Large scale demand response of heat pumps to support the national power system

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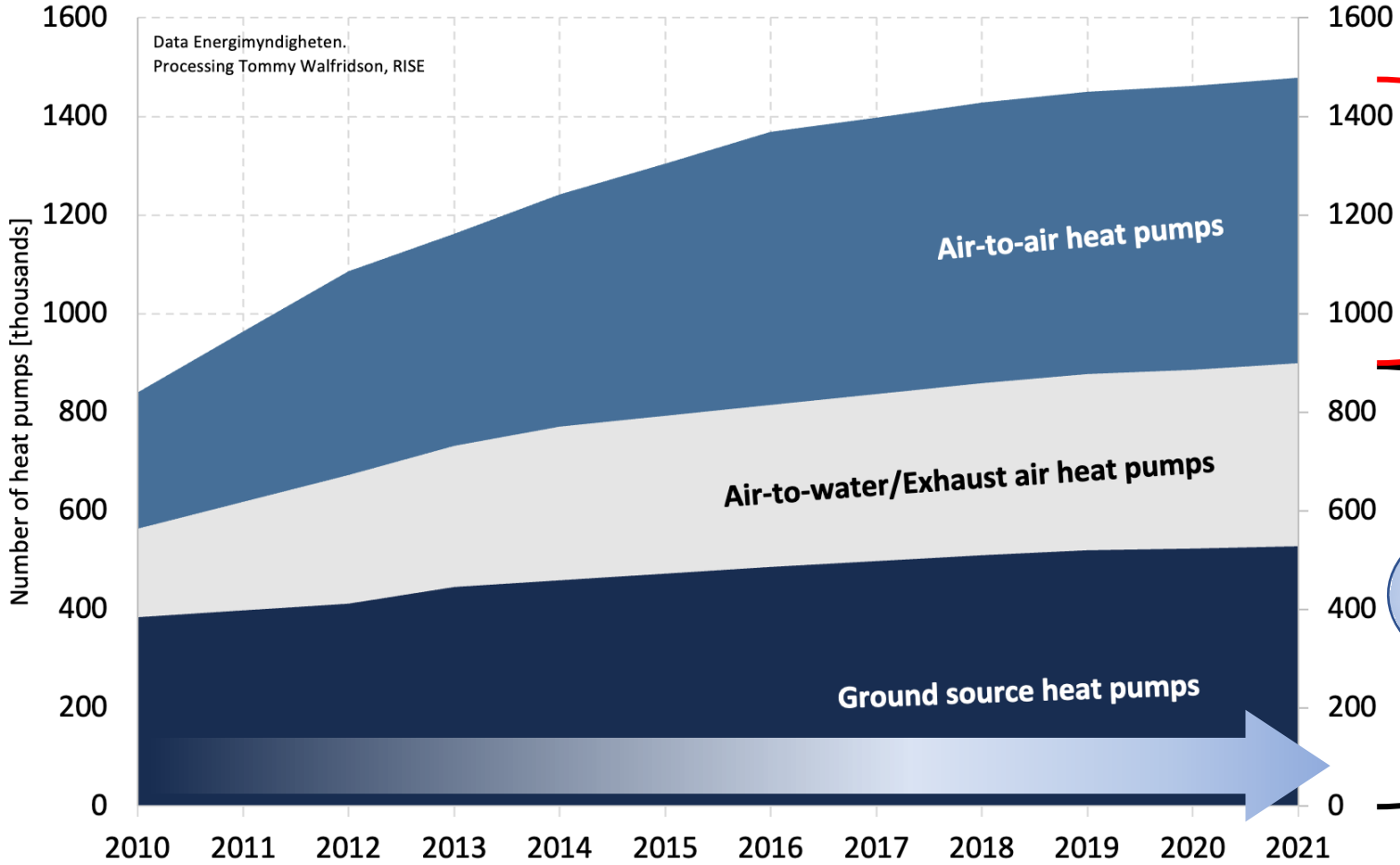
Energimyndigheten

