EBC

Energy in Buildings and Communities Programme

Proceedings of the IEA EBC Annex 98 Industrial Workshop on:

IEA EBC Annex 98:

”Flexibilization and optimization of heat pump systems in existing residential buildings through digitization”

September 24, 2026 in Copenhagen/Denmark and as a web meeting

Hosted by:
Aalborg University Copenhagen AAU

Organized by:
Fraunhofer Institute for Energy Economics and Energy System Technology IEE
Aalborg University Copenhagen AAU

Fraunhofer IEE

AALBORG UNIVERSITY

Proceedings:

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INTRODUCTION TO AALBORG UNIVERSITY

Industrial Workshop – IEA EBC Annex 98 | Aalborg University Copenhagen

DEPARTMENT OF THE BUILT ENVIRONMENT
AALBORG UNIVERSITY

Department of the Built Environment (BUILD)

RESEARCH
National and international research

EDUCATION
Research-based engineering education

COOPERATION
Industry, authorities and organisations

- Town, Housing and Property
- **Building Technology, Management and Indoor Environment** — Our division
- Architectural Engineering
- Civil and Environmental Engineering
- Structures, Geotechnics and Risk
- Sustainability of Buildings

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BUILDING ENERGY SYSTEMS and INDOOR ENVIRONMENT

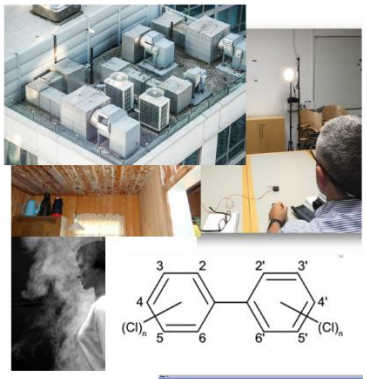


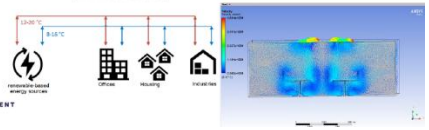
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BUILDING ENERGY SYSTEMS and INDOOR ENVIRONMENT

RESEARCH FOCUS

- Indoor environment quality (IEQ), perception
- Holistic evaluation methods for IEQ, user behavior
- Detection, control and prevention of harmful components in the indoor environment as a result of material choices, constructions, behavior, chemical compounds and microorganisms.
- Control systems and advanced control techniques
- Daylight, electric lighting
- Energy efficient ventilation, heating and cooling systems, air cleaning and filtration
- Air flow processes in rooms, risk assessment in connection with fire, dispersion of smoke, contamination, transport of bacteria, etc
- Energy flexibility and communication between indoor climate systems and grids
- Near room temperature heating and cooling systems
- Near room temperature district heating systems
- Thermal energy storage (TES)





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Presentation 1
Samira Rahnama: Opening: Welcome and Introduction to Aalborg University

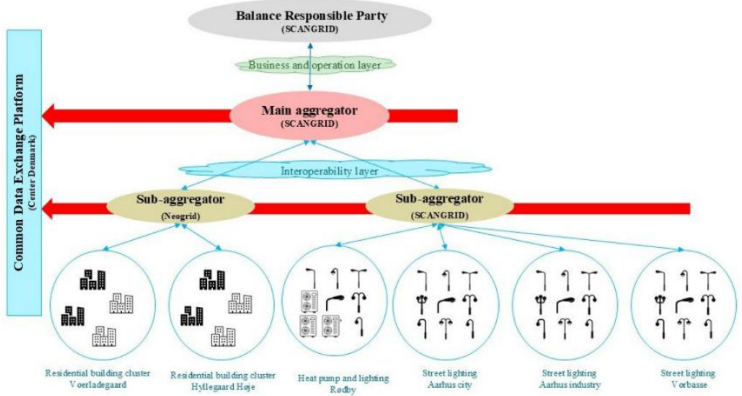
BUILDING ENERGY SYSTEMS and INDOOR ENVIRONMENT



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5

HiFLEX project: HIERARCHICAL ENERGY FLEXIBILITY MANAGEMENT OF RESIDENTIAL AND MUNICIPAL ASSETS



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6

IEA EBC Annex 98:

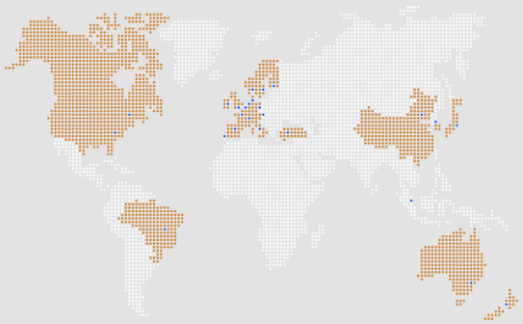
Welcome to the Industrial Workshop on:

"Flexibilization and optimization of heat pump systems in existing residential buildings through digitization"

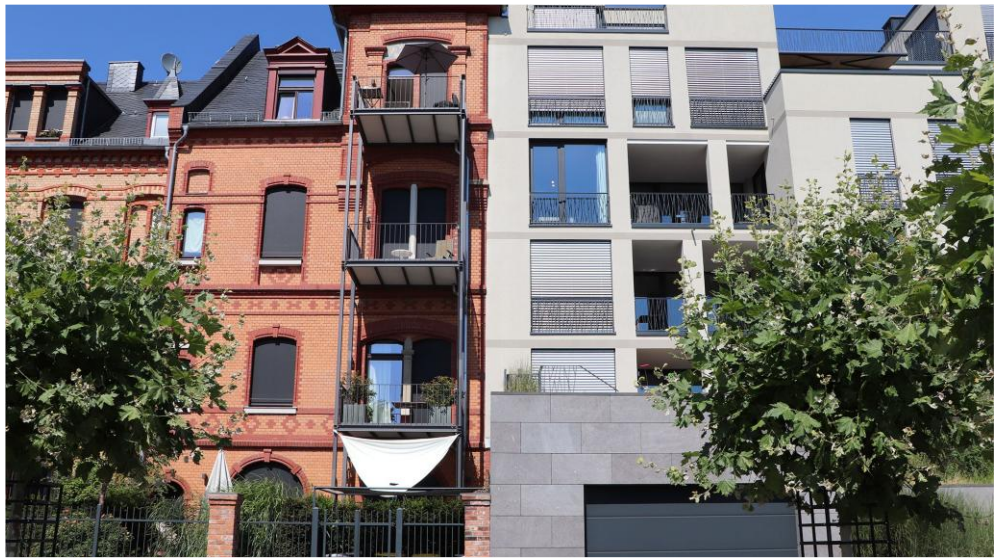
Dietrich Schmidt
Fraunhofer IEE/Germany

Fraunhofer IEE

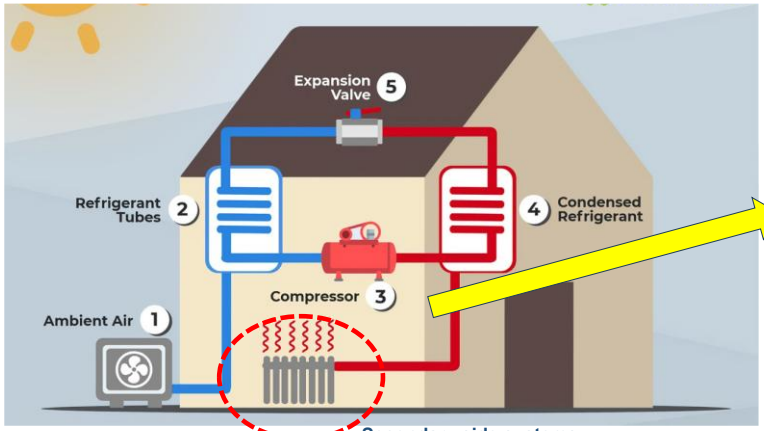
EBC Energy in Building and Communities Programme



September 24, 2026



Background



Why?

