# Journée micro et mini cogénérations

## Tests en laboratoire et monitoring in-situ d’une installation hybride pile à combustible – chaudière à condensation

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# Description of the project

- Collaborative study with Gas.be
- Study divided in two main parts:
  - Laboratory tests
  - Monitoring in-situ on residential buildings in Belgium
- Both parts will set a basis for create modeling tools oriented to simulate the impact of choices in terms of home heating systems.

- Different systems for heating and DHW
  - Vitovalor PT2 PEMFC
  - MyChi SOFC
  - Robur K18 condensing gas absorption heat pump
  - Remeha Tzerra hybrid electric heat pumps
  - BoostHeat hybrid Gas / Air / Water heat pump

Tests on climatic chamber



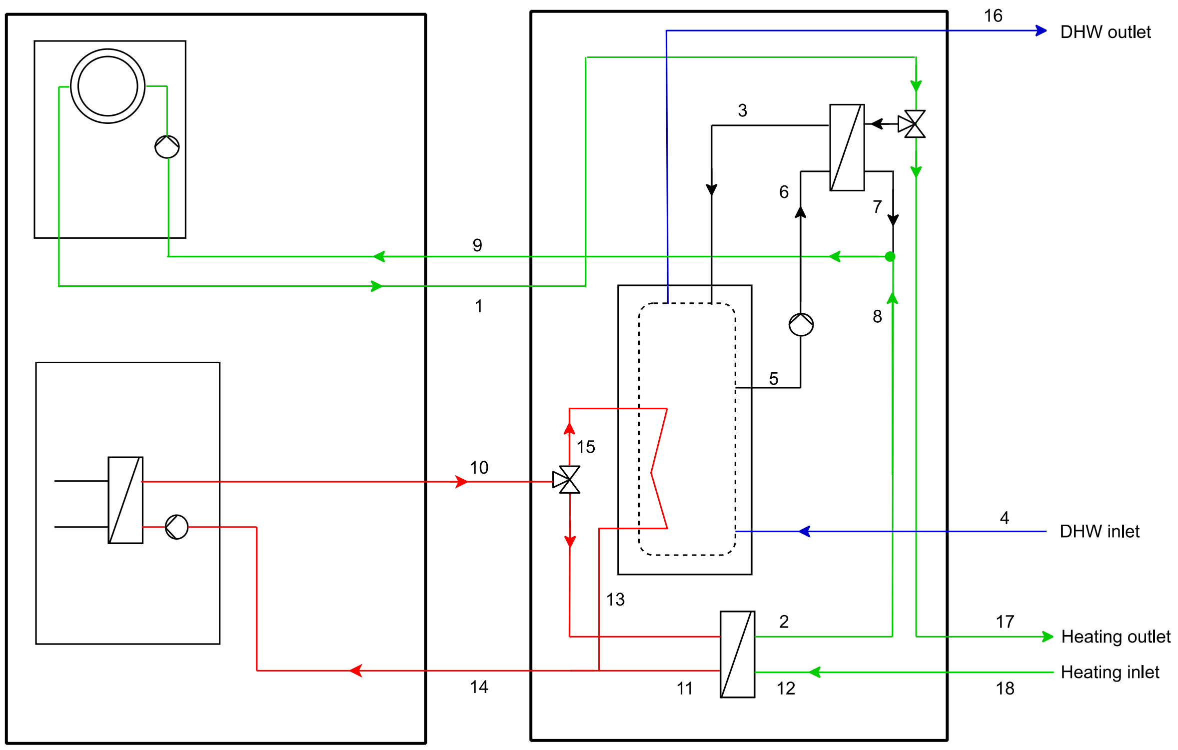
# Vitovalor PT2 – Main features

| | |
|---|---|
| Heating output | TV/TR 60/40 °C 30.8 kW<br>TV/TR 36/30 °C 0.9 kW |
| Electrical output FC | 750 W |
| Thermal output FC | 1.1 kW |
| FC electrical efficiency | 37% |
| Overall FC efficiency | Up to 92% |
| Peak load boiler termal efficiency | Up to 98% |
| Electr. Power consumption | 28 W standby<br>1400 W maximum |
| Gas consumption | 3.38 m³/h natural gas |
| Permissible ambient temperature | Max.: 40°C<br>Min.: 5°C |

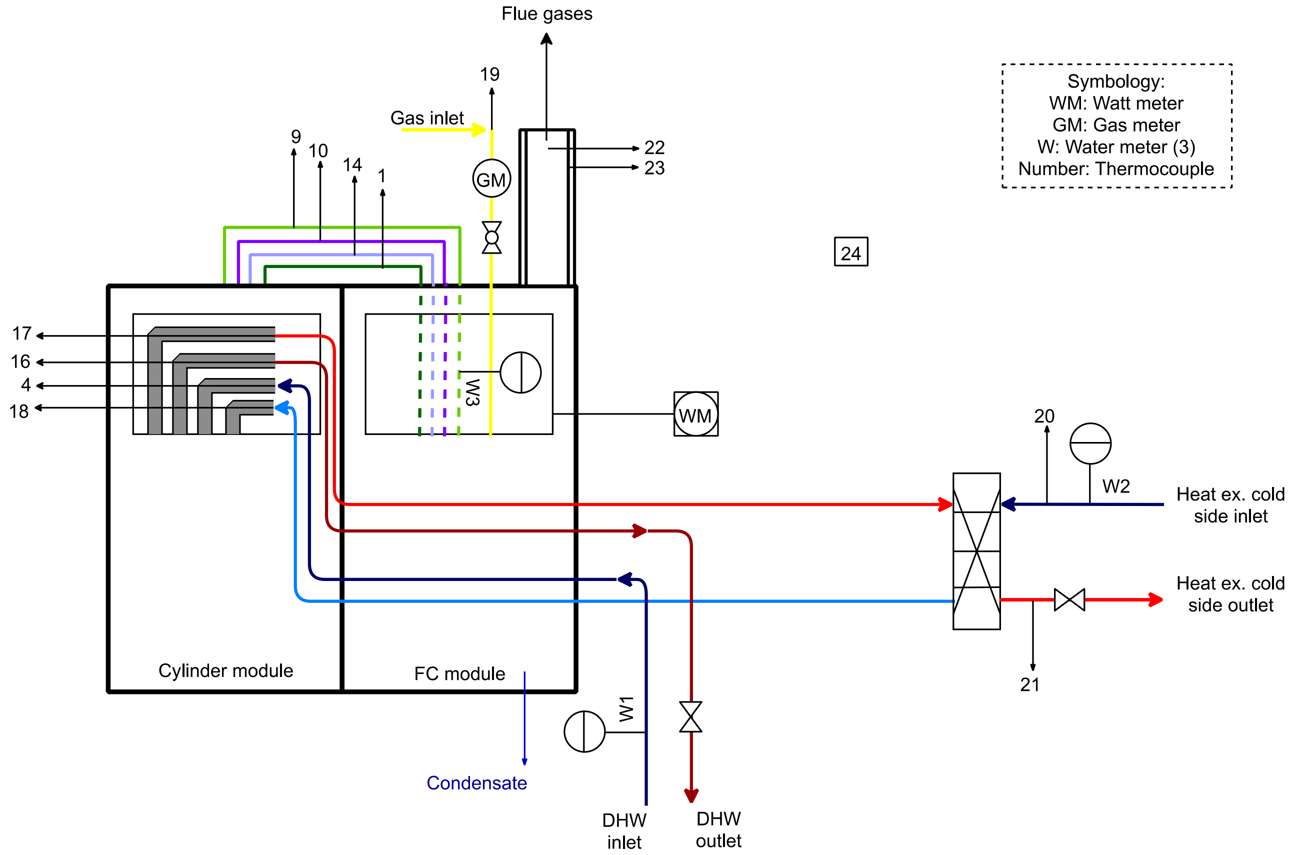

- System intended to produce domestic hot water and heating for residential buildings
- Two modules connected by four water lines