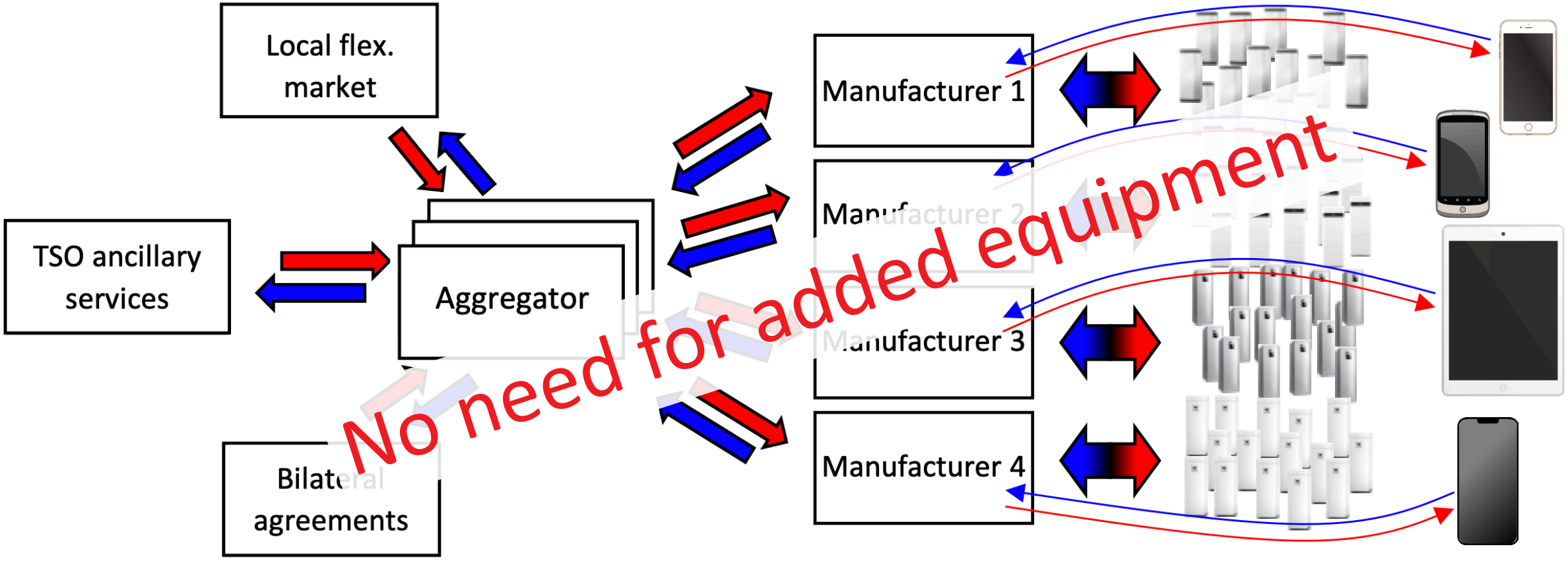
Background, heat pump stock and sales



In Sweden normally not suitable for demand response. Not part of the project

More than ten years of internet connected heat pumps!
Around 300.000 *hydronic* heat pumps *could* be connected (2022, RISE estimate)

Concept of power system support



TSO = Transmission System Operator, in US called RTO (Regional transmission organization)

Svensk kraftnät (TSO) Ancillary services etc

FFR – **F**ast **F**requency **R**eserve

aFFR –**a**utomatic **F**requency **R**estoration **R**eserve

FCR-N –**F**requency **C**ontainment **R**eserve-**N**ormal

TSO Ancillary services keep the power system in shape every day.

Financial system in place since years

FCR-D up/down – **F**requency **C**ontainment **R**eserve-**D**isturbance

mFFR – **m**anual **F**requency **R**estoration **R**eserve

TSO = Transmission System Operator, in US called RTO (Regional transmission organization)

Bilateral agreements

Still in research phases

Tiny markets

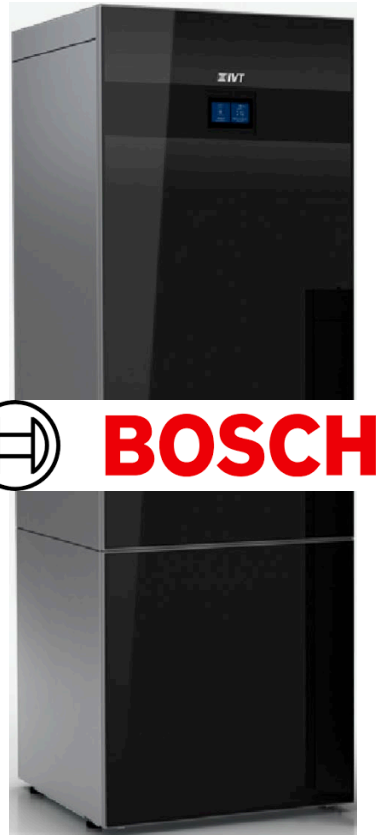
Local flex markets

sthlmflex

coordNET

Effekthandel Väst

Interviews with Swedish HP manufacturers



Other project members

Tekniska verken

MälarEnergi

DSO and electric power producers (etc)

VATTENFALL

POWER CIRCLE
Electricity for sustainable energy

Association working with electrification

POWER 2U

Aggregator

SVENSKA KYL&VÄRMEPUMP FÖRENINGEN

Swedish heat pump association

DSO = Distribution System Operator also called Electric power distribution

Power system obstacles

- Minimum bid size on same BRP (41 BRP in Sweden!)
- Prequalification necessary – how?
- Electronic communication in real-time
- Lack of standardization
  - Accuracy and frequency of reporting not yet defined for aggregators
- Power tariffs (ongoing) could delay, as they reduce the possible flexibility
- Lack of trust? Only 10% of total bid allowed from aggregators

BRP = Balance Responsible Party BSP = Balance System Provider

Power system obstacles, continued

- Aggregation is not used commercially (in scale in Sweden) today
- Future legislation still pending -> uncertainty
  - What responsibility will the BSP have in the future?

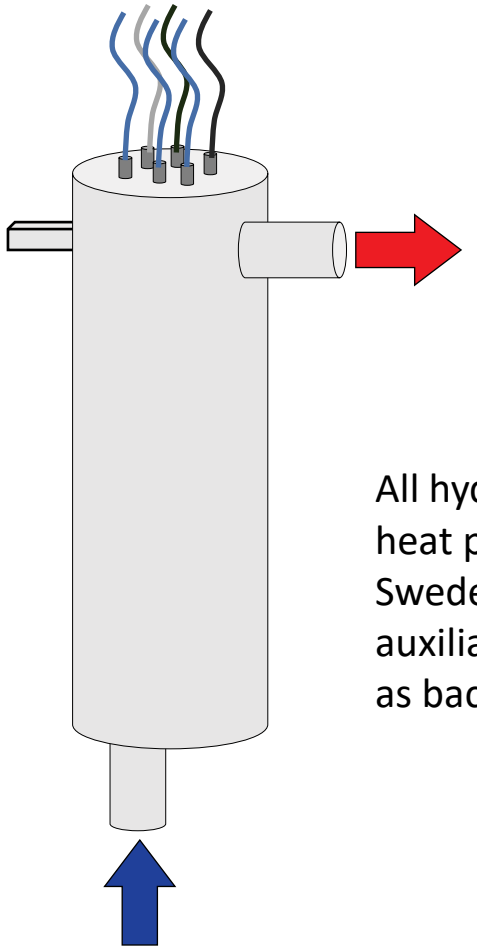
BRP = Balance Responsible Party BSP = Balance System Provider