- **Heat pump systems do not always operate effectively because the secondary side systems are not working properly.**
- **Potential for improving the functioning of space heating and domestic hot water preparation systems.**
- **Approach: Using digitalization approaches to determine malt function and optimize the system operation parameters.**

Background

IEA EBC – Annex 98:
Flexibilization and optimization of heat pump systems in existing residential buildings through digitization

By focusing on the digital optimization of secondary systems, this activity aims to enhance the efficiency of heat pump systems in residential buildings.

This approach is crucial for improving space heating and domestic hot water preparation in existing buildings, while promoting the transition to renewable energy sources in the construction sector.

The keys aims of this project are to:

- **Raise awareness** of the advantages of integrating signals and data from several areas as an enabler to ensure data-driven optimal and flexible control of heat pump systems in buildings through best practices and analyses.
- **Evaluation of** non-technical obstacles and facilitators, such as business models, legal aspects, and policy instruments, for the digitalization of secondary heat pump system processes.

The key stakeholders for this work are:

- Housing companies, project developer, building owners and operators
- Other target groups are:
  - Planners, installers (HVAC), and system providers
  - Actors from the energy supply business
  - Organizations involved in education, research, and academia

Industrial Workshop:

Thursday, September 24, 2026

9:45	**Coffee and testing of technical connections**
10:00	**Opening: Welcome and Introduction to Aalborg University** *(Samira Rahnama, Aalborg University, Denmark)*
10:10	**Overview and background** **Presentation of the international cooperation activity on "Flexibilization and Optimization of Heat Pump Systems in Existing Residential Buildings through Secondary-Side Digitalization" – IEA EBC Annex 98** *(Dietrich Schmidt, Fraunhofer IEE, Germany)*
	Block 1:
10:20	**Data Integration and interoperability** *(Qian Wang, KTH, Sweden)*
10:35	**Interoperable data exchange platforms and standardized data models** *(Peter Hejno Gustafsson, Center Denmark, Denmark)*

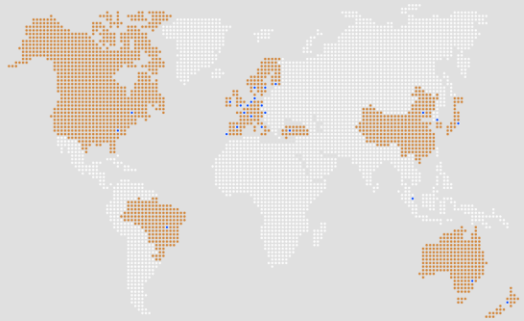
Industrial Workshop:

Thursday, September 24, 2026

12:05	**Open discussion on :** *(Moderated by Dietrich Schmidt, Fraunhofer IEE, Germany)* • Barriers of technical equipment in heat pump operation. Where are technical limitations? • Business models? • Legal issues • User engagement • Use of AI – advances/challenges
12:55	**Short resume and closing** *(Samira Rahnama, Aalborg University, Denmark & Dietrich Schmidt, Fraunhofer IEE, Germany)*
13:00	**Lunch**
	End of the Industrial Workshop

Contact us!

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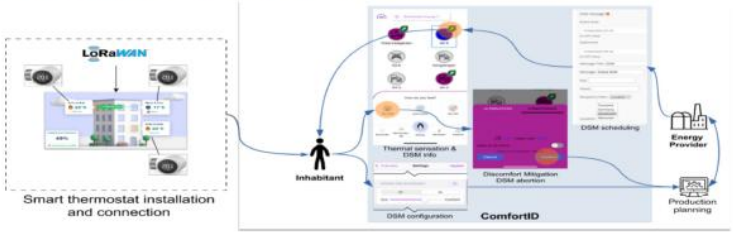


IEA EBC Annex 98
Swedish use case

KTH Royal Institute of Technology
Department of Civil and Architectural Engineering
Qian Wang

Swedish use case for secondary side comfort proven FlexServices

- 150 units were installed in 23 apartments.
- Each apartments were configured as one thermal zone, and the thermostats measure indoor temperature and humidity.
- Tenants are enabled to report thermal comfort via ComfortID.



Integrating Secondary Side in Semantics

Secondary side measurements

Indoor temperature;
Relative humidity;
Valve opening rate.

Thermostat readings

Semantic model

Extends existing ontologies for secondary side;
Sensor-actuator points on components;
Comfort feedback tied to zones as a node.

Hydraulic Balancing

Occupancy-Driven Balancing

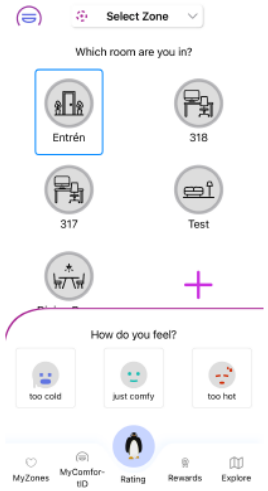
- Activated in unoccupied hours
- Adjust the supply temperature or the mass flow to lower return temperature

Peak-Shaving

- Moderately reduce the heating load in peak period
- Thermal inertial for maintaining comfort by preheating

User feedback Interaction

- Adjust heating conditions by users' feeling
- Prioritize comfort



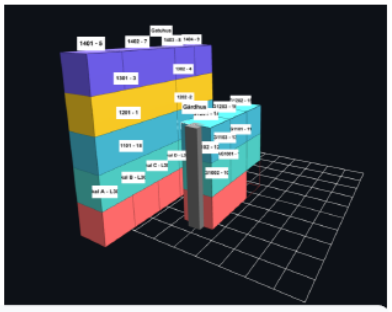
Flex-driven Heat Cost Allocation

Traditional Flat-Rate by Area

- Billed solely by floor area square meters.
- Zero correlation with actual valve behavior or user care.

Demand-Centric Dynamic Allocation

- Combines baseline quota with measured valve integration.
- Directly rewards conscious energy conservation habits.



1. Guaranteed base heating to prevent structural moisture and ensure fundamental living warmth.
2. Occupants balance preferred thermal comfort against marginal heating expenses via ComfortID Interaction.
3. Convert the valve opening data and temperature differences into transparent and traceable thermal comforts.

Outcomes

Real-comfort based Opt. Temperature

- Auto-adjusting in vacant zones cuts return temperature and network losses.
- Mitigates proximal overheating through active hydraulic balancing.

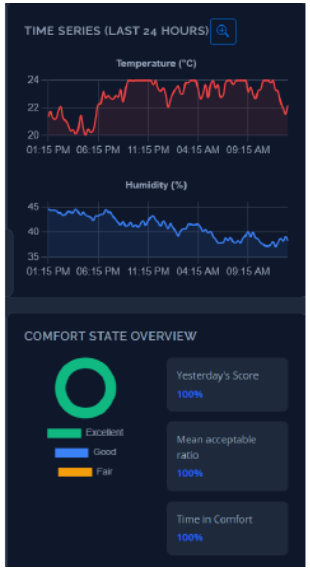
Flex service with Zero Comfort Loss

- Clips peak demand using building thermal inertia by preheating.
- Guarantees comfort compliance via ComfortID feedback.

Fair & Traceable for potential HCA for both HP and DH

Allocates heating costs via real utilization instead of floor area.

