An Introduction to Energy Systems Integration

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Quote by B. Obama:
(U.N. Climate Change Summit, New York, Sept. 2014)

We are the **first generation**
affected by climate changes,
and we are the **last generation**
able to do something about it!
Potentials and Challenges for Renewable Energy

- **Scenario**: We want to cover the world's 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 world's 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 / Intelligent Energy Solutions / Energy Systems Integration**

![Total of power consumption - Worldwide](image-url)
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 December 2013 and January 2014 more than 55 pct of electricity load was covered by wind power. And for several days the wind power production was more than 120 pct of the power load
Wind integration in Denmark
Latest production data for Tyra: 6,061,111 kWh
Applicable for 15. februar 2014 11:00-12:00

Natural gas right now
Gas flow – kWh/h:
- Nybro entry: 5,882,672
- Ellund exit: 1,002,678
- Dragør exit: 1,405,760
- Energinet.dk Gas Storage: 824,732
- DONG Storage: 0
- Exit Zone: 4,776,523
CO2 emission factor: 56,76 kg/GJ

LEGEND

Lille Torup gas storage facility Entry: 824,732 kWh/h
Calorific value: 12,150 kWh/m³

Nybro Entry: 5,882,672 kWh/h
Calorific value: 12,197 kWh/m³

Egtved Calorific value: 12,213 kWh/m³
CO2 emissionsfaktor: 56,76 kg/GJ

Dragør Exit: 1,405,760 kWh/h
Calorific value: 12,234 kWh/m³

Ellund Exit: 1,002,678 kWh/h
Calorific value: 12,228 kWh/m³

Stenlille gas storage facility: 0 kWh/h
Calorific value: 12,022 kWh/m³

Last updated 15. februar 2014 12:31
Solar district heating in Denmark

Planned in 2014
197.855 M2

Total collector area:
574023 m²
The **central hypothesis of ESI** is that by **intelligently integrating** currently distinct energy flows (heat, power, gas and biomass) in we can enable very large shares of renewables, and consequently obtain substantial reductions in CO2 emissions.

**Intelligent integration** will (for instance) enable lossless ‘virtual’ storage on a number of different time scales.
To establish methodologies and solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales
ESI – Concept Challenges

Energy Systems Integration using data and IT solutions leading to models and methods for planning and operation of future electric energy systems.
Example: Storage by Energy Systems Integration

- Denmark (2014): 48% of power load by renewables (> 100% at some days in January)
- (Virtual) storage principles:
  - Buildings 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

Control of Power Consumption (DSM)
Control of Energy Consumption
Control performance

Considerable **reduction in peak consumption**
Mean daily consumption shift

![Graph showing consumption and price over the hour of day]
Control and Optim. Challenges

Day Ahead:
Stoch. Programming based on eg. Scenarios
Cost: Related to the market (one or two levels)

Direct Control:
Actuator: **Power**
Two-way communication
Models for DERs are needed
Constraints for the DERs (calls for state est.)
Contracts are complicated

Indirect Control:
Actuator: **Price**
Cost: E-MPC at low (DER) level, One-way communication
Models for DERs are not needed
Simple 'contracts'

How can we make a difference?
Proposal (UCD, DTU, KU Leuven): ESI Joint Program as a part of European Research (EERA)
Addressing energy challenges through global collaboration

**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

**Activities 2014**
- Feb 18-19 Workshop (Washington)
- May 28-29 Workshop (Copenhagen)
- July 21 – 25, ESI 101 (Denver)
- Nov 17th Workshop (Kyoto)

**Activities 2015**
- Dublin, Hawaii, Brussels, Australia
Conclusions / Statements for discussion
(I was asked to be a bit provocative)

- Energy Systems Integration can provide virtual and lossless storage solutions (so maybe we should put less focus on physical storage solutions)
- Energy Systems Integration might be able to solve many of the problems Europe now is trying to solve by Super Grids (some of these huge investments might not be needed)
- Europe should put less focus on super-grids - I assume that ESI can solve a major part of the issues (the planned investments are huge - and maybe we don't need them)
- Focus on zero emission buildings - and less on zero energy buildings (the same holds supermarkets, wastewater treatment plants, etc.)
- District heating (or cooling) provide virtual storage on the essential time scale (up to a few days)
- We see a large potential in Demand Side Management. Automatic solutions and end-user focus is important
- We see a large potential in coupling cooling (eg. for comfort) and heating systems using DH networks
- We see large problems with the tax and tariff structures in many countries (eg Denmark). Coupling to prices for carbon capture could be advantageous.
- Markets and pricing principles need to be reconsidered; we see an advantage of having a physical link to the mechanism (eg. nodal pricing, capacity markets)