ADVANCED DATA ANALYTICS FOR FAULT DETECTION AND OPTIMIZED OPERATION IN DISTRICT ENERGY CONCEPTS

On the use of semantics, machine learning and optimization

Nicolas Réhault

Fraunhofer-Institut für Solare Energiesysteme ISE

ACA-MODES Workshop

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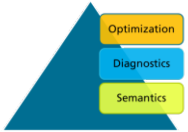
Current situation

Transformation of energy supply systems for districts

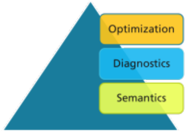


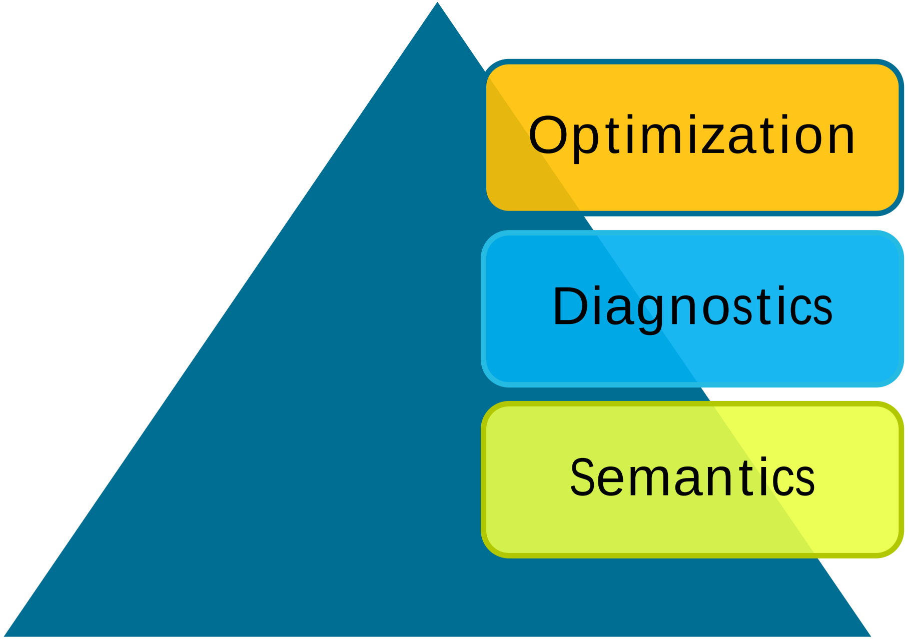
- Raising complexity of energy supply infrastructures
- Limited manpower for the operation phase of buildings and districts
- Need for new concepts for energy optimized districts enabling:
  - the integration of a high amount of local renewable energy
  - interactions between people, buildings and heating and power networks

We need digital methods to increase the degree of automation in the operational management of buildings

Digital methods for energy optimized buildings and districts

Enabling smartness





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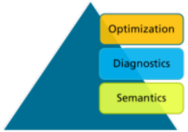
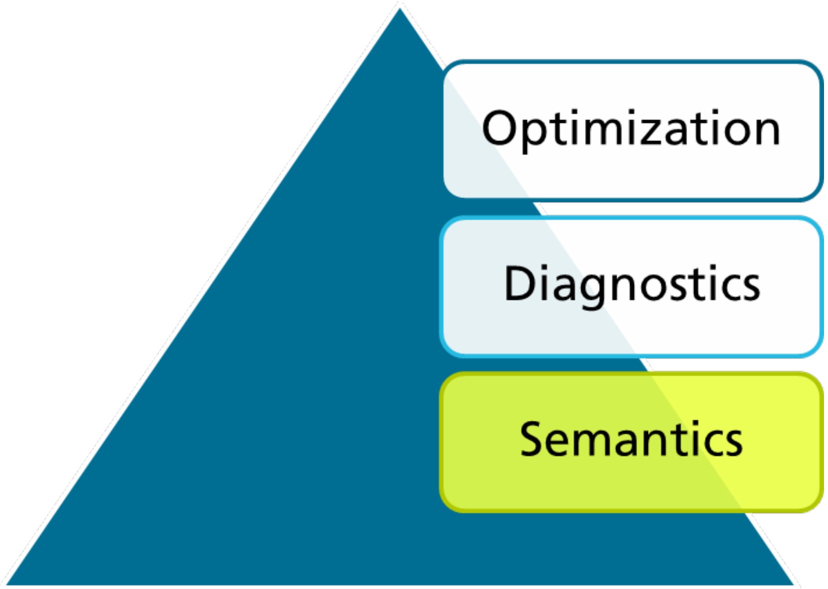
Digital methods for energy optimized buildings and districts



Enabling smartness



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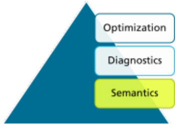
Semantic interoperability

Foundation to take benefit of data



- Data amount and availability in buildings are steadily increasing
- Ideally, this data should be structured on the basis of standardized data models:
  - to interoperate heterogeneous applications
  - to process data automatically
- In reality:
  - It often looks like that:

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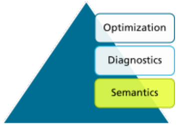
Optimization
Diagnostics
Semantics

