THERMAL STORAGE AND ELECTRICITY STORAGE IN THE RESIDENTIAL SECTOR

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The financial support of the **Walloon Region of Belgium** to Flexipac project and the other research presented here is gratefully acknowledged

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Plan

- The electricity market and its stakeholders

→ **Thermal storage** to increase the flexibility of the demand

- The prosumers

→ **Thermal storage and electricity storage** to increase self-consumption

- Conclusion

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The electricity market

- The stakeholders
  - Producers
  - Distributors
  - Distribution Network Managers (Gestionnaires Réseau Distribution)
  - Aggregators
  - Transmission system operator (ELIA)
  - Consumers and Prosumers
  - Purchasing platforms (BELPEX)
  - Federal and Regional Regulators

→ Need to balance electricity supply and demand

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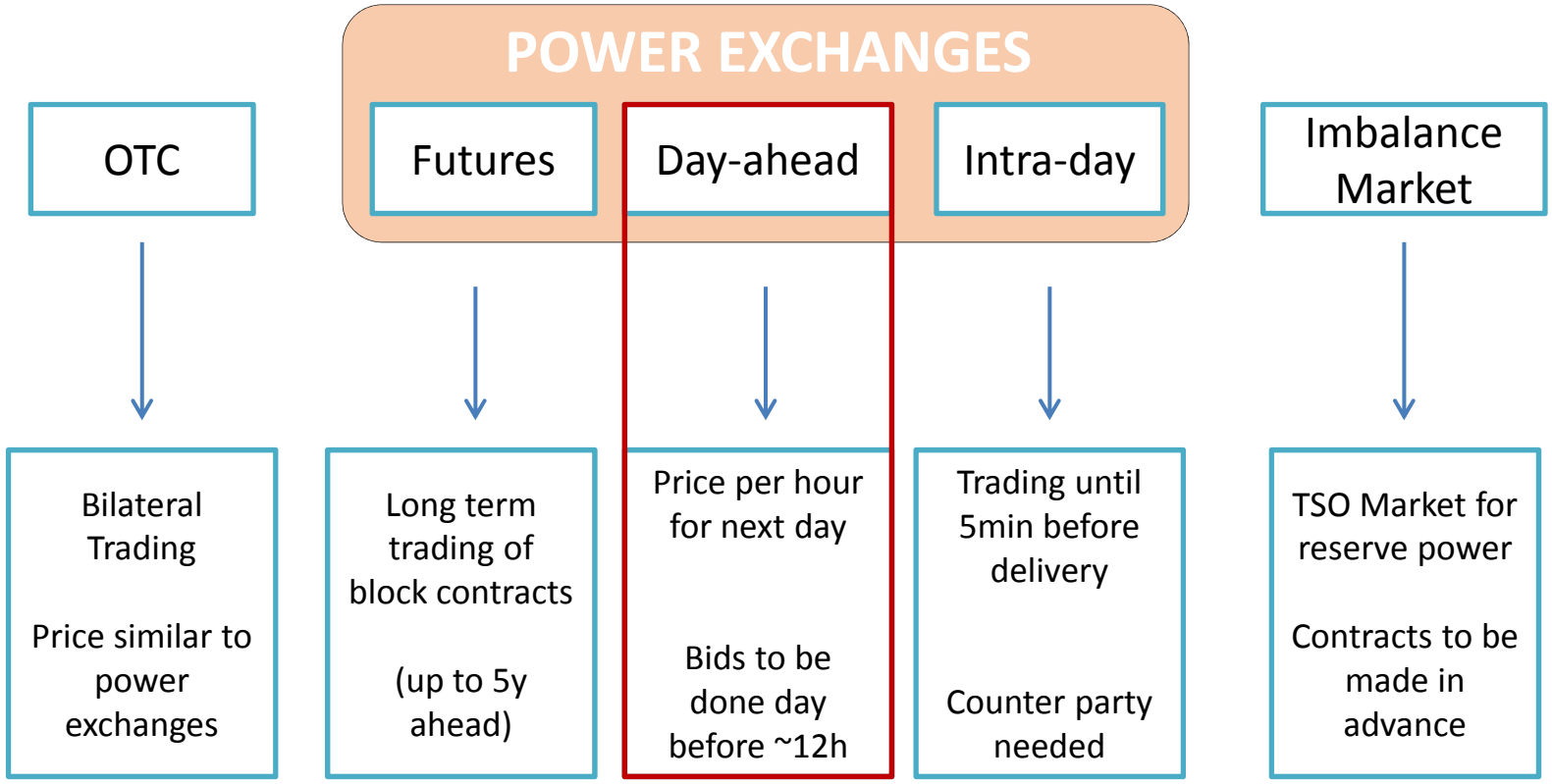
The electricity market



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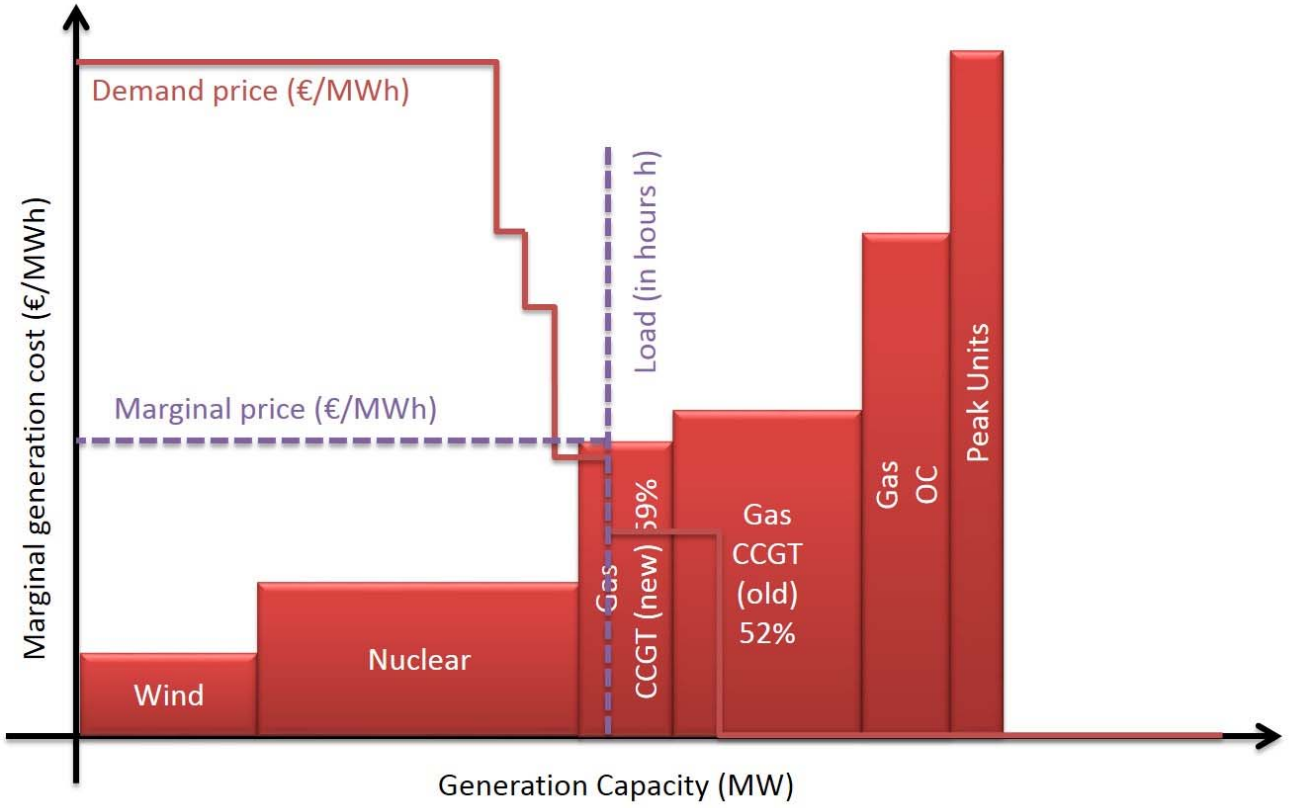
Belpex Day-ahead market

The electricity market



Ref: Fédération Belge des Entreprises Electriques et Gazières asbl https://www.febeg.be/fr/merit-order

