IEA EBC Annex 84

Demand management of buildings in thermal networks (DHC systems)

Closing webinar 24.04.2025

https://annex84.iea-ebc.org

Agenda

9:00 – 9:15: Introduction to the seminar and IEA Annex 84

9:15 – 10:00: Block 1 – Societal and technological challenges
Subtask A, Anna (AAU)
Subtask B, Ingo (AEE Intec)

10:00 – 10:15: Break

10:15 – 11:00: Block 2 – Digitalization challenges and case studies
Subtask C, Hicham (SINTEF)
Subtask D, Chris (Fraunhofer, IEE)

11:00 – 11:30 Block 3 – Q&A session and overall discussion

9:00 – 9:15: Introduction to the seminar and IEA Annex 84

EBC
Energy in Buildings and Communities Programme

Point of departure

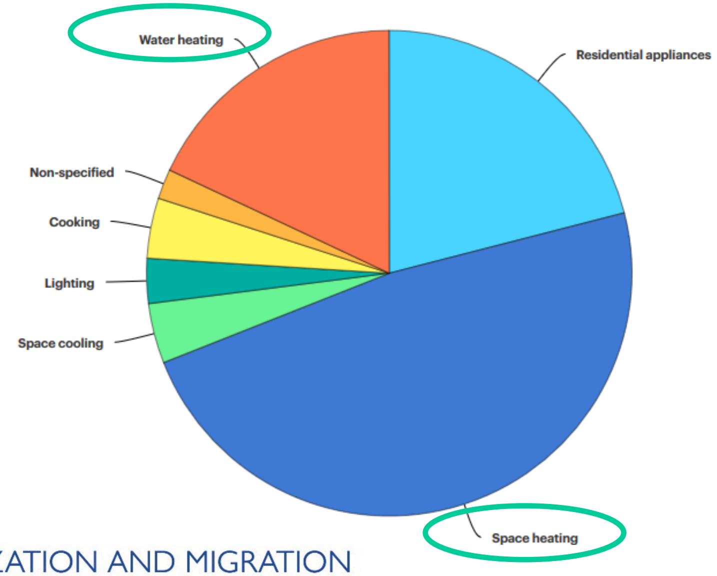
1. **Energy consumption in buildings**
   - energy use for heat and cooling accounts for >50% of the building emissions → 12% of the global energy and the process-related CO_2 emission
   - DHC networks are the most sustainable heating/cooling ways in densely populated areas

2. **Urbanisation**
   - Building floor area is expected to double by 2070
   - 60% of the population will live in cities by 2030

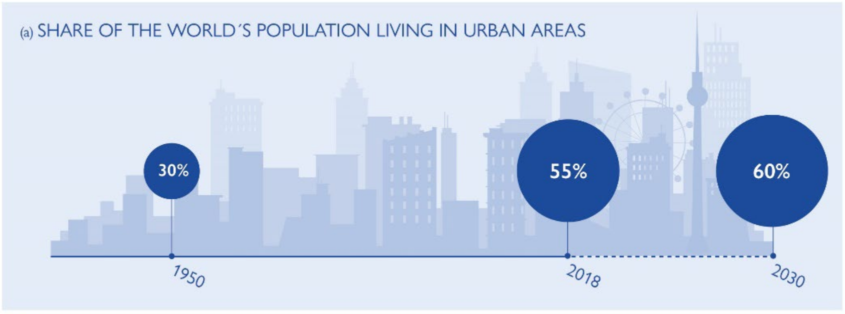
3. **Buildings' role in the transition towards a fossil-free society.**
   Buildings are capable of offering energy flexibility and short-term thermal storage

4. **Final users/customers engagement**
   OECD or EU and emphasise that the engagement of occupants, customers, and users must be parallel to technology development to achieve the decarbonisation milestones.

Energy use in residential buildings



URBANIZATION AND MIGRATION



Source#1: IEA; Source#2: UN report

Goal

The overarching goal of IEA EBC Annex 84 was to develop comprehensive knowledge used as guidelines for the successful activation of the DR in DHC systems. The work of IEA EBC Annex 84 explored both the **social** and **technical** challenges and how they can be overcome, as well as how **digitalisation** of the demand side can further facilitate large-scale DR utilization with the minimum investments.

Specific objectives:

- Provide knowledge on partners/actors involved in the energy chain and on collaboration models/instruments for successful demand management.
- Classify, evaluate and provide design solutions for new and existing building heating and cooling installations for successful demand management in various DHC networks.
- Classify methods and tools to utilize data from energy and IEQ monitoring equipment for real-time data modelling of thermal demand response potential in buildings and urban districts.
- Disseminate lessons learned from case studies collected by the Annex.

Structure

IEA EBC Annex 84
Demand Management of Buildings in Thermal Networks

Subtask A
Collaboration models – WHO
Denmark & Netherlands

- A.1 Existing situation in the field
- A.2 Definition and terminology
- A.3 Concepts for new collaboration models

Subtask B
Technology at building level - hardware
Austria & Germany

- B.1 Classification of buildings and DHC networks
- B.2 Supply, storage and distribution of energy in building
- B.3 Role of DHC substation
- B.4 Role of monitoring equip., sensors and control
- B.5 Framework for evaluation of technical options

Subtask C
Methods and Tools - software
Denmark & Singapore

- C.1 Smart thermal operation of buildings
- C.2 Smart buildings in urban-scale district thermal networks
- C.3 Smart algorithms for demand management of buildings in DHC networks

Subtask D
Case studies
Netherlands & Germany

- D.1 Type A - Existing buildings and networks (TRL7-9)
- D.2 Type B - New building (TRL6-7)
- D.3 Type C – Laboratory cases (technology) (TRL4-5)
- D.4 Type D - Virtual platforms (TRL3)
- D.5 Assessment and Evaluation

Annex 84 in numbers

- Timeframe June 2020 - June 2025
- 12 Participating countries (Austria, Belgium, Denmark, Germany, Italy, Netherlands, Singapore, Spain, Sweden, Switzerland, UK, Turkey)
- 19 Institutions
- 48 Participants joined 10 Annex 84 meetings

Annex 84 deliverables

D1 Collaboration models – overview of involved actors, existing practices, potential barriers and limitations, and recommendations for promising solutions for different building typologies and local context (STA, STD)

D2 Building technology for activation of the demand response in thermal networks - status, classification and development guidelines (STB, STD)

D3 Smart algorithms that realise the thermal DR potential in buildings by manipulating thermal actuators in building heating/cooling systems (STC, STD)

D4 Demand management of buildings in thermal networks – Case studies (STA, STB, STC, STD)

D5 Project Summary Report (STA, STB, STC, STD)

!! SOON AVAILABLE ON ANNEX 84 WEBPAGE !!

IEA EBC Annex 84
Demand management of buildings in thermal networks (DHC systems)

THANK YOU

Closing webinar 24.04.2025

https://annex84.iea-ebc.org

IEA EBC Annex 84

Demand management of buildings in thermal networks (DHC systems)

Closing webinar 24.04.2025

https://annex84.iea-ebc.org

Agenda

9:00 – 9:15: Introduction to the seminar and IEA Annex 84

9:15 – 10:00: Block 1 – Societal and technological challenges
Subtask A, Anna (AAU)
Subtask B, Ingo (AEE Intec)

10:00 – 10:15: Break

10:15 – 11:00: Block 2 – Digitalization challenges and case studies
Subtask C, Hicham (SINTEF)
Subtask D, Chris (Fraunhofer, IEE)

11:00 – 11:30 Block 3 – Q&A session and overall discussion

9:15 – 10:00: Block 1 – Societal and technological challenges

Subtask A

Subtask B

IEA Energy in Buildings and Communities Technology Collaboration Programme

IEA EBC Annex 84 – Subtask A: Collaboration models

Anna Marsza-Pomianowska
AAU, Denmark

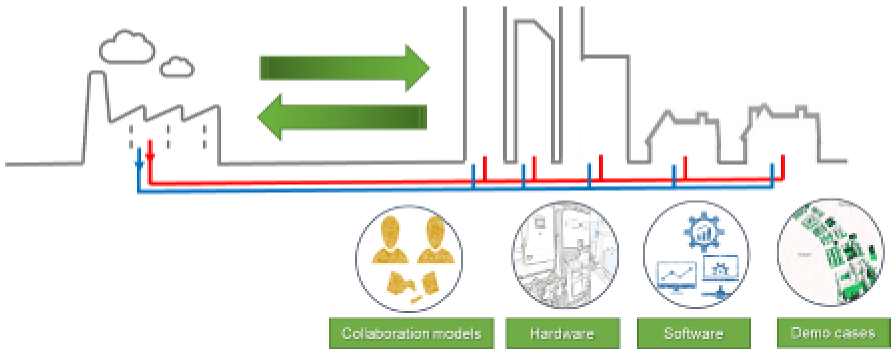
Christopher Graf,
Fraunhofer, IEE, Germany

Markus Schaffer,
AAU, Denmark

Toke Haunstrup Bach Christensen
AAU, Denmark

Subtask A in Context

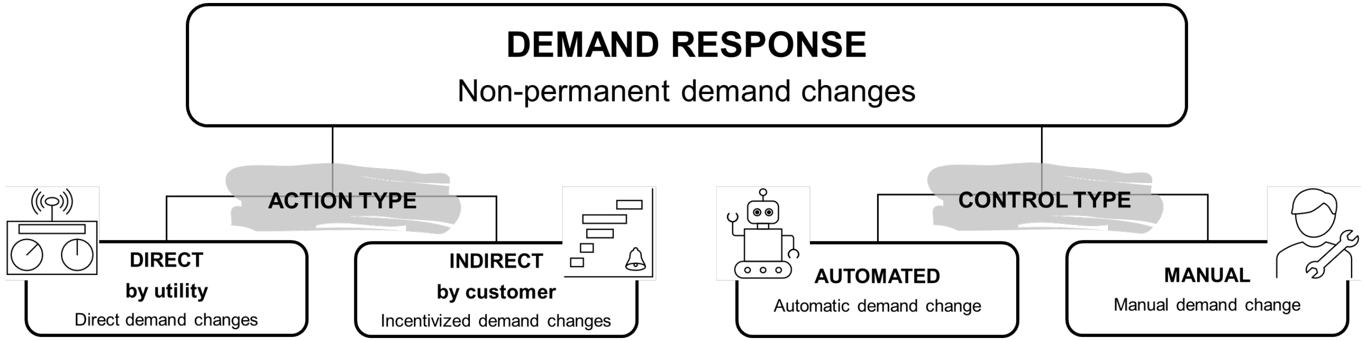
- Subtask A = "WHO – People" → What actors/stakeholders are necessary for successful demand response activation
  - Subtask B = HOW - Hardware
  - Subtask C = HOW – Software
  - Subtask D = Case studies



IEA EBC Annex 84 concept

- Objectives of Subtask A
  - Review existing terminology describing the DR concept and develop a common language
  - Provide knowledge on actors/stakeholders involved in the energy chain of DR
  - Review existing collaboration models and provide recommendations for the commercial utilisation of the DR

Demand Response terminology in Annex 84



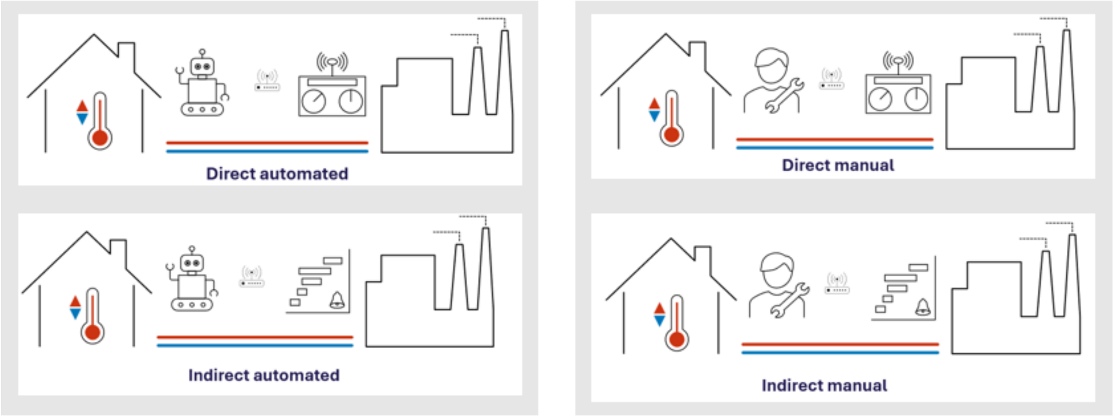
Direct DR: the change in the demand profile is directly activated in–the building by **the DHC grid operator** according to the agreement conditions made between the end-user and DHC utility. The DR event does not require constant customer engagement and reactions. The DR event/output has a low uncertainty and a high reliability.

Indirect DR: the change in the demand profile is expected to be the response to the variations in the broadcasted signal (e.g. energy price, environmental footprint, shot-down periods, flexibility market bid). **The end-user** is the actuator of the DR event. The DR event/output has a high uncertainty and a low reliability.

Automated: the change of the demand profiles is made by automated and remote adjustment of the settings of heat installation components. To execute the DR event, there **MUST** be interoperability components present. The DR event/output has a low uncertainty and a high reliability.

Manual: the change of the demand profiles is made by manual adjustment of the settings of heat installation components. To execute the DR event, there **CAN** be interoperability components present. The DR event/output has a high uncertainty and a low reliability.

Technology agnostic!!



Direct Automated - model predictive control in the building executing a forecast of the DHC grid operator (high & high reliability)
Indirect Automated - model predictive control in the building reacting to the DHC broadcasted signal (low & high reliability)
Direct Manual - DHC operator vising the house or sitting in the control room and pressing the button (high & low reliability)
Indirect Manual - end users changing the settings physically of via using the remote technology (walking in the house, sitting on the sofa and using app) as the reaction to the broadcasted signal (it is characterised by low & low reliability)

End-users’ engagement in DR programmes

Using literature review the following conclusions were formulated:

For DR solutions to be successful and functional in practice, two key criteria must be met:

- **Meaningfulness**: The solution must resonate with people and align with their values or motivations.
- **Practicality**: The solution should be easy for users to engage with, ensuring it is both functional and user-friendly.
  - Technological design
  - Competences/Skills and Know-how

End-users' engagement in DR programmes

Real-life DR experiments followed by interviews with end-users:

- The DR experiment took place for 10 weeks in February and March 2020 in 10 three-storey apartments owned by the social housing association
- The DR control strategies included only the direct automated types, where the thermostatic valve settings were changed remotely without the end-user actions
- The end-users could always override the DR event settings

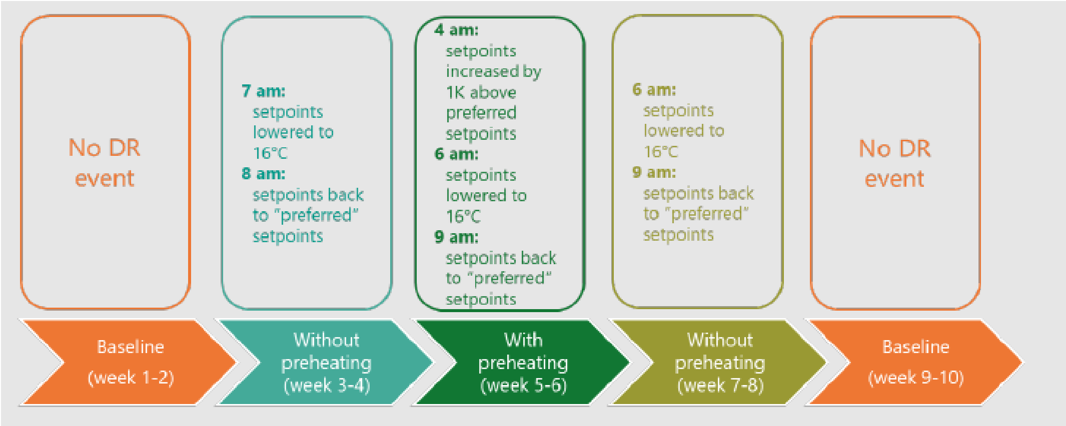


Figure 5. Overview of the DR strategies during the 10-week experiments and their characteristics.