Heat pump obstacles

- Interviews with all major manufacturers of hydronic villa heat pump, that are based in Sweden (Bosch, Enertech, NIBE and Thermia)
- RISE has long cooperation with all of these, both in research and as market/performance tester
- This gives us the strength to discuss even company confidential parameters.
- All information presented is cleared with each company

Heat pump obstacles: Auxillary heater

- All manufacturers says the auxillary heater *can* be controlled within a second
  - Intended to be used as slow backup at cold climate
- With dedicated *reprogramming* of the control system rapid control is possible
- Can be used to reduce power consumption during cold spells
- Almost always possible to use for increased power consumption.



All hydronic villa heat pumps in Sweden have an auxiliary heater as backup

Heat pump obstacles: On/Off compressors

- All manufacturers says On/Off compressors can be turned off within a second
- The start up procedure is up to 60 second
  - To have control over the ground source temperature (water freeze risk)
  - Preheating of compressor oil can also delay startup.

This is not a compressor of a villa heat pump. This On/Off compressor cools the freezers of the COOP grocery store in Karlshamn Sweden.

Heat pump obstacles: VSC compressors

- Variable speed control (VSC) compressors are slow to turn on and to control the speed
  - Several minutes
  - Likely possible to improve, but no need in the normal control of the heat pump

This is not a frequency controller of a villa heat pump. This controls the frequency of a large pump in an aquifer in Jönköping, Sweden.

Heat pump obstacles: Power measurements

- Variable speed control (VSC) compressors has relatively high accuracy on power consumption measurements, ±2-10% (measurement in the inverter)
- On/Off compressors has low accuracy on power consumption measurements, ±10-20% (no real measurement done)
- Auxiliary heater has relatively high accuracy on power consumption measurements, ±0,5-5% (lower if unknown voltage)

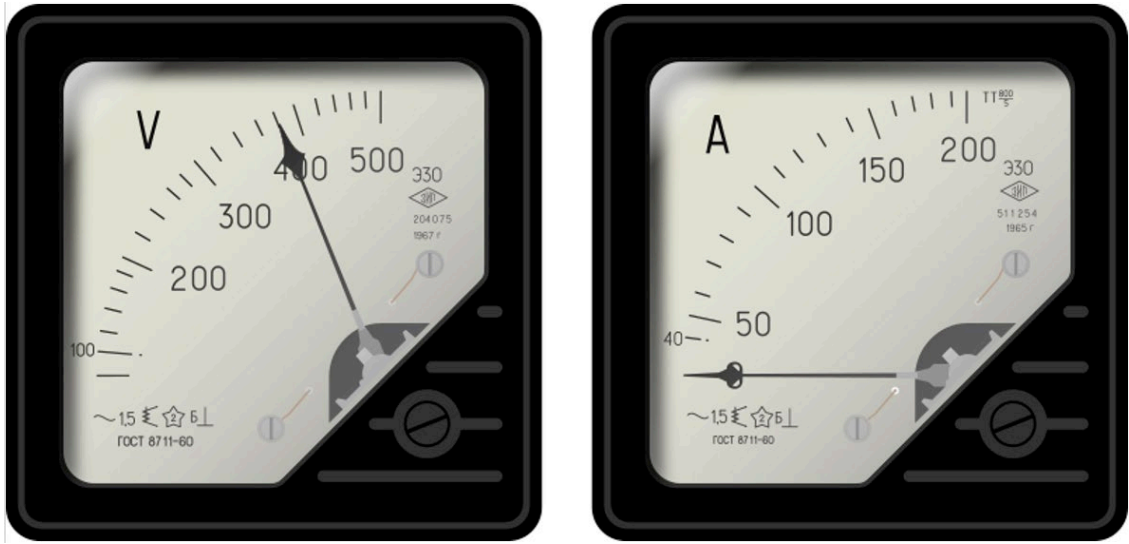
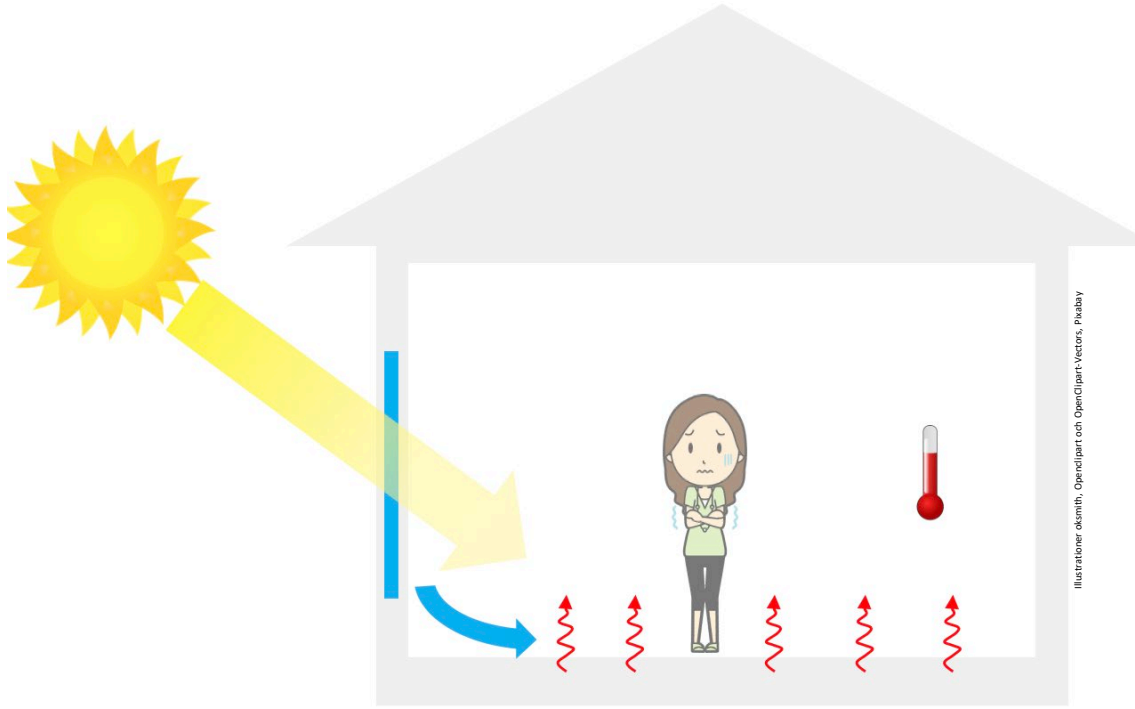


