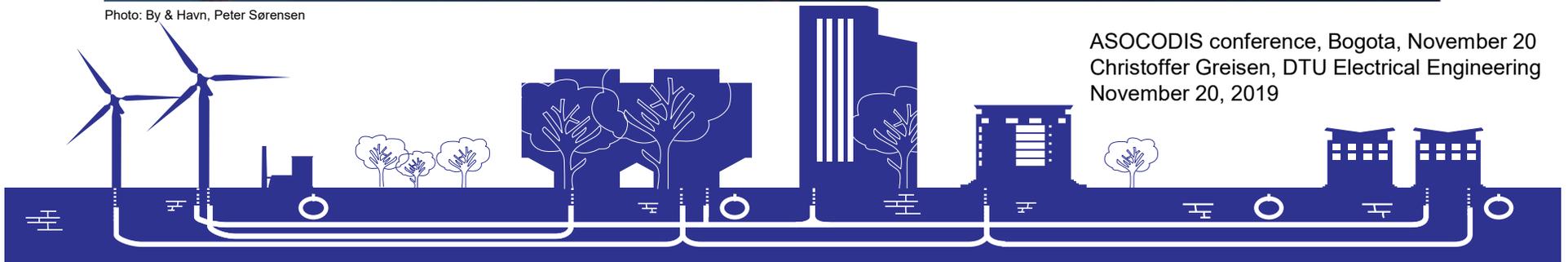


# EnergyLab Nordhavn

Integrated Energy Infrastructures and Smart Components



Photo: By & Havn, Peter Sørensen



ASOCODIS conference, Bogota, November 20  
Christoffer Greisen, DTU Electrical Engineering  
November 20, 2019



# Outline

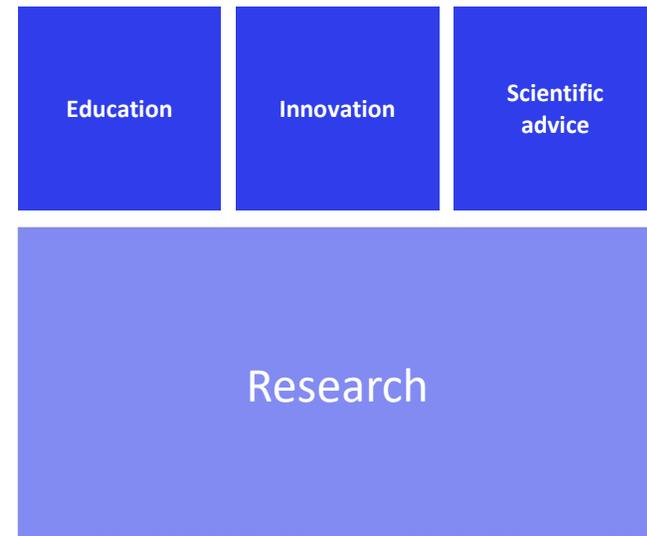
- Introduction and background
- Project examples and results
- Conclusions and lessons learned



## Our mission

”DTU will develop and create value using the natural sciences and the technical sciences to benefit society.”

H.C. Ørsted  
Founder of DTU in 1829





# Technical University of Denmark

- founded in 1829 by Hans Christian Ørsted

DTU Electrical Engineering

### Key figures

Student body

**11,221**

- including PhD 1,300  
- and int. MSc 1,500

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Research publications

**5,700**

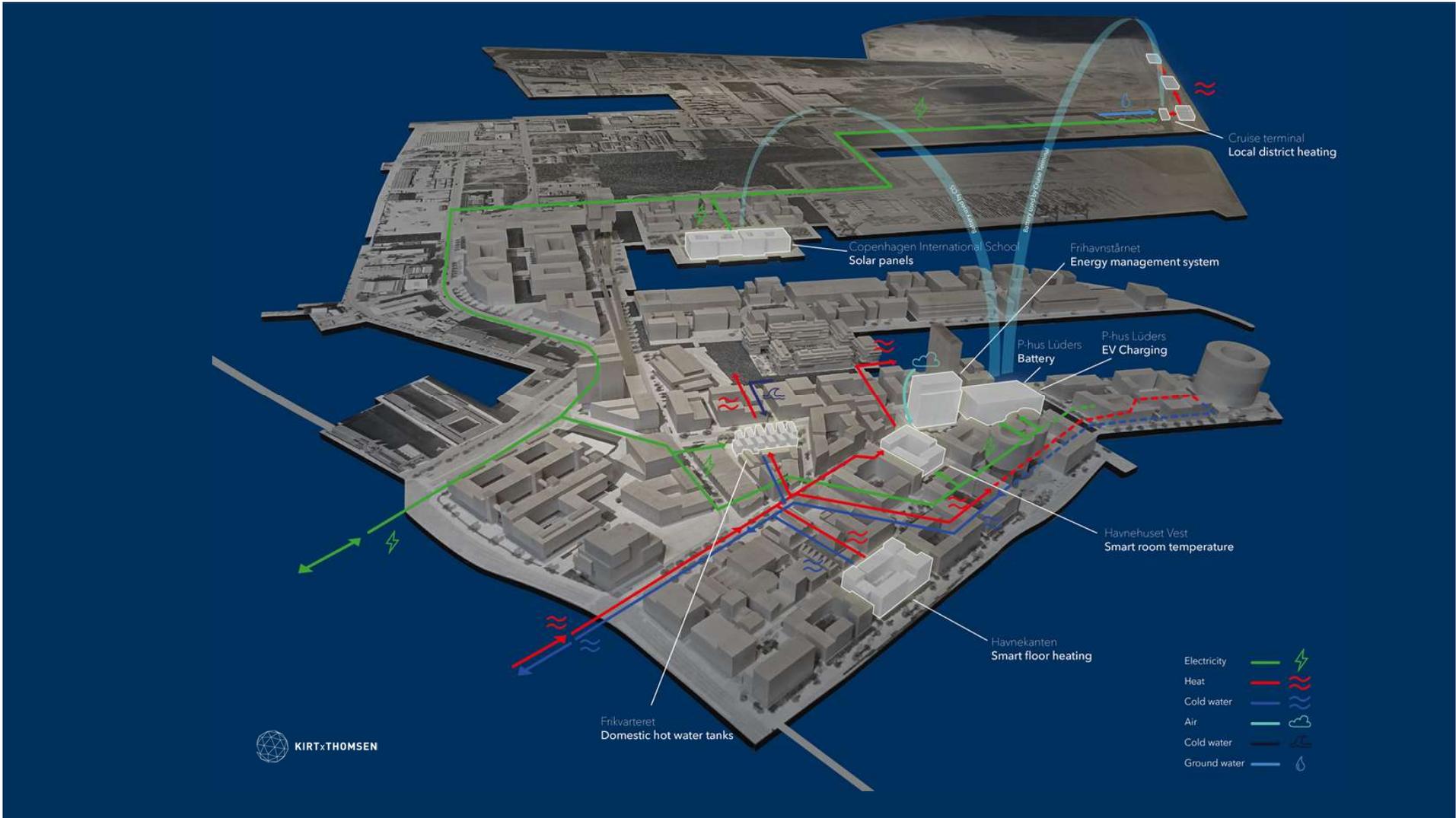
### Ranking

Leiden Ranking 2016:

