ENCAP SP1
Process and Power Systems

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Clas Ekström, Vattenfall

Reference cases and guidelines for technology concepts

ENERGI E2, all ENCAP industrial partners, SINTEF Energiforskning

- Reference power plants without CO2 capture.
  State-of-the-art technology year 2004

- Natural gas-fired 393 MWe gross Combined Cycle Gas Turbine
- Bituminous coal/ pet coke-fired 445 MWe gross Circulating Fluidised Bed Boiler
- Bituminous coal-fired 600 MWe gross Pulverized Fuel Boiler
- Lignite-fired 1000 MWe gross and 380 MWe gross Pulverized Fuel Boilers

Reference cases and guidelines for technology concepts

Cont.

- Guidelines and common basis for technical analysis and economic evaluations of power plants with CO2 capture.
- CO2 quality requirement scenarios for transport and storage
  - Design case. Pipeline transport (100- 150 bar, down to 0°C) and geologic storage
  - Pipeline transport and EOR (Enhanced Oil Recovery) + conservative water content requirements
  - Ship transport (future larger ships 6 – 7 bar, down to -50 °C) + strict limit values for toxics
- Definition of principles for the evaluation and benchmarking

Power systems evaluation and benchmarking

RWE Power, ENERGI E2, Vattenfall, Public Power Corporation, Statoil, ALSTOM, Siemens, SINTEF Energiforskning

No comparison of power plants with different fuels

Quantitative data

Qualitative data and information

Technologies with totally different realization perspectives

- Time scale
- Probability

Evaluation - Quantitative data

- Net electric efficiency
- Spec. CO_2 emissions
- Spec. investment costs (as NPV at start of operation)
- Electricity generation costs
- Spec. CO_2 avoidance costs

Sensitivities with

- Fuel price
- Interest rate
- Lifetime (25 and 40 years)

Results for all CO_2 capture technologies belonging to the same reference case, as absolute and relative figures

Evaluation - