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A Low-carbon roadmap for Belgium

Study realised for the FPS Health, Food Chain Safety and Environment

Buildings sector – October 2012

This document is based on content development by the consultant team as well as an expert workshop that was held on the 15-06-2012

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Content – Buildings sector

Key messages in the Building Sector

- Energy consumption in buildings relates to **fundamental needs of the population** (heating, cooking, hygiene). As a consequence, smart energy demand mitigation should occur while guaranteeing those fundamental needs. **Demography** is clearly one of the main parameters for the energy demand of the **residential** sector, while the evolution of **added value** is an important driver for the **tertiary buildings**.
- The **building sector is one of the few sectors presenting an increase in emissions between 1990 and 2010.**
- The evaluation of energy consumptions and emission levels of the building park over time is not as straightforward as it might be in other sectors : the energy consumption and emissions of the sector are strongly **correlated to** seasonal fluctuations (summer vs. winter) and annual variations (warm years vs. cold years) of the **weather conditions**.
- **Increasing the performance of the building envelopes** is crucial if wanting to reduce the overall energy consumption of the sector. One of the essential measures to reach a more energy efficient building park is through **ambitious standards for new buildings.**
- Considering the **long lifetime of buildings,** relying on the high energy performance of new-builts only will not be sufficient to reach emission reductions of the order of 80-95%. Therefore, attention should be paid to the **improvement of the current building park as well. Renovation speed and/or post-renovation performance of the buildings should be amplified.**
- Improving the performance of the building park might induce **additional emissions in other sectors** (industry, transport,…) due to increased activity in the short term. But these should be largely compensated over time. Inversely, intelligent urban planning (densification) can potentially **reduce emissions in other sectors as well**.
- Several technologies are at hand to provide the energy inside homes and tertiary buildings. These technologies present different energy-efficiencies, carbon-intensities and decarbonisation potentials. Depending on the geographical availability and the maturity of the technologies, the **optimal technologies will have to be selected** to progress towards a low-emission building park.

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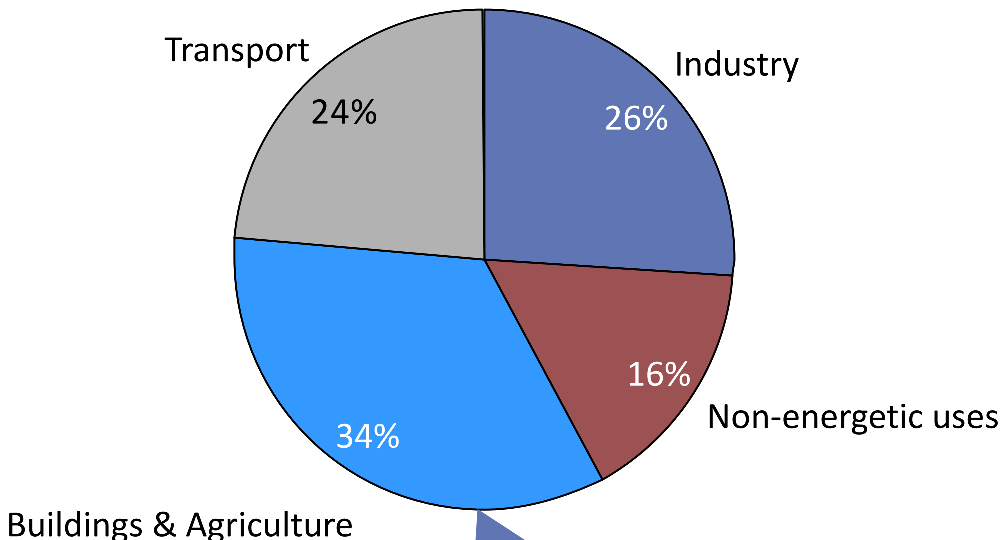
Content – Buildings sector

Final energy consumption is split between the industry (42%), Buildings (34%) and transport (24%)

Final energy consumption in Belgium, 2010

100% = 44,1 Mtoe



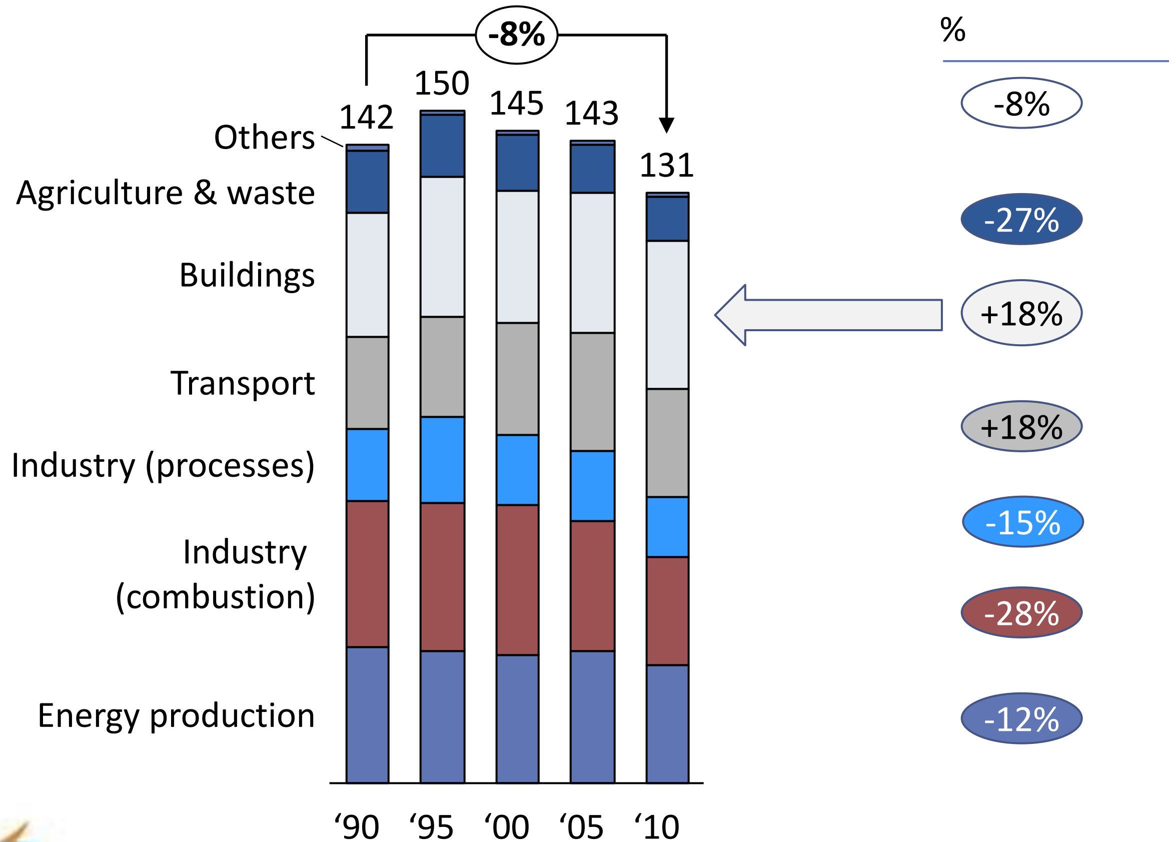
Mainly Buildings (~90%)

- The industry is the largest final energy user with ~42% (incl. non-energetic uses)
- Buildings and transport make up the rest of energy demand

Source: SPF Economie

While overall emissions decreased, buildings emissions significantly increased since 1990

GHG emissions in Belgium, $MtCO_2e$



- Belgian GHG emissions went down by ~8%, mainly as a consequence of reductions in the industry (combustion and process emissions) and in the power sector
- Emissions in both transport and buildings have grown significantly by 18% since 1990

Source: Belgium GHG Emissions Inventory,

Belgium needs to drastically increase its yearly GHG reduction pace in order to be in line with 2050 European objectives

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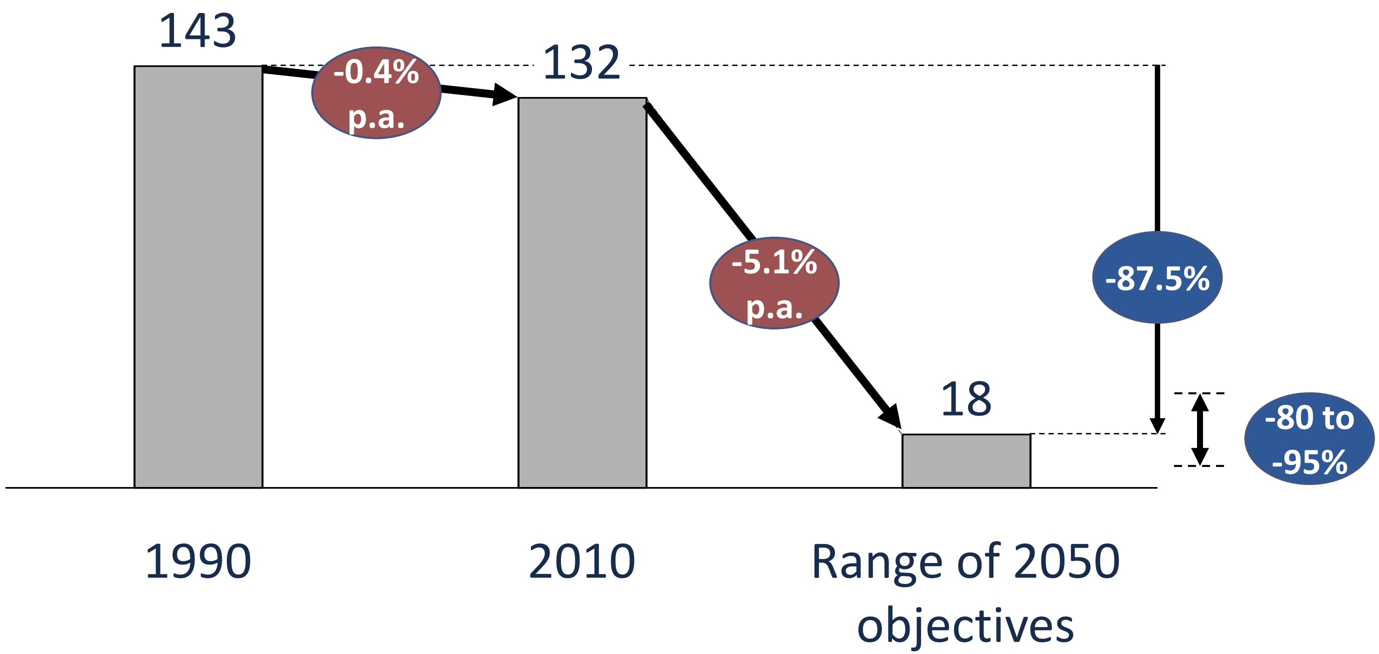
Belgian GHG emissions, $MtCO_2e$ per year



Source: Belgium GHG emissions inventory, Climact

Emissions in 2010 are relatively equally distributed between power, industry, buildings and transport

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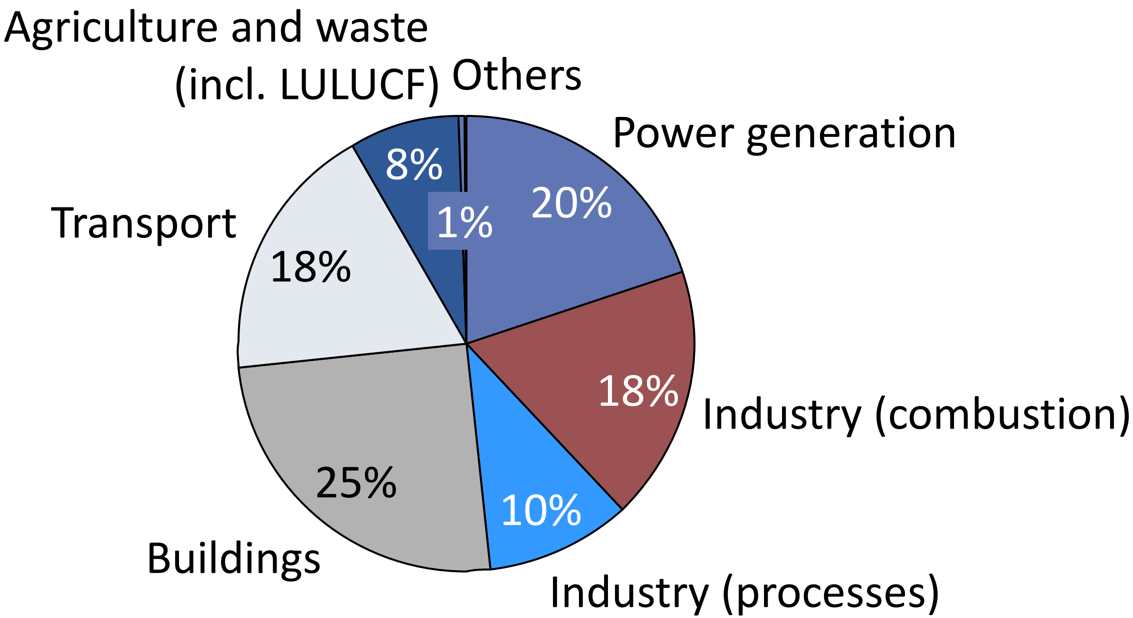
GHG emissions in Belgium, 2010, %

100% = 132 $MtCO_2e$



- 4 main sectors emit ~90% of emissions in relatively equal shares
  - Power generation
  - Industry with combustion and processes
  - Buildings
  - Transport
- Agriculture and waste make up the remaining 8%

Source: Belgium GHG emissions inventory, Climact

Residential

Natural gas and fuel oil are the most important fuels in residential energy balance

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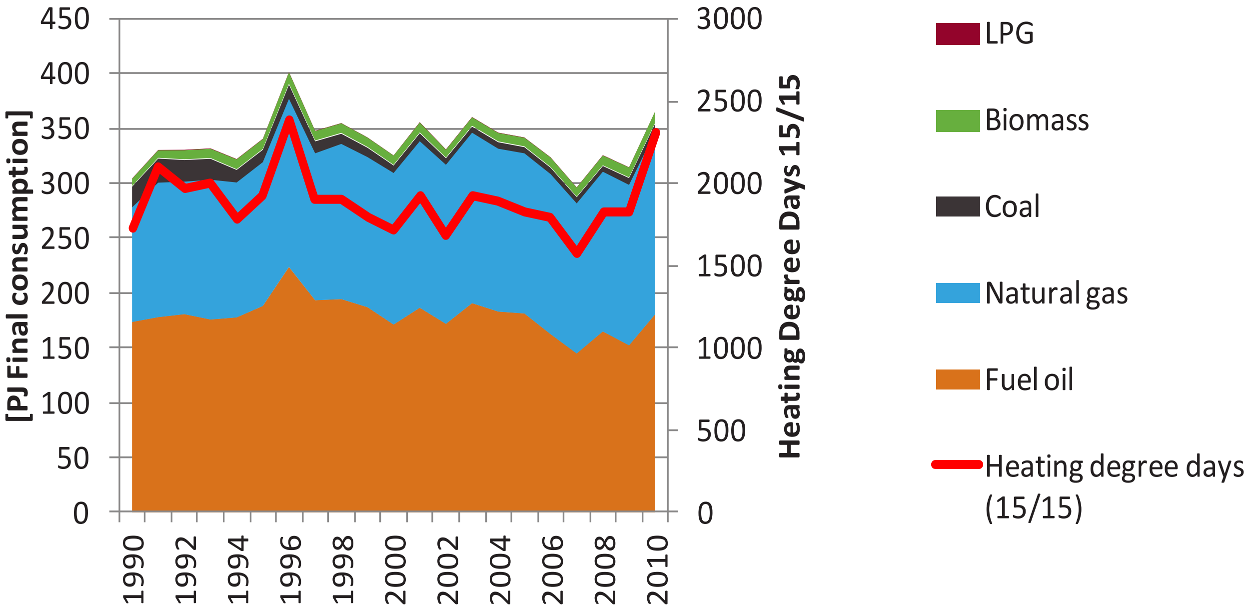
Total fuel consumption of residential sector in Belgium, 1990 – 2010, [PJ]



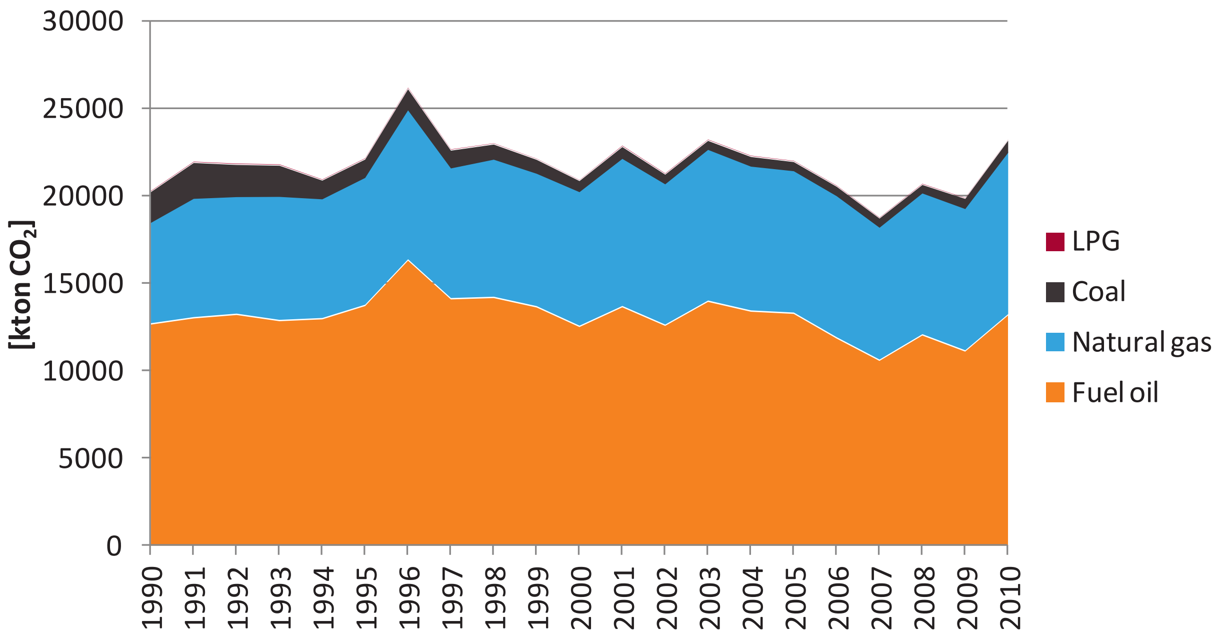
- **Natural gas and fuel oil are currently the most important fuels.**
- **The share of natural gas increased** from 35% in 1990 to 46% in 2010. At the same time, the share of liquid fuels decreased from 57% to 49%.
- The annual fluctuations are **strongly correlated to variation in the heating degree days.**

Source: Belgium, NIR April 2012

Residential

The share of natural gas is lower for CO_2 emissions than for energy consumption

Total CO_2 emissions of residential sector in Belgium, 1990 – 2010, [kton CO_2]



- In line with their energy shares, most of the CO_2 emissions originate from natural gas and liquid fuels (fuel oil).
- The higher emission factor of fuel oil leads to a higher share of fuel oil in emissions compared to its share in energy consumption. (57% of emissions vs. 49% of energy consumption in 2010)
- The share of natural gas increased from 29% in 1990 to 40% in 2010. At the same time, the share of liquid fuels decreased from 62% to 57%.