End-users' engagement in DR programmes

Real-life DR experiments followed by interviews with end-users, the following conclusions were formulated:

Part 1: Experience of the indoor environment during DR trial

Part 2: Perceived level of control of temperature in home.

- The frustration with the new thermostats was a key factor to consider when assessing the interviewees' perceptions of their control over the indoor temperature during the DR experiment.
- A clear understanding of the plan and objectives behind a DR strategy may significantly influence how households will experience indoor temperature variations.

Part 3: Attitudes towards participating in DR programmes in DH networks

- The interviews revealed that house owners were generally positive about their participation in future Demand Response schemes.
- However, this acceptance is conditional on maintaining some level of control
- Cost saving is an important incentive. Yet, the interviewees found it difficult to estimate how much they would need to save to make participation in DR programs worthwhile

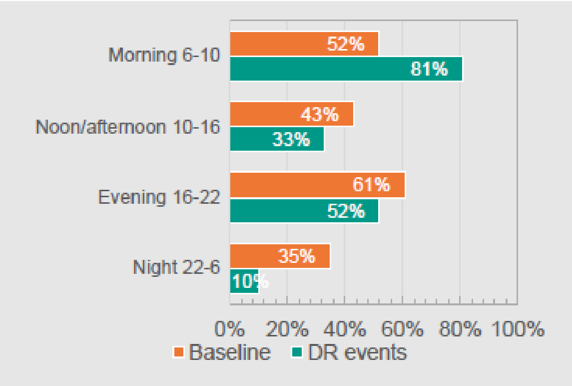


Figure 6. Distribution of answers to the question: what time of the day do you experience problems with too low temperatures? (Baseline weeks 1,2,9,10; DR period weeks 3-8).

Survey with DHC professionals

The survey was designed to gauge the opinions and attitudes of DHC professionals towards the DR concept.

1. It included

- 17 Likert Scale questions with a five-point agreement scale
- 2 open-text questions,
- 1 close-ended question

2. Translated to English, Danish, French, German, Italian and Spanish

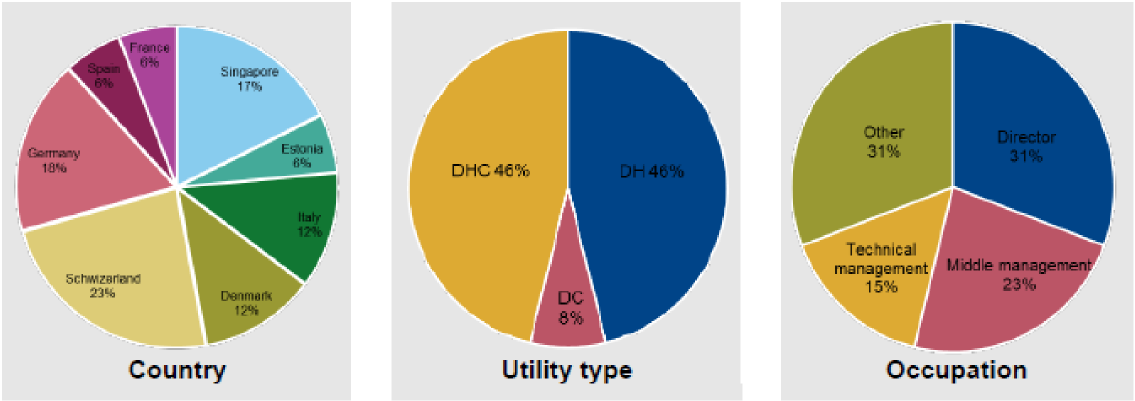


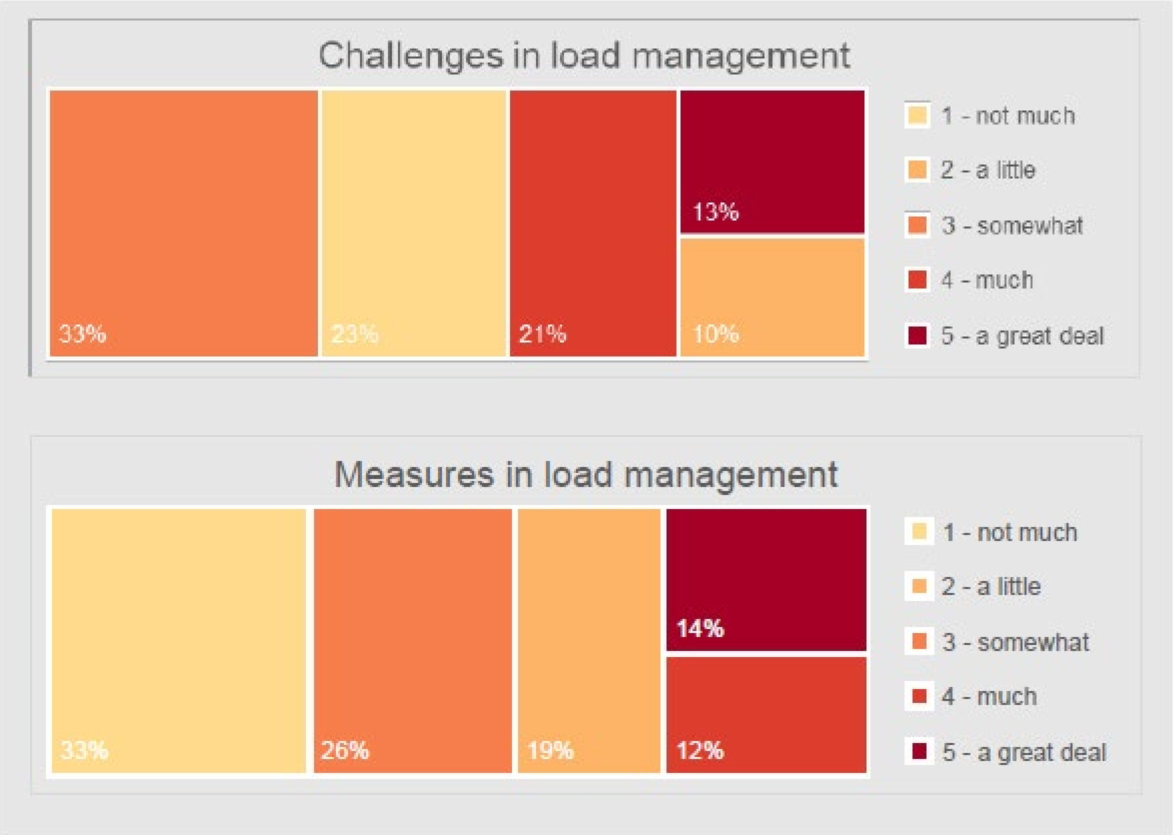
Figure 8. Characteristics of the survey respondents.

Topics of questions

1. **Load management: challenges and experience**
2. Relevance of the electricity market
3. **Familiarity with DR**
4. Willingness for system upgrades and investment enabling DR
5. **DR control limitations: data privacy, thermal comfort, legal responsibilities**
6. Benefits and barriers from DR and their importance
7. Incentives for customers to participate in DR programmes
8. Relevance of DR to future developments of DHC systems
9. Importance of policy measures to enable DR programmes

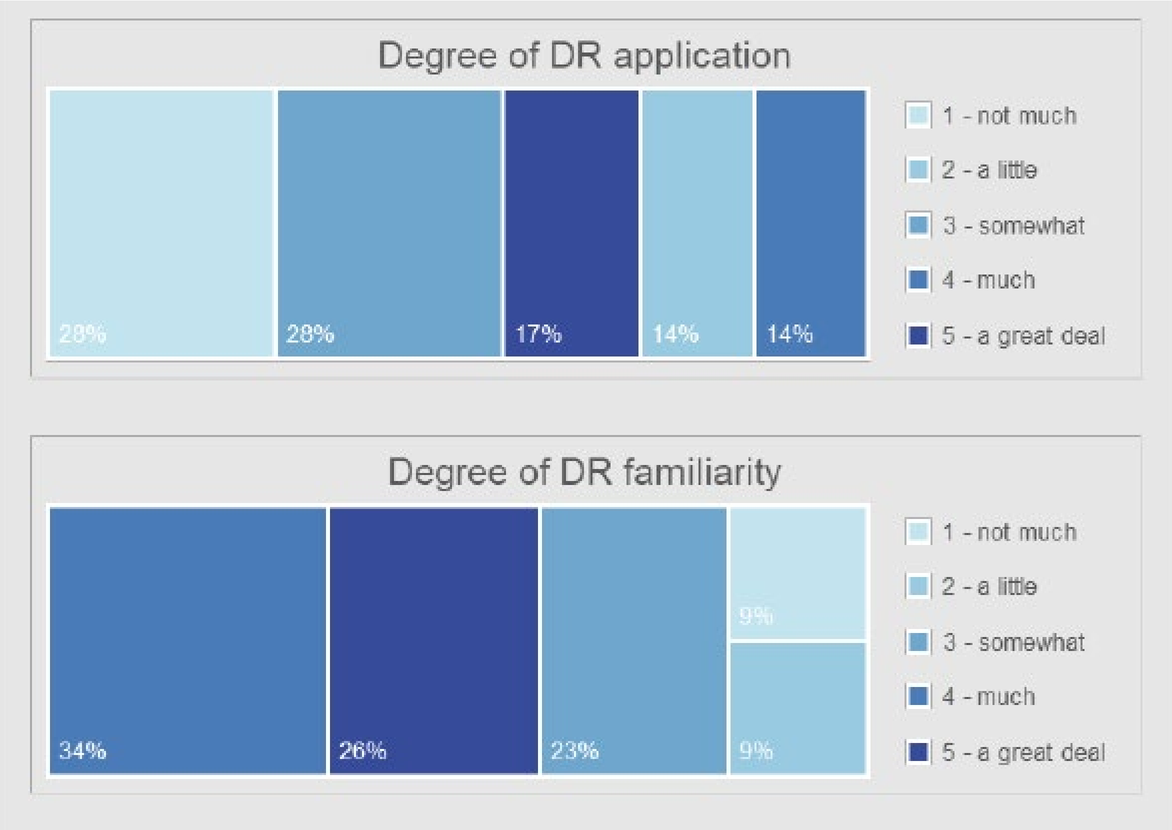
Topics of questions

1. Load management: challenges and experience



Topics of questions

3. Familiarity with DR



Topics of questions

5. DR control limitations: data privacy, thermal comfort, legal responsibilities

“Mostly contractual obligations than legal” (SIN)

“The electricity grid must have already put in place demand response mechanism”

“Old structure and known and safe practices” (DK)

“Split of cost customer / network operator” (DE)

“The technical effort is too great” (DE)

“Customer-facing marketing” (SP)

“Tariffs” (SP)

Likert Scale	Data privacy	Customers thermal comfort	Legal responsibilities
Absolutely not	38%	21%	25%
Mostly not	17%	20%	13%
Probably	33%	25%	38%
Mostly yes	8%	21%	17%
Absolutely yes	4%	13%	7%

Conclusions

- The results indicated that most DHC utilities currently do not implement significant measures to shift demand-side loads to manage daily load fluctuations in the network. Instead, their main strategies focus on the primary side, involving the control of production units and the optimization of distribution networks. However, the survey confirmed that many DHC utilities are familiar with the DR concept.
- The primary restrictions preventing the large-scale application of DR are legal and **contractual** responsibilities. Another major barrier is the lack of experience and knowledge transfer on DR applications between DHC utilities. Responses from professionals suggest a shortage of real-life DR application examples, despite subtask D in Annex 84 having collected multiple DR trial cases.
- Regarding customer participation in DR schemes, monetary incentives are considered the most effective motivation. However, there is also potential for leveraging environmental benefits and energy savings to engage DHC customers.

Main takeaways

1. Enhance Communication and Customer Engagement

- Inform customers about DR programme objectives, schedules, and expected impacts to mitigate frustration and increase participation.
- Provide user-friendly interfaces and controls that allow households to customize DR participation, ensuring comfort and convenience.

2. Develop Socially Equitable Pricing Models

- Introduce variable DH tariffs gradually, ensuring safeguards for low-income households to prevent affordability issues.
- Implement financial support mechanisms such as subsidies or low-interest loans to encourage energy-efficient renovations, mitigating negative social impacts.

3. Promote Knowledge Sharing and Best Practices

- Establish platforms for DHC utilities to exchange experiences and lessons learned from DR implementations.
- Encourage pilot projects and demonstration cases to showcase the benefits and feasibility of DR schemes.

Main takeaways

4. Address Regulatory and Contractual Barriers

- Advocate for policy adjustments that facilitate demand-side flexibility while ensuring legal and contractual clarity.
- Develop standardized DR frameworks to support consistent implementation across different market structures.

5. Leverage Multiple Incentives for Customer Participation

- Combine financial incentives with environmental and energy-saving motivations to appeal to a broader range of customers.

IEA Energy in Buildings and Communities Technology Collaboration Programme

IEA EBC Annex 84 – Subtask A: Collaboration models

Benedetto Nastasi, Sapienza University of Rome, Italy
Clemens Felsmann, Engineering and Heat Supply, TU Dresden
Emilia Motoasca, DAIKIN EUROPE
Elisa Guelpa, Department of Energy, Politecnico di Torino, Italy
Hicham Johra, SINTEF Community, Norway
Ingo Leusbrock, AEE Intec, Austria
Joaquim Romaní Picas, IREC, Spain
Michele Tunzi, Technical University of Denmark DTU, Denmark
Per Heiselberg, Aalborg University, Denmark
Tobias Schrag, Technische Hochschule Ingolstadt, Germany
Vittorio Verda, Department of Energy, Politecnico di Torino, Italy

IEA Energy in Buildings and Communities Technology Collaboration Programme

IEA EBC Annex 84 – Subtask A: Collaboration models

Thank you!

Questions?

