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Model-based fault detection for use in digital twins of large-scale heat pump systems

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Benjamin Zühlsdorf – Danish Technological Institute
Wiebke Meesenburg, Brian Elmegaard – Technical University of Denmark

bez@teknologisk.dk, +45 7220 1258

Agenda

- Project outline
- Heat pumps in integrated energy systems
- Digital twin-based services
- Modelling approaches
- Model-based monitoring and fault detection
- Conclusions and outlook

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Digital twins for large-scale heat pump and refrigeration systems

Motivation

Enhanced services through digital twins

Monitoring | Fault detection/diagnosis | Optimized operation

Objectives

Reducing the effort for creating digital twins

Improved services and better exploitation of potentials

Approach

Developing reusable, modular and self-learning models

Developing advanced methods for system analysis

Project facts

02/2020 – 01/2024 | EUDP Project

Budget: 18.6 mio. DKK | 8 Partners

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DTU

Technische Universität Braunschweig

Danfoss

AFFALDVARME AARHUS

TLK-Thermo GmbH

AK CENTRALEN

Superkøl A/S

www.digitaltwins4hprs.dk

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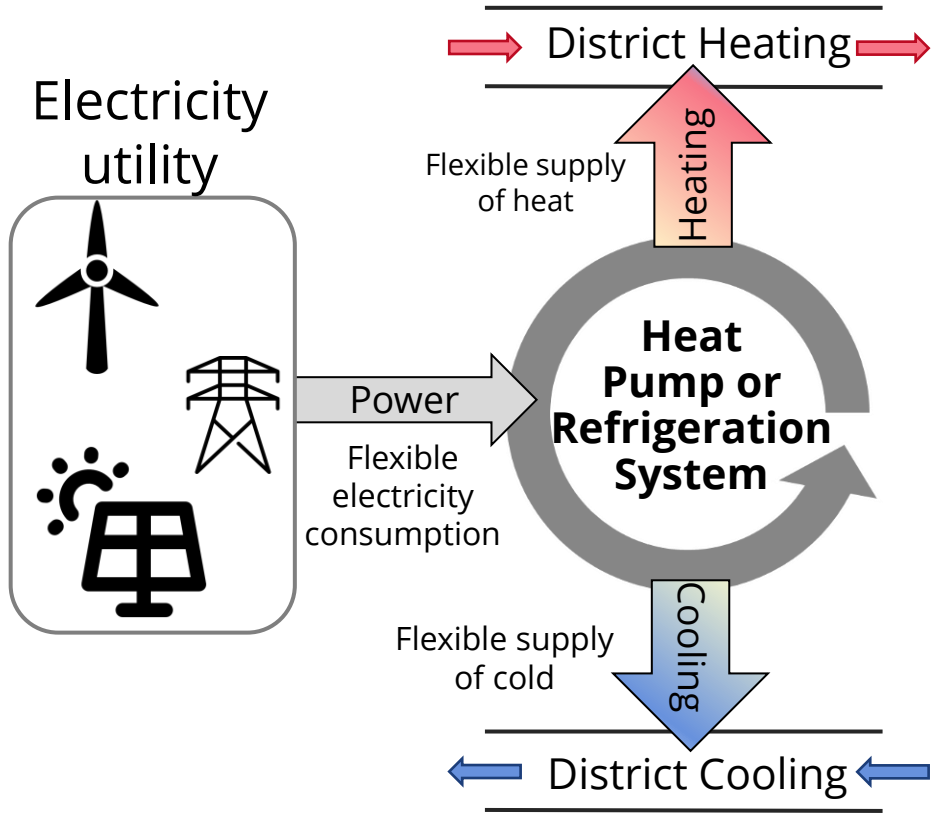
Heat pumps in integrated energy systems

- Key-components in integrated systems
- Delivery of multiple services
- Varying operating conditions

