

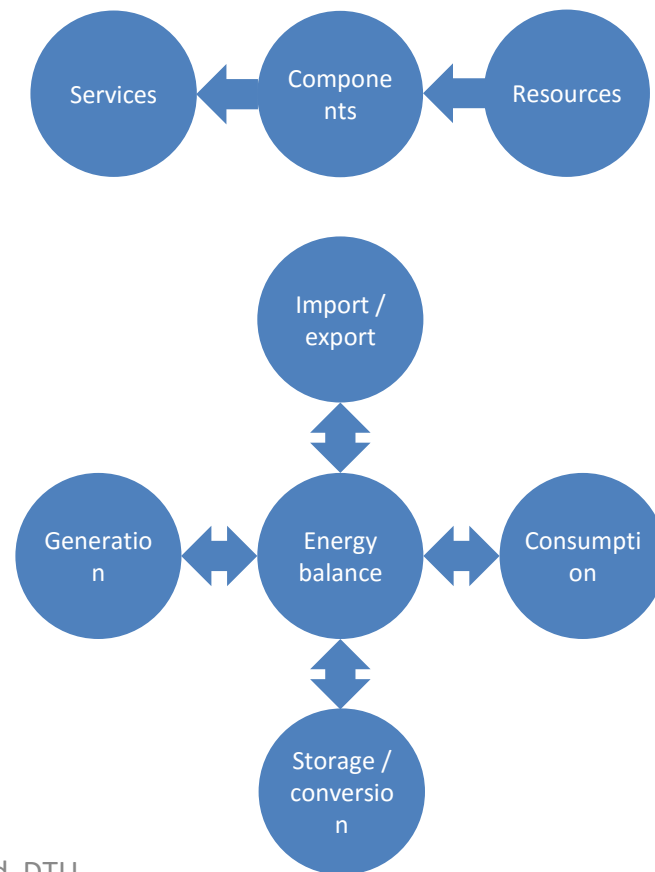
Bornholm as living lab for the future energy system

TwinPV Workshop
December 2016, University of Cyprus
Per Nørgaard, DTU

Energy system optimisation

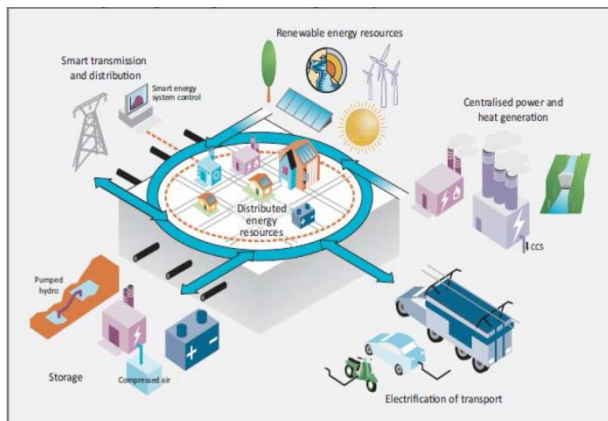
100% RE by 2050

- Planning
- Energy services
- Energy resources
- Energy system services
- Operation

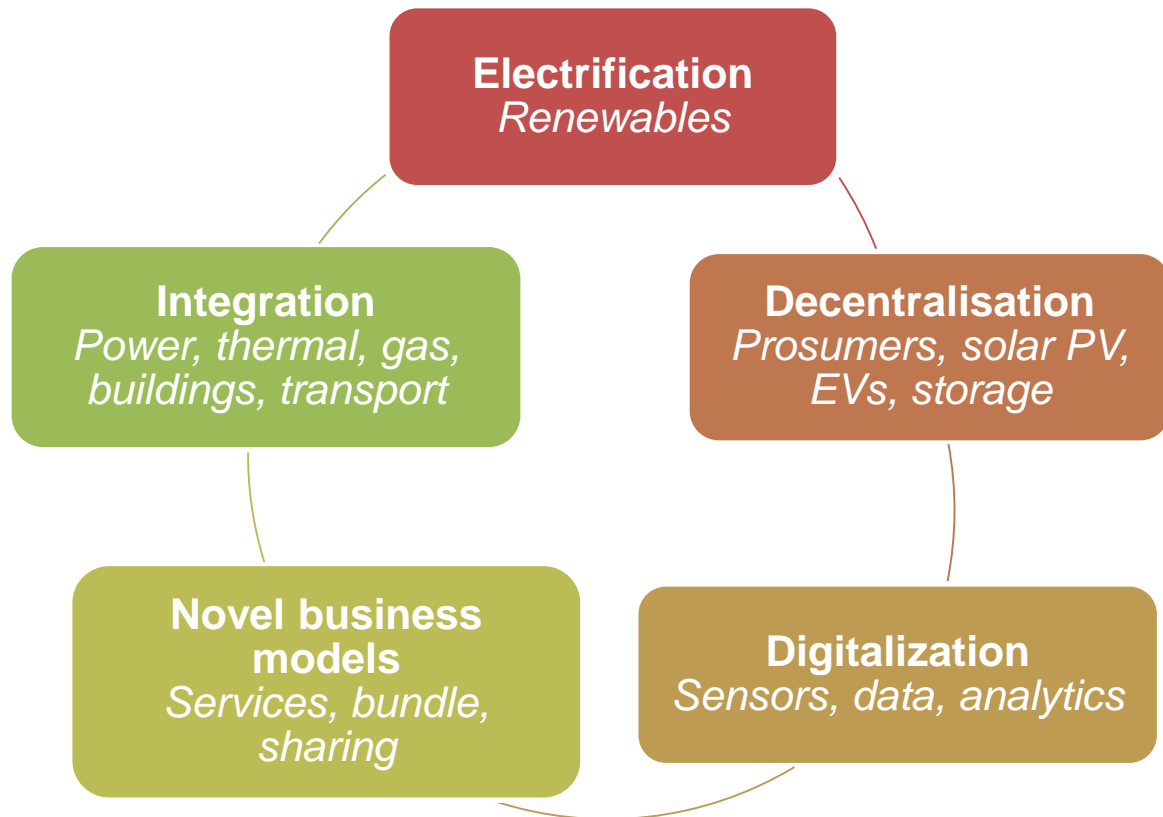


The Future Energy System

- Decarbonisation
- Cost-efficient transformation
- *DTU focus:*
Develop a reliable, cost-efficient and sustainable energy system based on renewable energy