IEA EBC Annex 84

Demand management of buildings in thermal networks (DHC systems)

Closing webinar 24.04.2025

https://annex84.iea-ebc.org

Agenda

9:00 – 9:15: Introduction to the seminar and IEA Annex 84

9:15 – 10:00: Block 1 – Societal and technological challenges
Subtask A, Anna (AAU)
Subtask B, Ingo (AEE Intec)

10:00 – 10:15: Break

10:15 – 11:00: Block 2 – Digitalization challenges and case studies
Subtask C, Hicham (SINTEF)
Subtask D, Chris (Fraunhofer, IEE)

11:00 – 11:30 Block 3 – Q&A session and overall discussion

9:15 – 10:00: Block 1 – Societal and technological challenges

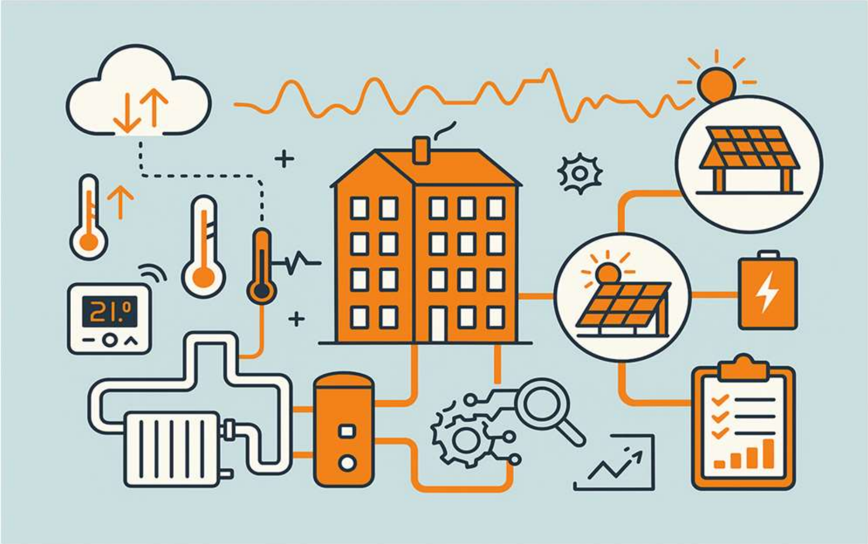
Subtask A

Subtask B

EBC
Energy in Buildings and Communities Programme

IEA Energy in Buildings and Communities Technology Collaboration Programme

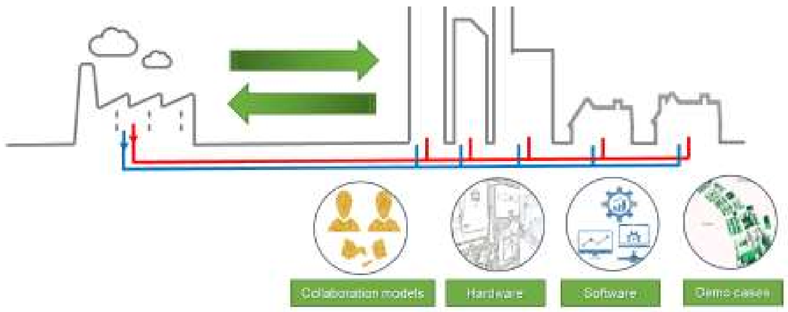
IEA EBC Annex 84 – Subtask B: Technology at building level



Keith O'Donovan, Basak Falay, Larissa Hamilton, Ingo Leusbrock
AEE INTEC, Austria
Juliane Schmidt, Clemens Felsmann
TU Dresden, Germany
Michele Tunzi
DTU, Denmark

Subtask B in Context

- Subtask B = "HOW – Hardware" → How buildings can technically allow for demand side management
  - Subtask A = WHO
  - Subtask C = HOW – Software
  - Subtask D = Case studies



IEA EBC Annex 84 concept

- Objectives of Subtask B
  - Collect and evaluate technological options for DSM at building level
  - Assess technical & economic potential, limitations, and synergies
  - Provide structured insight across five Work Items (B.1–B.5)

Overview work items

Building Classification – *Work item B.1*

Storage, Supply & Distribution – *Work item B.2*

Monitoring & Control – *Work item B.4*

Substations – *Work item B.3*

EBC
Energy in Buildings and Communities Programme

Overview work items

Building Classification – *Work item B.1*

Storage, Supply & Distribution – *Work item B.2*

Monitoring & Control – *Work item B.4*

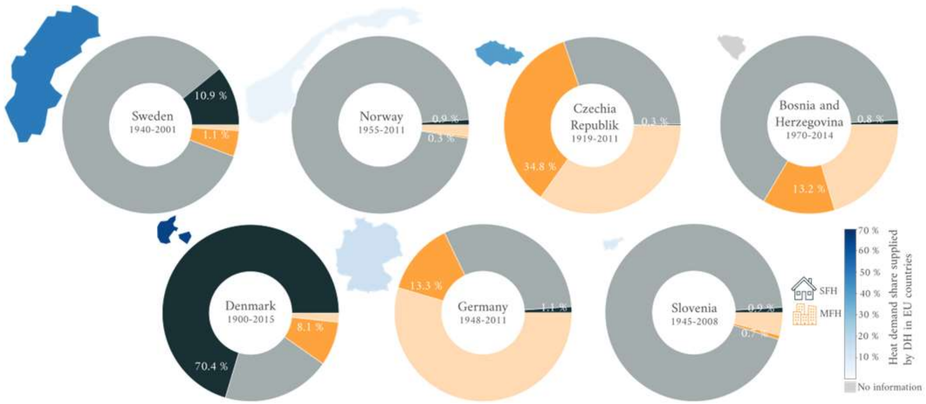
Substations – *Work item B.3*

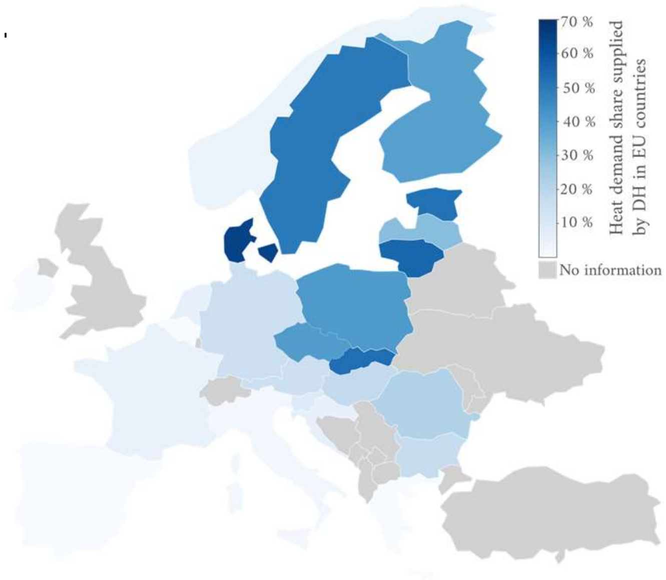
Evaluation & Summary – *Work item B.5*

Work Item B.1 – Building Classification

How do building type, age, and construction affect DSM potential?

- Comparison of different countries and databases
  - Denmark, Czech Republic, Sweden, Slovenia, Germany, Norway, Bosnia and Herzegovina
  - Tabula, Eurostat, Statistics Denmark, Statistik Austria,…
  - Papers and country reports

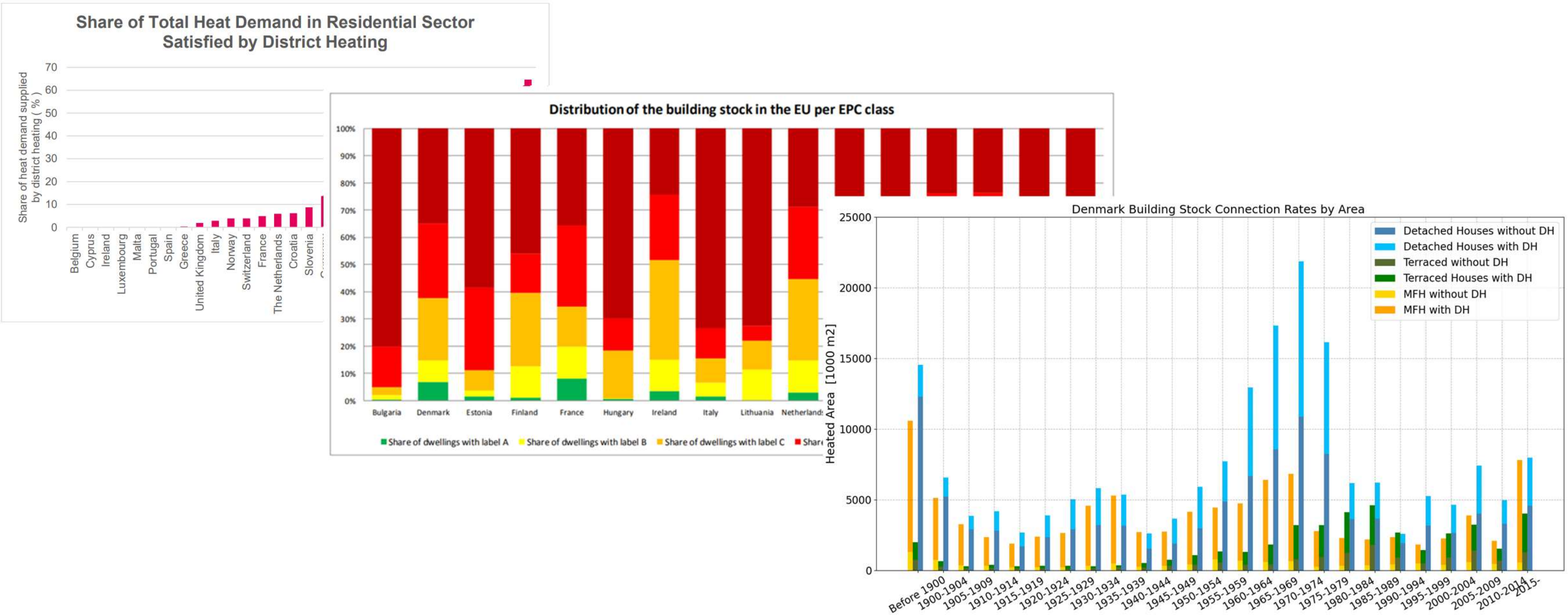




IEA Energy in Buildings and Communities TCP

Work Item B.1 – Building Classification

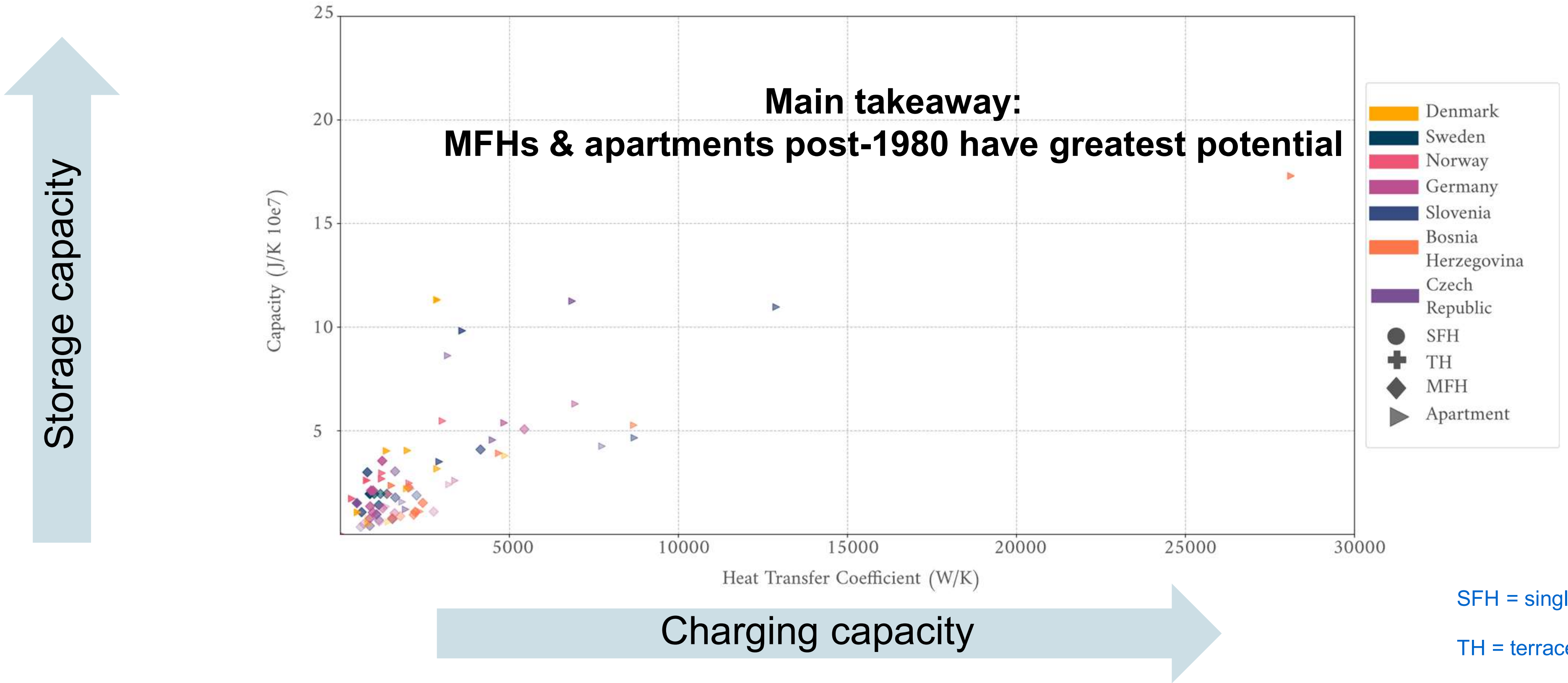
How do building type, age, and construction affect DSM potential?



AEE INTEC, Data: Statistics Denmark
RAMBOLL, ‘WEDISTRICT_WP2_D2.3-District-Heating-and-Cooling-stock-at-EU-level. Smart and local reneWable Energy DISTRICT heating and cooling solutions for sustainable living.’, Ref. Ares(2020)5595866-16/10/2020, Oct. 2020. Accessed: Mar. 20, 2025. [Online]. Available: https://www.wedistrict.eu/wp-content/uploads/2020/11/WEDISTRICT_WP2_D2.3-District-Heating-and-Cooling-stock-at-EU-level.pdf
Eurostat, ‘Energy balances (nrg_bal)’, Eurostat. Accessed: Mar. 25, 2025. [Online]. Available: https://ec.europa.eu/eurostat/cache/metadata/en/nrg_bal_esms.htm
Eurostat, ‘Disaggregated final energy consumption in households - quantities’, Eurostat. Accessed: Mar. 25, 2025. [Online]. Available: https://ec.europa.eu/eurostat/databrowser/product/page/nrg_d_hhq

Work Item B.1 – Building Classification

How do building type, age, and construction affect DSM potential?



