DTU

Seminar on Digitalization of Refrigeration and Heat Pump Systems, DTI, 04-07-2024

# Heat pumps providing flexibility services - the role of model-based tools

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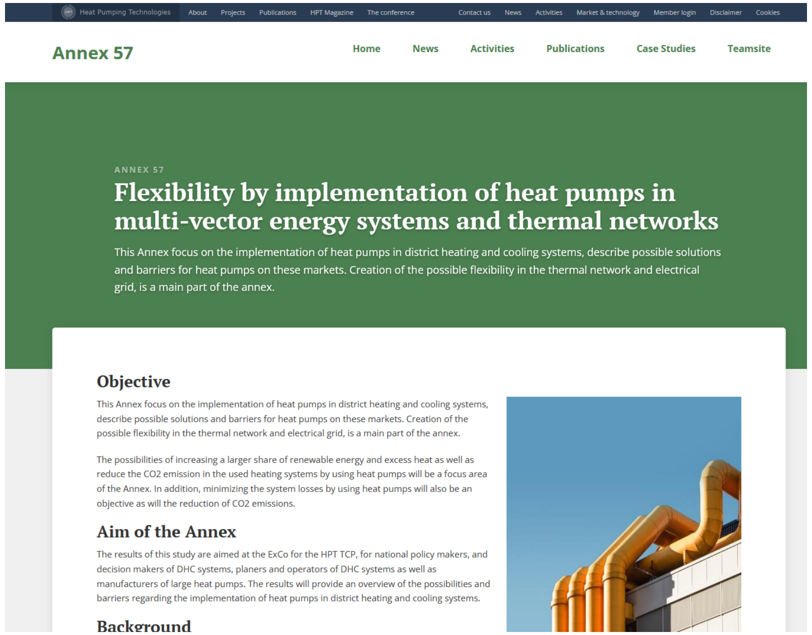
# Agenda

- What do we mean by flexibility and why do we talk about it?
- How can heat pumps provide flexibility?
- What are the barriers?
- What is the role of model – based tools?



# What do we mean by flexibility?

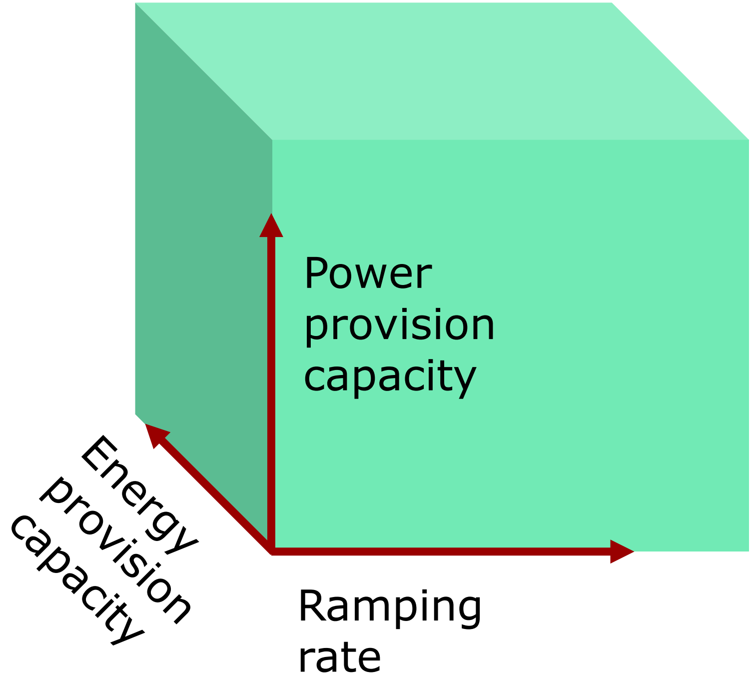
**Thermal flexibility**

- Adaption of heat uptake or heat output
- Adaption of delivered temperatures

**Electric flexibility**

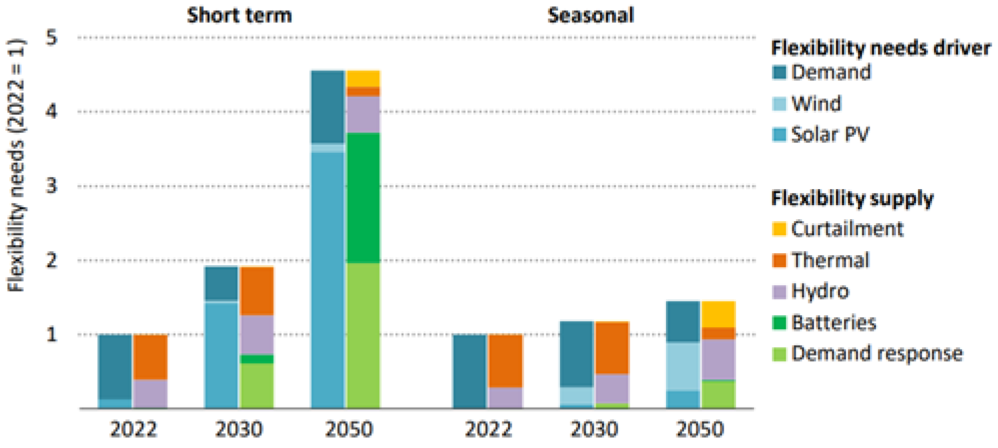
Capability to adapt the consumed electricity at a defined node in the grid