Source: Belgium, NIR April 2012

Natural gas is the most important fuel in the services sector

Services

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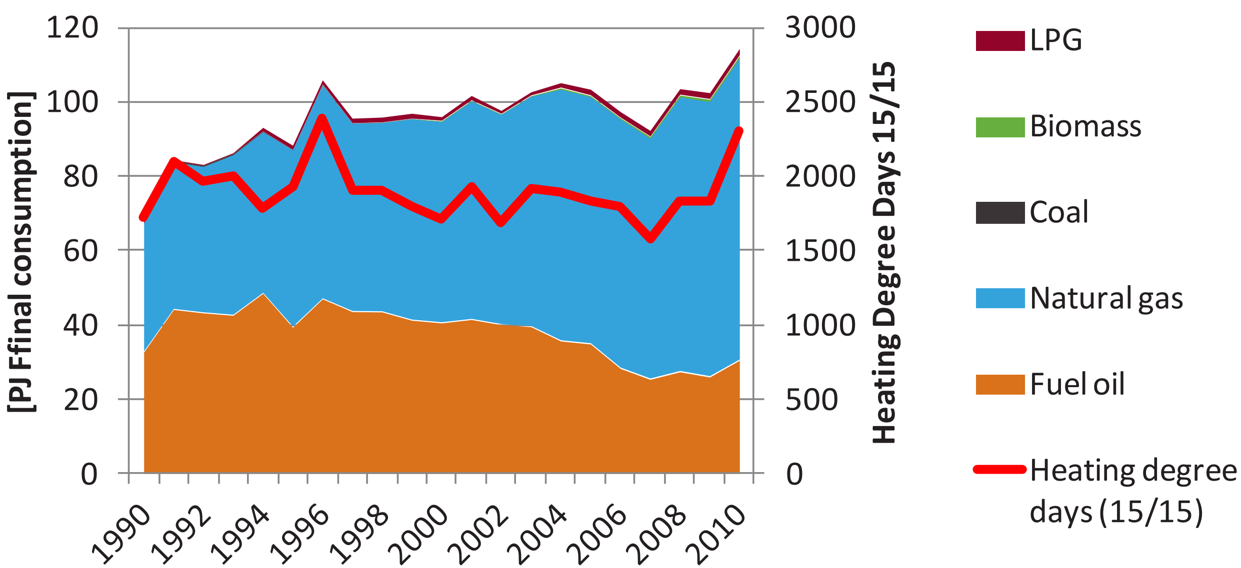
Total fuel consumption of services sector in Belgium, 1990 – 2010, [PJ]



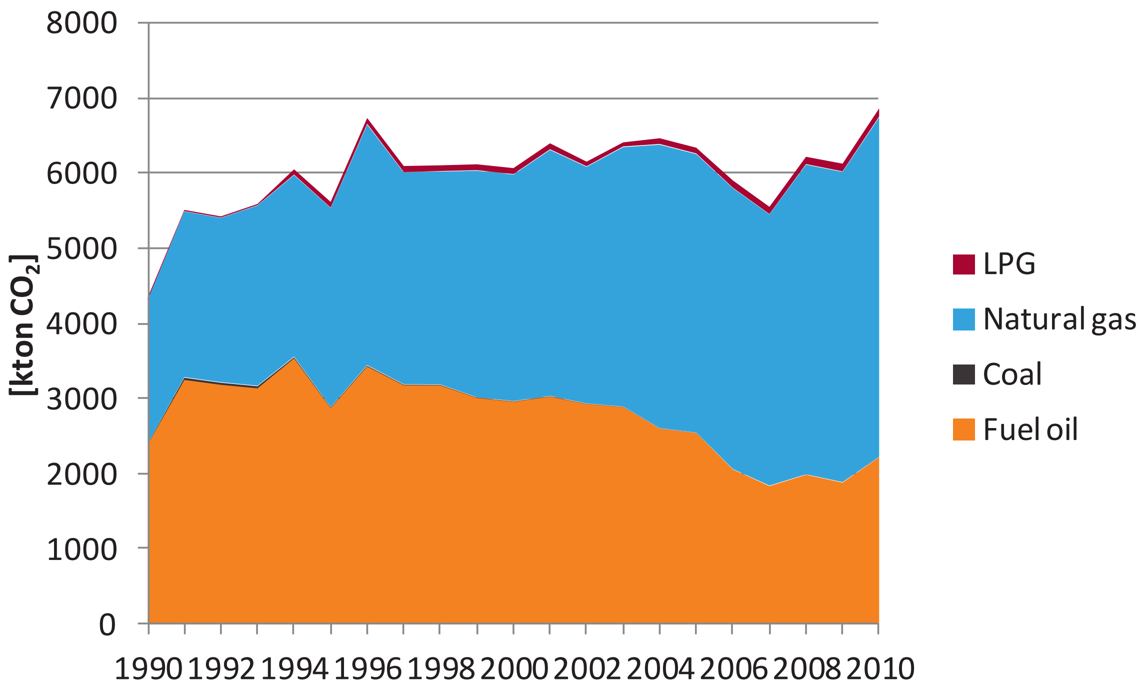
- Liquid fuels come second in importance, but have been losing share continuously (48% in 1990 vs 27% in 2010)
- That share has been taken mainly by natural gas (from 51% in 1990 to 71% in 2010)
- Large fluctuations strongly correlated to variations of heating degree days.

Source: Belgium, NIR April 2012

Services

The main CO_2 source in the services sector evolved from liquid fuels in 1990 to natural gas in 2010

Total CO_2 emissions of services sector in Belgium, 1990 – 2010, [kton]



- Natural gas & fuel oil: most important CO_2 emissions
- The share of natural gas increased from 44% in 1990 to 66% in 2010, while liquid fuels decreased from 55% in 1990 to 32% in 2010
- The switch to natural gas was not sufficient to compensate for the overall growth in energy consumption, which resulted in an increase of CO_2 emissions

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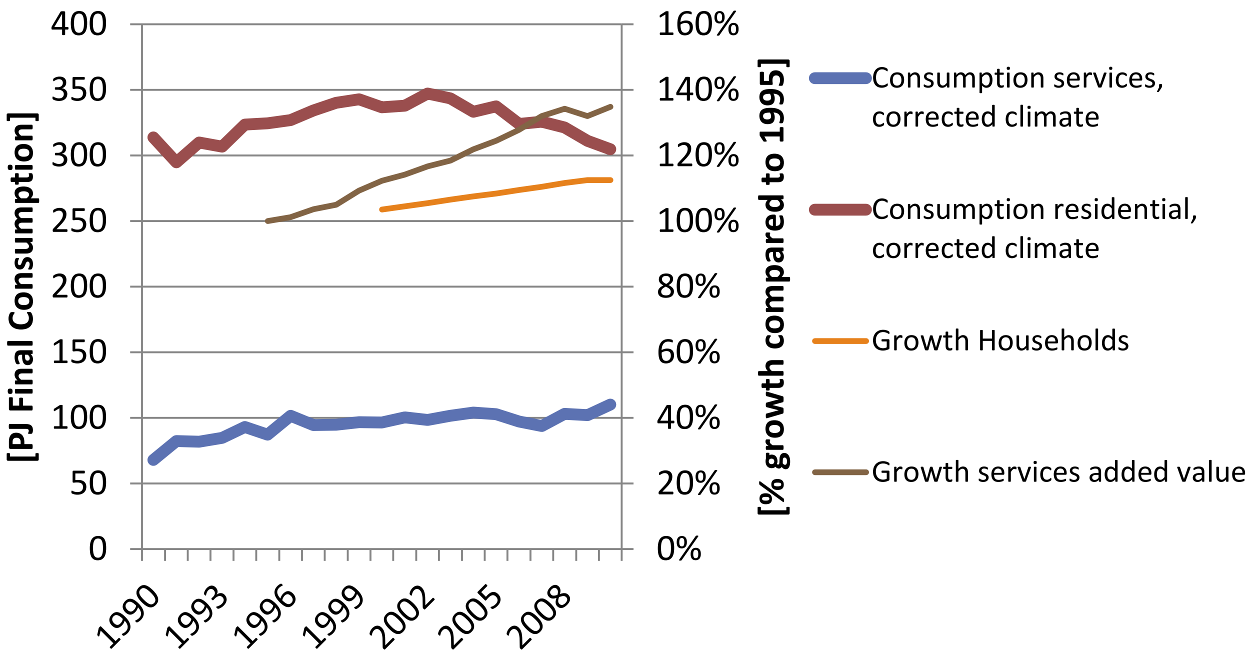
Source: Belgium, NIR April 2012

The total energy used in the residential sector is much higher than in the services sector

Total fuel consumption of buildings sector in Belgium corrected for HDD, 1990 – 2010, [PJ]



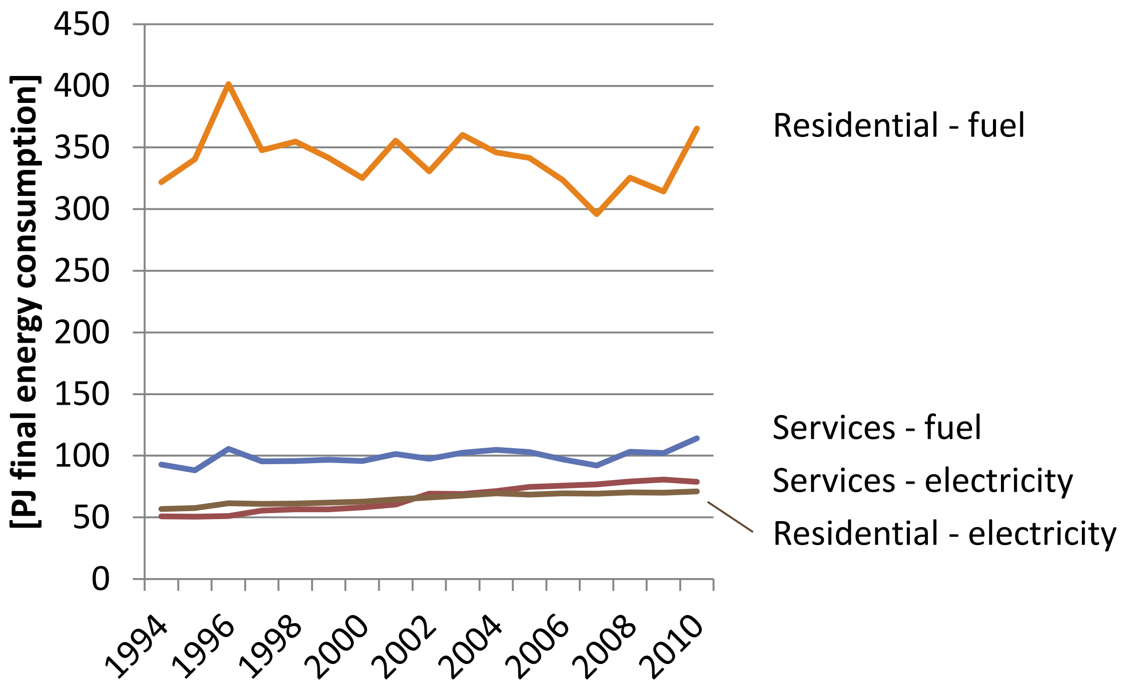
- Residential sector has much higher total fuel consumption compared to services sector: average share of 78% between 1990-2010.
- **Residential fuel consumption has been more or less stable**, even with demographic growth (+13% from 1995 to 2010).
- **Services fuel consumption saw a growth of ~28%** between averages of [1990-1995] & [2005-2010]. Added value increased with ~35% from 1995 to 2010.

HDD = Heating Degree Days - Energy consumption expressed in 1799 HDD (15/15) = average HDD between 2000-2009

Source: Belgium, NIR April 2012 – NIS - Federal Plan Bureau

Electricity consumption in the services sector accounts for about 40% of its total energy consumption

Total fuel & electricity consumption of buildings sector in Belgium not-corrected for HDD, 1994 – 2010, [PJ]

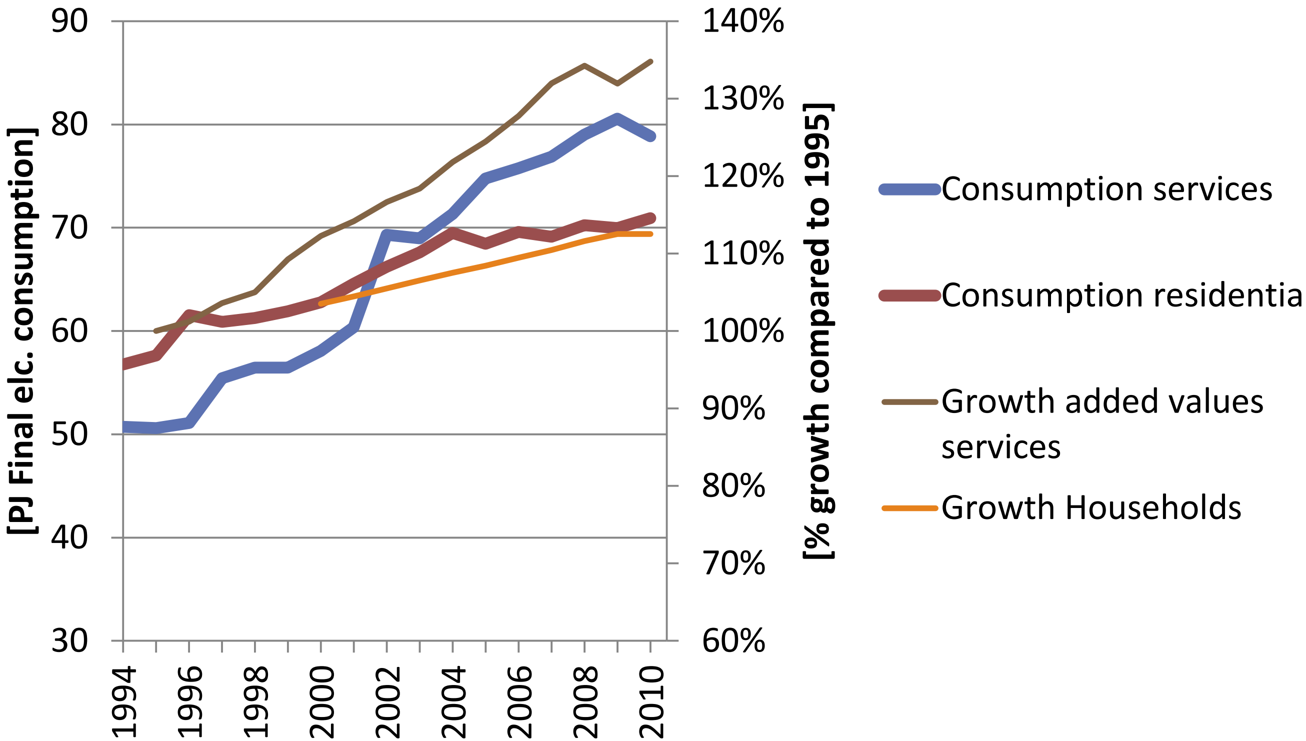


- Residential sector has much higher fuel consumption compared to electricity consumption: average share of ~85% between 1994-2010 in total energy consumption.
- For the services sector, this share of fuels in the total energy balance decreases to ~60%.

Sources: Three regional Energy Balances, NIR Belgium April 2012

Evolution of electricity consumption is strongly correlated to evolution of households and added value

Total, final electricity consumption of building sector in Belgium, 1990 – 2010, [PJ]



- Strong correlation with evolution of added value (services sector) and number of households.
- Strong increase of electricity consumption in services sector: from 88 PJ in 1990 to 150 PJ in 2010 (+ 169%).
- Remark: Emissions of electricity consumption is modelled in energy sector.