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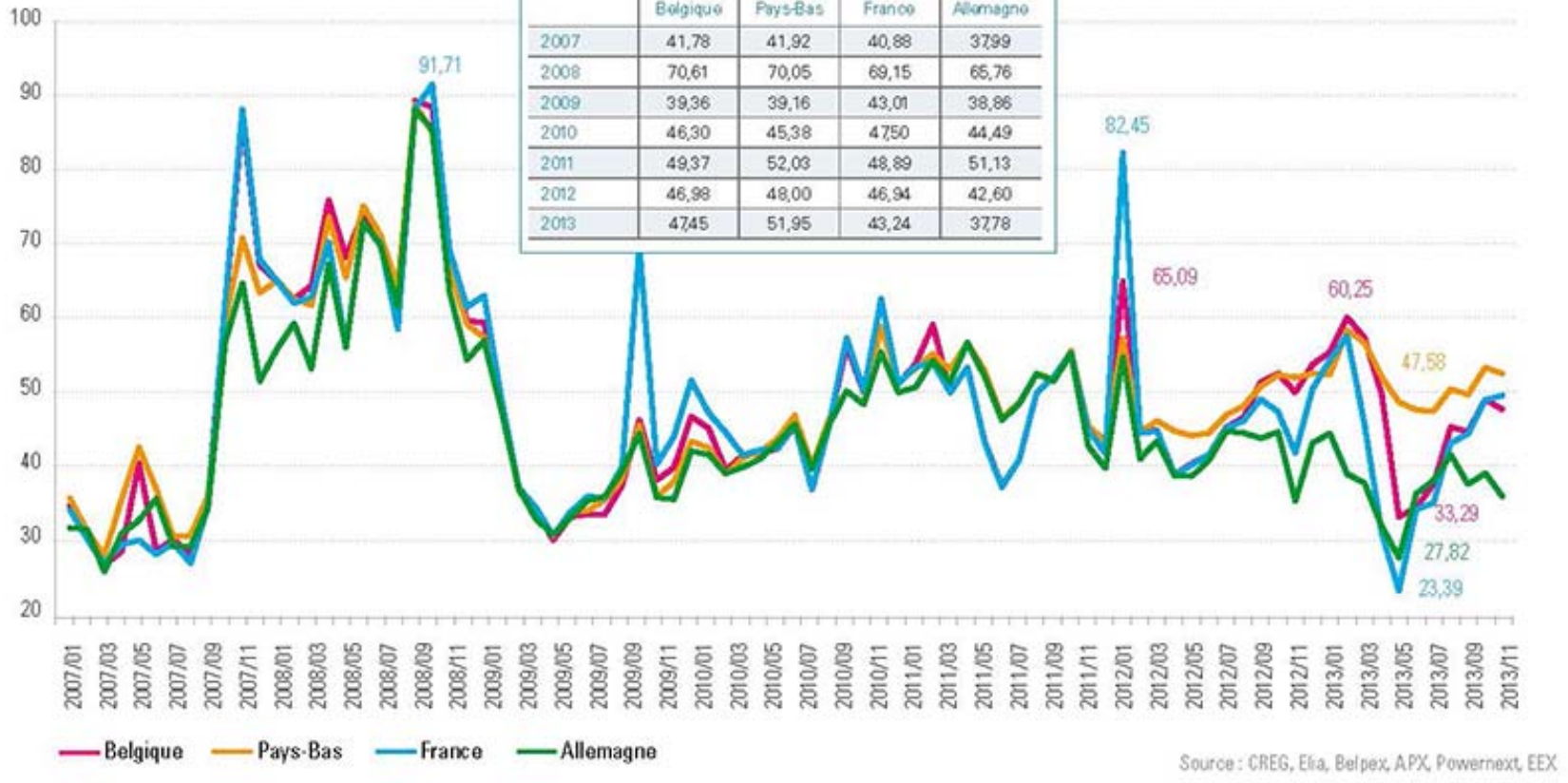
The electricity market

Prix *day ahead* moyens dans la région CWE (euros/MWh)

	Belgique	Pays-Bas	France	Allemagne
2007	41,78	41,92	40,88	37,99
2008	70,61	70,05	69,15	65,76
2009	39,36	39,16	43,01	38,86
2010	46,30	45,38	47,50	44,49
2011	49,37	52,03	48,89	51,13
2012	46,98	48,00	46,94	42,60
2013	47,45	51,95	43,24	37,78



Electricity Cost on day-ahead markets: Belpex, APX, EPEX FR, EPEX GE between 2007 and 2013.
CREG 2013 Annual report, page 42 - http://www.creg.be

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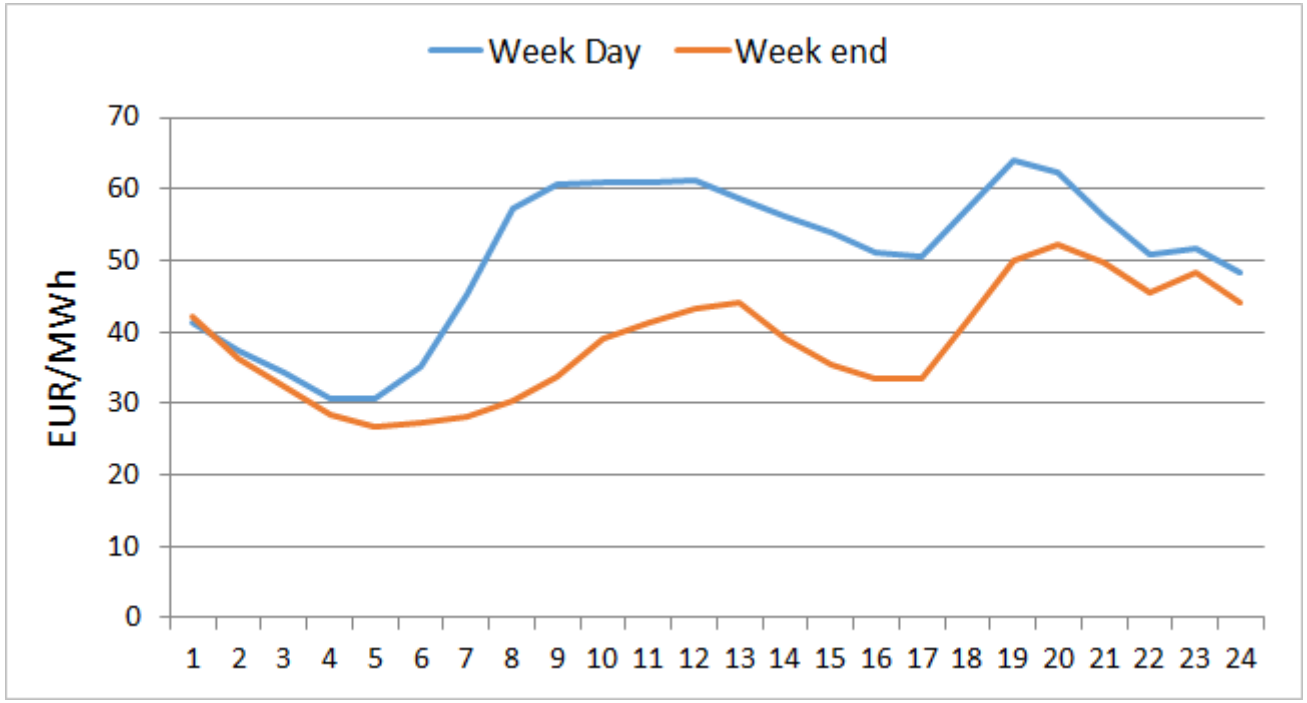
The electricity market



Average hour by hour Electricity Cost on Belpex day-ahead market – Year 2012
Final report – Flexipac Consortium

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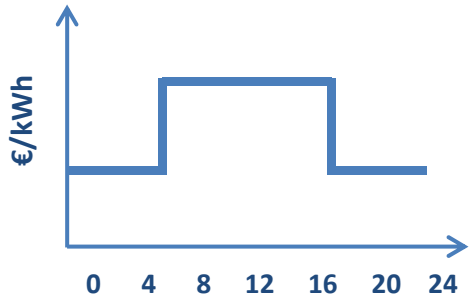
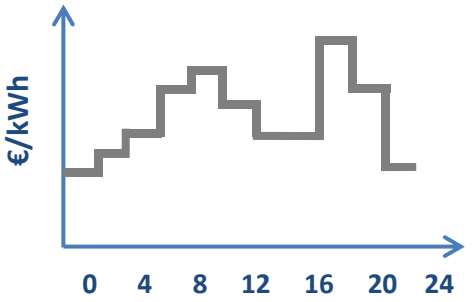
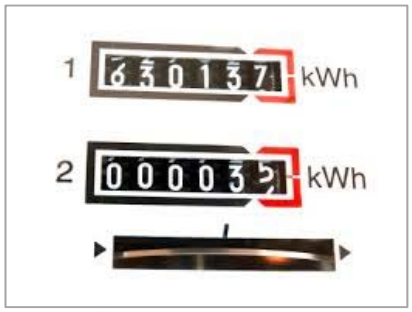
Electricity tariff

