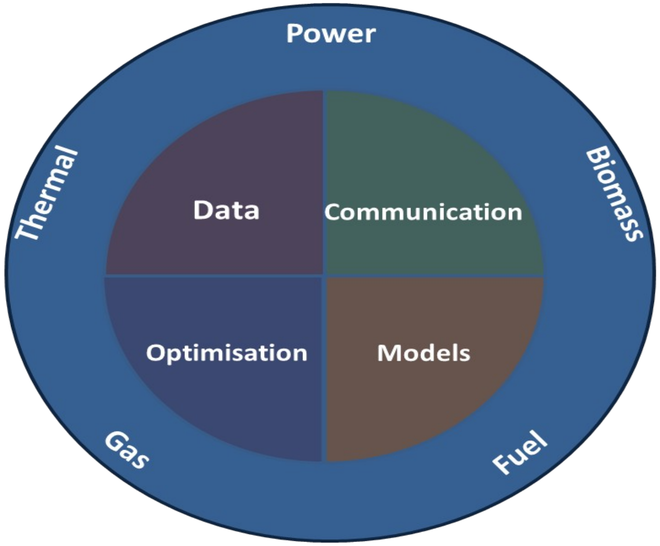
Intelligent Energy Systems Integration in Smart Cities



Henrik Madsen, DTU Compute

http://www.henrikmadsen.org

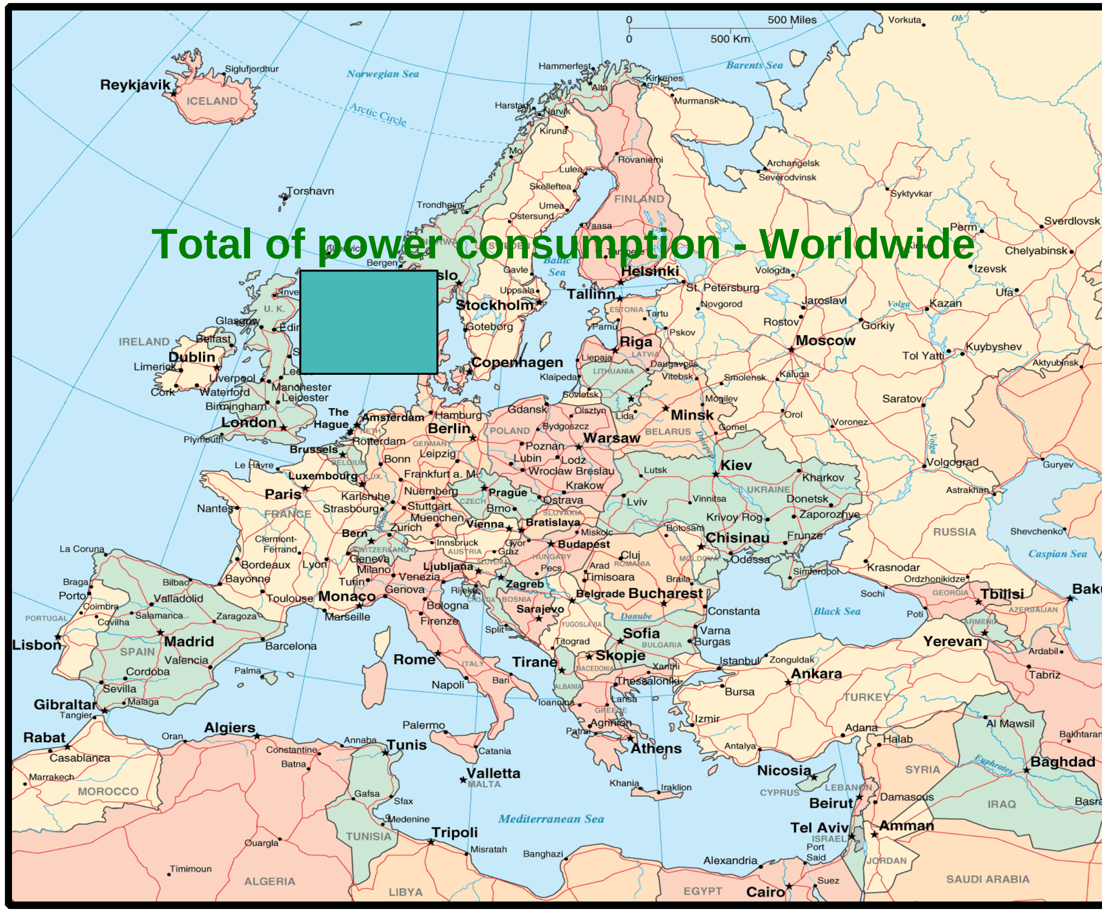
http://www.smart-cities-centre.org

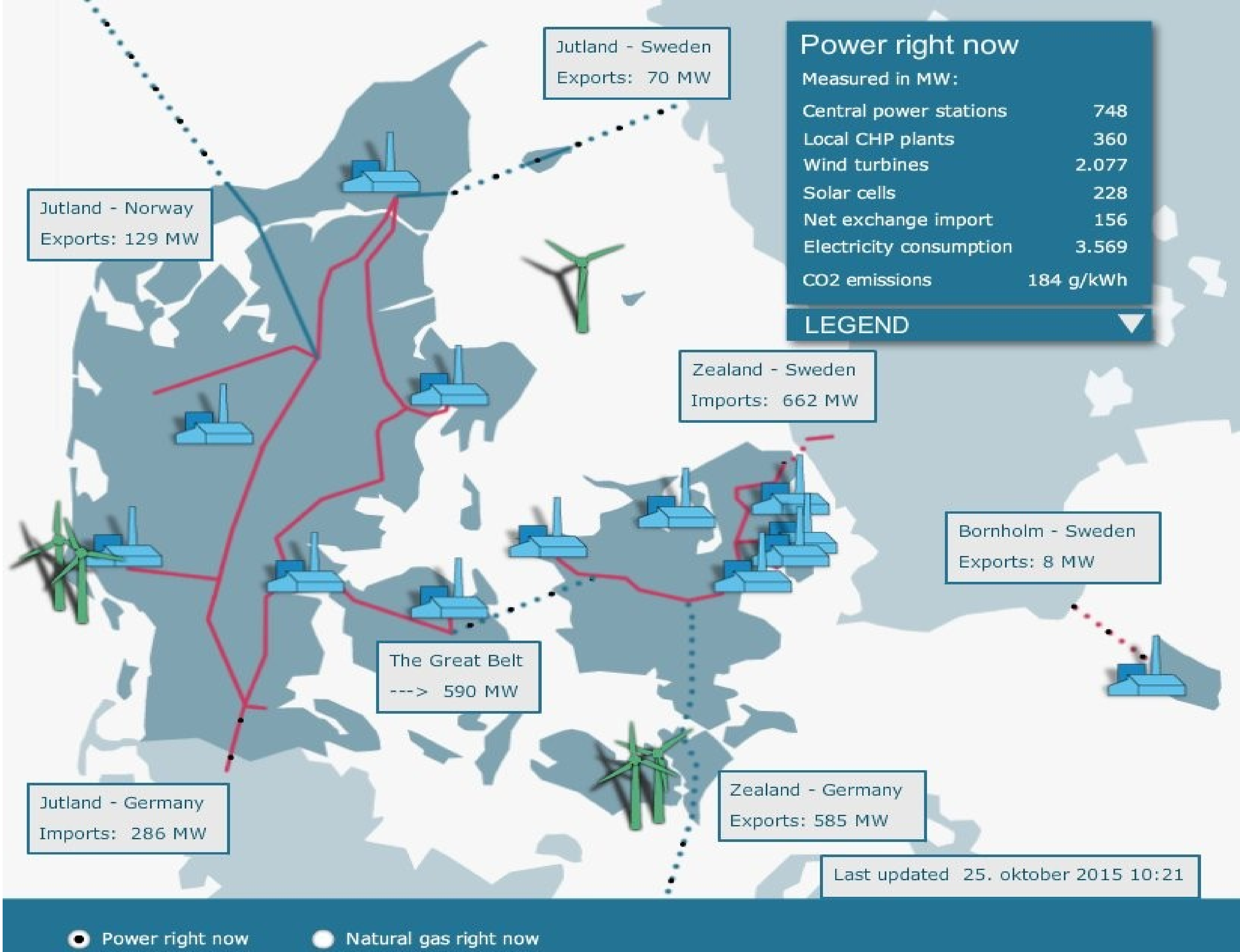
Potentials and Challenges for Renewable Energy

- **Scenario**: We want to cover the worlds entire need for power using wind power.
- How large an area should be covered by wind turbines?

Potentials and Challenges for Renewable Energy

- **Scenario:** We want to cover the worlds entire need for power using wind power
- How large an area should be covered by wind turbines?
- **Conclusion**: Use intelligence ....