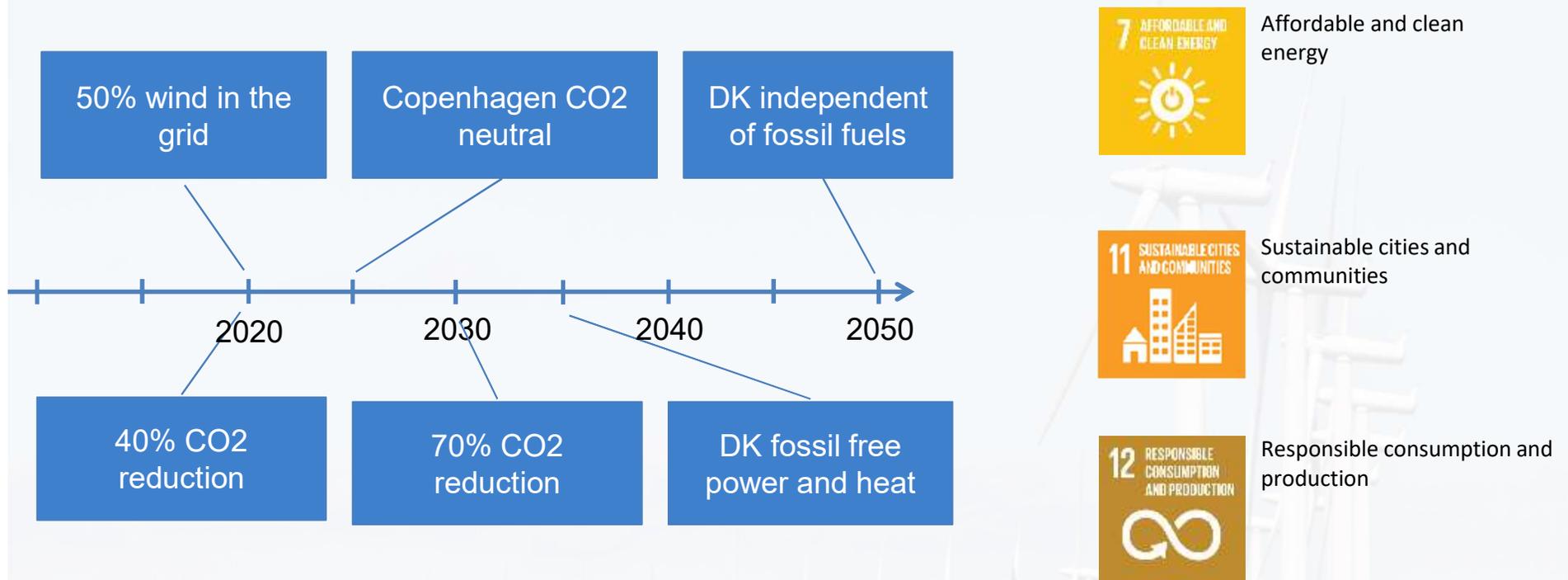
**No.1** in the Nordic region

**No.41** in Europa



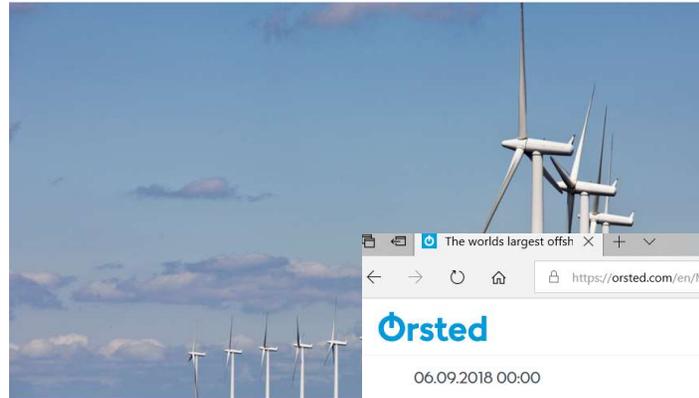


# National goals and SDG's supported



*"Dad.. I'm scared about all that with climate change.. That there will no world for my kids to grow up in..."*

Juliane, 11 years, August 2019



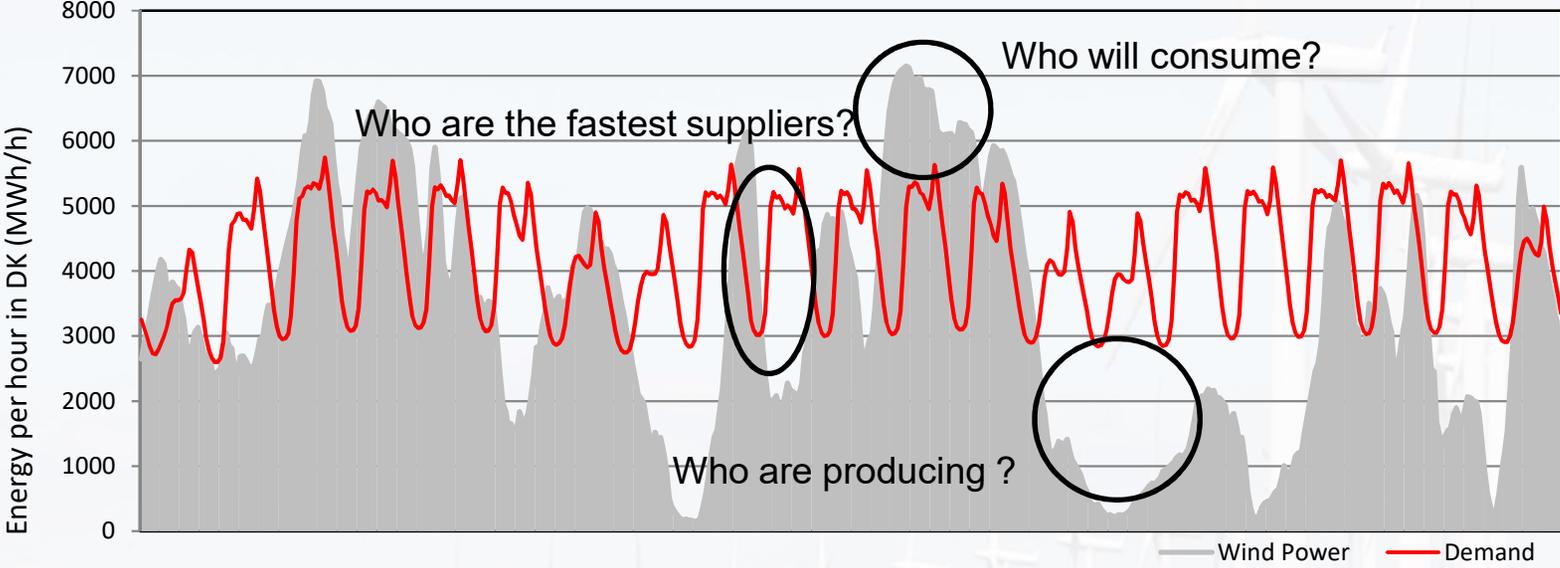
**The world's largest operational offshore wind farm, Walney Extension, will be officially opened today at a ceremony in Barrow in the north-west of England. Walney Extension, which is owned by Ørsted and its partners PFA and PKA, is the first project to use wind turbines from two different manufacturers.**