Day-Night pricing



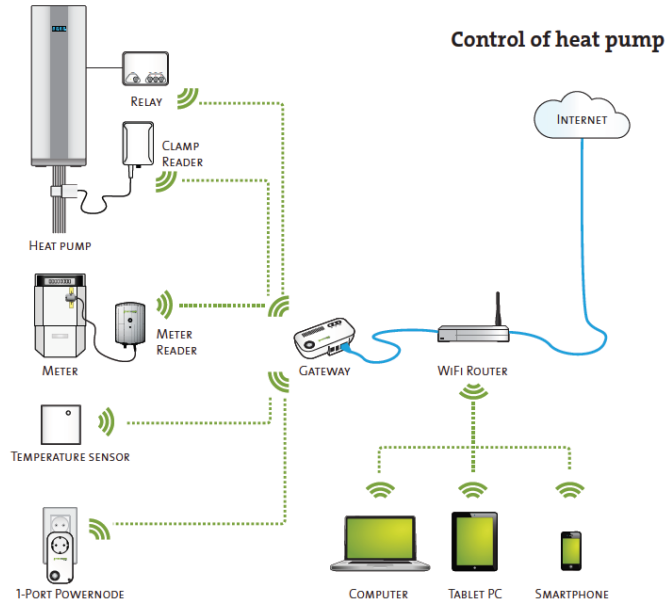
Dynamic pricing





Heat Pump

Smart Meters



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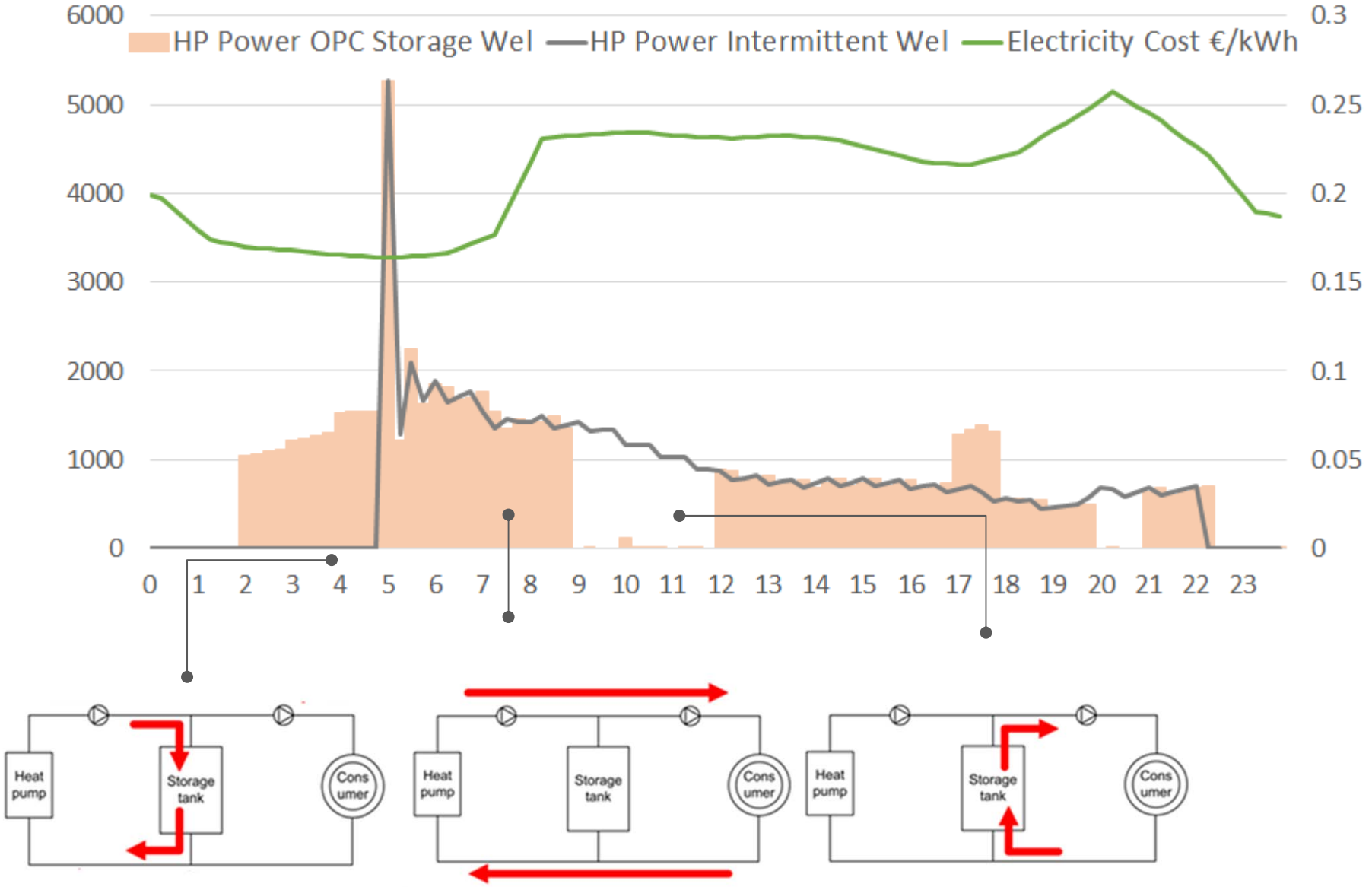
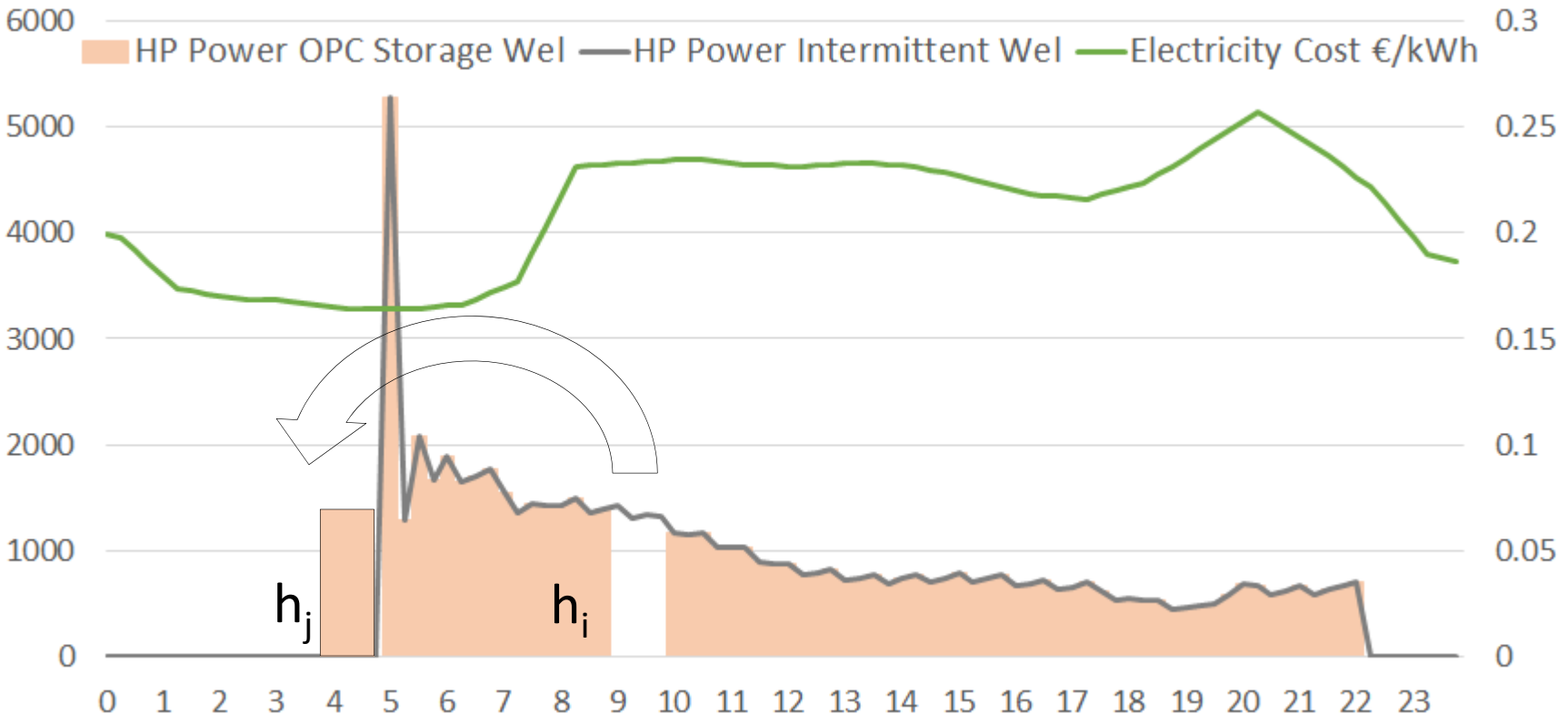
Reference Ecogrid, 2013

Load shifting



Optimization



$$\max_{i,j}\left(cost\ saving_{i\to j}\right) = \dot{Q}_{cd,i}\frac{cost_i}{COP_i} - \left(\dot{Q}_{cd,i} + \dot{Q}_{losses,j\to i}\right)\frac{cost_j}{COP_j} > 0$$

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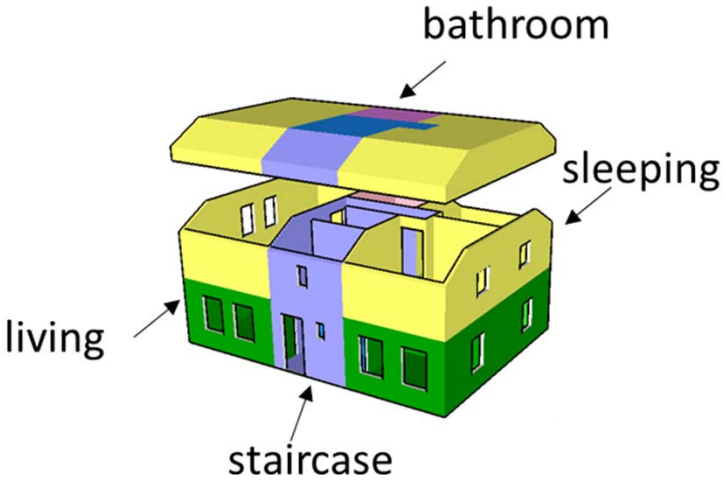
Constraint: indoor comfort maintained

Case study



Floor heated area 146 m^2
4 occupants
Concrete walls
External insulation
Double flow ventilation
Heat recovery exchanger efficiency 80 %
Summer free cooling: window opening
DHW: direct electric heating

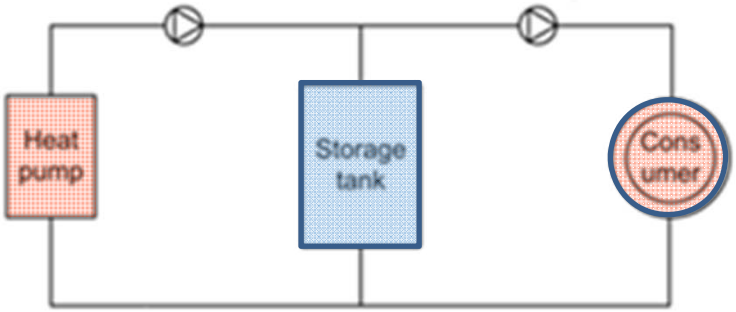
Insulation Level	Average U-value W/m^2K	n50 ac/hr	Space Heating Demand kWh/m^2a	Nominal Heating Power kW_{th}
K45	0.458	6.0	68	13.8
K30	0.305	3.0	36	11.5
K15	0.152	0.6	12	9.3

Belgium Standard

Case study

M = 1000 kg
AU= 0.522 W/K
t_{amb}=15°C

Air Water Heat Pump
COP_n= 3.95 A 7°C/W 35°C



Radiator
or
Floor heating

Heat Emission	Condenser Exhaust Temperature	Temperature Range Water Tank Storage
Radiators	55 °C	45 – 55 °C
Floor Heating	40 °C	35 – 45 °C