- Calls for **IT / Big Data / Smart Energy Solutions / IoT / Intelligent Energy Systems Integration**

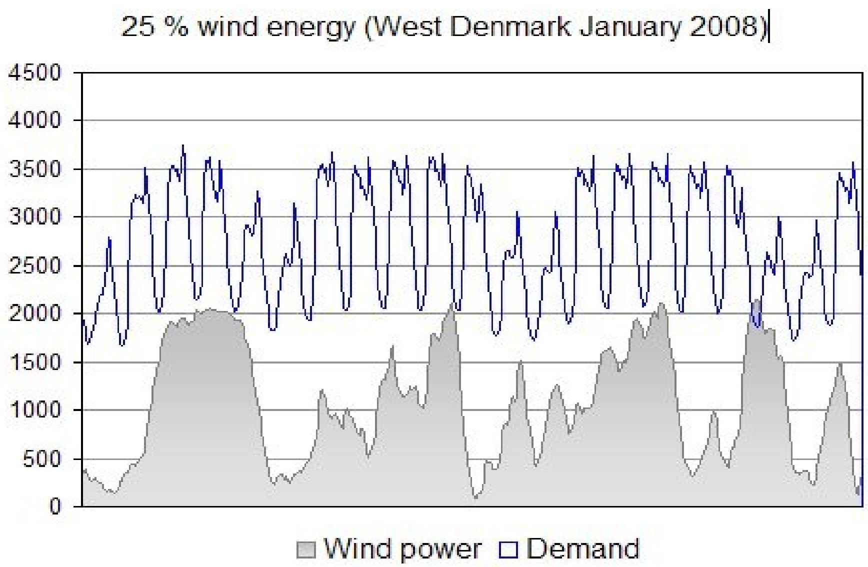




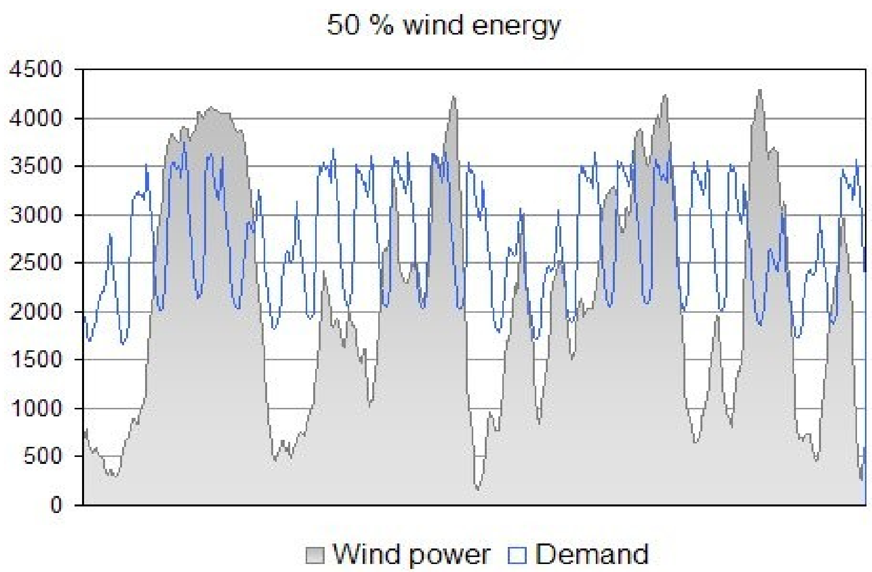
Jutland - Sweden
Exports: 70 MW
Power right now
Measured in MW:
Central power stations 748
Local CHP plants 360
Wind turbines 2.077
Solar cells 228
Net exchange import 156
Electricity consumption 3.569
CO2 emissions 184 g/kWh
LEGEND
Jutland - Norway
Exports: 129 MW
Zealand - Sweden
Imports: 662 MW
Bornholm - Sweden
Exports: 8 MW
The Great Belt
---> 590 MW
Jutland - Germany
Imports: 286 MW
Zealand - Germany
Exports: 585 MW
Last updated 25. oktober 2015 10:21
Power right now
Natural gas right now

