
DTU
Energy Security Through Demand Side Flexibility – the Case of Denmark
Jacob Østergaard and Haris Ziras
Technical University of Denmark
IEEE PES UNIVERSITY
IEEE

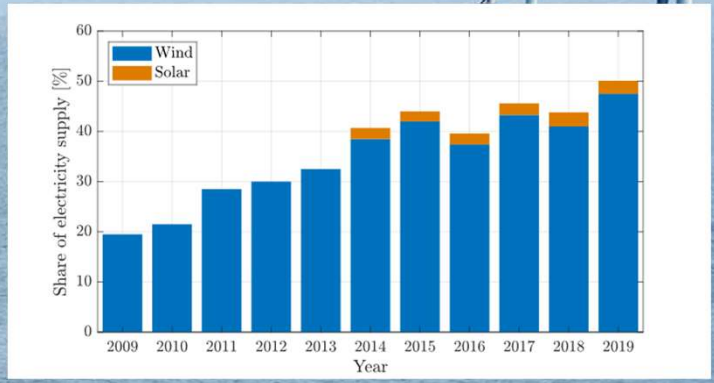
Outline

1. The Danish energy landscape
2. Demand side flexibility: the Danish case
3. Towards local flexibility markets
4. Local flexibility markets – Learnings from Ecogrid 2.0
5. Conclusions and future perspectives

The Danish energy landscape

Ambitious Danish energy system transformation

- Wind and solar power penetration has increased from 20% in 2009 to 50% in 2019
- By 2019, CO2-emmisions have been reduced by 34% compared to 1990
- Danish Climate Act: By 2030, the total Danish CO_2-emmisions must be reduced by 70% compared to 1990



Wind and solar power penetration in Denmark, 2009-19

Source: The Ministry of Climate, Energy and Utilities

IEEE PES UNIVERSITY

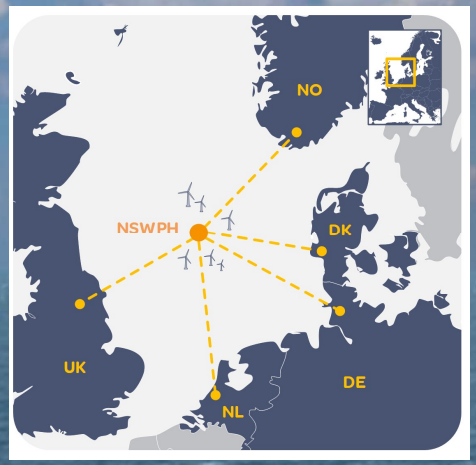
IEEE

The Danish energy landscape

Drivers behind the transformation

Offshore energy hubs

- Denmark to build world's two first 'energy islands' in 2030
  - 2 GW + 3(10) GW
  - Enable harvesting of far-offshore wind energy
- 180 GW wind power potential in the North Sea
- Power-to-X for production of green fuels for heavy transport and industry