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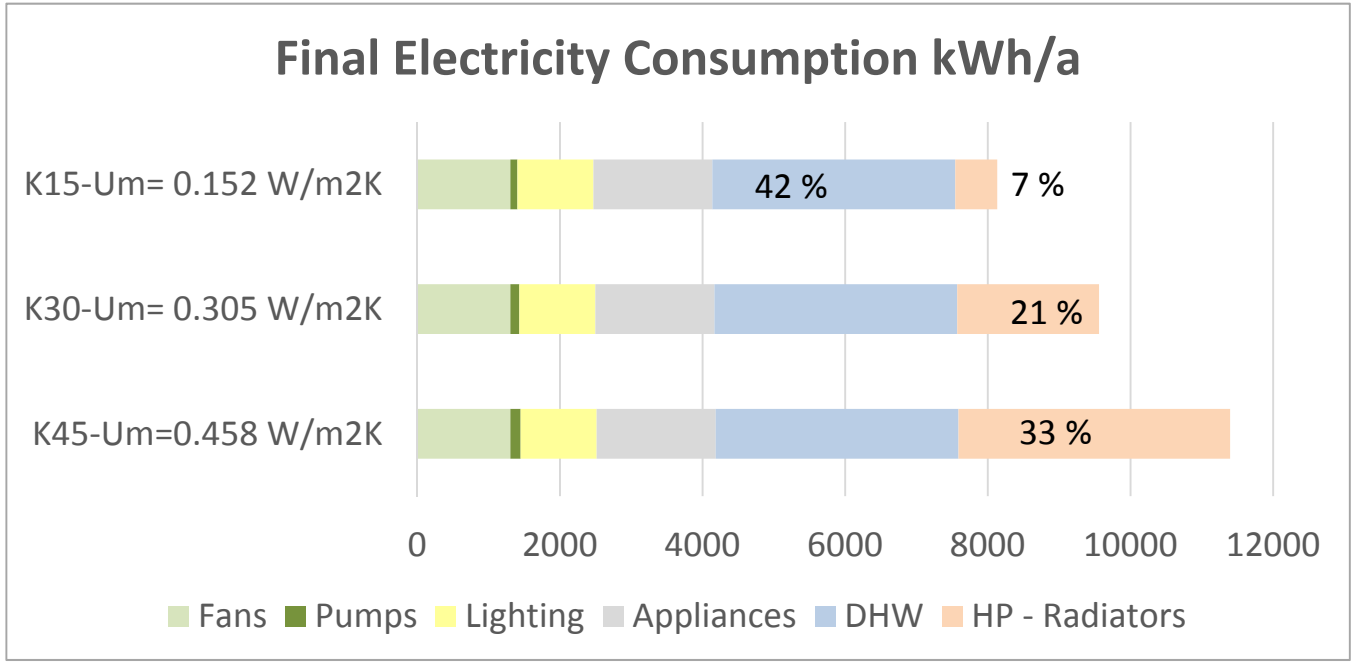
Intermittent Heating - no storage



Heat Pump Electricity consumption: 600 – 2000 – 3800 kWh/a

Domestic Hot Water - Direct el. Heating – 4 occupants: 3400 kWh/a

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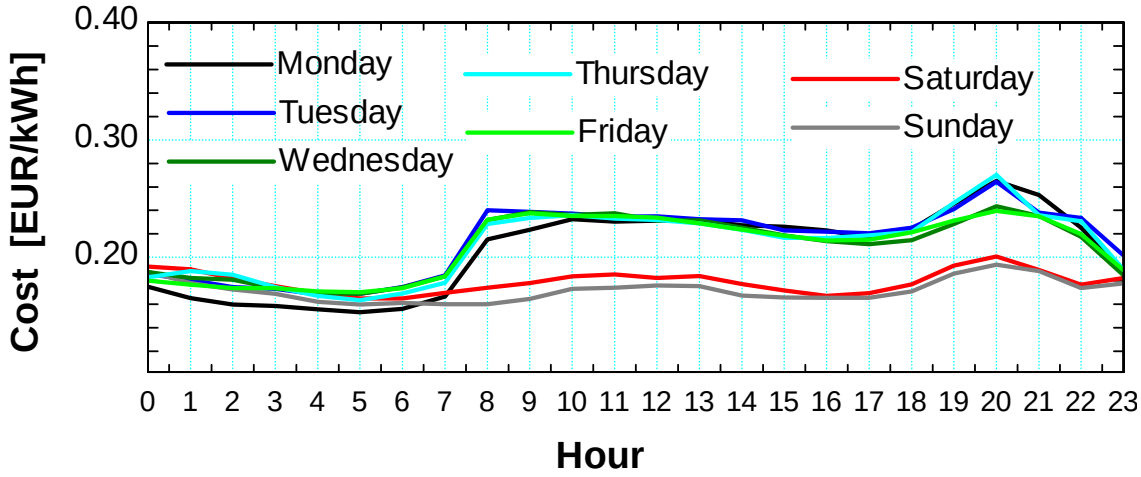
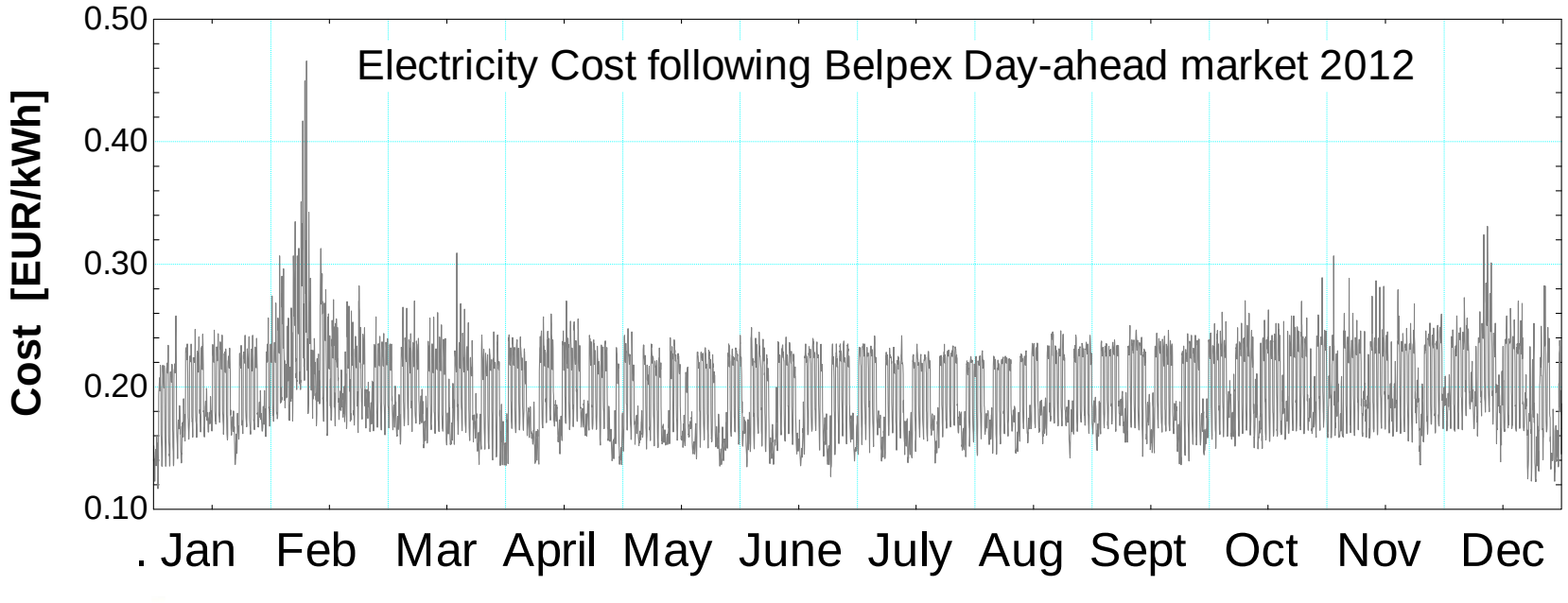
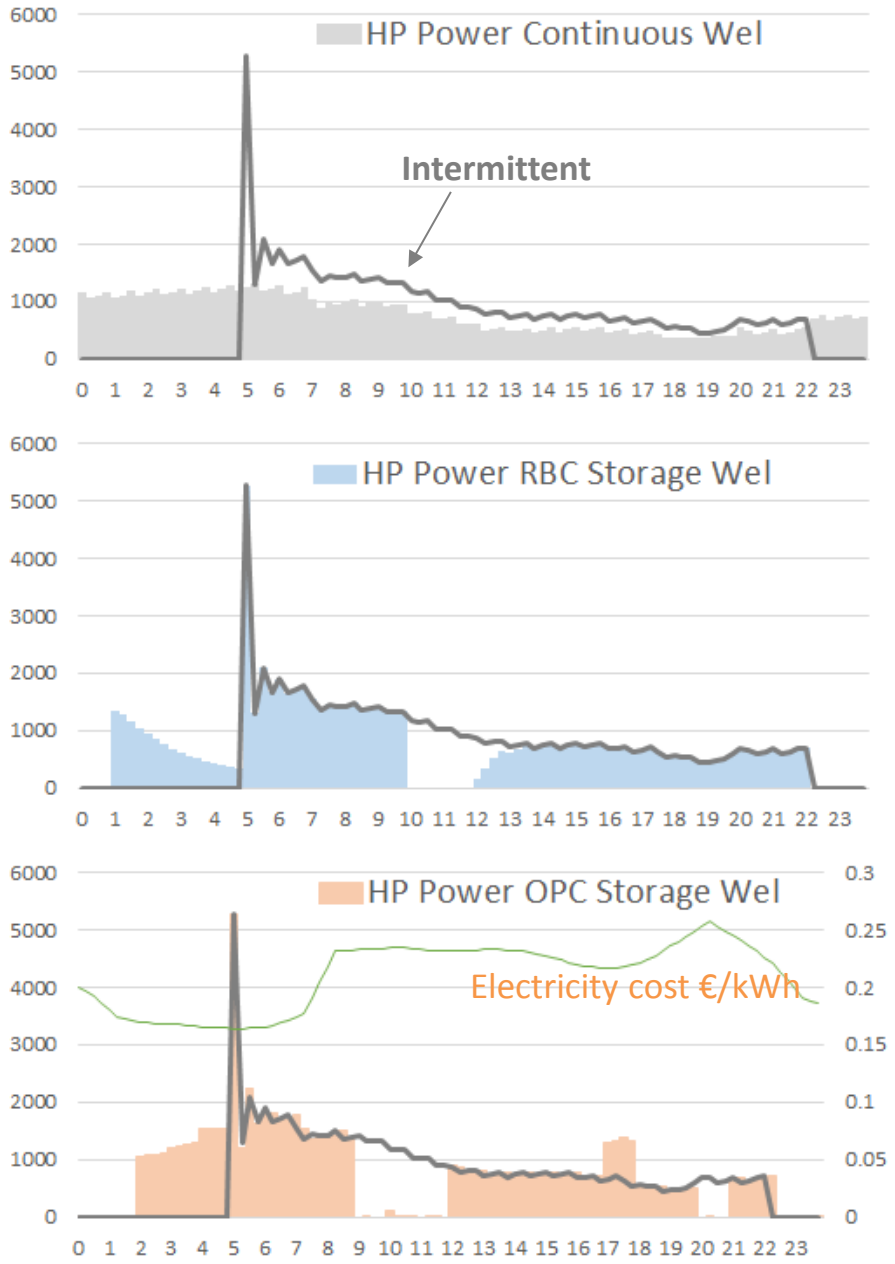
Cost of Electricity