Semantic interoperability

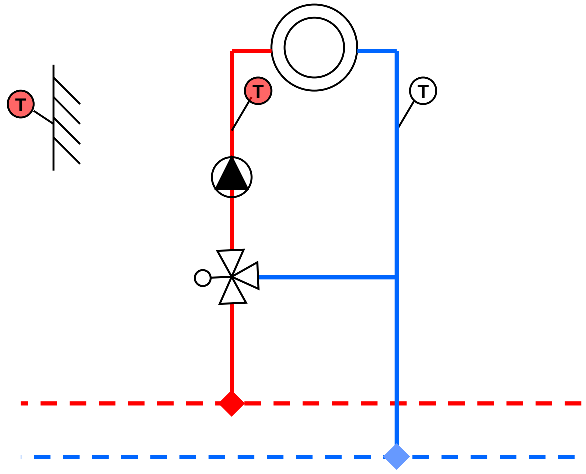
Solution pathways



- Unified semantics as base to cope with existing systems and to automate analysis
- Enable the usage of BIM and Ontologies

➢ Labeling of systems

1. **Building**
2. **Zone**
3. **System**
4. **Subsystem_1**
5. **Subsystem_2**
6. **Medium**
7. **Position**
8. **Kind**
9. **Datapoint**



Available data points:

BUI_WERK_WTH____OA__MEA_T

BUI_WERK_WC.H___HW_SUP.SEC_MEA_T

BUI_WERK_WC.H___HW_RET.SEC_MEA_T

BUI_WERK_WC.H.NO_PU__HW_SUP.SEC_SIG_CTRLSIG

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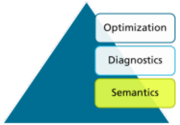
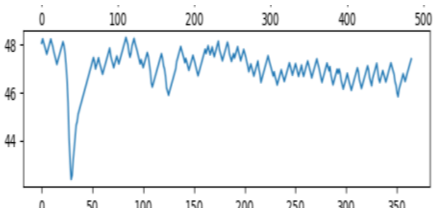
Semantic interoperability

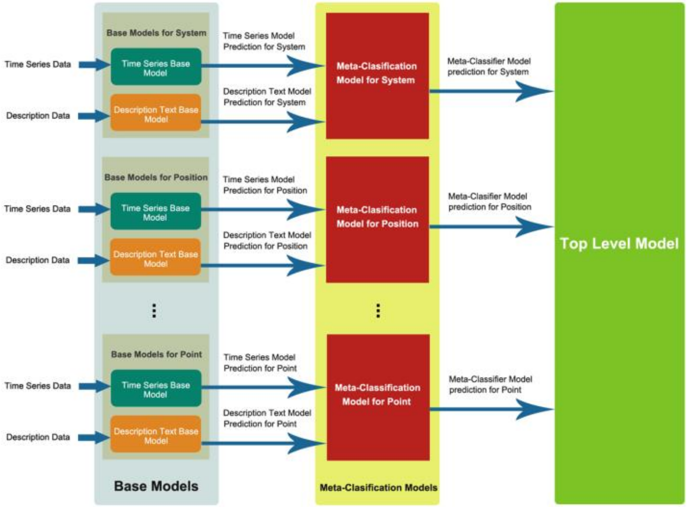
Solution pathways



- Automated identification of sensor types through meta data inference

VL-Temperatur HK-Z1





BUI_WERK_WC.H___HW_SUP.SEC_MEA_T

Combined Machine learning architecture

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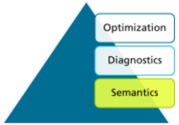
Semantic interoperability

Solution pathways



- Semantics as base for automatization

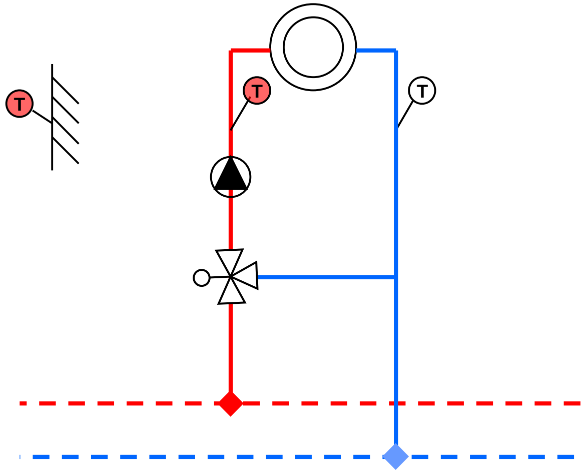
➢ Automatically trigger simple checking rules

$$T_{SUP,PuON} = T_{SUP}\,(PU_{SIG} > 0)$$

$$T_{SUP,PuOFF} = T_{SUP}\,(PU_{SIG} = 0)$$

$$\textbf{if } T_{SUP,PuOFF} > T_{SUP,PuON}:$$

$$fault = True$$



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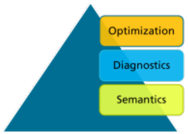
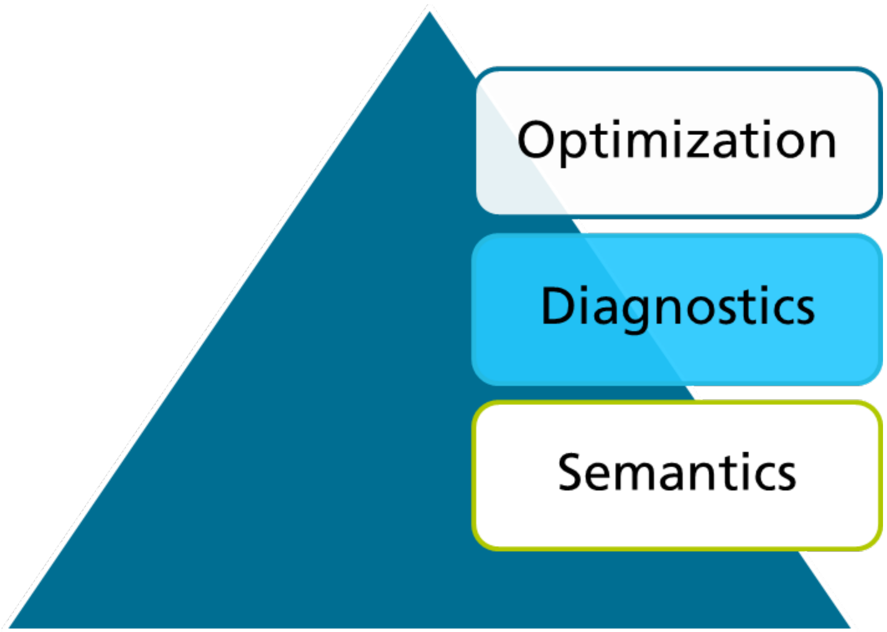
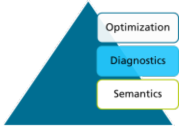
Digital methods for energy optimized buildings and districts



Enabling smartness

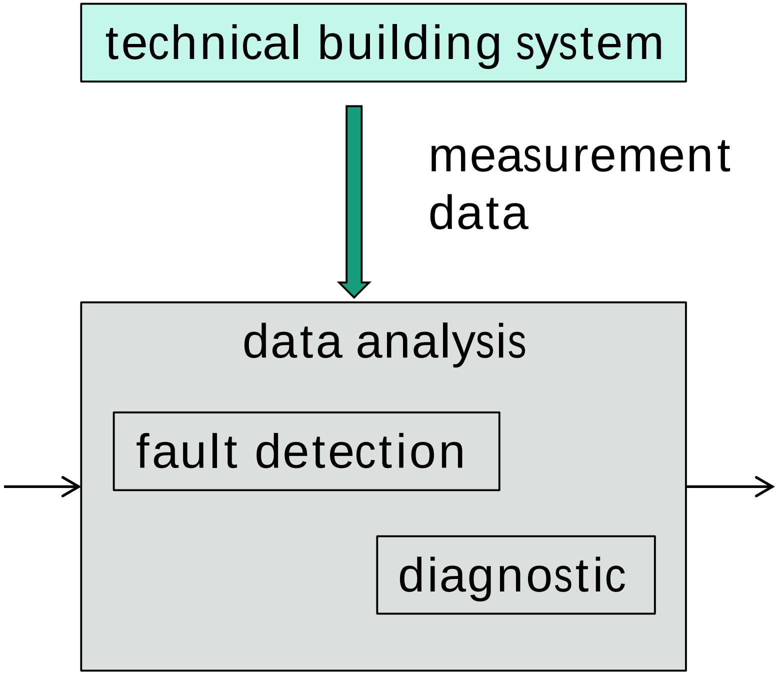


Fault Detection and Diagnostics
Principle



System information:

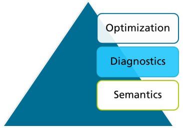
- System type
- Available sensors
- Control strategy
- …



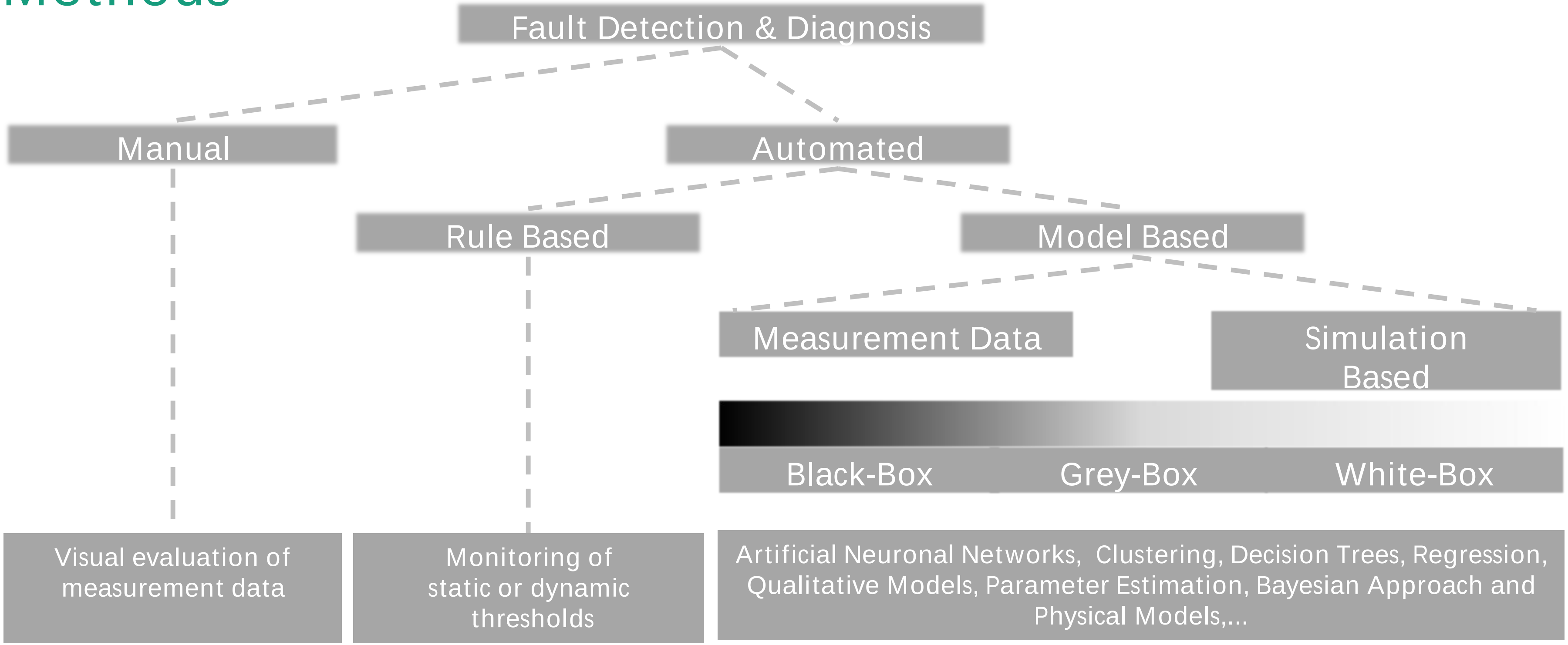
Information about errors, e.g.:

- Length / period
- Affected component
- Error type
- Impact
- Remedying

Fault Detection and Diagnostics



Methods



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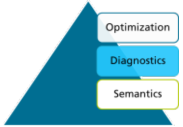
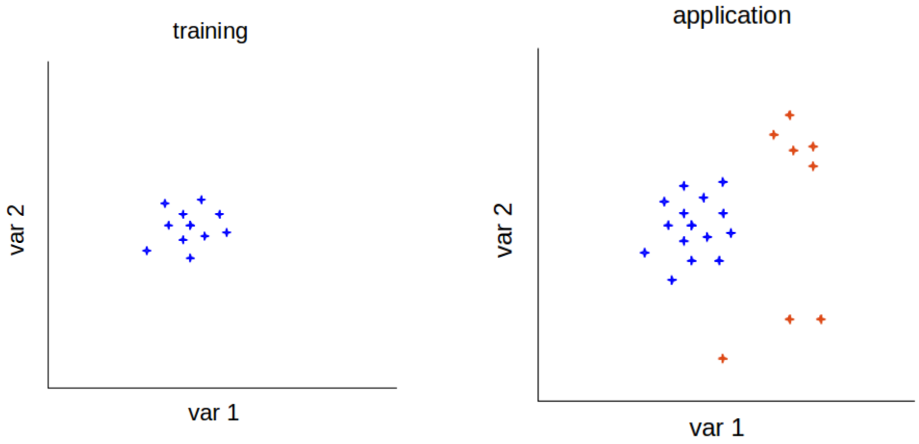
Fault Detection and Diagnostics
Clustering



- Density-based clustering (DBSCAN)
- Training on error-free data -> data are assigned to clusters
- Outliers correspond to incorrect data



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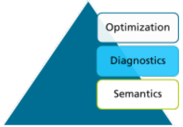
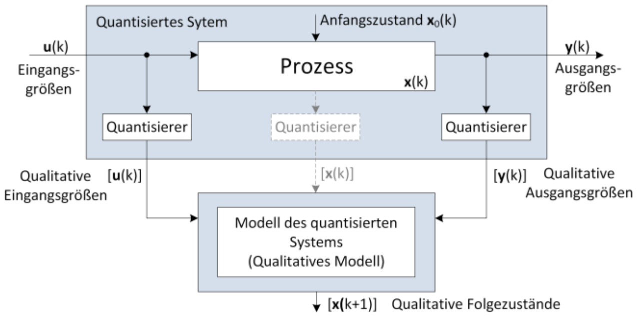
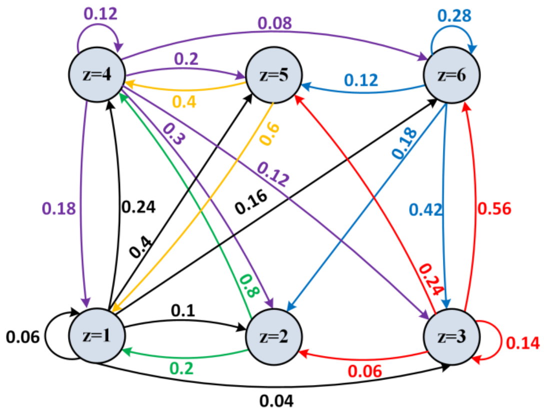
Fault Detection and Diagnostics



Qualitative models

- Approximate description of system behavior
- Use of qualitative values e.g. "a lot" or "little“
- The qualitative behavior of the process is represented by a quantized system