- High **performance** and **reliability** are crucial



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Digital twin-based services

Advanced system monitoring

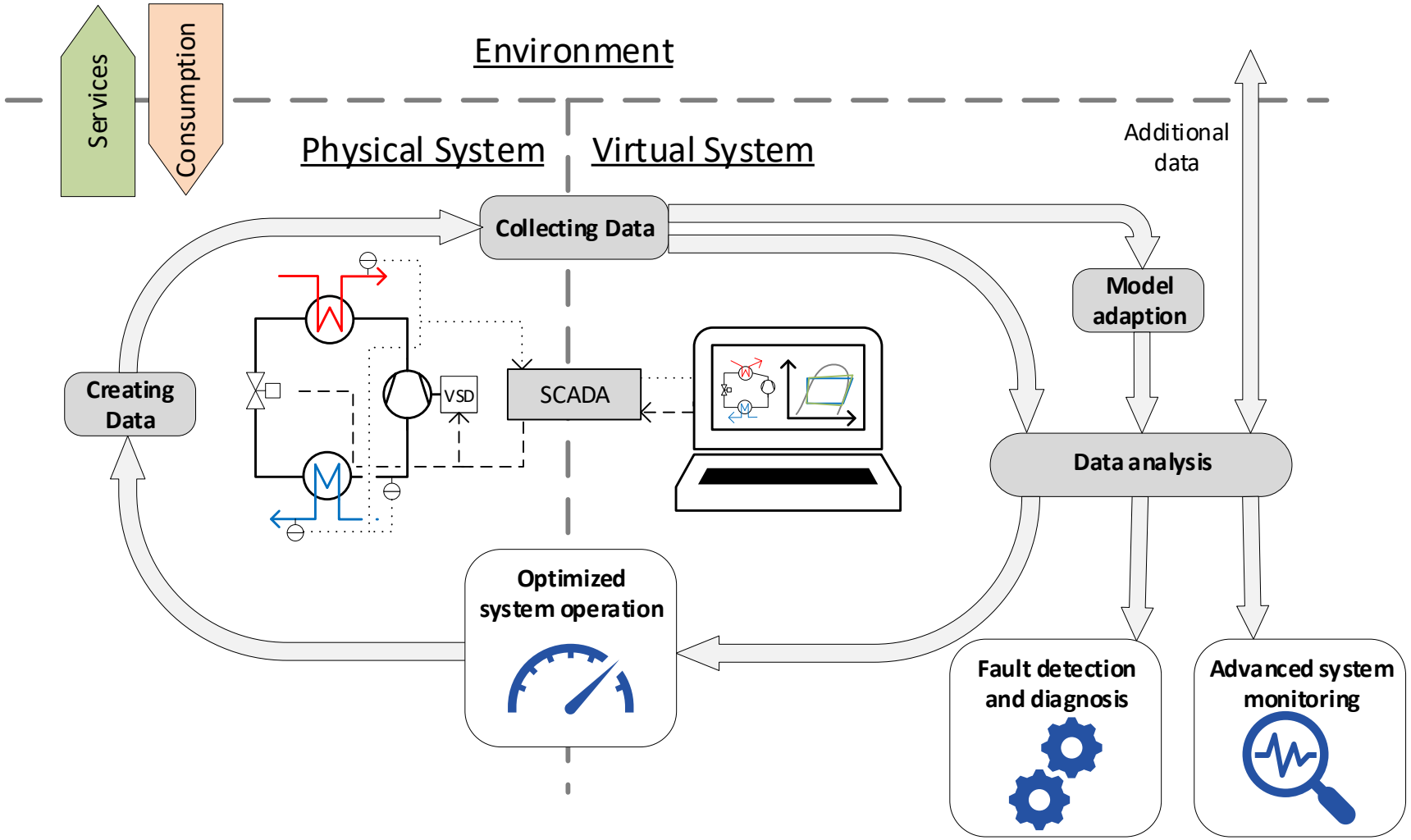
- Analysis of functionality and performance
- Performance benchmarking
- Validity check
- Soft sensors

Fault detection and diagnosis

- Fault mechanism monitoring incl. early-stage warning and predictive maintenance
- Model-based interpretation of system alerts