The Danish Wind Power Case

.... balancing of the power system



In 2008 wind power did cover the entire demand of electricity in 200 hours (West DK)

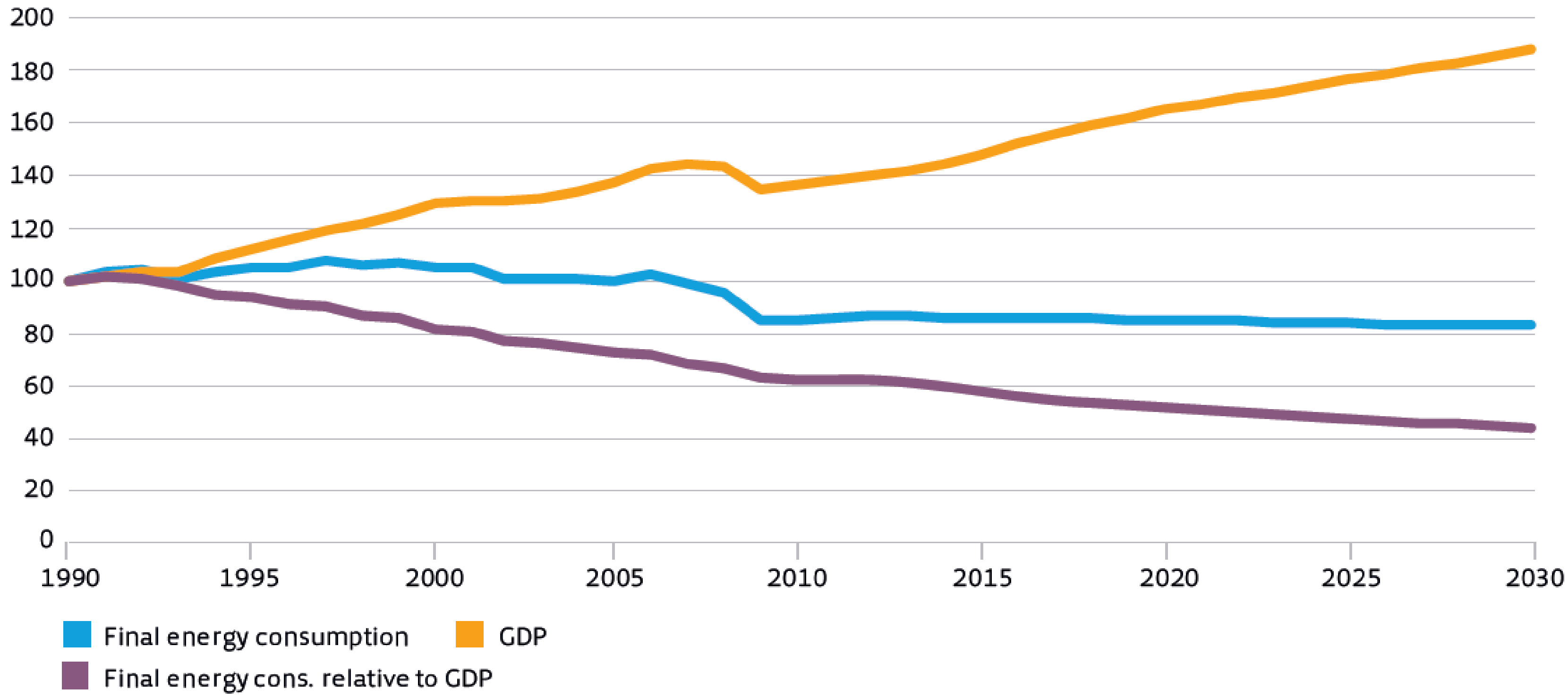


In 2014 more than 40 pct of electricity load was covered by wind power.

For several days in 2014 the wind power production was more than 120 pct of the power load.

July 10th, 2015 more than 140 pct of the power load was covered by wind power

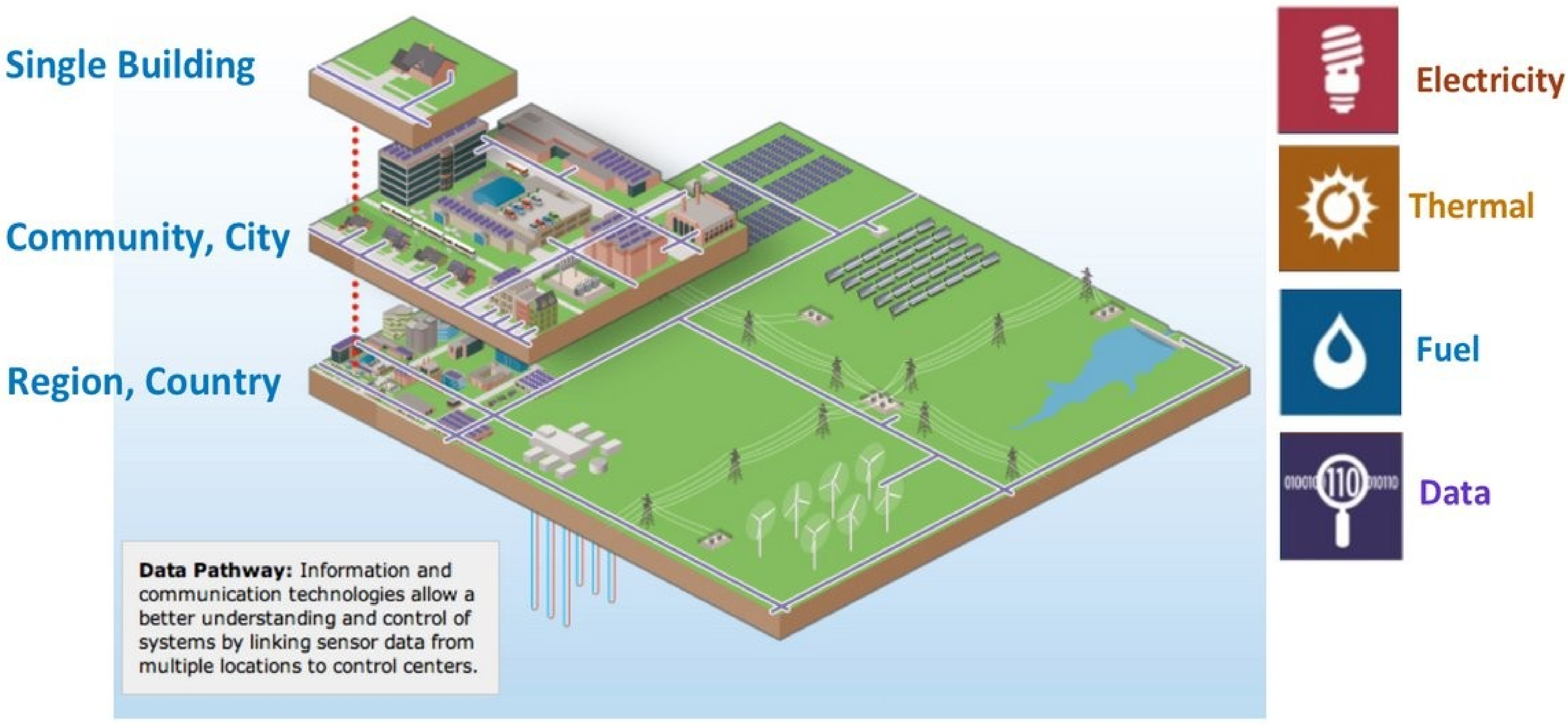
De-coupling of consumption and GDP growth



Source: Energy Policy in Denmark. Danish Energy Agency. December 2012

Energy Systems Integration

Energy system integration (ESI) = the process of optimizing energy systems across multiple pathways and scales

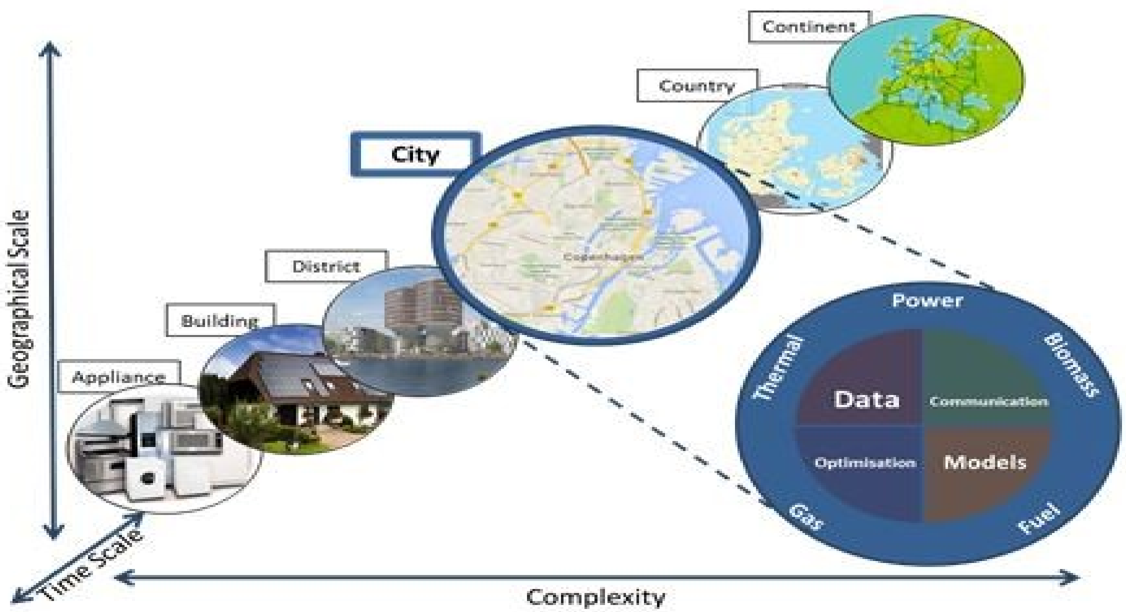


Intelligent Integration and CITIES

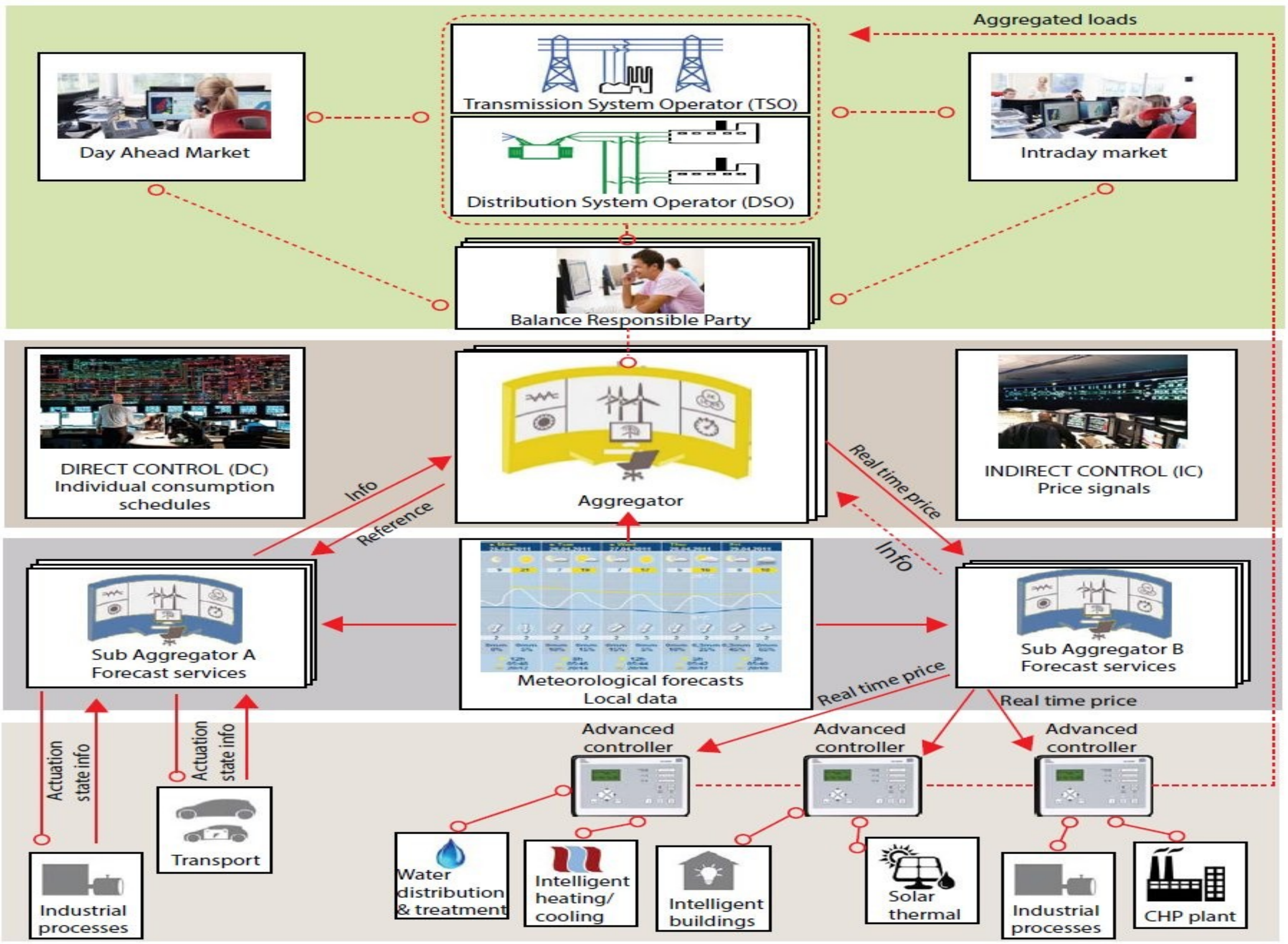
Cities play an important role – for several reasons ......

Center for IT-Intelligent Energy Systems in Cities (CITIES) is establishing ITC solutions for design and operation of integrated electrical, thermal, fuel pathways in Smart Cities at all scales.

CITIES is the largest Smart Cities and ESI research project in Denmark – see http://www.smart-cities-centre.org .



Smart-Energy-OS



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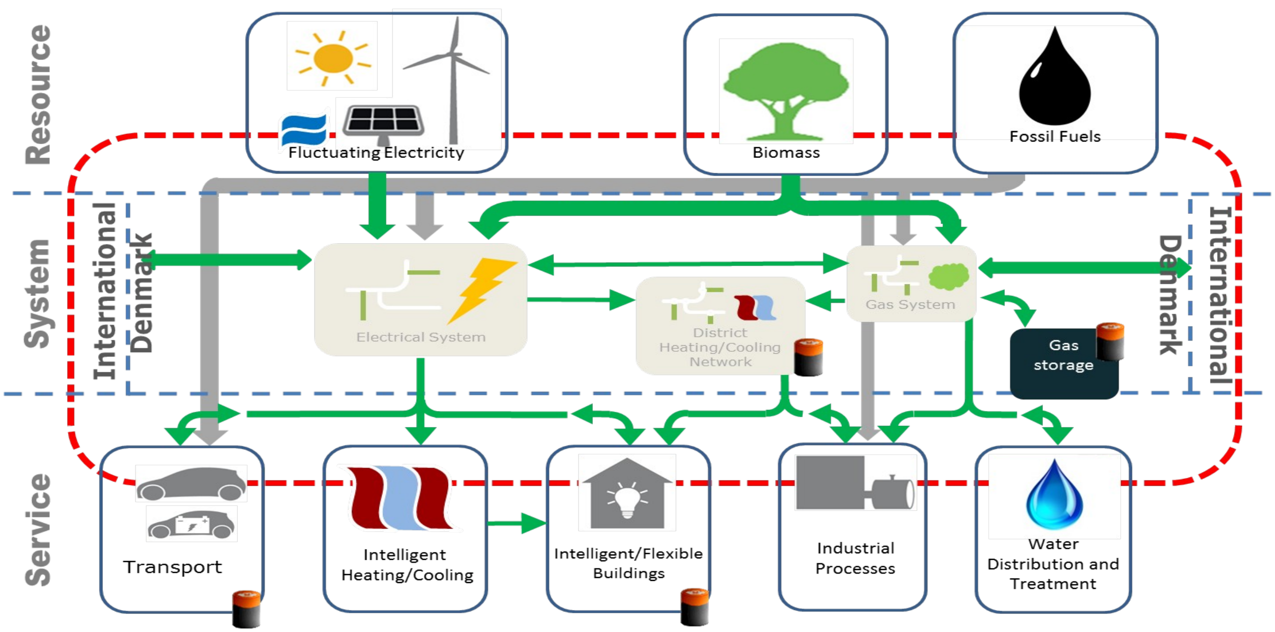
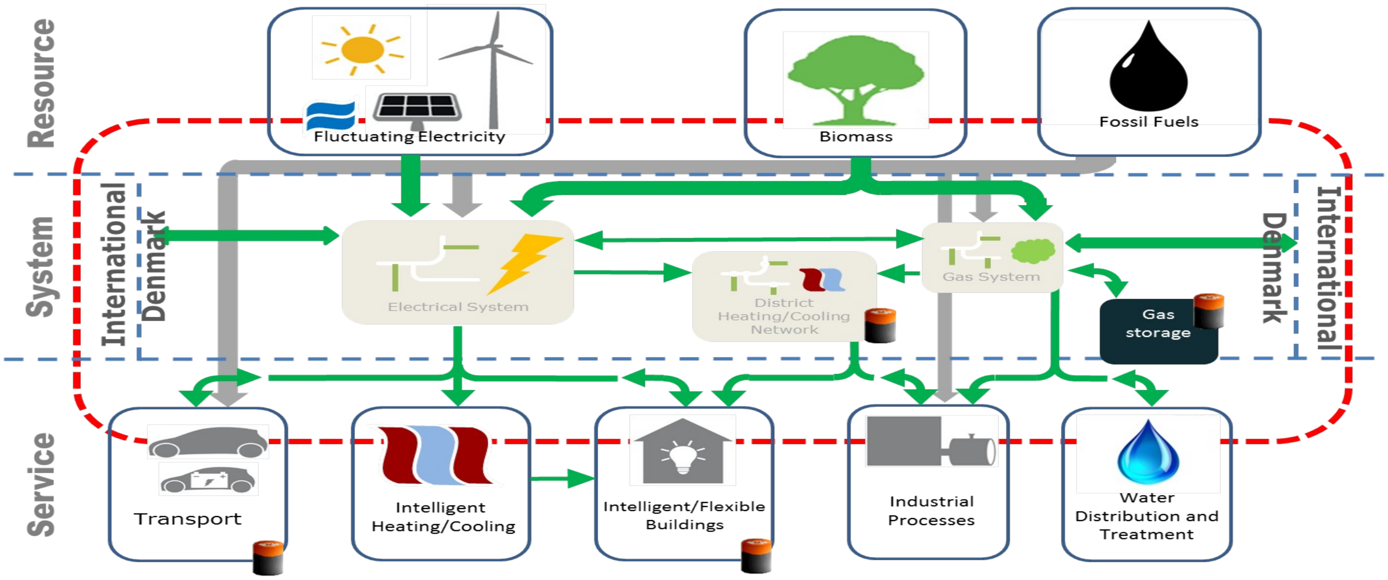
Mobility – Energy - Water

Energy Systems Integration using **data analytics and ICT solutions** leading to **models and methods for planning and operation of future integrated energy systems.**



Virtual Storage by Energy Systems Integration



- **Denmark (2014) : 48 pct of power load by renewables (> 100 pct for some days in January)**
- **(Virtual) storage principles:**
  - Buildings (thermal mass) can provide storage up to, say, 5-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - Gas systems can provide seasonal storage

Case study

Virtual Storage using Thermal Demand Response

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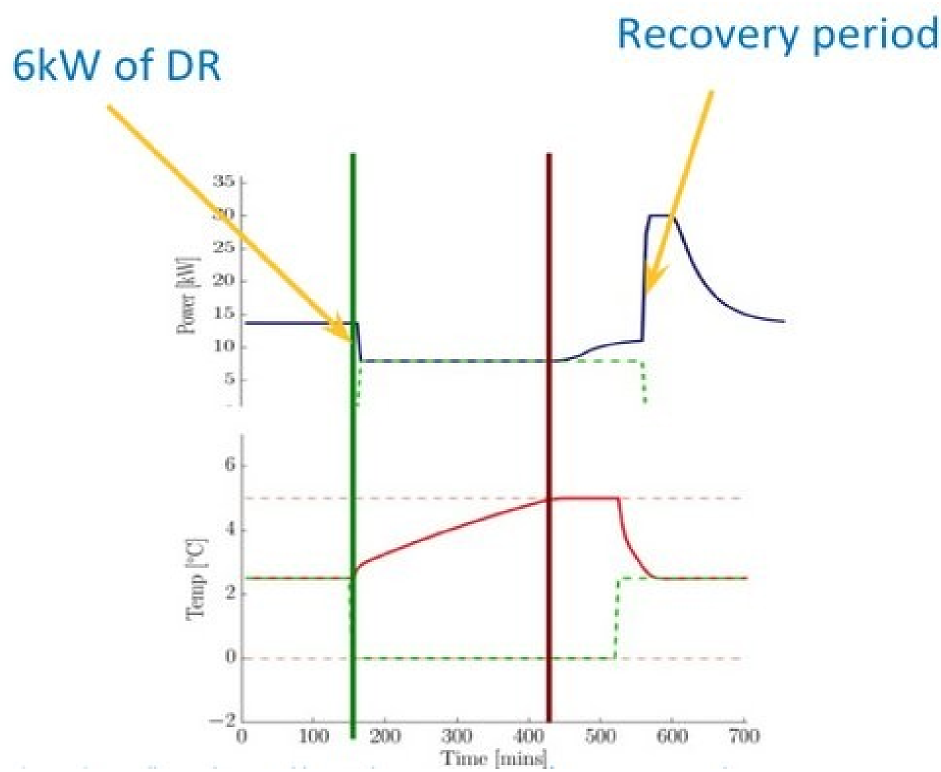
Synergize: Virtual Storage using Thermal Demand Response