Short-term | Mid-term | Long-term




Adapted from: Ulbig A, Andersson G. Analyzing operational flexibility of electric power systems. Int J Electr Power Energy Syst 2015;72:155e64. https://doi.org/10.1016/j.ijepes.2015.02.028.

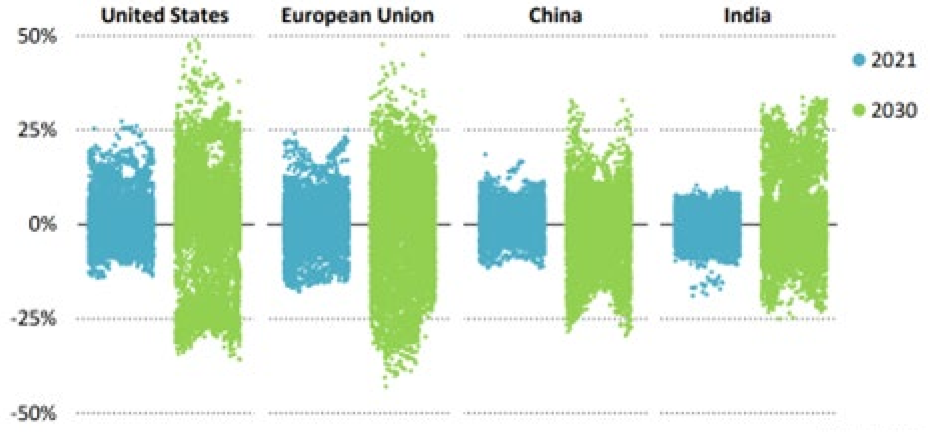
# Need for electric flexibility






*Short-term needs increase significantly, mainly due to solar PV, with batteries and demand response emerging as crucial suppliers of flexibility; seasonal needs rise less sharply*

Notes: Flexibility needs are computed for 2030 and 2050 taking into account changes in electricity supply and demand and weather variability over 30 historical years. Demand response includes the flexible operation of electrolysers.






*Hour-to-hour flexibility needs rise significantly by 2030 in major markets, driven by increasing shares of variable renewables and changes in demand patterns*

Note: Flexibility needs are represented by the hour-to-hour ramping requirements after removing hourly wind and solar PV production from hourly electricity demand, divided by the average hourly demand for the year.

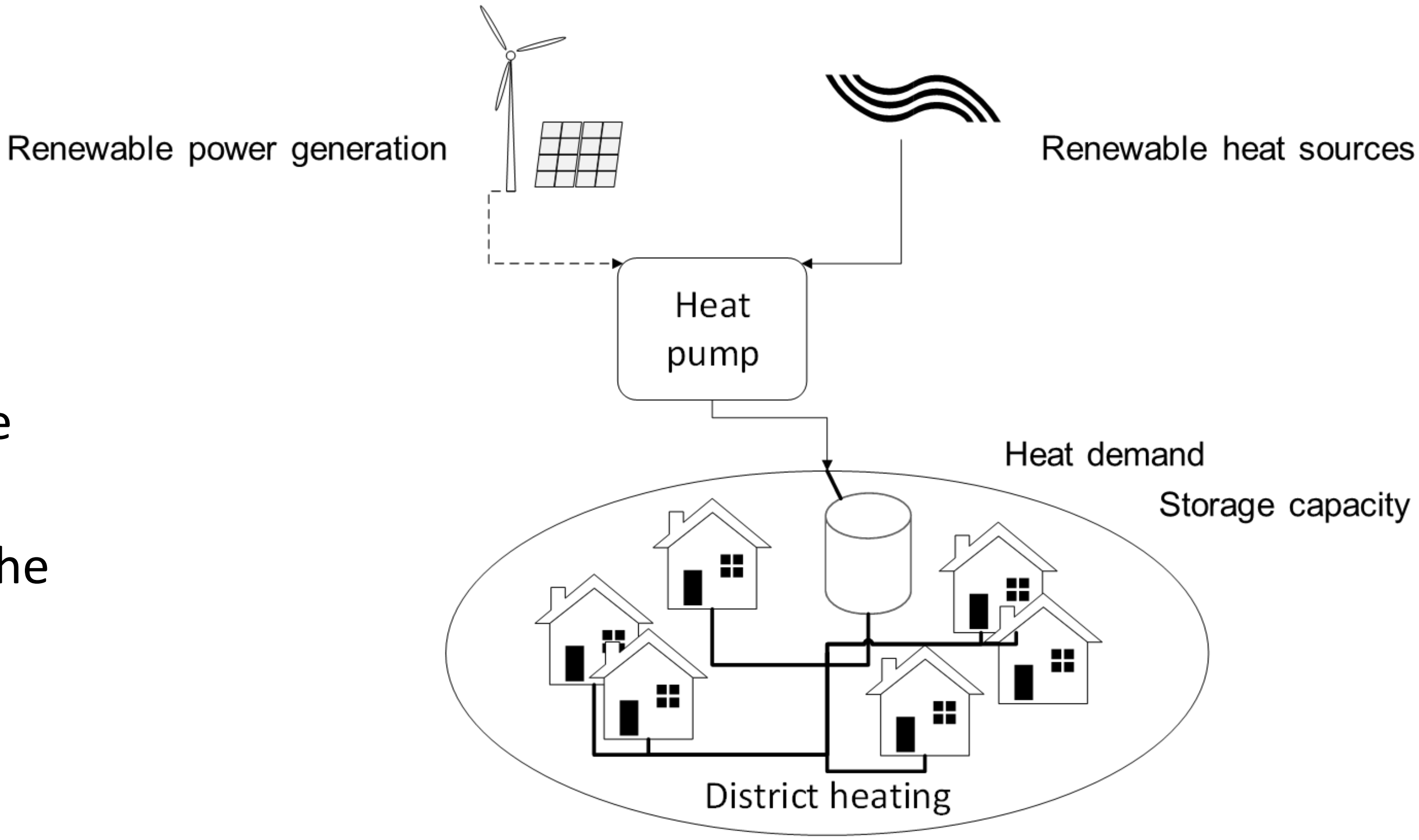
Source: IEA World Energy Outlook 2023

# How can heat pumps provide flexibility?

**Large-scale**: Here, centralized heat pumps in thermal grids

## Requirements

- Integration with thermal storage
- Efficient part-load operation
- Higher number of starts- and stops
- Fast reaction time (dependent on the service)
- Measurement and direct control of the power uptake



