Proceedings of the IEA DHC Annex TS4 Webinar:

Testbeds for Digitalization Solution in District Heating

27th of April 2022 as a web meeting

Hosted by:
Austrian Institute of Technology AIT

Organised by:
Austrian Institute of Technology AIT
In cooperation with
Fraunhofer-Institute for Energy Economics and Energy System Technology IEE
Testbeds for Digitalization Solutions in District Heating

Digitalization and sector coupling are key enablers for decarbonizing and integrating district heating systems. As discussed within the international cooperation program “IEA DHC Annex TS4, Digitalisation of District Heating and Cooling”, an increasing number of digital solutions for integrated operation are available. However, the development of such solutions is complex and involves considerable time and cost expenditure. Suitable testbeds could enable to overcome these obstacles by providing an environment for the evaluation, (further) development and integration of digitalization solutions for integrated district heating networks.

Aim of the webinar was

- to introduce current developments of digital solutions and testbeds for district heating
- to present the AIT Digital Energy Testbed, an open test environment for digitalization solutions for integrated district heating networks (including a life demonstration)
- to discuss the role of the different testbeds for supporting the digitalization of district heating networks

The webinar was directed towards:

- District heating network operators and energy suppliers
- Digitalization solution providers (soft- and hardware, consultancies)
- R&D institutes and universities
- Policy makers, energy authorities and associations

This Webinar is held in the framework of the international cooperation program “IEA DHC Annex TS4, Digitalisation of District Heating and Cooling“. The Austrian participation is financed by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK).
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The webinar was held in three blocks:

## Block I – Current Developments of Testbeds and Digitalization Solutions in District Heating

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## Block III – Workshop and knowledge exchange

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IEA DHC Annex TS 4:
Digitalization of District Heating and Cooling:
Optimized Operation and Maintenance of District Heating and Cooling Systems via Digital Process Management

Introduction of the Activity
27 April 2022

Dr. Dietrich Schmidt
Fraunhofer IEE

Aims of DHC Annex TS4

- The project aims at promoting opportunities of the integration of digital processes into DHC schemes and to clarify the role of digitalisation for different parts within the operation (and maintenance) of the district heating and cooling system.
- Furthermore, the implementation of these technologies is going to be demonstrated.
- On the other hand new challenges need to be tackled, such as data security and privacy as well as questions about data ownership.

Goals of DHC Annex TS4

- Create awareness for the advantages of the implementation of digital processes to the various stakeholders and users
- Provide a state-of-the-art overview of the digitalization of district heating schemes in terms of R&D projects, demonstrators and case studies
- Evaluate non-technical barriers and enablers for digitalization processes in district heating and cooling schemes such as business models, legal aspects and policy instruments
Our focus areas for a digitalization in DHC

- Increased efficiency in the planning procedures of assets and grids
- Optimisation of real-time operation, incl. predictive maintenance
- Implementation of new digital business models and processes

DHC Annex TS4 working structure

- ST A: Digitalisation of end use / consumption
- ST B: Digitalisation of infrastructure
- ST C: Digitalisation on the system perspective
- ST D: Digitalisation of business processes
- ST E: Dissemination and Management

cooperation with other initiatives

- German Heat & Power Association (AGFW)
- DHC+
- Danish Board of District Heating (dbdh)
- IEA EBC Annexes on:
  - "Demand Response of Buildings in DHC networks / Annex 84" & "Data-Driven Smart Buildings / Annex 81"
- And others... as IEA HPT Annex 57: "Flexibility by implementation of heat pump in multi-vector energy systems and thermal networks" & Annex 56: "Internet of things for Heat Pumps"

Technology Collaboration Programme

Or meet us in Denmark!
special session on IEA Annex TS4

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Presentation 1:
Introduction to the IEA DHC Annex TS4
The case for cloud and IoT-based control

**Trends**
- Intermittent energy generation
- New energy consumption patterns
- Energy prosumers
- Decentralized small-scale systems and assets
- Self-sufficiency on sustainable and renewable energy

**Challenges**
- Coordination of systems and assets
  - All systems must be connected and controlled to achieve an overall efficient energy system
- Complex control requirements
  - Traditional control systems (on-premise PLC, SCADA) often not sufficient to unlock full value