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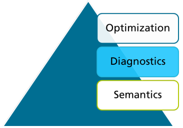
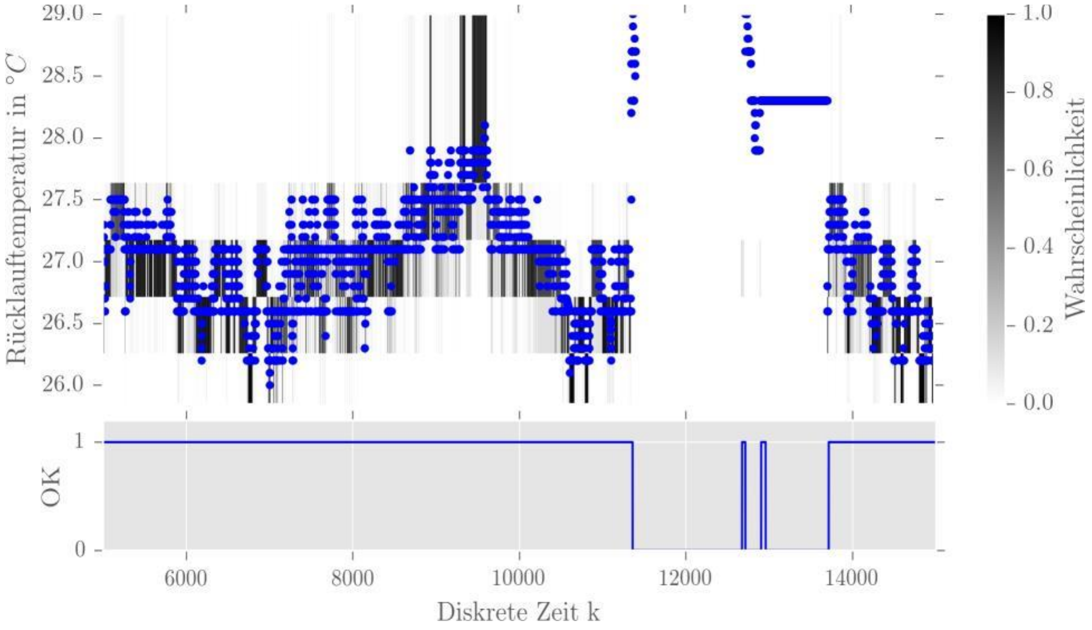
Fault Detection and Diagnostics

Qualitative models



Example: fault detection in supply temperature of thermal activated slabs



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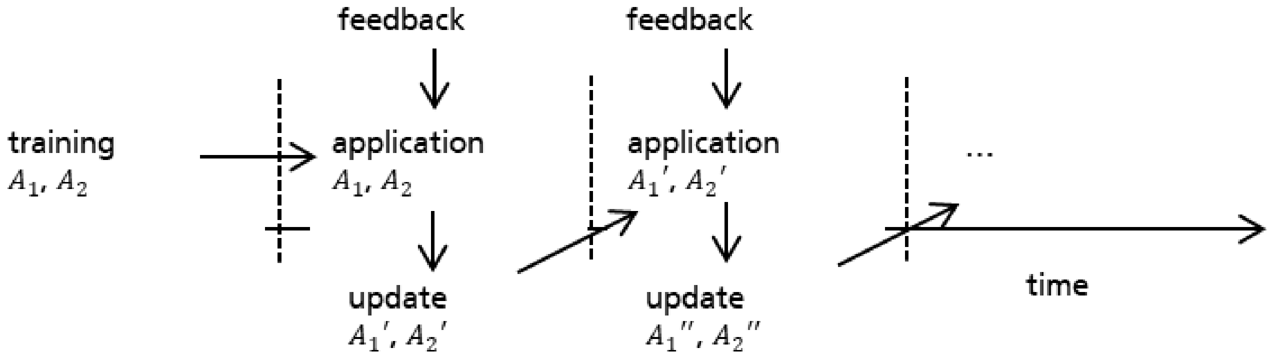
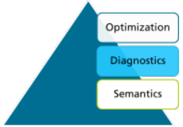
Fault Detection and Diagnostics

Method combination and feedback system

- Use of two complementary methods (e.g. clustering and decision trees)
- Continuous user feedback is used to adapt the methods

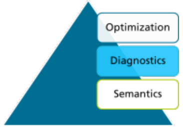




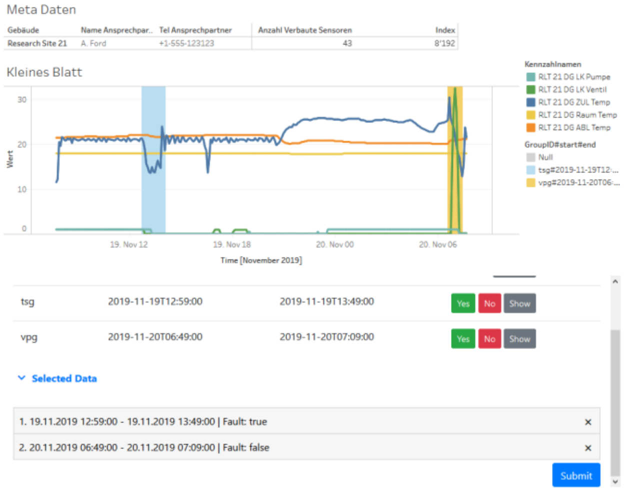
*) Patent filed PCT/EP2018/054709

Fault Detection and Diagnostics

Method combination and feedback system



- Benefits:
  - Initially only error-free training data necessary
  - Expert knowledge can be integrated
  - Error detection improves during use
  - Required feedback decreases