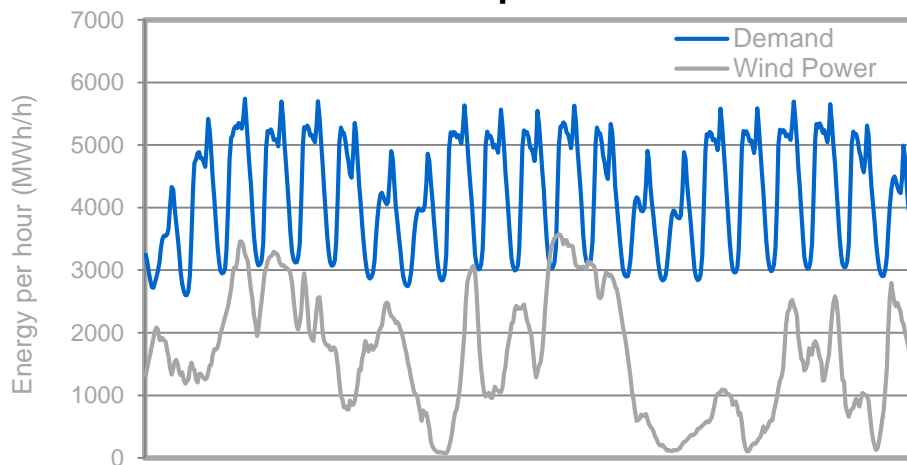


Kilde: IEAs scenario for 2050 (IEA – ETP 2014)