**Digital Platforms**
- Cloud
- IoT
- Data-driven services
- Distributed control
- Interoperability

**E.ON ectocloud™ - Distributed Control**
- Cloud Control
  - Orchestrates and controls on system-wide level
  - High data availability, computation power and tools for ML
- Edge Control
  - Semi real-time / local optimization
  - Communication robustness (offline functionality)
- Local Control Systems (OT)
  - Time-critical control of substations and assets
  - Industrial automation programming
  - Control of customer HVAC

Each control layer relies on underlying layers for correct application
E.ON ectogrid™ - E.ONs flagship solution for 5GDHC

Key features:
- Heating and cooling in the same system
- Low temperature grid
- Temperatures varied based on circumstances
- Highly decentralized
- Generation
- Pumping/distribution
- Bidirectional
- Electrified generation using heat pumps
- Recycles excess energy between prosumers
- Efficient integration of low temp waste heat
- Modular and flexible
- Built with standard components
- Managed by digital system ectocloud™
- Deep integration with all substations and assets

E.ON ectocloud™ Control and Optimization

Control:
1. Merit order prioritization and control of active balancing units
2. Control of the grid temperatures
3. Control and prioritization of heat pumps and chillers
4. Control of building’s heating and cooling loads

Value:
- Grid capacity (Quality of Service)
- Functional solution operating within technical envelope (Quality of Service)
- Energy performance (COP)
- Financial performance (C)
- Reduced emissions (CO2e)

E.ON ectocloud™ is a software ecosystem built for collaboration

- Technology reused for multiple E.ON initiatives in the energy sector
- New digital services provided continuously to connected E.ON energy systems and customers
- A flexible platform applying open standards, data models and APIs allows E.ON to integrate and collaborate with
  - Customers
  - Selected partners
  - Research groups and institutes
- In relation to E.ON ectogrid™ we could benefit from physical and digital test beds to more quickly evaluate ideas and enhance our products
- We are creating a digital ecosystem for operating energy system, enabling a more sustainable business together with customers and partners

Thank you!
The laboratory for Combined Smart Energy Systems (CoSES)

Daniel Zinsmeister, Technical University of Munich

Smart Energy System with 5 Buildings

Center for Combined Smart Energy Systems (CoSES) @ TUM MEP

Control Structure

Electrical House Emulator

Center for Combined Smart Energy Systems (CoSES) @ TUM MEP
Presentation 3:
Daniel Zinsmeister: The CoSES Lab: A Laboratory Environment for Combined Smart Energy Systems
CoSES Team

Daniel Zinsmeister: The CoSES Lab: A Laboratory Environment for Combined Smart Energy Systems

Key message:
- CoSES laboratory for smart energy system analysis
- Detailed emulation of the houses and the thermal and electric grid

Data is your next utility... Let’s utilise it!

The data-driven energy company
Tear down system boundaries & optimize the whole value chain

IEA DHC Annex TS4
2022-04-27

Johan Kensby, CTO & co-founder

DATA is the untapped waste of energy companies
We help energy companies create value from the data they collect hour by hour

A scalable digital platform for energy companies of the future

- More efficient Energy Systems: Lower Operating Costs & Reduced Investment Needs
- More efficient operations: More efficient internal processes & analysis
- Stronger customer relationships: Data-driven communication

About Utilifeed

Founder 2016
Göteborg, Sweden
Commercial launch 2021
50,000+ connected buildings
27 co-workers

We love district heating
District heating is smart
It is a system that converts waste into value for both the environment and the economy
The data-driven energy company - Tear down system boundaries & optimize the whole value chain
Testbeds for Digitalization Solutions in District Heating

**Presentation 4:**
Johan Kensby: The data-driven energy company - Tear down system boundaries & optimize the whole value chain
The data-driven energy company - Tear down system boundaries & optimize the whole value chain
Principle of the Experimental Facility “District LAB”

1. Flexible heating grid in a lab scale
2. Generation of artificial heat sources and sinks
3. Use of HIL for impress load and user profiles
4. Implementation of (generic) user and load profiles are possible
5. Software-based investigation of selected technologies at DistrictLAB

- Development and validation of a central control system as an interface for operating and regulating the test facility
- Creation and verification of a “digital twin” of the test facility (flexible heating network)
- Development of a virtual, reaction model “pipe-soil interaction” (pipe test section)
- Preparation of a measuring point plan for the implementation of investigations at the District LAB
Experimental investigations at the DistrictLAB test facility