SFH = single family house

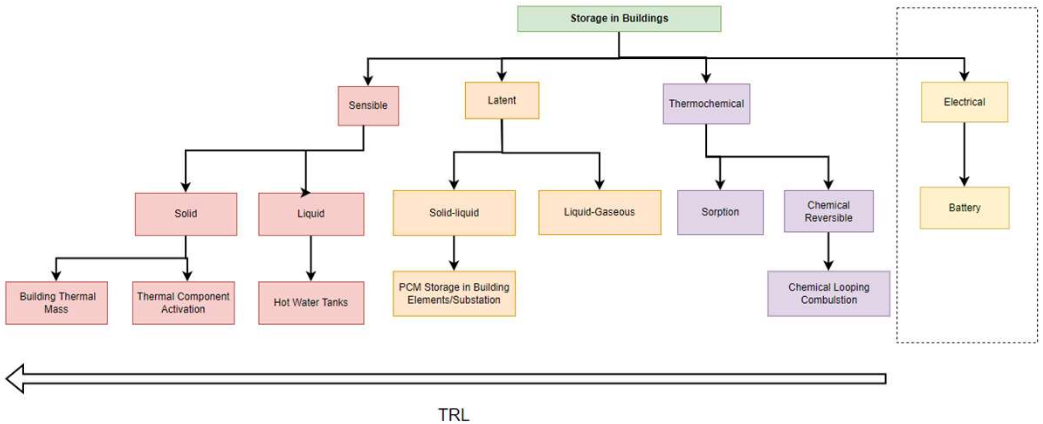
TH = terraced house

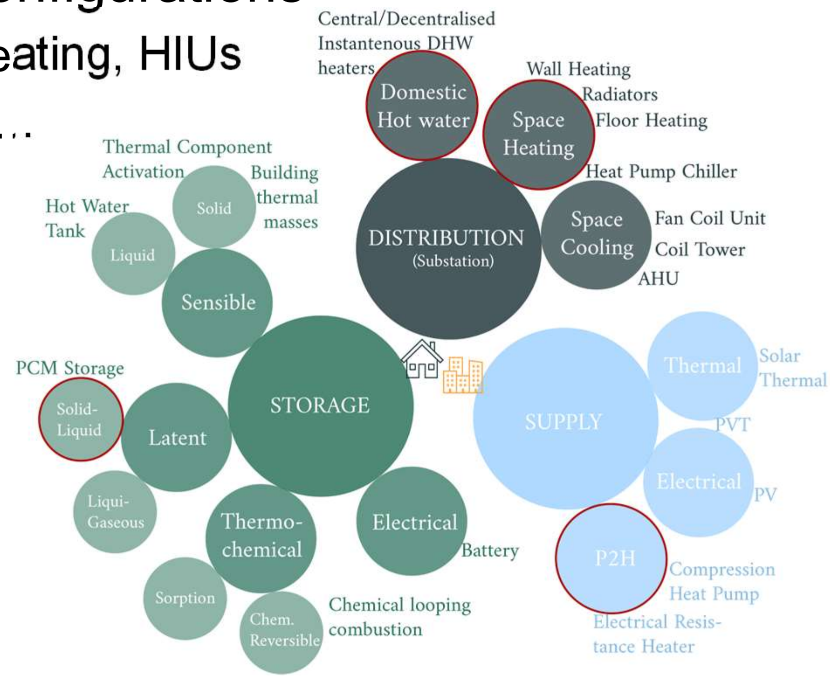
MFH = multi-family house

Work Item B.2 – Supply, Storage, Distribution

How to actively influence DSM potential

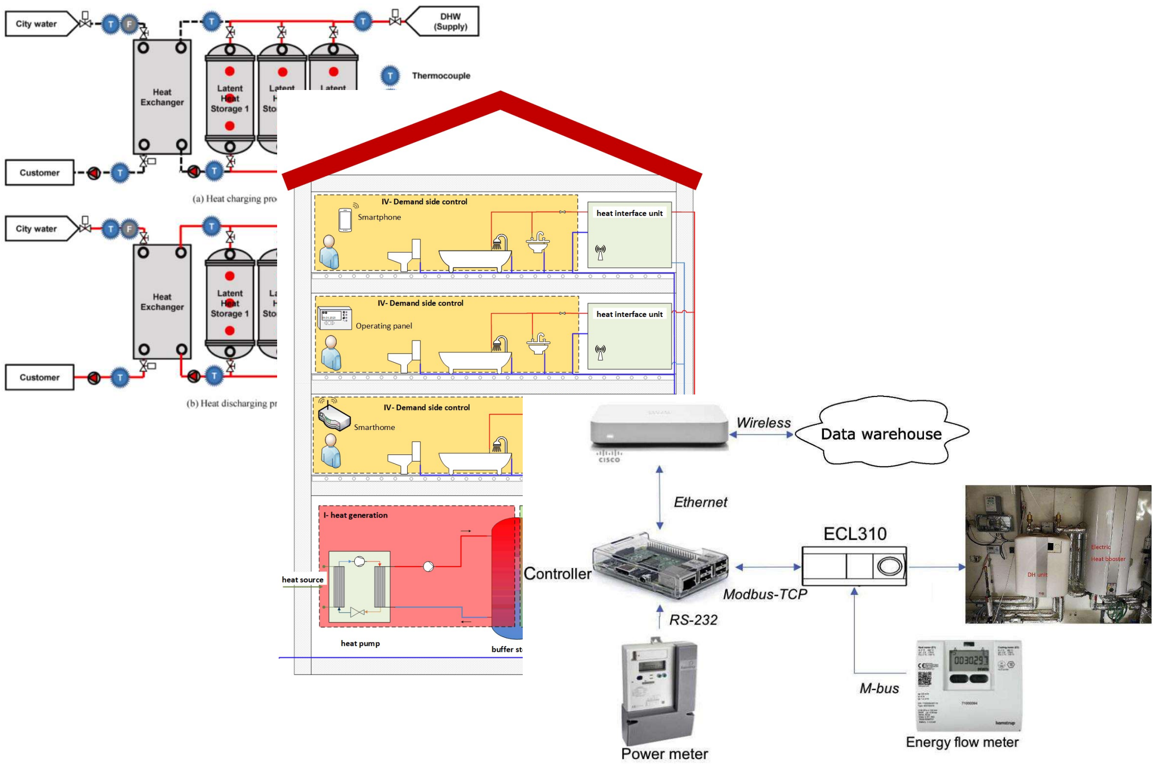
- Comparison of different technologies and configurations
  - Focus: Thermal storage (PCM, TABs), electric heating, HIUs
  - Based on case studies (including ST D), papers,…





Work Item B.2 – Supply, Storage, Distribution

How to actively influence DSM potential



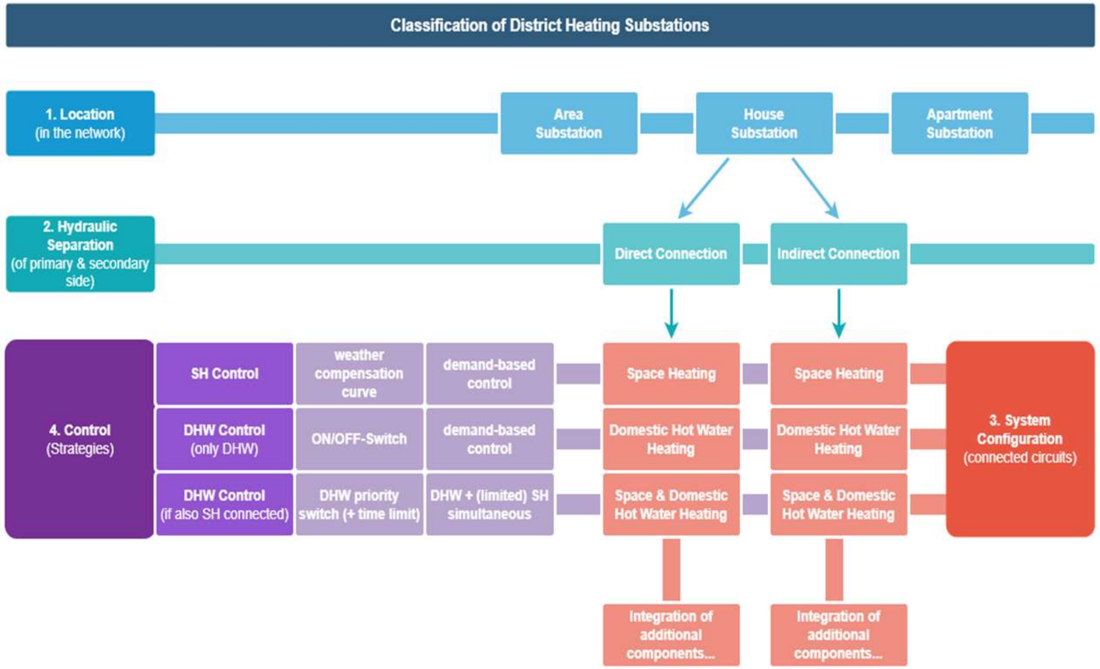
- Supply, storage, distribution not the limitation → high TRLs
- (most) DSM options have to be considered before construction
  - E.g., thermally activated buildings
    - https://iea-es.org/task-43/

D. Lee *et al.*, 'Peak load shifting control on hot water supplied from district heating using latent heat storage system in apartment complex' doi: 10.1016/j.csite.2022.101993.; M. Abugabbara, J. Lindhe, S. Javed, H. Bagge, and D. Johansson, 'Modelica-based simulations of decentralised substations to support decarbonisation of district heating and cooling', doi: 10.1016/j.egyr.2021.08.081. ; H. Cai, S. You, J. Wang, H. W. Bindner, and S. Klyapovskiy, 'Technical assessment of electric heat boosters in low-temperature district heating based on combined heat and power analysis', doi: 10.1016/j.energy.2018.02.084.

Work Item B.3 – Substations

How flexible are substations today?

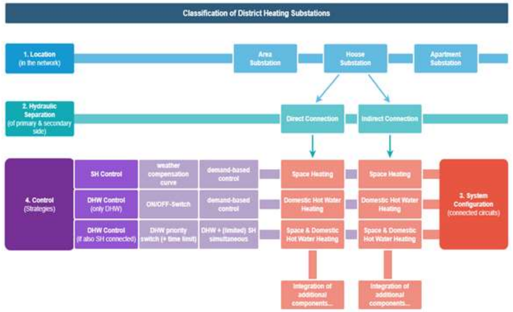
- Activities
  - Development of a DH substation classification

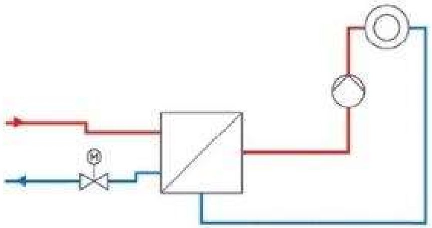


Work Item B.3 – Substations

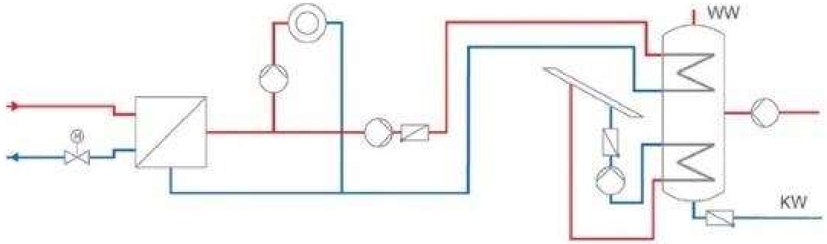
How flexible are substations today?

- Activities
  - Development of a DH substation classification

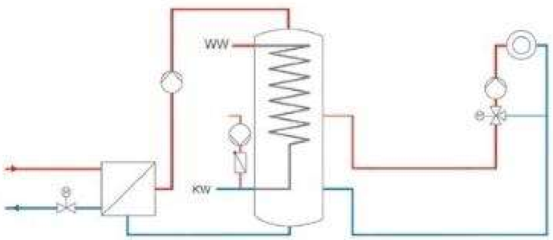




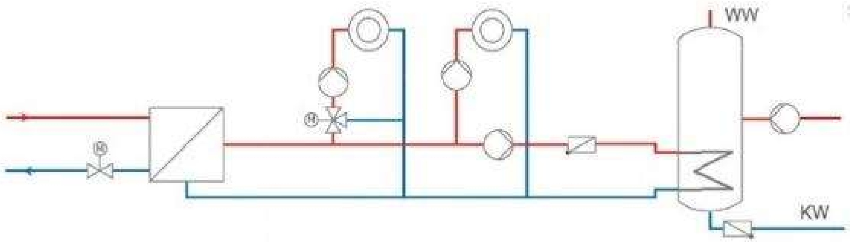
Only SH with 1 heating circuit



SH with 1 heating circuit, DHW heating with thermal solar support



Buffer storage supplies DHW and SH with 1 heating circuit



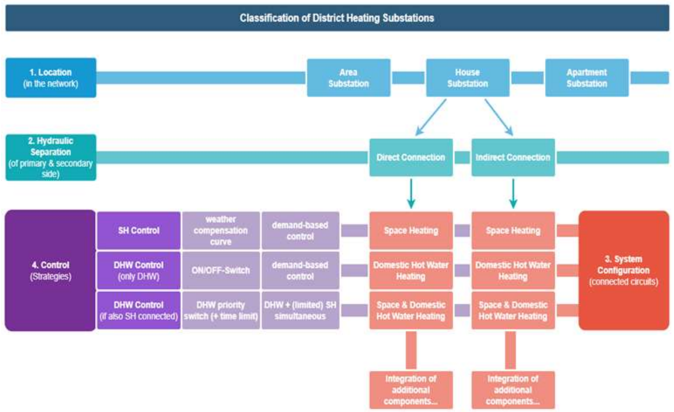
SH with 2 heating circuits (can be more) and DHW heating

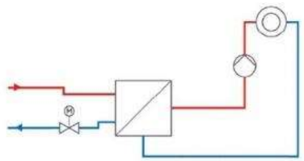
Work Item B.3 – Substations

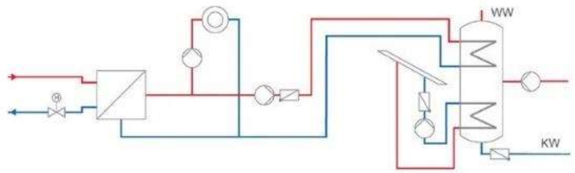
How flexible are substations today?

EBC
Energy in Buildings and Communities Programme

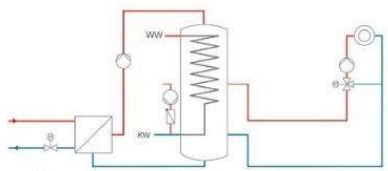
- Activities
  - Development of a DH substation classification
  - Special features of DC substations in contrast to DH substations
  - National pecularities (technical and legal)
  - Identification of thermal flexibility potential



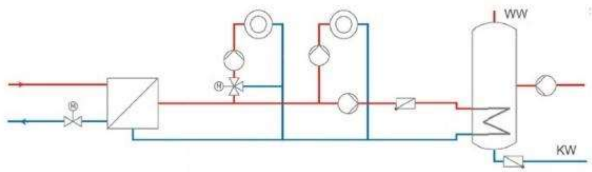

Only SH with 1 heating circuit



SH with 1 heating circuit, DHW heating with thermal solar support



Buffer storage supplies DHW and SH with 1 heating circuit

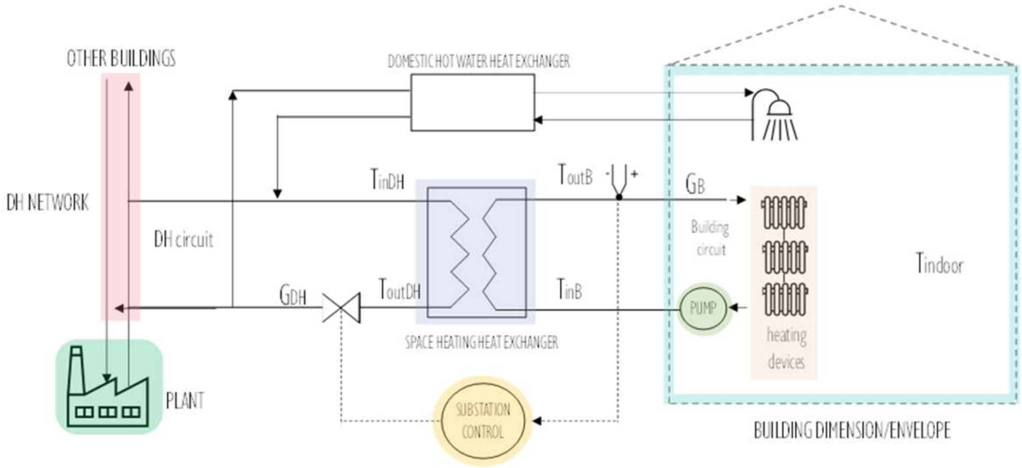


SH with 2 heating circuits (can be more) and DHW heating

Work Item B.3 – Substations

How flexible are substations today?

- Substation flexibility: What is it and affects it?
  - Heat exchanger
  - Control strategy
  - Interaction w/
    - Primary side
    - Seconday side



- Main takeaways
  - Substations need smarter sensors
  - Substations need better control logic
  - Substations need better integration

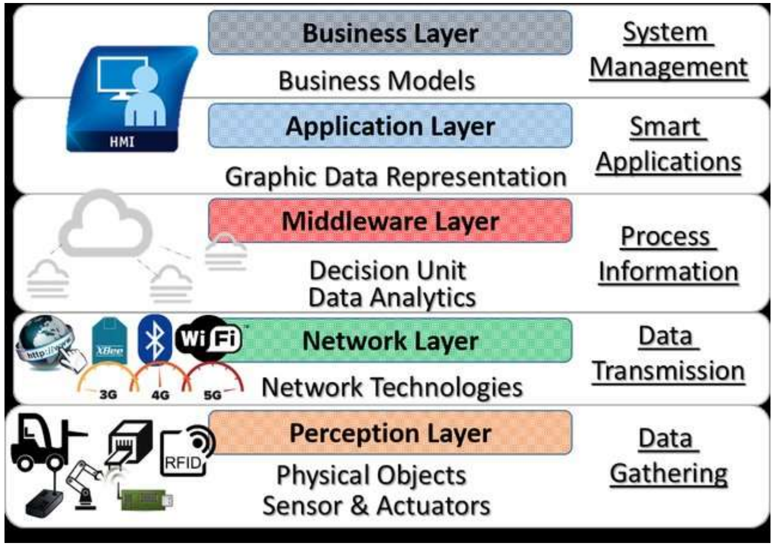
Work Item B.4 – Monitoring, Sensoring & Control

What to measure? How to monitor and control?