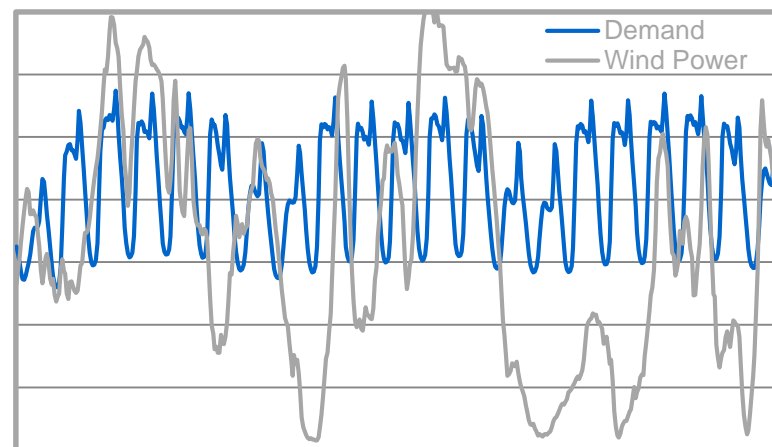


Challenges in the Future Electric Power System

DK 2012
25% wind power

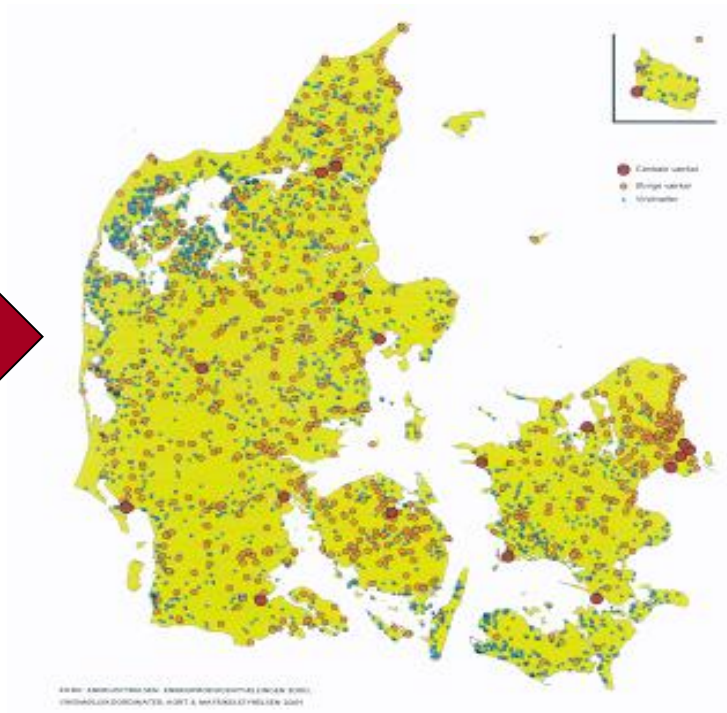


DK 2020
50% wind power

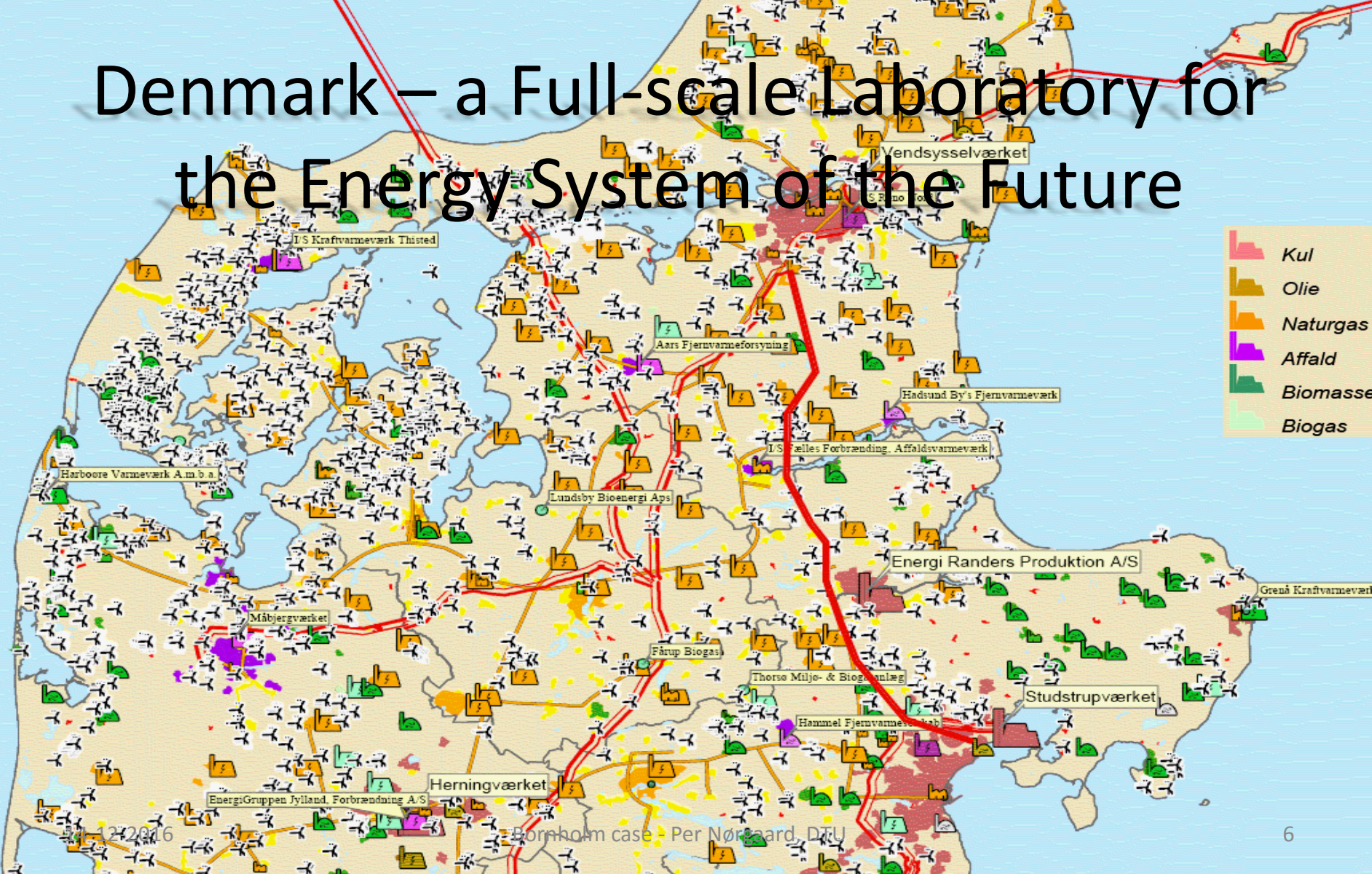


- Balance between generation and demand
- Stable and secure operation

The DK Power Generation Landscape



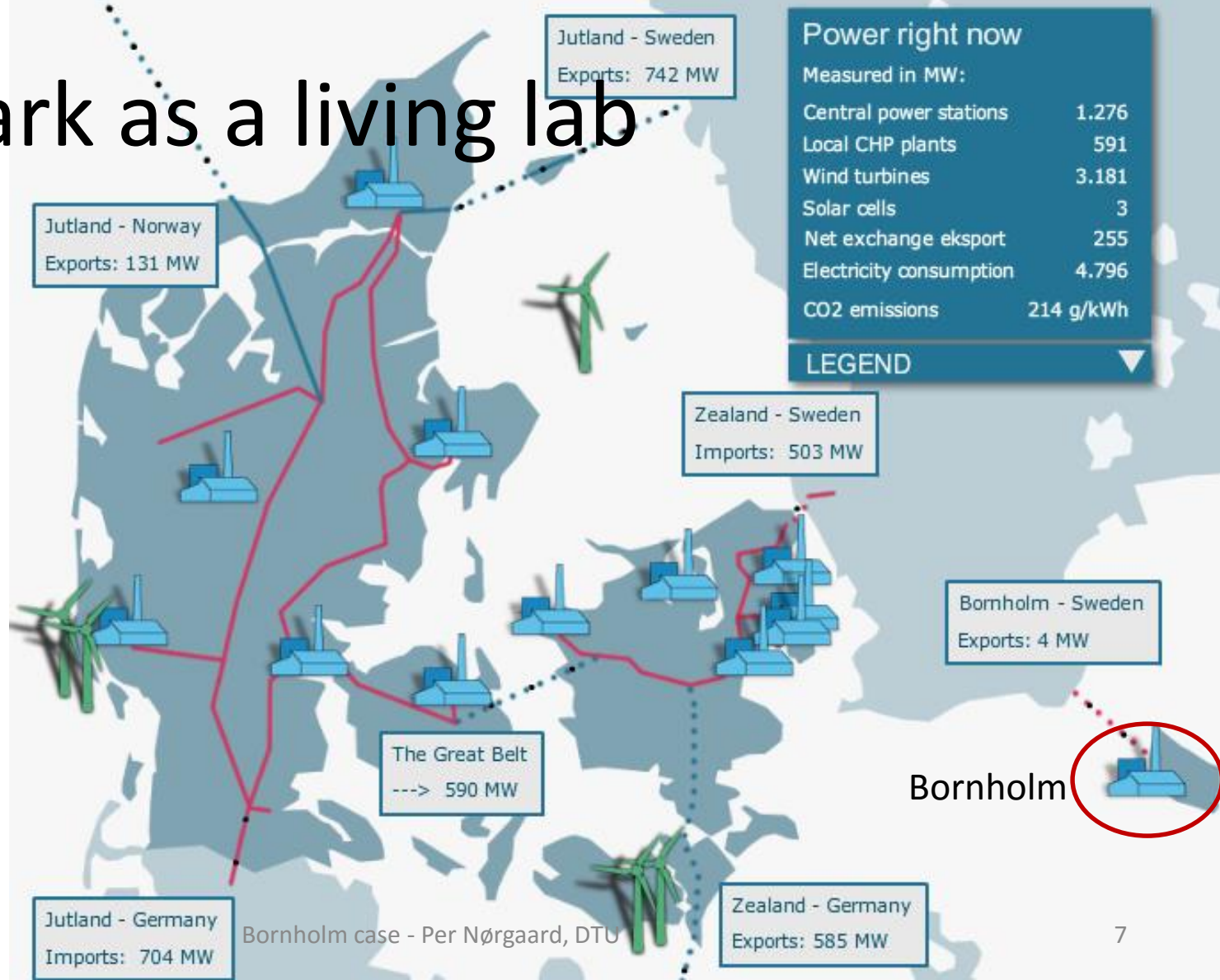
Denmark – a Full-scale Laboratory for the Energy System of the Future