Illustration rones, Openclipart

Aggregator accuracy still not defined

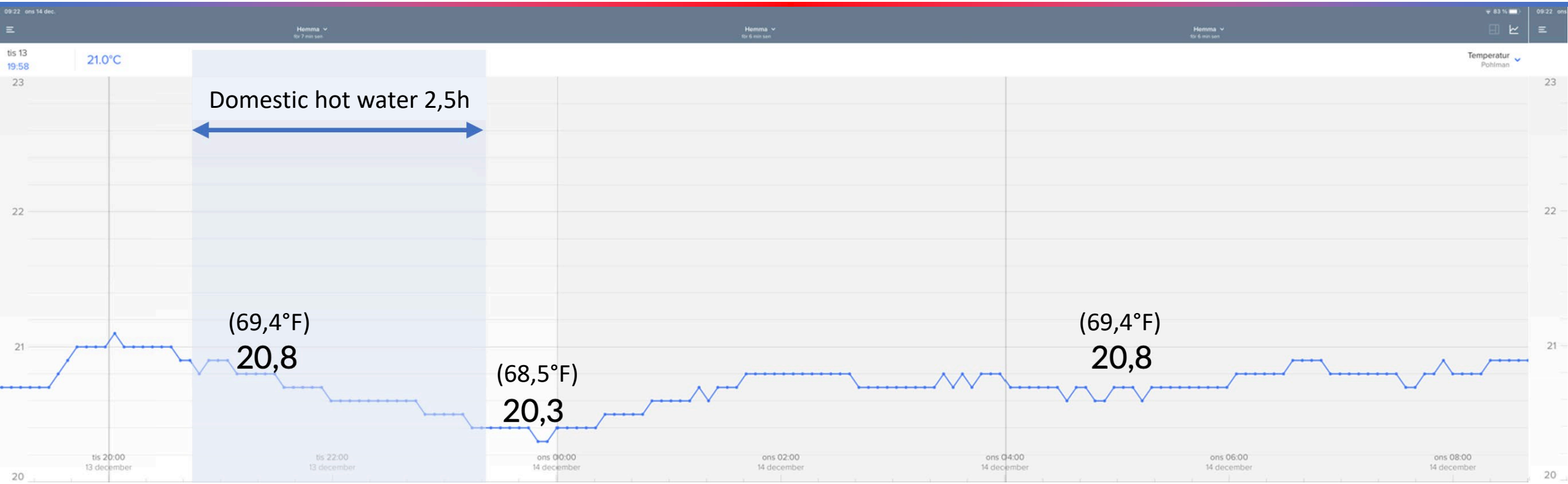
Heat pump obstacles: Thermal comfort

- Stopping the heat pump to aid the power system can cause thermal comfort issues
  - Cold air downdraughts by windows not compensated by radiator
  - Cold window surfaces are not compensated
  - Air temperature decreases
- Some studies shows large amount of heating can be shifted in time without major temperature decrease (operative temperature not addressed)
- Domestic Hot Water risk to be cold.



Illustrationer: oksmith, OpenClipart och OpenClipart-Vectors, Pixabay

Heat pump obstacles: Flex example



Optimal example: My own (near) passive house. Ambient -10°C (14°F). 300 l (80 US gal) buffer tank on heating side.