EBC Energy in Buildings and Communities Programme

- Focus:
  - Role of sensors, IoT, AI, and digital twins in DSM

- Main takeaways
  - No sensors → no monitoring & no control
  - Digitalization as enabler of flexibility
  - Interaction DHC operator & building owner needed
  - Interoperability & lack of standards as main barrier



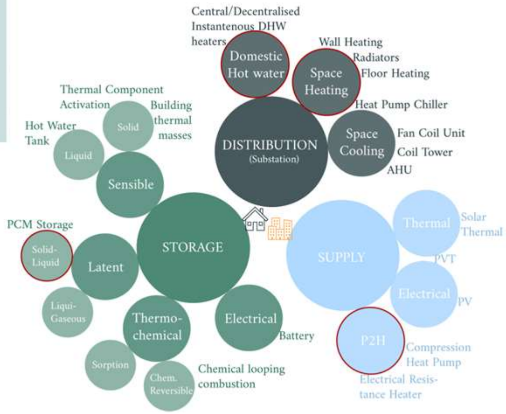
- More on digitization / digitalization in this context
  - IEA DHC TS4 & TS9 → https://www.iea-dhc.org/the-research/annexes/2024-2028-annex-ts9

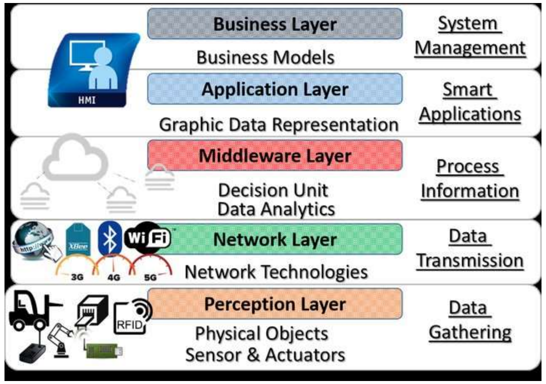
EBC
Energy in Buildings and Communities Programme

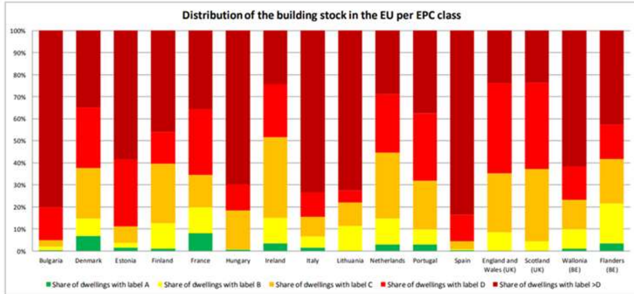
Work Item B.5 – Synthesis & Evaluation

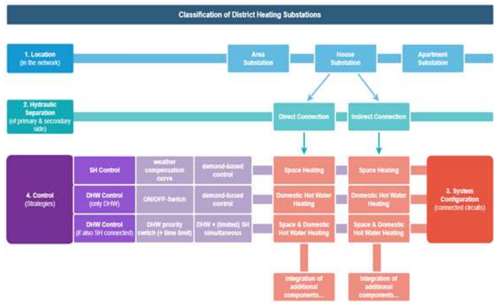
What have we learnt?

- Cross-cutting view on how technologies enable DSM
- Insight into technical readiness, limits, and interdependencies
- Structured tools for evaluating DSM flexibility









EBC

Energy in Buildings and Communities Programme

Main takeaways

- The hardware is not the limitation
  - But their interaction…
- DSM options have to be discussed
  - On a system level
  - Together with the DHC operators
- Evaluation framework necessary for impact and severity

Effectiveness in Peak Shaving

Feasibility of Implementation

Scalability Potential

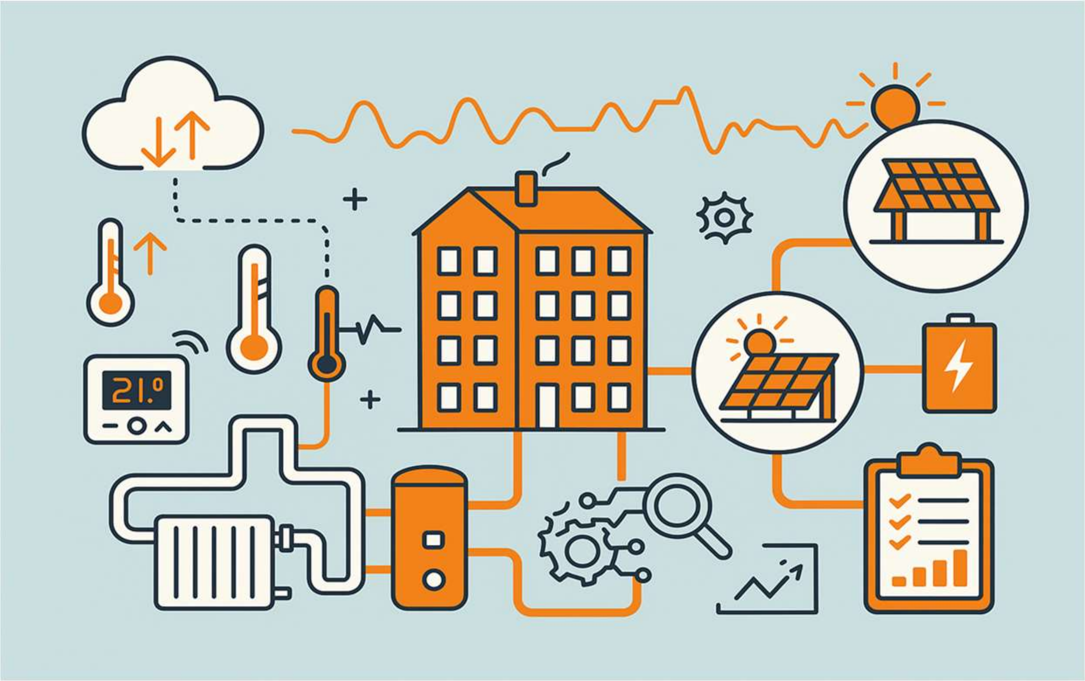
Cost-Effectiveness

User Acceptance and Engagement

Regulatory and Policy Alignment

EBC
Energy in Buildings and Communities Programme

IEA EBC Annex 84 – Subtask B: Technology at building level



Ingo Leusbrock
i.leusbrock@aee.at
AEE INTEC

Reports on Subtask B available at
https://annex84.iea-ebc.org/publications

Funded by
Federal Ministry
Innovation, Mobility
and Infrastructure
Republic of Austria

EBC
Energy in Buildings and Communities Programme

Potential follow-up activities

- Demonstration projects
  - assessing the impact of different DSM strategies in diverse building typologies
  - on dynamic pricing models incentivizing demand flexibility

- Research on user behavior and incentives to increase participation in DSM programs
- Exploration of business models for DHC operators to leverage DSM opportunities

IEA EBC Annex 84

Demand management of buildings in thermal networks (DHC systems)

Closing webinar 24.04.2025

https://annex84.iea-ebc.org

Agenda

Energy in Buildings and Communities Programme

9:00 – 9:15: Introduction to the seminar and IEA Annex 84

9:15 – 10:00: Block 1 – Societal and technological challenges
Subtask A, Anna (AAU)
Subtask B, Ingo (AEE Intec)

10:00 – 10:15: Break

10:15 – 11:00: Block 2 – Digitalization challenges and case studies
Subtask C, Hicham (SINTEF)
Subtask D, Chris (Fraunhofer, IEE)

11:00 – 11:30 Block 3 – Q&A session and overall discussion

9:15 – 10:00: Block 2 - Digitalization challenges and case studies

Subtask C

Subtask D

Energy in Buildings and Communities Programme

ANNEX 84

IEA EBC Annex 84 – Subtask C

Hicham Johra

SINTEF Community, Department of Architectural Engineering, Oslo, Norway

April 24th, 2025

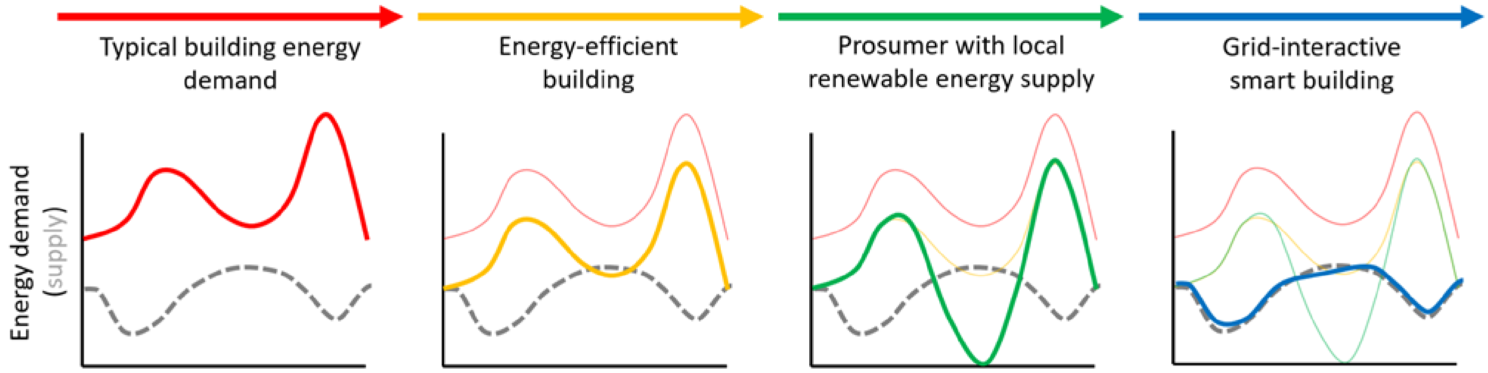
Tools and methods to leverage the thermal demand response potential in buildings connected to thermal networks

Introduction

EBC
Energy in Buildings and Communities Programme

The continuous digitalization of buildings and thermal networks unlocks new data-driven methods for the smart management of district heating and cooling systems, helping the latter to become more reliable, sustainable, and efficient, and to integrate renewable energy sources.

Subtask C of the Annex 84 looked into the different algorithms, methods, and numerical tools that can be useful for modelling the smart thermal operation of individual buildings connected to thermal networks, treating and analyzing large datasets from building clusters, and optimizing the smart management of heating/cooling grids with buildings performing demand response.



Modelling Demand Response of Buildings

EBC
Energy in Buildings and Communities Programme

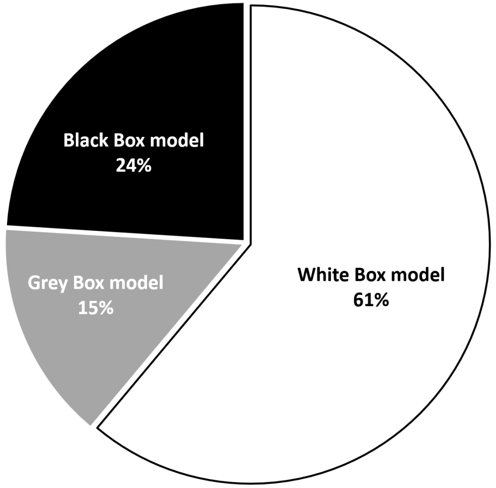
- Many simulation tools used by engineering and utility companies are not suitable for integrating building demand response and energy flexibility strategies.

- More advanced modelling tools exist to model buildings, thermal networks, and advanced control: e.g., TRNSYS, Modelica, SIM-VICUS, IDA ICE/Districts, DIMOSIM, CitySim.

- Increasing trend of using machine learning methods to generate black-box data-driven models of buildings and clusters of buildings.

- Co-simulation frameworks and tools (e.g., FMI)

can couple several domain-specific models:
E.g., EnergyPlus (buildings) and Modelica (thermal network).



Modelling Demand Response of Buildings

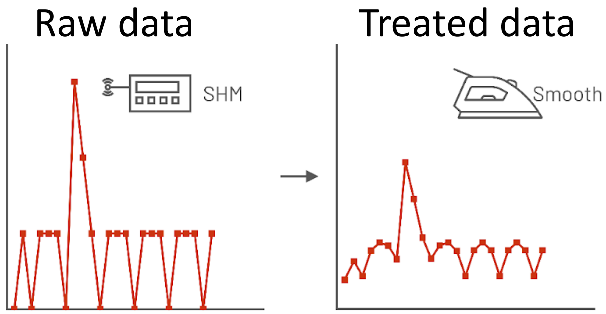
- Simulating large building clusters connected to thermal grids and performing demand response remains complex, require programming skills, with a steep learning curve.
- Need better documentation, seamless tool integration and interoperability.
- Need to solve bugs and improve model scalability towards hundreds or thousands of buildings.

Digital Twin Tools for Smart District Heating & Cooling

- Digital twin: virtual replica of physical assets, with a two-way data flow, continuously recalibrated, to simulate and optimize operation in real time.
- Key technology for transition to 4th and 5th generation district heating and cooling, with seamless integration of decentralized renewable energy sources, energy storage, demand response assets, and sector coupling with electricity and gas grids.
- Advanced multi-domain numerical models or co-simulation frameworks at the core of digital twins.
- Machine learning and AI methods for data-driven predictive and adaptive control, integrating weather forecasts, local energy and flexibility markets, to optimize operational costs and reduce environmental footprint.

Treatment of Large Data from Smart Heat Meters

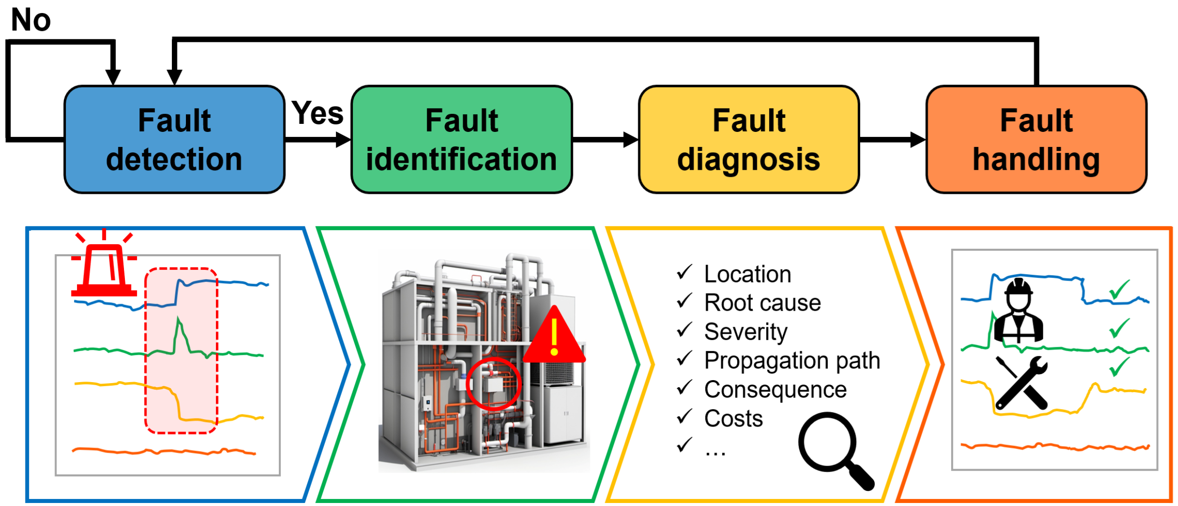
EBC
Energy in Buildings and Communities Programme



- Rapid deployment of smart heat meters generates large amounts of data.
- Valuable information: continuous monitoring of building heat demand.
- Crucial to understand consumers' behavior, forecast demand, design smart demand response management strategies, assess building performance, detect faults in large clusters of buildings and thermal networks.
- However, current smart heat meters are designed for billing purposes; raw data has restricted quality: limited time and measurement resolution (does not catch small and/or rapid events), large data gaps, and no sub-metering.
- New algorithms are developed to tackle low data resolution, impute missing data, and disaggregate space heating and domestic hot water production from total heat demand recordings.