# Vitovalor PT2 – Water circuits and test bench diagram

- Water diagram of the system



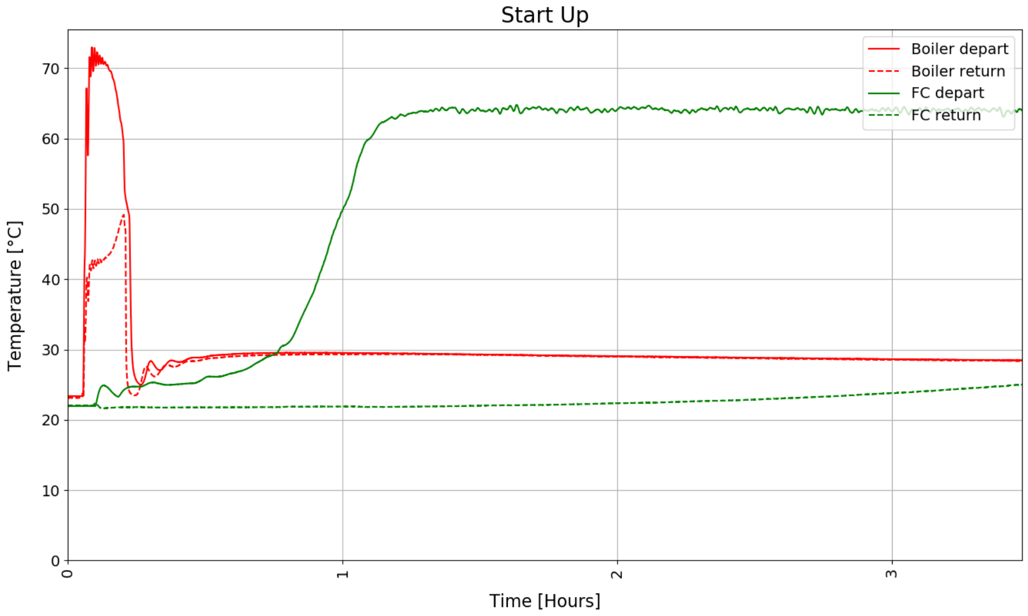

- Diagram of the test bench

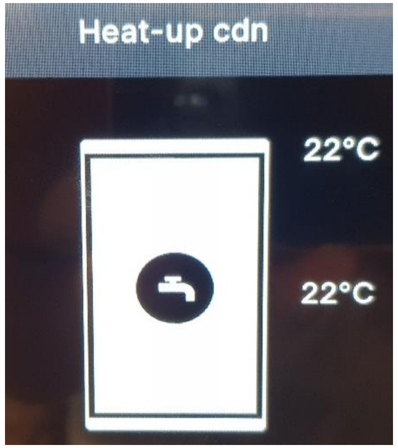


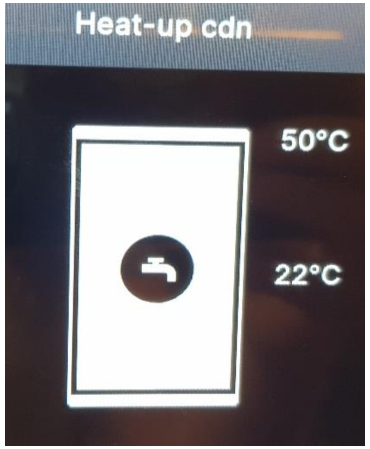

Symbology:
WM: Watt meter
GM: Gas meter
W: Water meter (3)
Number: Thermocouple

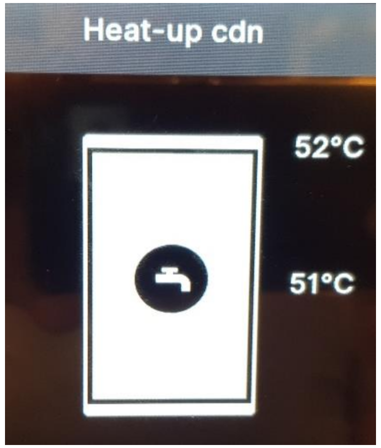
# Vitovalor PT2 – Start up, control and user’s access

- Start up process



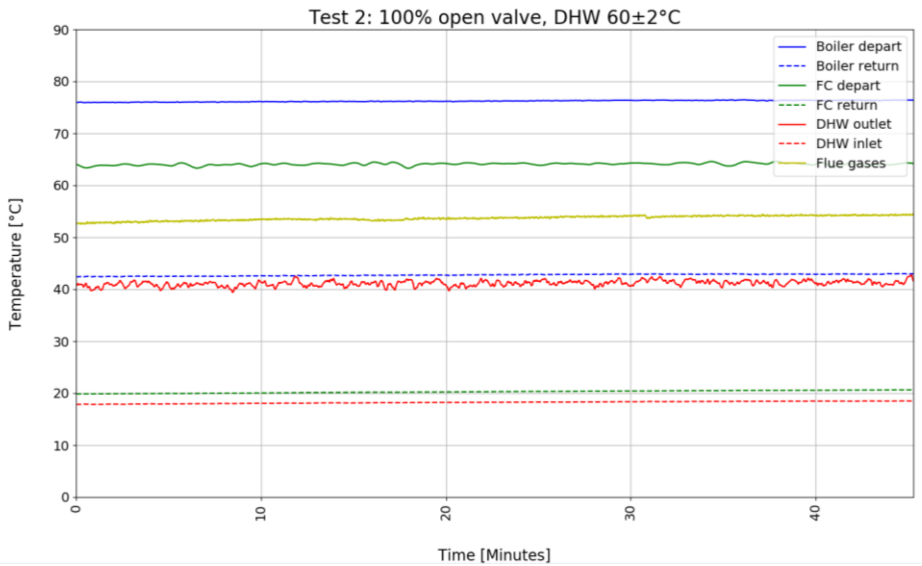



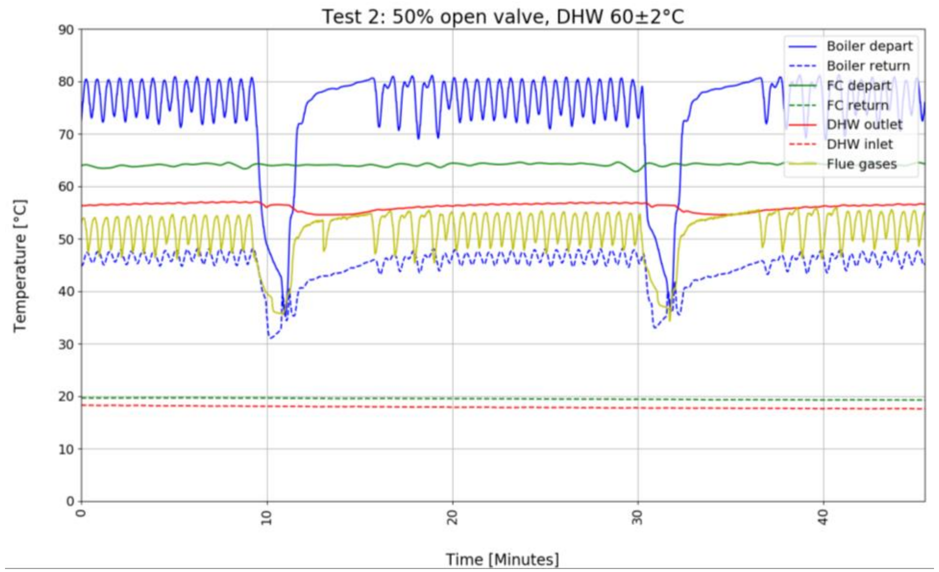



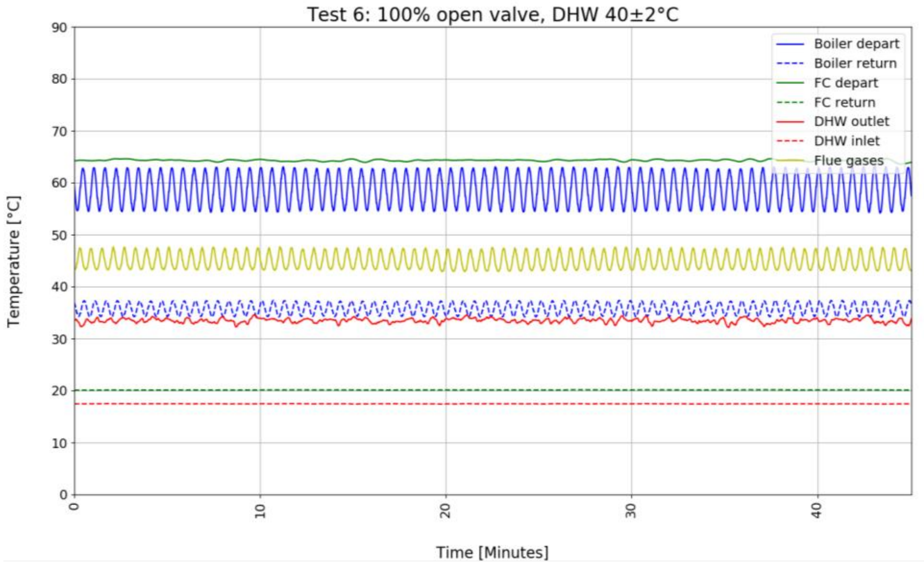

- Control and user’s access
  - Parameters of DHW T° and comfort room T° can be set by the user
  - The internal control of the system does not allow to operate just with the fuel cell
  - The system is driven by heat demand

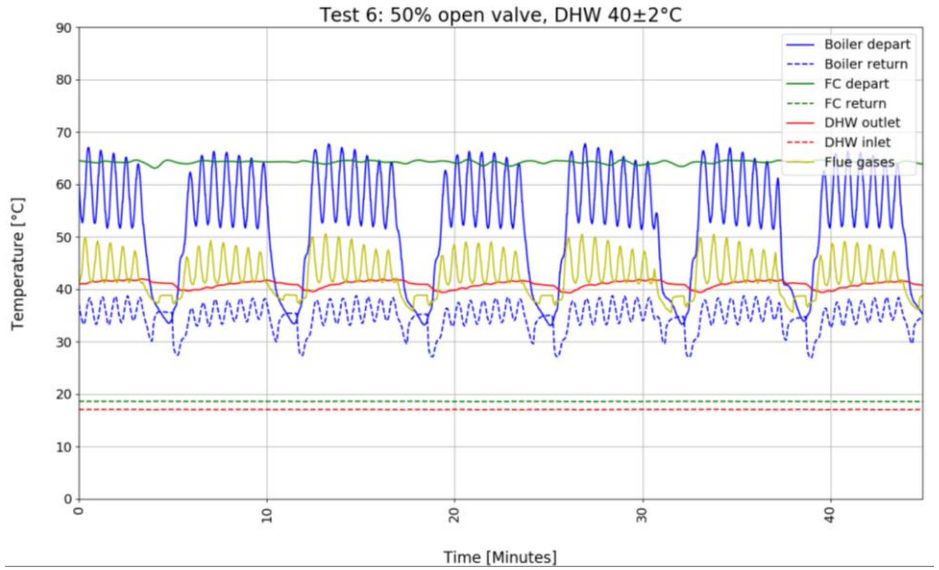
How can we use this information?

# Response of the system to DHW demand

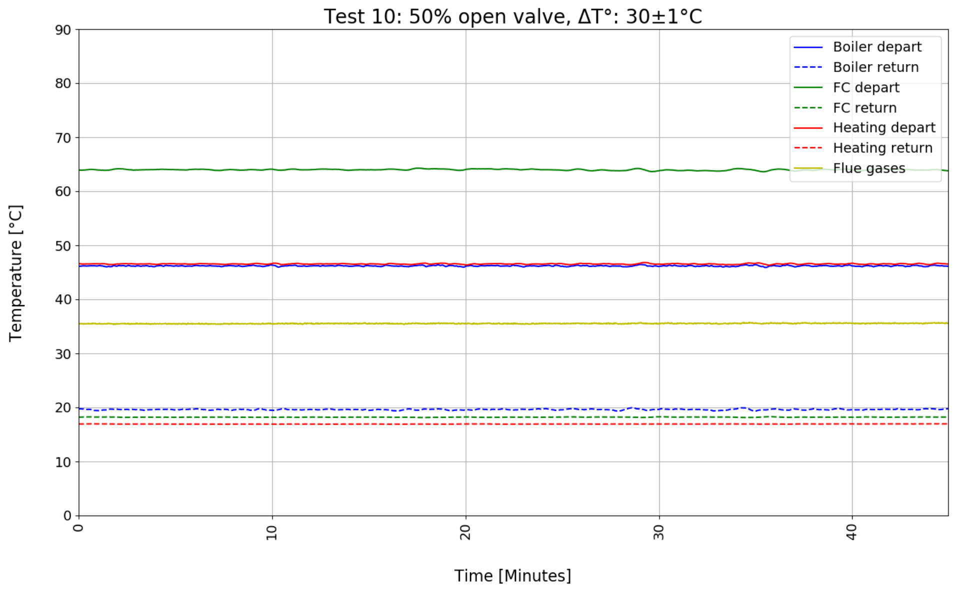


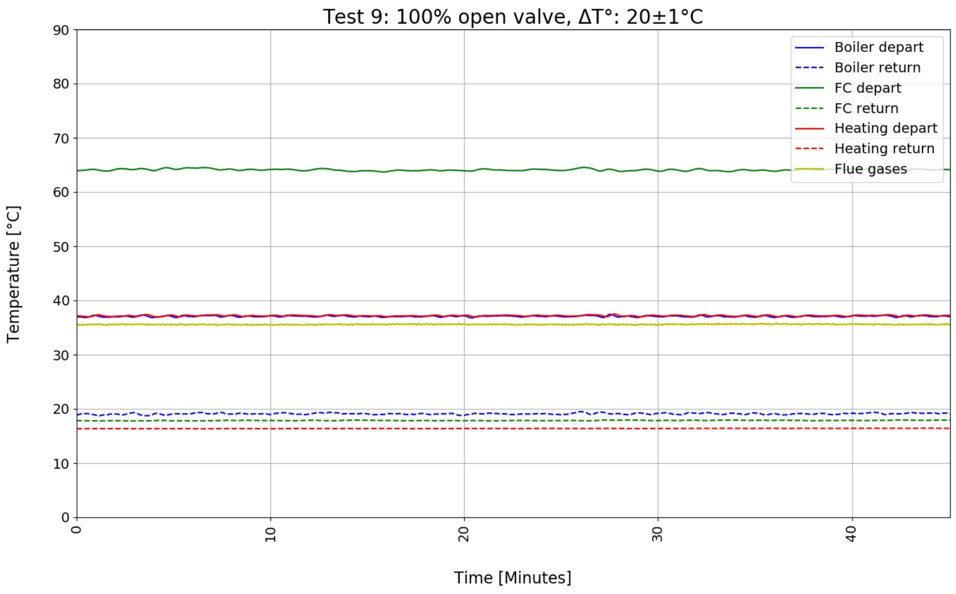



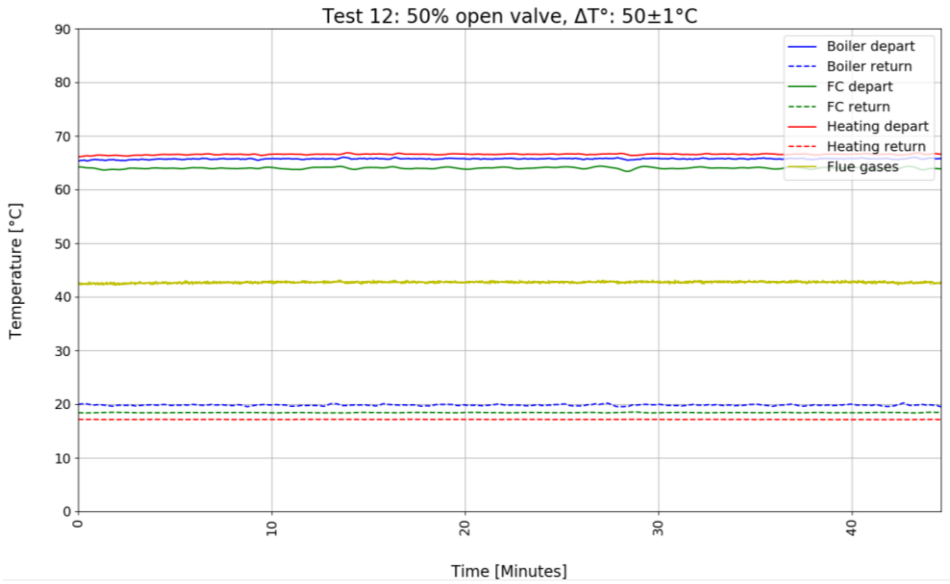



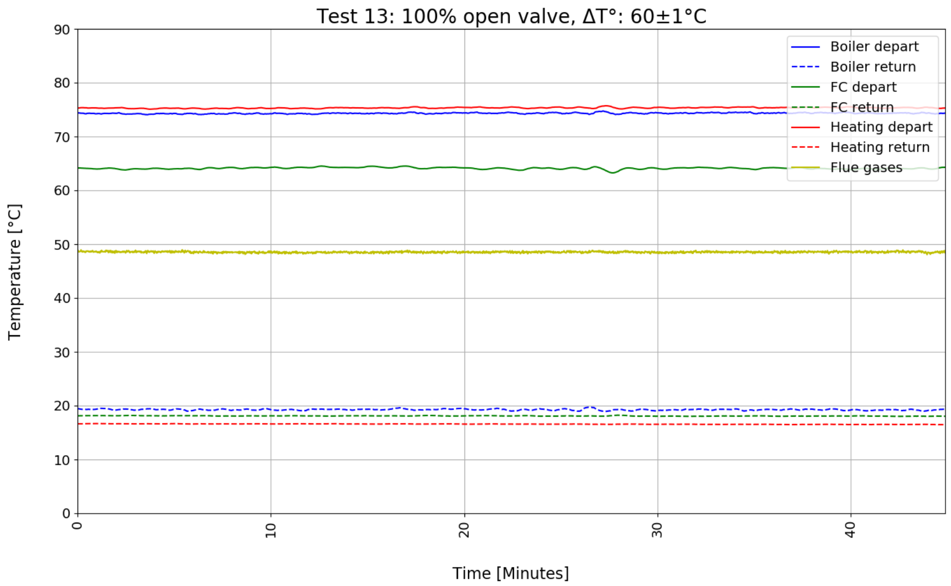



# Response of the system to heating demand



# Results – Test campaign and efficiencies

- A test campaign based on EN 50465 and the restrictions of the system is proposed
- For the efficiency estimations a daily value of PCS was used
- The efficiencies were estimated as

$$\eta = \frac{\dot{m} * cp * \Delta T + W_{el}/1000}{\dot{V}_{gas} * PCS}$$

Proposed test campaign:

| DHW | | | Heating | | |
|---|---|---|---|---|---|
| 60 ± 2 °C | Valve 50% | Valve 100% | Off | | |
| 55 ± 2 °C | Valve 50% | Valve 100% | Off | | |
| 50 ± 2 °C | Valve 50% | Valve 100% | Off | | |
| 45 ± 2 °C | Valve 50% | Valve 100% | Off | | |
| 40 ± 2 °C | Valve 50% | Valve 100% | Off | | |
| 35 ± 2 °C | Valve 50% | Valve 100% | Off | | |
| 30 ± 2 °C | Valve 50% | Valve 100% | Off | | |
| Off | | | Δ(20 ± 1) °C | Valve 50% | Valve 100% |
| Off | | | Δ(30 ± 1) °C | Valve 50% | Valve 100% |
| Off | | | Δ(40 ± 1) °C | Valve 50% | Valve 100% |
| Off | | | Δ(50 ± 1) °C | Valve 50% | Valve 100% |
| Off | | | Δ(60 ± 1) °C | Valve 50% | Valve 100% |

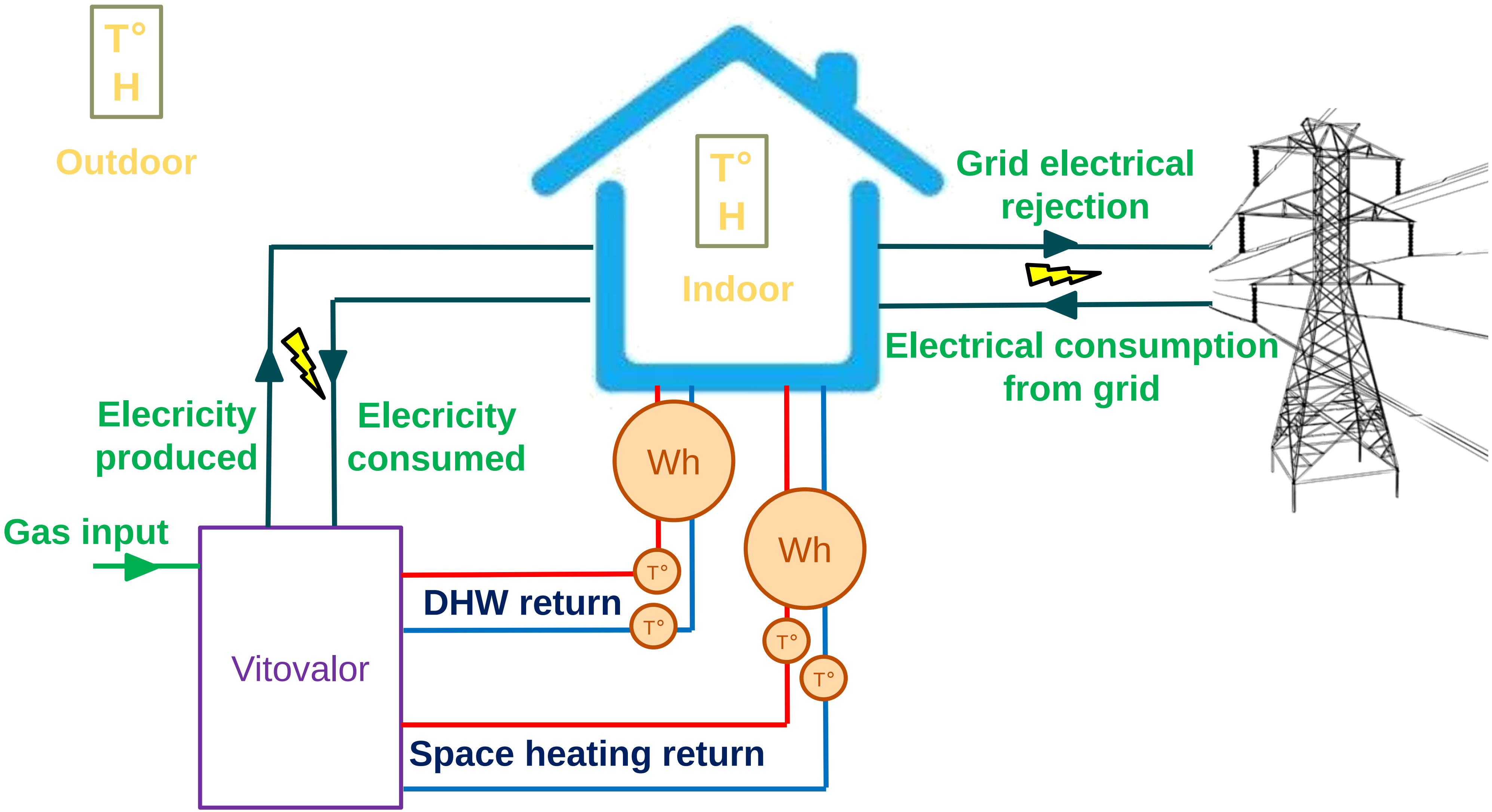
$\underbrace{\hspace{3cm}}_{\text{Variation of the demand}}$