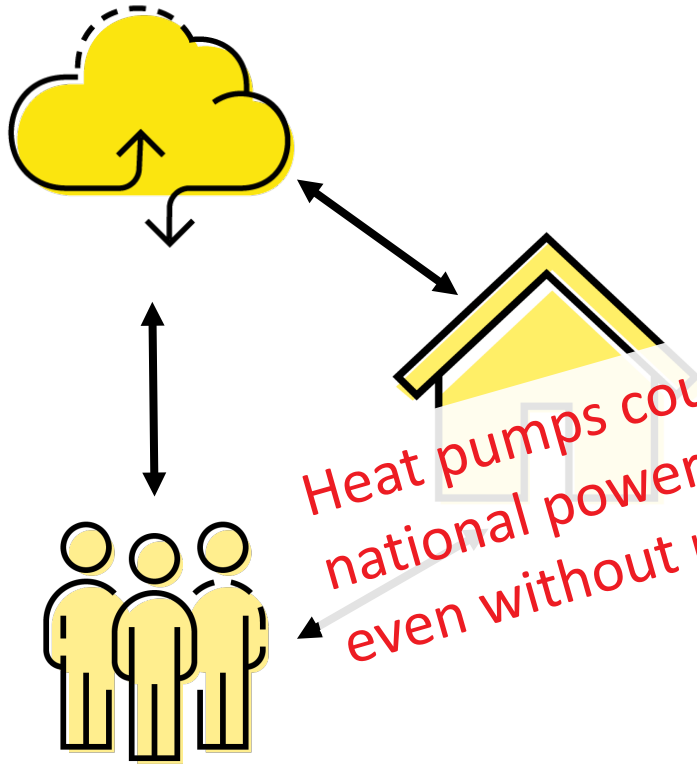
Communication

Protocol	Members	Free	Open source	Flexibility fully implemented	Cyber security	Heat pumps in flexibility operation
SG Ready	Several	No	No	No	N/A	since 2015?
IEEE 2030.5	285	No	Partly	Ongoing	Yes	-
OpenADR	130	Yes	Yes	Yes	Yes	?
EFI	15	Yes	No	No	?	?
EEBUS	60	Yes	Yes	No, EMS needed	Yes	?
IEC 61850	-	No	Likely not	Ongoing	Likely	-

Communication

- No communication protocol fulfills all demand from flexibility
- Heat pump manufacturers are following the development, not leading it
- Cyber security must be on very high level
  - RISE has recently shown that a large-scale hack attack on heat pumps could cause significant impact on the Swedish power system (spin off from this project)

Cyber security – heat pump attack vectors



Heat pumps could be attacked and used against the national power system just being connected to internet, even without participating in flexibility services

Heat pumps connected to cloud solutions introduces several attack vectors:

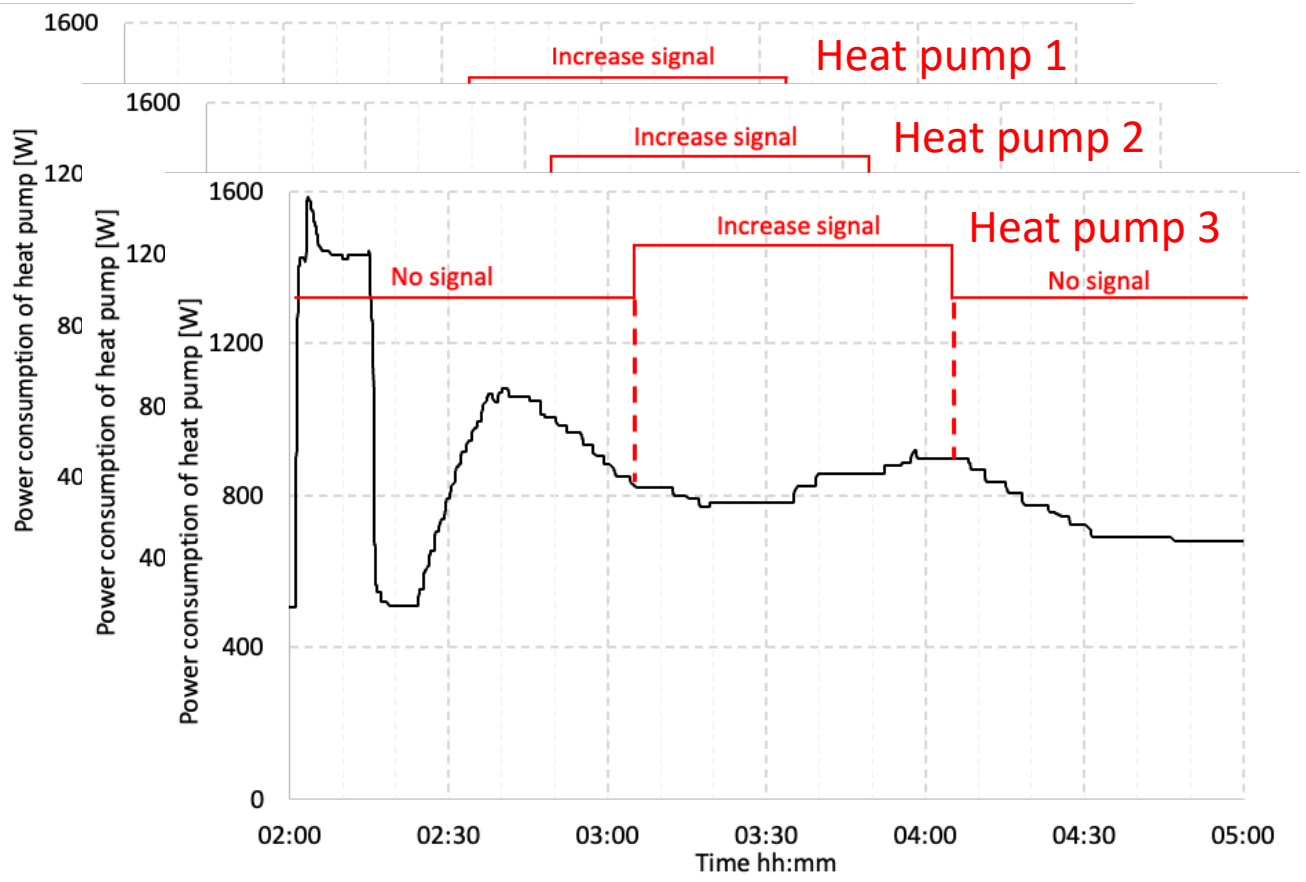
- **Cloud service** – could lack isolation between customers, being misconfigured, have insufficient physical protection etc
- **Heat pump** – could expose services by mistake, contain weak/hard coded passwords, have insecure update policy etc
- **Employees** – needs to protection not to leak information, by mistake or by extortion
- **Communication** – could be unencrypted, contain security flaws or have become to old due to the lifespan of the heat pump

