EVOLUTION OF THE ENERGY LOAD PROFILES OF THE BELGIAN RESIDENTIAL BUILDING STOCK WITH NEW HEATING TECHNOLOGIES FOR DEMAND SIDE MANAGEMENT

BERA – Demand Response Seminar

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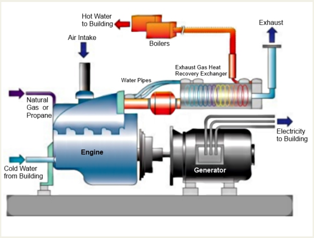
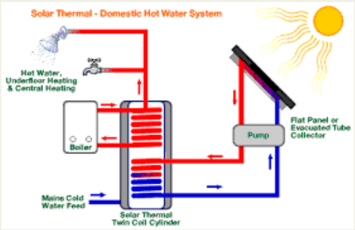
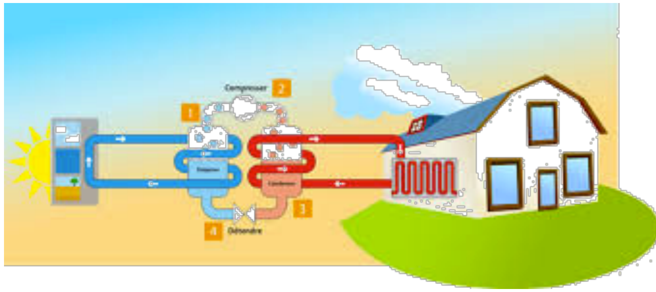
Context of the work

- **2012:** Electrabel and ULg launched the ProCEBaR project
- **Objective:** evaluating the impact of new HVAC and µ-CHP technologies as well as building shellimprovements on the evolution of the demand profiles of final energies (gas/electricity).
  - ✓ For **residential** buildings
  - ✓ At the **Belgium** level
  - ✓ **2030** horizon
  - ✓ For different **scenarii**
- **2015:** ProCEBaR tool has been used to investigate DSM strategies at national level.







Content of the presentation

1. Context
2. Residential building stock energy model
3. Scenarii until 2030
    a. Business as usual
    b. Heavy retrofit
    c. Massive introduction of heat pumps
    d. Heat pumps + TES + DSM
4. Conclusions

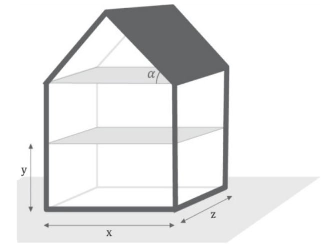
Residential building stock energy model

Bottom-up approach

Micro analysis

Set of Typical Buildings

Macro scale



Residential building stock energy model

Description of the Belgian residential building stock

- Type of building
- Year of construction
- Envelope insulation
- Space heating
- Domestic hot water
- % of the stock?

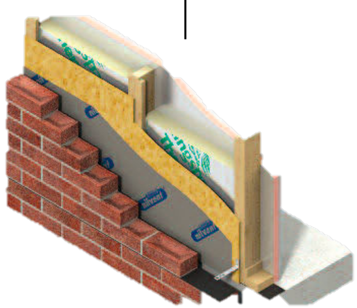
<1945

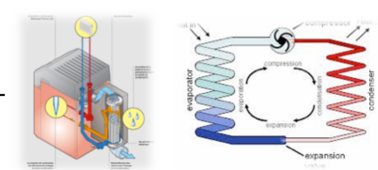
1946-1970

1971-1990

1990-2006

>2007

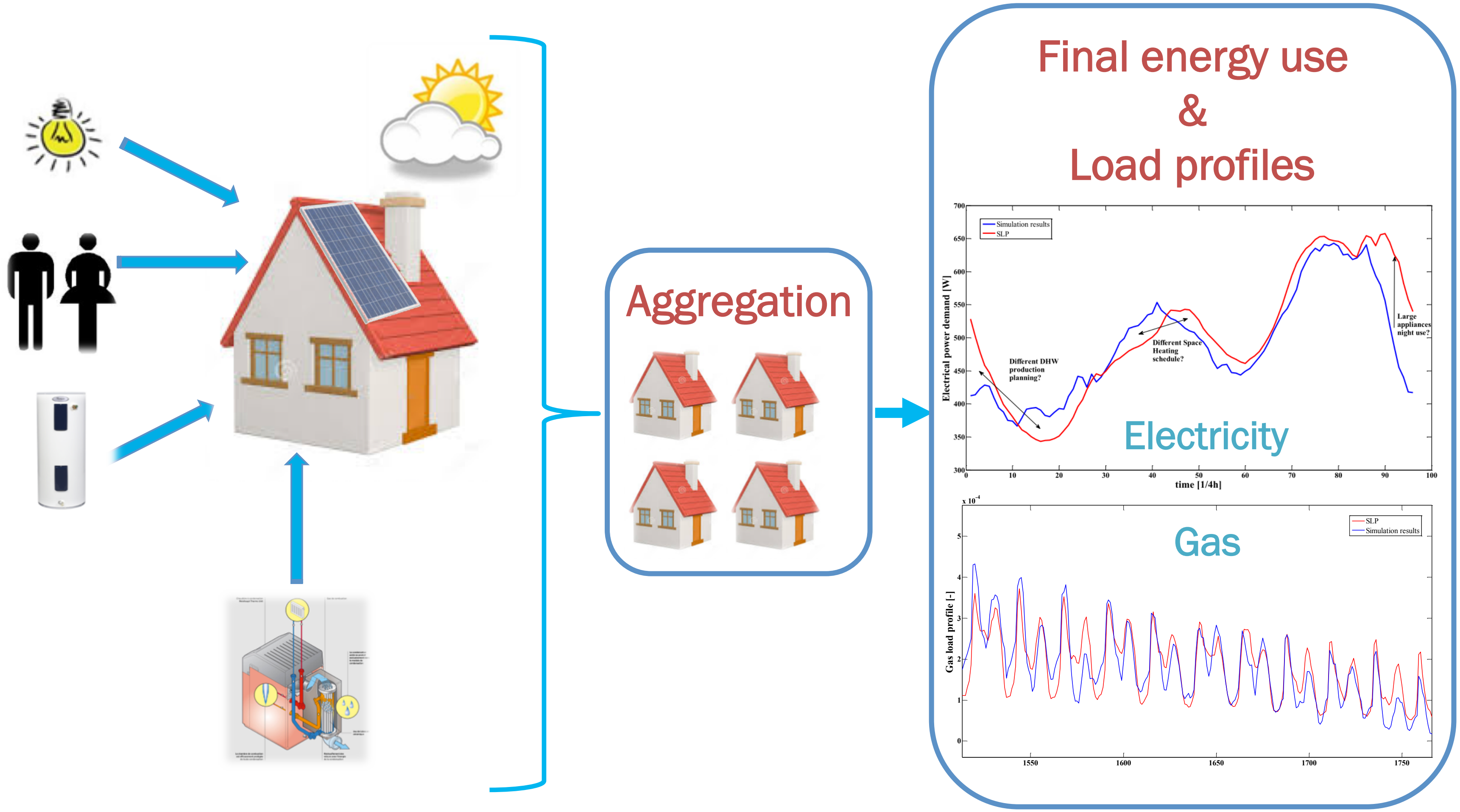




912 buildings in 2010

Residential building stock energy model

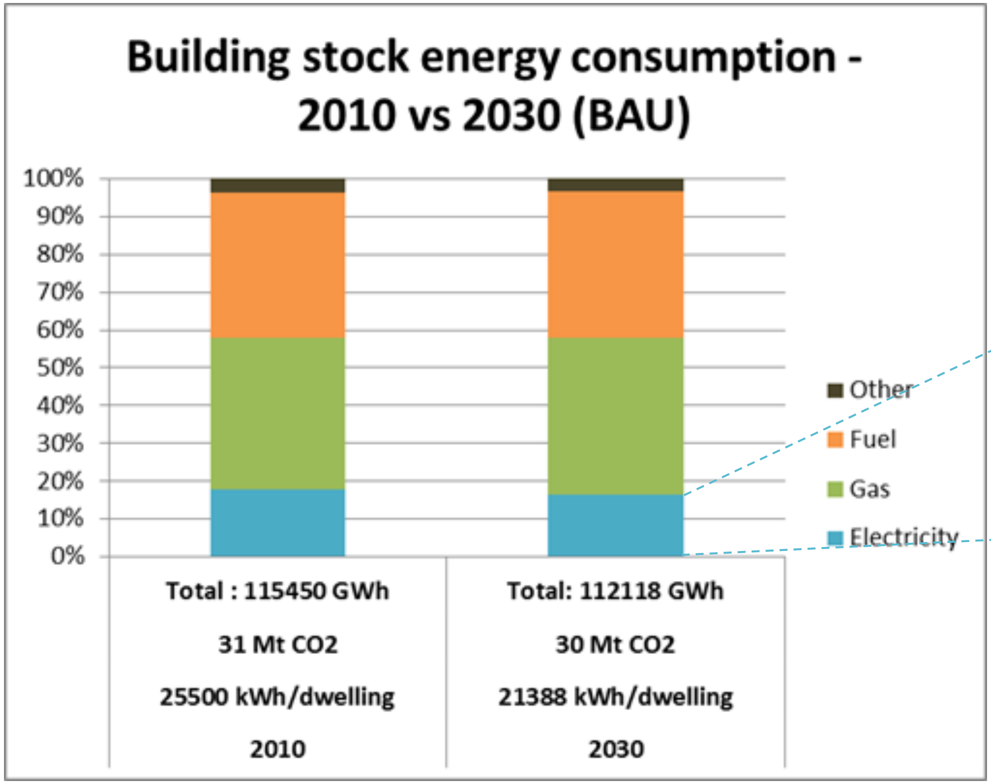
Simulation of buildings and systems

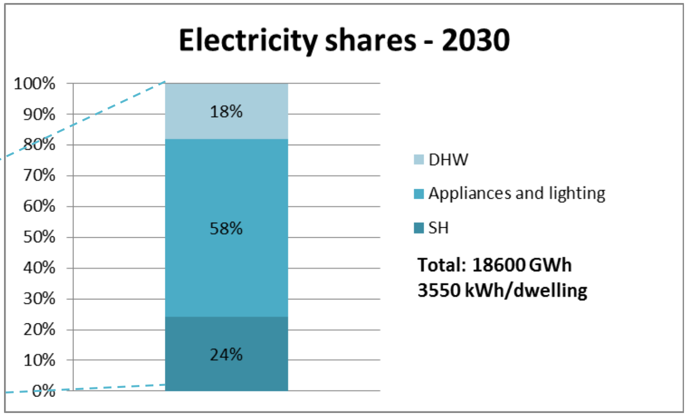


Scenarii until 2030

Business as usual scenario (BAU)

- ✓ Demolition/construction: 0.075%/ 0.9% per year,
- ✓ Retrofit: 0.8% light and 0.5% heavy renovation per year,
- ✓ Improvement in appliances consumptions.



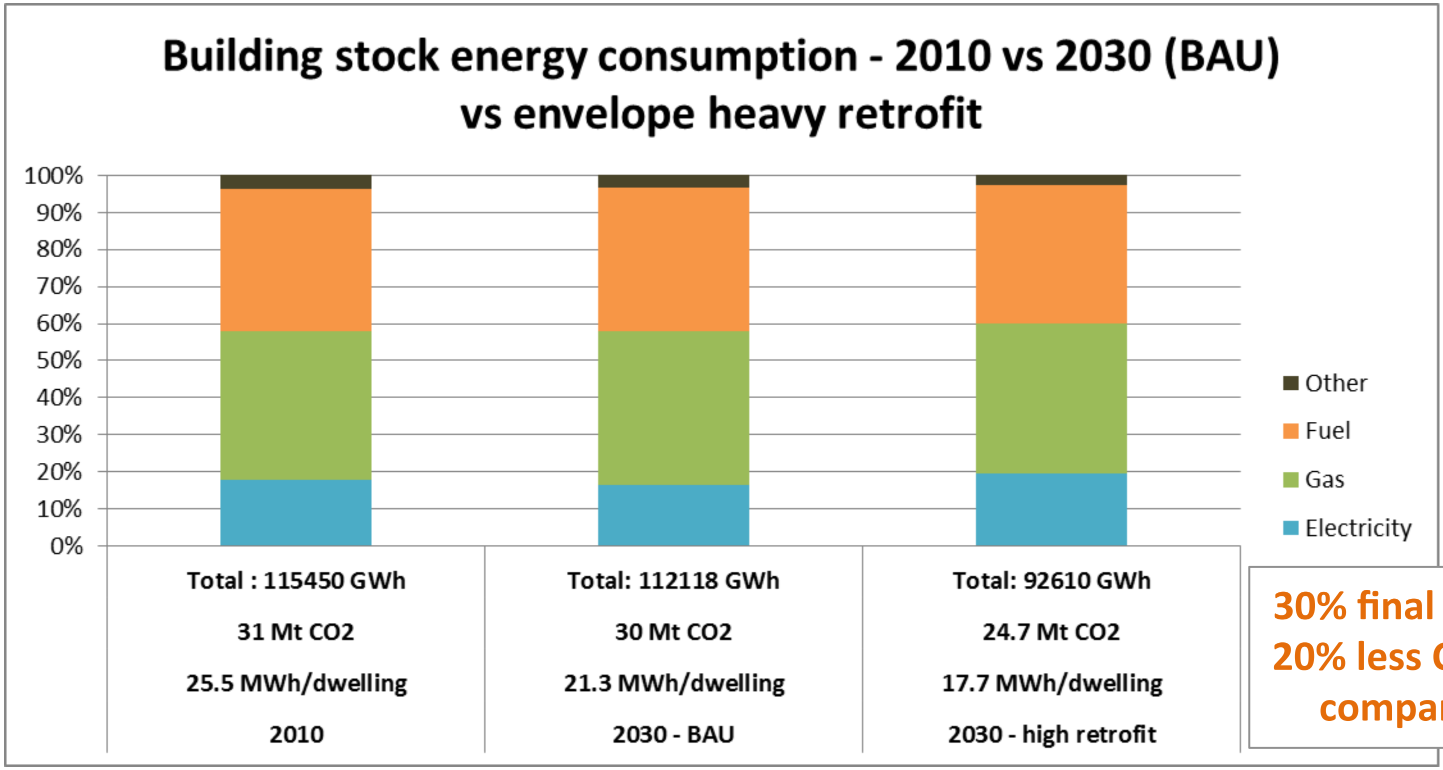


Scenarii until 2030

Heavy retrofit

✓ Heavy retrofit of the envelope: 1.5%/year

⇒ The percentage of houses heavily renovated between 2010 and 2030 reaches 25%



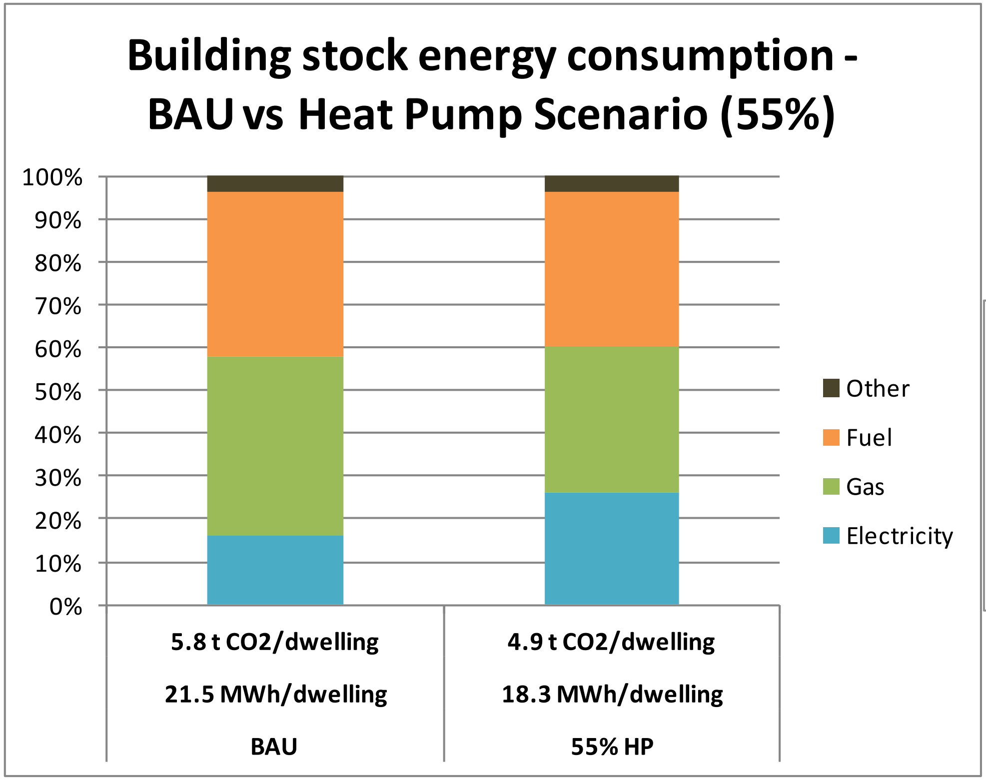
30% final energy saving
20% less CO_2 emissions
compared to 2010

Scenarii until 2030

Heat pumps

✓ Maximum penetration rate estimated to 55%

⇒ Equivalent to replacing 35% of the installed heating power of the building stock