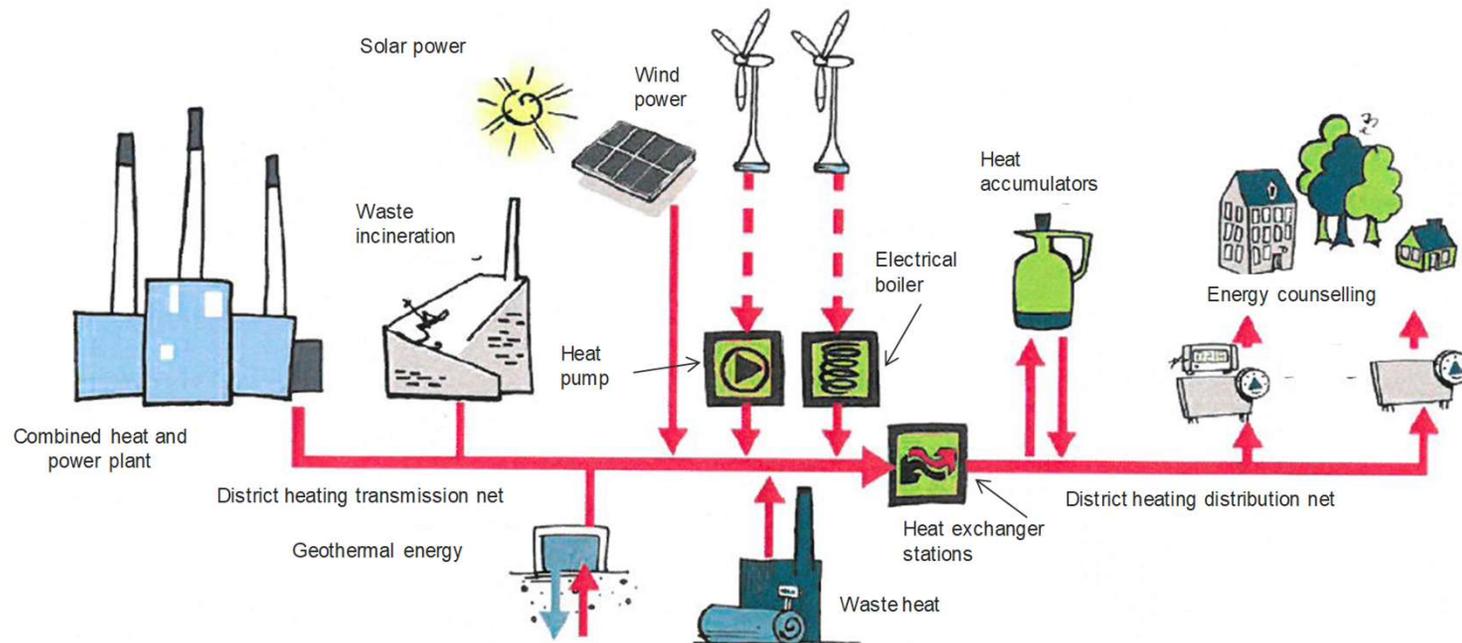
[From www.tvindkraft.dk]