Source: Three regional Energy Balances– NIS - Federal Plan bureau

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Buildings is one of the various sectors studied in the process of constructing the low carbon scenarios

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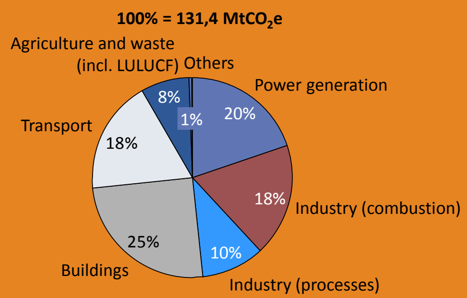
Focus of the Working Group

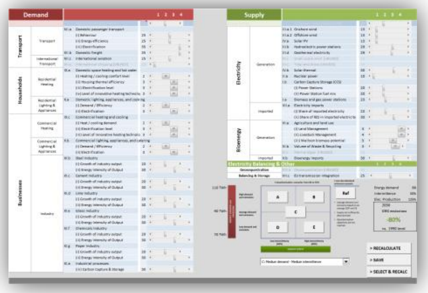
1 **Bottom up study by sector of feasible GHG reductions**



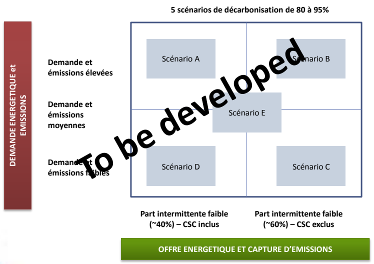
2 **Test each sector with external experts**

- Workshops by sector with external experts
- Discussions with international experts

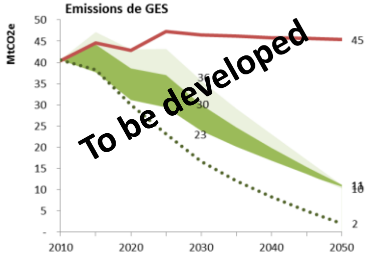
3 **Adapt the DECC model to Belgian data and improve it**



4 **Define and model various scenarios**



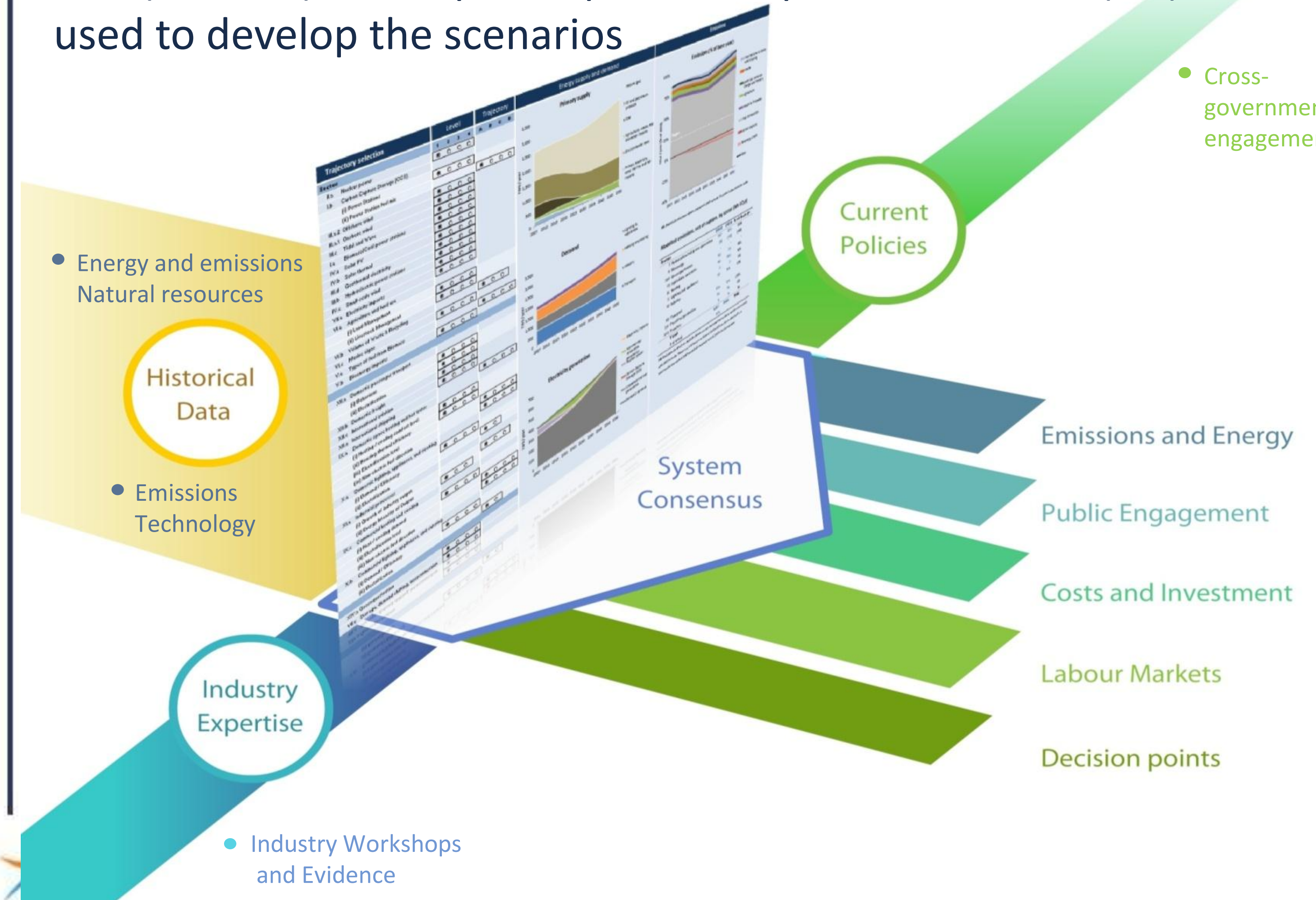
5 **Detail key implications for these scenarios**



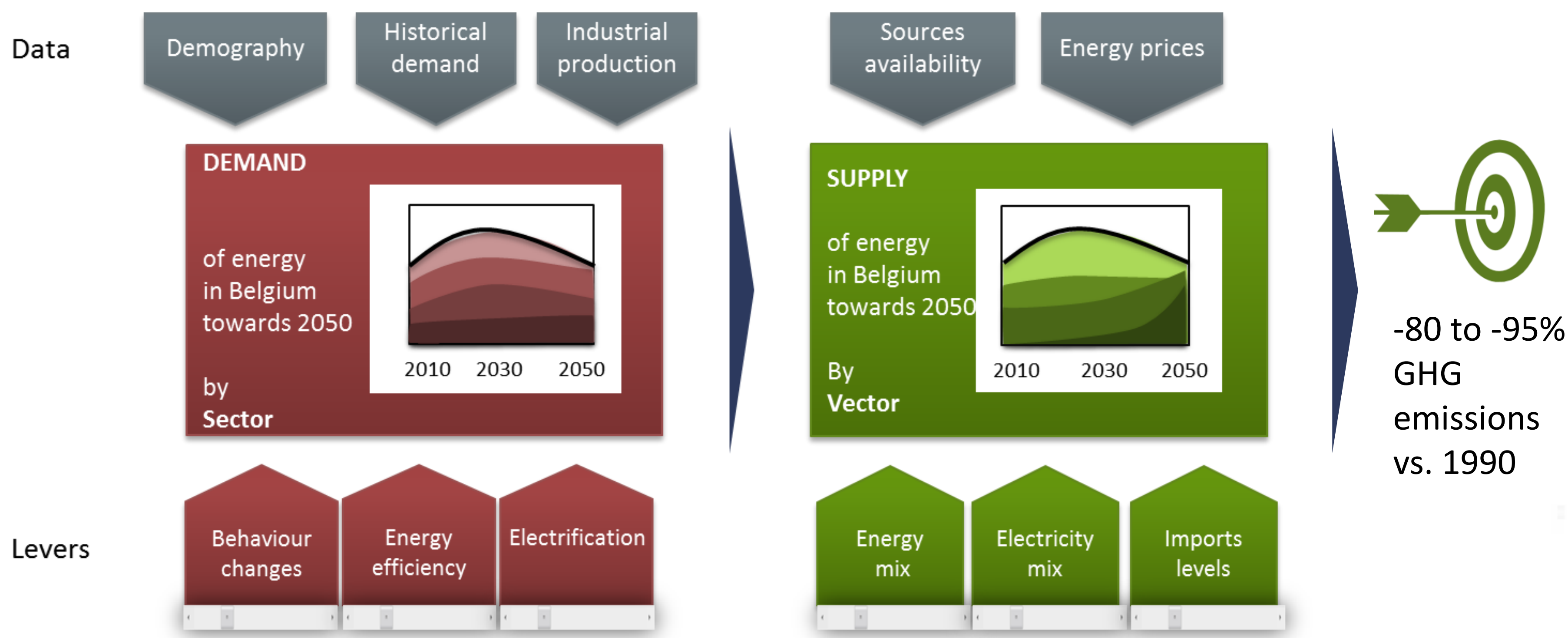
6 **Review conclusions with the steering and high level consultation committees**

- Federal administration
- Industry
- Civil organizations
- Academics
- …

The Open-source Prospective Energy and Emissions Roadmap Analysis tool (OPE²RA) developed in partnership with the DECC (UK) will be used to develop the scenarios



OPE^{2}RA balances demand and supply based on fixed input parameters as well as modifiable levers



4 ambition levels are defined for activity levels and emission intensity

Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation) • No additional efforts/policies • What will become a « Reference scenario »	• **Moderate effort** easily reached according to most experts • Equivalent to the development of recent programmes for some sectors	• **Significant effort** requiring cultural change and/or important financial investments • Significant technology progress	• **Maximum effort** to reach results close to technical and physical constraints • Close to what's considered reachable by the most optimistic observer

SOURCE: DECC, Climact

Key topics are covered to support the development of low-carbon scenarios

End-uses of Residential & Services sector	Current data
Heating	• Energy consumption for the different end – uses
Cooling	
Hot Water	• Number of households and total value added of services sector
Lighting, appliances & cooking	• Based upon recent literature and available data sources

Activity levels

- What is the evolution assumed for **population** and **number of dwellings**?
- Which potential evolution for heating, cooling & hot water **demand**?
- What's the impact of **behavioral changes** on the different end-uses?
- What are possible demand evolutions for **electric appliances & lighting**?

What is possible for 2050 ?

Efficiency

- What's the physical limit or **maximal efficiency** improvement of the different technologies?
- Which levels of **compactness of houses** can be expected in the residential sector?
- How fast can buildings be **renovated**?
- What level of **demolition /new buildings** will be realistic?

What will the situation look like in 2020/30/40/50 ?

Technology and energy vector

- What can be the maximum and minimum **share of the different heating & cooling technologies** (eg. Individual boilers, district heating)?
- What are the implications of the **fuel & technology shifts** in terms of energy consumption?

Which are the practical implications?

In practice, 4 main group of factors are covered to test the potential for decarbonizing the heating/cooling of building sector

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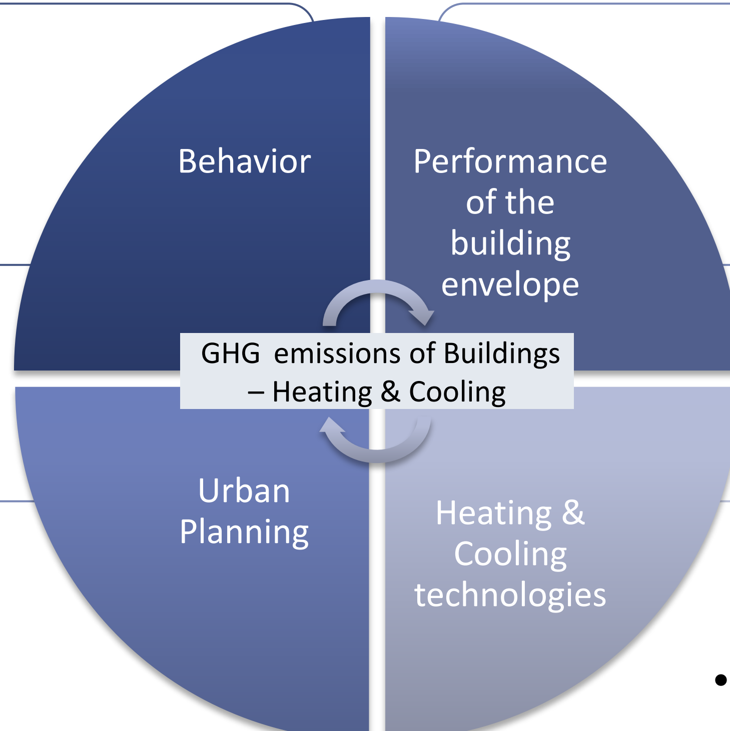
Evolution of the population & Number of dwellings; Evolution of the services sector (value added)

- Heating demand: desired internal temperature
- Cooling demand
- Hot water demand

- New buildings & existing buildings
- Renovation speed
- Speed of demolition/new buildings



- Evolution of surface per building
- Evolution of compactness: Share of flats

- Evolution of type of heating/cooling/hot water technologies
- Efficiency of these technologies
- Life span of technologies

In practice, 3 main group of factors are covered to test the potential for decarbonizing the electric appliances in the building sector

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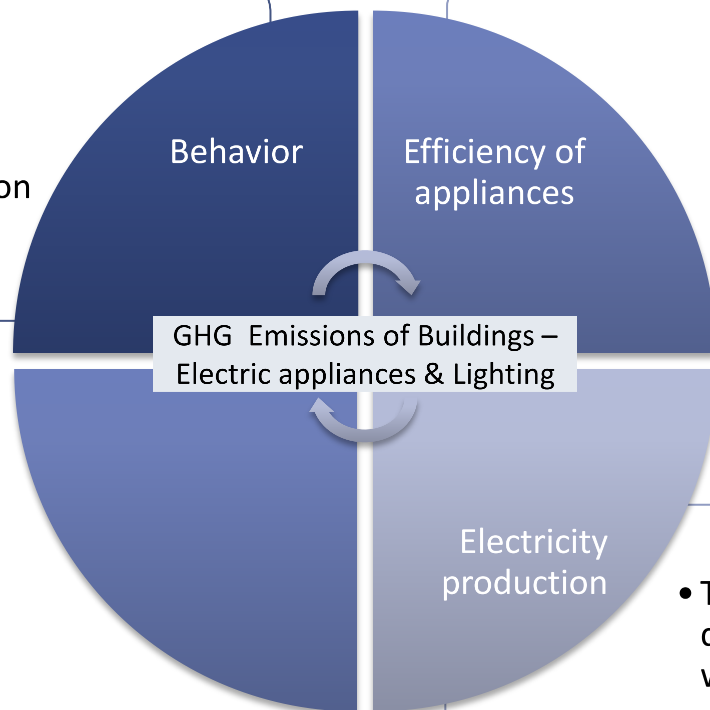
Evolution of population & number of households; Evolution of the services sector (value added)

- Demand [kWh] for:
  - Black goods - White goods
  - Lighting
  - Cooking
- This demand is dependent on utilisation level, purchase level etc.



- Technological potential of efficiency improvement:
  - Black goods - White goods
  - Lighting
  - Cooking

- The supply side will be discussed in a another workshop

4 ambition levels are defined for each lever

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation) • No additional decarbonisation efforts/policies • What will become a « Reference scenario »	• **Moderate effort** easily reached according to most experts • Equivalent to the development of recent programs for some sectors	• **Significant effort** requiring cultural change and/or important financial investments • Significant technology progress	• **Maximum effort** to reach results close to technical and physical constraints • Close to what's considered reachable by the most optimistic observer

One of the key objectives of the expert Working Groups is to support the estimation of these levels based on existing expertise

Besides the ambition levels, key parameters determining the cost of these levers are also assessed

	Costs modelled	Cost type impacted by these levers
1. Behavior	× No investment costs are modelled	• Overall energy bill
2. Efficiency level of building envelope	✓ Investments costs of different insulation levels (heat demands) for existing & new buildings – per heated floor area [m²] × Cost of awareness raising campaigns, external costs…	• Overall energy bill • Total investment costs required for efficiency level
3. Efficiency level of appliances	✓ General investment costs of overall efficiency improvements [€/kWh reduction] × Cost of awareness raising campaigns, external costs,…	• Overall energy bill • Total investment costs required for efficiency level
4. Heating/Cooling technologies	✓ Investment and operational costs per type of heating/cooling technology (eg. costs of heat pumps, district heating) – per kW or household × R&D costs, external costs,…	• Overall energy bill • Total investment costs of heating/cooling technologies
5. Urban planning	✓ Investment costs of new dwellings vs flats: investment costs per heated floor area – per heated floor area m²	• Overall energy bill • Total investment costs of new housing stock

General working hypothesis used for the buildings

- The building sector is **an important economic activity**, with much impact on other sectors of the economy
- **Some** of these **interactions are not integrated** in the modeling being used, for example :
  - **Building & renovation of building depends & has an impact on the development of other sectors** (transport, industry,…). Trajectories for these sectors could therefore influence the building sector & vice versa. This is not hard-coded in the model, but will be kept in mind to develop coherent scenarios.
  - Behavioral or technical changes could have unattractive consequences (e.g. **increases of GHG emissions in other sectors or building sector** due to **rebound effect**). These are not taken into account.
  - Emissions related to **electricity production are computed in the modules related to that sector**. Emissions computed in the building module are only related to fuel consumption. But, scenarios of final **electricity consumption** are estimated in building module.
- To keep neutral compared to other sectors consuming biomass, there is **no specific allocation of the biomass** potential in the model. The allocation of biomass in the model is performed through a homogeneous reduction of the overall demand for fossil fuels over the different sectors based on the overall biomass potential that can be used for energy purposes.
- **Buildings in the industrial sector** are not estimated in the building sector, but are part of the **industry module.**

