Big Data and 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!
**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 / Smart Energy Solutions/ Energy Systems Integration

Total of power consumption - Worldwide
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
From large central plants to Combined-heat and power production

1980

Today

From a few big power plants to many small combined heat and power plants – however most of them based on coal
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. This calls for Big Data solutions.

Intelligent integration will (for instance) enable lossless ‘virtual’ storage on a number of different time scales.
Research Challenges

To establish **IT methodologies and solutions** for design and operation of integrated electrical, thermal, fuel pathways at all scales.
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)**: 45 pct of power load by renewables (> 100 pct 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)
Data from BPA

Olympic Pensinsula project

- 27 houses during one year
- Flexible appliances: HVAC, cloth dryers and water boilers
- 5-min prices, 15-min consumption
- Objective: limit max consumption
Aggregation (over 20 houses)
Non-parametric Response on Price Step Change

Model inputs: price, minute of day, outside temperature/dewpoint, sun irradiance

Olympic Peninsula

![Graph showing consumption step response with 5 hours indicated.](image)
Control of Energy Consumption

Model parameters

Consumption references

Price generator (controller)

Prices

Price-responsive consumption

Price-responsive estimator

Aggregated consumption

![Diagram showing the control of energy consumption](image-url)
Considerable **reduction in peak consumption**
Mean daily consumption shift

![Graph showing consumption and price over time](image-url)
Control and Optimization
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'

New Wiley Book Chapter: Control of Electric Loads in Future Electric Energy Systems
Forecasting Challenges

Forecasting is very important

Type of forecasts:

- Point forecasts
- Conditional mean and covariances
- Conditional quantiles
- Conditional scenarios
- Conditional densities
- Stochastic differential equations
Gas systems are very important in ESI ... [Inserted Image]

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 using IT and Big Data solutions

**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

- Energy Systems Integration using IT solutions 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

- Focus on zero emission buildings - and less on zero energy buildings (the same holds supermarkets, wastewater treatment plants, etc.)

- District heating (or cooling) combined with IT solutions can provide virtual storage on the essential time scale (up to a few days)

- We see a large potential in Demand Side Management. Automatic IT based 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.

- IT and Big Data solutions are the key to future ESI solutions

- 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)