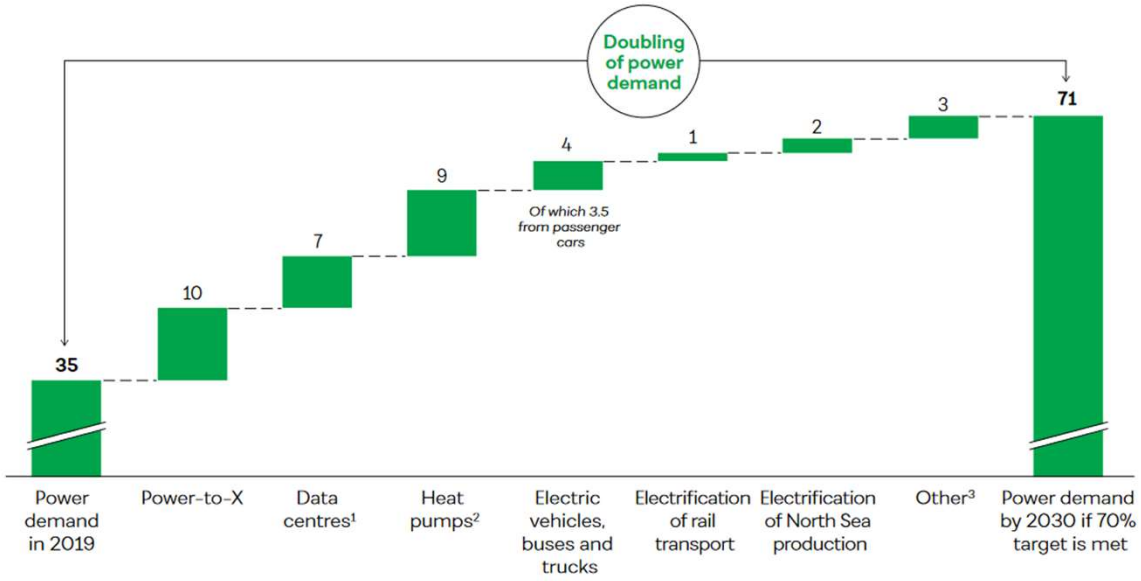


Source: The Ministry of Climate, Energy and Utilities

The Danish energy landscape

Drivers behind the transformation

Electrification of demand



Reference: The climate partnership for the energy and utilities sector, *Powering Denmark's Green Transition*, May 2020.

Demand side flexibility: the Danish case

Demand side flexibility in Denmark – some examples

Frequency service from Europe's first fully commercial V2G-hub

€155/month - Revenue per car from frequency regulation service during night and weekends (energy cost for driving is €54/month at 1,350 km/month).

Web: www.parker-project.com

Services from a large heat pump + a grid battery

Large heat pump (250 kWe) and grid battery (630 kW / 460 kWh) collaboratively provide flexibility services to the TSO.

Web: www.energylabnordhavn.com

Stacked services from EV faster charger via buffer battery

350 kW / 300 kWh buffer battery reduces the peak load on the distribution grid and enables flexibility services from a fast charging station.

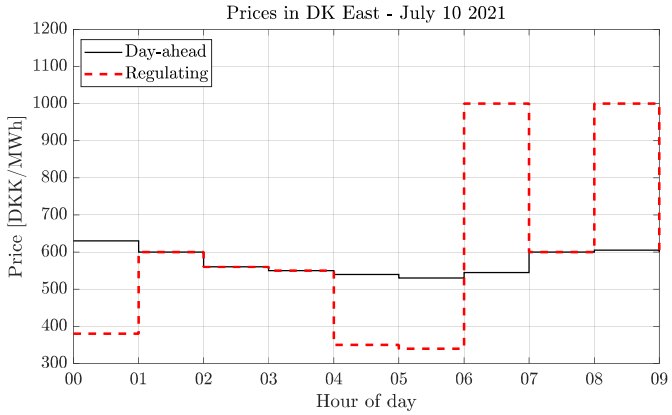
Web: www.topcharge.eu

IEEE PES UNIVERSITY IEEE

Demand side flexibility: the Danish case

When demand side flexibility becomes a “threat”

- Significant **electrification** increases loading in the distribution network (DN)
- Market participation of flexible demand will lead to challenges due to **load synchronization**
- **System integration** and **congestion management** become critical
  - This has led to an increased R&D-focus
  - And the need for “smart” solutions