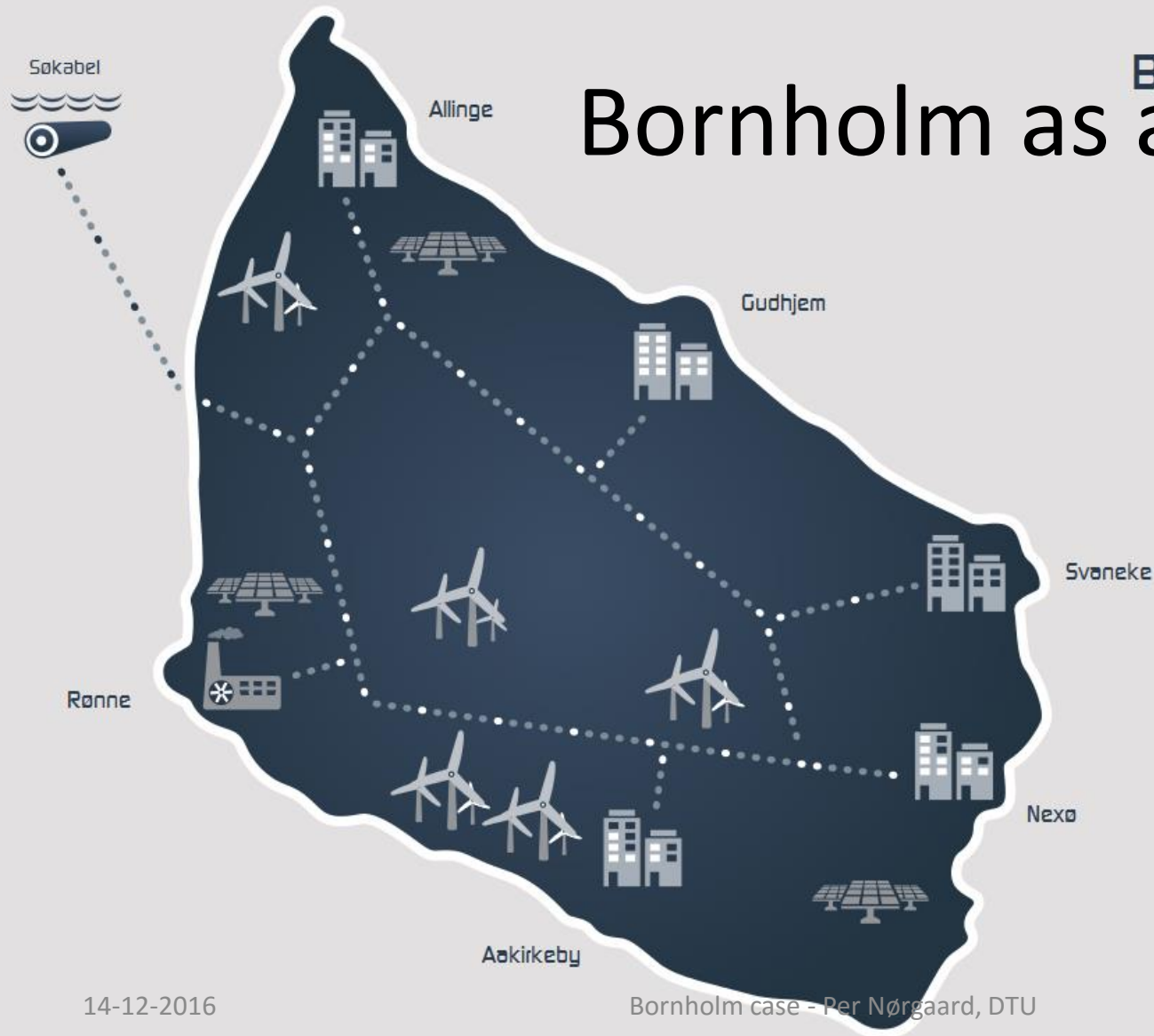
12/2016

Bornholm case - Per Nørgaard, DTU

Denmark as a living lab



Bornholm as a living lab





Copenhagen
Carbon Neutral
by 2025

Copenhagen CO₂-neutral



by 2025

A GREEN, SMART AND
CARBON NEUTRAL CITY

CPH 2025 CLIMATE PLAN

EnergyLab Nordhavn

Showroom and visualisation



Power grid operation



Flexibility from heat and cooling grids



Integrated markets and control centers



Storage flexibility



Smart network services



Smart charging infrastructure



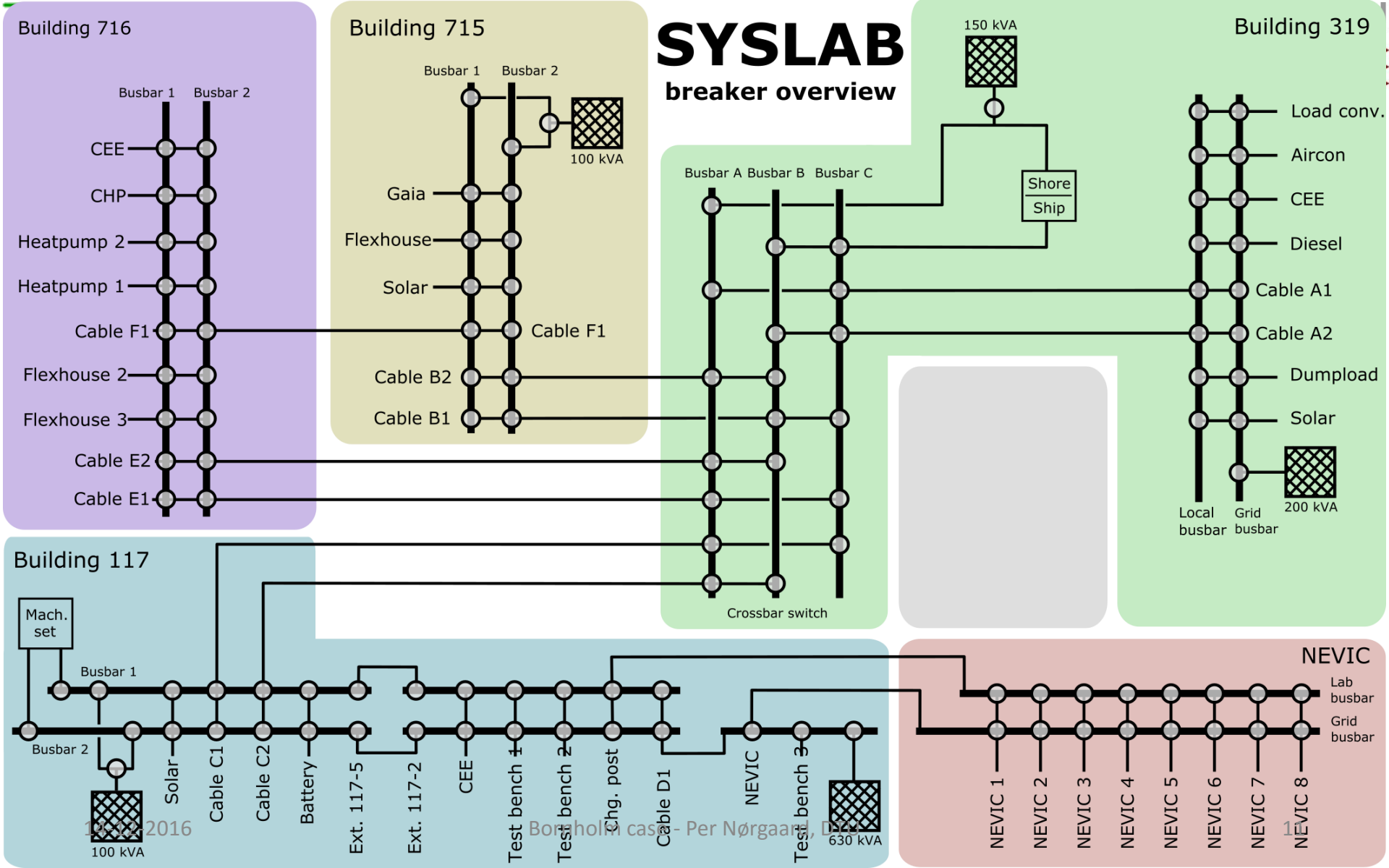
Measurements and data warehouse



Flexible buildings and users



SYSLAB breaker overview



19/04/2016

Borgholm case - Per Nørgaard, DTU

1

DTU Electric Lab

RTDS



3 x power amplifier



14-12-2016

Bornholm case - Per Nørgaard, DTU

12



High Power Lab



High Voltage Lab



Electric Vehicle Lab



Electric Lab



Control Center Lab



Energy System Simulation Lab



Energy System Integration Lab SYSLAB



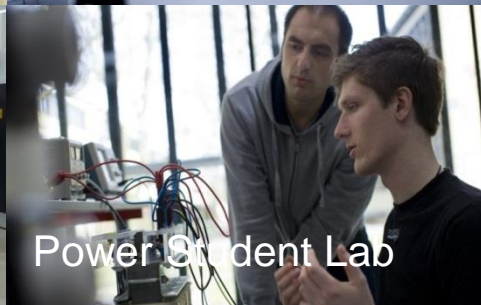
Power Flex Houses



Converters Lab



Drives Lab



Power Student Lab



Bornholm Smart Energy Community

PowerLab^{dk}

14-12-2016

Bornholm case - Per Nørgaard, DTU