# 50% wind already in 2020

Typical month in 2020

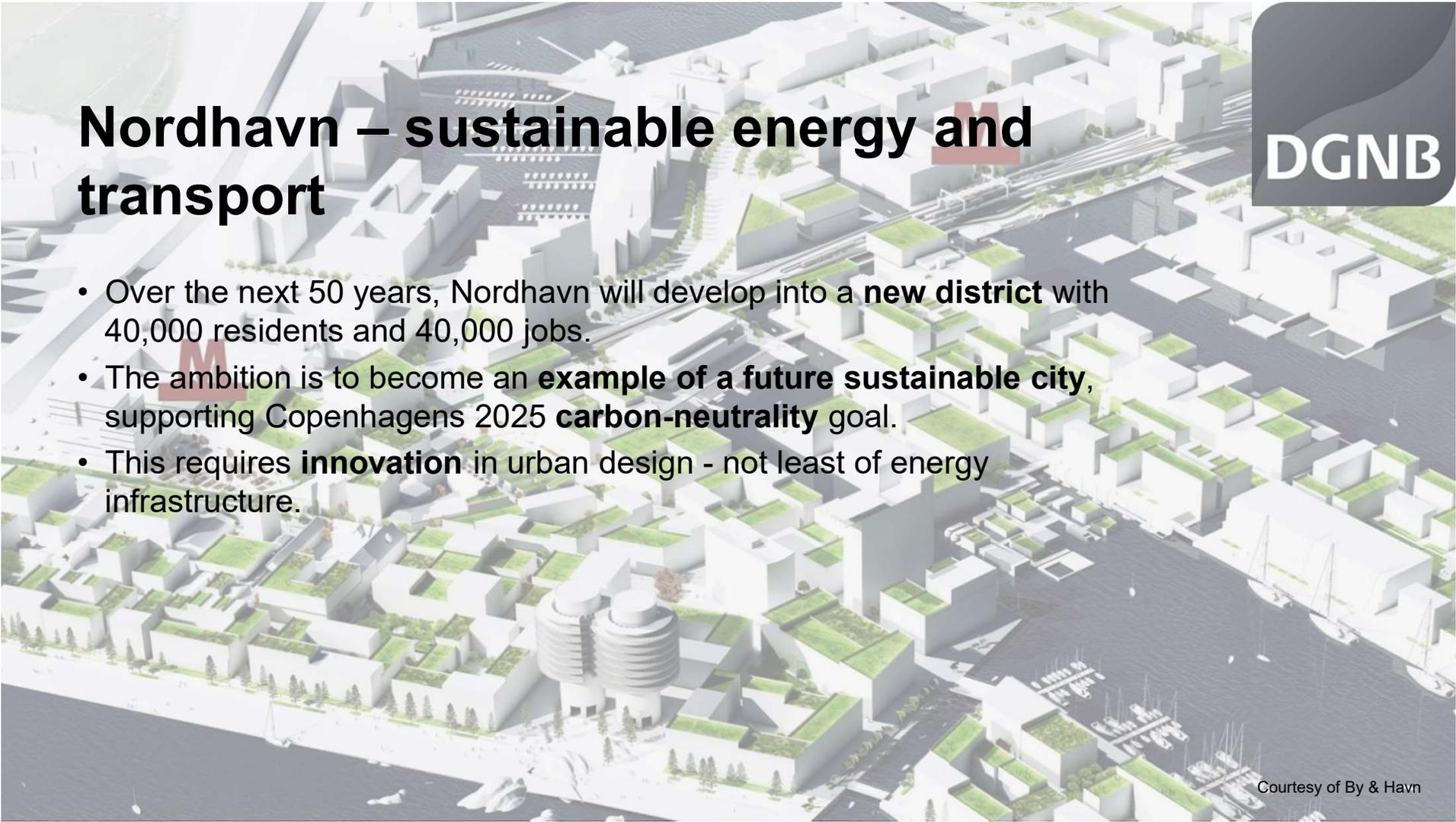


# Flexibility and integration - district heating



Production → Distribution → Consumption



An architectural rendering of the Nordhavn district in Copenhagen, showing a dense urban layout with white buildings, green roofs, and a waterfront area with a marina and sailboats. The rendering is viewed from an elevated perspective.

# Nordhavn – sustainable energy and transport

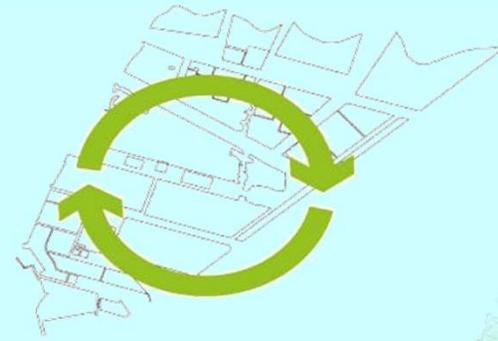
DGNB

- Over the next 50 years, Nordhavn will develop into a **new district** with 40,000 residents and 40,000 jobs.
- The ambition is to become an **example of a future sustainable city**, supporting Copenhagen's 2025 **carbon-neutrality** goal.
- This requires **innovation** in urban design - not least of energy infrastructure.

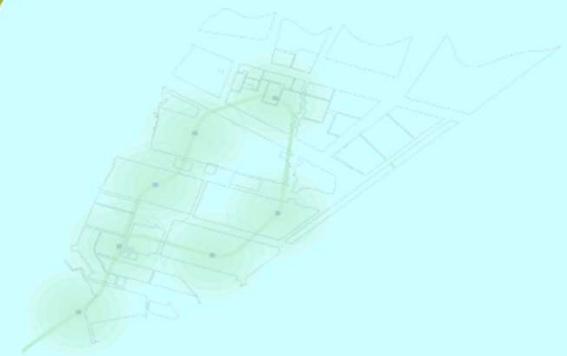
Courtesy of By & Havn



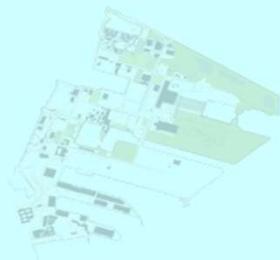
**ISLETS AND CANALS**  
HOLME OG KANALER



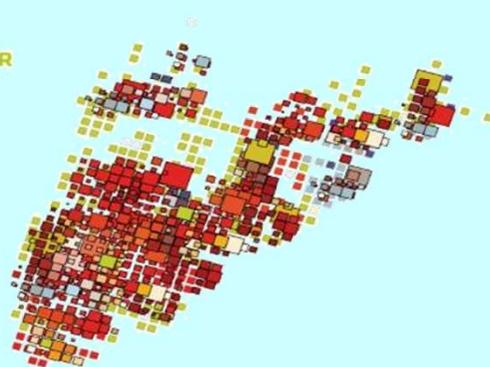
**CO2 FRIENDLY CITY**  
CO2 VENLIG BY



**FIVE-MINUTE CITY**  
FEM-MINUTTERS BY



**IDENTITY AND HISTORY**  
IDENTITET OG KULTURSPOR



**INTELLIGENT GRID**  
INTELLIGENT GRID



**BLUE AND GREEN CITY**  
BLÅ OG GRØN BY

# 6 THEMES

Courtesy of Københavns Kommune

# Project mission

To develop

**new methods and solutions**

for design and operation of the future

**cost-effective integrated energy  
system**

based on Nordhavn as a

**globally visible real-life  
laboratory.**



Photo: Kontraframe

# Partners from multiple sectors



BY&HAVN

Authority and city  
development



Radius

Energy  
Infrastructure



GlenDimplex  
NORDIC



COWI

Industry and consulting  
engineers



PowerLabDK

University and data  
infrastructure

2015-2019, Budget 19 M€, Danish public funding 11 M€



# Demonstrating in Nordhavn



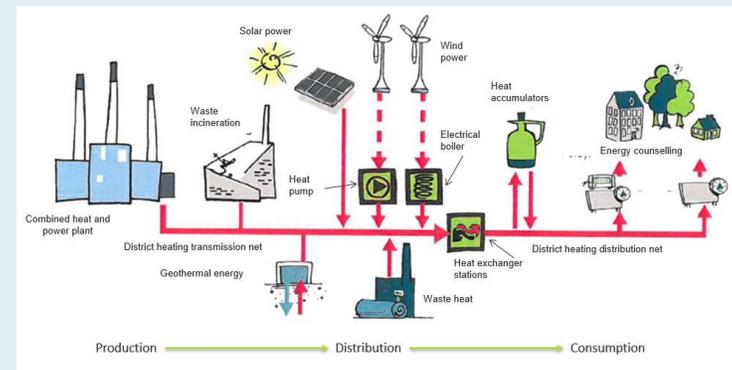
# Case – smart operation of a large heat pump

In the following we present:

- how the power system can use heat pump and storage in the district heating system, for both downward and upward regulation in the power system
- perspectives in combining heat pump in the district heating system with a battery