Investigation flexible heating grid

- Investigations of different supply scenarios (e.g., decentralized or bi-directional feed-in of volatile energy sources)
- Identification of possible critical operating variables (pressure, temperature, volumetric flow rate)
- Evaluation of the examined supply scenarios with regard to their potentials as well as obstacles

Joint Project: EnEff: Wärme: UrbanTurn:
Transformation of the urban district heating supply

- Transformation, decarbonization and digitalization of district heating, taking into account volatile pressures and temperatures when feeding in renewable energies and waste heat sources

Experimental investigations at the DistrictLAB test facility

Investigation pipe test bench

- Investigation of the interaction of pipeline and soil under consideration of dynamic operating conditions
- Investigation of the bedding reaction conditions under fluctuating pressures and temperatures
- Identification of new requirements or criteria for bedding materials and installation techniques

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Presentation 5: Anna Maria Kallert: DistrictLAB test center for innovative heating network solutions
The AIT Digital Energy Testbed – INTRODUCTION

IEA DHC Annex TS4 Webinar on Testbeds for Digitalization Solutions in District Heating, 27.04.2022 (online)

Edmund Widl, Ralf-Roman Schmidt, Andreas Sporr, Aurelien Bres, Catalin Gavriluta, Jawad Kazmi, Thomas Natiesta, Martin Mairhofer, Nicolas Marx

BACKGROUND, MOTIVATION

- Digitalization and sector coupling are key enablers for decarbonizing and integrating district heating systems
  - overcoming the complexity of a fully integrated energy system.
  - an increasing number digital solutions for integrated operation are available

- However, the development, adaptation and integration of such digital solutions is complex and involves considerable time and cost expenditure;

- furthermore, the transferability and comparability of results can be limited

BACKGROUND – REAL TESTBEDS

- Existing real testbeds for special purpose applications at AIT
  - Testbed for district heating substations
  - Testbed for heat pumps

- Smart grid laboratory at AIT
  - Configurable low-voltage networks
  - E-mobility, batteries, PV systems

- ...

BACKGROUND – VIRTUAL TESTBEDS

- Dynamic District Heating network simulations in Modelica (Dymola)
  - Thermal transients and hydraulic behaviour
  - Detailed models of supply units, substations, pipes, etc.

- Building system simulations
  - TRNSYS
  - EnergyPlus
  - Modelica (Dymola)

- ...

13/05/2022
THE AIT DIGITAL ENERGY TESTBED

- An open test environment for the evaluation, (further) development and integration of digitalization solutions for integrated district heating networks.

CURRENT IMPLEMENTATION

- As a proof-of-concept, a testbed prototype has been implemented around an existing DH substation test stand.
- Assess individual DH substation and the overall system in response to remote control signals sent by the network operator.

The DigitalEnergyTestbed is based on Lablink an open-source middleware for lab experiments,

- Communicating with test stands via the OPC Unified Architecture.
- Interfacing simulation tools via the Functional Mockup Interface (FMI) / Functional Mock-up Unit (FMU).
- Synchronization of the operation of test stand with simulators for thermal systems (Dymola, TRNSYS, EnergyPlus ...)

LABLINK CLIENTS

The AIT Digital Energy Testbed – THE LABLINK MIDDLEWARE
IEA DHC Annex TS4 Webinar on Testbeds for Digitalization Solutions in District Heating, 27.04.2022 (online)

Edmund Widl, Ralf-Roman Schmidt, Andreas Sporr, Aurelien Bres, Catalin Gavriliuta, Jawad Kazmi, Thomas Natiesta, Martin Mairhofer, Nicolas Marx

Testbeds for integrated energy systems

- So far, only few automation solutions for integrated energy systems exist
  - usually complex, specifically configured for (demo) projects, developed for specific requirements
- Hardware-in-the-loop (HIL) test environments are required for further development
  - critical components / subsystems realized as hardware
  - rest of the system emulated using real-time simulation
- Traditional HIL approaches are relatively expensive 🤑 rely on proprietary hardware and software
  - new developments try to establish cost-effective alternatives
  - new trends: open standards, open-source software & simulation coupling

Concept for open HIL testbeds

- Propose a concept for open HIL testbeds for thermal CPES
  - focus on smart applications for DH networks
- **Aim**: combine existing lab infrastructure and available simulation models
- **Goal**: create affordable HIL testbeds for integrated energy systems

Prerequisites and requirements for open testbeds

- Open Access
- Software
- Hardware
- P1: remotely accessible interface
- P2: sufficient quality of control
- R1: open-source software implementation
- R2: open standards for interfaces
- P3: data exchange interfaces
Conclusion & outlook

- Aim: combine existing lab infrastructure and simulation models
- Goal: create affordable testbeds for thermal integrated energy systems
- Key enabling technology: Lablink
  - open-source middleware for lab experiments
  - relies on open standards for interfacing automation systems (OPC UA) and simulation tools (FMI)

https://ait-lablink.readthedocs.io
https://github.com/ait-lablink

Thanks for your attention!