Load Shifting Strategies

Continuous Heating
No water storage

- Constant set point

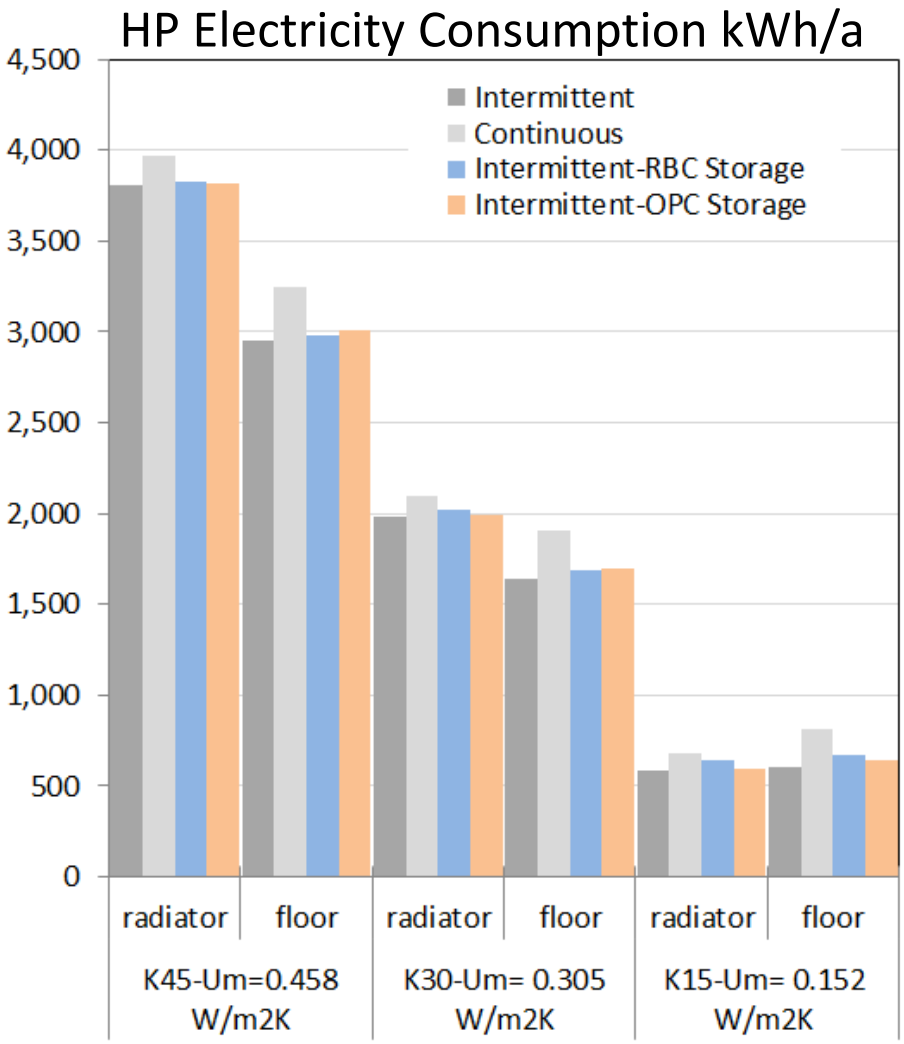
Rule Based Control
Water storage

- Load 1 AM to 8 AM
- Unload 10 AM to 12 PM

Optimized Predictive Control
Water storage (24h horizon)

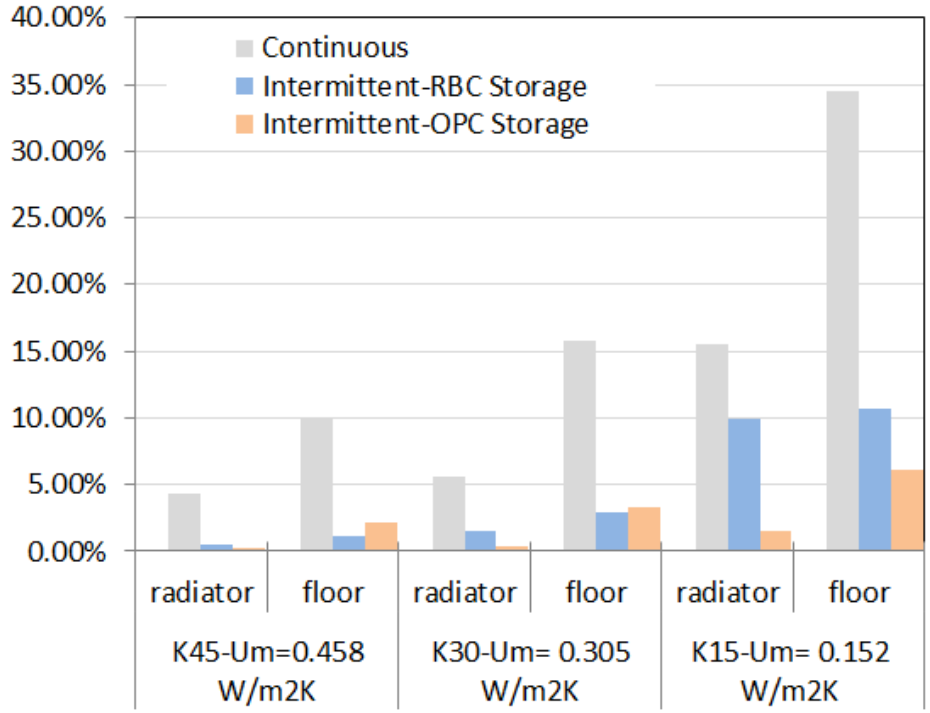
- Cost minimization
- Comfort maintained
- Perfectly predicted Building behavior

Consumptions



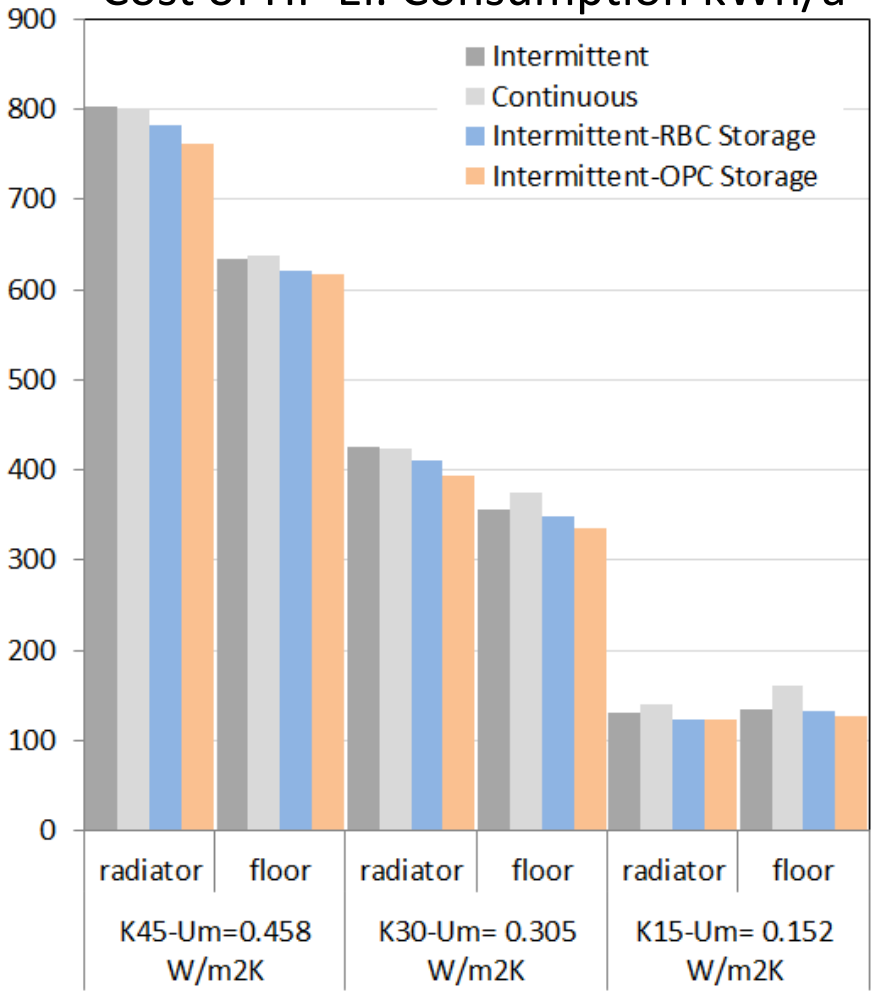
$$Overconsumption = \frac{E - E_{intermittent}}{E_{intermittent}}$$