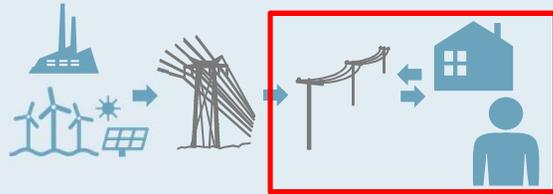
In conclusion:

- combining energy infrastructure system represent several ways of achieving flexibility.
- partnership between infrastructure utilities may be a way forward to mobilise flexibility



# Radius is one of the largest power distribution facilities

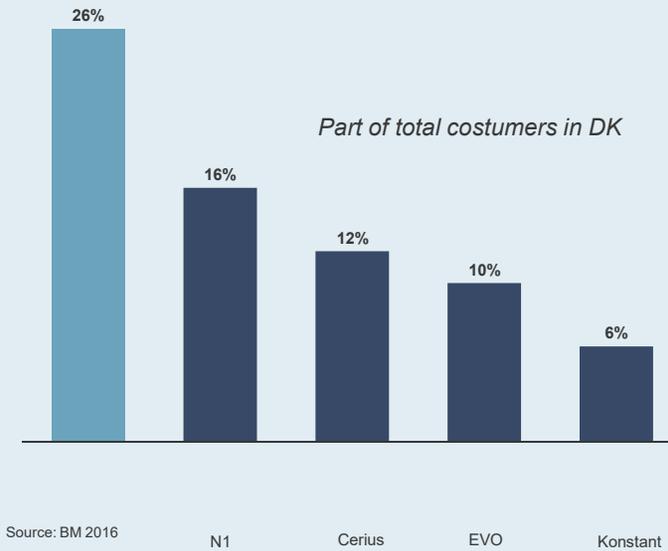
Distribution is the last part of the energy chain toward the customers



Radius distributes power in Greater Copenhagen, North Zealand and part of middle Zealand



- Radius connect 26% of all Danish customers to the power system

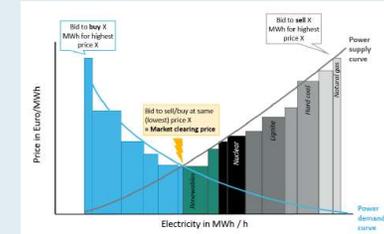


# Flexibility is the key issue in the future power system

1. Organic growth in transport of electricity due to increasing electrification



2. Balancing between increasing renewable energy supply and consumption is solved increasingly by market.



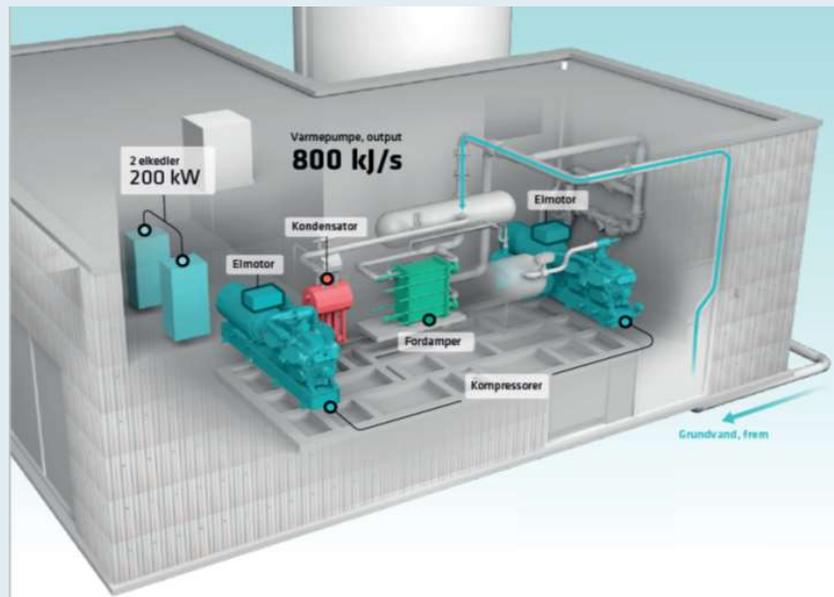
3. Increasing stochastic load due to new flexible technologies, growing energy managing, local renewable energy supply, and growing market solutions



4. New conditions and demands to DSO operation; primarily from EU



# Heat pump as downward and upward regulation service



Purpose:

Supplying cruiser terminal and UNICEF storage with district heating.

Small island district heating system.

Essentially build for experiments with intelligent electricity consumption.

Owned by HOFOR

Electrical heat pump is the primary heat generator with additional electric boiler for flexibility. Backed up with oil based boiler.

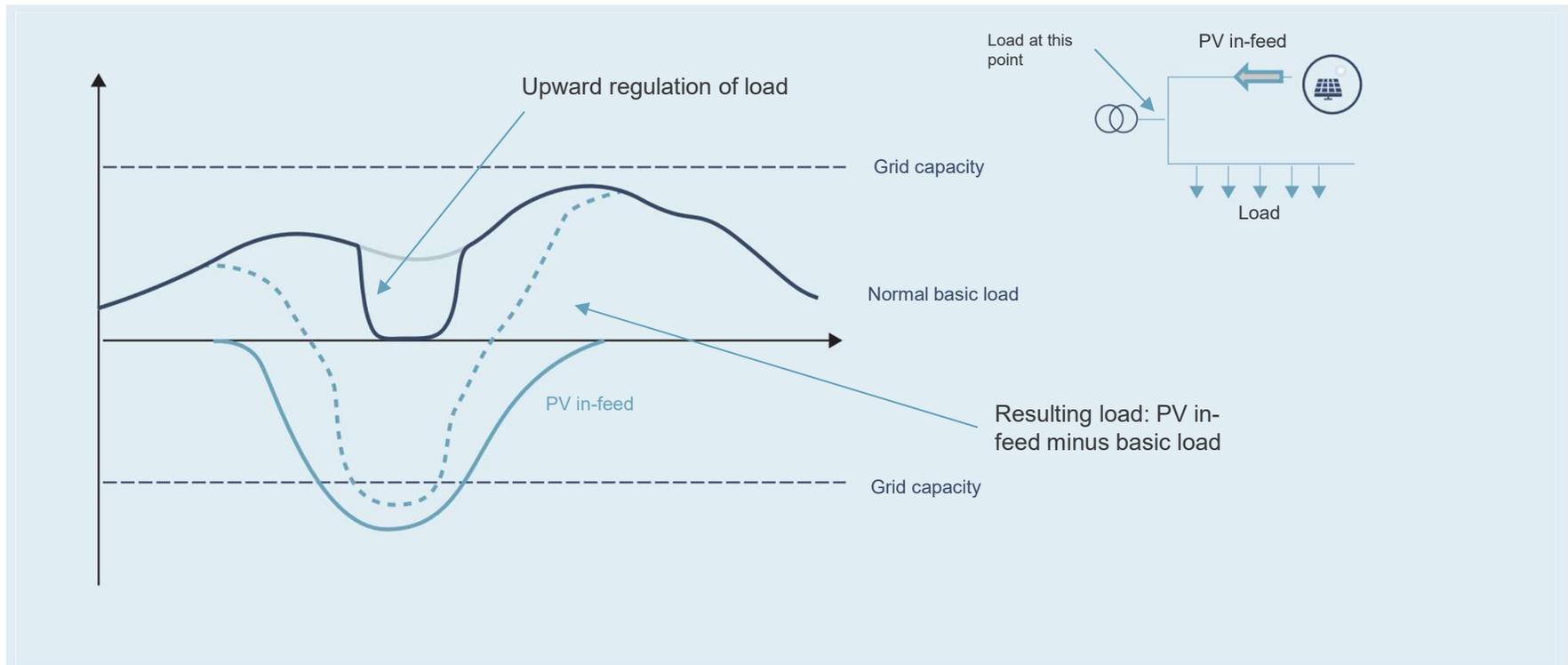
Heat pump 0.8 MW heat pump (heat side) ~ 0.2-0.45 MW power depending on COP