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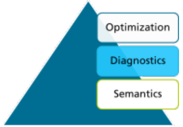
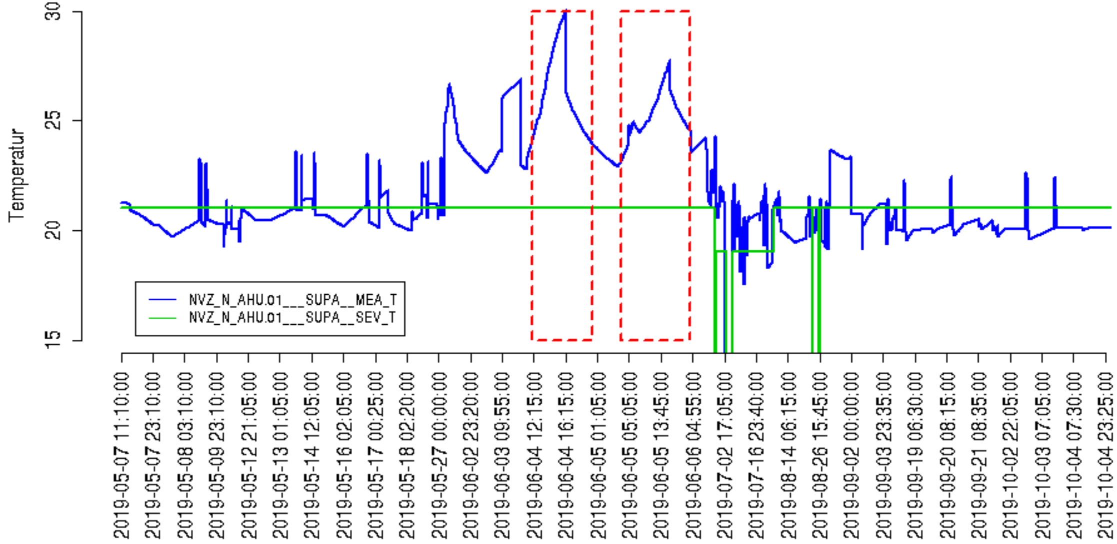
Fault Detection and Diagnostics

Example Rathaus im Stühlinger - Freiburg





- Very precise detection of increased supply air temperatures in an AHU by learning from user feedback

AHU: Air Handling Unit

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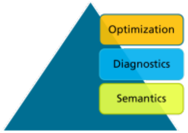
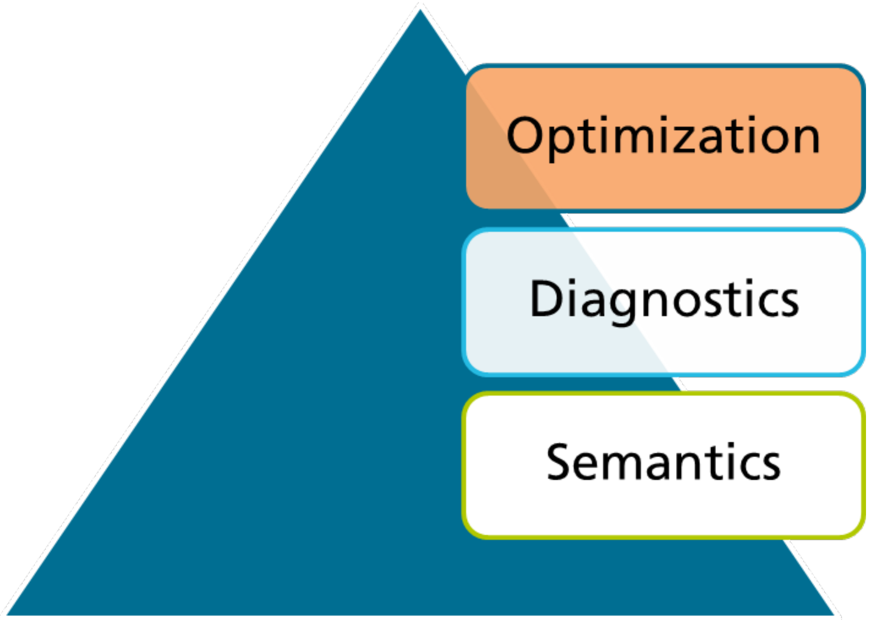
Digital methods for energy optimized buildings and districts