# Flexibility services to the power grid

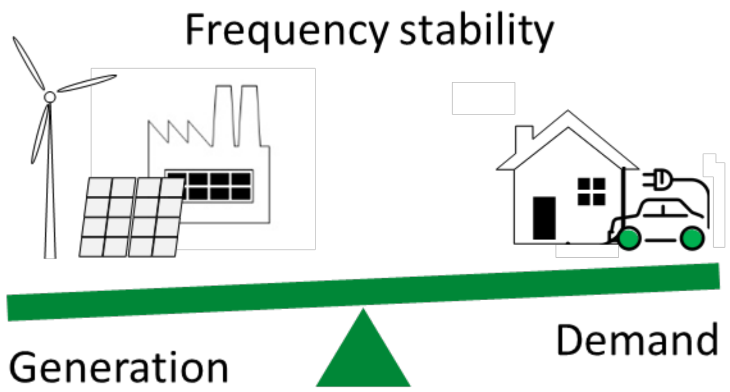
## Implicit flexibility

- **Variable electricity price**
- **Variable grid tariffs**

## Explicit flexibility

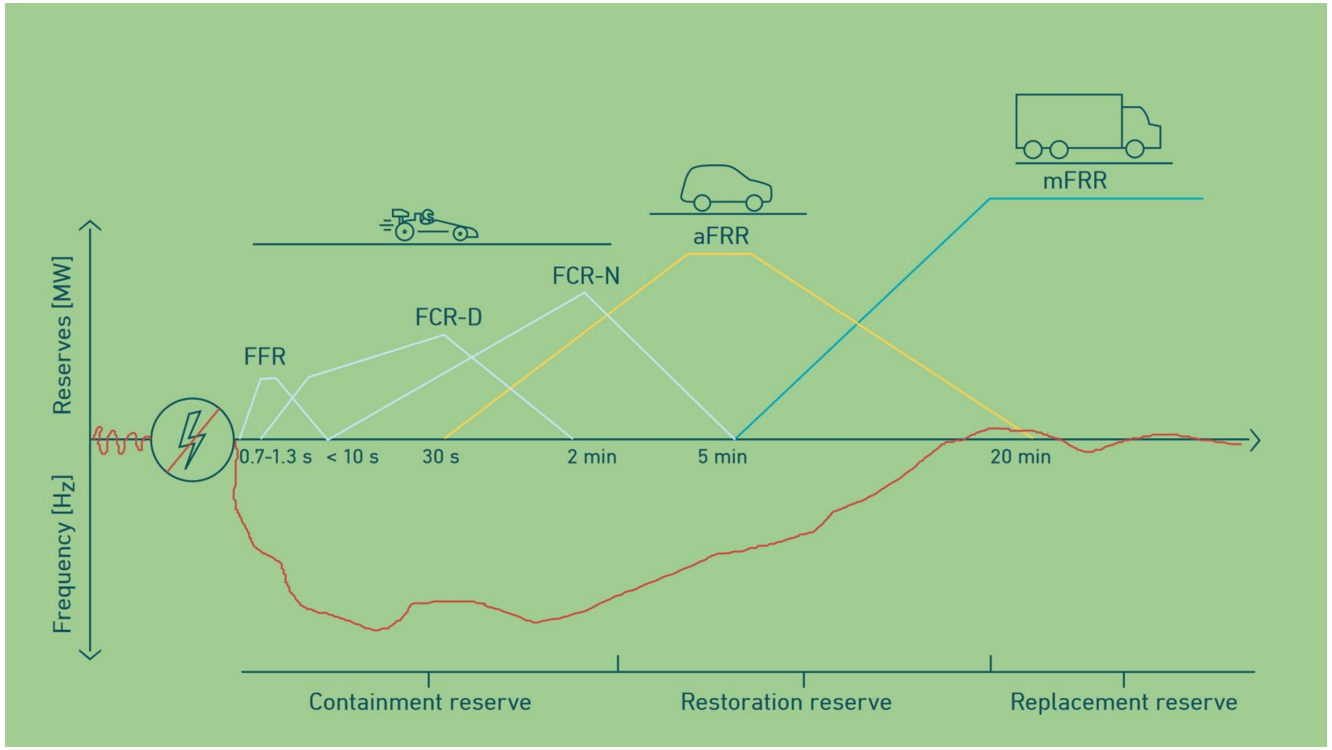
| Bilateral agreements | TSO ancillary services | Local flexibility market | Conditional agreements |
|---|---|---|---|
| Directly procured flexibility | Balance services, bids are activated upon calls | Flexibility market, bids are activated upon calls | Agreement with customer to adjust the power consumption when necessary |

# Services to the transmission system operator (TSO)




**Energy markets**
Day-ahead market
Intra-day market
Balancing market

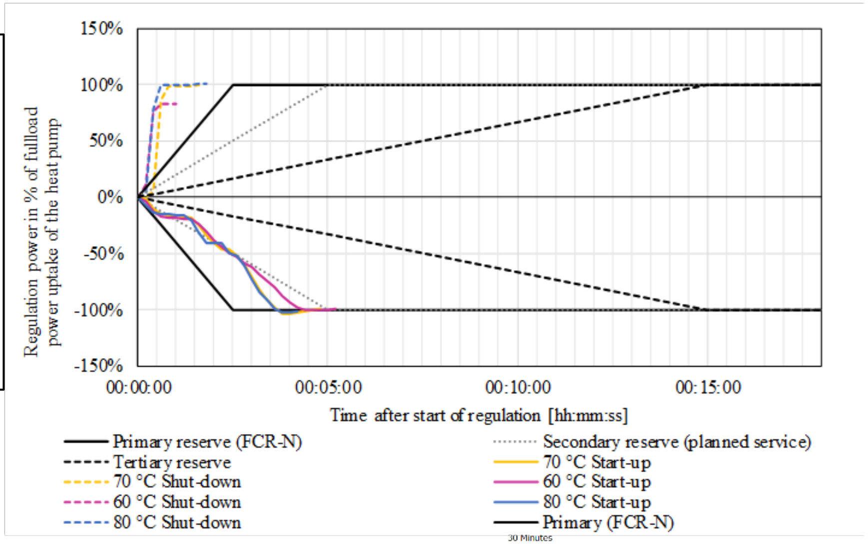
**Ancillary services**

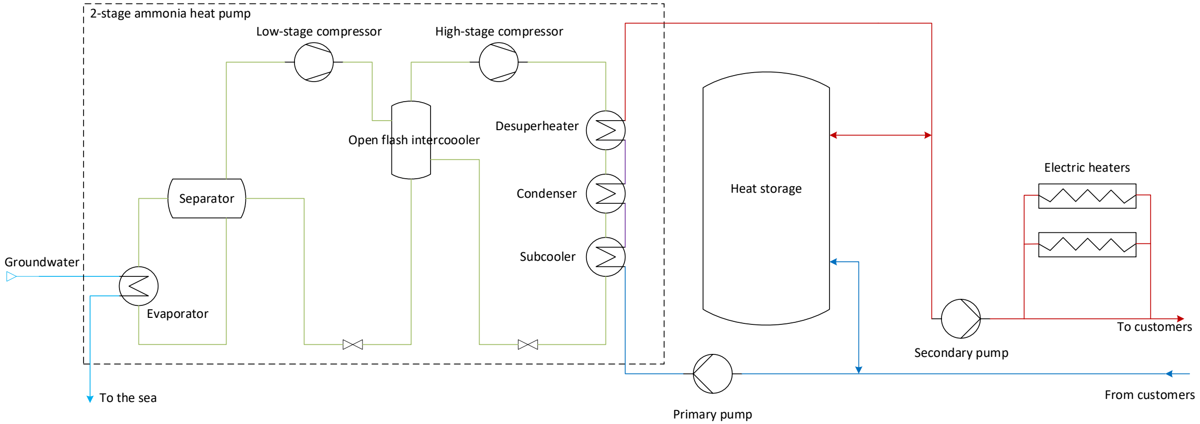


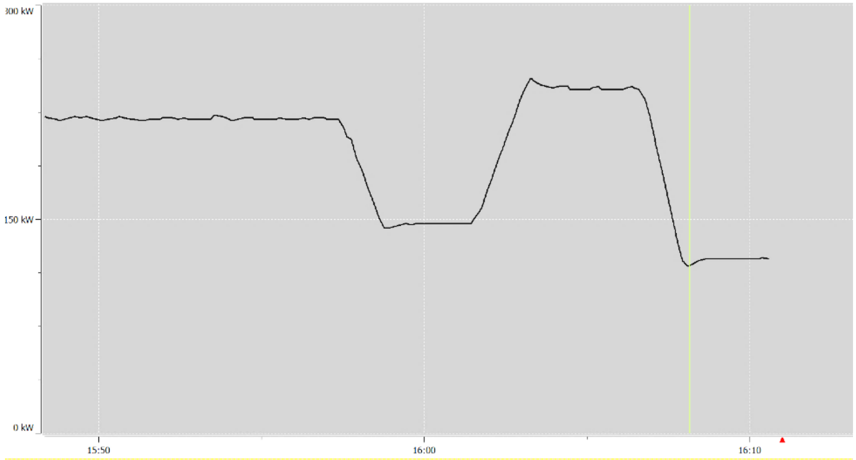

