Quality Control for HVAC Systems in Residential Buildings with IoT-based Fault Detection and Diagnostics

Stella Joos

Daniel Buchmiller

Andreas Gerber

Sebastian Herkel

University of applied sciences Biberach

Fraunhofer ISE

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HBC. Hochschule Biberach
Karlstraße 11
88400 Biberach/Riß
www.hochschule-biberach.de

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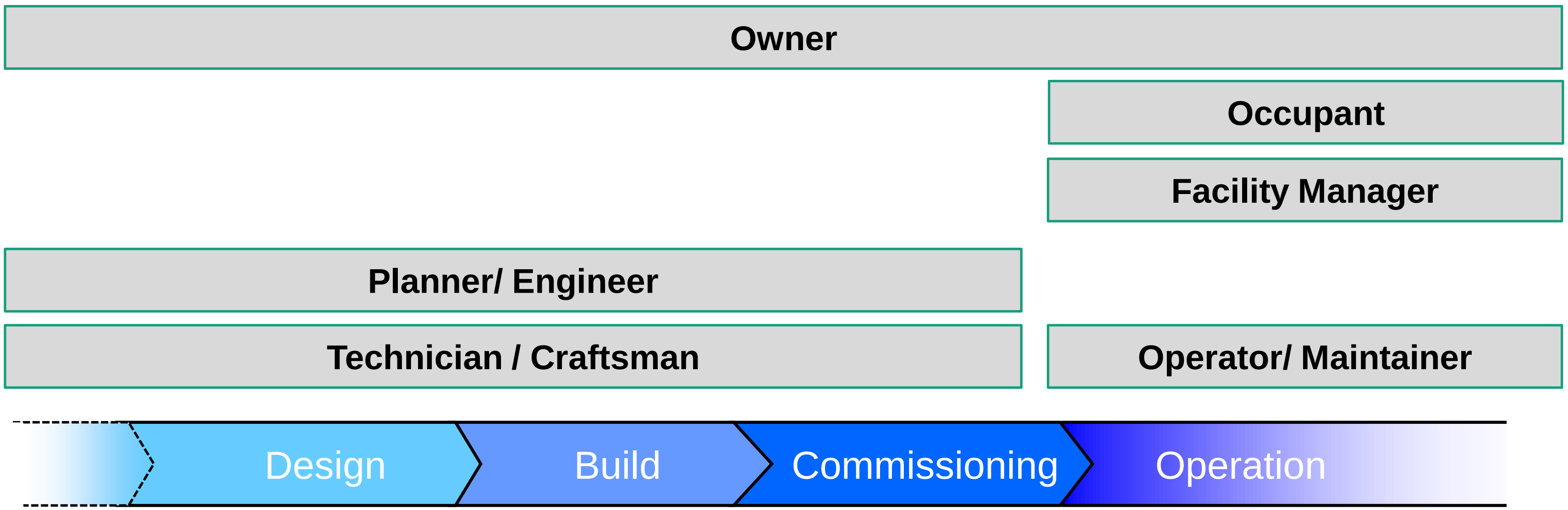
Introduction

- Residential buildings has a high potential of energy saving
- Performance gap: Mismatch of designed and measured performance
- Components vs. System
- Complex systems
  - Small faults increase primary energy consumption

- Increase efficient by quality control and optimization, therefore saving energy
- Find cost-efficient, easy, practicable approach by using IoT
- Is it possible to find faults before they increase consumption or decrease comfort?