Drivers - Fundamentals

- Key drivers for emissions of building sector in Belgium are :
  - **Population growth**: increase of number of households - **Economic growth** of services sector (expressed as added value)
  - **Size and compactness** of buildings
  - Evolution of heating & hot water **demand** per household (or per added value in the services sector)
  - Fuel mix of building sector and related **heating technologies**
  - Comfort level of the households (**behavioral** changes)
  - Heating degree days: assume constant level in model (1799 HDD (15/15))

- Certain factors are modeled implicitly :
  - The structure of the territory and the density of habitat (through size and compactness of dwellings)
  - Wealth of households – No impact of fuel prices on demand (!)
  - …

Content – Buildings sector

Subsectors of buildings

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A. Heating, hot water & cooling

B. Lighting & appliances

Residential

Heating of houses accounts for about 90% of fuel & electricity consumption for heating, hot water & cooling

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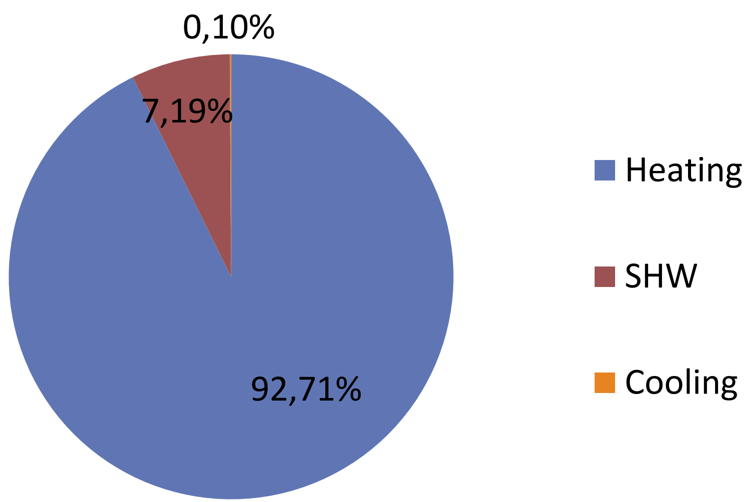
Share of heating, hot water SHW and cooling for residential sector in Belgium in 2010

100% = 110 TWh[1] in 2010 or 23 872 kWh per household



- Heating of houses has the highest share in the total energy consumption for heating, SHW & cooling
- Heating and SHW:
  - Fuel consumption as well as
  - Electricity consumption: 7% of Belgian households use electricity as main *heating* - 14% of Belgian households use it for *SHW*.
- Mainly electricity is used for cooling

[1] Not corrected for heating degree days

Assumptions:

Sanitary Hot Water (SHW) energy consumption of 1750 kWh/HH; Electricity consumption for cooling of 590kWh/HH

→ *Based on Belgian Energy Balance (NIR2012), derived energy consumption for heat (≠heat demand) amounts ~22 132kWh per household.*

SOURCE: NIR Belgium April 2012, VITO & ECONOTEC (Emissions heating of Buildings, 2011), Assumptions Flemish EPB methodology, VITO (Evolution heating & cooling demand, 2011)

Heating of buildings accounts for about 90% of energy consumption for heating, hot water & cooling

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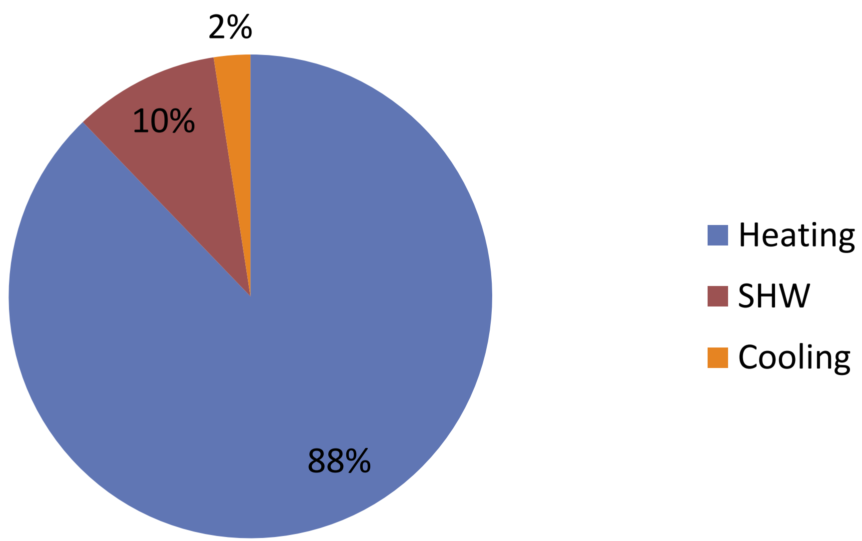
Share of heating, hot water SHW and cooling for services sector in Belgium anno 2010

100% = 31,3 TWh[1] in 2010 or 0,183 GWh/M€ added value



- Heating of buildings has the highest share in the total energy consumption for heating, SHW & cooling
- For heating and SHW mainly fuels are used - about 10% of fuel consumption is related to SHW
- For cooling is mainly electricity used : about 3.5% of total electricity consumption is related to cooling

[1] Not corrected for heating degree days

SOURCE: NIR Belgium April 2012, VITO (Energy and GHG scenarios according to REF, 2006), JRC (Electricity Consumption and Efficiency - Trends in European Union, 2009)

4 main group of factors are covered to test the potential for decarbonizing the heating/cooling of building sector

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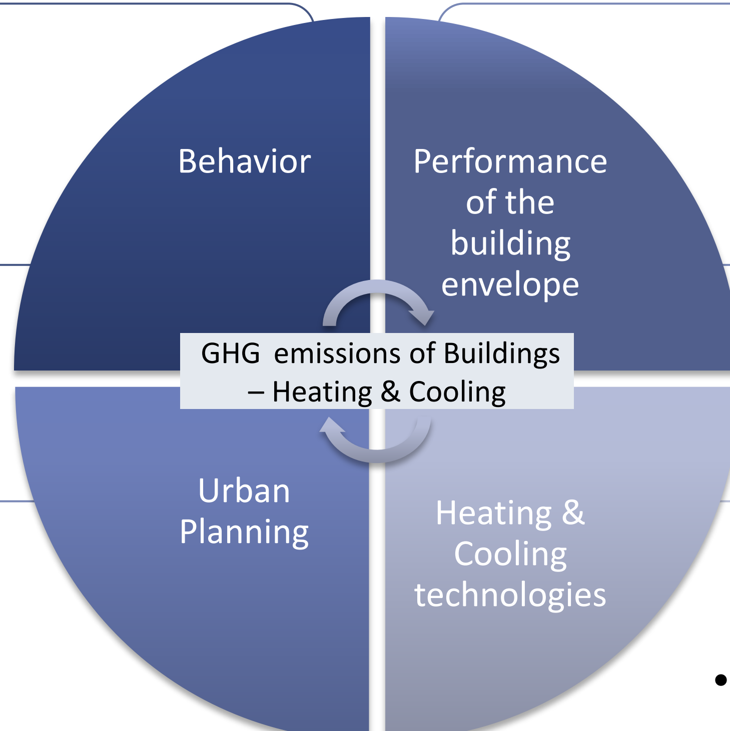
Evolution of the population & Number of dwellings; Evolution of the services sector (value added)

- Heating demand: desired internal temperature
- Cooling demand
- Hot water demand

- New buildings & existing buildings
- Renovation speed
- Speed of demolition/new buildings



- Evolution of surface per building
- Evolution of compactness: Share of flats

- Evolution of type of heating/cooling/hot water technologies
- Efficiency of these technologies
- Life span of technologies

Population is projected to increase with 21% between 2010 and 2050 by the Federal Plan Bureau

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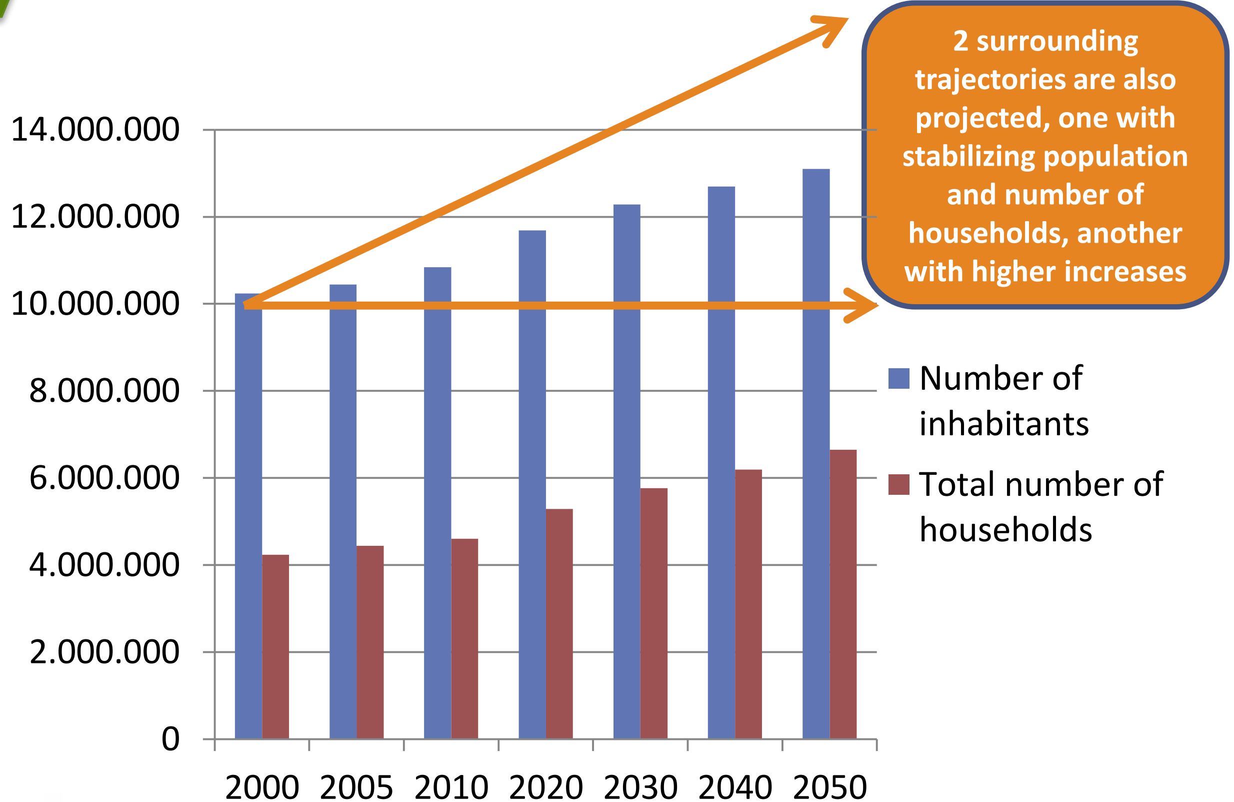
Evolution of number of households and inhabitants for Belgium between 2000 and 2050



- Projections based on *Projections Federal Plan Bureau 2060 (inhabitants) & 2020 (households)* (own linear extrapolation for HH between 2020-2050)
  - Number of inhabitants 2010-2050: +21%
  - Number of households[1] 2010-2050: +**44%.**
  - Decrease of person/HH 2010-2050: 2,35 to 1,97
- Expected increase in energy consumption by 2050 if no measures or behavioral changes: + 44%

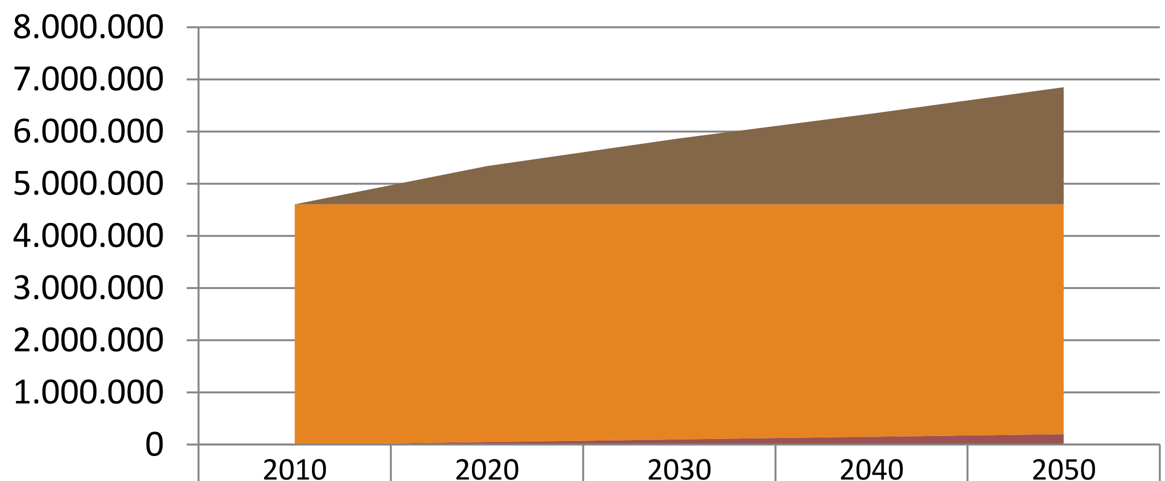
1 Remark: we assume that number of housing units equals number of households
SOURCE: Federal Plan Bureau, VITO

Demographic evolution reflects number of housing units: New houses – Existing houses - Demolition

Evolution of number of housing units for Belgium between 2010 and 2050

- Assumption: current rate of demolition, namely *5024 demolitions* of housing units *per year* *(= Doubled current number of registered demolitions = 2512 per year)*

The number of new housing units equals the increase in number of households. Between 2010-2020, this will result in a very high yearly increase (average of 73 000 new units per year). Therefore, this high demand level will probably results in a further subdivision of the existing stock (by eg. very strong renovations etc.)



	2010	2020	2030	2040	2050
New houses - Built after 2010		732.072	1.262.417	1.736.590	2.243.604
Existing housing - Built before 2010	4.606.544	4.556.120	4.505.696	4.455.272	4.404.848
Demolished housing units		50.424	100.848	151.272	201.696

SOURCE: Demolition permits, Federal Plan Bureau, VITO

Services

The added value realized by the services sector is projected to increase with 109% between 2010 and 2050.

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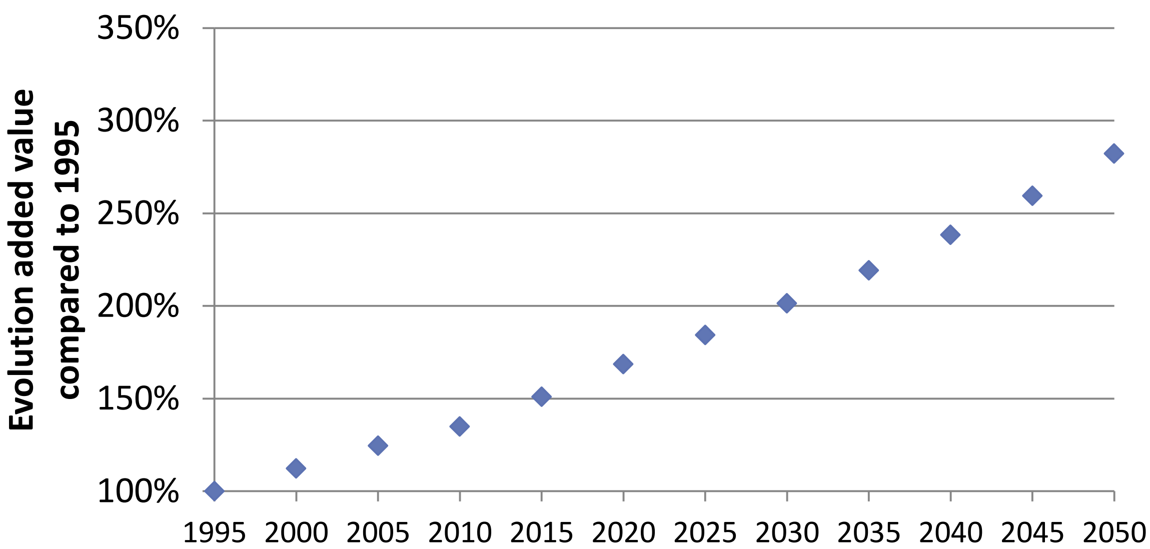
Evolution of the total added value of the services sector in Belgium, compared to 1995



- Projections 2010-2020: based on *Projections Federal Plan Bureau 2020;* Average annual growth of 2.3%
- Projections 2020-2050: Based on *general GDP Projections of Studiecommissie Vergrijzing:*
  - 2020/2030: 1.8% per year
  - 2030/2050: 1.7% per year
- Evolution of added value between 2010-2050: **+109%**
- No perfect 1-to-1 relationship between evolution of energy consumption for heating/cooling and added value: **correction** by elasticity

Expected increase of energy consumption for heating/cooling between 2010 - 2050, if no measures or behavioral changes: + 22%

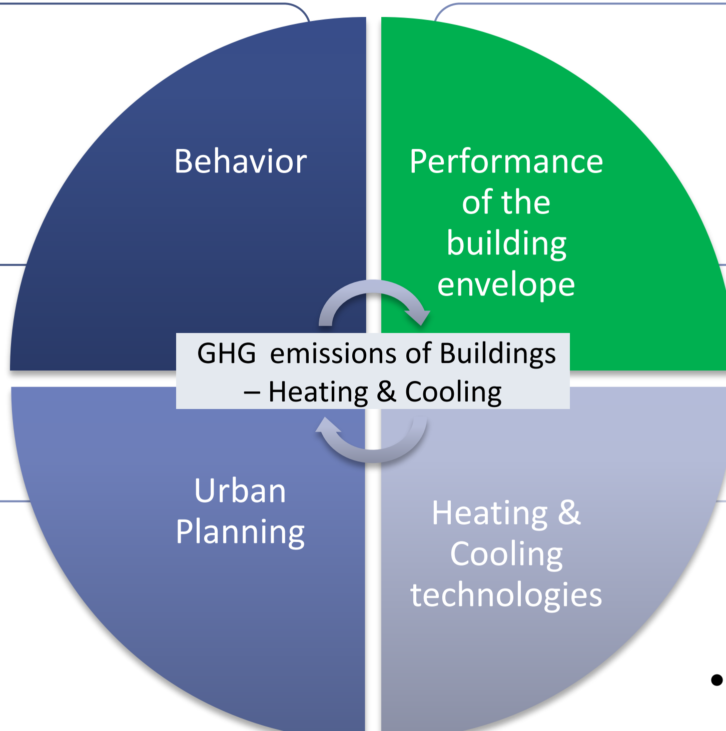
SOURCE: Federal Plan Bureau (Projections 2020), Studiecommissie Vergrijzing (Annual report 2011),VITO

Performance of the building envelope

Evolution of the population & Number of dwellings; Evolution of the services sector (value added)

- Heating demand: desired internal temperature
- Cooling demand
- Hot water demand

- New buildings & existing buildings
- Renovation speed
- Speed of demolition/new buildings



- Evolution of surface per building
- Evolution of compactness: Share of flats

- Evolution of type of heating/cooling/hot water technologies
- Efficiency of these technologies
- Life span of technologies

Heat demand of the residential sector – Some key parameters for which 4 levels have to be determined

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- Definition:
  - Heat demand is the net energy consumption of a house.
  - Final energy demand takes the energy efficiency of the heating installation also into account (= fuel or electricity consumption).
- Current performance of the building envelope is different for:
  - New houses: built after 2010 versus
  - Existing houses: built before 2010
- Key parameters in determining the heat demand of the housing stock in OPE²RA:
  - Evolution of heat demand [kWh] per heated floor area [m²] for
    - New houses
    - Renovated houses
  - Evolution of renovation rate
  - Evolution of heated floor area [m²] of new houses , which is dependent on the share of flats ~ urban planning

Explanations of the 4 levels for "**final energy demand for heating** per heated floor area for newly built & renovated stock"

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Level 1 – Minimum effort

- Renovation: minor changes - application of one to three low cost or easy to implement measures resulting in a heat demand of 111 kWh/m².
- New houses: Starting from current EPB legislation (99 kWh/m²) in 2010, the final demand of a dwelling will decrease until the level of a 'very low energy house' (30kWh/m²) by 2020.