- Incentivizes conscious energy-saving while preserving baseline warmth.



Interoperable data exchange platforms and standardized data models

- Center Denmark, 24th Sep. 2026

centerdenmark



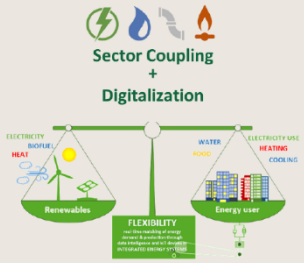
A **non-profit organisation** working to facilitate and accelerate the **green transition** through **digitalisation** and **sector coupled interoperability** - thereby unlocking **flexibility potential** by leveraging digital opportunities at all levels across the energy system.

Presentation Plan

- Introduction to Center Denmark
- Data Model for Flexibility Aggregation
- Other Interoperable Energy Data Models

centerdenmark

Data Infrastructure for Streamlining, Sector Coupling, and Publication of Utility Data



Independent
- Non-profit, Open Source Technologies

Standardised Access to Data across Users and Utilities
- Generic Data Models and Data Sovereignty

Sector Coupled Data Access
- Data Platform for Heat, Electricity, Water, Gas, Buildings, and Weather

Publication of Utility Data
- End-Points, Portal for Energy Utility Data in Denmark, and Energikortet.dk

centerdenmark

Center Denmark Projects

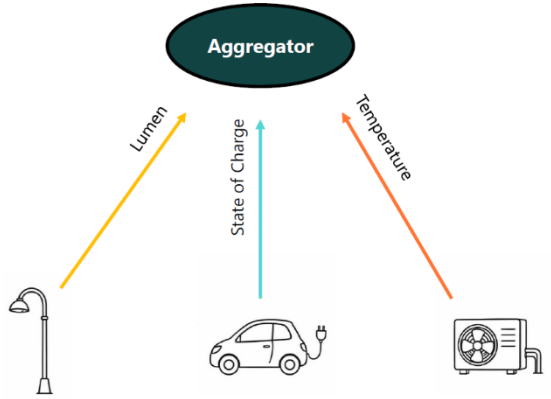
26 projects
EU Horizon, Digital Europe, Interreg, EUDP, and more

Data Platform
HeatSync, WaterSync, SEEDS

Data Spaces
INSIEME, BEGONIA, Co4RES, SONFOR SmartFlow

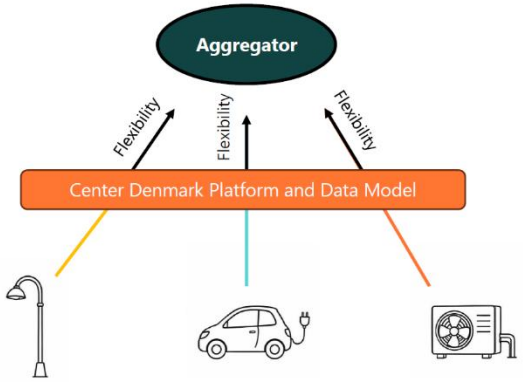
Data Models
ELEXIA, HiFLEX, BMS4Flexumers, Heatcheck

Center Denmark's Role in the HiFLEX Project



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Center Denmark's Role in the HiFLEX Project



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Interoperable Data Models

> Ved at bruge modelreglerne holder vi døren åben til fremtiden.
> By using common modelling rules, we keep the door open to the future.
> -Digitaliseringsstyrelsen, De fællesoffentlige regler for begrebs- og datamodellering

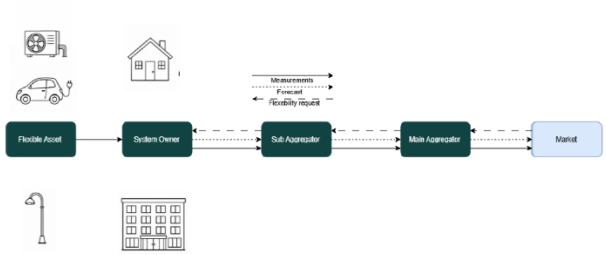
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Interoperable Data Models

> This will help improve transparency, trust, efficiency, and predictability in data exchanges, thereby lowering barriers for new market entrants.
>
> — European Commission, Directorate-General for Energy, Data interoperability guidance

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Using the Data Model for Flexibility



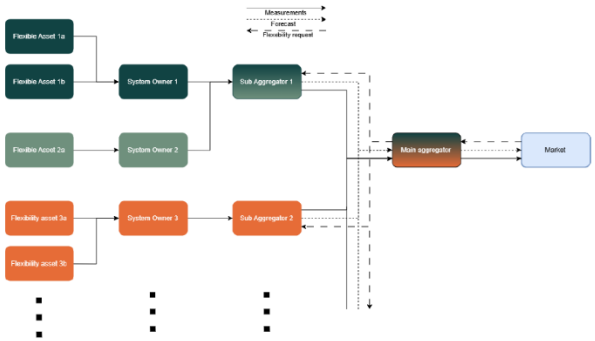
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Using the Data Model for Flexibility



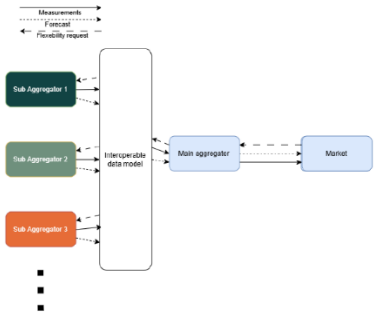
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Using the Data Model for Flexibility



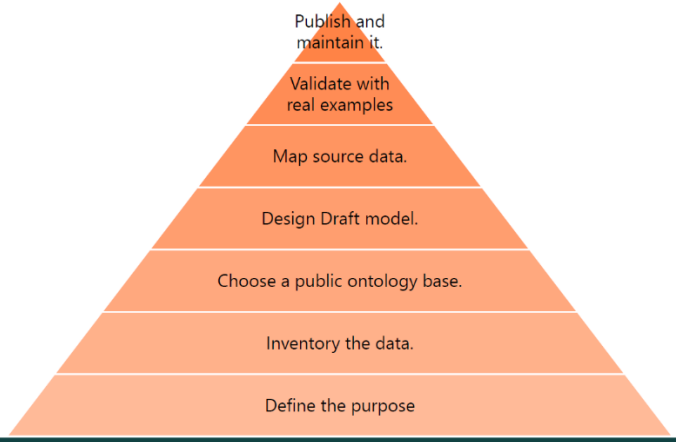
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Using the Data Model for Flexibility



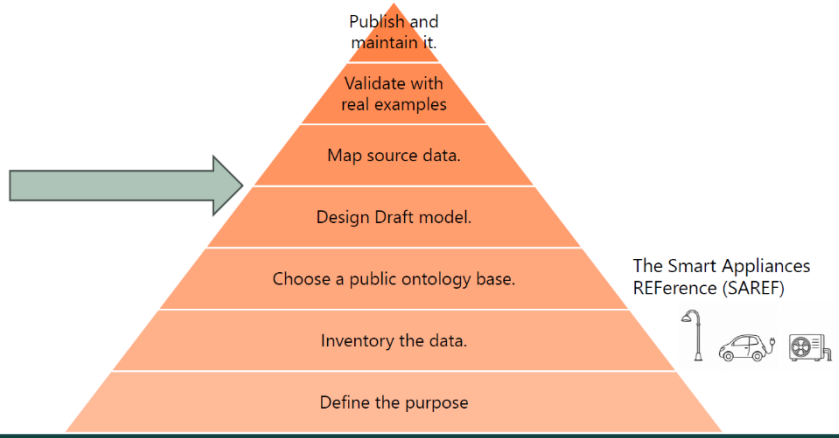
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The HiFLEX Data Model for Flexibility