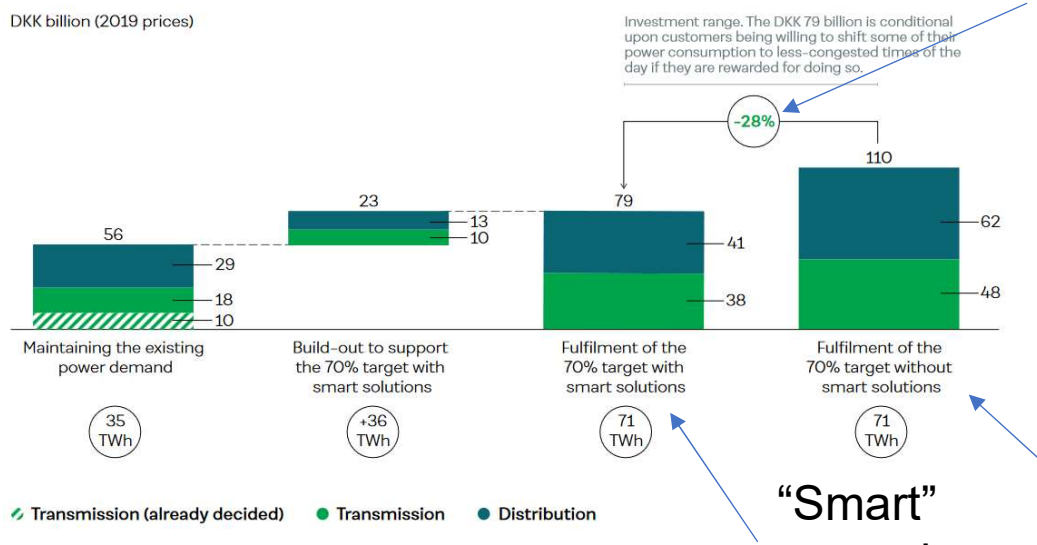
Snapshot of Danish day-ahead and regulating power prices

IEEE PES UNIVERSITY

IEEE

Demand side flexibility: the Danish case

Demand side flexibility and T&D network upgrade costs



A sizeable cost saving from "smart" solutions

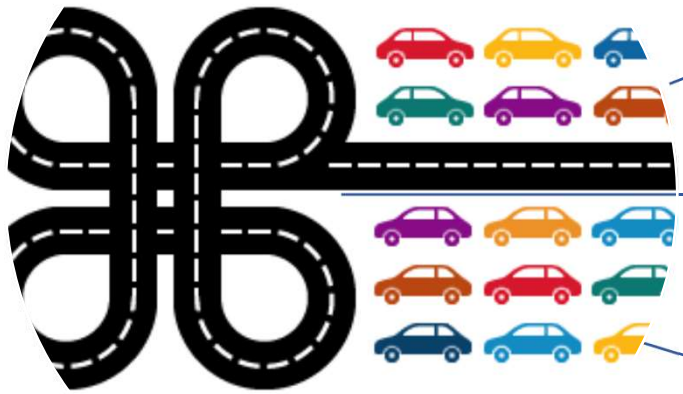
"Smart" scenario

Business as usual scenario

Reference: The climate partnership for the energy and utilities sector, Powering Denmark's Green Transition, May 2020.

Towards local flexibility markets

Objectives may cause conflicts



Congestion management

TSO

DER flexibility
Reliability
Low costs

DSO

Security of supply
Long-term guarantees
Flexibility vs expansion

DERs

Network access
Freedom to utilize flexibility
Secure supply

IEEE PES UNIVERSITY

IEEE

Towards local flexibility markets

DER impact on distribution networks

Congestion management options

ToU tariffs

Dynamic tariffs

Bilateral agreements

Finer geographical granularity

Local flexibility markets

IEEE PES UNIVERSITY

IEEE

For more details:

J. Østergaard *et al*., "Energy Security Through Demand-Side Flexibility: The Case of Denmark," in *IEEE Power and Energy Magazine*, vol. 19, no. 2, pp. 46-55, March-April 2021, doi: 10.1109/MPE.2020.3043615.