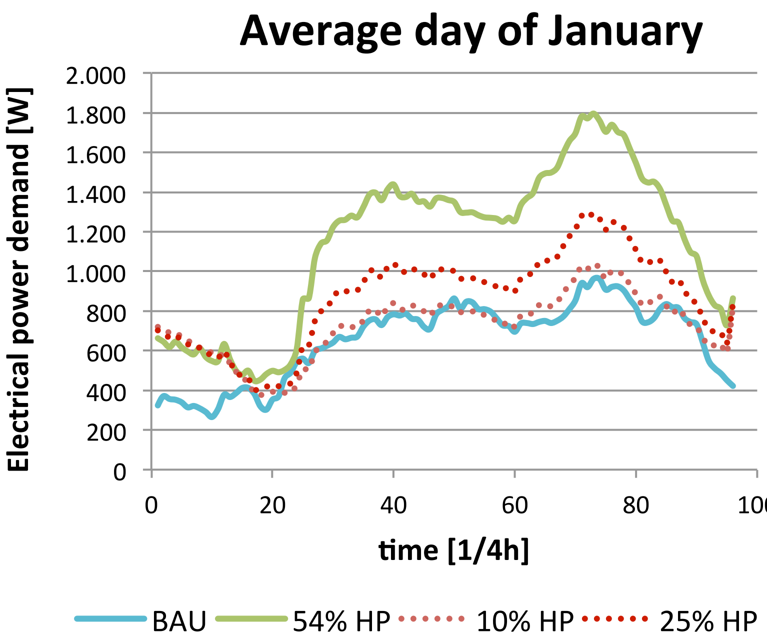
-15% reduction in final energy consumption and 12% reduction in CO_2 emissions

-Electricity share increased from 16% to 26%

Scenarii until 2030

Heat pumps

=> Important increase in winter peak consumption

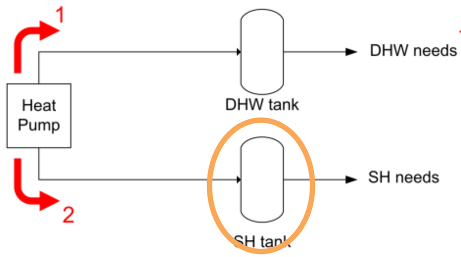


186% increase in peak demand for an average day of January

=> Load management is essential

Scenarii until 2030

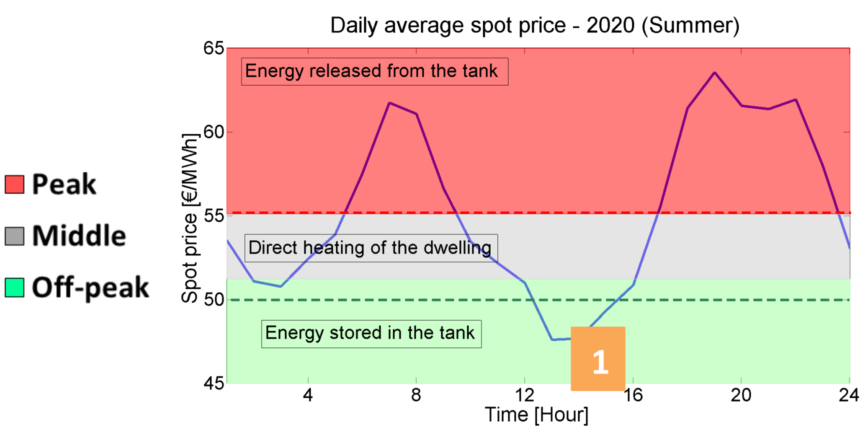
Heat pumps + TES + DSM

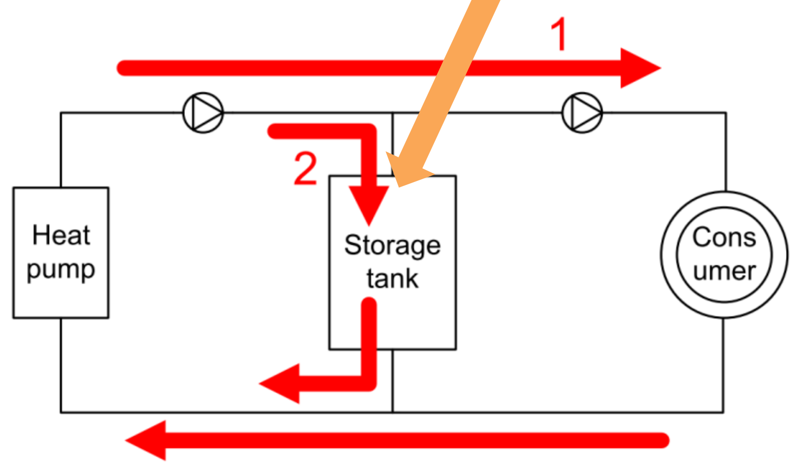


Topology: Parallel integration by Two-pipe connection

- Priority given to DHW
- Energy stored in the SH tank during low costs periods (high RES penetration) and retrieved during high costs ones:

1 If $cost \leq cost_{low}$: remaining part of the nominal power used to load the SH tank





Scenarii until 2030

Heat pumps + TES + DSM

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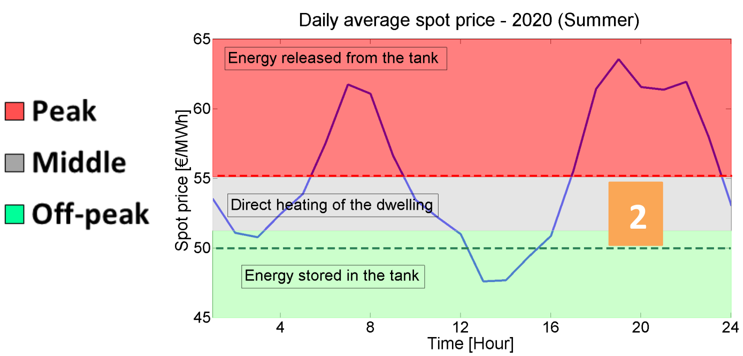
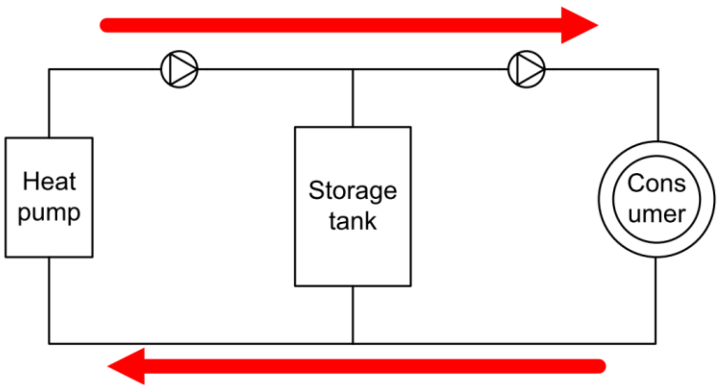
- Energy stored in the SH tank during low costs periods (high RES penetration) and retrieved during high costs ones:

1 If $cost \leq cost_{low}$: remaining part of the nominal power used to load the SH tank

2 If $cost_{low} < cost < cost_{high}$: SH tank neither unloaded nor loaded: direct supply





Scenarii until 2030

Heat pumps + TES + DSM

<u>Topology: Parallel integration by Two-pipe connection</u>

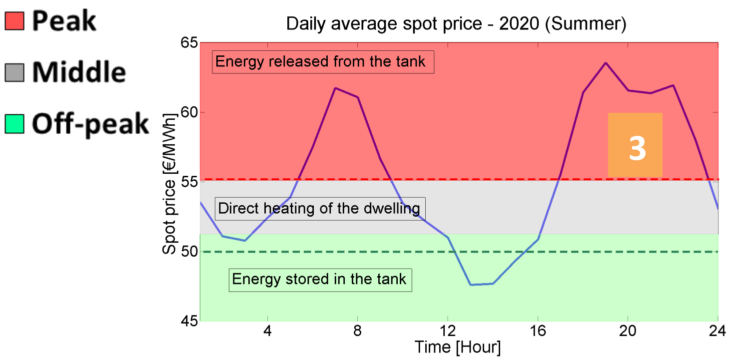
- Priority given to DHW

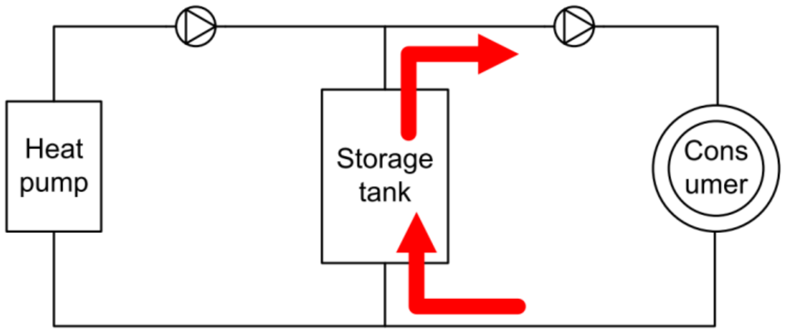
- Energy stored in the SH tank during low costs periods (high RES penetration) and retrieved during high costs ones:

1 If $\text{cost} \leq \text{cost}_{\text{low}}$: remaining part of the nominal power used to load the SH tank

2 If $\text{cost}_{\text{low}} < \text{cost} < \text{cost}_{\text{high}}$: SH tank neither unloaded nor loaded: direct supply

3 If $(\text{cost} \geq \text{cost}_{\text{high}})\ \&\ \dot{Q}_T > \dot{Q}_{su,dwelling}$: Energy stored in the tank used to heat the house





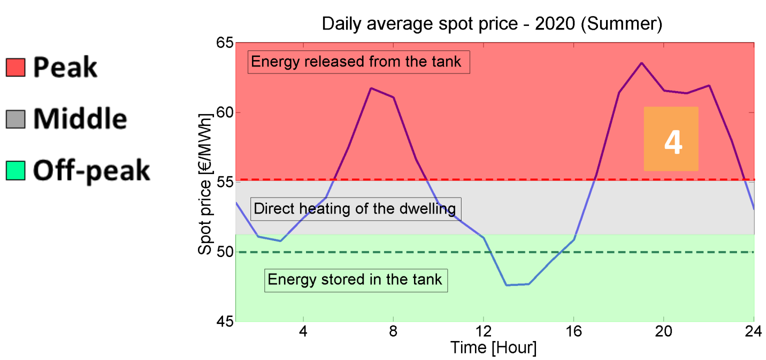
Scenarii until 2030

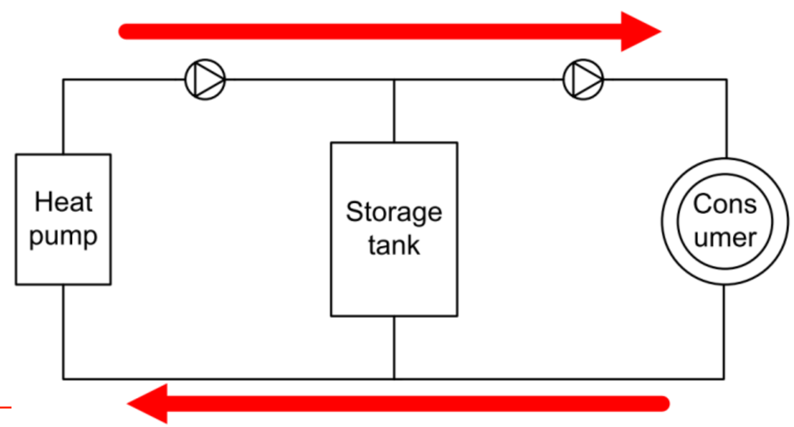
Heat pumps + TES + DSM

<u>Topology: Parallel integration by Two-pipe connection</u>

- Priority given to DHW
- Energy stored in the SH tank during low costs periods (high RES penetration) and retrieved during high costs ones:

1. If $cost \leq cost_{low}$: remaining part of the nominal power used to load the SH tank
2. If $cost_{low} < cost < cost_{high}$: SH tank neither unloaded nor loaded: direct supply
3. If $(cost \geq cost_{high})$ & $\dot{Q}_T > \dot{Q}_{su,dwelling}$: Energy stored in the tank used to heat the house
4. If $(cost \geq cost_{high})$ & $\dot{Q}_T < \dot{Q}_{su,dwelling}$: SH tank unable to supply the dwelling on its own: HP used





Scenarii until 2030

Heat pumps + TES + DSM

Topology: Parallel integration by Two-pipe connection: improvement

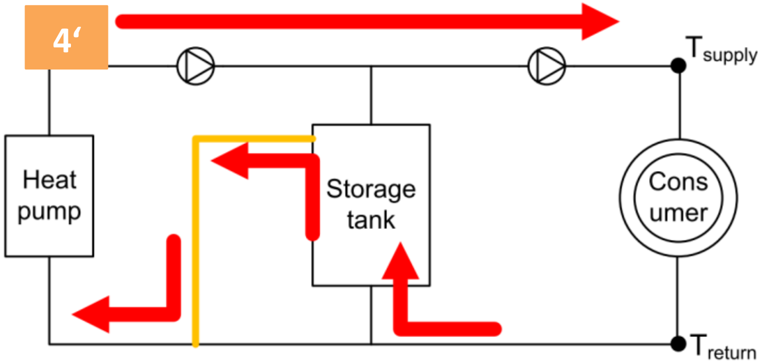
- **Purpose**: Improving flexibility potential by taking more advantage of the stored energy in the SH tank

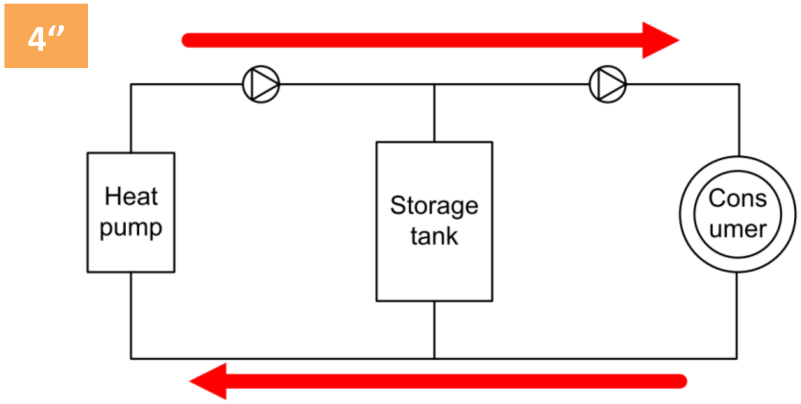
➔ If $(\text{cost} \geq \text{cost}_{high}) \,\&\, \dot{Q}_T < \dot{Q}_{su,dwelling}$

4' If $T_{tank} > T_{return}$: energy stored in the tank used to lighten the HP work

➔ HP providing the power to go from $T_{tank} \rightarrow T_{water,law}$ instead of $T_{return} \rightarrow T_{water,law}$

4'' If $T_{tank} < T_{return}$: HP used exclusively

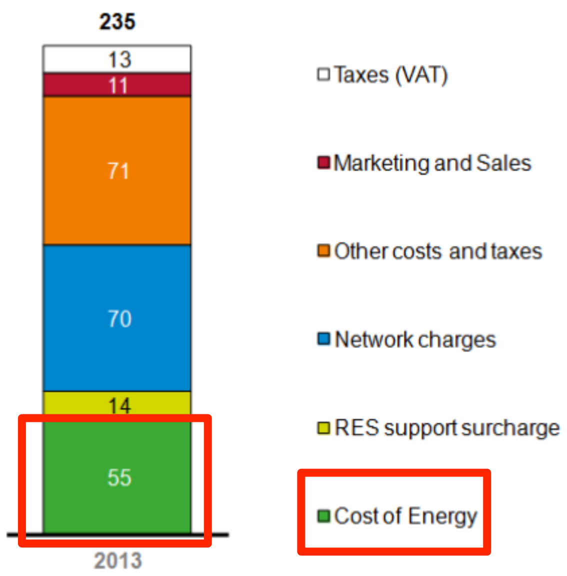




Scenarii until 2030

Heat pumps + TES + DSM

Which dynamic electricity tariff to sufficiently trigger the DSM?



1.Dynamic price TOU/Real time pricing (RTP):

= cost of energy (fluctuating) + fixed charges

BUT → fluctuation of cost of energy = small amount of final cost

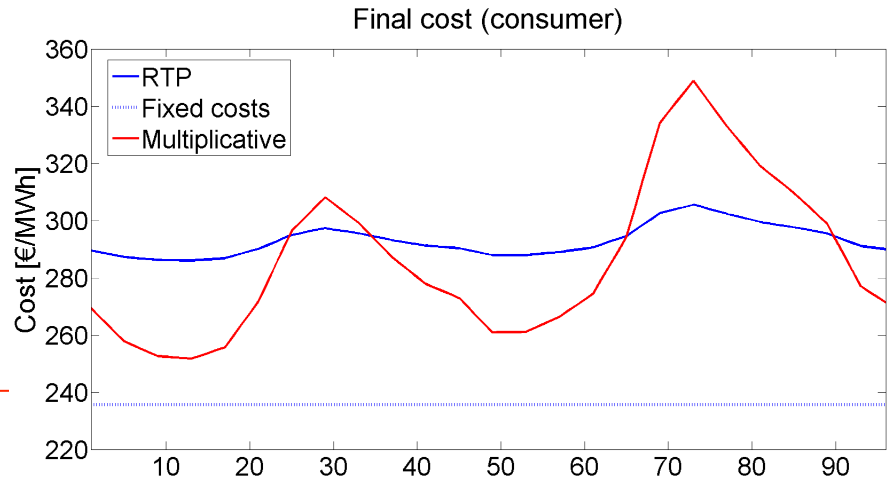
➔ Spot market signal too weak to trigger DSM