Field tests

- **Tests performed via NIBE MyUplink API**
  - **Three NIBE S-series ground source heat pumps**
  - **Heat pumps not being tampered with – all controlled with standard NIBE control system**
- **Heat pumps <u>not</u> being monitored on site while testing**
- **Signals sent to speed up or turn off heat pumps – using available API commands**

API = Application Programming Interface

Field tests



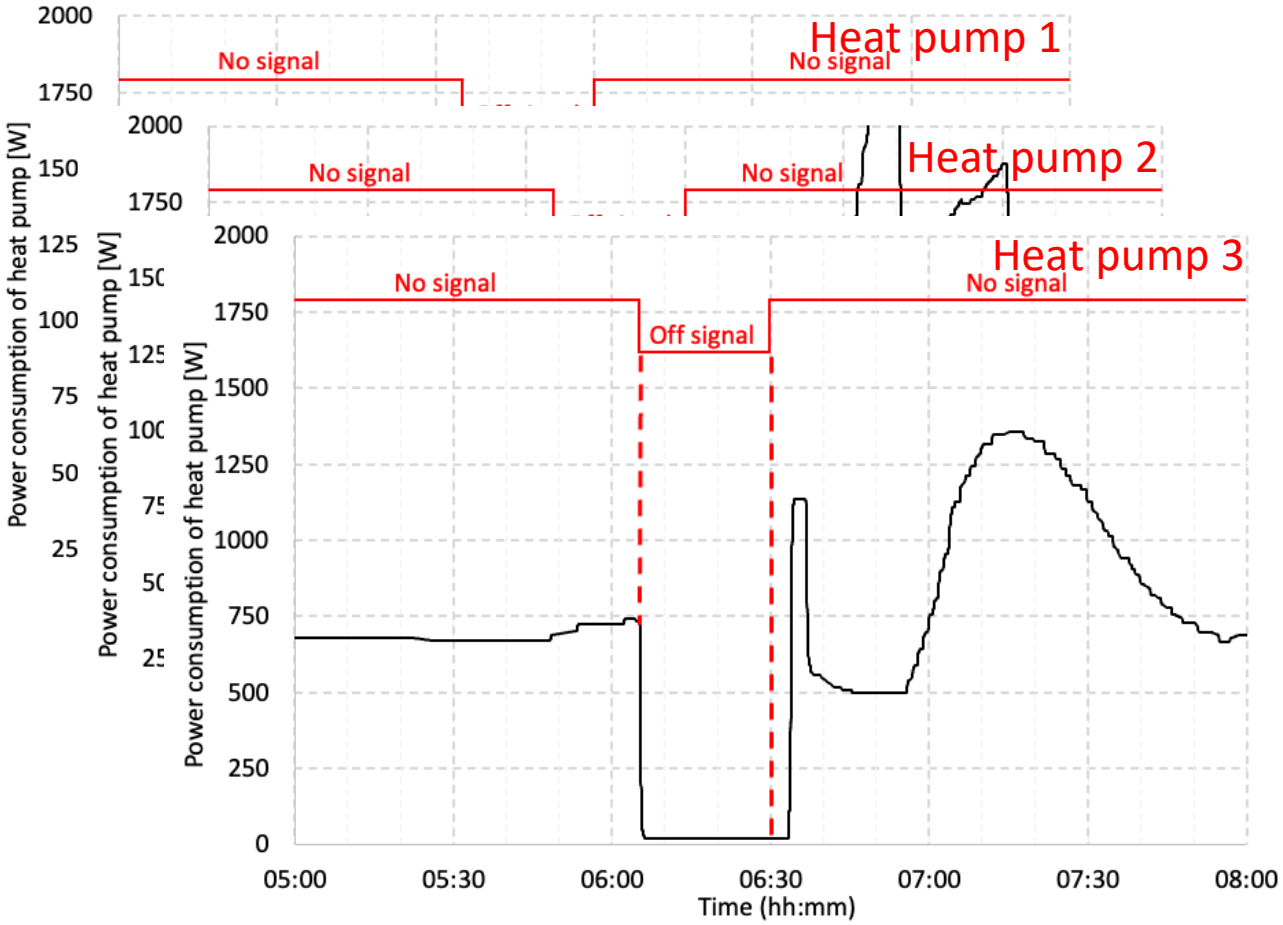
We could

- **control the heat pump to increase of power consumption with 50%**
- **holding it there for 40 minutes**
- **long response – 15 minutes**

But

- **Each heat pump needs individually "tuned" <u>increase</u> signal depending on heating state**
- **The other two heat pumps not as well controlled**