Open for all. Full service.
Self service. You decide.

EcoGrid EU

Flexible multi-purpose laboratories

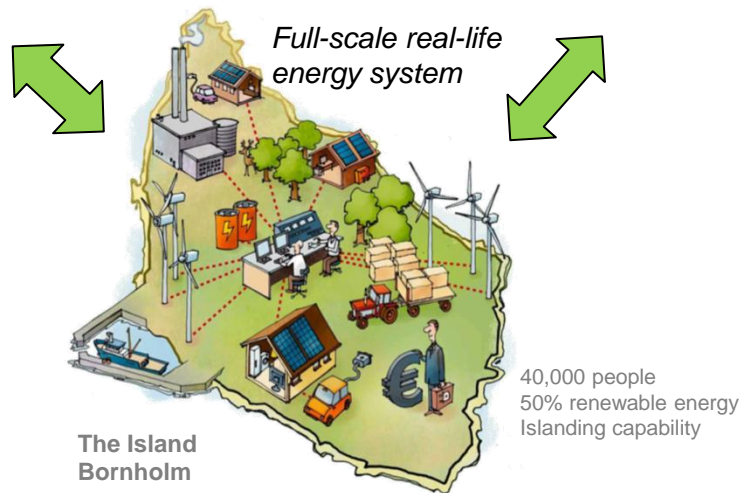


DTU Lyngby Campus

Large-scale test system



DTU Risø Campus



In collaboration with energy companies, industry and authorities



Supported by:

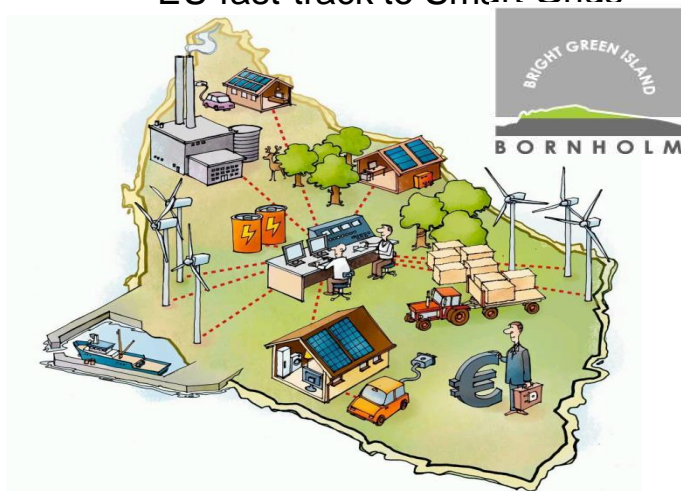


EcoGrid EU



Large-scale Demonstration of the Future Intelligent Distribution System

- EU FP7 ENERGY
- 2011-14
- Budget: 21 million Euro
- Integrated research and demonstration
- ~2,000 active customers
- EU fast-track to Smart Grids




DENMARK
Energinet.dk
Østkraft
DTU


BELGIUM
ELIA
FANDIS (+ORES)


GERMANY
Siemens
EnCT


SPAIN
Tecnalia


PORTUGAL
EDP

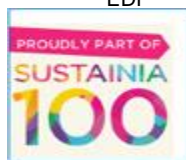
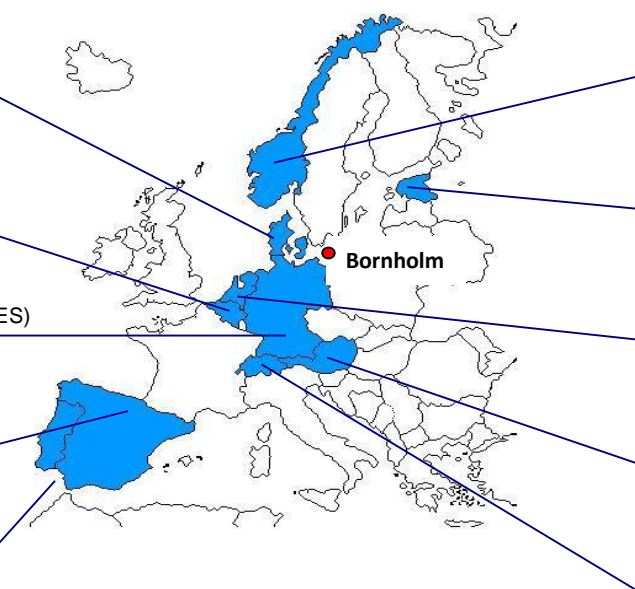

NORWAY
SINTEF ER
(Coordinator)


ESTONIA
Tallin University of
Technology


THE NETHERLANDS
ECN + TNO
IBM Research


AUSTRIA
Austrian Institute of
Technology


SWITZERLAND
IBM Research
Landis+Gyr



Best Sustainable
IT-project 2012
awarded by Arnold
Schwarzenegger et. al



The ISGAN Award of
Excellence in transforma-
tion of smart grid systems
"Consumer Engagement &
Empowerment".