Efficiency results:

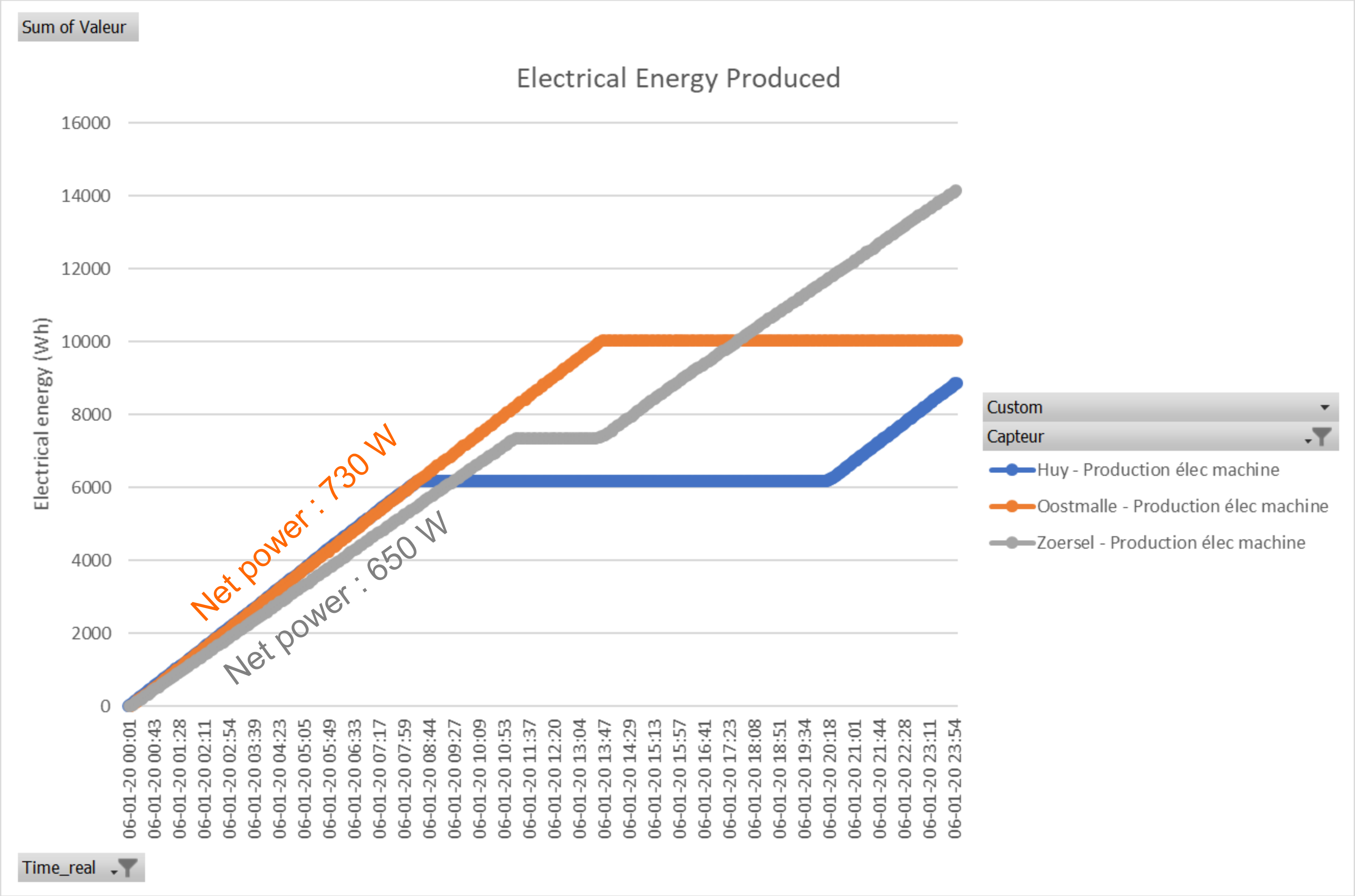
| | DHW 100% | | | DHW 50% | | |
|---|---|---|---|---|---|---|
| | η_Syst | η_Th | η_El | η_Syst | η_Th | η_El |
| T2, DHW 60°C | 0.81 | 0.79 | 0.02 | 0.82 | 0.80 | 0.02 |
| T3, DHW 55°C | 0.82 | 0.80 | 0.02 | 0.83 | 0.80 | 0.03 |
| T4, DHW 50°C | 0.82 | 0.80 | 0.02 | 0.83 | 0.80 | 0.03 |
| T5, DHW 45°C | 0.83 | 0.81 | 0.02 | 0.83 | 0.80 | 0.03 |
| T6, DHW 40°C | 0.84 | 0.81 | 0.03 | 0.86 | 0.82 | 0.04 |
| T7, DHW 35°C | 0.86 | 0.82 | 0.04 | 0.89 | 0.84 | 0.05 |
| T8, DHW 30°C | 0.87 | 0.82 | 0.05 | 0.88 | 0.81 | 0.07 |

| | Heating 100% | | | Heating 50% | | |
|---|---|---|---|---|---|---|
| | η_Syst | η_Th | η_El | η_Syst | η_Th | η_El |
| T13, ΔT 60°C | 0.83 | 0.81 | 0.02 | 0.85 | 0.83 | 0.02 |
| T12, ΔT 50°C | 0.86 | 0.83 | 0.02 | 0.86 | 0.84 | 0.02 |
| T11, ΔT 40°C | 0.87 | 0.84 | 0.03 | 0.87 | 0.84 | 0.03 |
| T10, ΔT 30°C | 0.88 | 0.84 | 0.04 | 0.89 | 0.84 | 0.04 |
| T9, ΔT 20°C | 0.88 | 0.82 | 0.06 | 0.89 | 0.83 | 0.06 |