Towards local flexibility markets

Local flexibility markets

- DSOs shall procure ancillary services for congestion management of DNs through transparent market-based procedures
- Demand side response and aggregators are enabled to fully participate in electricity markets without limitations

Features

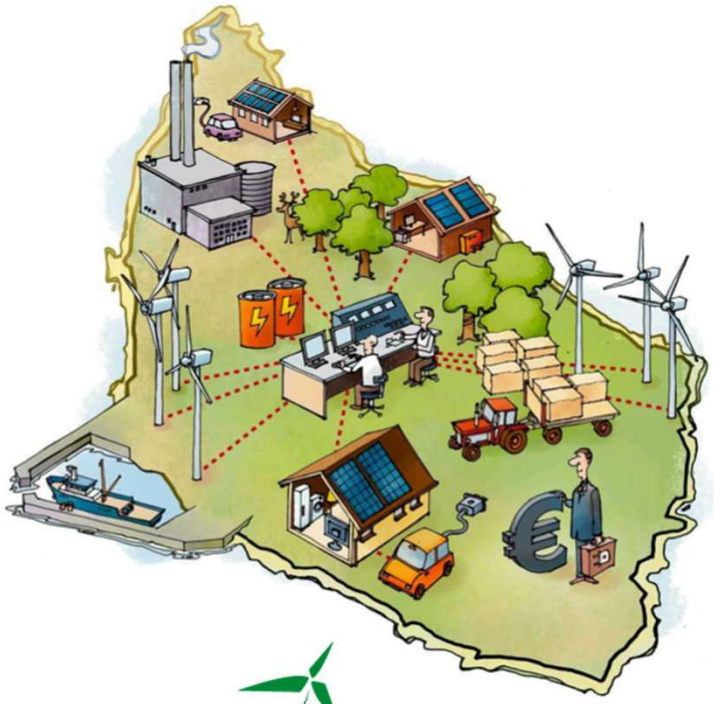
- ✓ Promote competition
- ✓ Allow DSOs to access flexibility
- ✓ Run in parallel to the current system
- ✓ May resolve TSO-DSO conflicts on the use of flexibility
- ✓ Maintain the structure of power markets and operation

IEEE PES UNIVERSITY IEEE

Local flexibility markets – Learnings from Ecogrid 2.0

Bornholm island

- 40,000 people
- 100% renewable electricity production
- 100% renewable district heating system
- A living lab for innovative solutions



PowerLab DK

IEEE PES UNIVERSITY

IEEE

Local flexibility markets – Learnings from Ecogrid 2.0

EcoGrid 2.0

- Designed, implemented and ran a local flexibility market
- In parallel to a mock-up of the balancing market
- Focus on both DSO and aggregator side
- 800 flexible customers
- 3 heating seasons / development cycles

IEEE PES UNIVERSITY IEEE

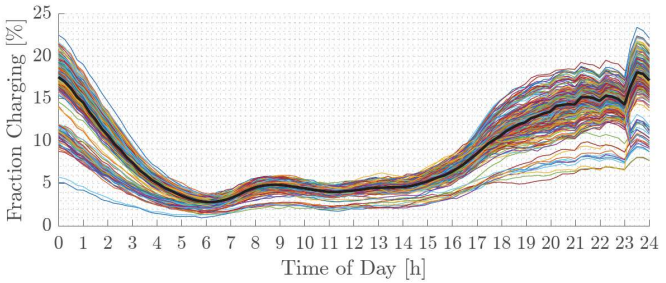
Local flexibility markets – Learnings from Ecogrid 2.0

Ecogrid 2.0 learnings

Congestion is primarily caused by demand side participation in wholesale markets

- HPs and EVs without smart control do not cause substantial load peaks
- **Reaction to price signals** may increase coincidence factors drastically, and **cause congestion**

Non-coordinated charging



EV load coincidence factors are relatively low (max 20-25%) without smart charging (move to caption)

Source: A. Thingvad, The role of electric vehicles in global power systems, PhD thesis