Actors in an ideal process during the life cycle of buildings



Actors and faults in a process during the life cycle of residential buildings

Owner

Occupant

Technician / Craftsman

Operator/ Maintainer

Design → Build → Commissioning → Operation

Design	Build	Commissioning	Operation
Faults	**Faults**	**Faults**	**Faults**
▪ Missing or faulty calculations ▪ Wrong components ▪ Wrong design/ incompatible components	▪ Faulty assembling ▪ Wrong positions of components	▪ Wrong parameterization ▪ Missing hydraulic balancing ▪ Wrong set points ▪ Wrong controller settings	▪ Components ▪ Missing service ▪ New terms of use

Quality in HVAC systems in residential buildings

- Problems
  - Planning process is not in focus
  - Human caused faults
  - No monitoring

- Specific features
  - Systems are simple and similar, means methods should be easily replicable
  - Low-cost solutions required
  - Closed systems

State of the art and science

- Quality of single HVAC components (ErP)
  - “Energy labelling of residential ventilation units”
  - “Ecodesign requirements for ventilation units”

25.11.2014 EN Official Journal of the European Union L 337/27

COMMISSION DELEGATED REGULATION (EU) No 1254/2014

of 11 July 2014

supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of residential ventilation units

(Text with EEA relevance)

L 337/8 EN Official Journal of the European Union 25.11.2014

COMMISSION REGULATION (EU) No 1253/2014

of 7 July 2014

implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for ventilation units

(Text with EEA relevance)

- Checklists for installation and commissioning

Beschreibung	OK	Bemerkungen
1 Kontrolle		
1.1 Allgemeine Installationskontrolle:		
• Anschlüsse korrekt	☐	
• Flussrichtung	☐	
• Sekundärseite gefüllt	☐	
• Wärmedämmung komplett	☐	
• Fühler eingebaut und angeschlossen	☐	
• Elektroinstallationen Regelung, Pumpe, Sicherungen definitiv angeschlossen	☐	
1.2 Installationskontrolle der Kollektoren, unmittelbar nach deren Installation (vor Abbau Gerüst, vor Schliessen Installations-schächte)	☐	
1.3 Dichtheitskontrolle durchgeführt und protokolliert?	☐	
1.4 Entlüftungs- und Entleerhahnen geschlossen?	☐	
1.5 Expansionsgefäss installiert, Vordruck gemäss Anlagehöhe eingestellt?	☐	
1.6 Sicherheitsventil auf Kollektorseite nicht absperrbar?	☐	
1.7 Abblaseleitung in Auffanggefäss geführt?	☐	
1.8 Ansprechdruck Sicherheitsventil überprüft?	☐	
1.9 Rückschlagventil (Schwerkraftbremse) installiert?	☐	
1.10 Füllvorrichtung mit Gefäss (Fass/Kanister) komplett und ausreichend dimensioniert?	☐	

Promising approaches

- Building Information Modelling (BIM)