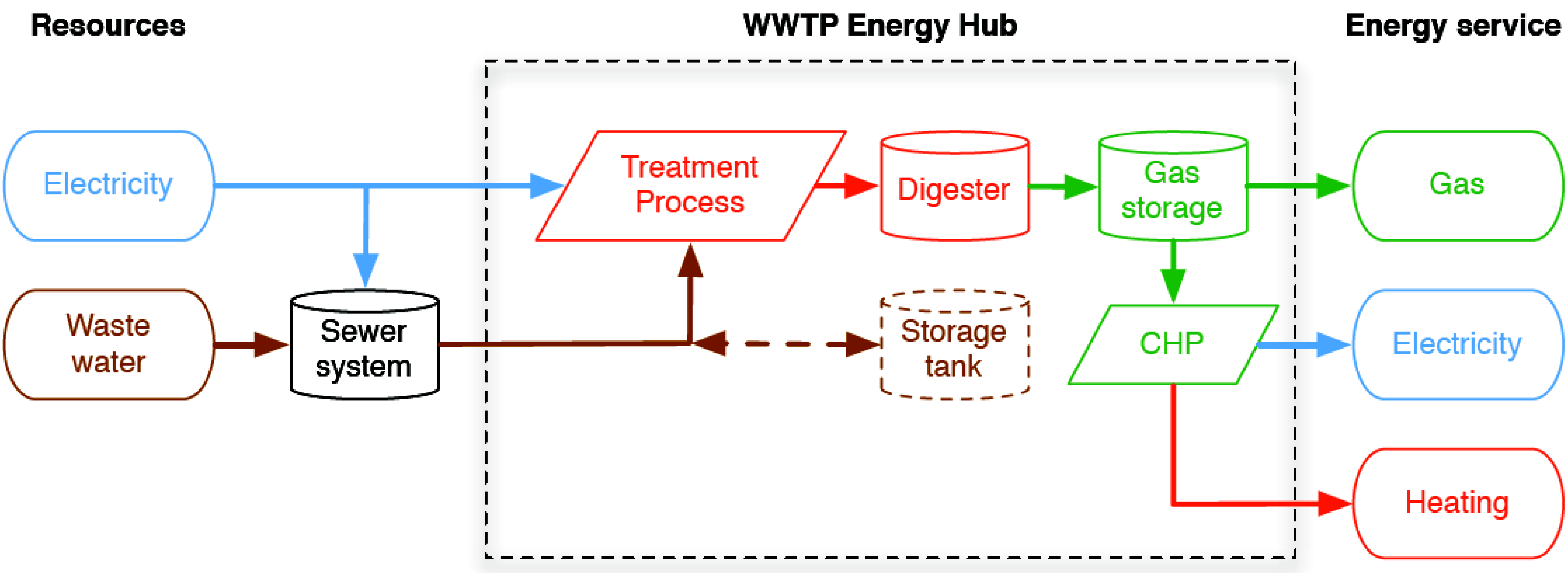
Thermal mass in refrigeration display cases facilitates the adjustment of power consumption while maintaining acceptable temperatures for food.



Case study

Control of Wastewater Treatment Plants

Waste-2-Energy



Energy Flexibility in Wastewater Treatment

- Sludge -> Biogas -> Gas turbine ->Electricity
- Power management of the aeration process
- Pumps and storage in sewer system

Overall goals:

Cost reduction

Minimize effluent concentration

Minimize overflow risk

Case study

Use of Sensors (Smart Meter Data)

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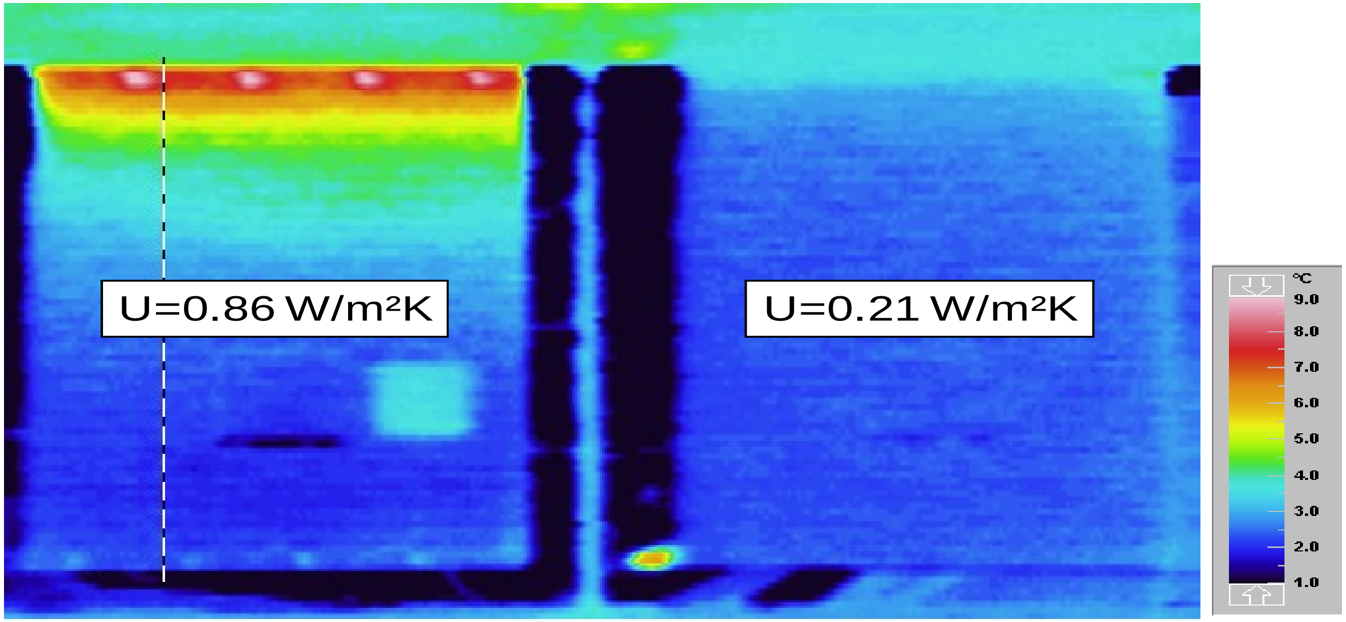
Energy Performance



Consequence of good or bad workmanship (theoretical value is U=0.16W/m2K

Results

	UA	σ_{UA}	gA^{max}	wA_E^{max}	wA_S^{max}	wA_W^{max}	T_i	σ_{T_i}
	W/°C		W	W/°C	W/°C	W/°C	°C	
4218598	211.8	10.4	597.0	11.0	3.3	8.9	23.6	1.1
4381449	228.2	12.6	1012.3	29.8	42.8	39.7	19.4	1.0
4711160	155.4	6.3	518.8	14.5	4.4	9.1	22.5	0.9
4836681	155.3	8.1	591.0	39.5	28.0	21.4	23.5	1.1
4836722	236.0	17.7	1578.3	4.3	3.3	18.9	23.5	1.6
4986050	159.6	10.7	715.7	10.2	7.5	7.2	20.8	1.4
5069878	144.8	10.4	87.6	3.7	1.6	17.3	21.8	1.5
5069913	207.8	9.0	962.5	3.7	8.6	10.6	22.6	0.9
5107720	189.4	15.4	657.7	41.4	29.4	16.5	21.0	1.6
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DTU