Level 2

- Renovation: moderate renovation level (99 kWh/m²)
- New houses: Starting from current EPB legislation (99 kWh/m²) in 2010, the final demand of a dwelling will decrease until the level of a 'very low energy house' (30kWh/m²) by 2020 and until the level of 'a passive house' (15kWh/m²) by 2040.

Level 3

- Renovation: strong renovation – low energy house (60 kWh/m²)
- New houses: Starting from current EPB legislation (99 kWh/m²) in 2010, the final demand of a dwelling will decrease until the level of a 'very low energy house' (30kWh/m²) by 2020 and until the level of 'a passive house' (15kWh/m²) by 2030.

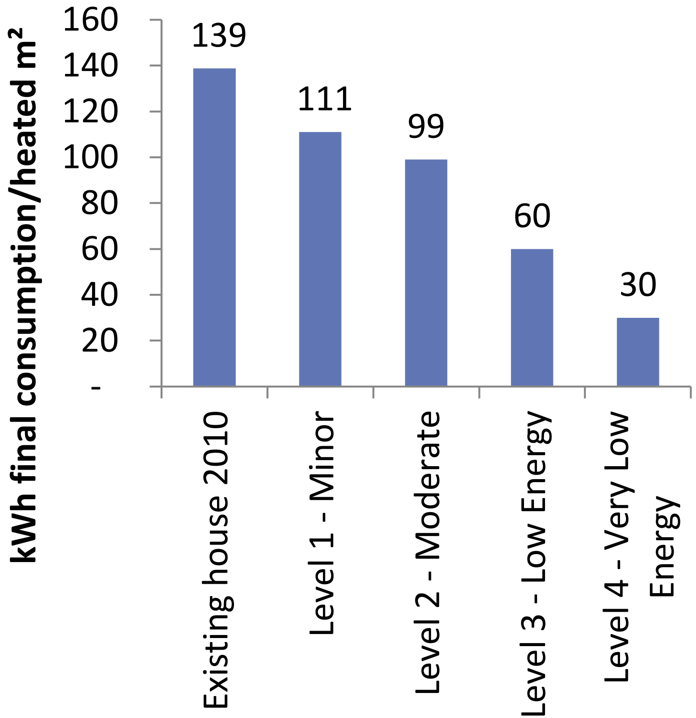
Level 4 – Maximum effort

- Renovation into very low energy house (30 kWh/m²)
- New houses: Starting from current EPB legislation (99 kWh/m²) in 2010, the final demand of a dwelling will decrease until the level of a 'passive house' (15 kWh/m²) by 2020.

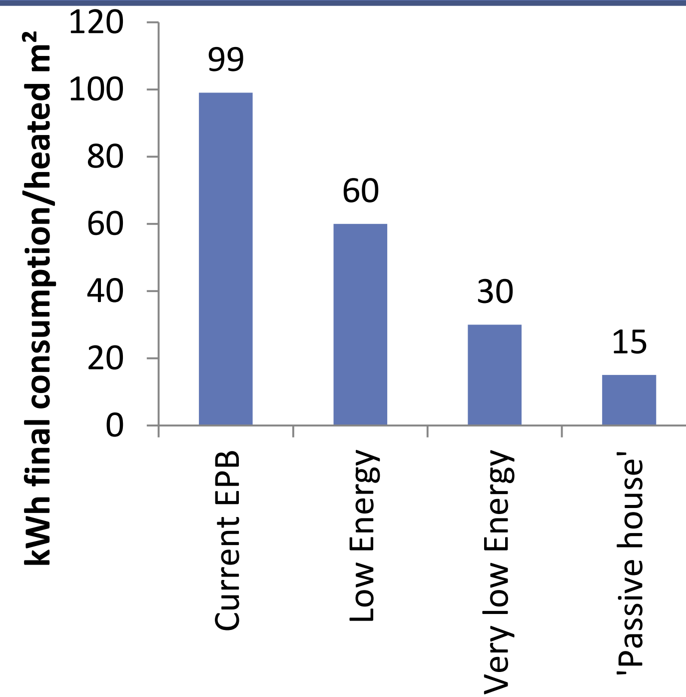
Visualisation of the 4 considered levels of “final energy demand for heating per heated floor area for newly built & existing stock”

Residential

Renovation level



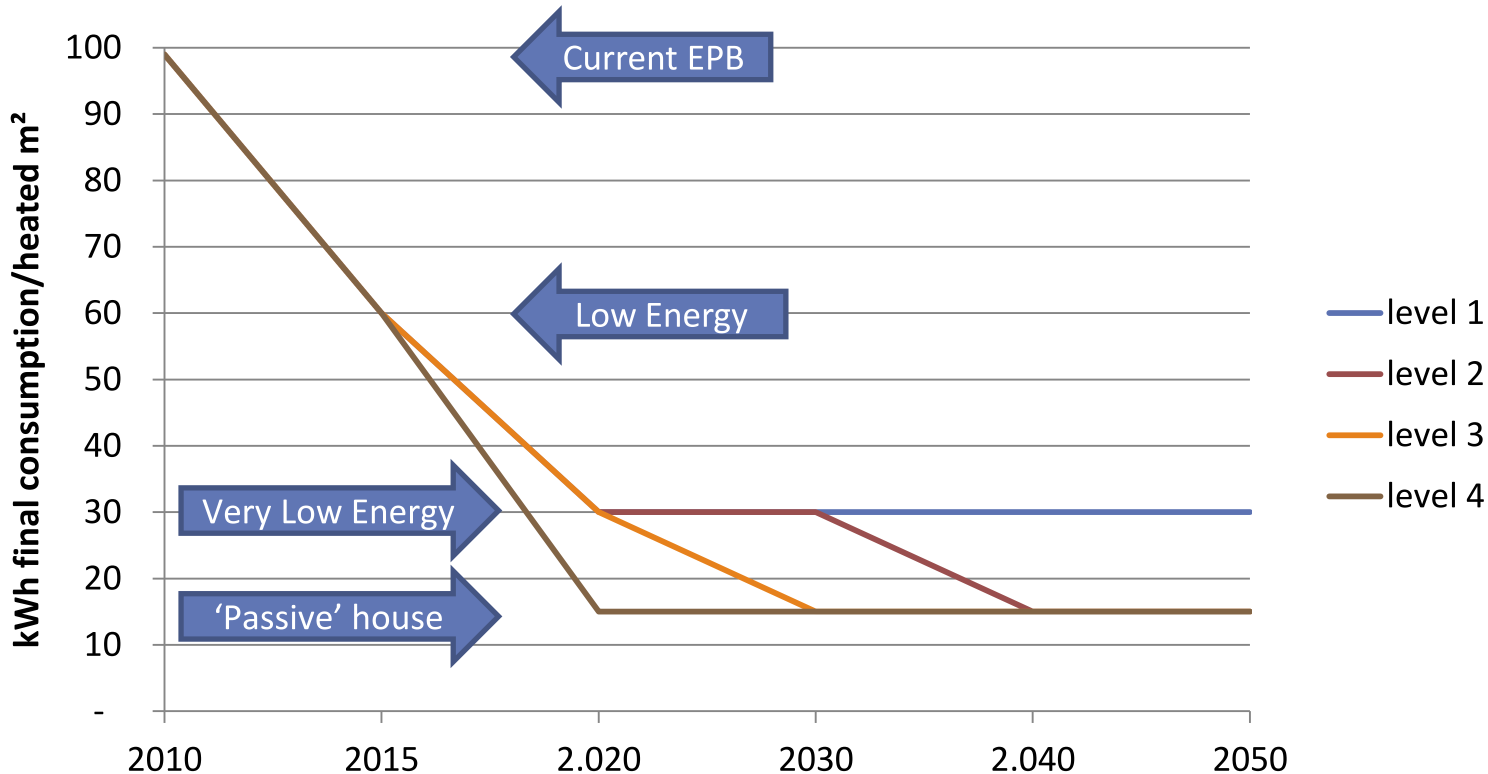
New houses – see also next slide: different levels of introduction speeds



Heat demand of existing house in 2010: based on Belgian Energy Balance 2010 (NIR 2012), assuming SHW energy consumption equals 1750 kWh/HH & average heated floor area of 124m².

Visualisation of the 4 considered levels of “final energy demand for heating per heated floor area for **newly built stock**”

Different levels of speed of the introduction of ‘passive houses (15 kWh/m²)’



Explanations of the 4 levels for "renovation rate per year"

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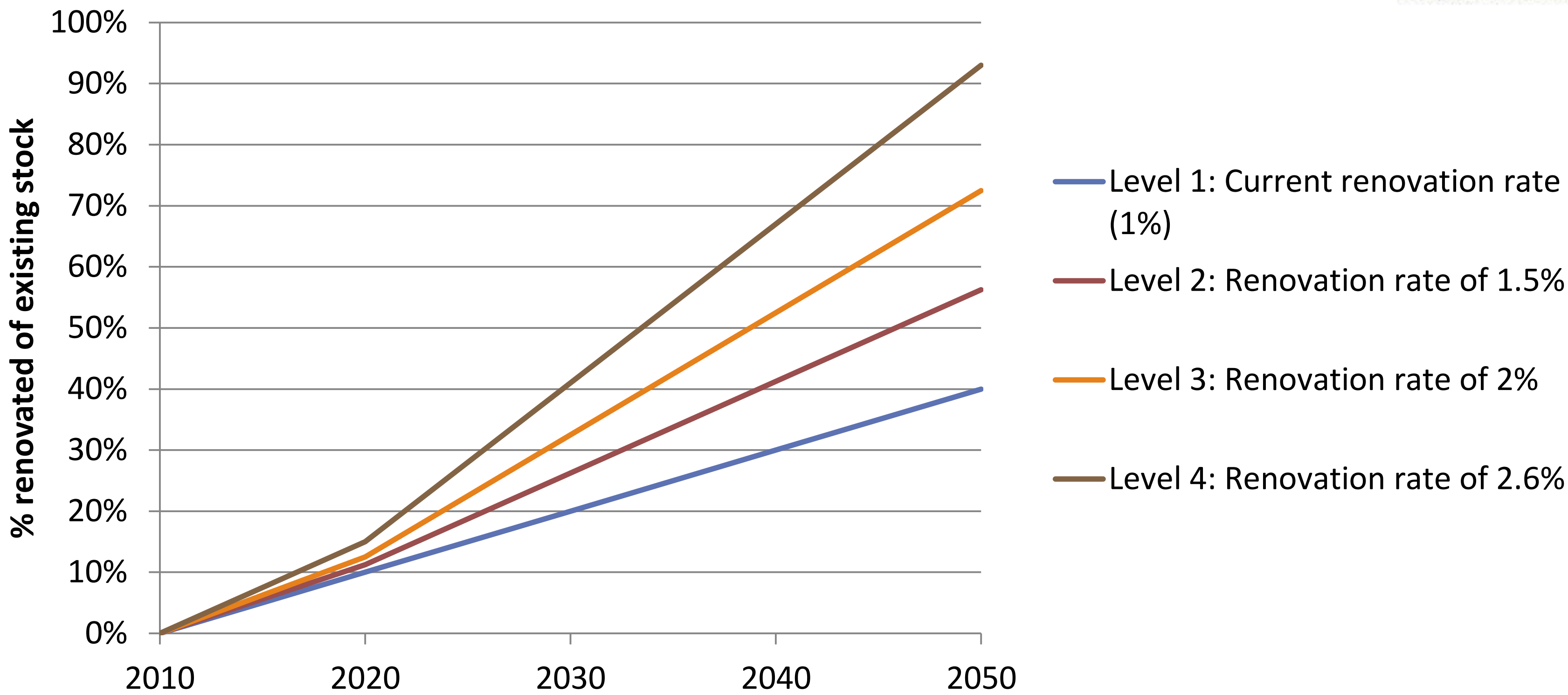
Level 1	Current renovation rate of 1% per year until 2050. In 2050, 40% of all houses will be renovated.
Level 2	A renovation speed of about 1.5% per year between 2020 and 2050. Between 2010 and 2020, the rate increases smoothly up to the level of 2020.
Level 3	A renovation speed of 2% per year from 2020 onwards. This speeds is twice as high as the current renovation speed.
Level 4	Almost all houses are renovated in 2050 (except eg. historic buildings). Therefore, a renovation speed of about 2.6% per year is required between 2020 and 2050.

SOURCE: Building permits of renovation; Kadaster Belgium 2010; VITO

Visualisation of the 4 considered levels of "renovation rate per year"

Residential



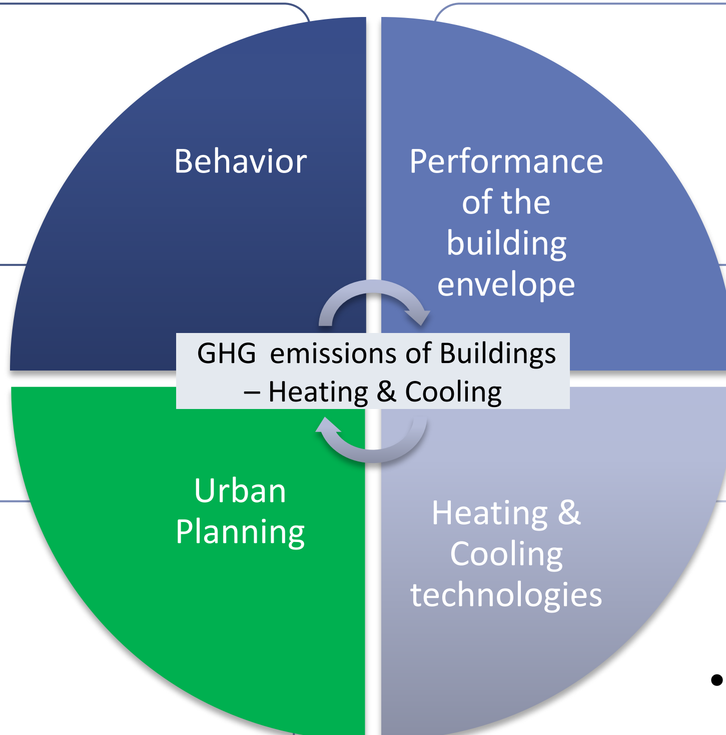
SOURCE: Building permits of renovation; Kadaster Belgium 2010

Surface & compactness of new houses

Evolution of the population & Number of dwellings; Evolution of the services sector (value added)

- Heating demand: desired internal temperature
- Cooling demand
- Hot water demand

- New buildings & existing buildings
- Renovation speed
- Speed of demolition/new buildings



- Evolution of surface per building
- Evolution of compactness: Share of flats

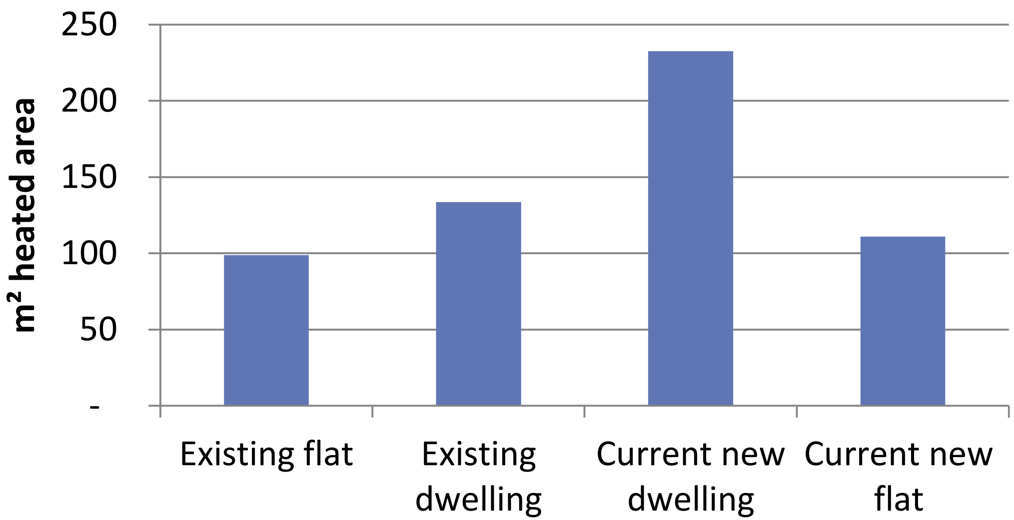
- Evolution of type of heating/cooling/hot water technologies
- Efficiency of these technologies
- Life span of technologies

The heated floor area of new dwellings is about 100m² larger than the area of existing dwellings

Residential

Heated floor area of Belgian houses: new versus existing flats & dwellings, [m²]

→ Acceptable sizes for new houses built between 2010 and 2050?