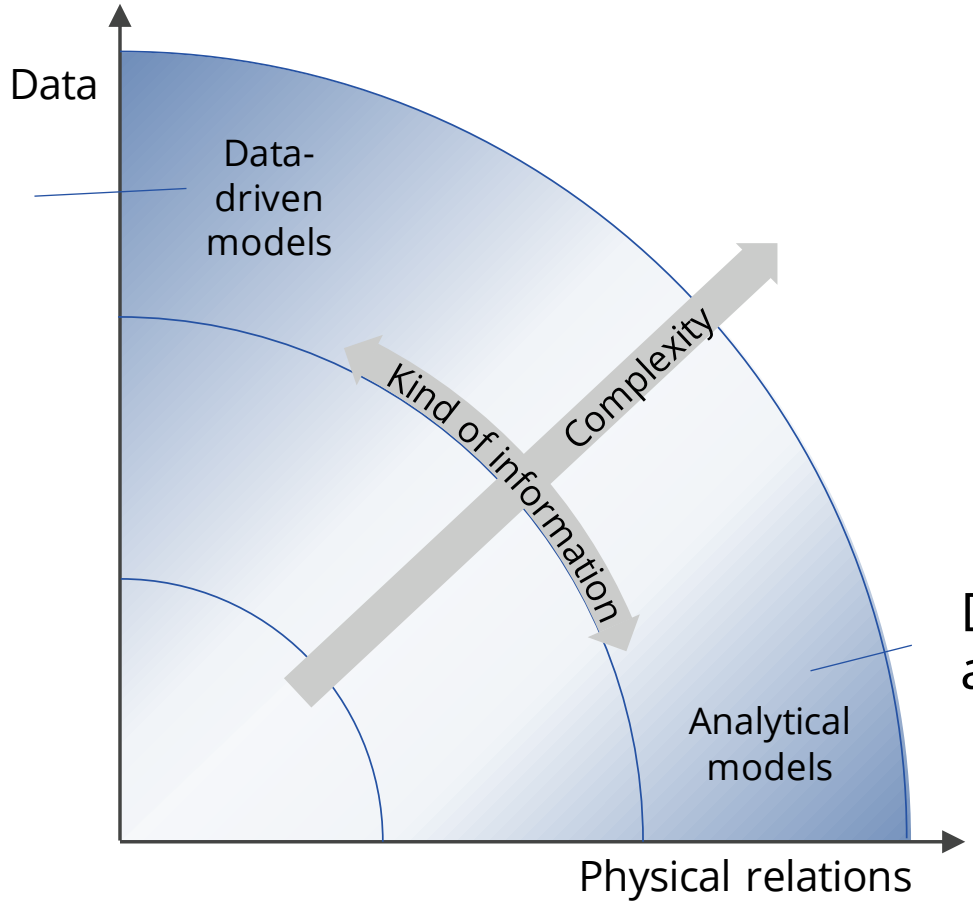
Optimized system operation

- Continuous set-point tuning
- Scheduling of production and downtimes


Environment
Services
Consumption
Physical System
Virtual System
Additional data
Collecting Data
Model adaption
Creating Data
VSD
SCADA
Data analysis
Optimized system operation
Fault detection and diagnosis
Advanced system monitoring