0.2 MW electrical boiler

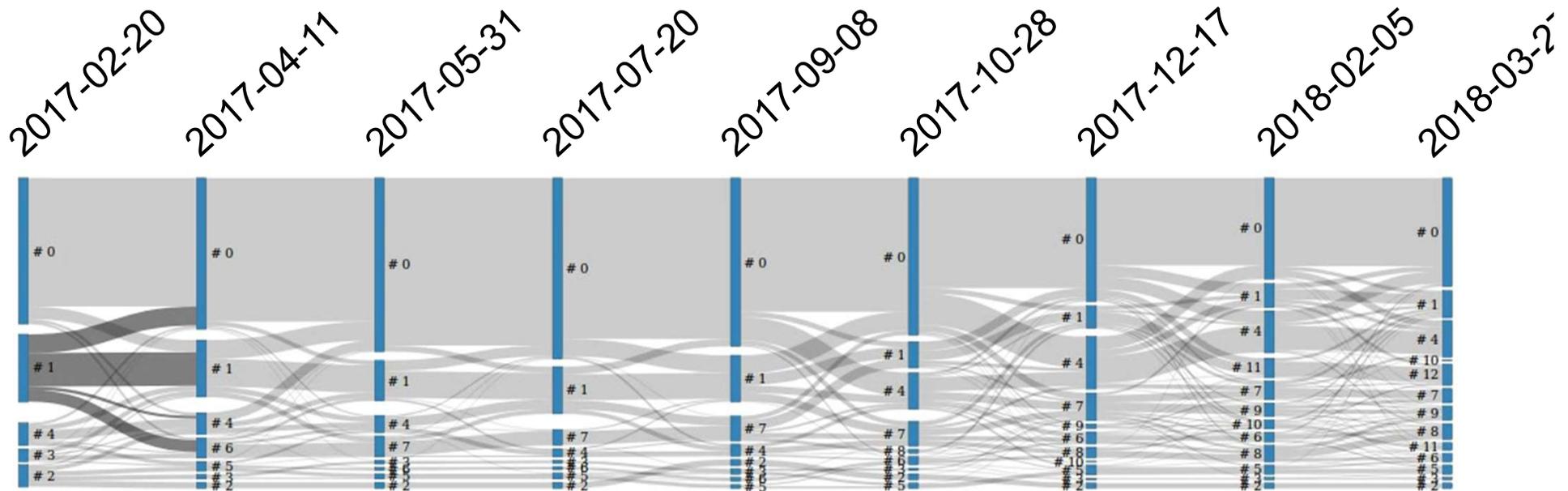
Heat source: ground water

Heat storage 100 m<sup>3</sup> ~ 4-5 MWh

## Case with RE input exceeding grid capacity but allowed due to expected basic load

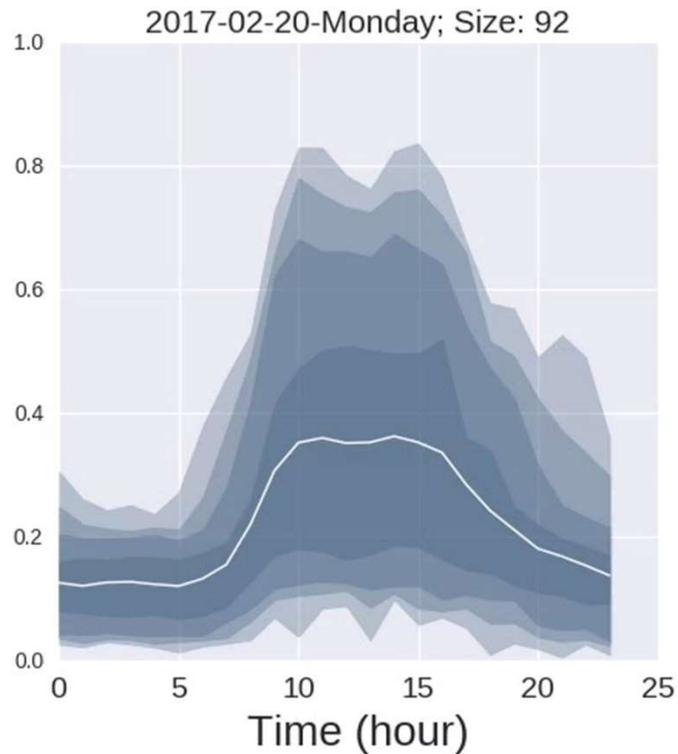


# Case: Dynamic profiling



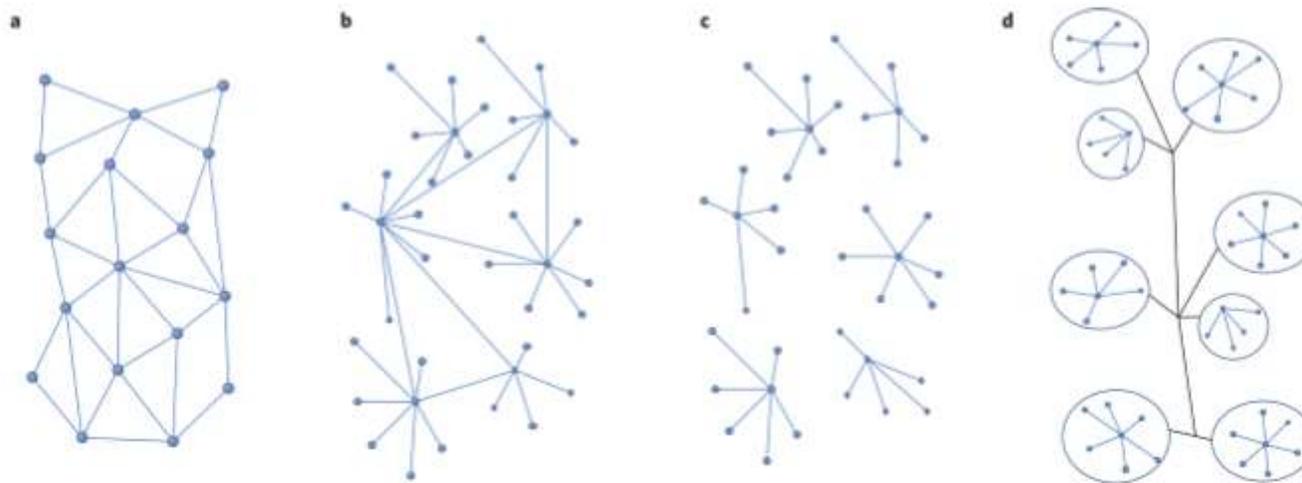
Customers can change cluster at each iteration (days)

# Dynamic profiling: Profile perspective



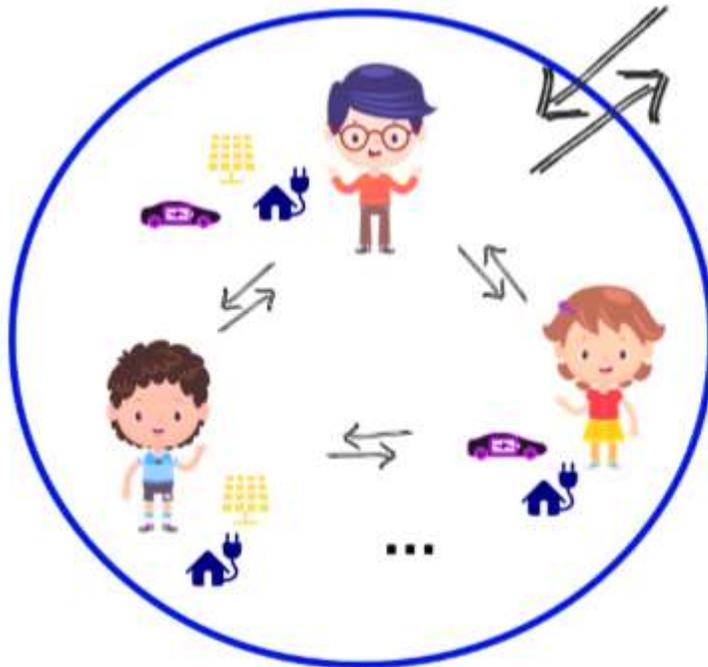
Profiles updated  
using newly generated data from  
assigned customers

# Outlook: Organization of consumer-centric electricity markets



**Figure 1 | Structural attributes of three prosumer markets.** **a.** Peer-to-peer model, in which prosumers interconnect directly with each other, buying and selling energy services. **b,c.** More structured models involving prosumers connected to microgrids. These entail prosumer-to-interconnected microgrids, in which prosumers provide services to a microgrid that is connected to a larger grid (**b**), or prosumer-to-islanded microgrids, in which prosumers provide services to an independent, standalone microgrid (**c**). **d.** Organized prosumer group model, in which a group of prosumers pools resources or forms a virtual power plant. Dots represent prosuming agents; lines represent a transaction of prosuming service; circles represent an organized group of prosumers.

# An example – Energy Communities



[Characters designed by freepik.com]

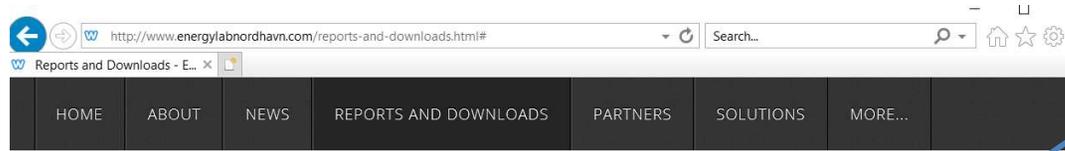
- Aidan, Eamonn, Niamh, etc., chose to gather in an *Energy Collective*
- They traditionally bought energy from the grid and sold their production back at a disadvantageous rate...
- They work at optimally matching their production and consumption
- They decide on how to share costs and benefits from import/export
- Exchanges within the community do not have to be settled against monetary transactions, but e.g., against a service or simply for free

# Co-creating tomorrow's energy system

- Co-creation space, conference or co-working
- 5000 guests in H1
- Researchers, as well as politicians and business developers from all over the world
- EnergyHub for smart city companies



# Learn more



## Publications 2018

- Online adaptive clustering algorithm for load profiling: Guillaume Le Ray, Pierre Pinson, Sustainable Energy, Grids and Networks, 2018
- Demand side management in urban district heating networks: Hanmin Cai, Ziras Charalampos, Shi You, Rongling Li,