Definition of dwelling: detached, semi-detached or terraced house.
Definition flat: housing unit within an apartment building.
Definition of house: flat or dwelling.

- The average heated floor area of an **existing house** anno 2010 (mixture of flats and dwellings) is about 124m².
  - Flats have an average floor area of about 99 m².
  - Dwellings have an average floor area of about 134 m².
- **New houses**: The average heated floor area of a current new dwelling is about 233m²; for flats about 111m².

SOURCE: New houses: Building permits 2004-2011; Existing houses: Times Belgium

Given the expected scarcity of available land for buildings and the evolution to smaller households, the heated floor area of new dwellings will decrease.

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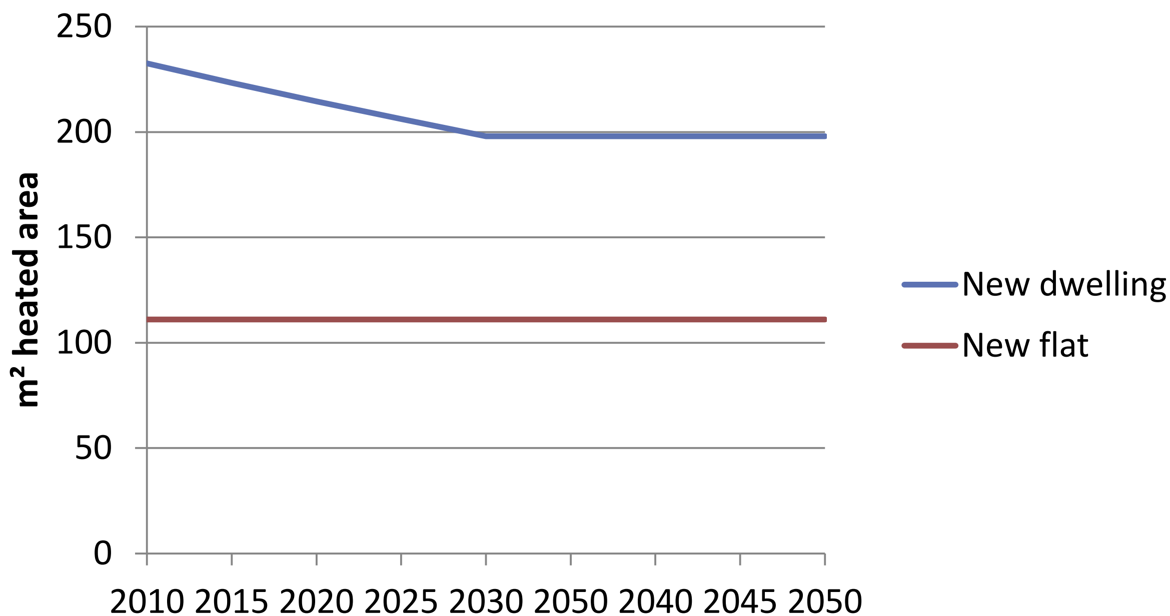
Based on the observed evolutions of the floor area in the Flemish new houses 2006-2010:

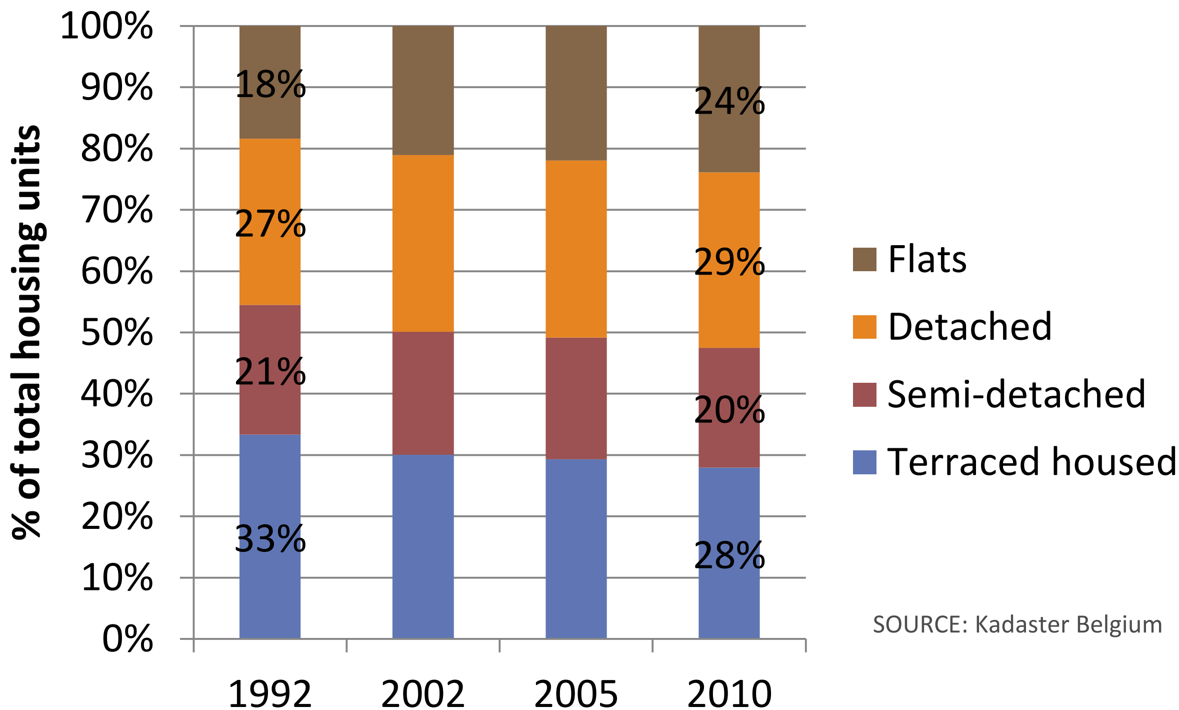
- The heated floor area of new dwellings will decrease with 0.8% per year between 2010-2030. From 2030, we assume that the heated floor area will remain constant (198 m²).
- The heated floor area of flats will remain constant until 2050 (111 m²).



SOURCE: Analysis of Flemish EPR 2006-2010 (VEA, April 2012)

The Belgian housing stock has a high share of (semi-) detached dwellings

Evolution of dwelling types in Belgium between 1992 and 2010, [% of total housing units]



SOURCE: Kadaster Belgium

- High share of detached & semi-detached dwellings in the total housing stock: 49% in 2010.
- Increase of compactness in current housing stock:
  - Share of flats: increase from 18% to 24% between 1992-2010
  - Share of terraced houses: decrease from 33% to 28% between 1992-2010

Share of flats in newly built houses *(source: Building permits)*:
Average share 2004-2011: 53% - Average increase 1,2% per year

Explanations of the 4 levels for "compactness of new houses determined by yearly share of flats"

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Level 1

- An important share of the people tend to live & work in suburban to rural areas. Tendency towards more 'Regional Communities'.
- A decreasing proportion of flats until 2030 up to the level of 40% – After 2030 remains constant.

Level 2

- Keep the share of flats constant until 2050 at the current level which are observed for new houses, namely 53%.

Level 3

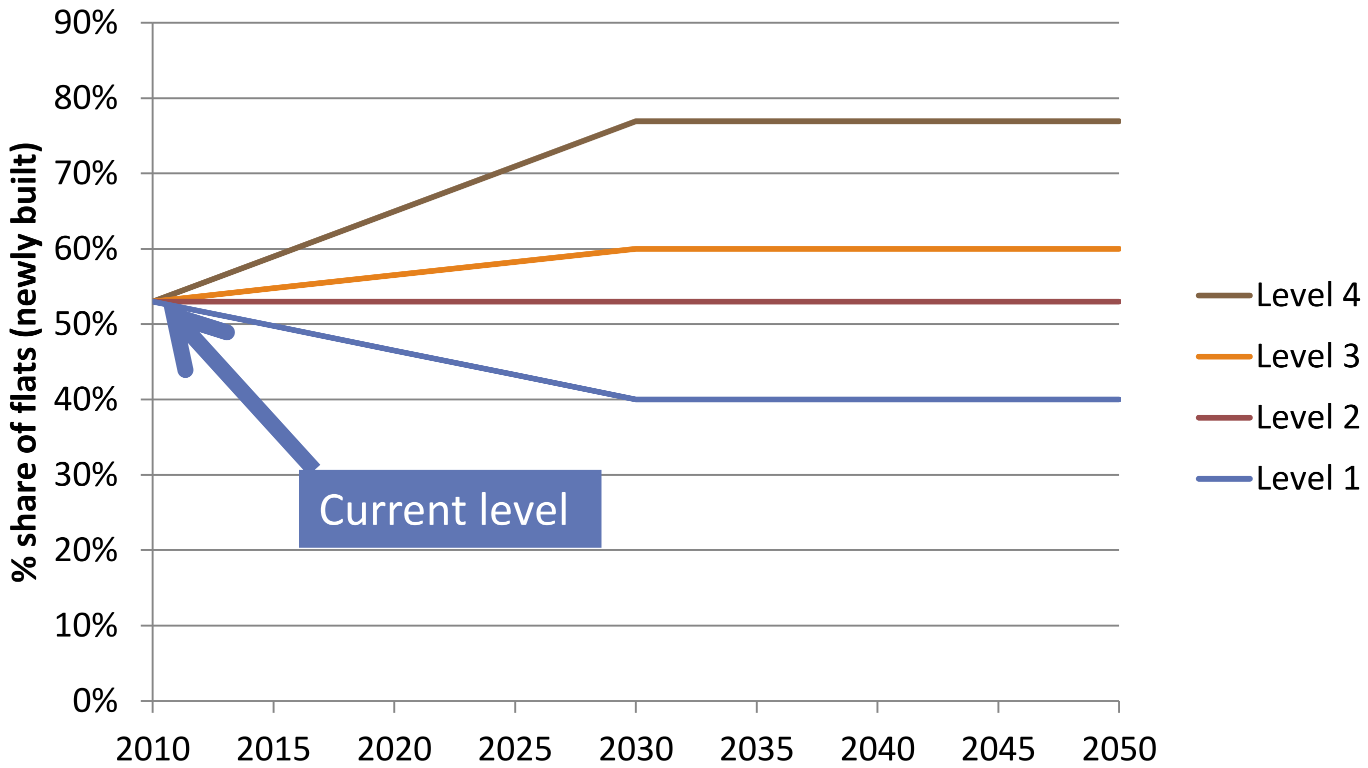
- Increase the share of flats until 2030 up to 60% - after 2030 remains constant.

Level 4

- An important share of the people tend to live & work in urban areas, which will result in more urbanisation.
- Extend the current trend observed for new houses (1,2% increase of flats per year) until 2030 – after 2030 remain constant at the attained level, namely 77%.

Visualisation of the 4 considered levels of “yearly share of flats”

Residential



SOURCE: Building permits 2004-2011; VITO

Behavioral changes

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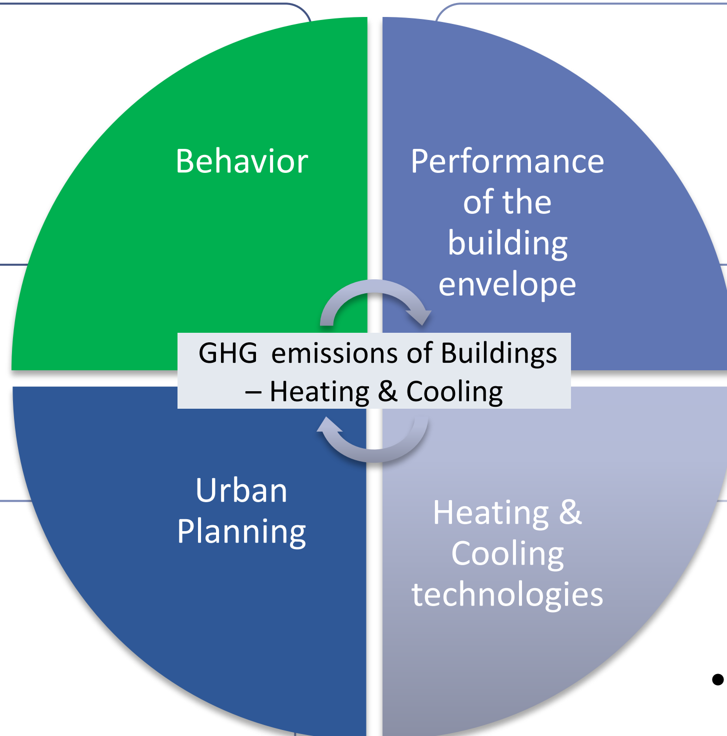
Evolution of the population & Number of dwellings; Evolution of the services sector (value added)

- Heating demand: desired internal temperature
- Cooling demand
- Hot water demand

- New buildings & existing buildings
- Renovation speed
- Speed of demolition/new buildings



- Evolution of surface per building
- Evolution of compactness: Share of flats

- Evolution of type of heating/cooling/hot water technologies
- Efficiency of these technologies
- Life span of technologies

4 levels for “hot water demand”

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Level 1	**20% increase** in hot water demand per household in 2050. This reflects the impact of economic growth leading to an increased use of hot water, and a larger number of hot water using appliances.
Level 2	Keep hot water demand per household at **current level**, namely **1202 kWh/HH.**
Level 3	**20% decrease** in hot water demand per household in 2050.
Level 4	There is a **50% decrease** in hot water demand per household in 2050. This is thought to be the limit that could be achieved with greater consumer awareness of hot water efficiency, and more water efficient fittings.

SOURCE: Assumptions EPB software Flanders (protected volume 400m³) – DECC - VITO

4 levels for "cooling demand"

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Residential

Level 1

It is assumed that **60% of the household in Belgium has air conditioning by 2050**, in response to increased wealth. This means an increase of 56% of the total share of cooling compared to 2010. Cooling demand per HH remains at current level, namely **1460 kWh/HH.**

Level 2

It is assumed that **40% of Belgian households has air conditioning by 2050**. Cooling demand per HH remains at current level, namely **1460 kWh/HH.**

Level 3

It is assumed that **20% of Belgian households has air conditioning by 2050**. Cooling demand per HH remains at current level, namely **1460 kWh/HH.**

Level 4

Keep total cooling demand of Belgium **constant at current level**: **4% of households** has an average cooling demand of **1460 kWh/HH.**

SOURCE: VITO (Evolution heating & cooling demand, 2011) - DECC

4 levels for "average internal temperature, reflecting households preferences".

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Level 1

Average internal temperature in households rises to **20ºC by 2050**, representing a significant increase of 2°C. This is in response to increased wealth.

Level 2

Average internal temperature in households rises to **19ºC by 2050**.

Level 3

Average internal temperature in households keeps **constant at current level**, namely **18ºC.**

Level 4

Average internal temperature in households falls to **16ºC by 2050**, representing a significant decrease of 2°C. The effect that internal temperature has on comfort and health varies depending on the type of occupant, activity levels and clothing. The evidence shows that 16°C is a safe minimum in occupied rooms for vulnerable groups.