  →Information can be shared between all actors in all phases of life cycle

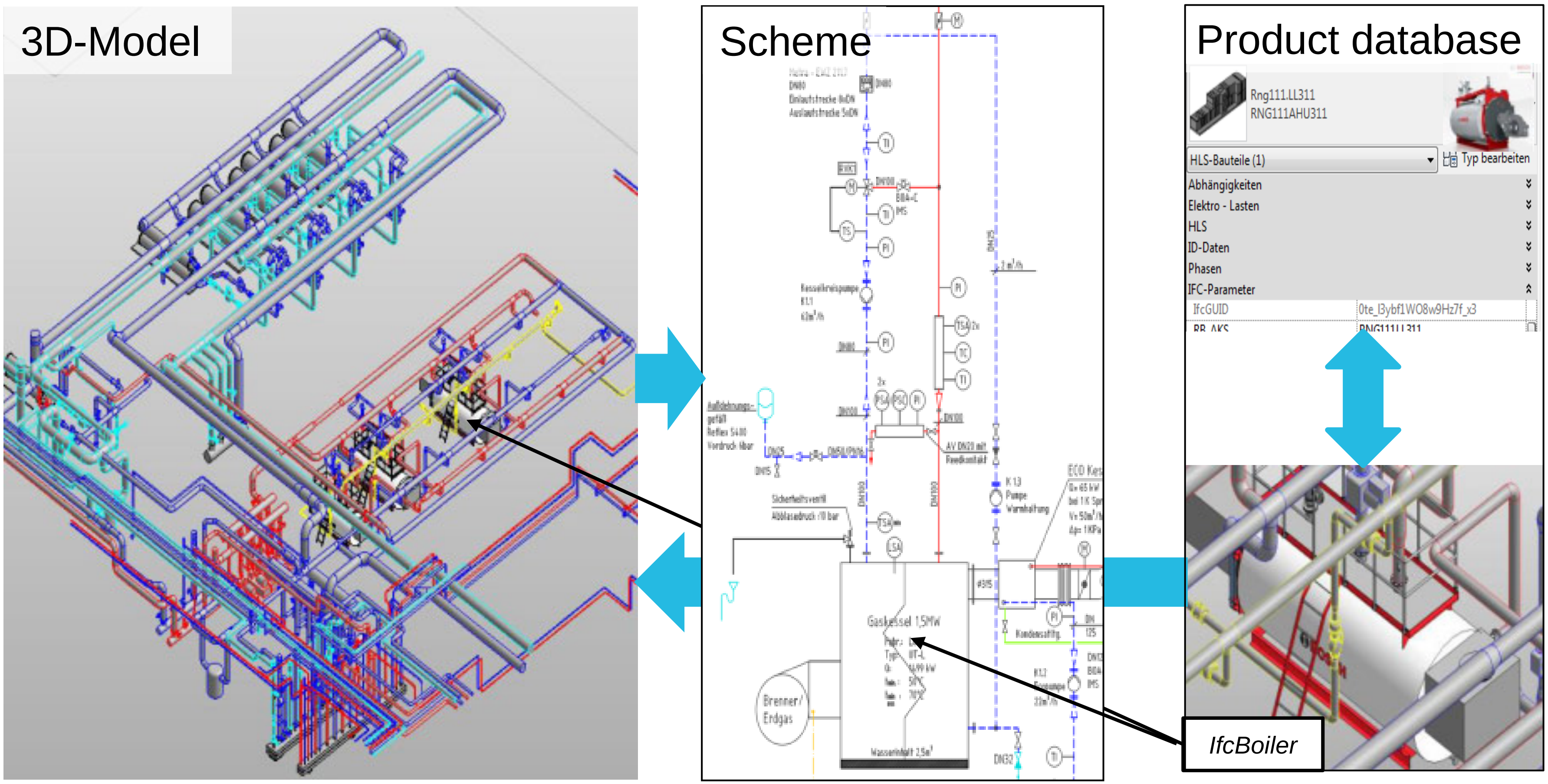
- IoT based data generation (Monitoring)

  →All data in a centralized place with same format

- Fault detection and diagnostics (FDD)

  →Faults can be detected and the cause can be found

Use of BIM for operation supervision of HVACs
Design process - boiler and hot water loop



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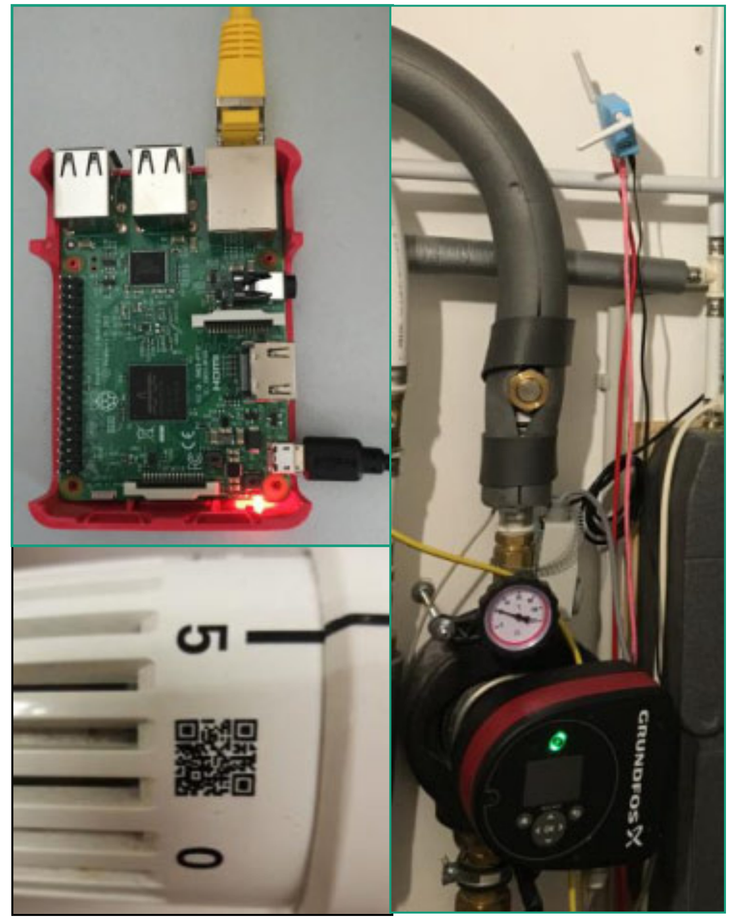
Internet of Things (IoT)