Modelling approaches

Description of uncertain and unknown phenomena



Model characteristics
- Reusable
- Modular
- Self-learning

→ Reduced effort

Description of well known and quantifiable phenomena

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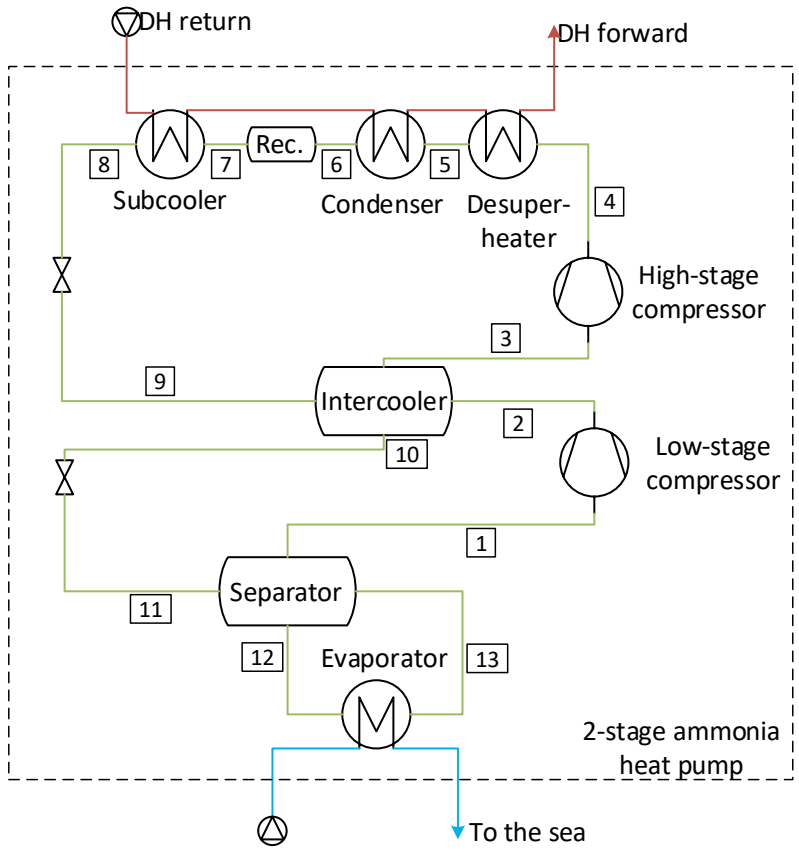
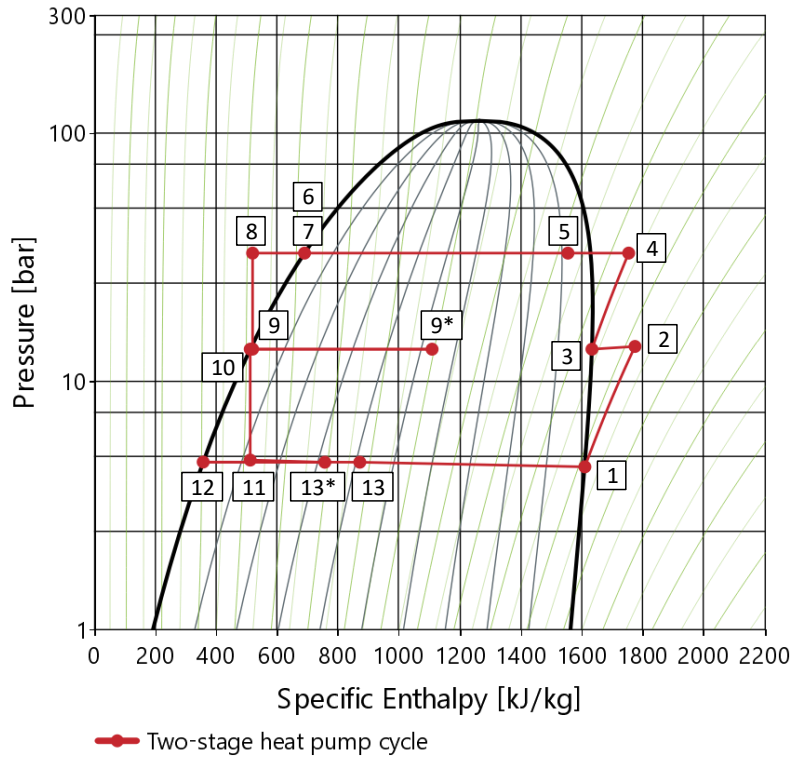
Analytical heat pump model

Example:

- 2-stage ammonia HP
- Piston compressors
- Validation with measurement data





Reference: W. Meesenburg, 2020, "Heat pumps supplying district heating and ancillary services for the power system", PhD Thesis