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Try it out yourself, complete setup available on Github: https://github.com/AIT-JESE/detect-lablink-example
The AIT Digital Energy Testbed
Layout and Models of the DigitalEnergyTestbed

Edmund Widl, Ralf-Roman Schmidt, Andreas Sporr, Aurelien Bres, Catalin Gavriluta, Jawad Kazmi, Thomas Natilesta, Martin Mairhofer, Nicolas Marx

OVERVIEW

Virtual Environment

Edge Devices

Real Environment

District Heating Test Bench

District Heating Substation

TEST BENCH OVERVIEW

13.05.2022

13.05.2022

13.05.2022

13.05.2022
SECONDARY SIDE (BUILDING HEAT SUPPLY)

Component: cold storage tank
Capacity: 6000L
min. Temperature: 10°C

SECONDARY SIDE (BUILDING HEAT SUPPLY)

Component: 3-way valve
Control variable: return temperature
Temperature range: 15°C – 60°C

SECONDARY SIDE (BUILDING HEAT SUPPLY)

Component: 2-way valve
Control variable: mass flow
Mass flow range: 0.1kg/s – 0.5kg/s
Mass flow range: 0.1kg/s – 0.2kg/s

DISTRICT HEATING SUBSTATION
Testbeds for Digitalization Solutions in District Heating

DISTRICT HEATING SUBSTATION

Component | heat exchanger
Thermal power | 45kW
Temperature (in/out) primary | 90°C / 60°C
Temperature (in/out) secondary | 55°C / 75°C
Mass flow (prim/sec) | 1.23m³/h / 1.84m³/h

DISTRICT HEATING SUBSTATION

Component | 2-way valve
Control variable | flow temperature
Temperature range | 25°C - 80°C

SUMMARY

Virtual Environment

Real Environment

BUILDING MODEL

- Modelled building
  - 860 m² gross floor area
  - 30 kW nominal power
  - Radiator heating
- Interfaces
  - Inputs: secondary supply temperature
  - Outputs: secondary return temperature, secondary mass flow
- Model
  - Modelica language
  - Dymola modeling environment
  - Based on Modelica Buildings Library
  - Model exported as Functional Mock-up Unit (FMU)
BUILDING MODEL CHARACTERISTICS

- System boundaries (secondary side of substation)
  energy conversion | heat distribution | heat delivery | building envelope

- HVAC system modeling approach:
  idealized | system-based | component-based | equation-based

- Physical quantities: powers | mass flows | temperatures | pressures

- Connection logic: causal | acausal

- Modeling approach: black-box models | white-box models

- Dynamics: static | dynamic

THANKS FOR YOUR ATTENTION!

Dr. Aurelien Bres
Dr. Andreas Sporr

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Presentation 8:
Andreas Sporr & Aurelien Bres: Layout & Models of the Digital Energy Testbed
the AIT Digital Energy Testbed - CONCLUSIONS & OUTLOOK
IEA DHC Annex TS4 Webinar on Testbeds for Digitalization Solutions in District Heating, 27.04.2022 (online)

Edmund Widi, Ralf-Roman Schmidt, Andreas Sporr, Aurelien Bres, Catalin Gavrilita, Jawad Kazmi, Thomas Natiesta, Martin Mairhofer, Nicolas Marx

CONCLUSIONS

- As a proof-of-concept, a testbed prototype of the Digital Energy Testbed has been implemented around an existing DH substation test stand
- There is still some optimization potential on the substation test stand (i.e. responsiveness, dynamic operation), however, static testing is possible already
- The software functionalities are well developed, especially the connection and communication via LabLink have been successful tested – key enabling technology

OUTLOOK

- The Digital Energy Testbed is available for static testing procedures
- Optimization of the hardware for dynamic operation
- Implementation of other AIT testbeds (smart grids, heat pumps …)
- Extension of the Digital Energy Testbed to partners outside AIT
- Possible application of the Digital Energy Testbed in research projects

FUTURE APPLICATIONS

- Lablink’s flexibility and extensibility offers a large range of possibilities to devise testbed setups
- including the integration of various digitization solutions and test stands
POSSIBLE USE CASES

- Supporting the design and operation of **innovative systems combining different (hardware) components**
  - such as substations, heat pumps, batteries, electric boilers, thermal storages, and fluctuating renewables (e.g., wind or PV via direct power lines).