- All physical sensors, devices and actors have a unique identity in the internet
- They can communicate via the same protocols with each other
- Parameters
  can be changed remotely with
  smart end devices

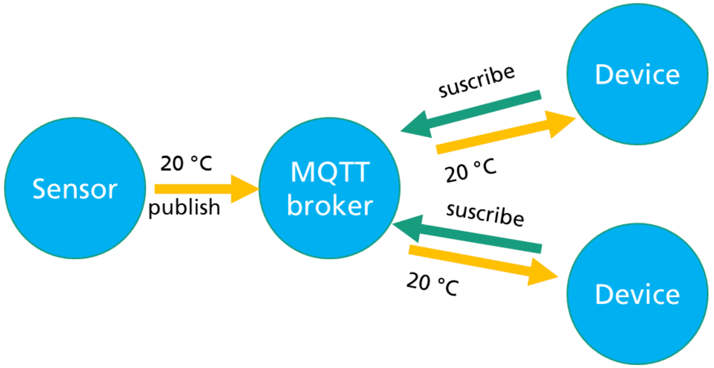
- QR-Codes/ RFID
  - Prepare information
  - Digital device informations

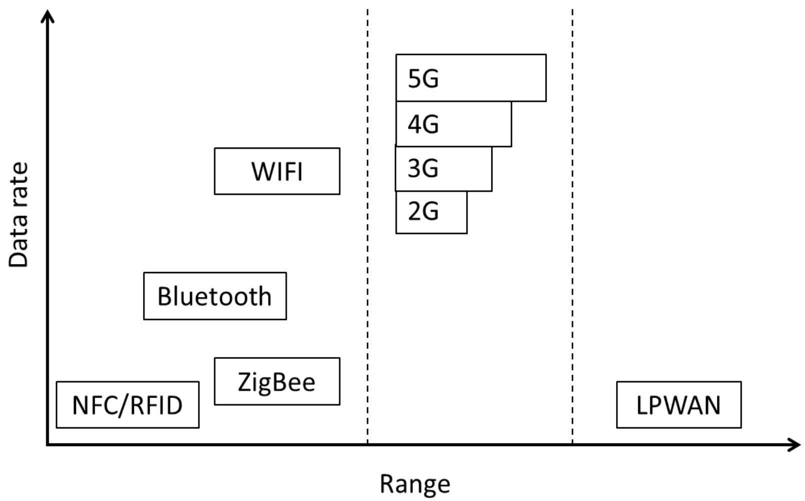
    → Digital system information

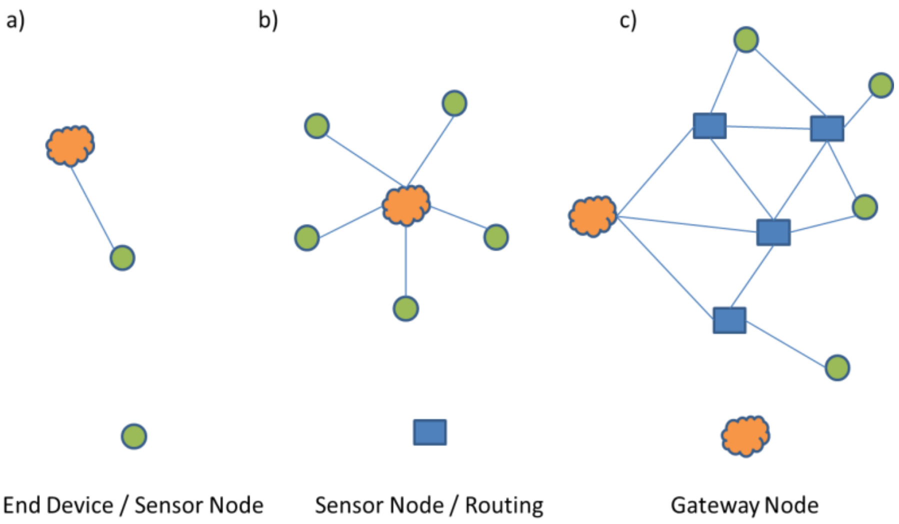


Internet of things (IoT)

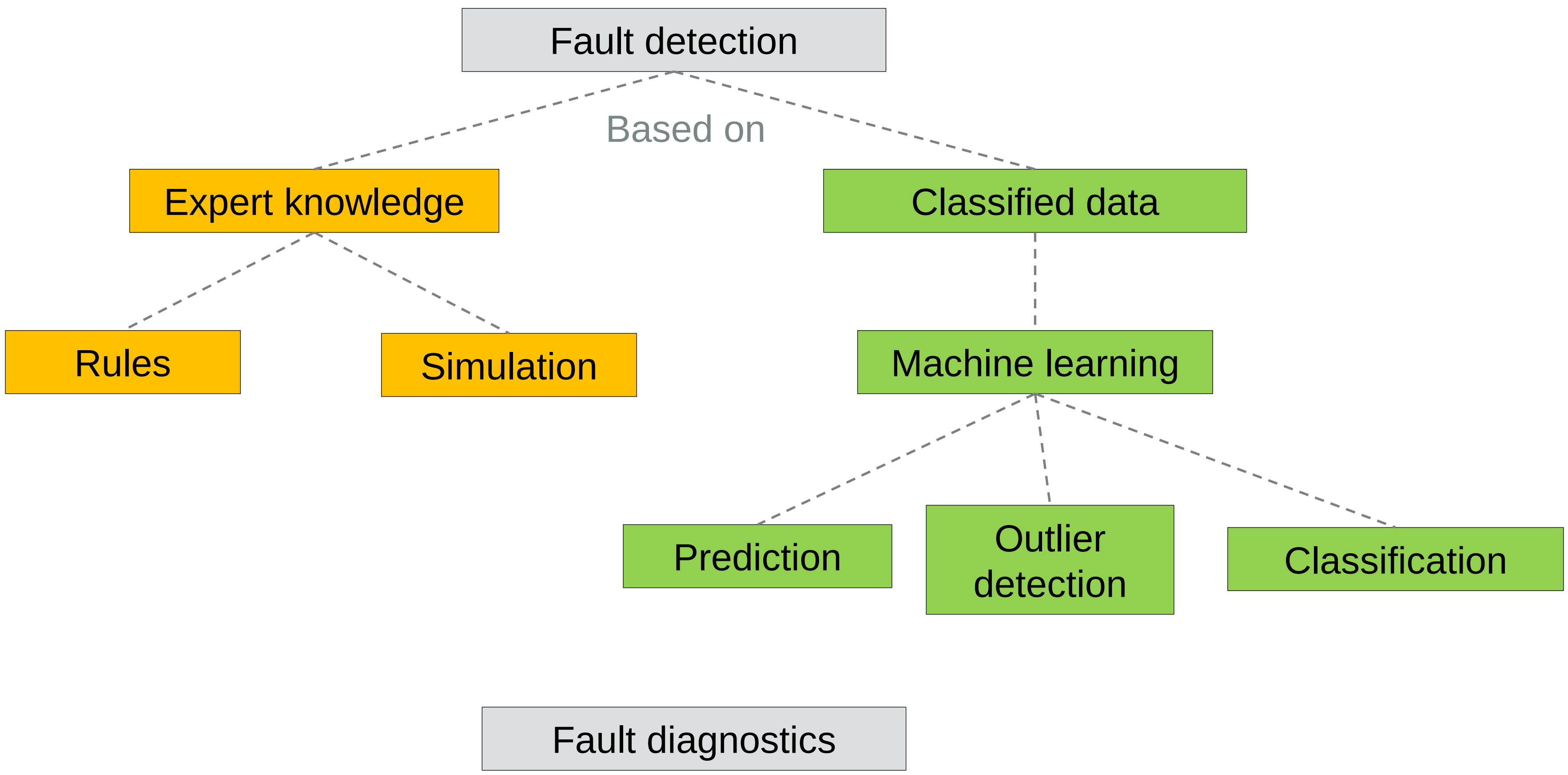
- Energy supply
- Range vs. data rate: e.g. LoRaWAN® with high range but low data rate
- Different protocols
- Different topologies