Automated Fault Detection & Diagnosis

- To enable efficient thermal networks and buildings performing demand response: need fault-free systems.
- Large prevalence of faults in district heating sub-stations and building heating systems.
- Cause large energy inefficiencies, high return temperature, leakages, pumping losses, poor performance and reliability.
- Recently, computer-assisted and automated fault detection and diagnosis methods are developed for thermal networks.
- Reduce fault detection and repair time, enable proactive or predictive maintenance.
- Mostly rule-based methods, anomaly detection and model-based comparison.



Automated Fault Detection & Diagnosis

EBC
Energy in Buildings and Communities Programme

Limitations in the development of automated fault detection & diagnosis for thermal networks:

- Very little high-quality data with ground truth and information on faults in district heating systems and building substations: crucial to develop and test methods and algorithms.
- Smart heat meter measurement data and time resolution is too low for the detection and identification of many faults before they create larger issues.
- The collection, curation, and structuration of quality data with ground truth should follow clear and accepted taxonomies for system faults.
- District heating companies, utilities, building portfolio managers, and research institutions should prioritize the compilation, anonymization, standardization, and sharing of data to drive advancements in the field.

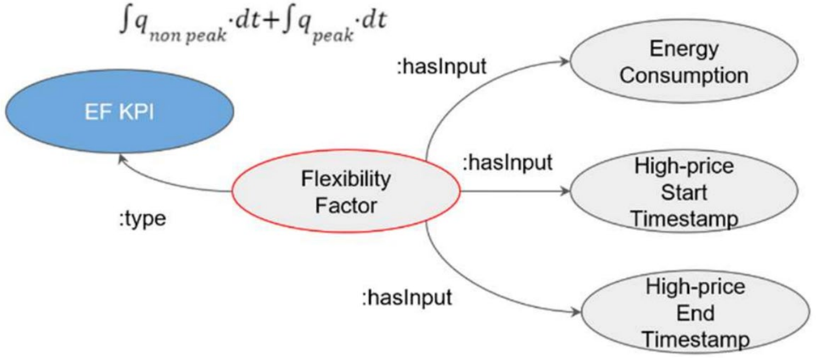
Model & Data Interoperability

Energy in Buildings and Communities Programme

- Scalable deployment of smart control, fault detection and analytics solutions require common data structures and inter-comprehensible data flow frameworks.

- Semantic modeling using ontologies is a methodology for creating standardized, machine-readable representations of buildings and energy networks, and structuring domain-specific knowledge.

$$FF = \frac{\int q_{non\ peak} \cdot dt - \int q_{peak} \cdot dt}{\int q_{non\ peak} \cdot dt + \int q_{peak} \cdot dt}$$



- In the domain of demand response and energy flexibility, the EFOnt ontology was developed to streamline demand response assessment: Ontology for demand response KPIs.

- Interoperable with other building-related ontologies like SAREF and Brick.

- Demonstration projects show significant time saving when using BIM and building ontologies to deploy demand response control applications in real buildings.

Conclusions

EBC

Energy in Buildings and Communities Programme

- Digital twins are key to smart management of district heating and cooling networks with buildings performing demand response and energy optimization.
- Need to improve modelling tools capable of detailed dynamic simulation of thousands of buildings performing demand response and smart control in thermal networks and other energy grids.
- Smart heat meter data is very valuable, but its low resolution hinders its usefulness.
- New algorithms are developed to impute missing data, smooth data and disaggregate space heating and domestic hot water production from main metering data.
- Continuous development of automated fault detection & diagnosis methods, but lack of quality training/testing dataset with labelled ground truth on fault in district heating systems.
- Ontologies and semantic principles are key to scalable deployment of smart building and thermal network applications.

Thank you for your attention
Questions?

Hicham Johra

SINTEF Community
Department of Architectural Engineering
Oslo
Norway

hicham.johra@sintef.no

Energy in Buildings and Communities Programme

IEA EBC Annex 84

Demand management of buildings in thermal networks (DHC systems)

Closing webinar 24.04.2025

https://annex84.iea-ebc.org

Agenda

Energy in Buildings and Communities Programme

9:00 – 9:15: Introduction to the seminar and IEA Annex 84

9:15 – 10:00: Block 1 – Societal and technological challenges
Subtask A, Anna (AAU)
Subtask B, Ingo (AEE Intec)

10:00 – 10:15: Break

10:15 – 11:00: Block 2 – Digitalization challenges and case studies
Subtask C, Hicham (SINTEF)
Subtask D, Chris (Fraunhofer, IEE)

11:00 – 11:30 Block 3 – Q&A session and overall discussion

9:15 – 10:00: Block 2 - Digitalization challenges and case studies

Subtask C

Subtask D

Energy in Buildings and Communities Programme

IEA EBC Annex 84 - Demand Management of Buildings in Thermal Networks

Subtask D – Case Studies

Christopher Graf, Anna Cadenbach

Fraunhofer Institute for Energy Economics and Energy System Technology IEE, Thermal Energy Technology

Fraunhofer IEE

April 24th, 2025 – Closing Webinar

EBC
Energy in Buildings and Communities Programme

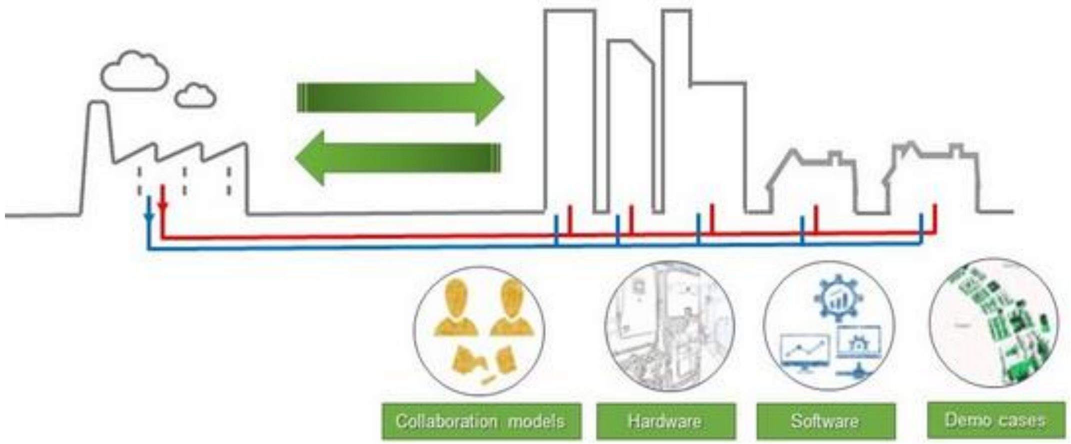
Subtask D of IEA EBC Annex 84

IEA EBC Annex 84
Demand Management of Buildings in Thermal Networks

- **Subtask A**
  Collaboration models – WHO
  Denmark & Netherlands
  - A.1 Existing situation in the field
  - A.2 Definition and terminology
  - A.3 Concepts for new collaboration models
- **Subtask B**
  Technology at building level - hardware
  Austria & Germany
  - B.1 Classification of buildings and DHC networks
  - B.2 Supply, storage and distribution of energy in building
  - B.3 Role of DHC substation
  - B.4 Role of monitoring equip., sensors and control
  - B.5 Framework for evaluation of technical options
- **Subtask C**
  Methods and Tools - software
  Denmark & Singapore
  - C.1 Smart thermal operation of buildings
  - C.2 Smart buildings in urban-scale district thermal networks
  - C.3 Smart algorithms for demand management of buildings in DHC networks
- **Subtask D**
  Case studies
  Netherlands & Germany
  - D.1 Type A - Existing buildings and networks (TRL7-9)
  - D.2 Type B - New building (TRL6-7)
  - D.3 Type C – Laboratory cases (technology) (TRL4-5)
  - D.4 Type D - Virtual platforms (TRL3)
  - D.5 Assessment and Evaluation

Subtask D: Objectives and Scope

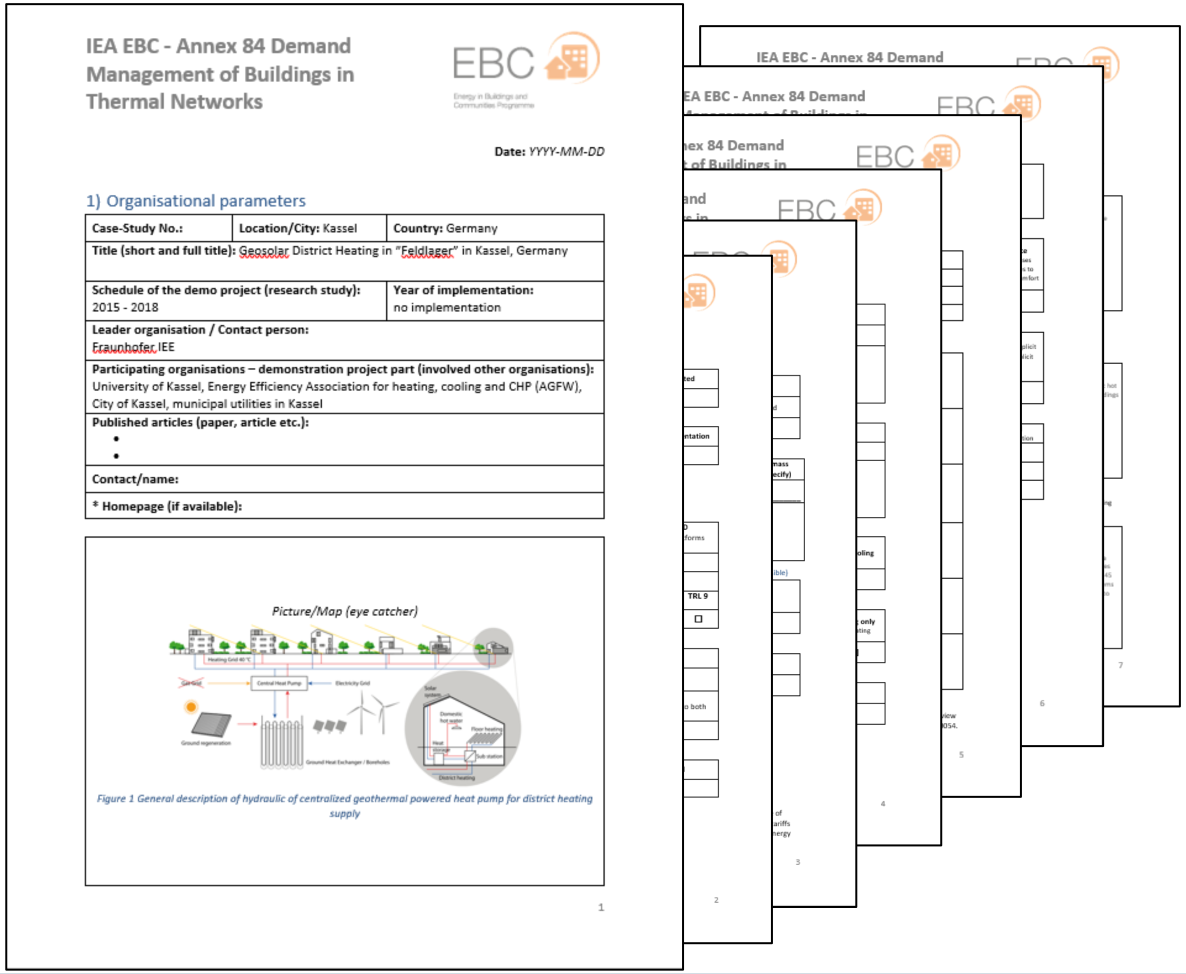
- Identification and classification of case studies
- Assessment of case studies based on “key features”
- Collection of lessons-learned from case studies regarding technology, buildings or districts
- Summary of results and comparative analysis
- Derivation of recommended actions (implementation and transferability)



Collection of case studies for the knowledge transfer regarding the implementation of novel concepts and technologies for Demand-Side-Management in thermal networks.

EBC
Energy in Buildings and Communities Programme

Questionnaire of Subtask D


IEA EBC - Annex 84 Demand Management of Buildings in Thermal Networks

EBC

Date: YYYY-MM-DD

1) Organisational parameters

Case-Study No.:	Location/City: Kassel	Country: Germany
Title (short and full title): Geosolar District Heating in "Feldlager" in Kassel, Germany		
Schedule of the demo project (research study): 2015 - 2018		Year of implementation: no implementation
Leader organisation / Contact person: Fraunhofer IEE		
Participating organisations – demonstration project part (involved other organisations): University of Kassel, Energy Efficiency Association for heating, cooling and CHP (AGFW), City of Kassel, municipal utilities in Kassel		
Published articles (paper, article etc.): • •		
Contact/name:		
* Homepage (if available):		

Picture/Map (eye catcher)

Figure 1 General description of hydraulic of centralized geothermal powered heat pump for district heating supply

1

1. Organizational Information
   Research Project, Implementation Status and More
2. Building Parameters
   Case Study Scope, TRL Level, Type Of Building Use
3. Energy Storage
   Type Of Storage, Type of DSM utilizing Storage
4. Thermal Grid Parameters
   Energy Sources, Energy Generator, Temperature, Demand Type
5. Demand-Side Management (DSM) Evaluation
   Importance, Operation, Purpose and Benefit of DSM Measure, Involvement Of Customer, System Boundary, Time Scale
6. Detailed Information
   Project, Buildings and Systems, Energy Supply Scheme, Flexibility and Demand Response, Collaboration/Business Model and Barriers

EBC
Energy in Buildings and Communities Programme

Overview of collected Case Studies I

	Title	Research Project	Implementation	Affiliation
1	Peak shaving in Turin District Heating	completed	completed	Politecnico di Torino
2	Data-driven automated DSM technology	completed	completed	AEE INTEC
3	100% renewable District Heating Leibnitz	completed	completed	AEE INTEC
4	Flexible energy system integration	completed	completed	AIT
5	Smart energy in homes	completed	completed	Aalborg University
6	Substitution of conventional controllers	in progress	completed	TU Dresden
7	DSM in Danish single-family house	in progress	completed	Aarhus University
8	Geo-solar low-temperature DH network	completed	no implementation	Fraunhofer IEE
9	Digitizing DH supply infrastructure	completed	completed	Fraunhofer IEE
10	DH networks within hybrid energy systems	in progress	in preparation	Fraunhofer IEE
11	Renewable energy integration in DH grid	in progress	in preparation	Fraunhofer IEE
12	Flexible and innovative DH grid operation	completed	completed	Fraunhofer ISE

Overview of collected Case Studies II

	Title	Research Project	Implementation	Affiliation
13	Acceptance of fluctuating indoor temperatures	completed	completed	Aarhus University
14	Remote control of radiator thermostats	completed	completed	Aalborg University
15	Temperature optimisation for LTDH	completed	completed	VITO / Energy Ville
16	Energy and cost savings in office building	completed	completed	DTU
17	DSM in smart homes: living-lab experiments	completed	completed	DTU
18	Energy flexibility of low-energy buildings	completed	completed	DTU
19	Buildings as thermal energy storage in DH grids	completed	completed	Chalmers University
20	Thermal conditions and flexibility potential	completed	completed	Aalborg University
21	Occupant fade-out from demand response	completed	completed	Aalborg University
22	Application of the STORM controller in Rottne	completed	completed	VITO
23	Optimal dispatch of heat in DH grid	in progress	in preparation	Idiap Research Institute
24	Load shifting in buildings connected to DH	completed	completed	UC London

EBC
Energy in Buildings and Communities Programme

Overview of collected Case Studies III

	Title	Research Project	Implementation	Affiliation
25	Perceptions of indoor climate during DR	completed	completed	Chalmers University
26	DR in Student Apartment Buildings	completed	completed	VTT Finland
27	Thermostats overrides during DR events	completed	completed	DTU
28	DR events in a university building	completed	completed	Aalto University
29	Smart grid flexibility in single-family houses	completed	completed	Aalborg University

Energy in Buildings and Communities Programme

Case Study Brochure and Case Study Profiles

Peak shaving in Turin District Heating

With the development of a genetic optimizer algorithm, the optimal anticipation time could be found to reduce the morning peak loads.