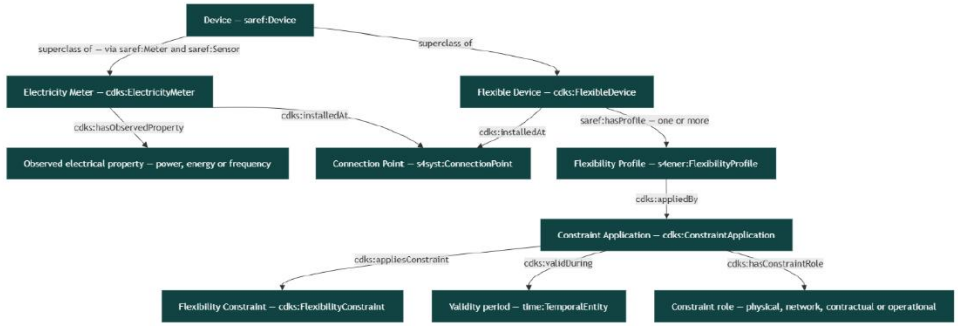
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The HiFLEX Data Model for Flexibility

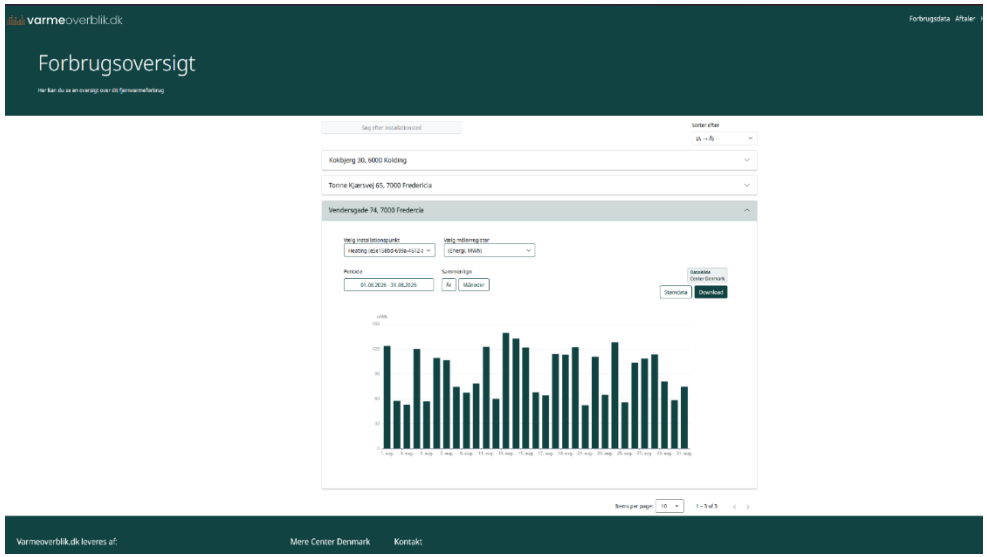


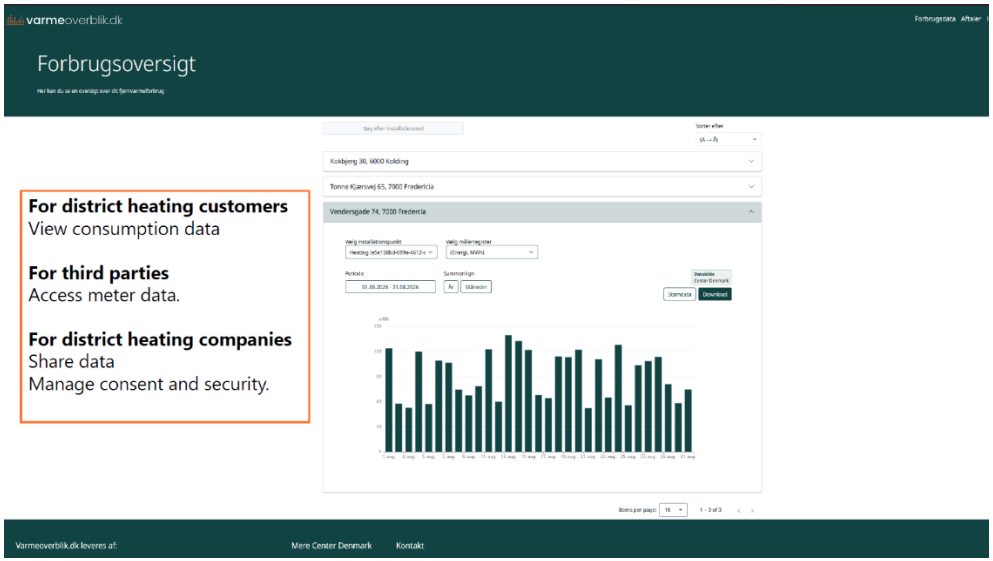
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The HiFLEX Data Model for Flexibility

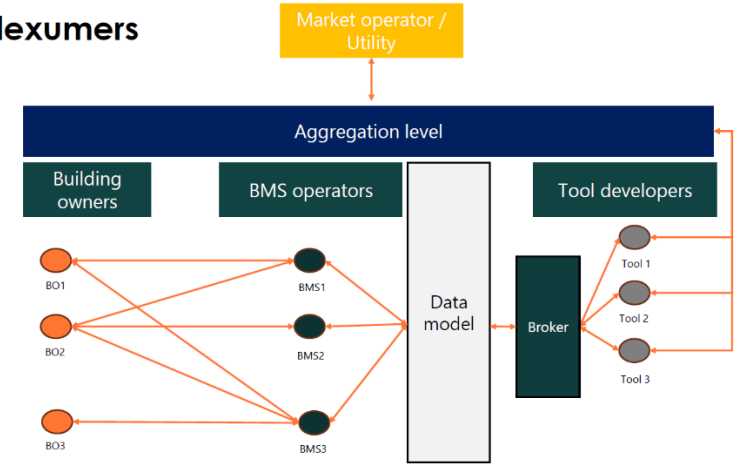


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BMS4Flexumers



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Model Creation and Optimization

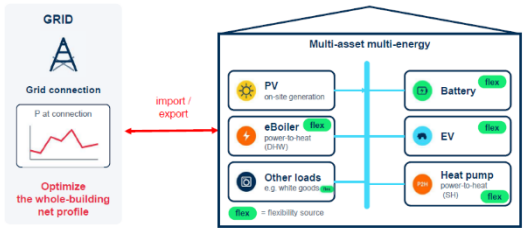
Integrating HP in whole-building multi-energy MPC

Chris Caerts | VITO (Belgium)
IEA EBC Annex 98 – Industrial Workshop
Aalborg University Copenhagen | 24 September 2026

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Whole-building coordination and optimization

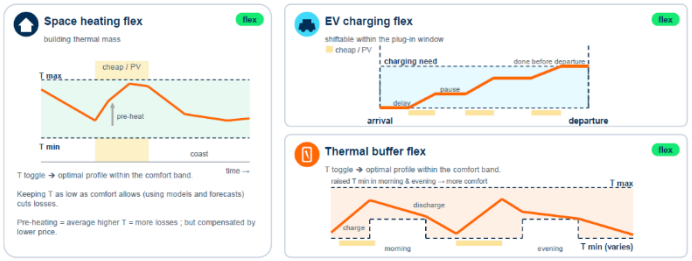


The heat pump is just one of several flexible consumers: optimize the whole building, not the HP alone.