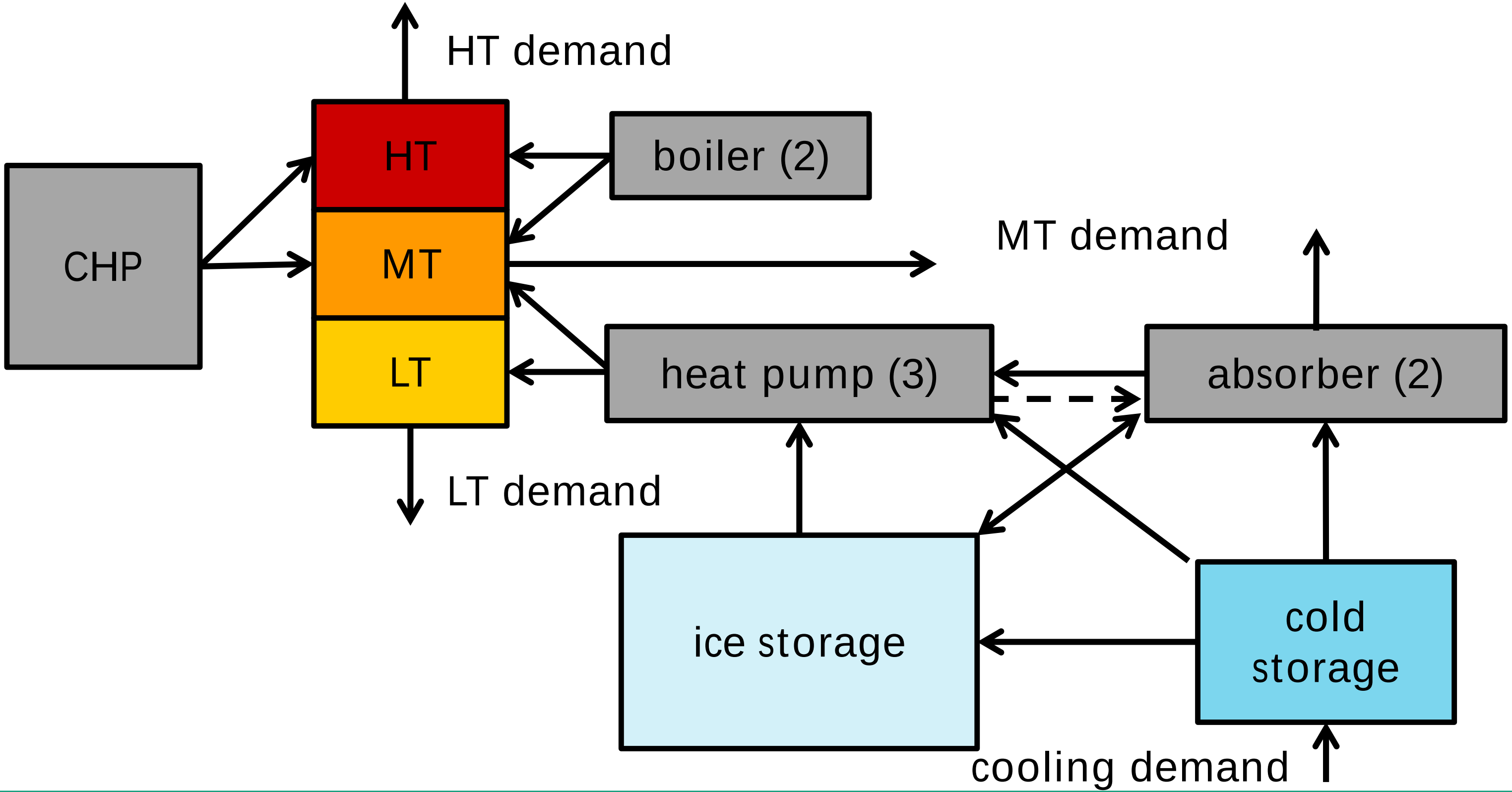
Enabling smartness





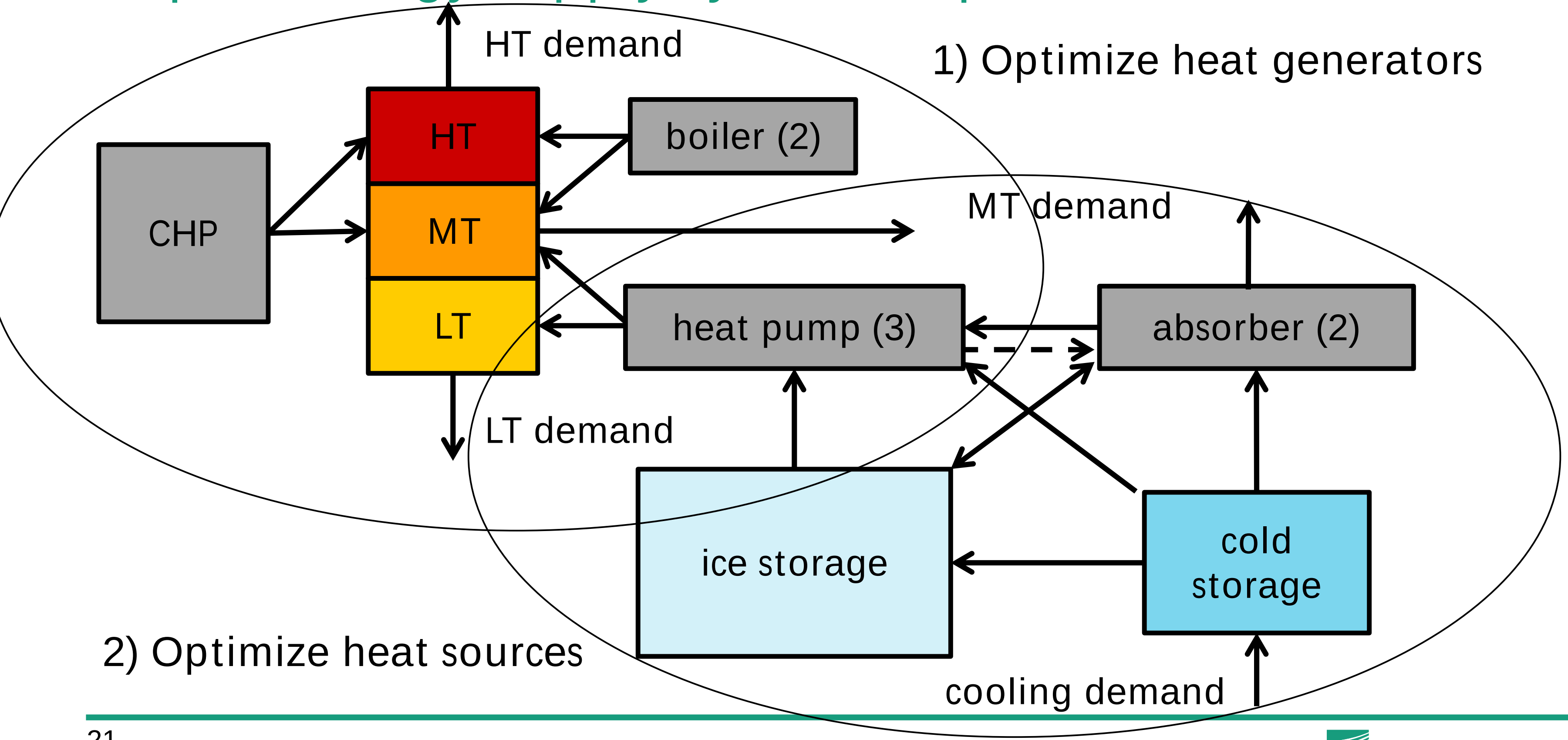
Optimization

Complex energy supply system - overview



Optimization

Complex energy supply system – optimization tasks



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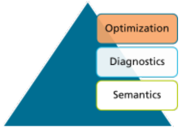
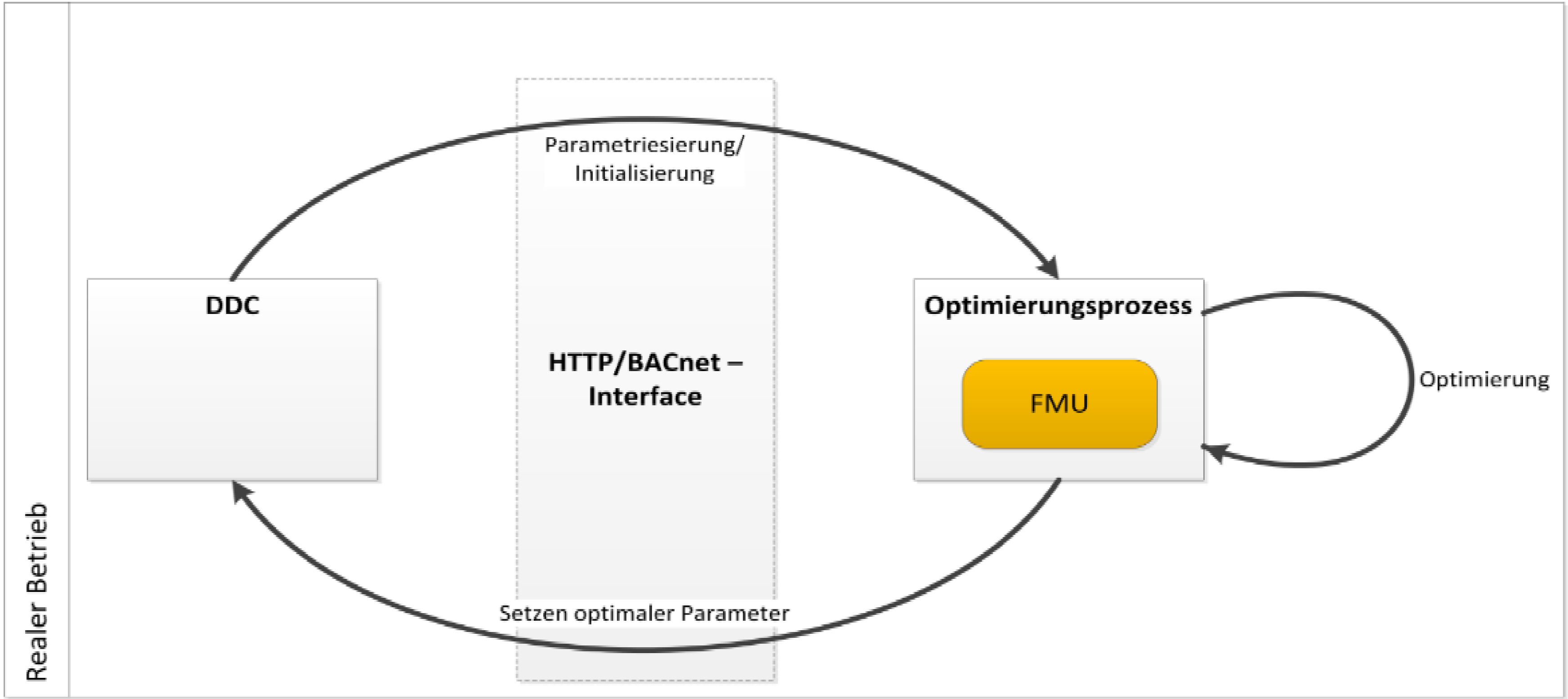
Optimization

Complex energy supply system – methods





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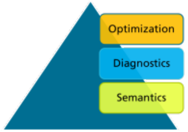
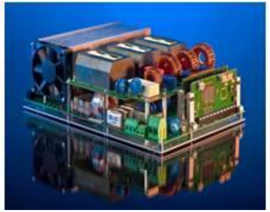
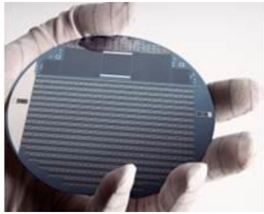


Conclusion and outlook

- Digital methods are key enabler for energy and cost efficiency in complex disctrict and building energy systems
- Unified data models and semantics are essential to inter-operate complex systems
- Analytics methods and connectivity technologies are mature for implementation and test in field
- New business and incentives models need to be developed to enable scalable solutions with high replication potential

Vielen Dank für Ihre Aufmerksamkeit!

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Nicolas Réhault - nicolas.rehault@ise.fraunhofer.de
www.ise.fraunhofer.de

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