Field tests



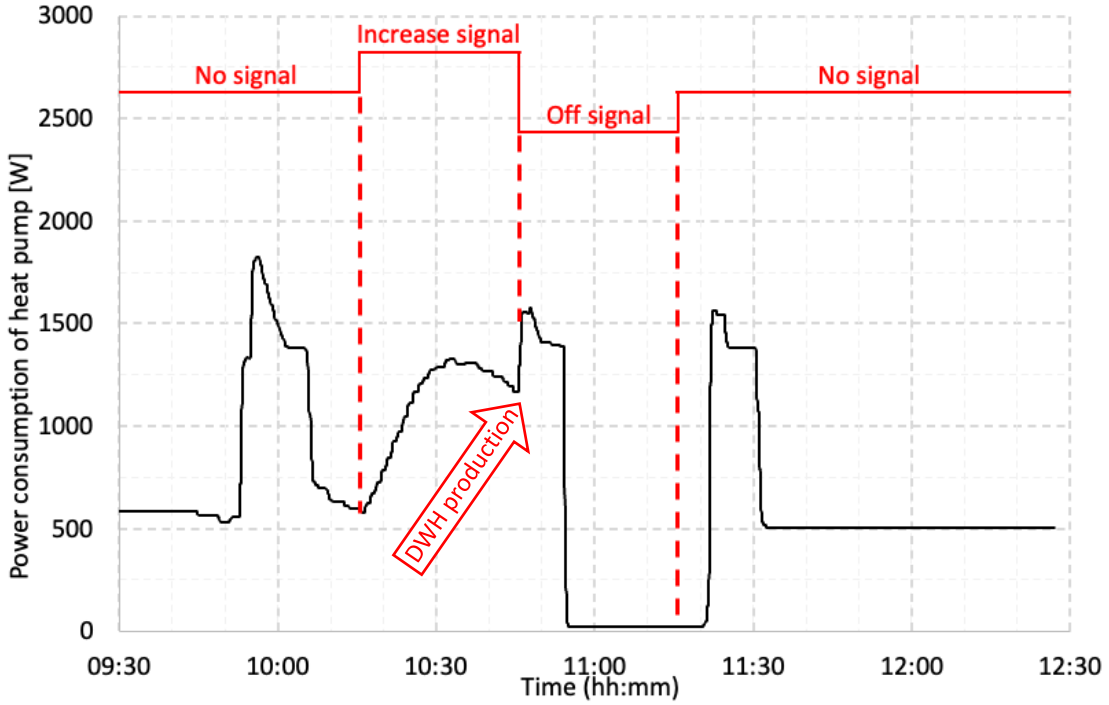
We could

- **instantaneously turn off all heat pumps**
- **keep them turned off as long as we wanted**

But

- **there will be an increased need for heat afterwards – might need to be controlled not to cause new problems in the power system**

Field tests



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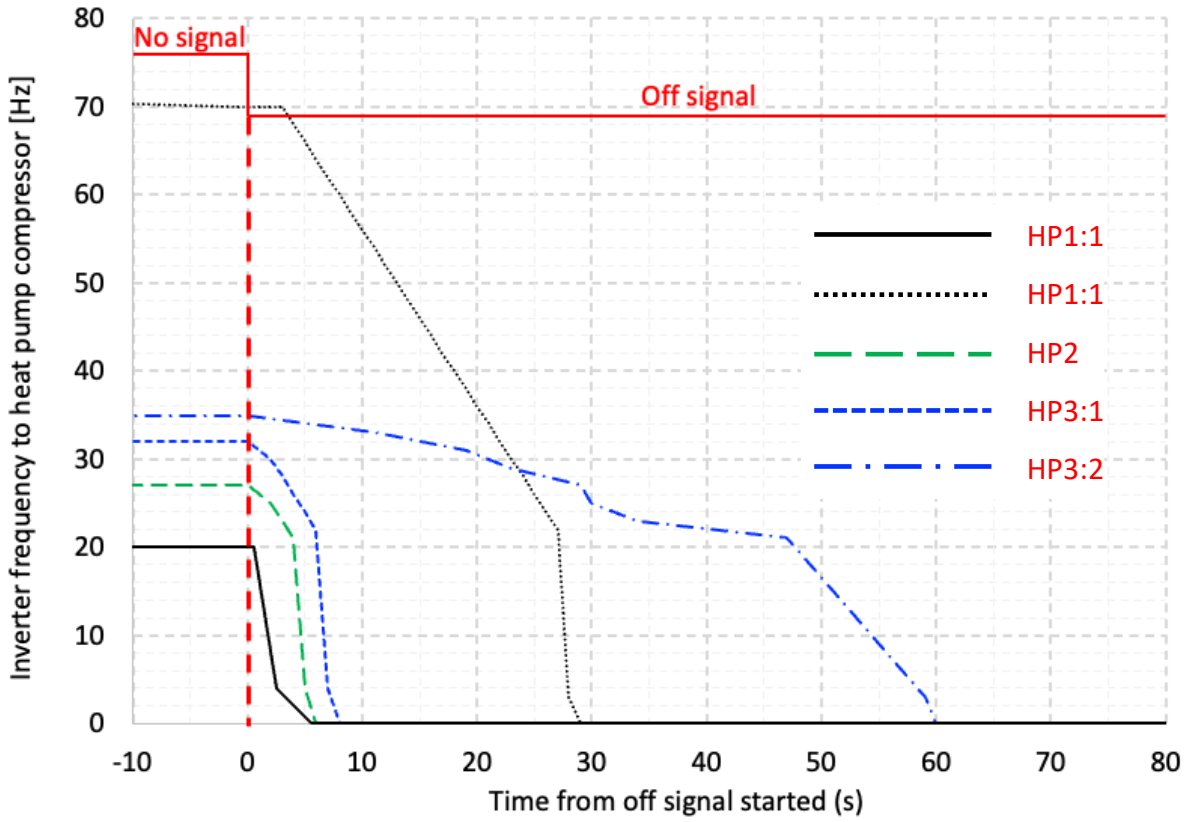
But