2.Dynamic Multiplicative tariff: final retail price calculated by multiplying day-ahead spot price (residential tariff)

Aim: **stronger market signal** by considering **Dynamic RES surcharges** (v.s. static):

- Low RES surcharges at low energy price
- High RES surcharges at high energy price

➔ *Bundesnetagentur* proposal



Scenarii until 2030

Heat pumps + TES + DSM

- **Generalisation: dwellings equipped with HP + no coordination**

– **No coordination**: all consumers react simultaneously to the same cost signal

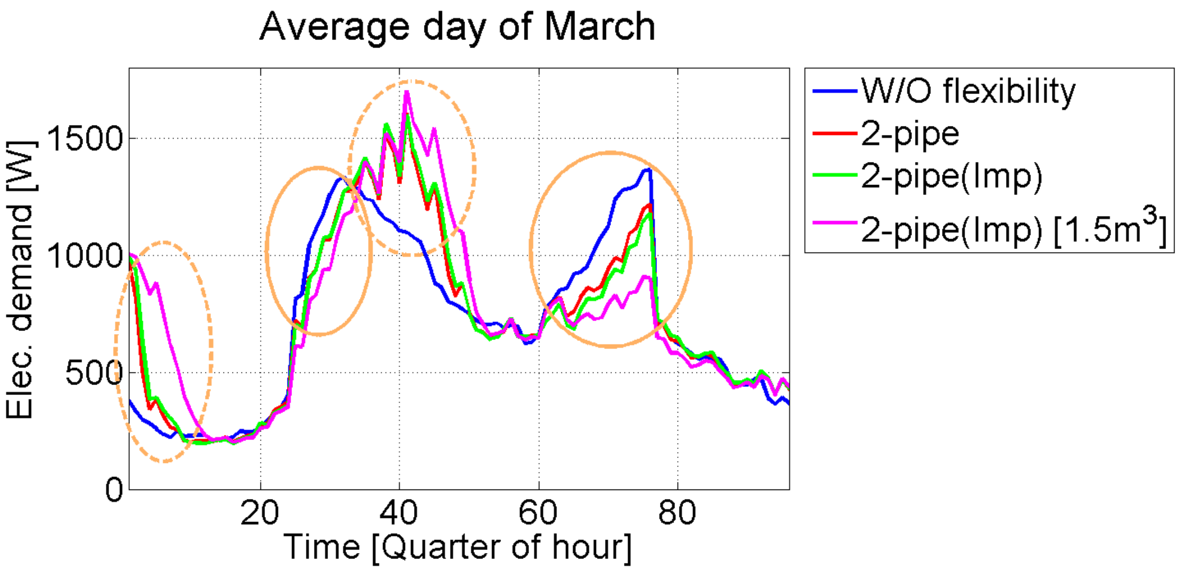
- *Two-pipe (Impr)* & larger SH tank volume → cost savings ↑
- Overconsumption but limited (i.e. thermal losses)
- Peak issues partially explained by *no coordination:* when cost<$cost_{low}$, all building managers activate their HP to store energy

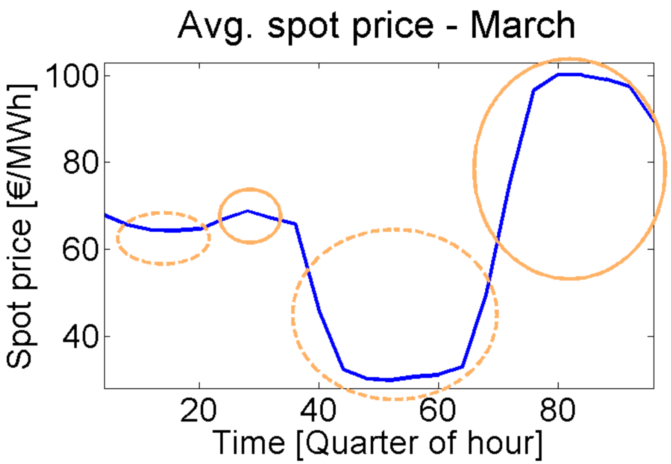
	Avg. Cost [€/dw/year]	Avg. Annual elec. Cons. [kWh/dw/year]	Peak [kW]
Reference	1398.9	3783.7	3.51
2-pipe 0.45[m³]	-4.4%	+2.4%	+31%
2-pipe: Impr. 0.45[m³]	-5.8%	+2.4%	+31%
2-pipe: Impr. 1.5[m³]	-11.6%	+5.3%	+37%