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Flexibility in practice: three examples



Flexibility vs. efficiency: using flexibility can raise total consumption, but shifts it to cheaper, lower-carbon moments: a small efficiency trade for lower cost & CO_2, with comfort kept.

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What MPC adds: whole-building coordination



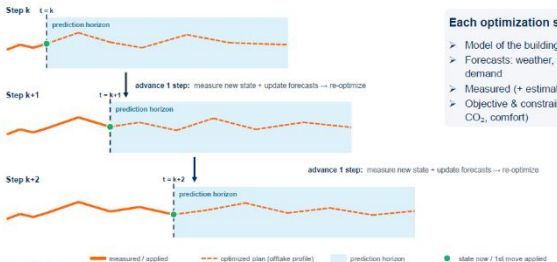
Same price signal, three controllers: traditional temperature control heats in costly hours and may cause peaks; an uncoordinated rule-based (using forecasts) aligns with cheap hours but does not minimize losses and may cause peaks ; whole-building MPC aligns with cheap hours, minimizes losses, and avoids peaks.

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MPC: receding horizon optimization

A succession of optimizations, each re-planned on updated state and forecasts.



Each optimization step uses

- Model of the building & assets
- Forecasts: weather, prices, PV, demand
- Measured (+ estimated) state
- Objective & constraints (cost, CO_2, comfort)

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MPC for flex: three use cases

One MPC core, three flex use cases — each re-optimizes the trajectory for a different purpose.

One receding-horizon MPC core models · forecasts · algorithms · objectives & constraints

Behind-the-meter optimization

Single building

- Objective: **cost & emissions** (balance efficiency with other goals)
- Robust to uncertainty in models & forecasts → **robust MPC**

Responding to demand-response signals

Building ↔ grid / DSO

- Re-optimize the trajectory to honour a **DR signal**
  - Implicit: **Δ price**
  - Explicit: **grid-connection-point constraint**

Input for multi-building coordination

Building ↔ District / community

- Share information for **district / community** coordination & flex requests
  - **Self-declared baselines & nominations**
  - **Flex envelopes**
- Accounting for uncertainties

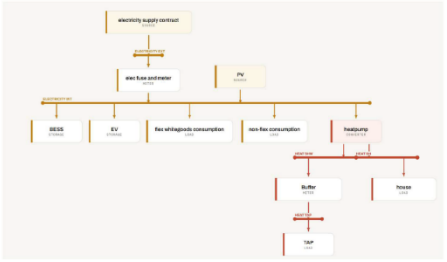
Scope widens: single building → grid / DSO → district & community

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Example : analysis UI and building configuration

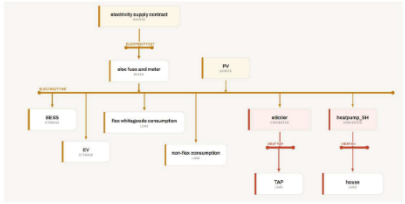


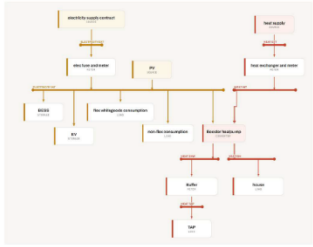


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Example : alternative building configurations

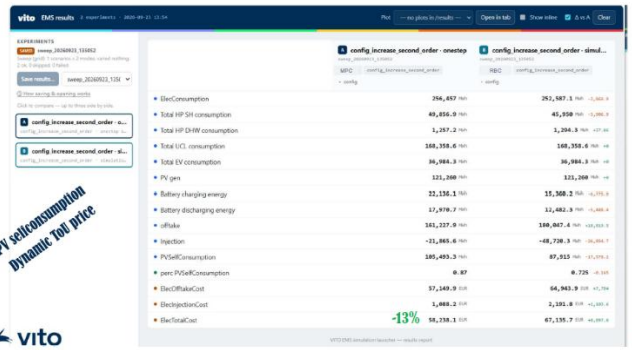




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Example : whole-building MPC versus RBC performance



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MPC optimization = algorithms + forecasts + models

The building model — thermal mass & heat emission (the flex)

HEAT — a 'thermal battery'

- The building model — Thermal mass and heat emission system
- Thermal buffer
- The production and distribution model

Building thermal mass (zone dynamics)

- Model the zone temperature: $T_{zone} = f(Q_{del}, \text{gains, losses, t})$
- Physics-informed reduced-order (grey-box) models

Heat emission (emitter model)

- Sets the delivery potential (Q_{del}) per zone
- Heat into a zone: emitter capacity = $Q_{del} = f(T_{zone}, T_{supply}$, mass-flow rate, emitter type: radiators ↔ underfloor)
- Min (HP Pmax, emitter's capacity)

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MPC optimization = algorithms + forecasts + models

The production & distribution model (the control of flex)

HEAT — a 'thermal battery'

- The building model — Thermal mass and heat emission system
- Thermal buffer
- The production and distribution model

Heat distribution

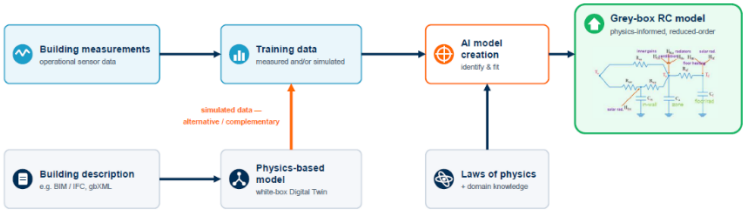
- Carries heat from the HP to the emitters: temperatures, flow, hydraulic balancing
- Delivered heat = produced heat (by HP) − losses
- Control levers: hydraulic balancing, flow rate control, valve settings, circuit balancing

Heat-pump production, control & efficiency

- Heat production is bounded by the heat pump's max output (P_{max})
- COP is driven by the required supply temperature: keep it as low as delivery allows
- Control levers: HP setpoints (T_{supply}, compressor power, …)
  - **Determinism and granularity of control ! Indirect ⇔ Direct**

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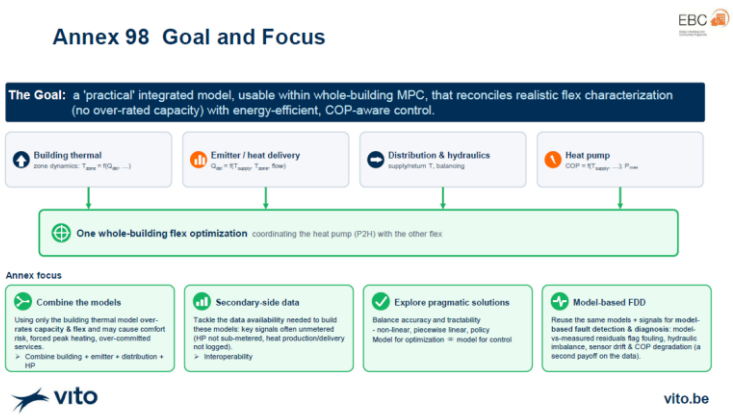
Building thermal model creation