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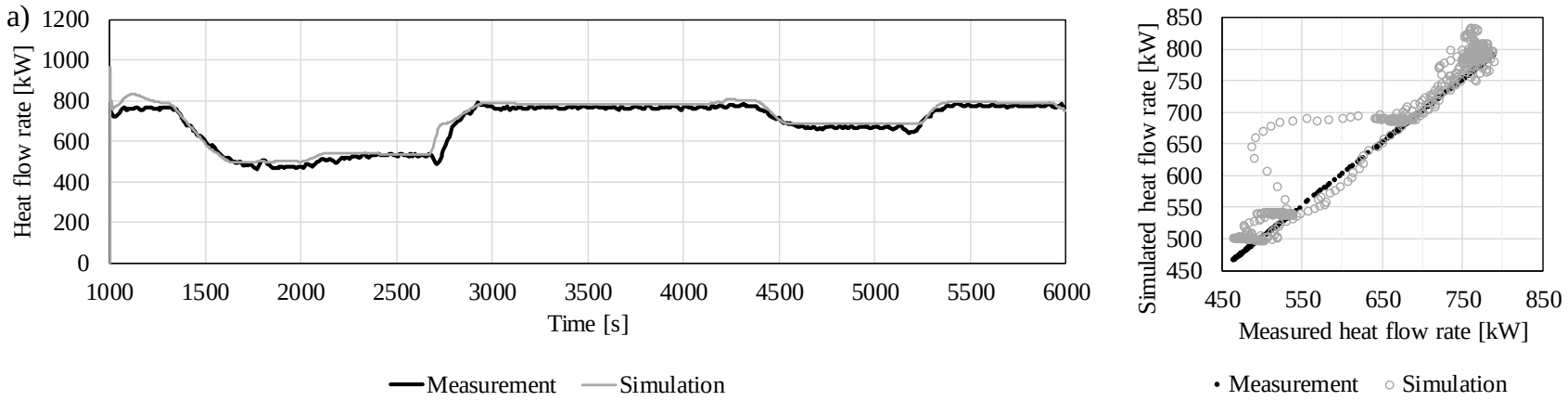
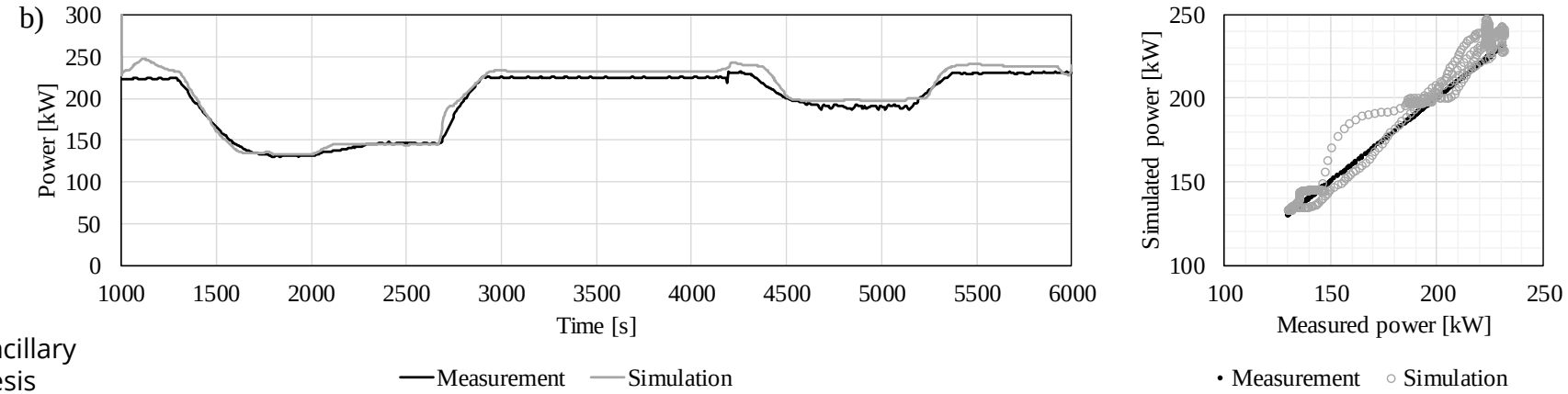
Analytical heat pump model - validation

Heat flow rate (supplied to DH)



