Research Center for IT-Intelligent Energy Systems
http://www.smart-cities-centre.org
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Background and Motivation
Danish Climate and Energy Policy / Goals

2020: 50 pct of electricity from wind power, and 35 pct of total energy consumption from renewable sources

2035: 100 pct of electricity and heating from renewable sources

2050: 100 pct of all (electricity, heating, transport, industry) from renewable sources
**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 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 and Smart Cities** solutions.
Concepts in CITIES

Integration based on *IT solutions and forecasting* leading to methods for *operation, and planning* for future energy systems.
Example: Storage by Energy Systems Integration

Operational (simplified) models for integration, optimization and control

(Virtual) storage principles:
- Buildings can provide storage up to, say, 5-12 hours ahead
- District heating systems can provide storage up to 1-2 days ahead
- Gas systems can provide seasonal storage
Grey-box modelling concept

- Combines prior physical knowledge with information in data
- Equations and parameters are physically interpretable
Grey-box model building

1. Model (re)formulation
2. Non-parametric modelling
3. Statistical tests
4. Falsification or unfalsification
5. Stochastic state-space model
6. Parameter estimation
7. Residual analysis
Grey-Box Modelling

- Bridges the gap between physical and statistical modelling
- Provides methods for model identification
- Provides methods for model validation
- Provides methods for pinpointing model deficiencies
- Enables methods for a reliable description of the uncertainties, which implies that the same model can be used for k-step forecasting, simulation and control.
Energy System Models for CITIES

- **Grey-box models** are simplified models for the individual components facilitating system integration.
The central hypothesis of CITIES is that by intelligently integrating currently distinct energy flows (heat, power, gas and biomass) in urban environments we can enable very large shares of renewables, and consequently obtain substantial reductions in CO2 emissions.

Intelligent integration will enable lossless ‘virtual’ storage on a number of different timescales.
Which type of forecast to use?

- Point forecasts
- Conditional mean and covariances
- Conditional quantiles
- Conditional scenarios
- Conditional densities
- Stochastic differential equations
Example

Solar Power Forecasting in CITIES
Solar Power Forecasting

- Grid connected PV-systems mainly installed on rooftops
- Average of output from 21 PV systems in Brædstrup
Method

- Based on MET forecasts and online readings of output
- Two-step method:
  1) Transformation to atmospheric transmittance with statistically clear sky (see above),
  2) A dynamic model + adaptive quantile regression.
Morning and afternoon difference: Tilt of sensor?
Dip before noon: maybe a chimney?
Clipped at maximum
Scatter before correction
Adaptive correction method
Adaptive correction method
Adaptive correction method (correction function)
Adaptive correction method
Scatter after correction

- **Morning**
- **Afternoon**
- **Model morning**
- **Model afternoon**

DTU Compute
Department of Applied Mathematics and Computer Science

CITIES
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Example
(quantile forecasts - up to 36h ahead)
Thanks to DSF
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For more information:
www.smart-cities-centre.org