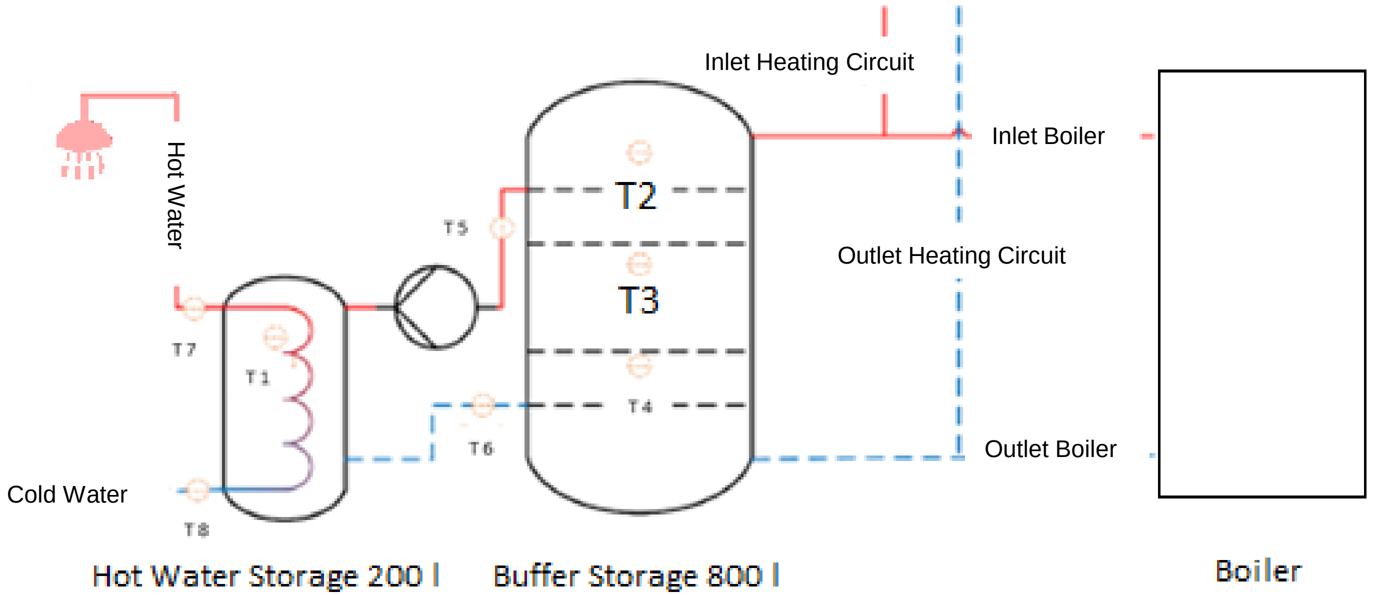


Fault detection and diagnostics

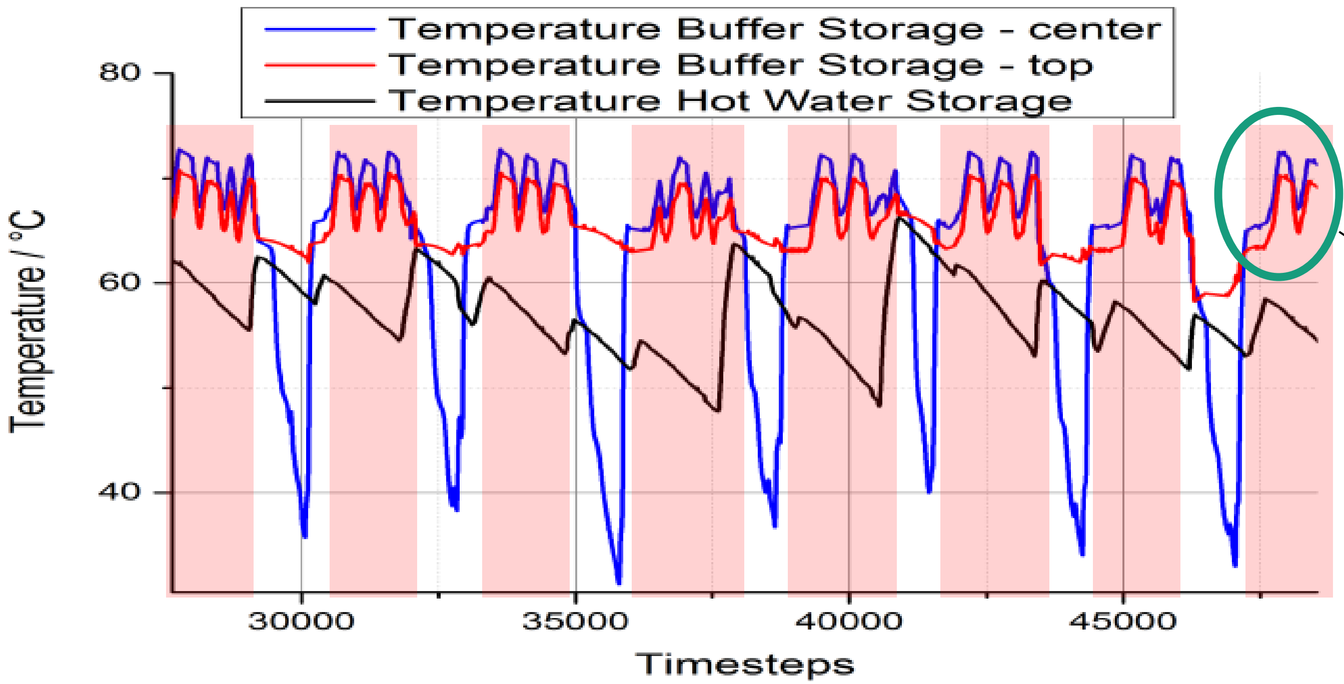


An example of a system with boiler, hot water tank and buffer storage

- Additional sensors were added
- Faults could be detected



Results of case study



$T_{top} < T_{center}$

missing stratification

or faulty sensor

- Fault detection rules

  (i) If $T_{top} < T_{center}$ → fault or (ii) If $T_{bottom} > T_{center}$ → fault
  (iii) If $T_{top} < T_{bottom}$ → fault

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Conclusion and Outlook

- Conclusion
  - Quality of installation and operation of small supply systems is needed to close the performance gap
  - Fault detection methods using Artificial Intelligence algorithms could be applied even in small systems
  - IoT is a promising technology to enable economical quality control solutions in residential buildings during all phases (building, commissioning and operation)
- Outlook
  - Demonstration on HVAC systems in existing residential buildings
  - Benchmarking for quality in small residential buildings
  - Simulation for validation and further investigations

Thank you for your attention!

Stella Joos, M. Sc.

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Fraunhofer-Institut für Solare Energiesysteme ISE

Stella.joos@ise.fraunhofer.de