## Master theses

- Maria Palumbo, "Greenfield planning of Nordhavn area: An optimal design of the power distribution network", 2018
- Pierre Winkler, "A data-driven framework for demand flexibility detection and evaluation", 2018
- Mads Rønn Kramer and Jairam Ramakrishnan, "State of Health (SOH)

## Deliverables

- D1.3 Reporting and Administrative Plan
- D2.1a Data Infrastructure
- D2.2a and 2.2b Design specification and Commissioning Report
- D2.4 SAT test report
- D2.6a Specification of data collection system
- D1.6 Data Collection System SAT test



## Demand side management in urban district heating networks

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 \*\*Department of Civil Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark  
 \*NORVA A/S, 2300 København S., Denmark

### HIGHLIGHTS

- Realistic method for DSM was developed for a district heating network.
- The method was applied in a real DSM in Denmark.
- Feasibility of the optimal solution to energy, comfort and pumping costs is analyzed.
- Result shows up to 11% energy cost saving.

### ARTICLE INFO

**Keywords:**  
 Smart energy system  
 An open-loop district heating  
 Demand side management  
 Data-driven modeling  
 Optimization  
 Energy flexibility

### ABSTRACT

This paper proposes a realistic demand side management mechanism in an urban district heating network (DHN) to improve system efficiency and manage congestion issues. Comprehensive models including the circulating pumps, the district heating network, the building open heating (OH) and domestic hot water (DHW) demand were employed to support data-driven energy flexible optimization for district heating solutions. Flexibility in both OH and DHW were fully explored and the impact of both nearby pattern and building type were considered and identified in detail. The energy consumption scheduling problem was formulated for both the individual subdivisions and the district heating operation. Three main factors were considered in the formulation: user comfort, the heat market and network congestion. A case study was performed based on a representative urban DHN with a 1.5 MW peak demand including both residential and commercial buildings. Results show an up to 11% reduction of energy costs. A sensitivity analysis was conducted which provides decisive insights with insight into how sensitive the optimum solution is to any change in energy, user comfort or pumping costs.