Accumulated power uptake



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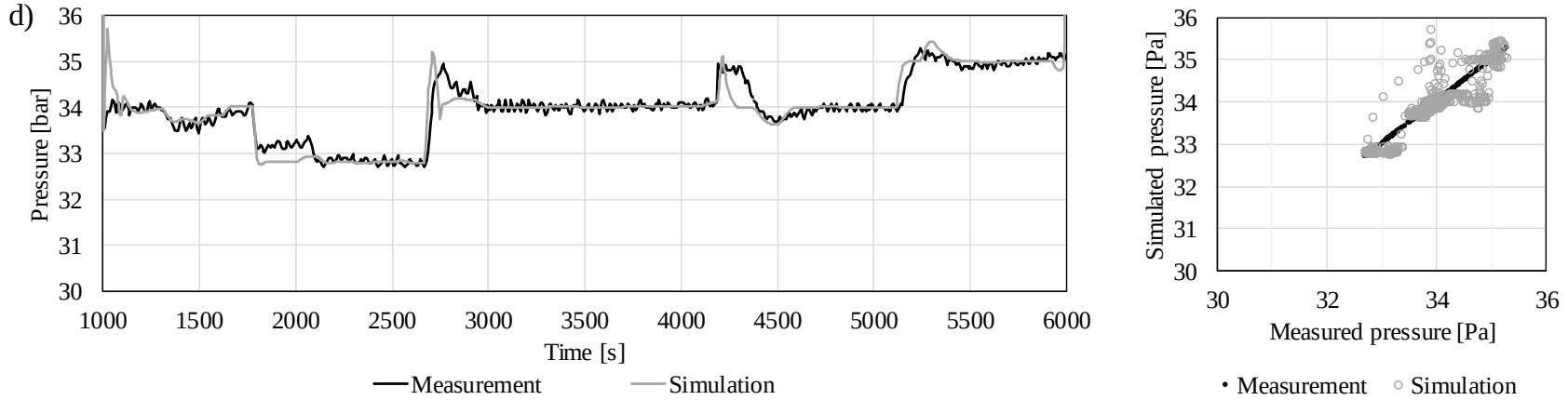
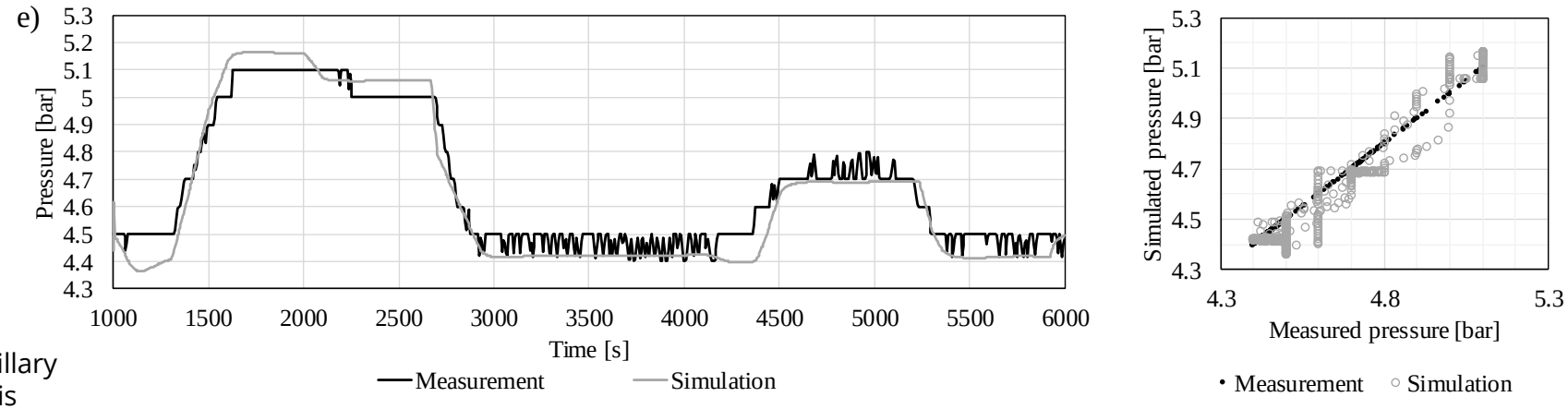
Analytical heat pump model - validation

Condensation pressure



Evaporation pressure



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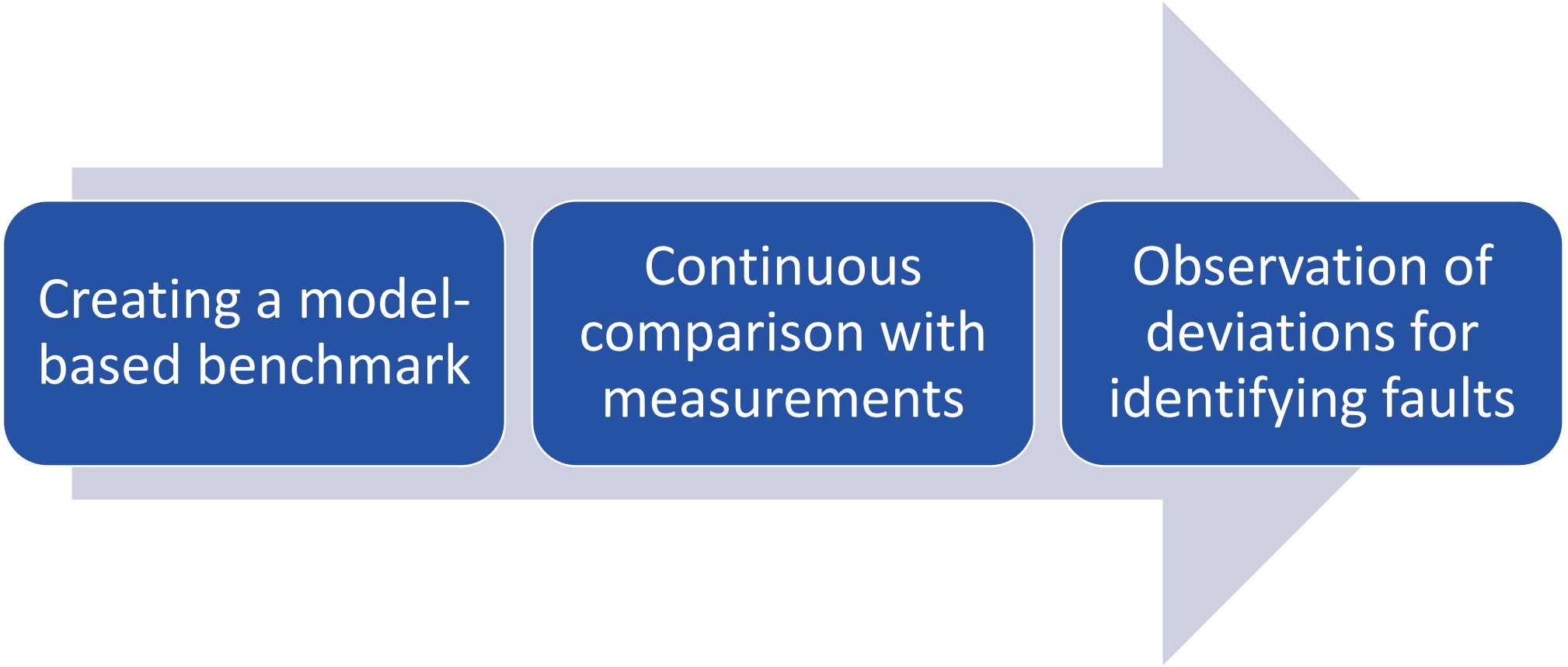
Model-based fault detection



Conclusions and Outlook

- Large-scale HP systems are key-components in integrated energy systems, where high performance and reliability are crucial
- Monitoring, fault detection and diagnosis and set-point optimization are promising services
- Hybrid modelling implies the possibility to model sophisticated models for wide range of applications at low implementation effort
- Analytical models were found to be promising for providing a benchmark

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Thank you very much for your attention!

Questions or comments? Please reach out by mail or phone!

Benjamin Zühlsdorf
Consultant, PhD
bez@dti.dk, +45 7220 1258
Danish Technological Institute – Energy and Climate

EUDP

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