The district heating network in Turin is the largest in Italy. This project tested load shifting with some of the buildings connected to a distribution network in the Turin DH grid. The heat is generated in two large, combined heat and power plants and in various boilers.

The heating systems in most of the buildings are turned off overnight and reactivated in the morning between 5 and 6 am. This results in a load peak due to the system cooling down overnight. The peak is characterized by the mass flow rate and, consequently the thermal profile.

The implementation of demand response aims to reduce the peak load and the proportion of heat generated by the heat-only boilers. To mitigate peak loads, an optimizer has been designed to adjust the schedules of the heating systems installed in buildings to flatten the total thermal load as much as possible. The primary aim was to find the best timing for activating a building's heating system to achieve maximum peak shaving.

The best anticipation time is found by using a genetic algorithm optimizer. The optimization considers the predicted thermal demand for each building, utilizing data collected at substation level.

The genetic algorithm is incorporated to a network simulator. Combined, these tools can determine the optimal time for activating the heating systems.

Peak can be reduced by 5 % when fewer than 30 % of the buildings are considered, with a maximum anticipation of 20 minutes. Generally, these results support the inclusion of demand response strategies in DH networks.

Throughout the project, the maximum anticipation time was limited to 20 minutes to minimize effects on the internal temperature. However, simulation analyses show the peak effects can be entirely avoided by setting the maximum anticipation to 60 minutes.

Contact Details

Department of Energy,
Politecnico di Torino

Dr. Elisa Guelpa
elisa.guelpa@polito.it

Dr. Vittorio Verda
vittorio.verda@polito.it

www.polito.it

6 PEAK SHAVING IN TURIN DISTRICT HEATING EBC ANNEX 84 CASE STUDIES

Purpose: Provides stakeholders with short descriptions of a curated collection of exemplary case studies

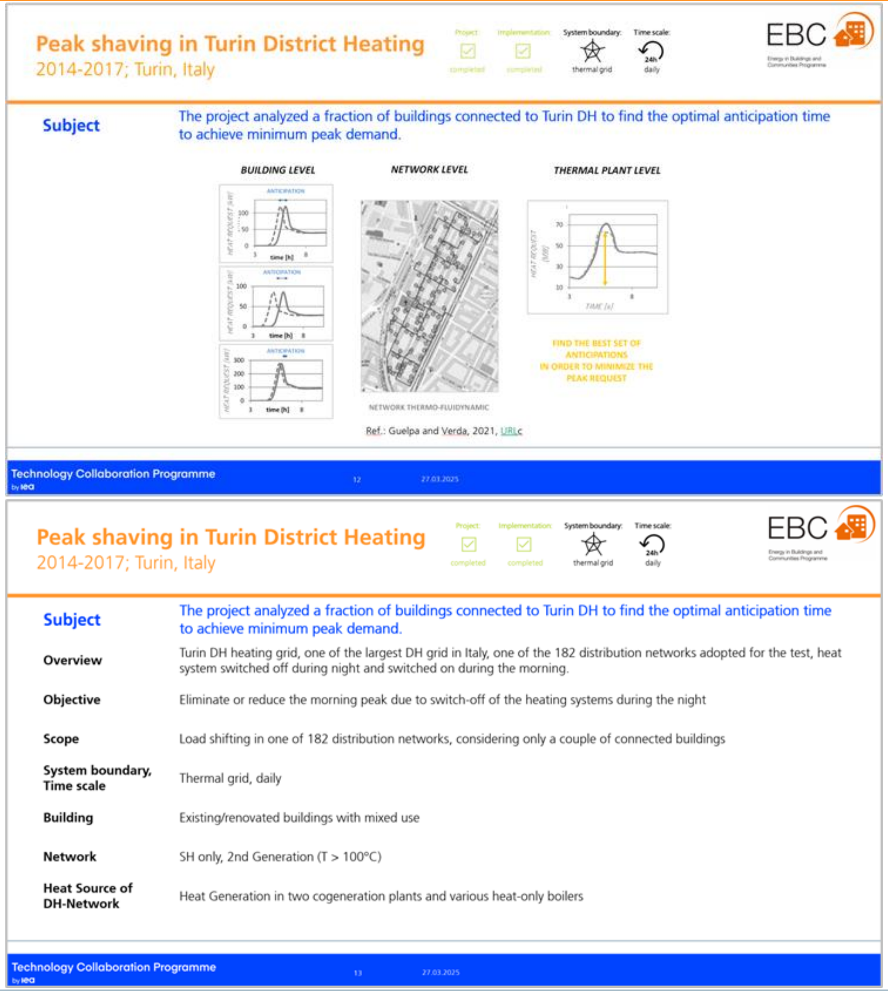
Content:

- Selected cases that align well with annex scope and goals and include practical implementations
- Project context and objectives; Technical implementation incl. customer collaboration and control systems; Quantifiable results and outcomes; Knowledge transfer through lessons learned and best practices

Published on the IEA EBC Annex 84 webpage
Available at: https://annex84.iea-ebc.org/publications

EBC Energy in Buildings and Communities Programme

Case Study Brochure and Case Study Profiles


Peak shaving in Turin District Heating
2014-2017; Turin, Italy

Project: completed | Implementation: completed | System boundary: thermal grid | Time scale: daily

Subject: The project analyzed a fraction of buildings connected to Turin DH to find the optimal anticipation time to achieve minimum peak demand.

Ref.: Guelpa and Verda, 2021, URLc

Technology Collaboration Programme by iea 12 27.03.2025

Peak shaving in Turin District Heating
2014-2017; Turin, Italy

Project: completed | Implementation: completed | System boundary: thermal grid | Time scale: daily

Subject	The project analyzed a fraction of buildings connected to Turin DH to find the optimal anticipation time to achieve minimum peak demand.
Overview	Turin DH heating grid, one of the largest DH grid in Italy, one of the 182 distribution networks adopted for the test, heat system switched off during night and switched on during the morning.
Objective	Eliminate or reduce the morning peak due to switch-off of the heating systems during the night
Scope	Load shifting in one of 182 distribution networks, considering only a couple of connected buildings
System boundary, Time scale	Thermal grid, daily
Building	Existing/renovated buildings with mixed use
Network	SH only, 2nd Generation (T > 100°C)
Heat Source of DH-Network	Heat Generation in two cogeneration plants and various heat-only boilers

Technology Collaboration Programme by iea 13 27.03.2025

Purpose: Provides a comprehensive and consistent analysis and thorough description of all case studies

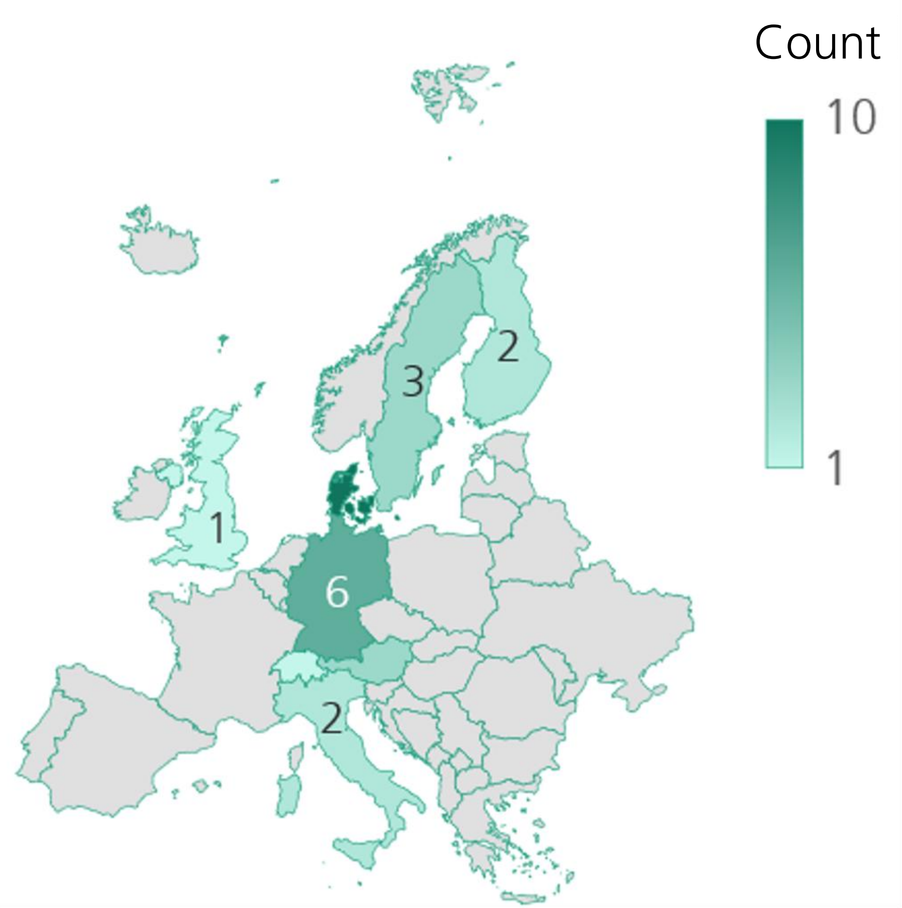
Content:

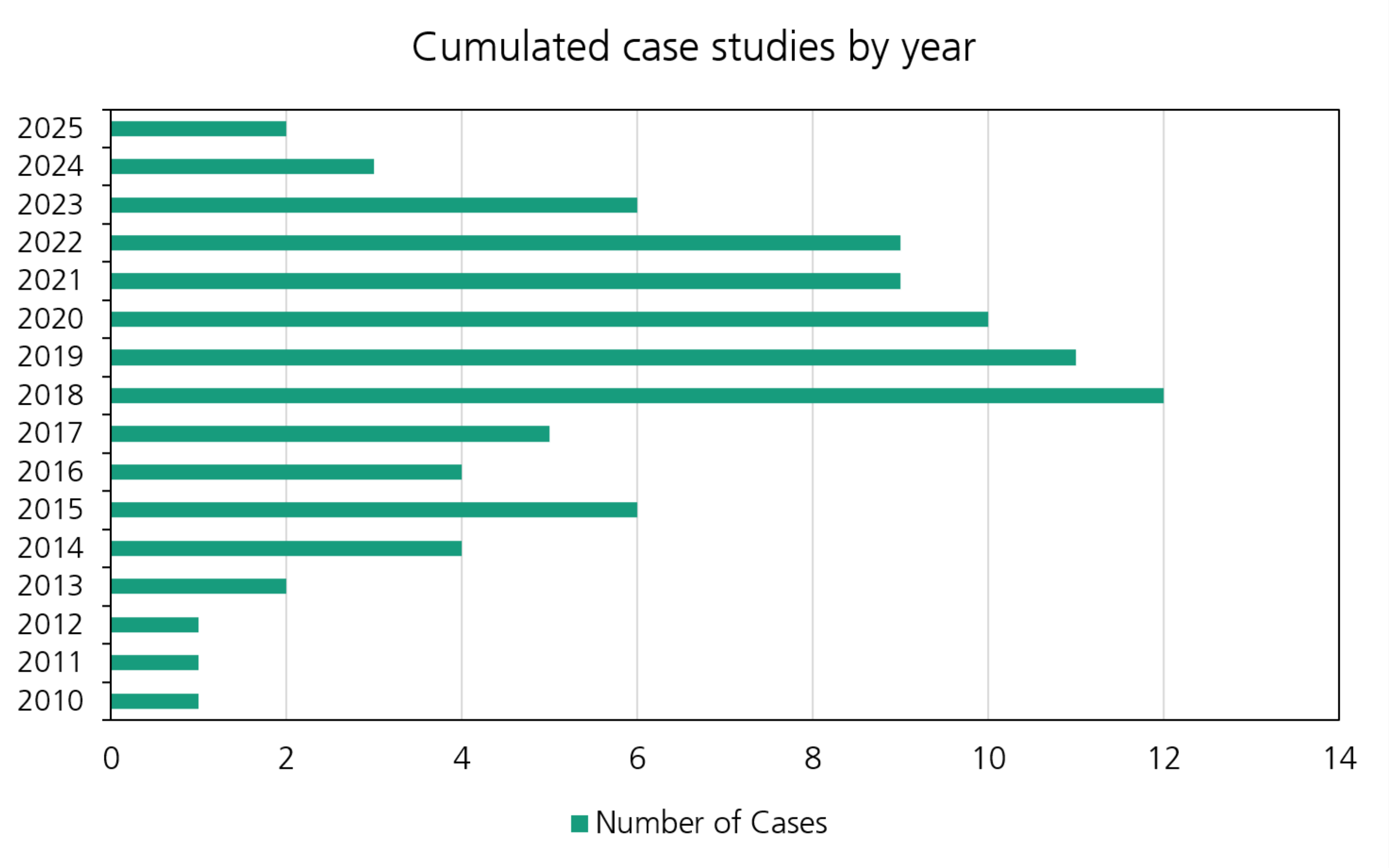
- Context: Project objectives, scope, system boundaries
- Infrastructure: Buildings, network specifications
- DSM: Active/passive approach, storages, time scales
- Stakeholder: Customer involvement, beneficiaries, collaboration details
- Technology: Control mechanism, sensors, IT infrastructure

Published on the IEA EBC Annex 84 webpage
Available at: https://annex84.iea-ebc.org/publications

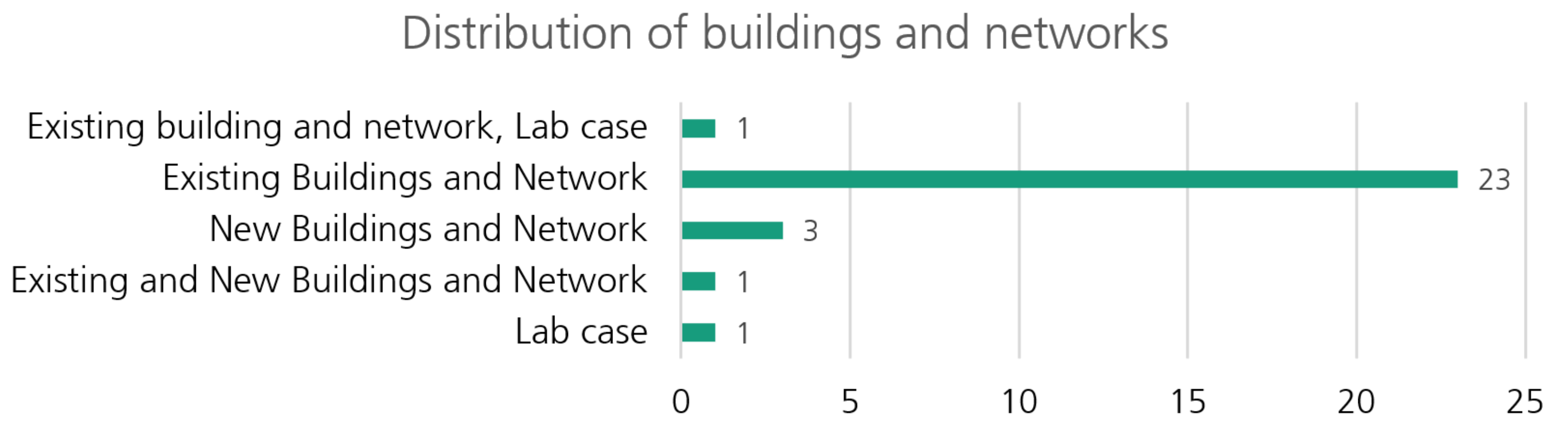
Energy in Buildings and Communities Programme