1% of DK

33% Wind Power Penetration; 28,000 Customers

28,000 Customers
55 MW Peak load
16 60/10 kV substations

Power plants:
34 MW Diesel (Oil)
25 MW Steam (Oil)
35 MW Steam (Oil/Coal/Wood)(CHP)
30 MW Wind (Wind)
2 MW Biogas

4 District heating systems
6 Heat generators

Energy strategy
Political & public drive

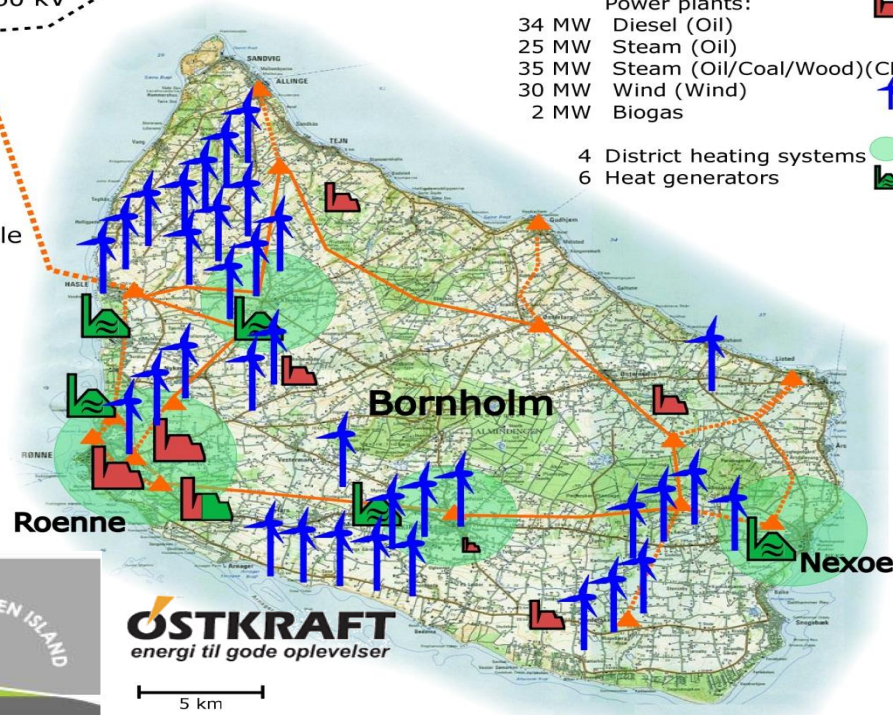


Energy resources:

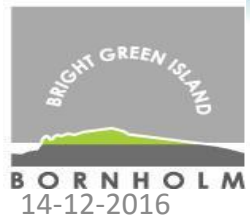
- Customers
- Wind power
- Biogas plant
- Combined heat and power
- District heating
- Solar power plants
- eMobility

Features:

- Nord Pool market (DK2)
- Islanding capability

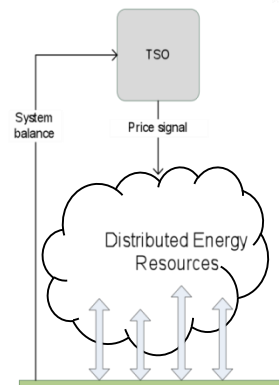
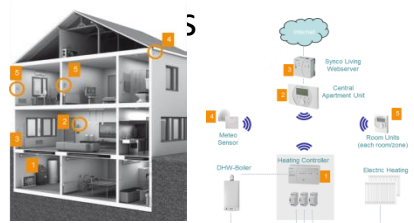
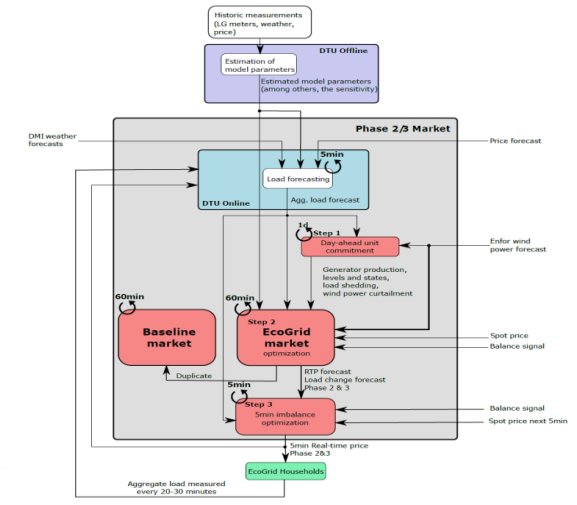


OSTKRAFT
energi til gode oplevelser



EcoGrid EU

- Integrated research and demonstration
- Novel 5-min market empowering 2,000 private and commercial customers managing their energy
- Smart meters and automation equipment installed in buildings and



Co-funded by EU.



EcoGrid EU



EU Sustainable Energy Award 2016; most outstanding and innovative energy project with consumers.

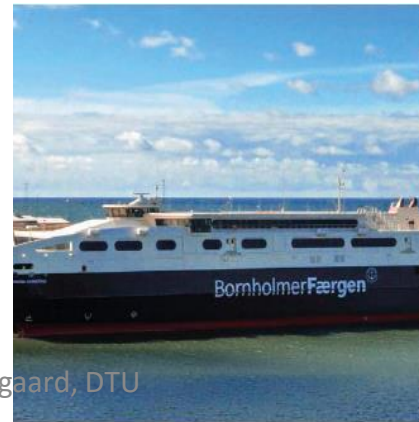
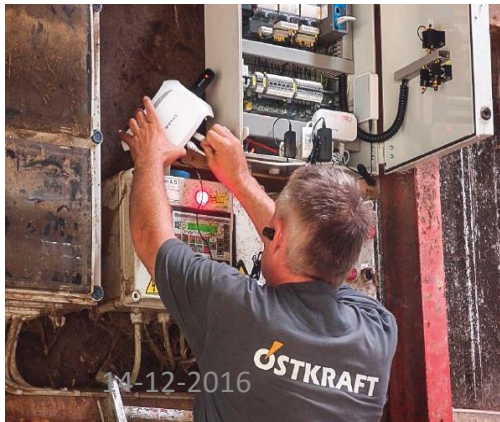


IEA ISGAN Award of Excellence in smart grid systems 2014, "Consumer Engagement & Empowerment"



Best Sustainable IT-project 2012, awarded by Sustainia 100 (Arnold Schwarzenegger et. al)