SOURCE: BIM, DECC

Evolution of heating & cooling technologies

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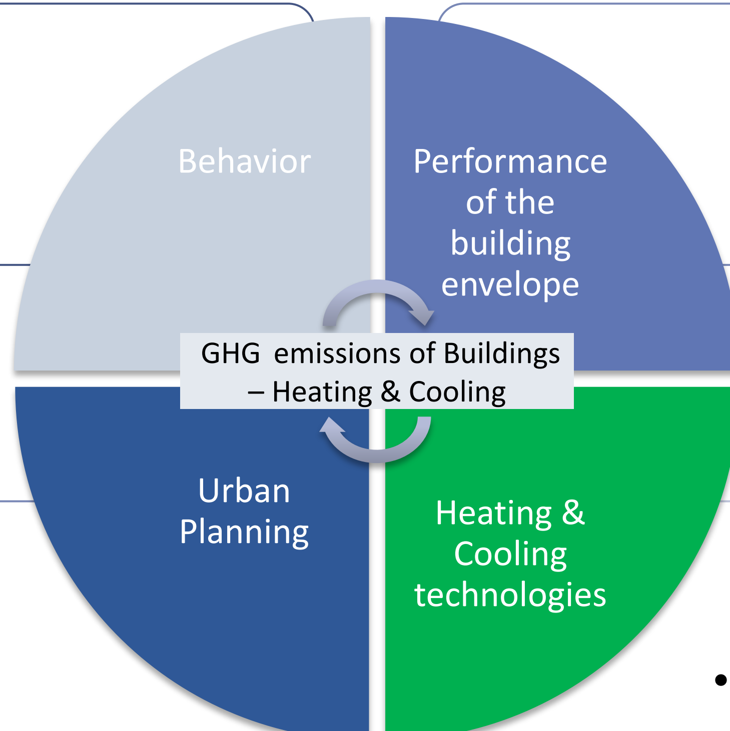
Evolution of the population & Number of dwellings; Evolution of the services sector (value added)

- Heating demand: desired internal temperature
- Cooling demand
- Hot water demand

- New buildings & existing buildings
- Renovation speed
- Speed of demolition/new buildings



- Evolution of surface per building
- Evolution of compactness: Share of flats

- Evolution of type of heating/cooling/hot water technologies
- Efficiency of these technologies
- Life span of technologies

Residential

Characteristics of 3 types of heating technologies

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	Share **2010** Heating	Share **2010** SHW	Technical or max. **Potential** in **2050**
Gas boiler (old)	42%	42%	90%
Gas boiler (new)	8%	8%	90%
Solid-fuel boiler	4%	4%	75%
Oil-fired boiler (old)	37%	30%	75%
Oil-fired boiler (new)	1%	1%	75%
Resistance heating	7%	14%	100%
Air-source heat pump	1%	1%	100%
Ground-source heat pump	1%	1%	55%
Stirling engine µCHP	0%	0%	90%
Fuel-cell µCHP	0%	0%	90%
Geothermal	0%	0%	45%
Community scale gas CHP	0%	0%	45%
Community scale solid-fuel CHP	0%	0%	45%
District heating from power stations	0%	0%	45%

Conventional (gas and oil boilers, solid-fuel boiler)

Electric (resistance heating, air-source heat pump)

Innovative (ground-source heat pump to district heating)

Limited by space availibility

Largest feasibility in rural & urban areas

Limited by gas network

Largest feasibility in urban areas

SOURCE: Climact, VITO & ECONOTEC (Emissions building sector, 2011), VITO Milieukostenmodel Huishoudens)

Residential

16 possible combinations of technologies in 2050 are modeled

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- Share of different heating technologies depends on two parameters:
  - **Electrification** level: 4 levels
  - **'Conventional' versus 'Innovative technologies'**: 4 levels
- 16 possible combinations of heating technologies.

				Conventional ⟷ Innovative			
				a	b	c	d
Level of electrification	High	90%	D	1	2	3	4
	Medium	65%	C	5	6	7	8
	Low	30%	B	9	10	11	12
	Very Low	10%	A	13	14	15	16

■ Electric heating (Heat pumps + electric resistance heating)
□ Non-electric heating

SOURCE: DECC, Climact, VITO

The non-electric technologies are composed of conventional and more innovative technologies

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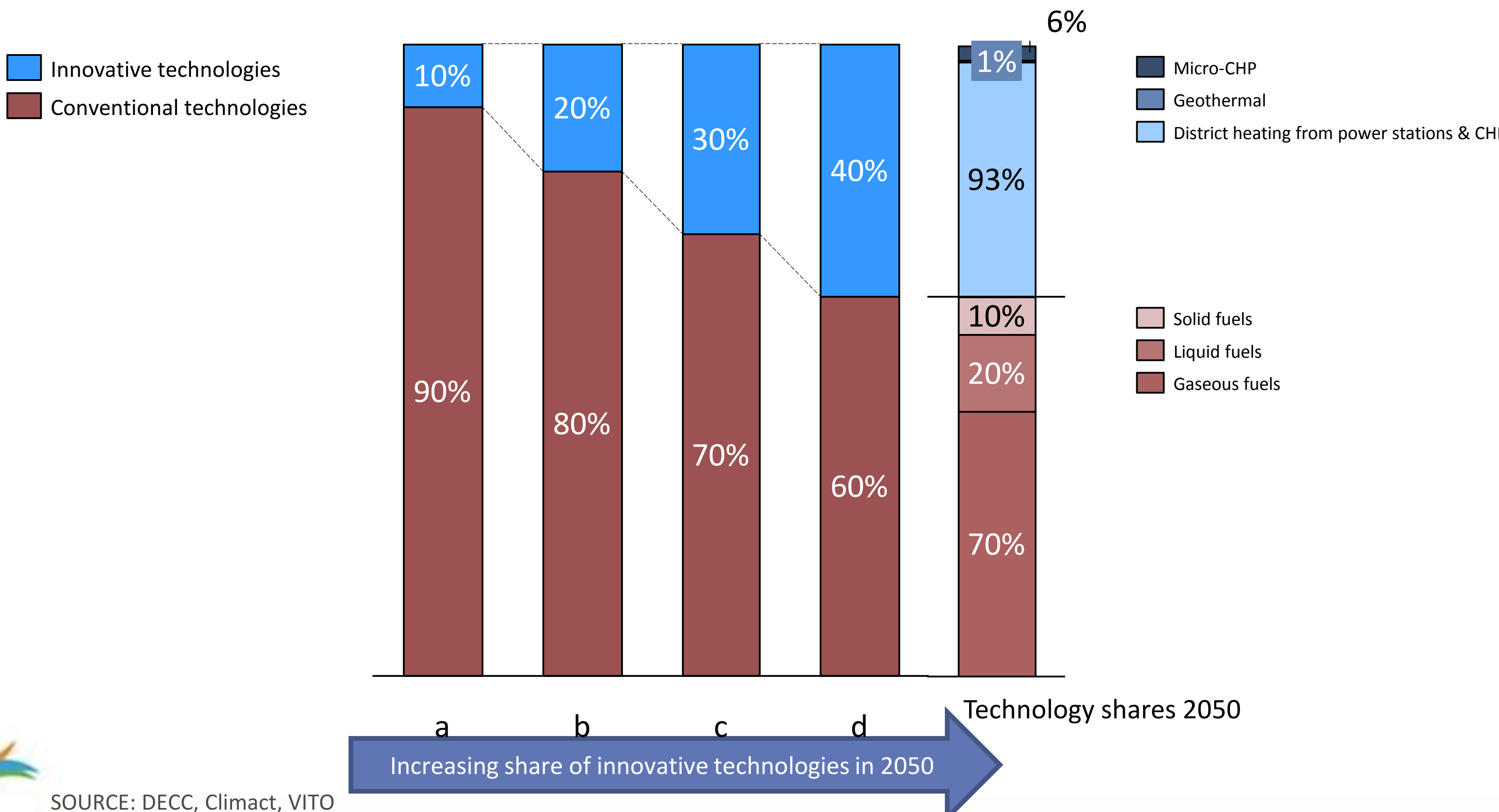
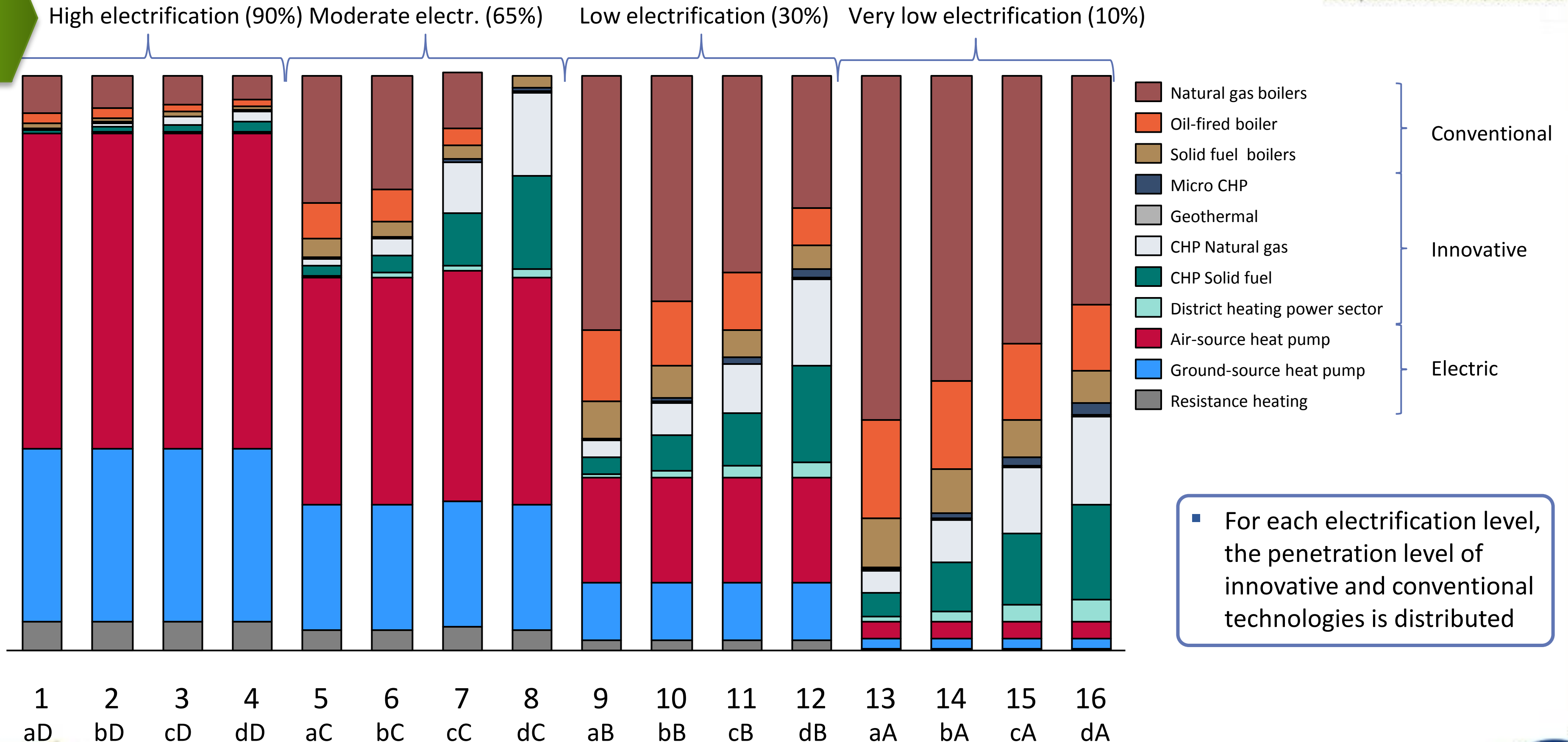
Share of conventional technologies in non-electric technologies in 2050, %



SOURCE: DECC, Climact, VITO

Combining the technologies provide a wide range of possible mixes by 2050

Residential



- For each electrification level, the penetration level of innovative and conventional technologies is distributed

SOURCE: DECC, Climact, VITO

Services sector is modelled in less details due to limited data availability and subsector heterogeneity

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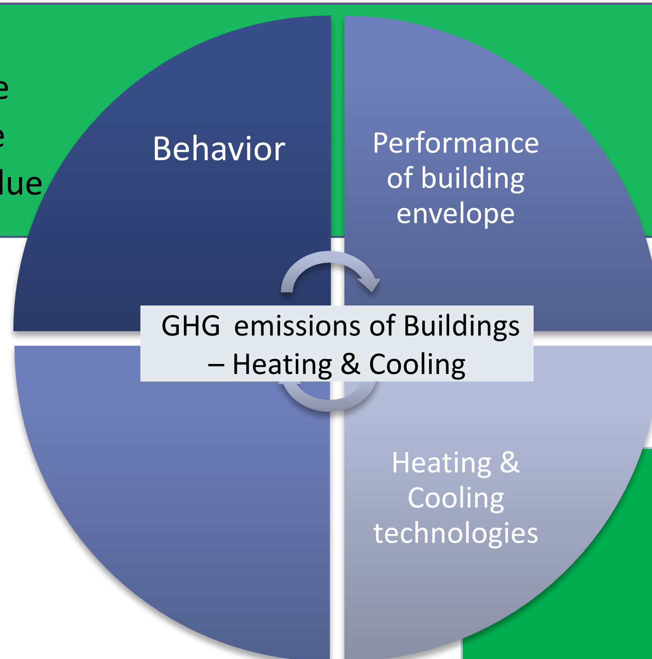
Evolution of the population & Number of dwellings; Evolution of the services sector (value added)

- Evolution of:
  - Heating demand per added value
  - Cooling demand per added value
  - Hot water demand per added value



- Resembles residential sector, but higher share of gas boilers [NIR2012]

Explanations of minimum & maximum efforts for "heating & cooling demand per added value" by 2050

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Services

Level 1 – Minimum effort

- Heating demand:
  - Application of low cost/easy to implement measures or the implementation of current EPB regulation for new buildings.
  - Same evolution as assumed for the residential sector: a reduction of **13% compared to the level of 2010.**
- SHW demand: this demand will remain constant
- Cooling demand: today almost 66% of the floor space of offices has active cooling. In 2050, we assume that **90% of the offices will be actively cooled (+25%)**.

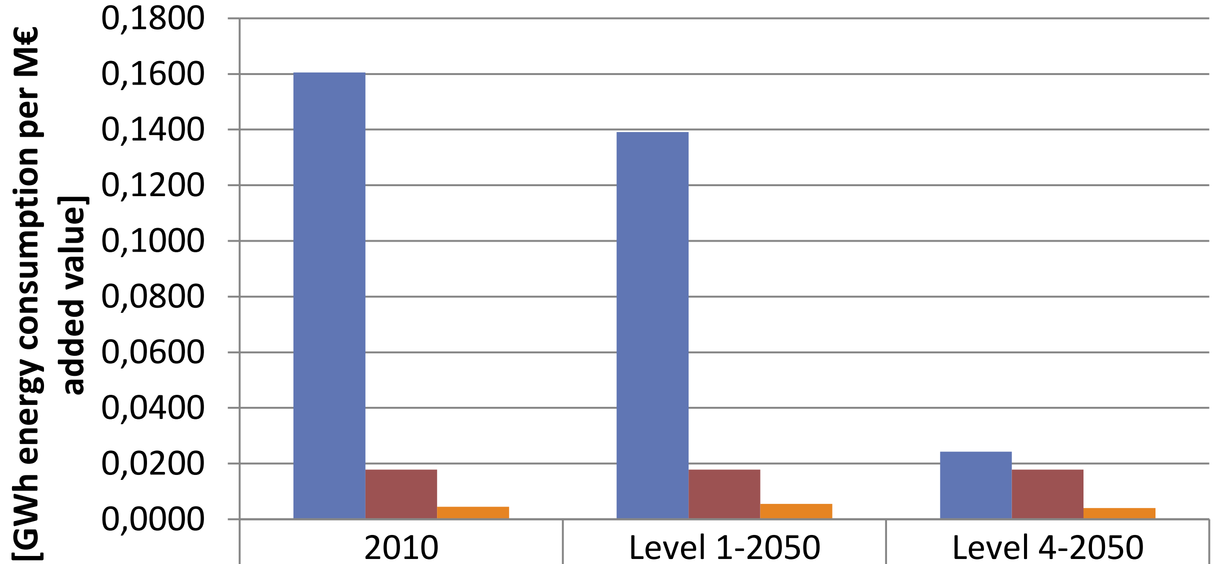
Level 4 – Maximum effort

- Heating demand:
  - Evolution to passive buildings
  - Same evolution as assumed for the residential sector: a reduction of **85% compared to the level of 2010.**
- SHW demand: this demand will remain constant
- Cooling demand: the fraction of non-residential floor space with airco is reduced by 50% due to increase in the use of passive cooling systems. Nearly all new build airco is achieved through passive design measures, achieving a **90% reduction in cooling demand** compared to the level of 2010.

SOURCE: DECC, VITO (Evolution heating & cooling demand, 2011), VITO

Visualisation of minimum & maximum efforts of "heating & cooling demand per added value" by 2050

Energy consumption for heating, cooling & SHW per added value in 2010 & 2050, [GWh/M€]



	2010	Level 1-2050	Level 4-2050
Heating	0,1606	0,1392	0,0243
SHW	0,0178	0,0178	0,0178
Cooling	0,0045	0,0056	0,0040

Note: heating demand expressed in 1799 heating degree days

Source: NIR Belgium April 2012; Federaal planbureau; VITO (Energy and GHG scenarios according to REF, 2006); JRC (Electricity Consumption and Efficiency - Trends in European Union, 2009)

Subsectors of buildings

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A. Heating, hot water & cooling

B. Lighting & appliances

Black & white appliances have highest share in electricity consumption for household appliances & lighting

Share of different end-uses in final consumption

- *Lighting* demand per household : 365 kWh electricity consumption per household in 2010
- *White appliances* demand per household: 1140 kWh electricity consumption per household in 2010
- *Black appliances* demand per household: 1160 kWh electricity consumption per household in 2010
- *Electric cooking* demand per household:200 kWh electricity consumption per household in 2010

Explanations of minimum & maximum efforts for "demand for lighting & appliances per household" by 2050

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Level 1

If we **do not make much effort to reduce demand further** in this sector, a hypothetical trajectory could involve the following:

- Total demand for energy for lighting could stabilize at today's levels as efficiency levels continue to improve as they have in the past;
- Demand for white appliances could increase very slightly in line with historic trends: +10% increase in demand.
- Demand for energy for black appliances could increase by 15% by 2050;
- Demand for energy for cooking could remain stable at current levels.
- There may be no significant change in the way we manage our use of lighting or appliances.

Level 4

At the extreme end, we could possibly **decrease demand in 2050 by 40%**. Eg.:

- We could replace all lights with extremely efficient lights (such as LEDs at 75 lumens/watt): about 50% decrease in demand;
- We could replace all cold appliances with extremely efficient cold appliances by 2050 (each appliance uses about 80% less energy through technological improvements).
- When replacing our consumer electronics and home computing products, we could adopt only the best practice products until 2050: about 50% decrease in efficiency. But we assume an increase of the implementation level of 50% (~level 1).
- We could use 15% less energy through more careful use of lighting and appliances.