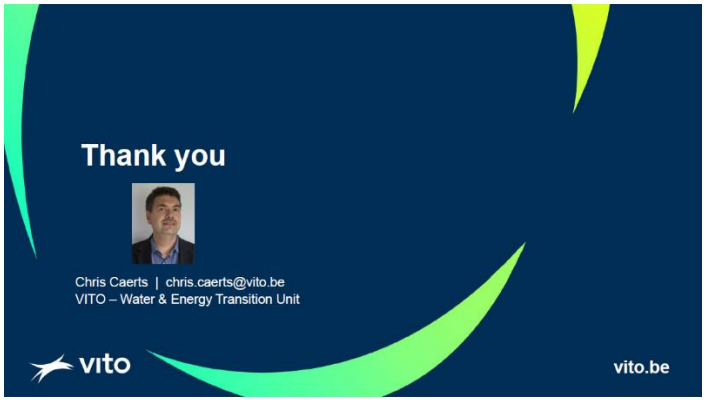


The model-creation challenge — building good models cheaply, at scale

- **Scalable & cheap:** automated, repeatable model creation across a heterogeneous building stock
- **Minimal sensing:** keep sensor & meter cost low; standardized, interoperable data as the foundation
- **Identifiability:** must yield a control-grade model from limited, noisy data
- **Sparse measurements:** key signals often unmetered, e.g. HP not submetered, heat production/delivery not logged
- **Missing descriptions:** lacking building documentation, and rarely in standard formats (BIM/IFC, gbXML)

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Annex 98 Goal and Focus
EBC
The Goal: a 'practical' integrated model, usable within whole-building MPC, that reconciles realistic flex characterization (no over-rated capacity) with energy-efficient, COP-aware control.
Building thermal
Emitter / heat delivery
Distribution & hydraulics
Heat pump
One whole-building flex optimization coordinating the heat pump (P2H) with the other flex
Annex focus
Combine the models
Using only the building thermal model over-rates capacity & flex and may cause comfort risk, forced peak heating, over-committed services.
Combine building + emitter + distribution + HP
Secondary-side data
Tackle the data availability needed to build these models: key signals often unmetered (HP not sub-metered, heat production/delivery not logged).
Interoperability
Explore pragmatic solutions
Balance accuracy and tractability
- non-linear, piecewise linear, policy
Model for optimization ≠ model for control
Model-based FDD
Reuse the same models + signals for model-based fault detection & diagnosis: model-vs-measured residuals flag fouling, hydraulic imbalance, sensor drift & COP degradation (a second payoff on the data).
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Thank you
Chris Caerts | chris.caerts@vito.be
VITO – Water & Energy Transition Unit
vito
vito.be

NEOGRID TECHNOLOGIES

From heat pump to flexible energy resource

Field lessons from domOS, SERENE, FLEXDIS and HiFLEX

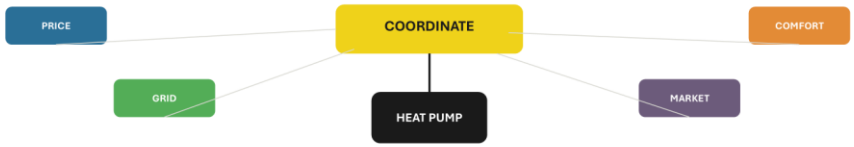
Morten Veis Donnerup · NEOGRID Technologies · 24 September 2026

PreHEAT
Forecast heating.

Five control regimes

Different signals, response times and value pools can coexist in one installation.

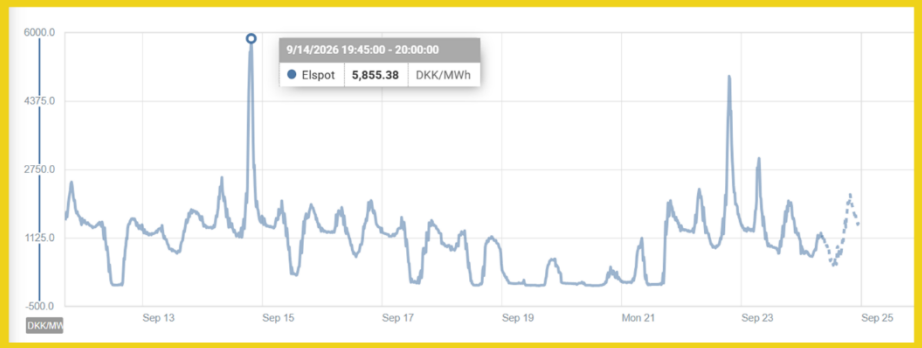
0	1	2	3	4
AUTONOMOUS	PRICE-RESPONSIVE	GRID-RESPONSIVE	MARKET-RESPONSIVE	COMMUNITY-RESPONSIVE
Heat curve	Spot + tariff	Local V + Hz	Aggregator activation	PV + BESS + internal price
No external signal	Hours	Seconds	Seconds to minutes	Minutes to hours



The hard problem is coordinating conflicting price, grid, market and comfort signals.

What if COP means Cost of Production?

A deliberate reframing of the industry focus on Coefficient of Performance.



What if COP means Cost of Production?

A deliberate reframing of the industry focus on Coefficient of Performance.

ENGINEERING COP	COMMERCIAL COP
Coefficient of Performance	**Cost of Production**
How efficiently is heat produced?	What does each delivered kWh of heat cost?

13%	8%	-4.8°C
lower cost per kWh delivered heat compared to reference week	worse engineering COP than reference week	colder than reference week

The highest efficiency does not necessarily produce the lowest-cost heat.

Engineering COP remains essential, but it is not the only optimization objective.

Controllability is not binary

The interface determines whether flexibility can be requested, enforced and verified.

CONTROL FUNCTION	SG-READY	TEMP. MANIPULATION	MODBUS	API
Request start	YES	YES	YES	YES
Force start	NO	YES	YES	YES
Force stop	YES	YES	YES	YES
Set supply temperature	NO	NO	YES	YES
Read operating metrics	NO	NO	YES	YES

SG-Ready Simple requests, limited verification

MODBUS Rich local access, may require hardware

API Easy deployment, writable functions vary

An open API can still expose fewer writable points than local MODBUS.

Flexibility is asymmetric

A heat pump offers several actions with different speed, direction and efficiency.

SLOWER RESPONSE — FASTER RESPONSE

Slowest
COMPRESSOR START

Internal logic and minimum-off constraints

Faster
COMPRESSOR STOP

Subject to interface and protection logic

Fastest
IMMERSION HEATER

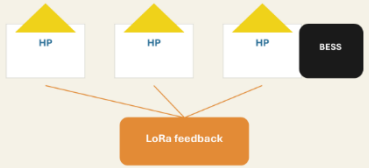
Fast upward load, with efficiency penalty

The pool must disclose what is available now, not only nominal heat-pump capacity.

Fast control requires a fast data path

Hyllegård Høje and Voerladegård answer different questions.

HYLLEGÅRD HØJE
Community-scale realism



5-15 min residential feedback

Coverage and scalability

VOERLADEGÅRD
Dynamic validation



200-300 ms local electrical metering

Speed and observability

Separate measurement, control and visualization

Expected best case: 1-2 seconds over stable LAN. Observed field loop: approximately 10 seconds.



1-2 s
Expected best case
Stable LAN

~5 s
Realistic expectation
Online and stable

~10 s
Observed today
Field loop

>10 s
Worst case
Or offline

Graph rendering belongs to the observation path, not the control loop.

Speed determines the accessible value pool

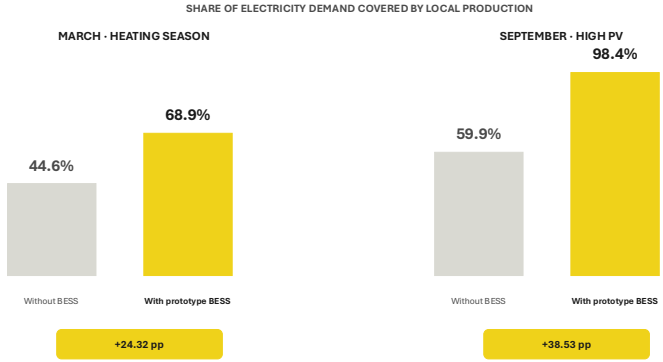
Fast response without sufficient aggregated volume is not enough.