Scenarii until 2030

Heat pumps + TES + DSM

- **Generalisation: dwellings equipped with HP + no coordination**





– Consumption ↓ at high cost periods and ↑ at low cost periods → load-shifting

– Load-shifting and peak issues emphasized with larger SH tank

Scenarii until 2030

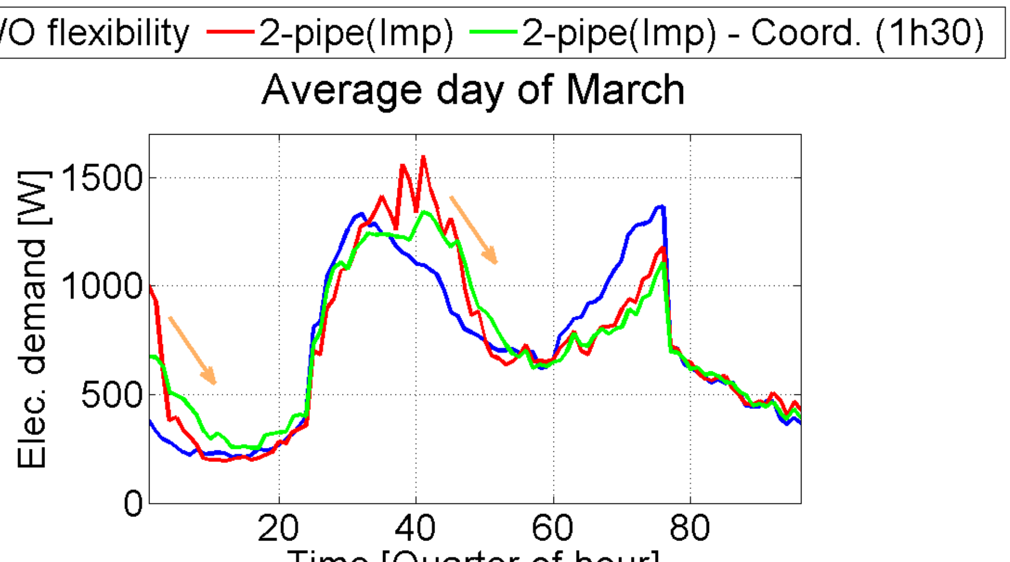
Heat pumps + TES + DSM

- **Generalisation: dwellings equipped with HP + coordination**

→**Coord./Allocation between consumers**: temporizing the perception of the low cost signal → consumers will NOT simultaneously activate their HP to store energy

- Cost savings and consumption not greatly influenced
- BUT significant decrease of the peak demand

	Avg. Cost [€/dw/year]	Avg. Annual elec. Cons. [kWh/dw/year]	Peak [kW]
2-pipe: Imp – No coord	-5.8%	+2.4%	+31%
2-pipe: Imp – Coord (1h30)	-5.8%	+2.4%	+19%



Scenarii until 2030

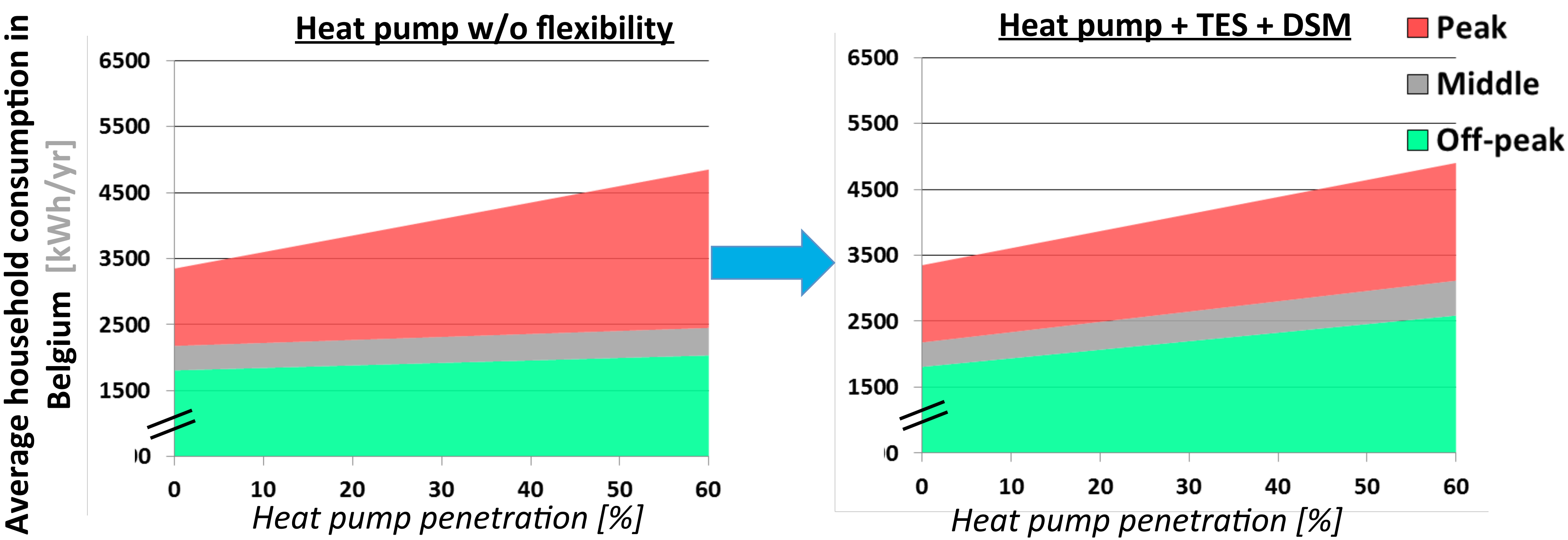
Heat pumps + TES + DSM

- **Generalisation to the whole tree-structure**

« Can dwellings equipped with HPs and controlled by flexible strategies (TES) impact sufficiently the national electricity demand curve to fulfill the flexibility purpose? »

➔ Generalisation to the whole Belgian tree-structure: max HP penetration rate in 2030: 58.65%

➔ Similar conclusions



Source: Electrabel

Conclusions

- A simulation model of the Belgian residential building stock has been developed

- Scenarios:
  - BAU: improvement at the average building level is significant, but due to the increase in the number of dwellings, the total final energy consumption and CO_2 emissions remain sensitively similar.

  - Heavy retrofit of the building envelopes: 20% reduction in CO_2 emissions were observed for the overall building stock, compared to 2010.

  - Heat pumps: the final energy saving only represented 15% and important increase in winter electricity peaks => Need for load management strategies

  - Heat pump + TES + DSM:
    - ✓ Over-consumption (2.4% @ 0.45[m3] & 5.6% @ 1.5[m3])
    - ✓ Costs savings (5.8% @ 0.45[m3] & 11.6% @ 1.5[m3]) due to load shifting to off-peak hours
    - ✓ Shifted volumes emphasized with larger SH tank volumes
    - ✓ Peak issues (suggested solution: coordination between consumers)

Thank you!
Any questions?

Acknowledgements

- Electrabel for its technical and financial support
- Pierre Garsoux, who largely contributed through its Master Thesis.