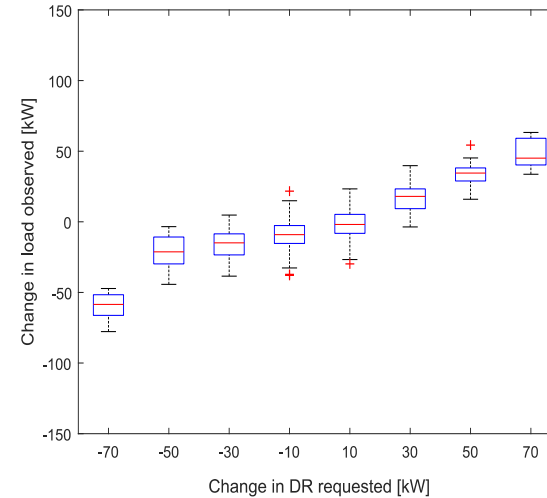
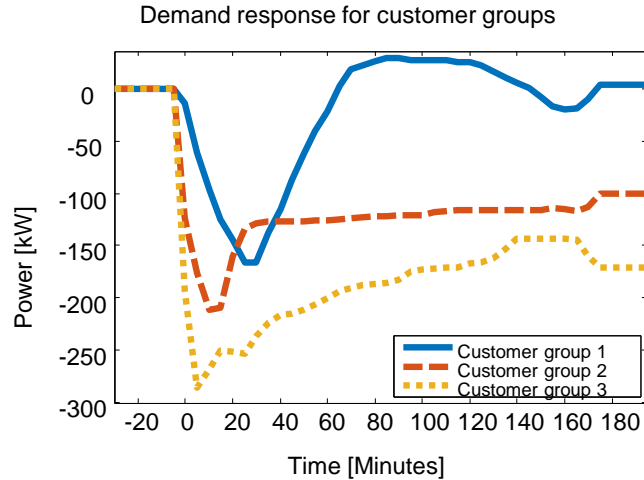
- Multiple customer motivations
 - Lower electricity bill by smart control
 - Knowledge about own energy use
 - Using green electricity
 - Possibilities with new technology
 - Being part of a community(!)



The EcoGrid

Market and Demand Response Performance

Performance of the 5-min market



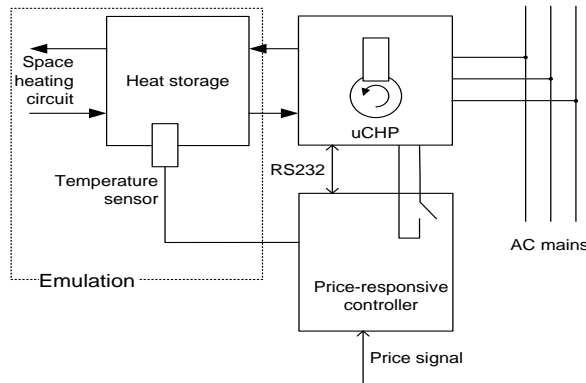
- Different response from customer group have to be taken into account in the market design
- Response to prices with uncertainty
- Activating demand reduces the peak load by 670 kW (corresponding to 27% flexibility)

- The societal costs from balancing are reduced by 5.4%
- The EcoGrid market allows to integrate 8.6% more wind power than the baseline market

Read more: www.eu-ecogrid.net

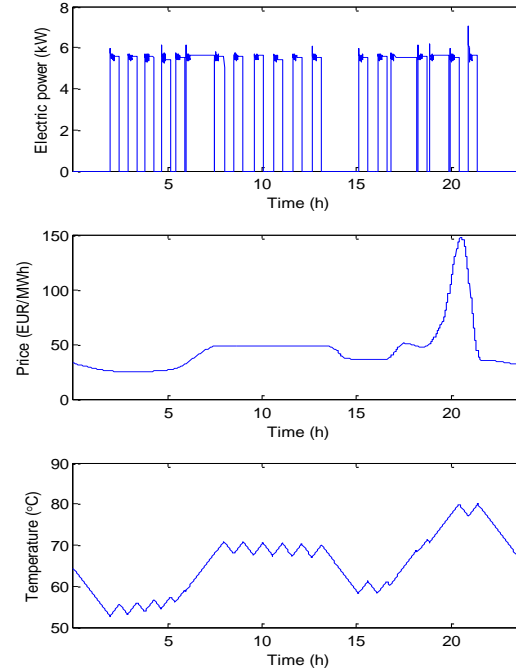
Control-by-price concept with 5 min real-time market

Lab. setup with micro CHP:



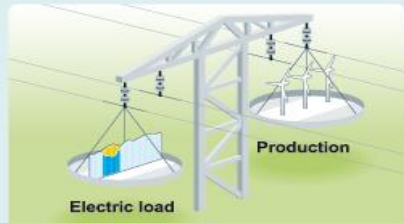
| | |
|------------------------|-----------|
| Elec. gen. | 5 kW |
| Heat gen. | 10.5 kW |
| Heat demand (constant) | 5.25 kW |
| Storage | 750 liter |
| Min. temp. | 50 ° C |
| Max. temp. | 80 ° C |

Measurements:



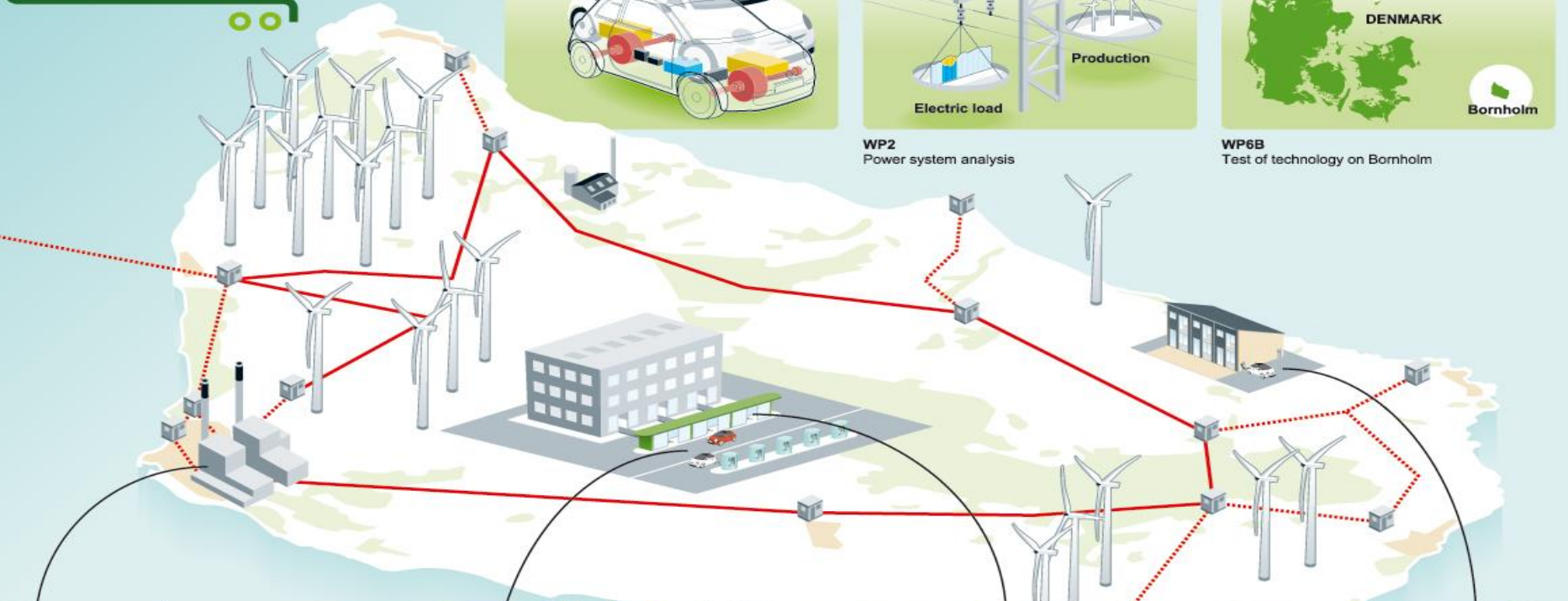
Increased income = **7.3%**
 wo/ comfort changes (and very simple algorithm)