### 1. Introduction

According to the Danish National Energy plan, the electricity and heating sector should be 100% renewable energy based by 2050 [1]. Such ambitious target demand considerable efforts in energy conversion and the integration of renewable energy sources (RES) into energy systems. Over the years, a large number of RES, such as wind power plants, have been connected to the energy system in Denmark. Meanwhile, the Danish Building Regulations now require newly constructed buildings to achieve a progressively lower energy consumption [2]. These new developments demand the restructuring and redesign of the current energy system and a transition to a smart energy system [3]. Digital solutions are starting to be utilized to upgrade current infrastructure to enable agile system operation. To put it in another way, the

energy system must accommodate an increasing proportion of intermittent RES production and must also adapt to a changing load profile. Smart grids [4] and 4th generation district heating [5] represent the state-of-the-art research concepts in the electricity and heating sectors. This paper aims to contribute to this increasingly important research area by developing a comprehensive demand side management (DSM) mechanism to improve the energy efficiency of a district heating network (DHN) and to provide solutions for congestion management. To be more precise, the DSM implemented in this paper can be further categorized by demand response according to the classification proposed by Palensky et al. [6] and the term congestion will refer throughout the paper to the reduced quality of service that occurs when a DSM is required to deliver more heat than its designed capacity. A comprehensive survey of hotbeds in Swedish DHNs carried out

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<https://doi.org/10.1016/j.apenergy.2018.06.106>  
 Received 29 May 2018; Received in revised form 26 July 2018; Accepted 18 August 2018  
 Available online 11 August 2018  
 0360-2691/ © 2018 Elsevier Ltd. All rights reserved.

# Conclusions and selected learnings

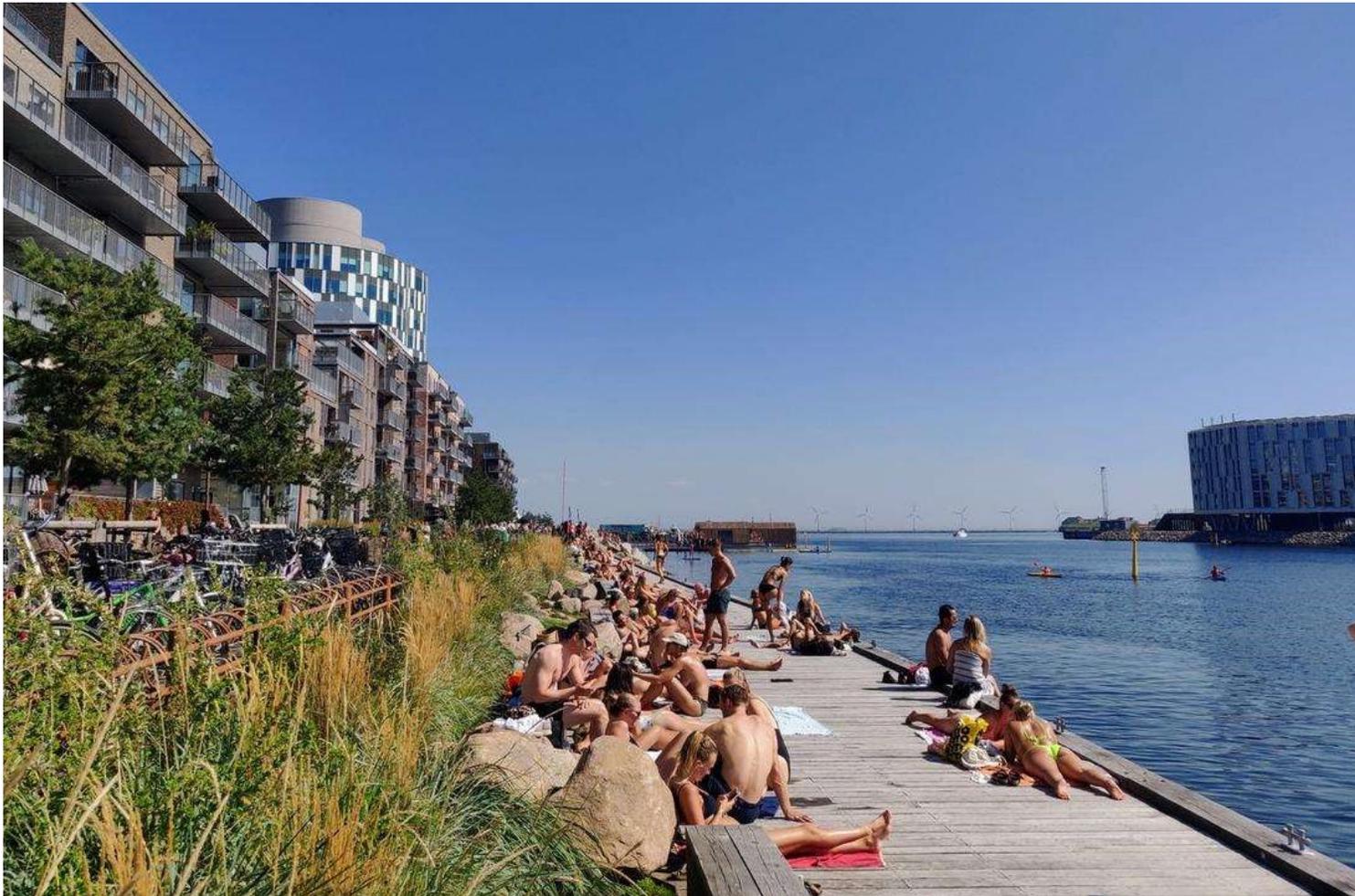
- Significant flexibility in the heating system can be unlocked, using home automation
- It is possible to accommodate much more renewable energy than today.
- Power sector is unbundled – Heat sector is not > organizational aspects are just as relevant as technology
- DSO products go through a lengthy approval process, and bandwidth at regulator is small > slowing innovation.
- Shared observability in real time
- Very different interpretation of personal data legislation in different organizations
- Service stacking is key
- Demonstration is necessary – also for finding regulatory barriers
- A combined showroom, physical presence and innovation space brings cross-organizational innovation and co-creation about.



*The consumers shall co-build the energy system,*

*Knud Pedersen, Radius Elnet, 2018*





# ENERGYLAB NØRDHAVN



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Radius

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NERVE  
ENERGY SYSTEM



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