/nurseries/care homes/hospitals). All other things being equal, this smoothed heating needs curve supports cogeneration, which will be more cost-effective the longer it operates. Accordingly, district heating can be seen as a tool for achieving an environment that is conducive to cogeneration 	<p><u>Economic dimension:</u></p> <ul style="list-style-type: none"> • One of the major line items in a district heating project is the cost of the network. As such, the ease with which the network can be installed will impact directly on the project's profitability. Clearly, if a network is to be installed in a grassed area, the cost will be less than if it has to cross one or more existing roads, or a paved area. • All other things being equal, a district heating network will be even more cost-effective if it can take advantage of a source of waste heat. Nonetheless, it should be noted that there is limited technical potential for waste heat in the Brussels Region, and the sale price of waste heat can undermine the cost-effectiveness of the project.

II. DEFINITION OF POSSIBLE COURSES OF ACTION

Priority is given below to courses of action that can promote the development of cogeneration and district heating within the Brussels Region. As indicated in connection with Task 5, the economic potential of cogeneration is highly likely to contract within BCR between now and 2030, particularly as a result of improved housing energy performance. Consequently, it must be stressed that there is a need to develop courses of action that can ensure the development of cogeneration and district heating, but that will not hinder the improvement of building energy performance within the Brussels Region.

II.1 ECONOMIC AND FINANCIAL COURSES OF ACTION

- In light of the investment by project owners in the benchmark solutions, it is essential that the current assistance for cogeneration (including green certificates) be maintained. In particular, this means providing the investor with a medium to long-term guarantee of price stability for the green certificates for which they will qualify during the project's operational period.
- Granting green certificates with provision for a multiplier in the case of projects that combine the installation of a cogeneration unit with a district heating network, where such projects have been confirmed as technically feasible and economically viable.
- Promoting the third-party investment system for cogeneration and/or district heating projects. Third-party investment offers multiple advantages for project owners: no need for immediate investment of equity, no technical skills required, no obligation to arrange for maintenance, etc.

II.2 LEGAL COURSES OF ACTION

- Provide for a mechanism that could encourage the purchase of the electricity fed in. In this regard, there could be value in encouraging/imposing forced marketing (as far as the supplier of the gas/supplementary electricity is concerned)⁴³. For systems of sufficient size (> 50 kVA), the introduction of an obligation to buy could be considered as a priority. Other possible courses of action could also be explored, such as pooling⁴⁴ purchases.
- Consider the options for optimising the legal framework such that electricity produced by cogeneration systems financed by several parties (households, individuals, etc.) and installed in multi-family housing can be shared.
- Provide a simple and effective framework to allow for proper sizing of cogeneration facilities in joint ownership contexts.
- Adjust the pricing for network gas to encourage 'prosumers' to better match their production flows to their consumption on an ongoing basis.

⁴³ As things stand, it is permissible to sell electricity produced through cogeneration. However, electrical energy suppliers, who could be the main customers for decentralised producers, have shown no interest in this.

⁴⁴ Joint buying organisation following the related – or complementary – model used by aggregators.

II.3 TECHNICAL COURSES OF ACTION

- Encourage BOT⁴⁵ bids. Experience to date suggests that the separation of investment in and management and maintenance of cogeneration facilities is a source of problems. A useful recommendation in addressing this shortcoming is to set up contracts where the system supplier is also involved in maintenance and operation over a 10-year period.
- Encourage storage. Since variations in the production schedule exert a significant negative impact on purchasing by energy suppliers and even individual customers, the introduction of measures to support localised storage could help in developing cogeneration on a larger scale. This course of action is therefore recommended in a context where storage facilities are increasingly competitive.

II.4 OTHER POSSIBLE COURSES OF ACTION

- Publish guides for individuals/businesses covering the steps for installing a cogeneration system in each of the possible scenarios.
The Brussels Environmental Authority's website gives examples (see in particular: <http://www.ibgebim.be/Templates/documentation>).
- Continue to arrange training/information sessions for building and construction professionals to raise awareness of the opportunities offered by cogeneration.
- In addition to those mentioned above (obligation to purchase, etc.), remove all the restrictions that prevent producers of cogenerated LV electricity from accessing the energy market to sell any surplus that is not self-consumed: transparent pricing, metering, grid code and load shedding obligations where constraints apply.
- Introduce a mechanism to provide for a cost/benefit analysis for centralised (with/without a network) and cogeneration solutions in projects to develop new residential and/or service sector districts within the Brussels Region.

It should be remembered that under current market conditions, there is a very significant need for subsidies to achieve financial equilibrium between the basic options (boilers) and the alternatives examined (cogeneration, heat pumps and/or district heating). By way of comparison, the following table summarises the cost-benefit analysis for the scenarios examined. Depending on the technologies used, some of the ranges given are very wide.