Load shifting entails overconsumption

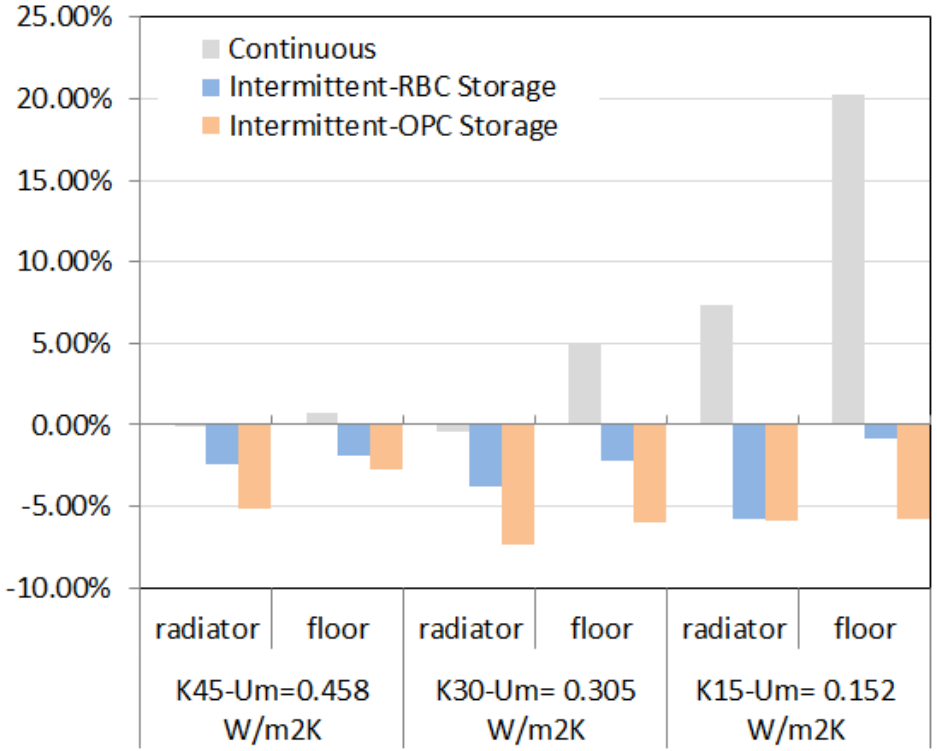


Costs

Cost of HP El. Consumption kWh/a



Optimal Predictive Control leads to larger benefits than Rule Based Control (Reference: intermittent)



Plan

✓ The electricity market and its stakeholders

→ The **thermal storage** to increase the flexibility of the demand

- The prosumers

→ The **thermal storage and electricity storage** to increase self-consumption

- Conclusion

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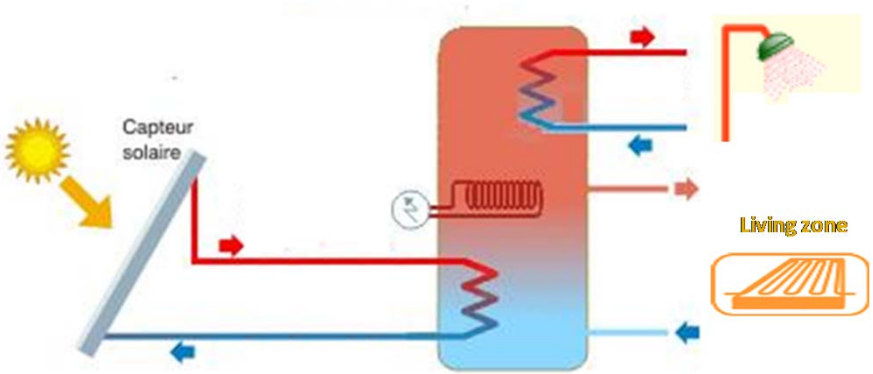
Prosumers

PV cell: 22.5 m2 ⇨ 4.5 kW **ST: 4 m2**

Insulation level: K19



Glazed areas:
44 m2 with 31 m2 South facing windows

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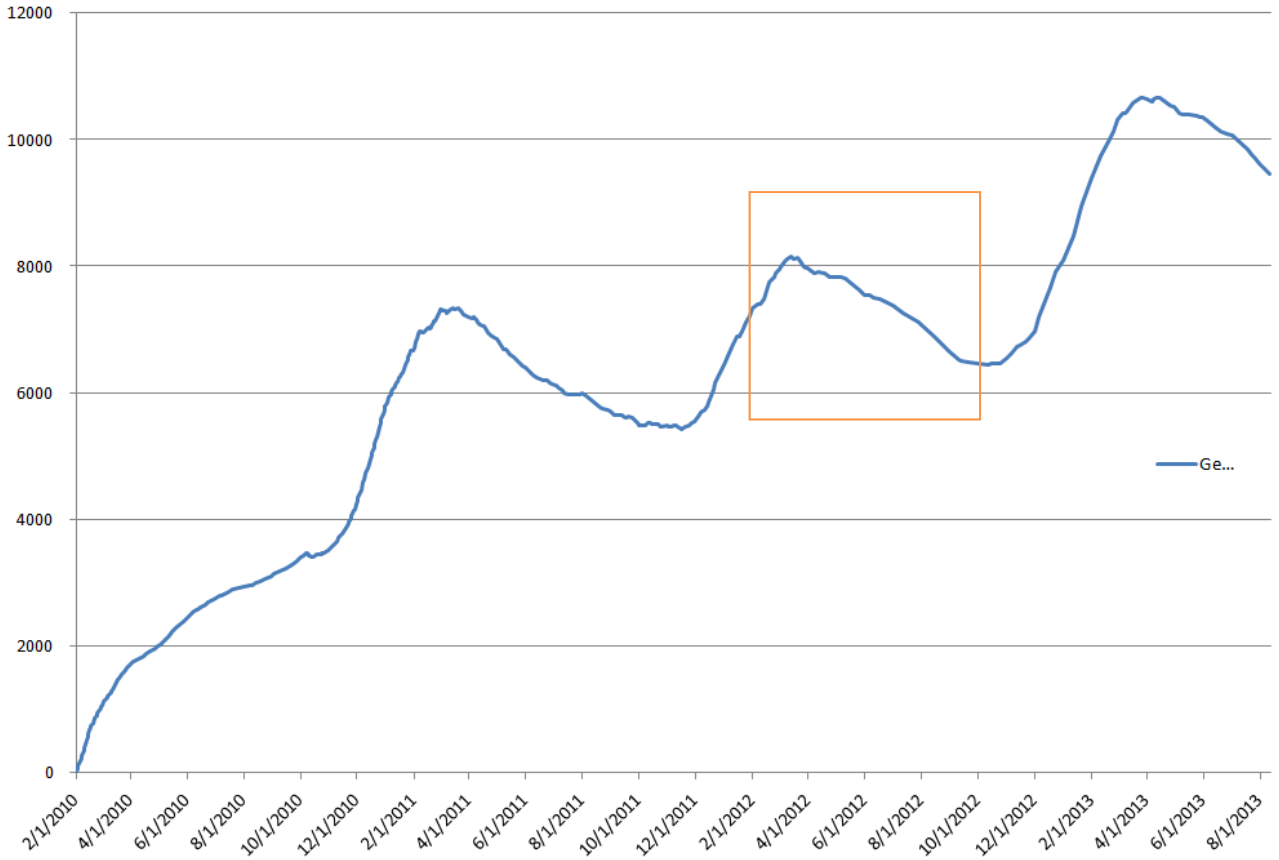
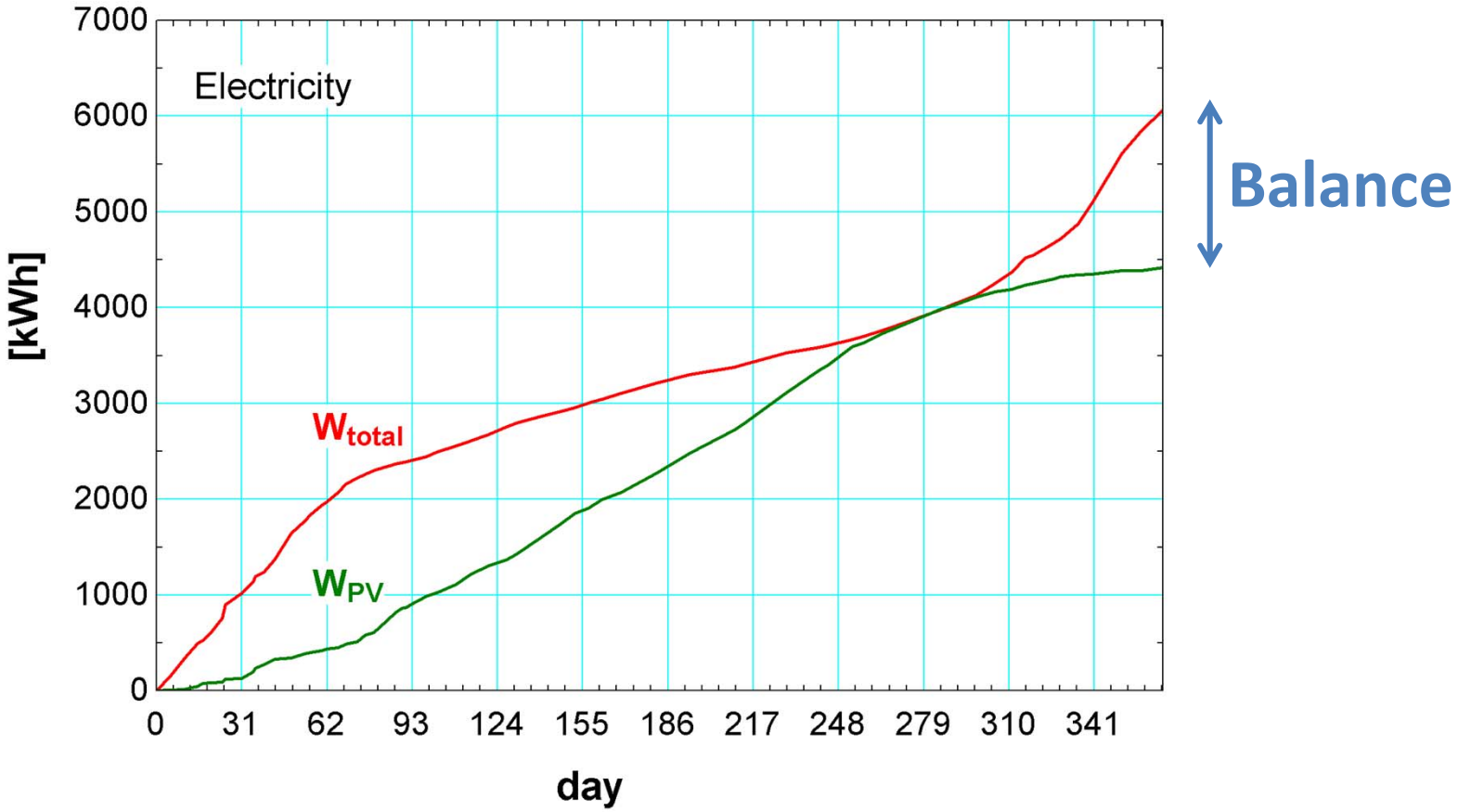
Prosumers