SOURCE: DECC, SERPECC (Ecofys & E3M-lab, 2009)

Residential

Visualisation of minimum & maximum efforts of "demand for lighting & appliances per household" by 2050

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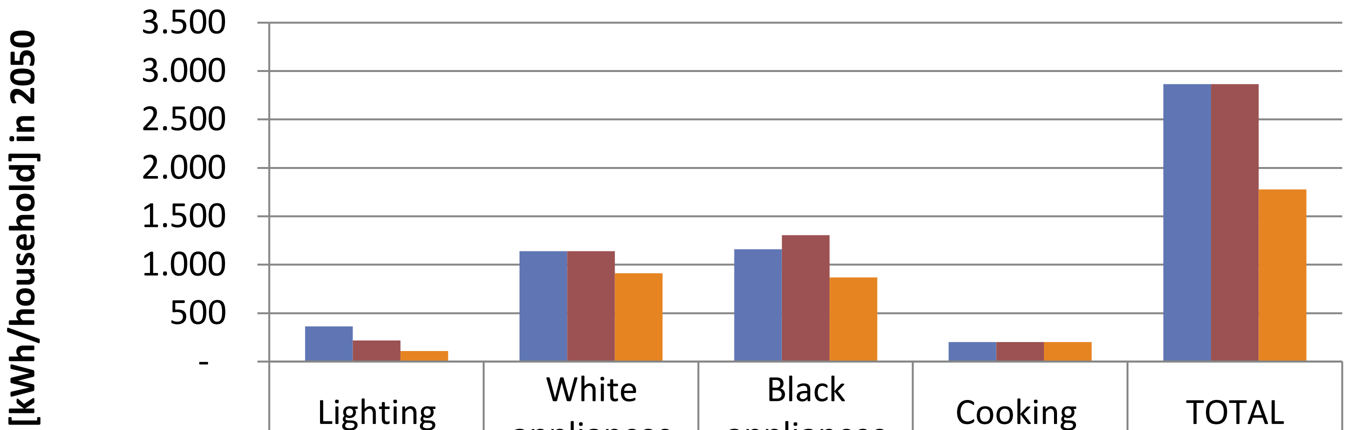
Electricity consumption for lighting, white & black appliances, cooking per household in 2010 & 2050, [kWh/HH]



	Lighting	White appliances	Black appliances	Cooking	TOTAL
Current 2010	365	1.140	1.160	200	2.865
Level 1 - 2050	219	1.140	1.305	200	2.864
Level 4 - 2050	110	912	870	200	1.778,20

SOURCE: Energy balances of 2010 for Flanders, Wallonia and Brussels (Wallonia & Brussels extrapolated based on 2009); DECC; SERPECC

3 types of demands modelled for the services sector

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Services

Share of different end-uses in final consumption

- *Office lighting demand* per added value: 0,0363 GWh electricity consumption per M€ added value in 2010
- *Street lighting demand* per added value: 0,0048 GWh electricity consumption per M€ added value in 2010
- *Demand for appliances* per added value: 0,0893 GWh electricity consumption per M€ added value in 2010

Explanations of minimum & maximum efforts for "demand for lighting & appliances per added value" by 2050

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Level 1

- Office Lighting: this demand will **stabilize** at today's levels as efficiency levels continue to improve as they have in the past.
- Street lighting: this demand will remain **constant.**
- Appliances: the electricity consumption for appliances will **growth with 25%** between 2010 and **2050**, because of an increasing implementation degree.

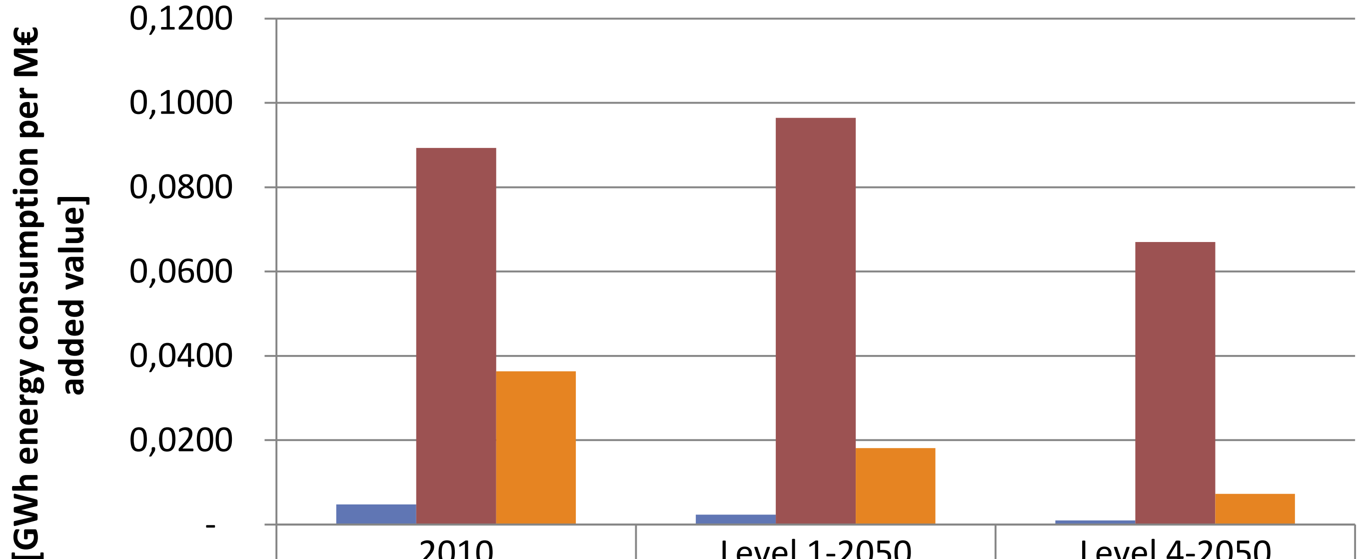
Level 4

- Office Lighting: demand for lighting per added value could **halve by 2050** through, for example, the increased use of LEDs instead of other, less efficient lighting technologies and through the use of motion detective lighting.
- Street lighting: this demand will remain **constant.**
- Appliances: through increasing adoption of more efficient technologies, we could **reduce electricity consumption by a quarter by 2050**.

SOURCE: DECC, VITO

Visualisation of minimum & maximum efforts of “demand for lighting & appliances per added value” by 2050

Electricity consumption for lighting & appliances per added value in 2010 & 2050, [GWh/M€]



	2010	Level 1-2050	Level 4-2050
Street lighting	0,0048	0,0024	0,0010
Appliances	0,0893	0,0965	0,0670
Office lighting	0,0363	0,0182	0,0073

Source: Three regional Energy Balances; Federal Plan Bureau; JRC (Electricity Consumption and Efficiency - Trends in European Union, 2009); DECC; VITO

Structure of the cost modeling

Fuel costs evolutions are covered in the energy supply sector

Capital investments + Fuel costs + Operations and Maintenance | Externalities

Total costs

Investments, operations and fuel costs are included, not externalities

Fuel costs evolutions are covered in the energy supply sector

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Sector		Investments	O&M	Fuels	Externalities
Buildings	**Behaviour changes**	n/a	- Maintenance based on technology distribution - Information campaigns, trainings,...	- Consumption volumes - Takes fuel shift into account - Taxes on fuels	- Impact of climate change - Air quality (cost on health and reduction in life expectancy) - Congestion costs (transport) - Reduction in noise disturbances (transport) - Visual impact (éoliennes) - Impact on required resources - Preservation of fossil fuel ressources - Dependance on new ressources - Impact on biodiversity services - Reduction/increase in nuclear risk - Impact of energy (in)dependence (reducing the impact of oil crises, etc.)
	Energy efficiency	■ Refurbishing (insulation, windows, etc.)			
		■ Replacing heaters/boilers			
		■ Replacing electric appliances			
		■ Improvements of appliances by manufacturers (R&D)			
	Electrification	■ Replacing boilers			
Transport	**Behaviour changes / evolution of the organization of society**	■ Vehicles (cars, buses, trains, trucks, boats)	- Maintenance based on technology distribution - Information campaigns, trainings,...	- Consumption volumes - Takes fuel shift into account - Taxes on fuels	
		■ Rail infrastructure			
		■ Costs related to the structure of the territory (for example a reduction in the cost of maintaining roads)			
	Energy efficiency	■ Cost of the replacement of the fleet over time			
		■ Improvement of fleet efficiency by manufacturers (R&D)			
	Electrification	■ Replacement by electric vehicles (batteries included)			
		■ Cost of the electric charging infrastructure			
Industry	**Carbon intensity**	■ Investments to improve carbon intensity (new products or processes, energy efficiency, cogeneration, etc.)	- Maintenance based on technology distribution	- Consumption volumes - Takes fuel shift into account -Funcioning of CCS	
	CCS	■ Equipment to capture, transmit and store CO2			
		■ Cost of R&D of developing CCS			
Energy supply	**Electricity**	■ All production plants (wind or gaz turbines, etc.)	- Maintenance based on technology distribution	- Biomass, fossil fuels and electricity imports - Cost of producing biomass	
		■ Electric transmission network, back-up plants			
		■ Distribution network (simplified approach)			
		■ Cost of CCS for electricity			
		■ Cost of R&D for geothermal systems			
	Biomass	■ Biomass transformation plants			

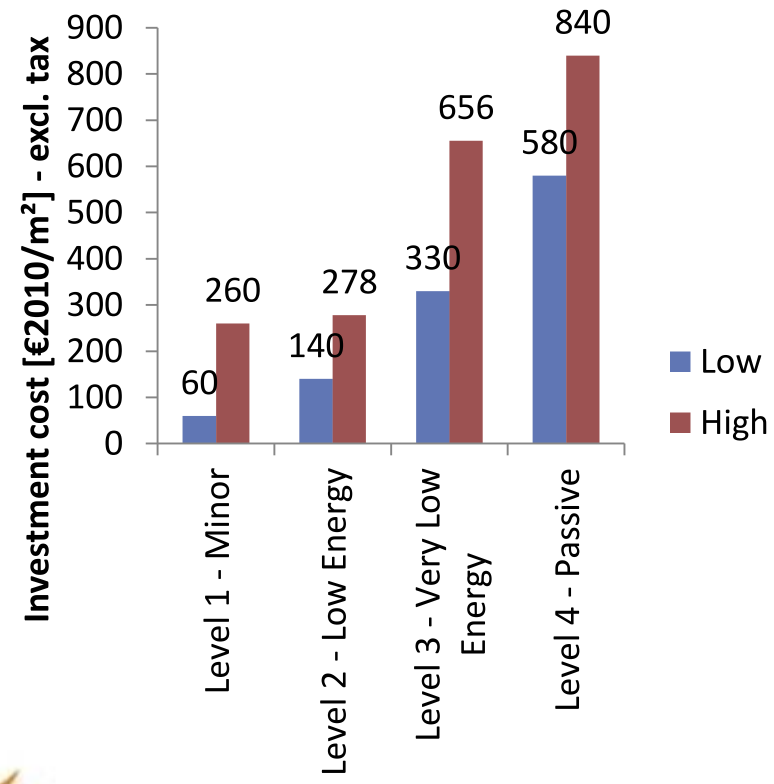
■ Included
■ Non-included

Residential

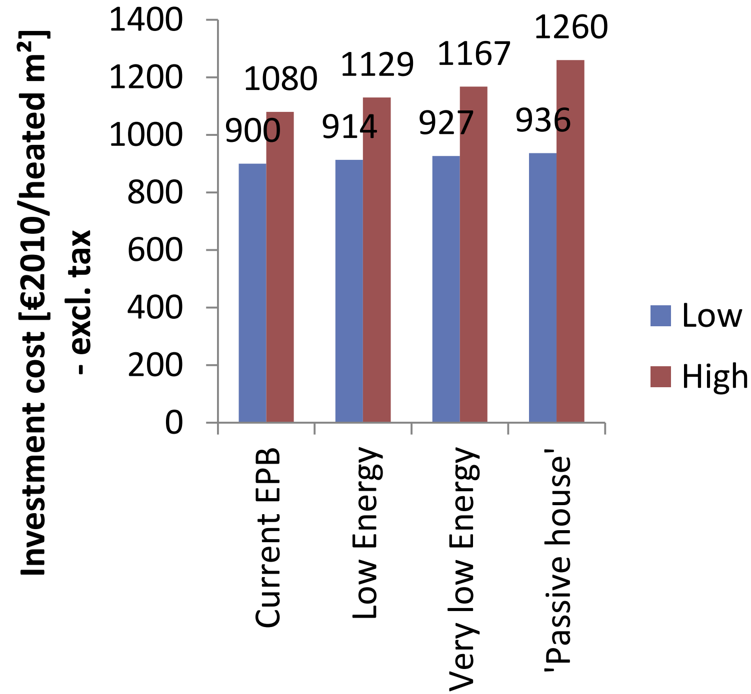
Investment ranges for the 4 considered levels of "heat demand per heated floor area for newly built & existing stock"

Investment ranges of 4 levels of heat demand per heated floor area, exclusive of taxes, [€2010/m²]

Renovation



New houses



Source: BPIE (Europe's buildings under the microscope, October 2012), CERAA 2008, SEI 2009, VEA Evaluatienota ERP 2010

Residential

Investment ranges for the different heating technologies in the residential sector

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	Investment cost [€2010] **per household**		Average size of installation per HH
	Low	High	kW
Gas boiler (new)	4150	5099	20
Resistive heating	1880	3600	20
Oil-fired boiler (new)	4420	6868	20
Solid-fuel boiler	9125	13185	20
Stirling engine µCHP	6234	12468	1 $kW_{electric}$
Fuel-cell µCHP	6234	12468	1 $kW_{electric}$
Air-source heat pump	9000	12600	14
Ground-source heat pump	14000	14575	11
Geothermal	9435	17913	20 kW_{heat}
Community scale gas CHP	12987	21465	20 kW_{heat}
Community scale solid-fuel CHP	12987	21465	20 kW_{heat}
District heating from power stations[1]	4987	13465	20 kW_{heat}

[1] Only cost of distribution network – cost of electricity production = cost of energy production sector

[2] Sum of investment costs related to network & CHP. Concerning costs of CHP, only costs related to heat production (~66% of total investment cost of CHP) are considered.

Source: VITO & ECONOTEC 2011, Times Belgium, DECC, VITO (MKM Huishoudens), …

Investment cost for the services sectors

- Investment ranges of heat demand & heating technologies

  → Can we consider them at the same level as the residential sector?
  - Cost per m² of heated floor area &
  - Cost per kW

We will assume the costs for the services sector are on average 10% lower compared to investment ranges of the residential sector. (economy of scale).

What about evolution of costs of the different technologies & measures in time?

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- The differences in costs between a new 'current EPB house' and a 'passive house' can be very low (eg. low cost levels in slide 93 – difference of 4%). This difference mainly reflects that a house is more than a mixture of efficiency measures (eg. comfort, kitchen, ...) and that the 'learning costs' of the reduction technology 'passive' can be very small.
- Concerning renovation of houses, the costs of reduction measures are mainly related to the materials (eg. insulation) and the labour costs for installing these materials. The expected learning effects at this level are rather small. On the other hand, a positive impact due to increasing volumes of activity in the building sector is possible for all efficiency measures (cfr. *BPIE – Europe's buildings under the microscope*).
- In our OPEERA model, the use of ranges of price levels (low – high) is a good way of dealing with this uncertainty. For district heating, you can expect that the costs will decrease in time, but at the moment the cost estimations of this technology are very uncertain due to the lack of Belgian specific data (lack of practical experience).

➔ **Therefore, we assume no evolution of the cost levels in time.**

Content – Buildings sector

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Barriers to remove to ensure sufficient decarbonisation of Buildings

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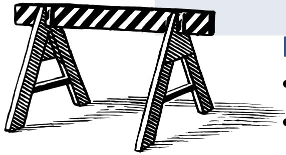
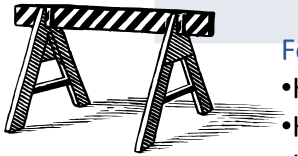


1 A global vision needs to be developed for building policies in Belgium

For example:

- Important role of urban planning in the evolution of district heating, dwelling types, insulation level etc.
- The level of insulation standards will impact the profitability of heating technologies
- Stimulating the implementation of reduction measures for all target groups (eg. tenants versus proprietors)



2 Work is required on organizational, psychological and behavioral levels

For example:

- Households and the services sector experience non-economical thresholds (eg. time, intransparancy of market)
- Historical observations show an increasing demand for hot water and cooling
- High share of detached houses or a high floor area requires a high heating demand
- Availability of work forces in the building sector

3 Belgium is dependent to other evolutions at the international level

For example:

- Energy prices have a large impact on the technology/fuel choices of policy and consumers.
- Innovation level of technologies (eg. lighting) will be exploited at global level .
- Legal competences concerning buildings and GHG emissions are spread between various power levels at EU, federal, regional, provincial and municipality level. A large coordination effort is required between various entities.

Barriers discussed during the expert workshop

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- Poverty, mainly in urban areas – social justice
- Good financing models for deep renovations
- Requirement of raising public awaraness of consumers
- Devaluation of existing building stock due to strong energy requirements
- System and long term approach at & between different government levels
- Importance of local authorities (eg. Building regulation can be a barrier for energy renovations etc.)
- Limited number of manpower in the building sector + proper education of workers
- Need for adaptation of electricity network
- Coherent spatial planning:
    - improve location of services, roads, buildings
    - Evolution towards smaller lot for buildings
- Solve owner/tenant-problem: need for stimulation of owners to renovate their property

Thank you.

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