# Field Monitoring – Configuration and sensors



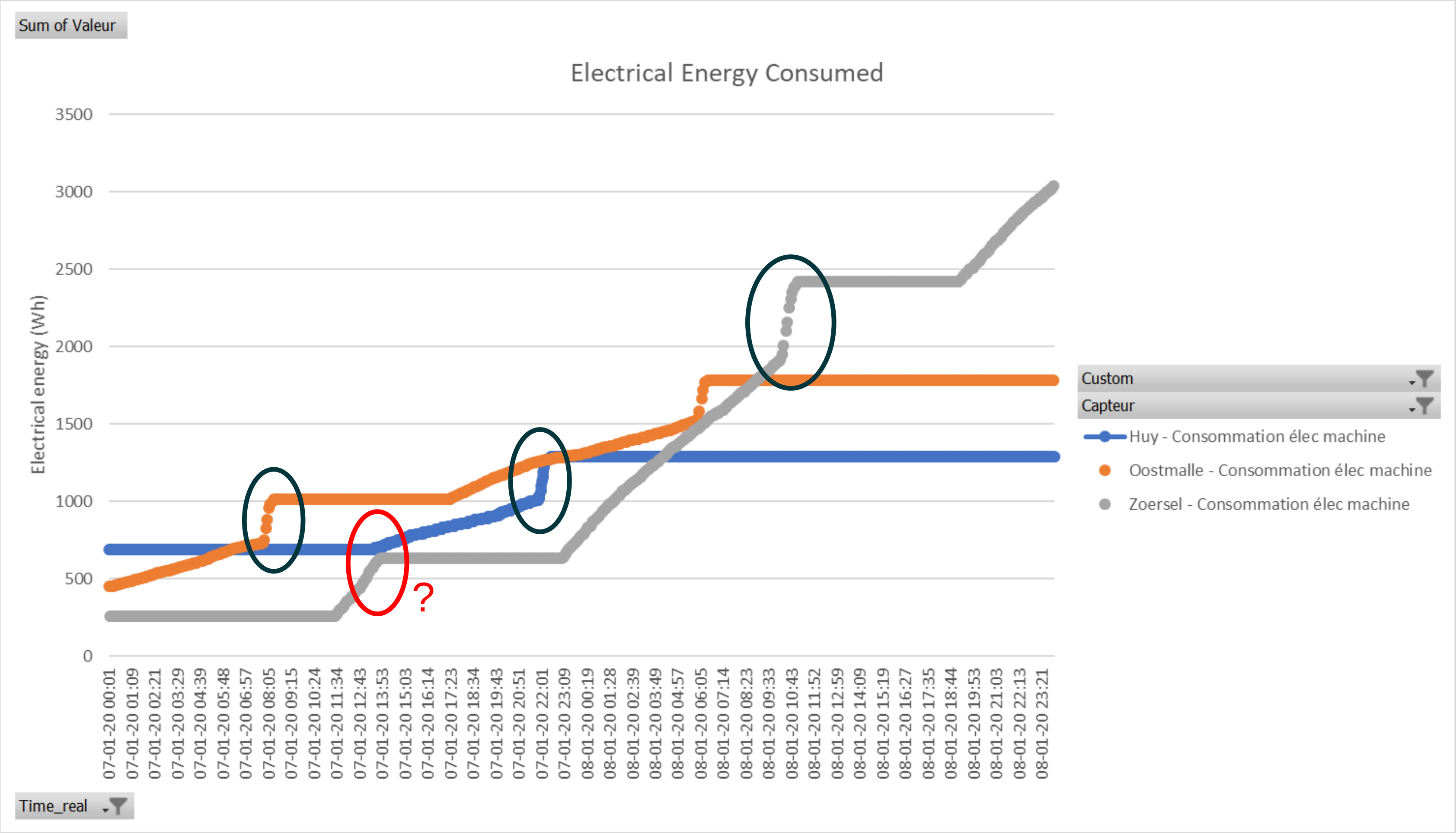
# Field Monitoring – Vitovalor electricity produced (Wh)




Electrical power delivered repeatability noticeable

Less power for Zoersel site → What about the electrical consumption of the machine ?