Source: Energinet (2023). Outlook for ancillary services 2023-2040

# Example 1: FlexHeat, Copenhagen, DK

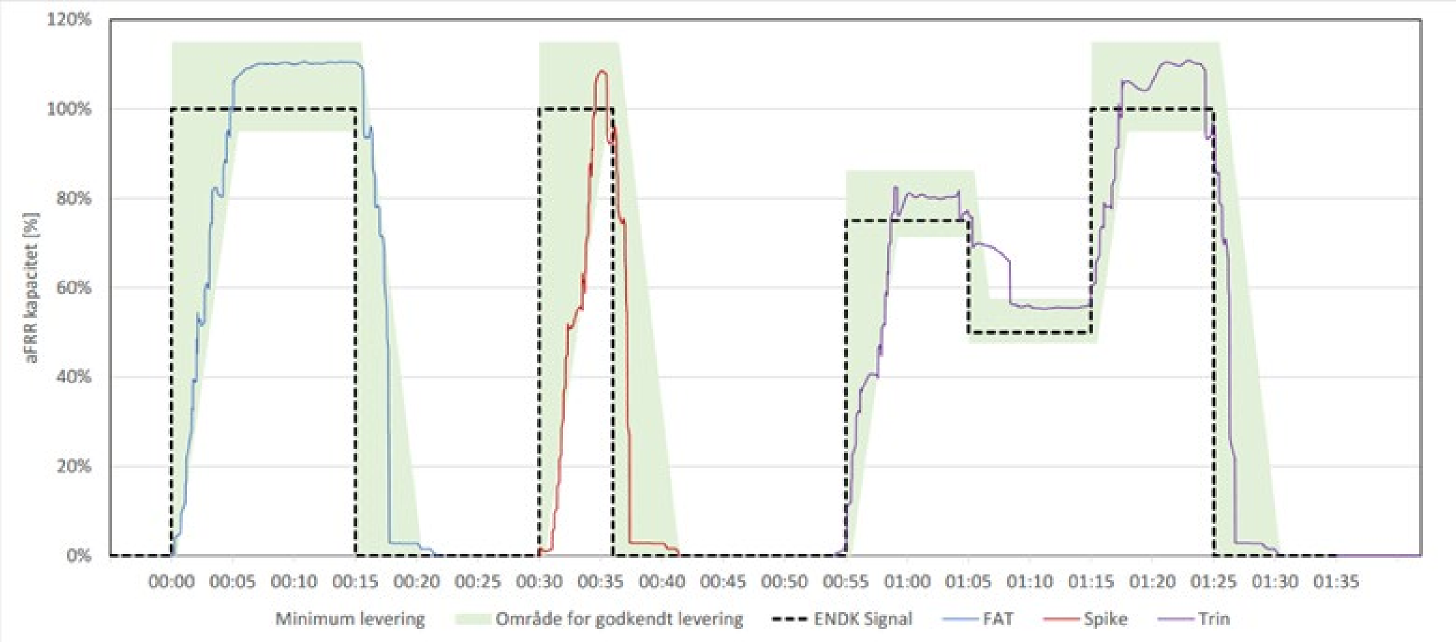
- 2-stage ammonia heat pump
- 800 kW thermal
- DH supply: 60-84 ℃
- Part-load: 20-100 %