FFR	Fast Frequency Reserve Contains rapid frequency deviations	Sub-second	Not feasible today
FCR-D	Frequency Containment Reserve - Disturbance Automatic response during larger deviations	Tens of seconds	Possible if loop is tightened
mFRR	Manual Frequency Restoration Reserve Activated to restore system balance	Minutes	Addressable today
DSO support	Voltage and capacity support Local response to distribution constraints	Minutes	Addressable today

Frequency services are an aggregation journey, not a single-site product.

Community optimization changes the objective

Tested and simulated with a temporary 124 kWh / 36 kW prototype battery using second-life modules.



Selected representative weeks. Without-BESS values are counterfactual calculations.

Three conclusions for Annex 98

Secondary-side digitalization is a chain of interfaces, measurements and control decisions.

01	VALUE	**Price optimization can create value now, even when engineering COP is not maximized.**
02	FEASIBILITY	**The interface and communication path decide which services the asset can deliver.**
03	SCALE	**Grid and market services require both fast loops and aggregation across sites.**

Design the data path for the service you want to deliver, before the assets are installed.

Thank you.

?

DISCUSSION

Where should fast intelligence live?

In the heat pump, at the edge, or at the aggregator?

Morten Veis Donnerup · mvd@neogrid.dk · neogrid.dk



Motivation

Why collect best practice projects for secondary-side digitization?

Secondary-side digitalization is seen as key to unlocking heat pump flexibility, but experience from real projects stays scattered across individual pilots.

Non-technical barriers, cost, business models, regulation, user acceptance, matter as much as the technology,
but are rarely documented in a comparable way

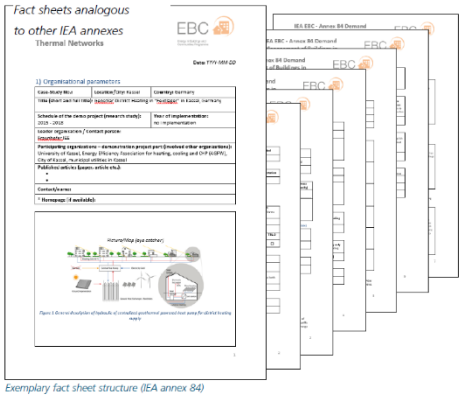
- **Learn** from other countries' new approaches
- **Multiplicator effect**: what can be envisioned can be achieved
- **Avoid mistakes and extra-costs, anticipate barriers and user acceptance**
- Show the **diverse possibilities** of secondary-side improvements

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Goals and outcomes

Which result do we aim at?

- **Collect and review** existing case studies on digitalization for heat pump flexibility
- **Create knowledge base** for flexibilization and optimization through digitization on the public Project Website (e.g. via fact sheets)
- Meaningful **classification** of case studies
- **Comparative analysis** of collected case studies, for example.. (see next slide)
- Collection and **synthesis of lessons learned**



Exemplary fact sheet structure (IEA annex 84)

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Goals and outcomes

Which result do we aim at?

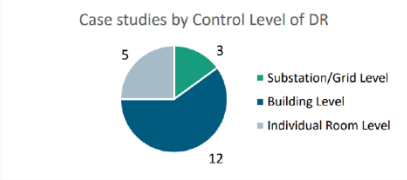
- **Comparative analysis** of collected case studies, for example:
  - Degree of digitalization, Components digitized
  - User acceptance, user involvement
  - Business model considered? Which?
  - Beneficiaries
  - Stakeholder involved in digitalization process
  - Flexibility time scales
  - Control strategy
  - …
- Synthesis of **lessons learned and recommended actions**
- **Dissemination:** publish fact sheets and comparative analysis on the project website

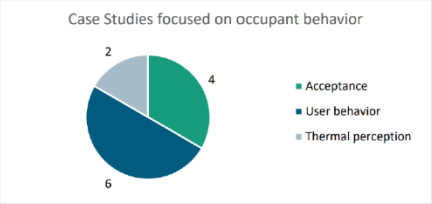
Examples of measures undertaken
- Automated hydraulic balancing
- Fault detection and diagnosis (FDD) integrated into real-world building controls
- MPC (Model Predictive Control) with Heat Pumps and weather forecasting
- HEMS interacting with electricity providers
- New business models that incentivize flexibility
- Standards for secondary side setups (e.g. Switzerland) that reward reusing similar hydraulic and comms setups
- Adapted buffer storage loading based on digitalized controls

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Example for comparative analysis
IEA EBC Annex 84

Subtask D of Annex 84 aims to **promote best practices and facilitate the effective integration of demand response in thermal networks**.
A **case study questionnaire** developed for Subtask D serves as a standardized framework for **collecting and documenting relevant information about demand-side management implementations and projects in DH networks**.

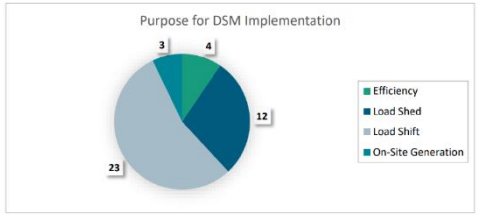




https://annex84.iea-ebc.org/Data/publications/EBC_Annex%2084_STD_Report_2025.pdf

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Example for comparative analysis
IEA EBC Annex 84







https://annex84.iea-ebc.org/Data/publications/EBC_Annex%2084_STD_Report_2025.pdf

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Outlook

Next steps

Case study identification
- Collect inventory of relevant case studies
- Establish clear selection and evaluation criteria

Integration of expert knowledge
- Gather information from different stakeholders

Comparative Analysis
- Benchmark technical performance
- Extract scalable technical solutions
- Identify research gaps and development strategies

How can you participate?

Indicate relevant case studies to us, receive the questionnaire and fill in information with our help

Present your success stories, inspire and help others in digitalization efforts

Discover the concise and clear knowledge base, connect with other projects and develop new ideas

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Questions to the industry

- Which aspects are absolutely necessary to cover in the fact sheets?
- Which KPIs would you consider to evaluate the success of an intervention?
- Can you name best practice projects from the field? Do you know of potential studies which should be incorporated in our database?
- How motivated are housing companies in your country to adopt measures?
- How much data (and which data) is collected by design in your systems?
- Do you use digital twins? If so, for what purpose?

Thank you!

—

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christopher.graf@iee.fraunhofer.de

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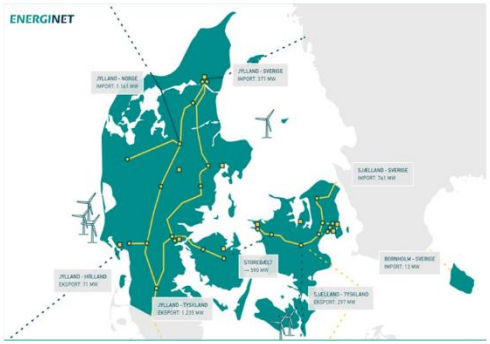

SCANGRID
SAMMEN SKABER VI BALANCE
Scangrid
Company Presentation
Workshop on Heat Pump Flexibility and Energy Systems.
24-09-2026


SCANGRID
SAMMEN SKABER VI BALANCE
Introduction
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Operational management & employees
SCANGRID
SAMMEN SKABER VI BALANCE
Carsten Vammen
Gert Abildskov
Vibeke Laurberg
Victor Kronborg Karlsen
Harald Saelen
Livnat Sorani Gelvan
+
2X Andrii Pokora Full Stack Developer
Nikolaj Abrahamsen Automation Engineer
3


SCANGRID
SAMMEN SKABER VI BALANCE
Market description
4

The electricity infrastructure in Denmark - Energinet



The Danish electricity supply grid is owned by a state-owned company **Energinet (TSO), which is responsible for the operation, expansion and maintenance of the overall electricity supply infrastructure.**

A central task for Energinet is to ensure that the grid maintains a **constant frequency (50 Hertz)**, which matches demand at any given time.