# Field Monitoring – Vitovalor electricity consumed (Wh)

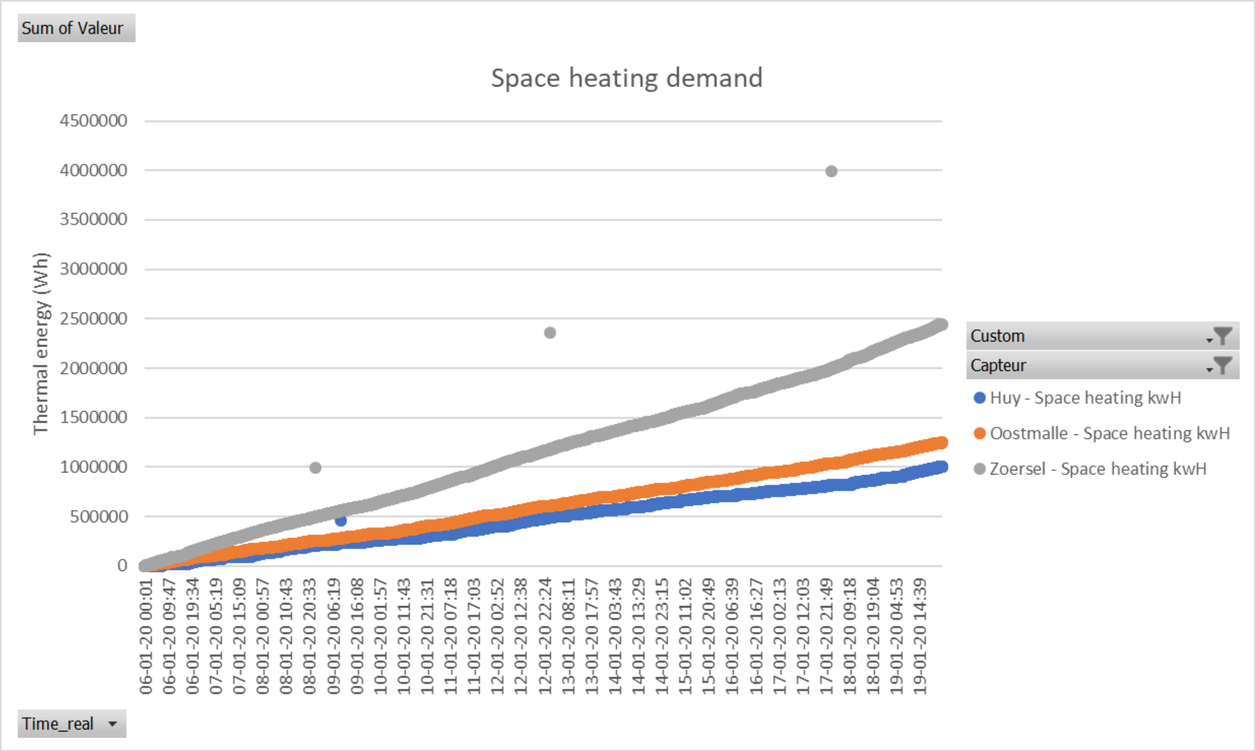



Electrical power consumed similar for Huy & Oostmalle

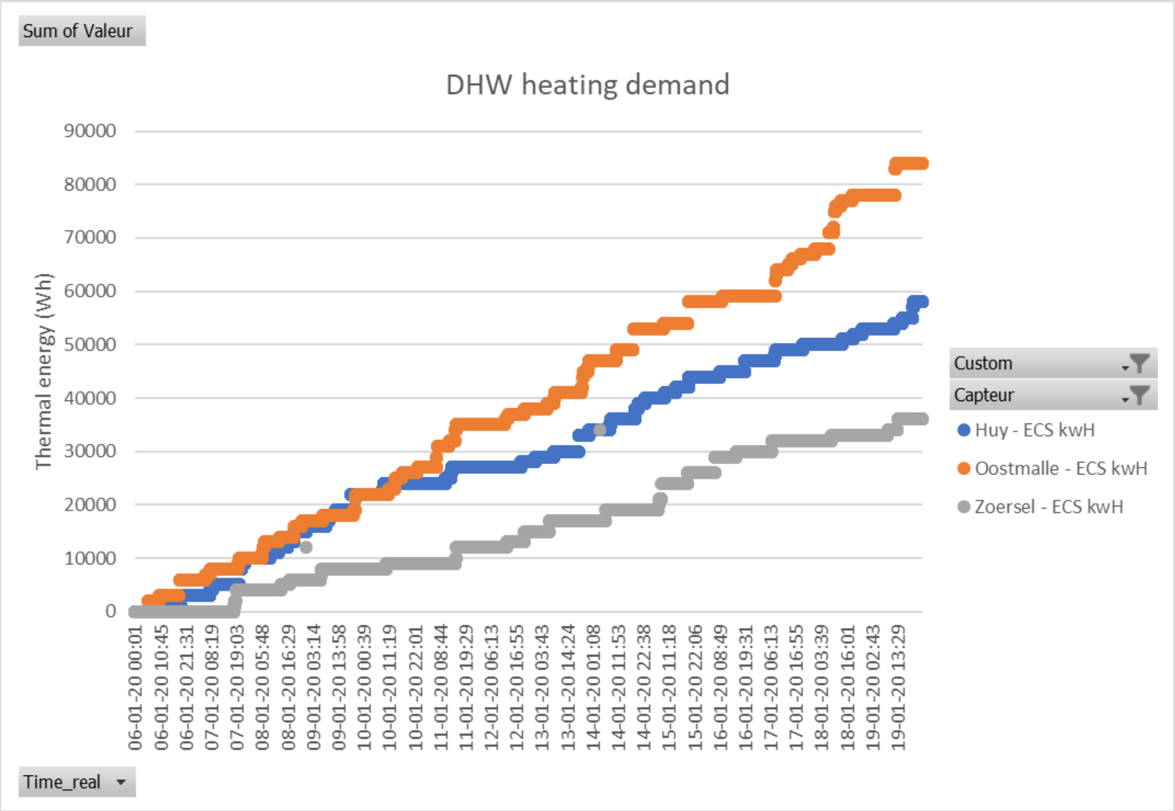
About 2 times greater for Zoersel (probably due to pressure drops within the installation – way bigger house)

For Huy & Oostmalle, big power demand of the machine when the fuelcell stops. Happens also sometimes in Zoersel…
→ Under investigation

# Field Monitoring – Vitovalor heat generation (Wh)

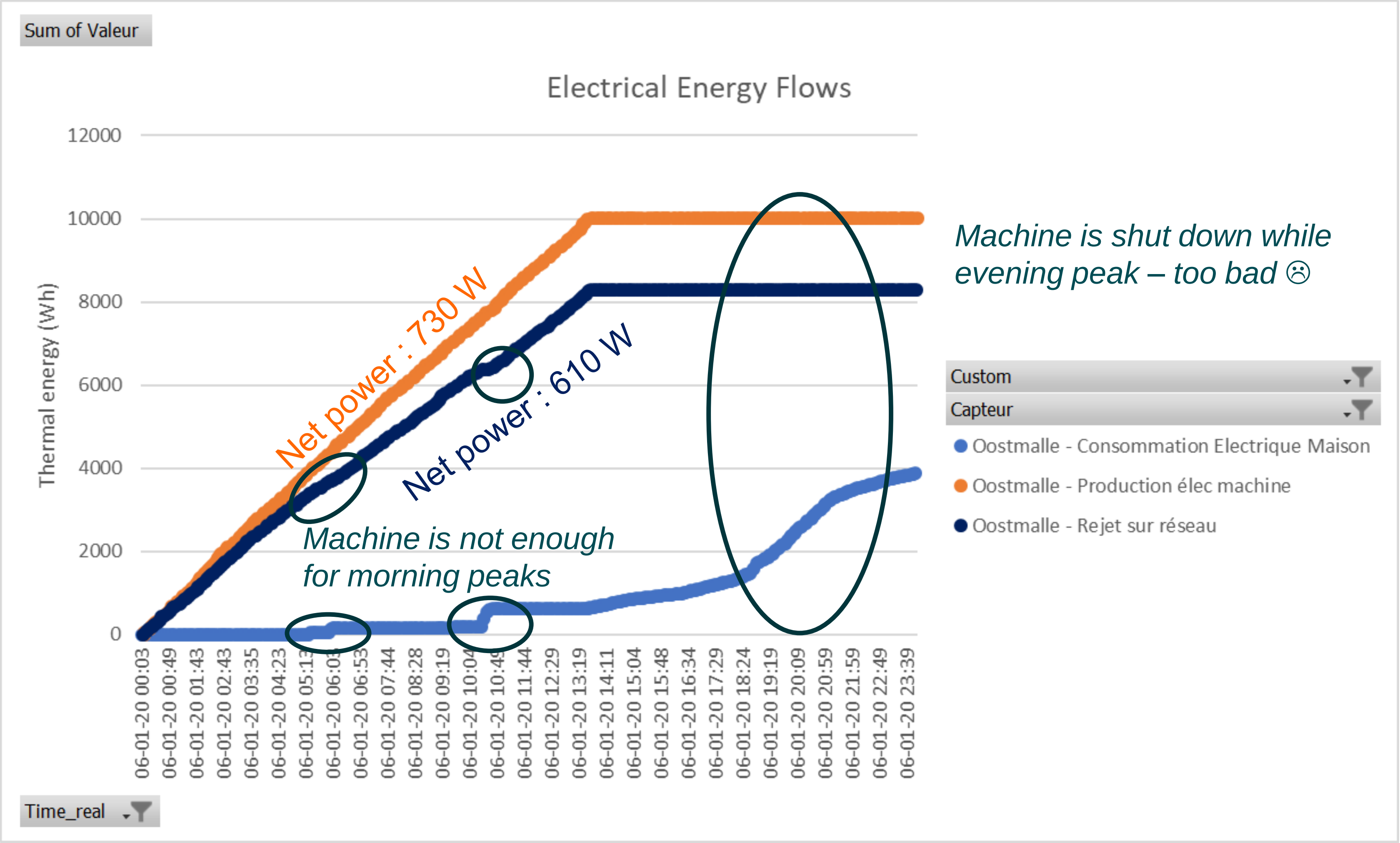



Indeed, Zoersel is a way bigger house




But they shower less ?