Use of Meter Data

- Reliable Energy Signature.
- Energy Labelling
- Time Constants (eg for night set-back)
- Proposals for Energy Savings:
  - Replace the windows?
  - Put more insulation on the roof?
  - Is the house too untight?
  - ......
- Optimized Control
- Integration of Solar and Wind Power using DSM

International Alliance on Energy Systems Integration

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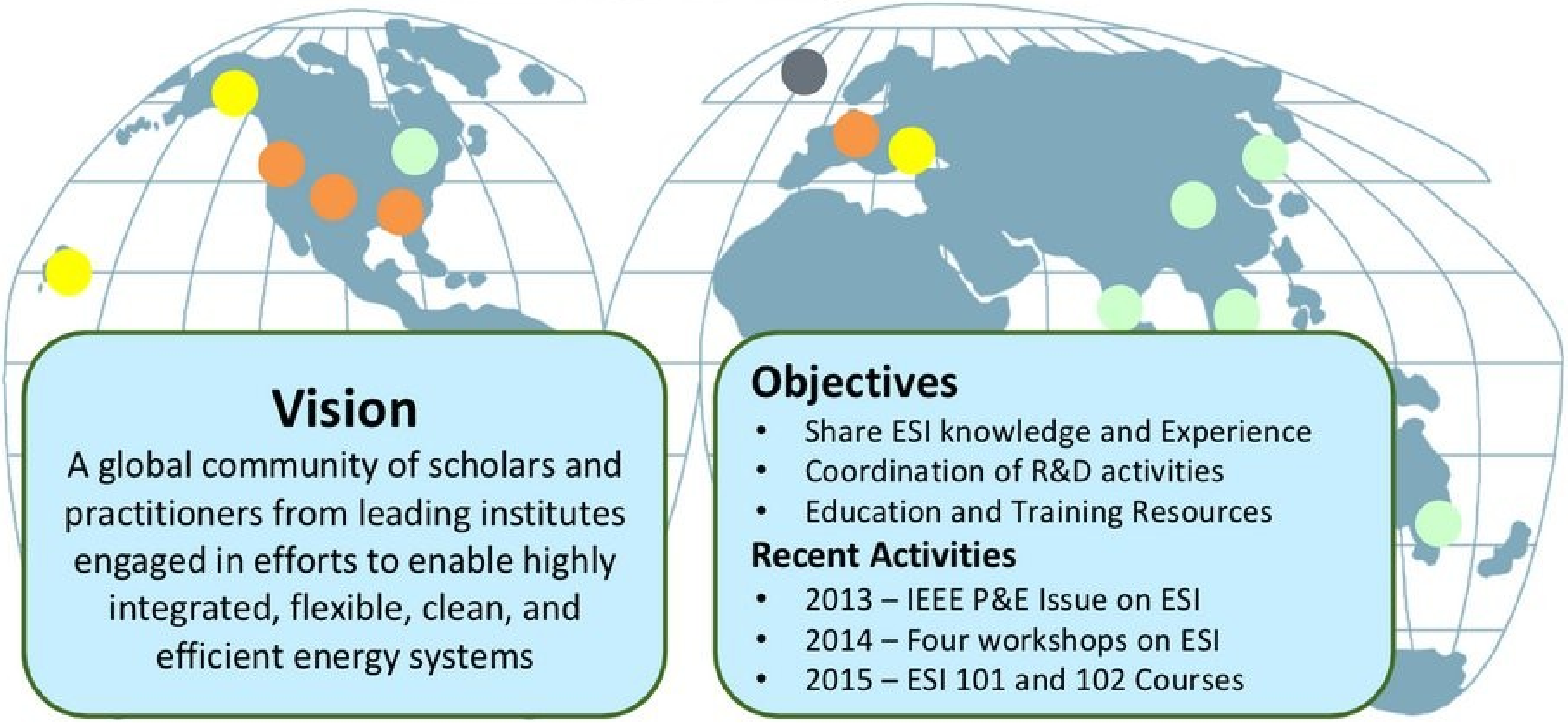
Foster a Global Community

www.iiesi.org

iiESI International Institute™ for Energy Systems Integration



Vision

A global community of scholars and practitioners from leading institutes engaged in efforts to enable highly integrated, flexible, clean, and efficient energy systems

Objectives

- Share ESI knowledge and Experience
- Coordination of R&D activities
- Education and Training Resources

Recent Activities

- 2013 – IEEE P&E Issue on ESI
- 2014 – Four workshops on ESI
- 2015 – ESI 101 and 102 Courses

NREL National Renewable Energy Laboratory · Pacific Northwest National Laboratory · EPRI Electric Power Research Institute · UCD Dublin · DTU · KU Leuven

Conclusion / Discussion

- Intelligent Energy Systems Integration can provide virtual and lossless storage solutions (so maybe we should put less focus on physical storage solutions)
- Big Data, ICT, IoT, Data Analytics, and Energy-Systems Operation System (ES-OS) are essential for implementing future low carbon energy systems
- Focus on zero emission buildings – and less on zero energy buildings (the same holds supermarkets, wastewater treatment plants, etc.)
- Use of sensor (and meter) data is important
- Gas systems (incl. gas from waste) provide seasonal virtual storage solutions.
- We see a large potential in Demand Side Management. Automatic solutions and end-user focus are important
- We see large problems with the tax and tariff structures in many countries (incl. Denmark). Coupling to prices for carbon capture could be advantageous.

Danish Partners

Aalborg Universitet
ENFOR – Forecasting and Optimization for the Energy Sector
Dansk Energi
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DONG energy
Energinet.dk
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NEAS Energy
Grøn Energi
Frederikssund Kommune
DFF EDB
Dansk Fjernvarme
Lean Energy Cluster
DI Dansk Industri
Grundfos
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Horsens Varmeværk
Syd Energi
Bright Green Business ProjectZero
EURISCO Research & Development
Fjernvarme Fyn
Aarhus Kommune
CITIES – Centre for IT Intelligent Energy
Danfoss
Høje Taastrup fjernvarme amba
Teknologisk Institut

International Partners

Thanks to DSF

(DSF – 1305-00027B)

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