PhD-course: Energy System Analysis of large-Scale Integration of Wind Power

DAWE (Danish Academy in Wind Energy)
Aalborg University, 14-16 November 2005
PhD-course: Energy System Analysis of large-Scale Integration of Wind Power

The EnergyPLAN model

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Content
1. The EnergyPLAN model
2. Data and Methodologies
3. Example: Technical Analysis
4. Example: Market Economical Analysis

www.plan.aau.dk/~lund

- Download EnergyPLAN
- Download documentation
- Links to journal articles (results)
- Links to research reports (Danish)

Electricity Excess Production

Reference excess production

Energy 21 (Government Energy Plan 1995)
The EnergyPLAN Model

Energy System Analysis Model
- Excel—Visual Basic—Delphi Pascal
- Main focus: Compare different energy/regulation systems ability to integrate and trade RES (Wind)
- Simplified modelling of energy system.

Windows program:

EnergyPLAN Model 6.0

Input

Output

Distribution Data:
Electricity
District H.
Wind

Regulation strategy:
- Meeting heat demand
- Meeting both heat and electricity demand

Electricity Market Strategy:
Import/export optimisation

Critical surplus production:
- reducing wind
- replacing CHP with boiler or heat pump
- Electric heating and/or Bypass

Results:

(Annual, monthly and hour by hour values)
- Heat productions
- Electricity production
- Electricity import/export
- Forced electricity surplus production
- Fuel consumption
- Payments from import/export
- CO2 emissions
- Share of RES

Results:

Market
Technical
Heat
Electricity

Fuel
Heat Pump
Solar Thermal
Heat Storage
Import/Export
Transport
CSP unit
VHP unit
Boiler
Solar boiler

Energy System

EnergyPLAN model

Electricity
Heat

Technical
Market
Energy System 6.2

Version 7 under development

New components
- Implemented:
  - Nuclear power
  - River-off hydro power
  - Hydro power (reservoirs)
- To be implemented:
  - Compressed Air storage systems
  - Cars (V2G, H2-storage systems)
  - District cooling
  - …

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Methodology
- Define energy system (Reference, altern.)
- Different share of different RES

Results:
- Rate of excess electricity production
- Ability to decrease CO2 emission
- Ability to exploit exchange on external electricity markets

Example of Results:
**Wind energy**

**Input:**
- Data from total productions of wind turbines in the TSO Eltra area (West Denmark).

**Wind production Eltra 1996 (2042 MWh pr MW)**

**Wind production Eltra 2000 (2083 MWh pr MW)**

**Wind production Eltra 2001 (1964 MWh pr MW)**

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**Photo voltaic**

- Data from the Danish Sol300 project (Total 267 installations, app. 100 included in the data base)
- Additional “synthetic data” from Test Reference Year

**Photo Voltaic produktion (TWh)**

**Excess production (TWh)**

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**Wave Power**

- Calculated from measurements of Wave height and periods in the North Sea
- 5 percent efficiency
- Max installed capacity

**Photo Voltaic**

**Photo Voltaic produktion (TWh)**

**Excess production (TWh)**
Comparison of results

Different Renewable Energy Sources
Excess Electricity Production

RES production (TWh)

Excess production (TWh)

PV 2001
Wave 2001
Wind 2001

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Electricity Excess Production

Principle Diagram

Reference excess production

Energy 21 (Government Energy Plan 1995)

MW

Reference
Ref50KV
RefTrans

Different Energy Systems

Surplus electricity production (Percent of electricity demand)

Wind input (per cent)
Electricity Balance and Grid Stability

System 1: Activating DG CHP-units

System 2: CHP-units and Heat Pumps

System 3: Activating RES via additional demand

Principle results of technical analyses

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Modelling of NordPool
- Standard system price hour by hour distribution (based on recent years)
- Construction of “Wet” “Dry” and “Normal” years (Hydro in Norway)
- Modelling of influence for DK trade and splitting in price areas due to bottleneck in transmission
- Modelling of influence from Trade on the German Boarder.

Reference regulation system (CO2 Price = 100 DKK/t)

Wind Power Production Costs
220 DKK/MWh

Different Production Costs and CO2 Prices

Feasibility of Alternative Regulation Systems

Marginal trade income

Trade income
(Compared to "No trade", "No wind")

Marginal trade income and wind production costs

Trade income: Alternative Regulation Systems

Marginal trade income
Conclusions:

- If wind production exceeds 5 TWh (equal to 20%) investments in CHP regulation and Heat Pumps are feasible.

- Such investments at the same time makes wind power more feasible. For production costs of 220 DKK/MWh and CO2-prices of 100 DKK/t the feasibility of wind power raises from 6 TWh in the reference system to 11 TWh in the “Heat Pump” system.

Sensitivity Analysis

- Increase in Heat Pump Costs
- Variations in CO2 payment
- Change in Wind Power costs
- Change in fuel costs
- Change in CO2 influence on Nordpool
- Change in Nordpool average price
- Change in import/export to Germany
- Change in Nordpool price variations

Only small changes in the main results

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5. More cases...

Optimal Wind and PV combinations

Comparison of results
Optimal mix of RES

Optimal combination of RES

Danish Reference 2020

Danish Alternative 2030

New projects

DESIRE EU-project

- Nuclear and Hydro power in existing German, UK, Polish, Estonian and Spanish Energy Systems
- District cooling, Heat pumps, CHP regulation, etc. etc. in potential future energy systems.

Compressed Air Storage
V2G's

Electricity Excess Diagram (NON-DK system)

Wind production (TWh)

Excess (TWh)

Ref
BEV
InBEV
V2G

CO2 emissions in a Closed System (NON-DK)

Wind production (TWh)

Ref
BEV
InBEV
V2G

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