Integrated total electricity consumption (electricity counter)

Prosumers



Integrated electricity consumption and PV cell production for year 2012

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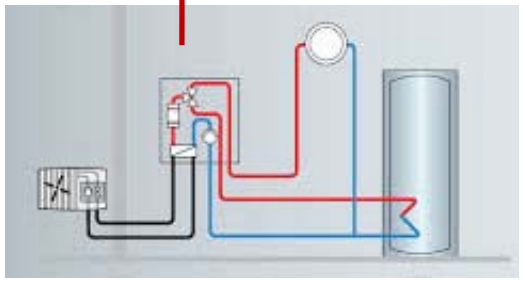
Prosumers

Heat Pump



ST: 5 m2

PV: 20 m2

PV: 3 x 16 m2

Electricity Storage 7 kWh

Dethier Architecture: http://www.dethier.be/

Hypothesis

- Floor heated area 58 m^2
- 2 occupants:
  - 40 l DHW at 60°C per occupant per day
- Double flow ventilation
  - Recovery efficiency 82 %
- Summer free cooling: window opening
- Space and DHW Heating system:
  - Direct electric heating
  - Air-Water HP
- Heat emission radiators: 55 - 45°C

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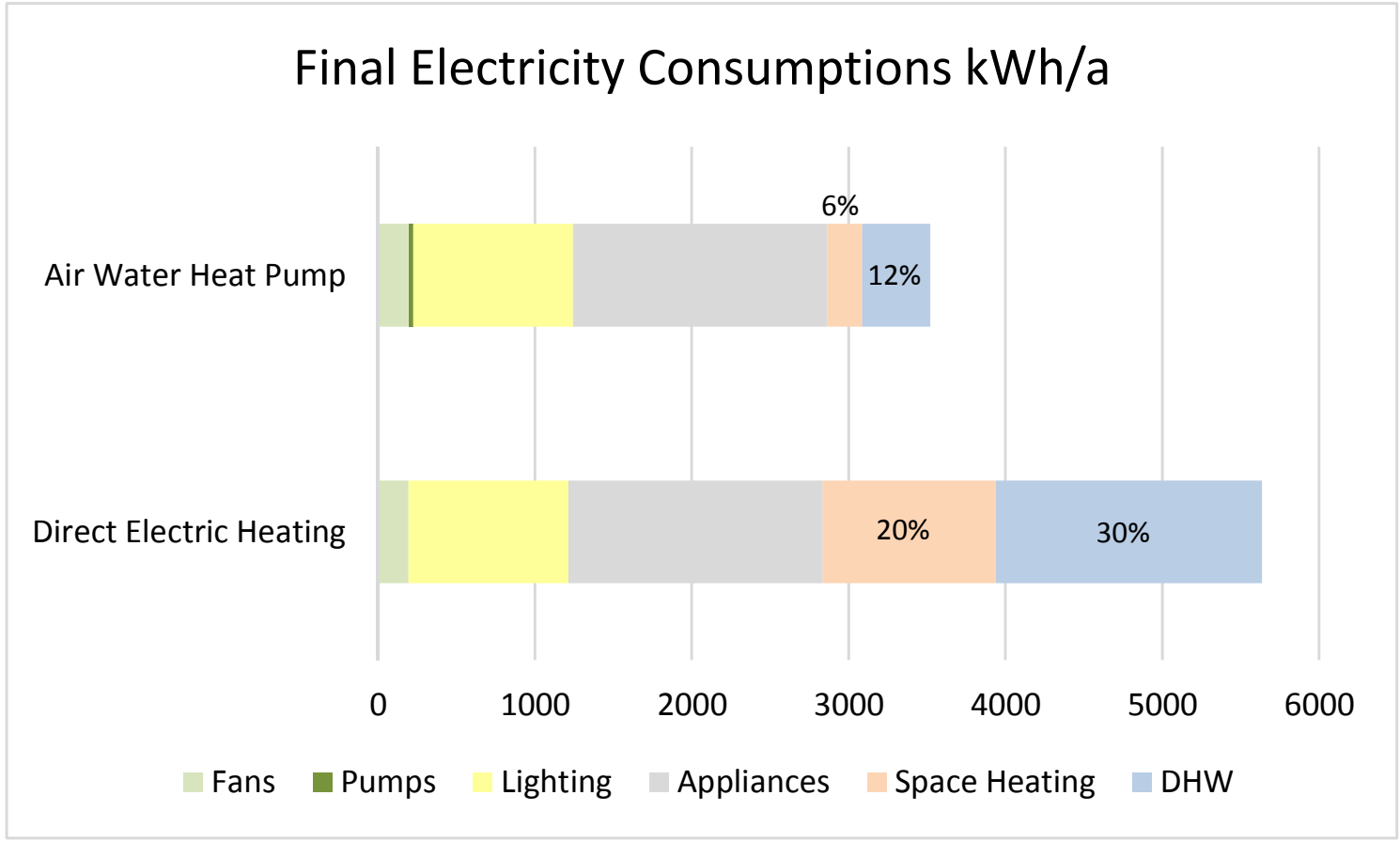
Continuous Heating - no storage



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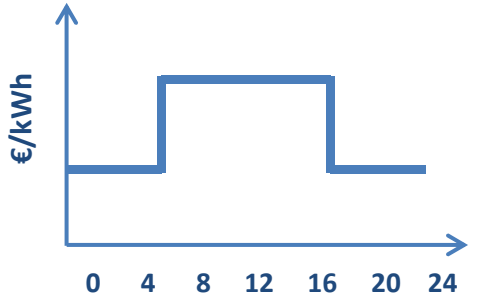
Electricity Cost

- Day-Night Pricing
  - Day time 0.25 EUR/kWh
  - Night time 0.17 EUR kWh



- Water tank storage: 200 l
- Electricity storage: capacity 7 kWh efficiency 85%
- Objective : maximize Self-Consumption

Final Consumption	Self-Consumption	Consumption from Grid	
PV Production	Self-Supply	Supply to Grid	Balance

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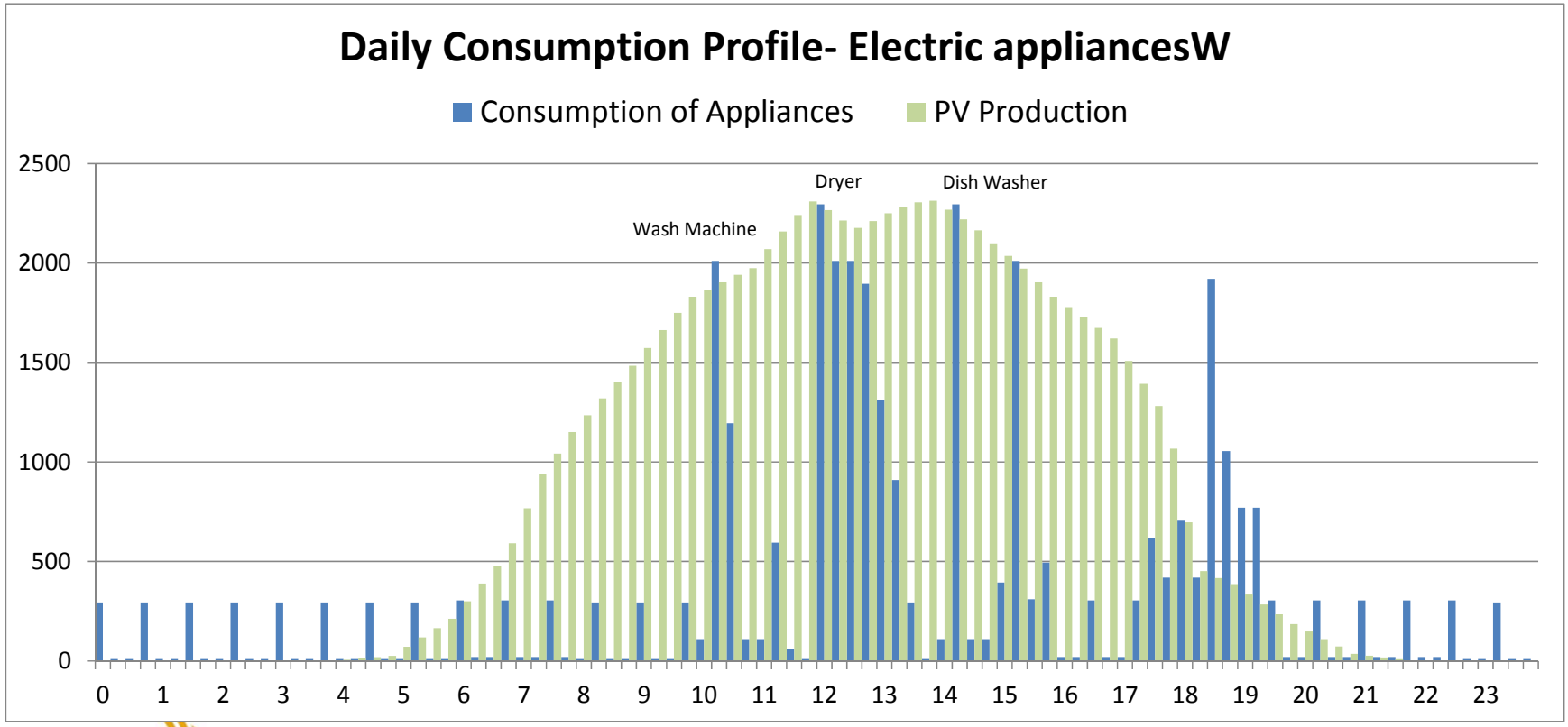
Load shifting