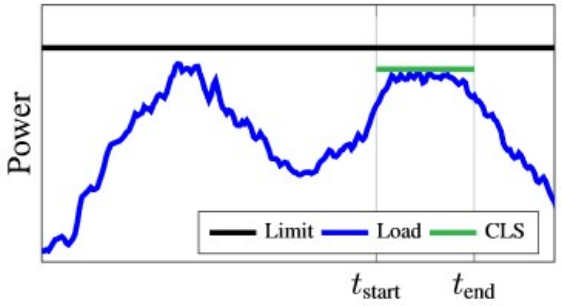
IEEE PES UNIVERSITY IEEE

Local flexibility markets – Learnings from Ecogrid 2.0

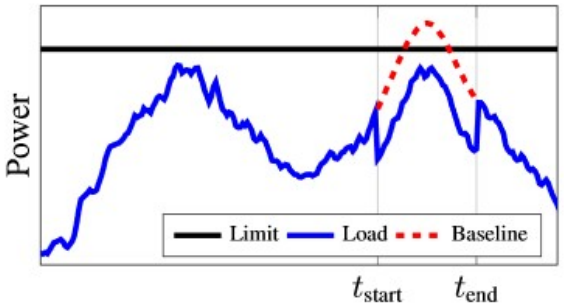
Ecogrid 2.0 learnings

Defining proper services is crucial

- A large part of the project focused on service definition, verification and the associated implications
- Two main types of services: capacity and relative
- DSO-level services need to:
  - Be compatible with both DSO and flexibility providers operation and risk management
  - Be easy to verify
  - Be transparent and accepted by all parties



A capacity service



A relative service based on a baseline

IEEE PES UNIVERSITY

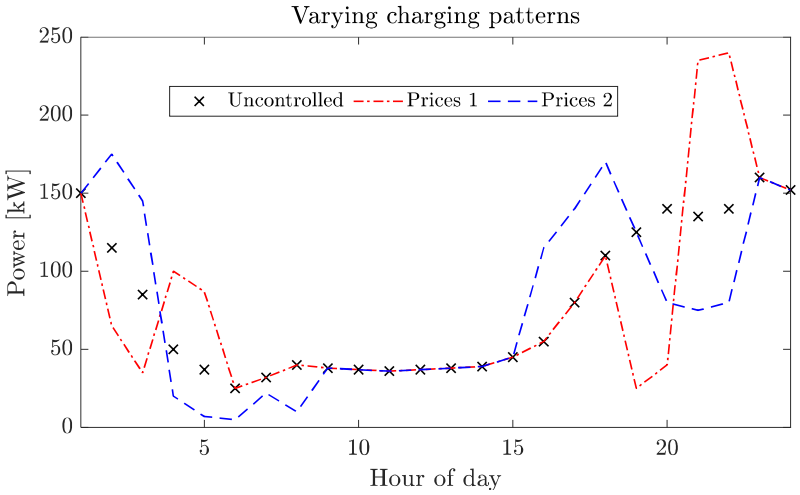
IEEE

Local flexibility markets – Learnings from Ecogrid 2.0

Ecogrid 2.0 learnings

Relative services relying on baselines are not suitable for DNs

- Under flexibility utilization, DERs stop following “typical” patterns
- Baselines are thus hard to be established, in the absence of expected behavior
- Usually those are defined arbitrarily, resulting in various implications
- Capacity limitations are a more suitable product



The absence of “natural behavior” under demand response utilization of EVs

C. Ziras, C. Heinrich, H. W. Bindner, Why baselines are not suited for local flexibility markets, *Renewable and Sustainable Energy Reviews*, Volume 135, 2021, 110357