- **there will be an increased need for heat afterwards – might need to be controlled not to cause new problems in the power system**
- **DHW needs to be controlled!**

Field tests



Zoom in on turning off

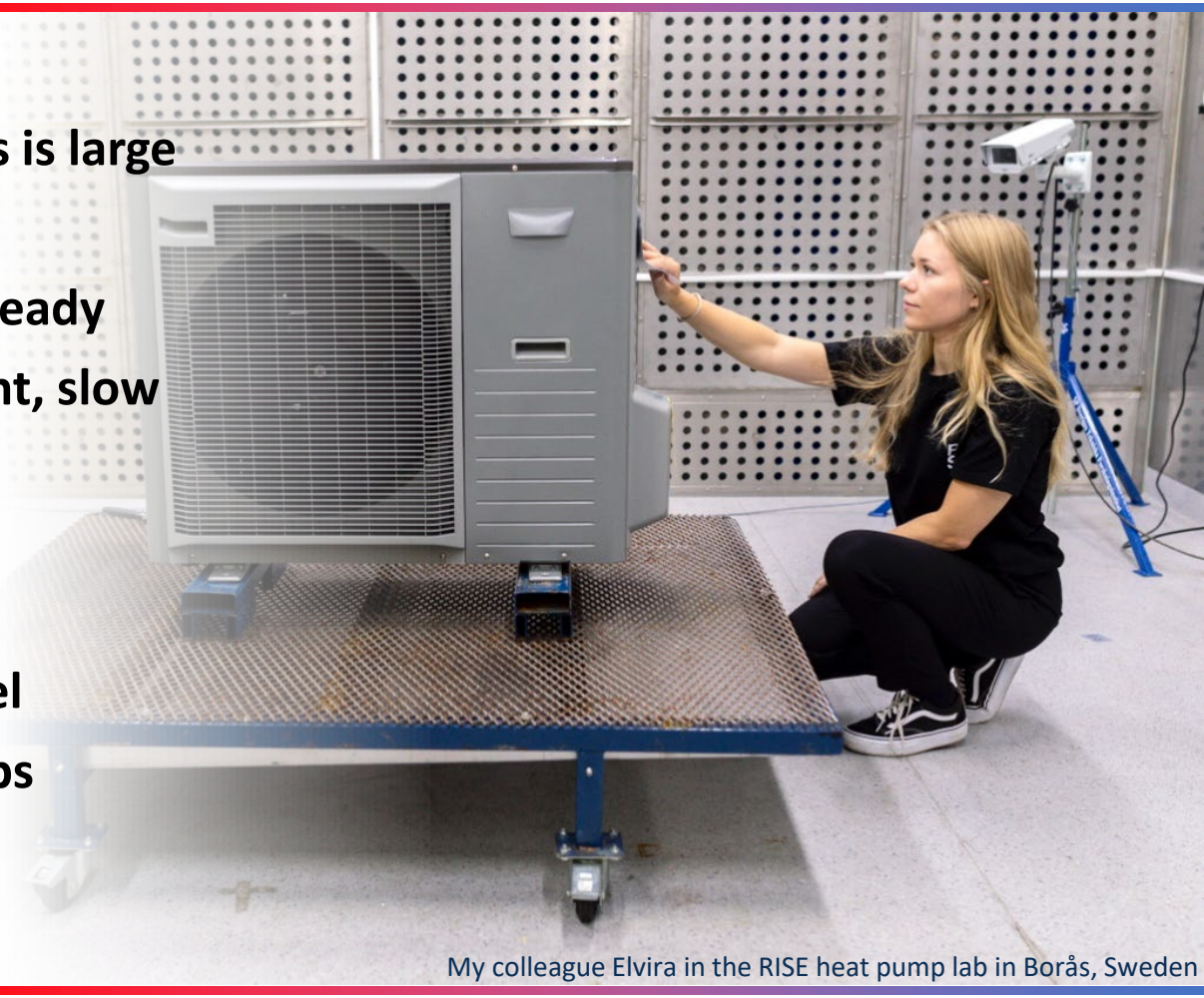
- **compressor off within 10 seconds in most case**
- **higher start frequency means longer stop time**

This means

- **stopping (NIBE) variable speed control compressor cannot meet demand from the two fastest TSO ancillary services (aFFR and FCR-D up/down) without significant changes**
- **signaling through internet could further delay stopping the compressor**

Summary

- **The potential of already existing and new heat pumps is large**
- **No additional equipment needed**
- **Many obstacles in the power system – market is not ready**
- **Heat pumps can be controlled rapidly – to some extent, slow in some cases**
- **Accuracy in measurement is low to medium**
- **Communication protocols not ready for use**
- **Significant cyber security risks – even on national level**
- **Functionality tested – API works to control heat pumps**



My colleague Elvira in the RISE heat pump lab in Borås, Sweden

Thank you!

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