# Field Monitoring – Vitovalor electrical flows (Wh)

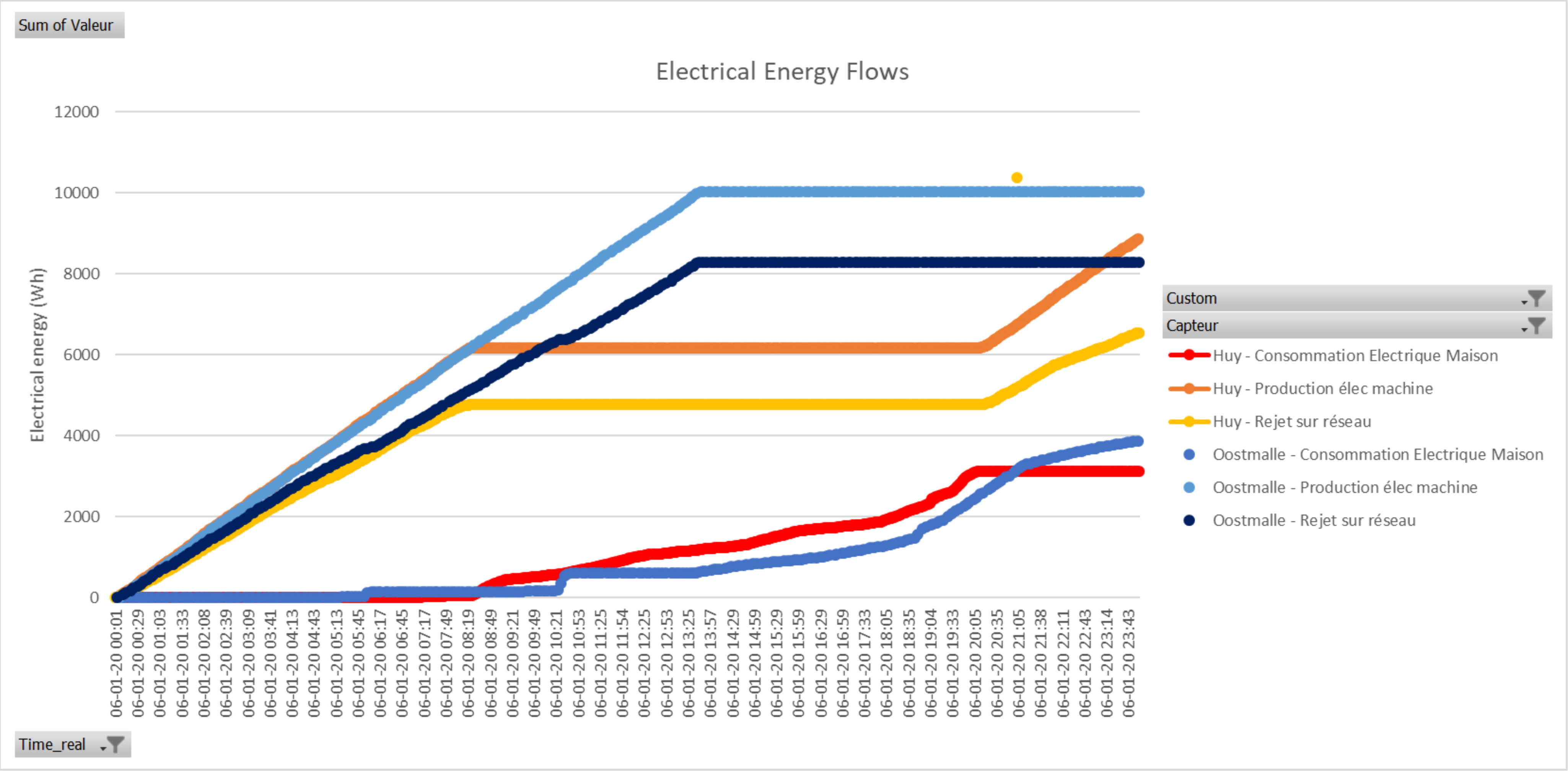



In those winter days : - Electricity produced is about 180% higher than <u>needed by the house</u> but still they have to take electricity from the grid

- Lot of energy is rejected on the grid (about 80% of the production)

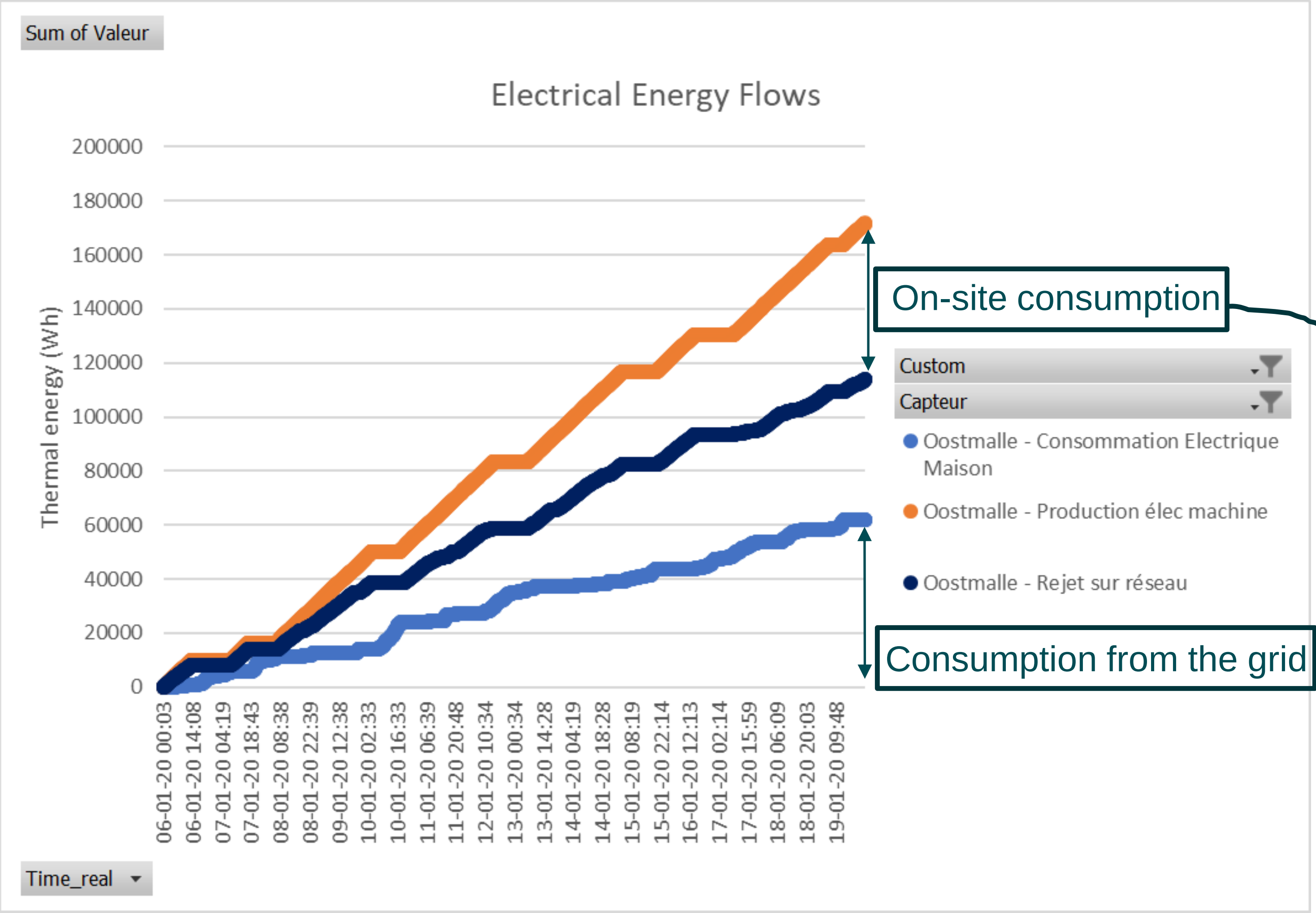
**Draft numbers → they depend on the time scale and day chosen as it will be shown later**

# Field Monitoring – Vitovalor electrical flows (Wh)




Behavior is similar for both houses and not ideal (machine shut down during **that** day – January 6th) – high rejection on the grid **that** day

# Field Monitoring – Vitovalor electrical flows (Wh)




On-site consumption + Consumption from the grid = Total electricity consumed

$$\gamma_s = \text{Supply cover factor} = \frac{\text{On-site consumption}}{\text{On-site production}}$$

$$\gamma_d = \text{Demand cover factor} = \frac{\text{On-site consumption}}{\text{Total electicity consumed}}$$

Both factors depend on the time scale you are studying :

| | | January 6th | Whole 2 weeks |
|---|---|---|---|
| **Oostmalle** | Supply cover factor | 20% | 34% |
| | Demand cover factor | 31% | 48% |
| **Huy** | Supply cover factor | 27% | 27% |
| | Demand cover factor | 42% | 35% |

# Conclusions and further work

Conclusions

- Due to the size of its components, the fuel cell contribution to the global performance is small compared to that of the boiler
- Variations of the global efficiency linked mainly to the depart water temperature (between 3-6%)
- More analysis should be done, but the suitability of the system will be linked to the final user's behavior and application
- Monitoring has just started & will go on for 2 more heating seasons → monitoring numbers needs to be confirmed

Further work

Laboratory: - Future test campaign to estimate the performance of the fuel cell and the boiler separately
- Analysis of the flue gases: NOx, SOx, CO2 and fine particles
- A SOFC MyChi from Elugie will be tested this year

Monitoring: - Two houses with MyChi systems will be monitored

Global: - Compare laboratory and monitoring results between them and also with other systems monitored and tested at ULiège