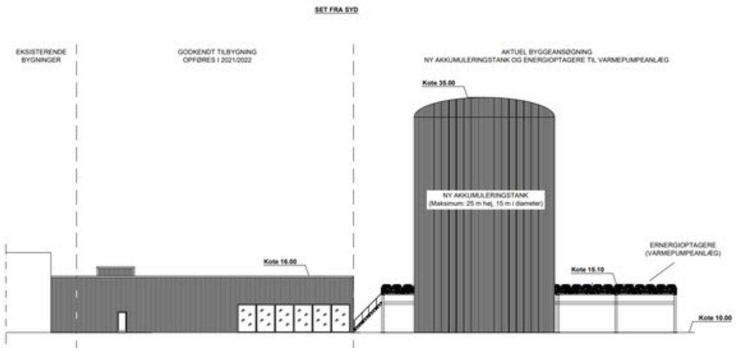



# Example 2: CO2 heat pump in Søndre Felding, DK



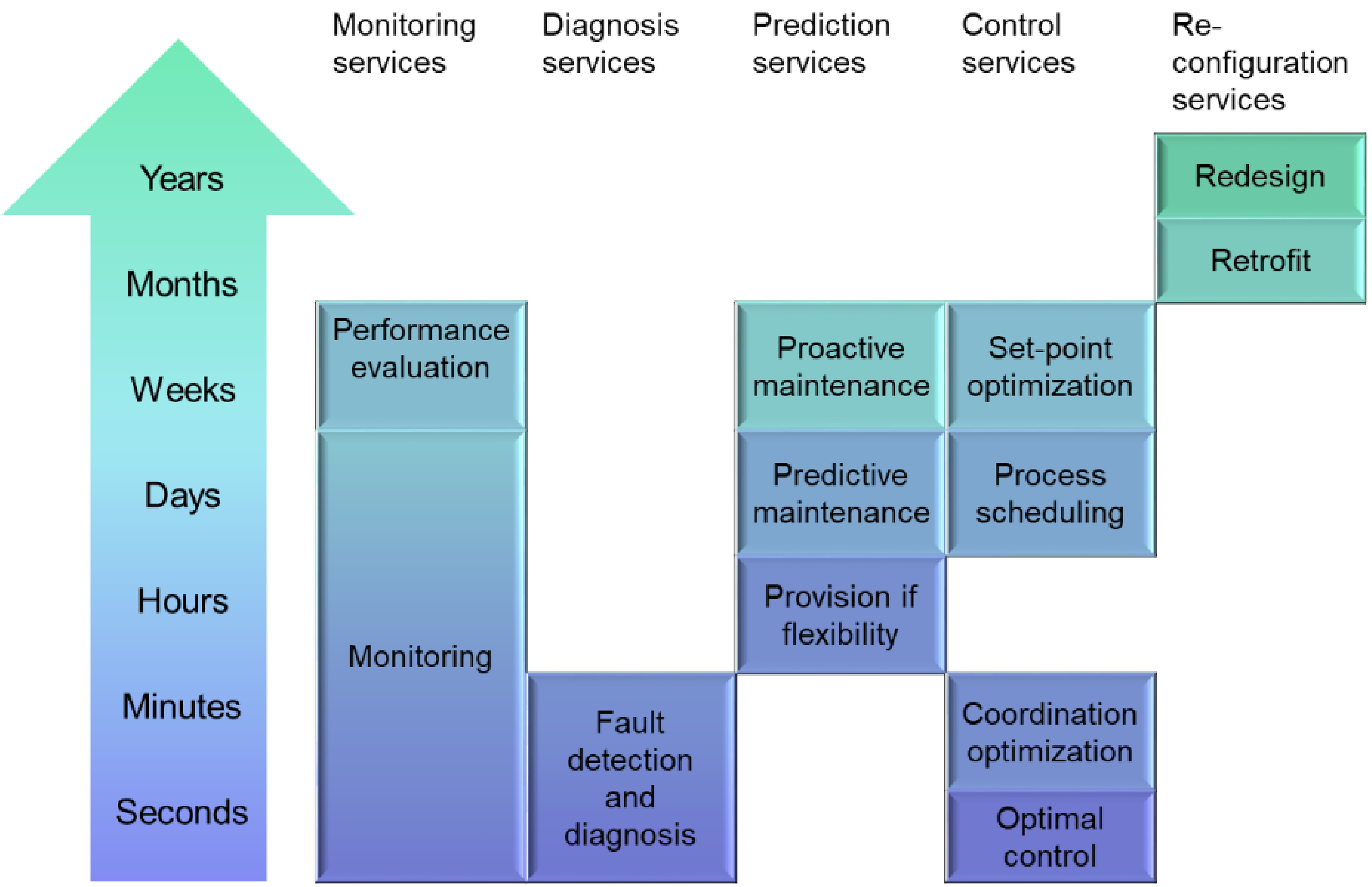

- $CO_2$ Heat pump
- Multiple parallel compressors
- 3.3 MW thermal
- Source: Ambient air



# What are the barriers?

- Ramping times
- No direct measurement and control of power uptake
- Communication and aggregation
- Coordination with neighbouring systems
- Lack of experience
- Add-on service vs. system design requirements

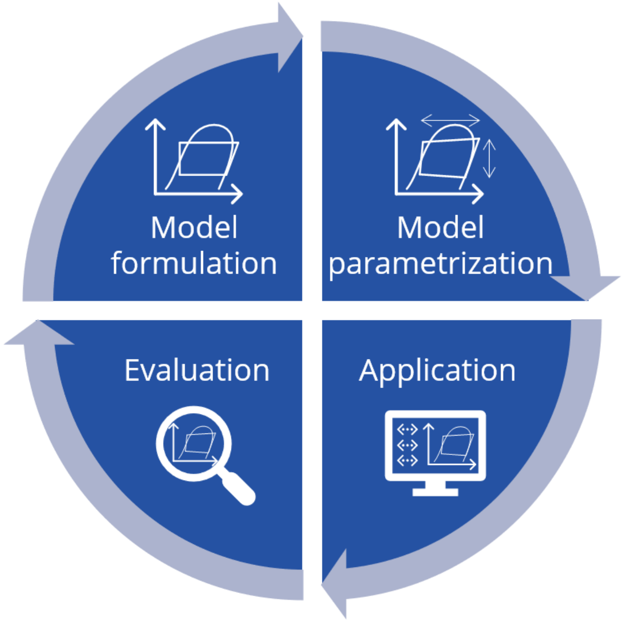
# Model-based tools supporting flexible operation of heat pumps