- Supporting the development and validation of **system-level software such as IoT platforms and their applications**. This includes
  - the development and validation of digital twins (based on analytical and/or data-driven models) for predictive simulation and controls in integrated energy systems.
Testbeds for Digitalization Solutions in District Heating

IEA DHC Annex TS4 Webinar - summary

Wednesday, 27th April 2022, 13:30 to 17:30 (CET)

Edmund Willi, Ralf-Roman Schmidt, Andreas Sporr, Aurelien Bres, Catalin Gavriluta, Jawad Kazmi, Thomas Natera, Martin Marhofer, Nicolas Marx

This webinar is a test in the framework of the international cooperation program “IEA DHC Annex 73, Digitalization of District Heating and Cooling”, the Austrian participation is financed by the Federal Ministry for Climate Action, Environment, Energy, Technology, Innovation and Technology (BMK), more information on https://www.bmk.gv.at/stellenausschuss-2018-2020-annex-73/, and the Austrian project “Digitalisierung Pfahlbahnen” funded by the “Siche- und Energiebruthar”, and carried out within the framework of the Energy Research Programme 2021 (project #B1132).

AGENDA

ALIDADE

Block I – Current Developments of Testbeds and Digitalization Solutions in District Heating (IEA Annex)

13:30 Introduction to the Workshop (Ralf-Roman Schmidt, AIT)

13:35 Introduction to the IEA DHC Annex 73 (Andreas Sporr, Fraunhofer-Institut für Energiewirtschaft und Energietechnik, IEA)

13:40 kickoff: The role of cloud and fog based control for highly decentralized energy systems (Andreas Sporr, AIT)

13:45 The C4-Lab – A Laboratory for Combined Smart Energy Systems (Dipl.-Ing. Thomas Natera, AIT)

13:50 The data-driven energy company – from system boundaries to optimize the whole system (Johannes Krain, AIT)

14:00 District level test center for innovative heating network solutions (Jörg Fronius, Fraunhofer-Institut für Energiewirtschaft und Energietechnik, IEA)

14:15 End of Block I and Coffee Break

Block II – AIT Digital Energy Testbed (AIT Campus)

14:40 Testing of technical connections

14:45 Introduction to Block II (Ralf-Roman Schmidt, AIT)

14:50 Introduction to the Digital Energy Testbed Hardware (Thomas Natera, AIT)

14:55 The Labview Platform (Andreas Sporr, AIT)

15:00 Layout of the Digital Energy Testbed (Andreas Sporr, AIT)

15:15 Mike demonstration of the Digital Energy Testbed (Thomas Natera, AIT)

15:30 Conclusions and outlook (Ralf-Roman Schmidt, AIT)

15:35 End of Block II, Coffee Break and starting from TEAMS to wonder.me

Block III – Workshop and Knowledge Exchange (Wonder.me)

16:05 Testing of technical connections and the wonder me online discussion tool

16:40 Introduction to the Workshop (Ralf-Roman Schmidt, AIT)

16:45 The participants have the opportunity to discuss the lab infrastructures and software solutions with the presenters, as well as experience live demo results of the Digital Energy Testbed

17:00 End of Block III

18 hours in CET

GROUP PICTURES

- In total up to 50 participants

Appendix

Results from the workshop
Appendix

Results from the workshop

THE AIT DIGITAL ENERGY TESTBED

→ An open test environment for the evaluation, (further) development and integration of digitalization solutions for integrated district heating networks

The AIT digital energy testbed is open source!
https://ait-lab.ait.ac.at/testbed

THE AIT DIGITAL ENERGY TESTBED

CURRENT IMPLEMENTATION

• As a proof-of-concept, a testbed prototype has been implemented around an existing DH substation test stand

• → assess individual DH substation and the overall system in response to remote control signals sent by the network operator.

THANKS FOR YOUR ATTENTION!

Dr.-Ing. Ralf-Roman Schmidt

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Appendix
Results from the workshop