Over- or under-production of electricity could cause grid outages and be fatal to sensitive installations.

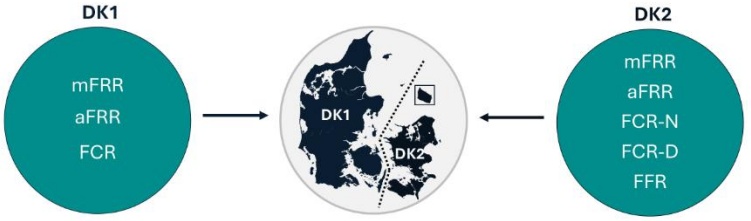
Historically, it has been easy to manage and secure this balance with power plants based on fossil fuels because:

A) Production could quickly be adjusted up and down
B) The number of producers was manageable and coordinating the effort was simpler to handle

DK 1 and DK 2 represent the two bidding zones. DK 1 is connected to the Central European frequency area and DK 2 is connected to the Nordic frequency area, including SE1 - SE4 (Sweden).

Overview of Ancillary Services

- Denmark is split between two Synchronous Areas. In each part exists a bidding zone where we procure our ancillary services for that region.



Overview of Ancillary Service product specifications

	FCR (DK1)	aFRR (DK1)	mFRR (DK1)	FFR (DK2)	FCR-D (DK2)	FCR-N (DK2)	aFRR (DK2)	mFRR (DK2)
Reaction time (Full delivery)	>0% within 2 sec 30 sec	15 min	15 min	0,7-1,3 sec	86% power within 7.5 seconds. 3.2s energy within 7.5.	60% within 60 seconds	5 min	15 min
Contract period	4 hours	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour or 1 month
Min. Bid size	1 MW	1 MW	5 MW (1 MW ultimo 2023)	0,3 MW	0,1 MW	0,1 MW	1 MW	5 MW (1 MW ultimo 2023)
(A)symmetric	Symmetric	Symmetric	Asymmetric, upregulation	Asymmetric, upregulation	Asymmetric, upregulation and downregulation	Symmetric	Asymmetric, upregulation and downregulation	Asymmetric, upregulation
Level of activations	Medium	High	High	Rarely	Rarely	High	High	High
Energy delivery	Low	High	High	Extremely low	Very low	High	High	High
Responsible Party BSP: Balancing Stability Party BRP: Balancing Responsible Party	BSP	BRP	BRP	BSP	BSP	BRP	BRP	BRP

The business model

Presentation 8
Carsten Vammen: Aggregation of flexible loads: business models, legal aspects, and policy frameworks

Primary partners

Stabilization partners
- Deliver "deferred electricity consumption" to the VPP
- Have large constant electricity-consuming installations that can be reduced in short sequences without notice
- E.g. NCC Roads, ice rinks, wastewater treatment plants

Settlement
- eSett

Suppliers
- IT system and HW
- Terminals and SW

Primary activities

Stabilization partner
- Conclusion of agreement
- Installation of SW and HW (RTU)
- Settlement

Submit auction bids for delivery of ancillary services to TSOs

Primary resources

The company
Accumulated know-how
VPP platform (HW and SW)
Capital
Terminal installers

Product / service / value

Stabilization services for the Nordic Transmission companies (TSO)

Defers electricity consumption at the stabilization partners when the grid frequency drops, thereby reducing/avoiding the use of fossil power plants to deliver the missing power

Green and fossil-free solution

Documentation of reduced CO^2 consumption

Customer relations

Aggregator agreement has been concluded with Energinet, which has thereby endorsed the solution and Scangrid as a system supplier

Channels

Stabilization is delivered via a **"virtual power plant" (VPP)**, where the stabilization partners defer their electricity consumption to a later time

Customer segments

Energinet, which as the system operator (TSO) runs the electricity transmission grid and the electricity system in Denmark.

Energinet must ensure a constant voltage, corresponding to a frequency of 50 Hertz. If the voltage drops, either more power must be supplied to the grid, or someone must reduce their consumption to make room for others' electricity use.

Scangrid today covers Energinet's entire area, DK1 and DK 2

Cost structure

Settlement of stabilization partners for winning bids (share of settlement from Energinet):
- Fixed settlement for being available
- Variable settlement when stabilization is used, by deferring electricity consumption

Investments
- RTU units for stabilization partners
- IT system and platform (VPP)

Operations
- Rent, salaries, etc.

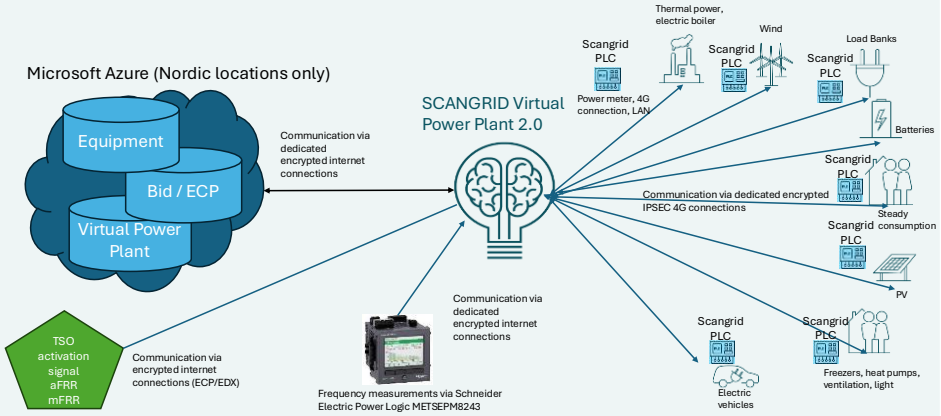
Revenue streams & pricing

Energinet:
- Daily bids/auctions for services
- If the bid is won, a fixed price is settled in hourly intervals for being available with the offered volume of ancillary services

Stabilization partners:
- Fixed price for delivery and installation of the RTU, which is required for them to deliver the stabilization service to Energinet

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System overview for SCANGRID aggregated VPP 2.0



11 Confidential SCANGRID

Segmentation of stabilization partners

Examples of electricity-consuming units that can be deferred at short notice.

Utility companies
- Mechanical aerators
- Mixers
- Bottom Aerator/Mixer
- Electric piston pump

Municipalities & Authorities
- Ice rinks
- Swimming pool circulation pump
- Cooling compressor ice rink
- Dehumidifier ice rink
- Ventilation ice rink
- Ice rink heating coil
- Solar cell inverter

Maritime companies
- Cooling systems
- Cooling compressor
- Tank heating / cooling



Industry & Production
- Asphalt production
- Mechanical mixers
- Tank heating

Logistics & Cold stores
- Cooling systems
- Circulation pump
- Cooling compressor
- Dehumidifier
- Ventilation
- Heating

Properties & Greenhouses
- Cooling systems
- Circulation pump
- Cooling compressor
- Dehumidifier
- Ventilation
- Heating

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Femern (Hiflex Pilot)

13

Presentation 8
Carsten Vammen: Aggregation of flexible loads: business models, legal aspects, and policy frameworks

Properly one of the larges pilot of Heat pumps (in numbers) in Denmark so fare.. 1.332 pcs.