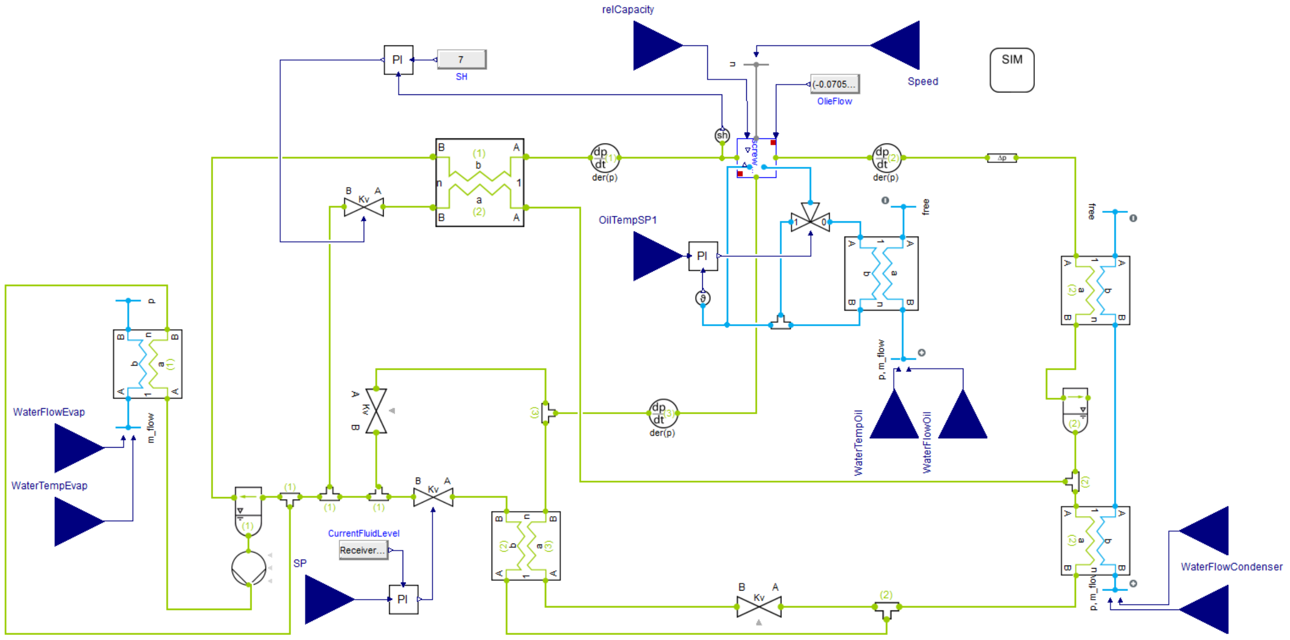

- Design and control optimization using dynamic models
- Monitoring: Current “flexibility potential” and “cost of flexibility”
- Process scheduling: when should the service act on which market
- Control: Adaption of control signal to ensure the desired flexible load adaption
- Coordination with neighbouring systems (secondary streams, industrial processes, storages, etc.)
- …

# Example: DEVELOPMENT OF FAST REGULATING HEAT PUMPS USING DYNAMIC MODELS, EUDP

Modelling procedure:




- Challenge
  - Screw compressor
  - PI-controller
  - Thermosyphon

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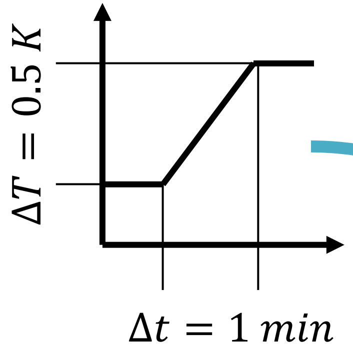
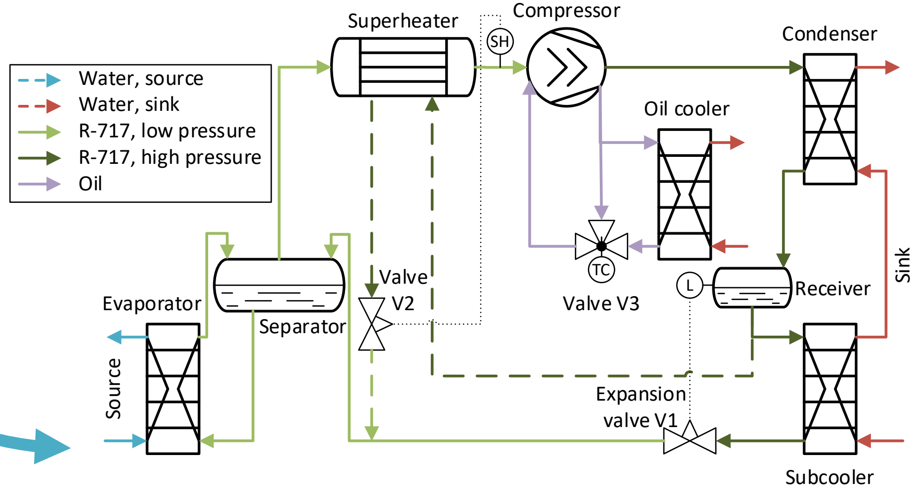
Johnson Controls

# Experiments




- ❑ Response of pressure levels
- ❑ Response of superheating in suction line
- ❑ Risk of liquid floodback (indicator: gasvelocity in separator)

Use of validated dynamic models to optimize system control taking secondary streams into account

Optimization of system design regarding the dynamic behaviour of the system

# Perspectives

Already today

- The need for ancillary services from demand side units is increasing
- Heat pumps can react within seconds to minutes
- Heat pumps offer connection to a large energy storage capacity
- Manufacturers begin to take the required flexibility and robust operation under dynamic conditions into account when designing new systems

Future developments and open questions

- Coordination of heat pump control with neighbouring systems
- Digital services targeting flexible operation (scheduling, monitoring,…)

# Teaser: Digital Heat Pump Lab at DTU Construct

Digital
Heat Pump
Lab

- Vision: A place where research and education meet, targeting both the need for digital solutions and for skilled graduates
- State-of-the art laboratory for small-scale heat pumps enabling real time interaction between models and units
- Expected start of operation: August 2025

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Thank you ☺

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