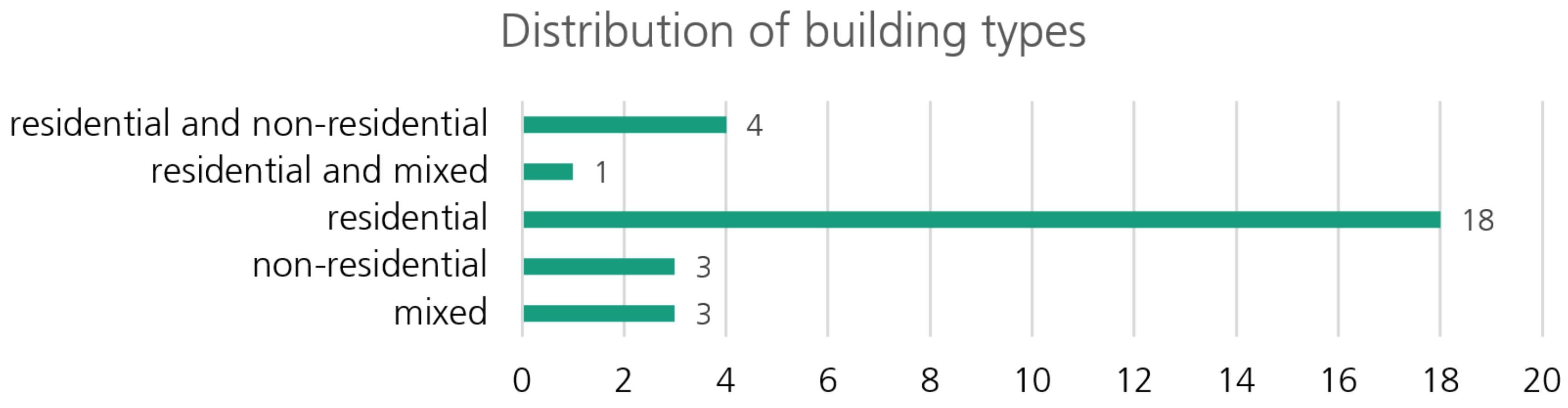
Case Study Analysis I: Location and Year





Case Study Analysis II: Buildings and Thermal Grid





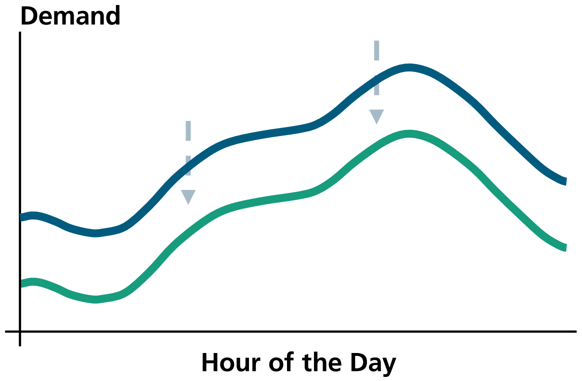
EBC
Energy in Buildings and Communities Programme

Evaluation of Demand-Side Management

Permanent

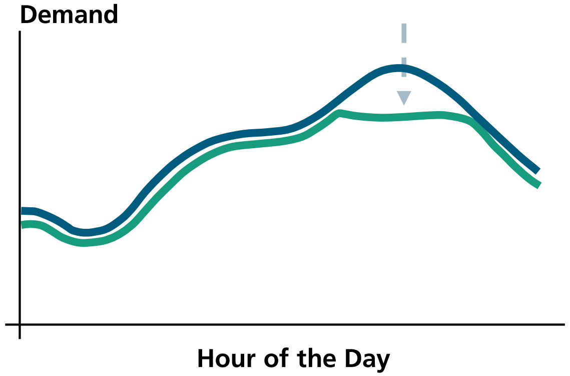
Non-permanent demand changes (Demand Response)

Efficiency



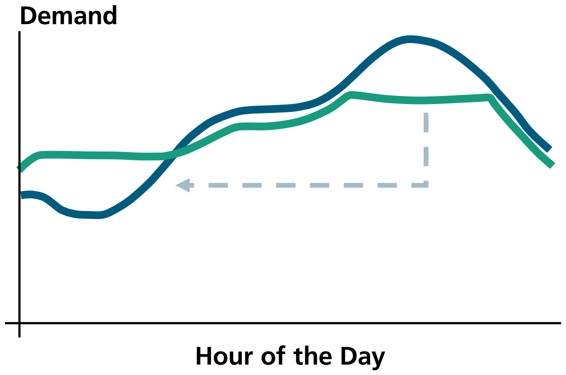
Definition: Persistent heat demand reduction regardless of time.

Load Shedding



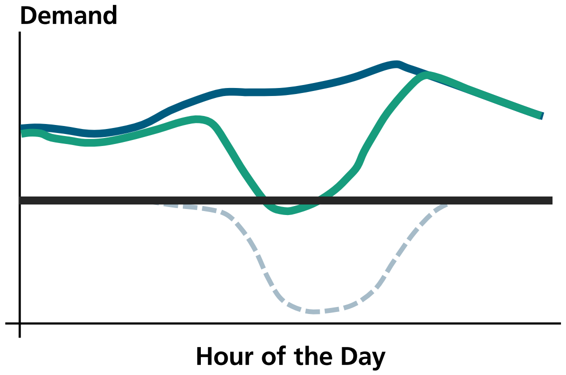
Definition: Short-term heat demand reduction during peak demand periods or emergency events.

Load Shifting



Definition: The building changes the energy use timing to reduce the heat demand during peak demand periods or to exploit renewable generation.

On-Site Generation

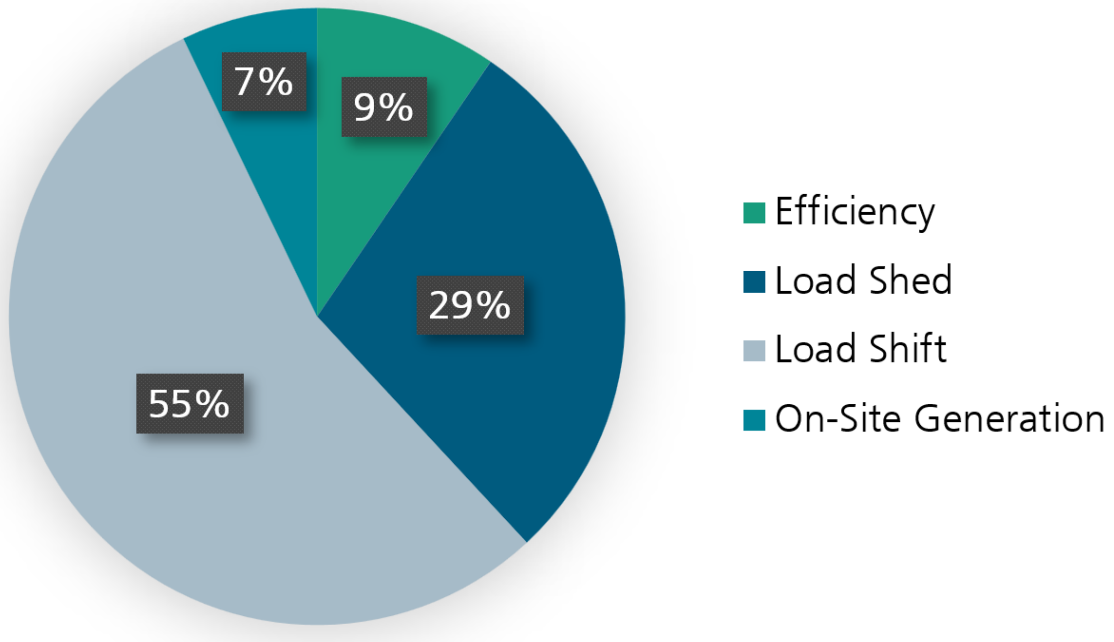


Definition: The building generates heat for on-site use or dispatch to the DH network during peak demand periods.

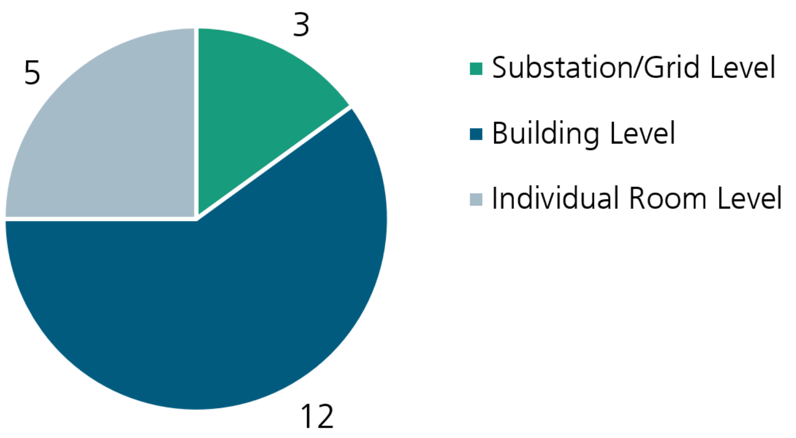
Own representation based on Li et al. (2021). https://doi.org/10.1016/j.adapen.2021.100054

EBC
Energy in Buildings and Communities Programme

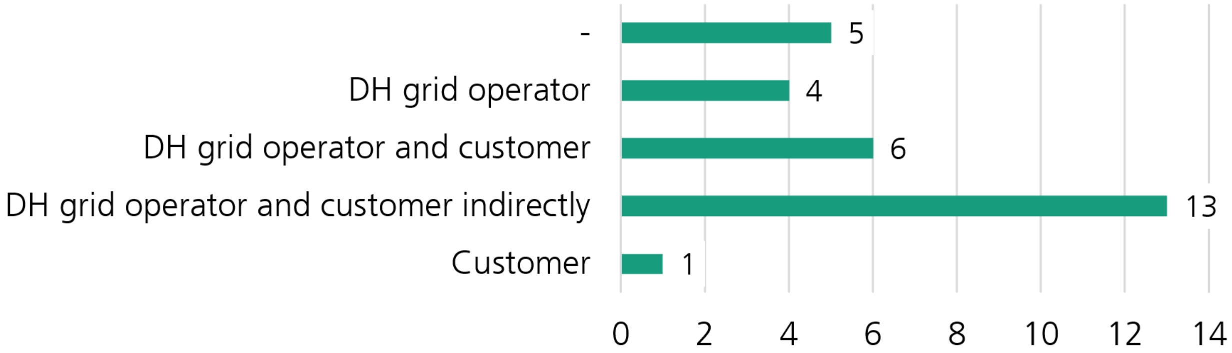
Case Study Analysis III: DSM Evaluation



Case studies by Control Level of DR



Who benefits from DSM measure?



Case Study Analysis IV: Lessons learned

Lessons Learned

- **Category 1**
  User behavior, thermal comfort and acceptance of demand-side management
  - Individual Consideration of Buildings and Occupants
  - Occupant Acceptance through Understanding and Information
  - Thermal Comfort Boundaries
  - Financial Incentives
  - Control and User Autonomy
- **Category 2**
  Flexibility sources, DSM strategies and technical aspects
  - Thermal Building Mass Utilization
  - Peak Load Management Strategies
  - Motivational tariffs and Economic model predictive control
  - Seasonal Operational Strategies and hybrid networks

EBC
Energy in Buildings and Communities Programme

Case Study Analysis IV: Lessons learned

- Category 1
  User behavior, thermal comfort and acceptance of demand-side management
  - Individual Consideration of Buildings and Occupants
  - Occupant Acceptance through Understanding and Information
  - Thermal Comfort Boundaries
  - Financial Incentives
  - Control and User Autonomy

Considering buildings and occupants as individuals rather than simple load points:

- Indoor temperatures can vary by up to 7K between different spaces within and across dwellings
- Room-level decentralized control strategies better manage temperature variations while maximizing energy flexibility

Four key determinants of occupant perception and acceptance:

- Setting appropriate indoor climate conditions
- Careful timing and magnitude of load shifts
- Provision of individual control options
- Effective communication with occupants

Control and autonomy:

- Perception of control significantly impacts occupant acceptance of DSM interventions
- DSM schemes should allow occupants to adjust temperature according to individual needs

Participation incentives:

- Most participants willing to join demand-side management schemes for modest financial rewards
- Combined financial and environmental benefits particularly effective in gaining acceptance

Case Study Analysis IV: Lessons learned

Thermal Building Mass Utilization:

- Effective method for load shifting and increasing district heating system flexibility
- Building mass utilization software with optimization tools improves system efficiency
- Building renovations typically increase flexibility potential (improved insulation and heat retention)

Peak Load Management Strategies:

- Delayed heating activation during morning peaks for peak reduction/elimination
- Preheating the thermal network during off-peak hours has been proven successful (efficiency increase of a central heat pump and reduced operating costs)
- Data-driven demand-side management solutions offer cost-effective utilization without hardware investments (though might be limited for larger networks)
- Advanced control systems shift expensive peak heat production to cheaper base load generation
- Dynamic supply temperature control in apartment buildings nearly eliminates morning peak loads
- Prioritizing domestic hot water over space heating decreases peak loads by 14-15%
- Room-specific control reduces morning peak demand by 85% compared to control groups
- Load shifting strategies may create new, smaller peaks at different times – greatest benefits achieved with coordinated energy management systems (between energy providers and users)

Main Takeaways: Recommended Actions

Building and System Considerations

- Even short intervention periods (20 minutes) can deliver peak reductions of 5-6% (without increase of complaints)
- Recognize heavy buildings with concrete structural cores as superior thermal storage assets
- Advantage of implementing decentralized room-level control: Prioritize targeted preheating in specific zones

Control Strategies and Technology

- Prioritizing DHW over space heating during peak periods can already yield 14-15% peak reduction
- Coordinate DSM triggers with energy management systems or thermal storage management
- Use dynamic supply temperature control to eliminate morning peak loads

Occupant Engagement and Communication

- Thoroughly explain DSM functions and benefits before implementation and allow occupants some freedom to adjust settings
- Emphasize both economic savings and environmental benefits and frame participation as part of collective achievement
- Select active/passive rooms for DR based on load shifting potential and occupant preferences

DSM implementation approach

- First address building-related problems, e.g. poor insulation or system operation, before implementing DSM
- Implement thorough stakeholder consultation processes before deployment
- One solution could be developing simple, cost-effective data-driven DSM solutions that don’t require hardware retrofits

EBC
Energy in Buildings and Communities Programme

Contact and Project Information

Christopher Graf
Fraunhofer IEE
Thermal System Technology
christopher.graf@iee.fraunhofer.de

Dr.-Ing. Anna Cadenbach
Fraunhofer IEE
Head of Thermal System Technology
anna.cadenbach@iee.fraunhofer.de

National Research Project „EnOB:Trans2NT-TWW“ (ID: 03EN1027A)
Analysis and development of necessary measures to reduce the domestic hot water temperature in low-temperature supply systems

IEA EBC Annex 84 - Demand Management of Buildings in Thermal Networks
Subtask D „Experimental case studies of building heat demand response in existing DHC networks“

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag
ID: 03EN1027A