Scenario	Surface area (m ²)	Balancing subsidies (EUR/year)
1. Residential district	3 780	New: 2 168-8 337
		Renovated: 1 148-13 601
2. Residential apartment blocks	1 092	New: 19 332
		Renovated: 2 316

⁴⁵ Equivalent to a BOT contract: Build, Operate, Transfer.

Service sector 3. heating	4 800	New: 1 185
		Renovated: 23 053
Service sector 4. cooling	4 800	New: 19 332
		Renovated: 3 957 to 70 417

III. ACTION PLAN

The recommendations set out above can be implemented independently of one another, although the question of priority order remains open. An analysis is set out below to address this, highlighting a number of criteria as follows:

1. timescales for implementation;
2. ease of implementation;
3. the potential impact.

These criteria are rated on a qualitative scale.

The proposed priority ranking is shown in column 3. More particularly, it reflects the timescales for implementation and the impact.

No	Recommendations (summary)	Priority ranking	Timescales for implementation	Ease of implementation	Potential impact	Subsidies	Remarks
1.1	Economic and financial courses of action						
1.1.a.	Keep green certificates for cogeneration	1	Short-term	Easy	High	Yes	Subject to political support and arrangements for financial assistance. There is a need for support to be predictable in the medium term (to reassure investors). Assistance drives investment owing to the low competitiveness of the proposed technologies (cogeneration, district networks).
1.1.b.	Grant green certificates with a multiplier	3	Medium-term	Easy	High	Yes	As above. This measure is slightly more difficult to introduce than the previous one as it includes an additional mechanism (driver), and timescales for implementation are therefore longer.
1.1.c.	Encourage the system of third-party investment	7	Medium-term	Moderately easy	Medium	No	Depends on the prospects for project profitability and, in particular, on the stability and reliability of assistance measures.
1.2.	Legal courses of action						
1.2.a	Introduce a mechanism for purchasing feed-in electricity	4	Medium-term	Easy	High	No	Constraints relating to the implementation of legislative recommendations (political support, timescales, etc.). It should be noted that first and foremost, the purchasing measures concern the very largest facilities and/or those which are sized such that the amount of electricity produced exceeds what is required for self-consumption alone.
1.2.b	Introduce a simple and effective framework for sizing cogeneration systems in individual properties	10	Medium-term	Moderately easy	Low	Possibly	Both regulatory and subsidy aspects to be examined. A contribution to/assistance for feasibility studies as part of new projects could be considered. To ensure credibility, these studies must be carried out by an organisation which does not generate any conflicts of interest for the investor or the equipment supplier.
1.2.c	Adopt network gas pricing to encourage localised production	11	Long-term	Difficult	Low	No	Will ultimately require a complete overhaul of the current bases for pricing, such as energy-based pricing, which is currently inappropriate for 'prosumers'.
1.3.	Technical courses of action						
1.3.a.	Involve suppliers in operational responsibility for an adequate period	2	Short-term	Easy	High	No	Review of terms and conditions laid down in calls for tender, to assign operational responsibility for works to installers as well. This is a BOT framework (or BOOT if third-party investors are involved).
1.3.b.	Encourage localised storage	12	Medium- to long-term	Difficult	Low	Yes	Remains very largely dependent on progress in terms of storage technologies and the opportunities available for granting subsidies. The associated costs will be a further

							addition to the system installation expenditure, however, and this may compromise project profitability if assistance is not available.
I.4	Other courses of action						
I.4.a.	Disseminate promotional documents for individuals/businesses	8	Short-term	Easy	Low	No	Most of the documents required are already available (see IBGE and similar websites for other regions of the country). Amendments may be needed to reflect the specific nature of the goals in this case (cogeneration and district heating).
I.4.b.	Arrange training sessions for building and construction professionals	9	Short-term	Moderately easy	Low	Possibly	May be arranged internally (with the bodies of the BCR) or subcontracted. Also requires a budget for preliminary work, logistics and organisation.
I.4.c.	Address constraints relating to the sale of cogenerated electricity	6	Medium- to long-term	Difficult	High	No	One of the main constraints is metering. 'Smart meters' would be required for the target segments, but this can only be a large-scale undertaking (Smart meters cannot be installed on case-by-case basis because data concentration and transmission mechanisms must also be provided).
I.4.d.	Introduce mechanisms for evaluating the costs and benefits of new urban development projects	5	Short-term	Moderately easy	Medium	No	Can be achieved in principle by reviewing the regulatory framework and potentially by the conditions for granting building permits and subsequent documents.