Investment requirements in European electricity-generation infrastructure towards 2050

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Aim

• Based on the ambitious climate and energy targets set up by EU, this project has the aim to assess and illustrate in a transparent way what the transformation of the electricity generation system will require in terms of investments in energy infrastructure.

• The aim is to quantify investments in number of plants per time period and to discuss this in relation to required financial resources and number of new sites (mainly for renewables) and existing sites (mainly thermal plants)

• To compare with historical investments. The work takes departure in existing model results generated in a large research programme
Overall conclusions

• **RES-E will grow substantially in all scenarios.** Growth is a matter of pace and total volume
• **Massive investments** needed in both generation capacity and grid
• **Total generation investments typically above historical annual investments.** Depending on scenario the balance in technology investments differs significantly
• Efficiency goals a way to relax pressure on supply investments -> increasing the realism of reaching the targets?
• **Siting will not present limitation to new thermal power plants** with a possible exception for biomass
• **Substantial need for regulating power** (e.g gas turbines) due to increase in vRES and/or (if electricity demand is not increased vRES will crowd-out dispatchable power plants)
Scenarios – Pathways & NEPP

- Existing policy measures
- EC "Current policy"

Reference

- Climate, RES and efficiency policies
- EC "High energy efficiency"

Regional policy

- International carbon trade
- EC “Diversified supply techn.”, “High GDP”

Climate market

- Very ambitious renewables policy
- EC “High renewable”

Green policy

Technological dimension

Policy dimension
ELIN (EPOD) modeling (EU27+NO+CH) + Chalmers power plant database
Example: European electricity-generation (EU27+NO+CH)  
Historical development vs scenarios to year 2050  
Annual capacity installation [GW/year]

Reductions in CO₂ emissions relative to 1990:

99%  
Wind & solar

93%  
Wind & solar

Annual capacity installations [GW]

Historical development vs scenarios to year 2050

Thermal (fuel) power plants

Other
Aging of existing power plants
(including official decommissioning plans)

In 2035, approximately half of existing European capacity is still available (or “young enough”)

If no official decommissioning plans:
- coal and lignite: 40 yrs
- PV: 30 yrs
- wind: 25 yrs
- nuclear: 60 yrs
- etc.
Europe Electricity-generation scenario, ”Climate market”

Today (2013): 33% RES, 42% fossil and 25% nuclear

- One overarching CO₂-reduction goal post 2020, -95% by 2050
- Common EU effort
- All technologies optional
- CCS available
- Increased electrification

→ Increasing ETS and wholesale electricity prices after 2020
Europe Wind power: Total installed capacity
Europe PV power - Total installed capacity
Europe: Large investments in interconnector capacity
**Europe:** Number of existing and new **thermal** power plants ("Non-peak")

"Green policy"  
"Climate market"
The Nordic countries

Reference

Year

TWh

Other
Other renew
Wind
Biomass cofire CCS
Biomass and waste
Natural gas CCS
Natural gas
Oil
Coal CCS
Coal convent
Nuclear
Hydro
Total demand

Climate Market

Year

TWh

Other
Other renew
Wind
Biomass cofire CCS
Biomass and waste
Natural gas CCS
Natural gas
Oil
Coal CCS
Coal convent
Nuclear
Hydro
Total demand

Regional Policy

Year

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Green Policy

Year

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Natural gas
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Coal CCS
Coal convent
Nuclear
Hydro
Total demand
Sweden

"Green policy"

"Regional policy"
Implications from investment needs…

Planned work: To develop Key Performance Indicators
Sweden: Year 2030 – Increased share of Wind Power gives lower average whole-sale electricity price, reduced share of nuclear increase price

Yearly average whole sale electricity price for different production profiles

Price as seen by wind power and CHP
Sweden High cost periods - duration

50 TWh wind
With nuclear

70 TWh wind
Without nuclear
⇒ Better case for thermal generation
Sweden, Low cost periods - duration
Energy storage required; e.g. electricity to fuels “electrofuels”
challenge for wind power operators – not for customers

50 TWh wind
With nuclear

70 TWh wind
Without nuclear
Manage variations by trade

- Regional policy 2020
- Nordic countries surrounded by wind
  - Nordic hydropower to manage variations
- Regionally high but nationally moderate
  - Trade with neighbouring regions to reduce system impact
Nordic hydropower to manage variations

Large impact on system operation in the Nordic countries...

...but not the final solution to variability in Europe
Management of intermittent power

**Supply**

Regulated/Dispatchable

Variable generation

**Transmission**

Trade

Balance

**Demand**

Load

**Storage**

**Electrical Power & Energy Storage Comparison**

- Gasoline
- Hydrogen
- Batteries
- Flywheels
- DOE Target for Ultrapower
- Projected Power
- Redox Flow
- Projected Cars
- CAPEX
- 2013
- 2018
- 2023
- 2028

**Management**

GE Targets Net Zero Energy Homes by 2015
Thermal systems – long lead times for development
Example gasification
Decentralized system – New markets

Conventional System

System

Prosumer System

Prosumer

Electric Vehicle
Some reflections - the electricity system

• We must replace the system during the coming decades
  • Whatever action taken, the investments must be covered (with or without nuclear)
  • ”Certificate for ever” or a new electricity market
  • We cannot expect low electricity prices

• Increased share of short but frequent high-cost periods gives better business case for load following generation

• A challenge to maintain an ”energy-only” market
  • Traditionally ”25%” investment cost”, ”75%” operational (fuel)
  • Future ”75%” investment, ”25%” operational

• Implications from the decrease in rotating mass?

• Increased share of decentralized systems ”prosumers” can be expected (Solar PV, home battery, PHEV, DSM, DR,…..)
Key energy intensive (basic material) industries
Existing BAT technologies sufficient to meet EU year 2020 targets, but not the 2050 targets – **CCS is required**

Key energy intensive industries in the Nordic countries

Reduced activity level in refineries

Biomass in iron and steel and cement industries

Reduced fraction of clinker in cement

BAT replacing existing process technology

Without CCS Total potential -35% reduction in Year 2050 relative to Year 2010

Fuel shift?

*One month fuel consumption for SSABs blast furnaces*

Timber storage at Byholma from the tree fell due to the “Gudrun” storm
With CCS Total potential -85% reductions in Year 2050 relative Year 2010

Significant costs due to increased energy use

Large volumes of CO₂ to handle

New ways of pricing emissions....
Nordic basic material industry

Measures to comply with Year 2050 targets

~100€/ton CO₂

EU-ETS < 10 €/ton CO₂

Att göra basmaterial klimatneutrala skulle öka priset kraftigt, men den färdiga konsumentprodukten ökar bara marginellt i pris

**Cementindustrin**

Så mycket dyrare blir cementen

+70%

**Stålindustrin**

Så mycket dyrare blir stålet

+25%

Så mycket dyrare blir bilen

+mindre än 0,5%

Så mycket dyrare blir huset

+mindre än 0,5%

Rootzén and Johnsson, (2015)

Se

http://www.dn.se/debatt/plan-saknas-for-att-minska-basindustrins-klimatpaverkan/
In conclusion

- **All scenarios** which fulfill Year 2050 CO₂ emission reduction targets yield large amount of renewable electricity (wind and solar)
- Siting of new production capacity
- Increased demand for regulating power
- The Nordic countries exporter of (green) electricity in all scenarios
- **Different possibilities** to meet variations in electricity generation
  - Technical challenge
  - Business challenge
- Efficiency improvements important – yet, limited effect as climate mitigation measure
- Society must find ways for **risk taking** to promote innovations and industrial development
- New business models are required to price emissions