WP1
Electric vehicle technology



WP2
Power system analysis

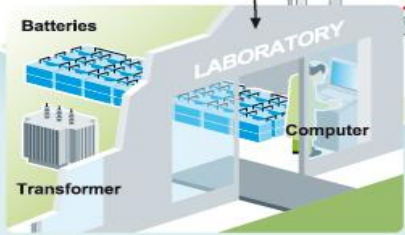
WP6B
Test of technology on Bornholm



WP3
Aggregated charging control software
14-12-2016



WP4
Assessment of fast charging and battery swapping



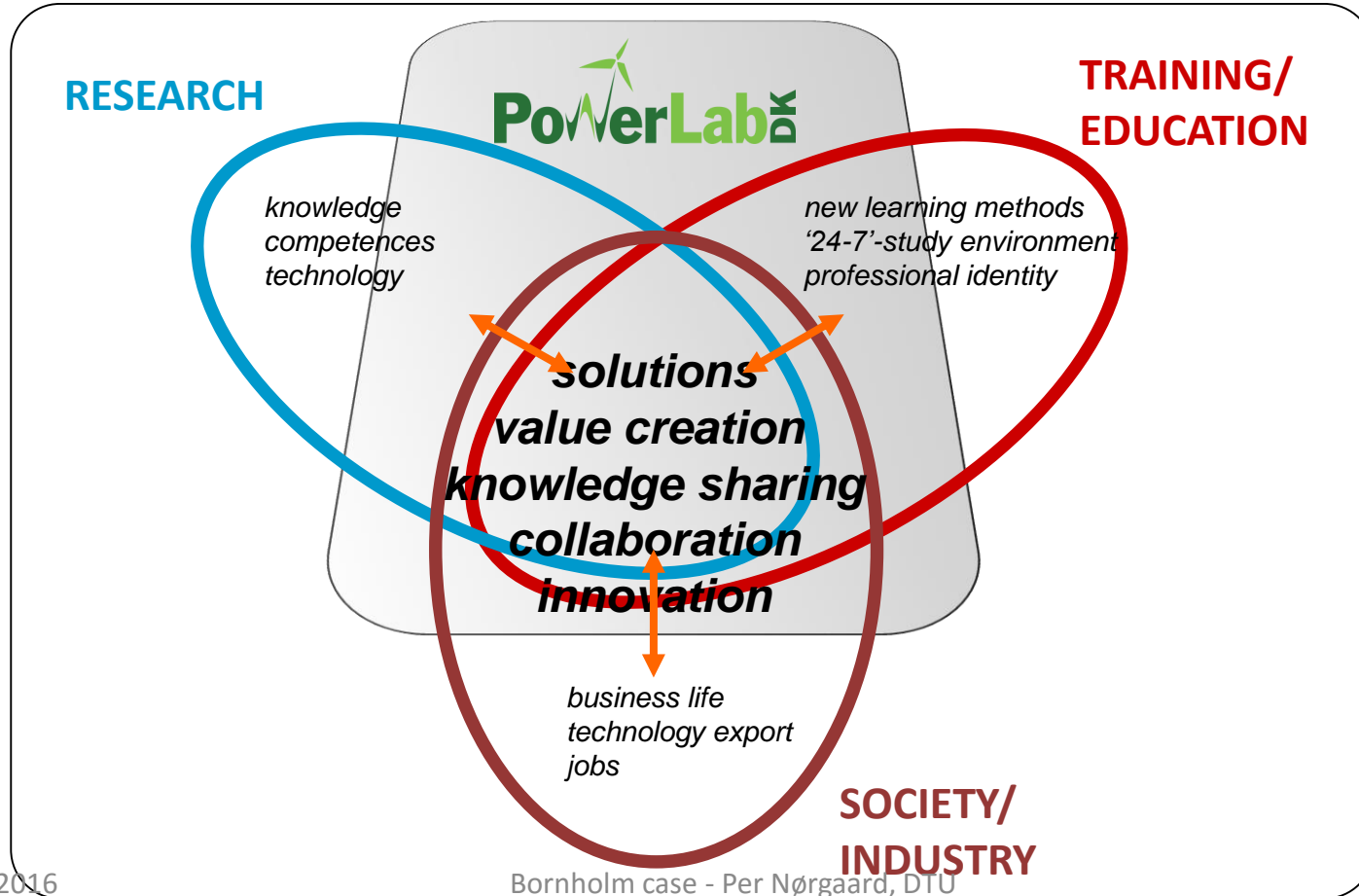
WP6A
Test of technology in laboratory



WP5
Communication between car and charge spot



Platform for synergy and collaboration



Strong national and international collaboration

Academic partners:

ETH Zürich (CH) TU Delft (NL) NANYANG TECHNOLOGICAL UNIVERSITY (SG) AALBORG UNIVERSITY (DK) NORDIC FIVE TECH

University of Strathclyde Glasgow (UK) Berkeley UNIVERSITY OF CALIFORNIA (US) UNIVERSITY OF DELAWARE (US) THE HONG KONG POLYTECHNIC UNIVERSITY 香港理工大學 (HK) DTU (DK) NTNU (NO) A" Aalto University School of Science and Technology (FI) CHALMERS (SE) KTH (SE)

+ many more

Commercial and industrial partners:

ENERGINET/DK (DK) DONG energy (DK) SIEMENS Siemens Wind Power (DK) elia (BE) ØSTKRAFT energi til gode oplevelser (DK) nationalgrid (UK) IBM (CH) Vestas (DK) Pacific Northwest NATIONAL LABORATORY (US) Danfoss (DK)

KØBENHAVNS KOMMUNE (DK) seas onve (DK) SIEMENS (DE) VESTFRØST SOLUTIONS (DK) nkt cables (DK) + many more

Networks:

SMARTGRIDS (EU) EERA European Energy Research Alliance (EU) IEEA Energy Technology Network (Global) IEGAN International smart grid action network (Global) IEEE PES Power & Energy Society (Global) EES-UETP (EU) Electric Energy Systems University Enterprise Training Partnership

Some thoughts ...

Vision for Cyprus:

- *Cyprus will demonstrate energy and cost efficient large-scale integration of wind and solar in an island energy system.*

Per Nørgaard

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www.cee.dtu.dk

www.powerlab.dk