Behavior: wash machine, dryer, dish washer used during daytime



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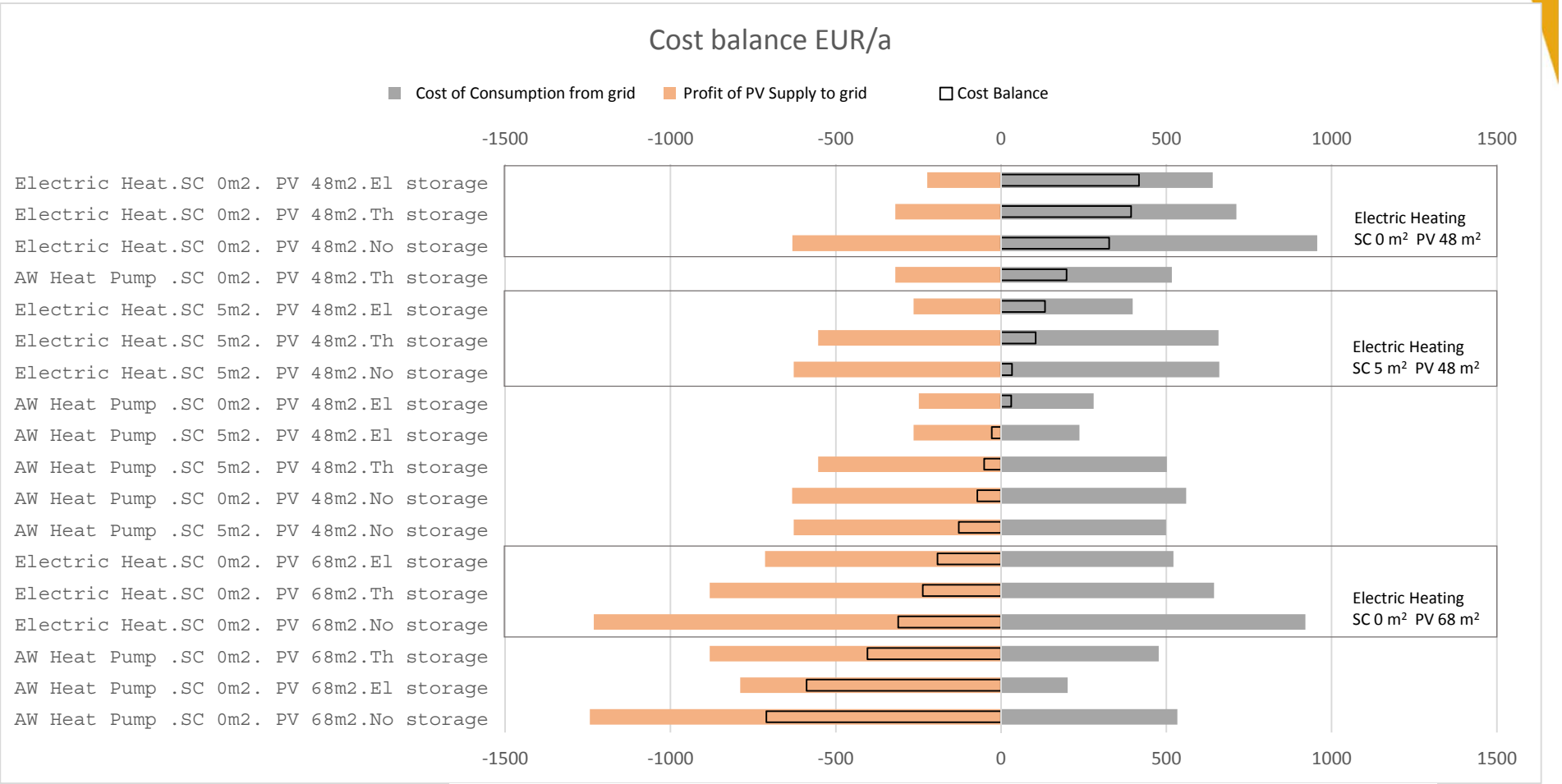
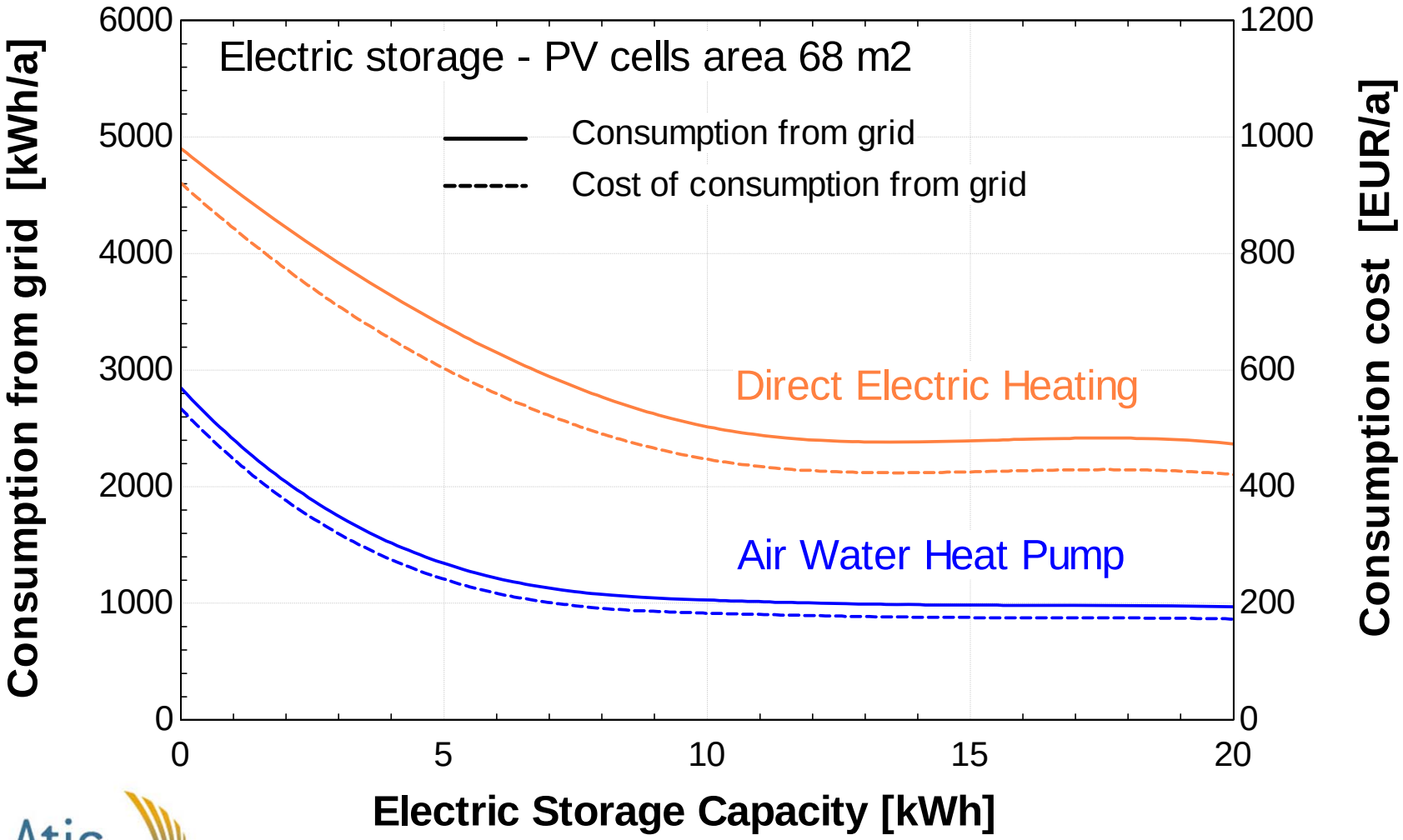
Cost Balance



Buy back ratio = 0 **Electricity storage: 2700 €** → **ROI : 5 à 8 ans**

Electricity Storage Capacity



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Conclusion

- **Thermal storage** to increase the flexibility of the demand
  - Cost reduction
  - Integration of renewable electricity production
- **Thermal storage and electricity storage** to increase on site consumption
  - Cost reduction as function of the buy back ratio
- Need for **optimized predictive control**
  - Weather forecast
  - Human bevavior

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