IEEE PES UNIVERSITY

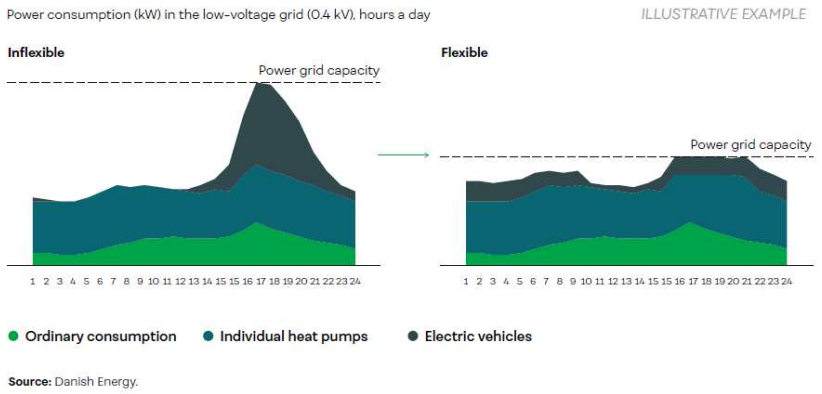
IEEE

Local flexibility markets – Learnings from Ecogrid 2.0

Ecogrid 2.0 learnings

Demand-side flexibility is not DSO-exclusive

- Demand-side flexibility is often considered as “static”
- This flexibility is used only for the purpose of serving DSO objectives
- Wholesale market participation and conflicts are disregarded
- Not in line with the EU Clean Energy Package

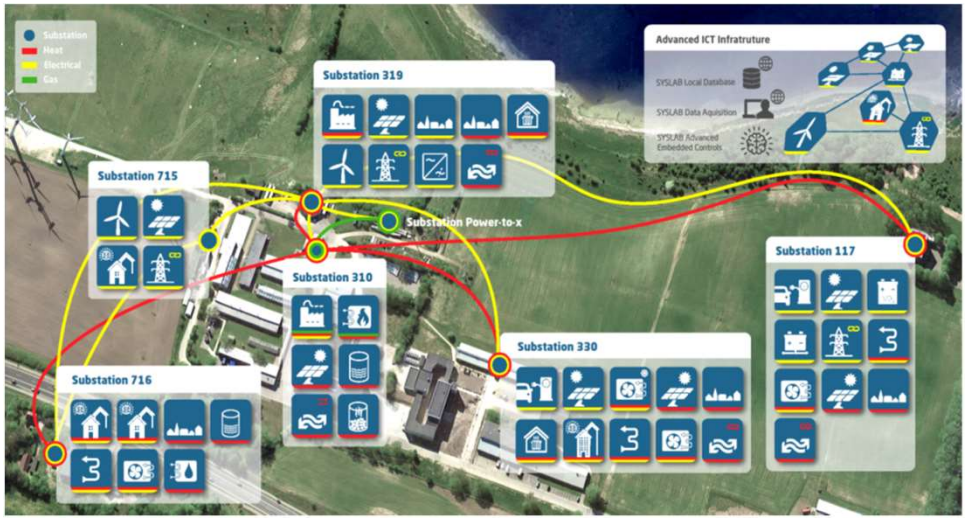


Example of demand side flexibility used only for the DSO, without participating in wholesale markets

IEEE PES UNIVERSITY IEEE

Conclusions and future perspective

- Denmark has **ambitious goals** regarding reduction of CO_2 emissions and integration of renewable energy
- **Electrification** and the replacement of fossil fuels with **renewables** are key enablers, e.g. through energy islands and sector coupling
- To do this in an economically efficient manner we also need to utilize **demand side flexibility** at the grid edge
- The flexibility can be provided by demand, but more research is needed in **system integration** and frameworks for efficiently utilizing and coordinating the flexibility.



IEEE PES UNIVERSITY

IEEE

Conclusions and future perspective

- **Local flexibility markets** seem to be the most attractive framework for utilizing flexibility at the distribution level in power systems similar to the Danish
  - Defining proper flexibility services is crucial
  - Services relying on baselines are not suitable
  - Demand side flexibility is not DSO-exclusive
- Tools are needed to integrate flexibility services in **operation and planning** of distribution networks, and turn them into **viable alternatives to grid expansion**

THANK YOU!

Further reading: J. Østergaard *et al.*, "Energy Security Through Demand-Side Flexibility: The Case of Denmark", in *IEEE Power and Energy Magazine*, vol. 19, no. 2, pp. 46-55, March-April 2021, doi: 10.1109/MPE.2020.3043615.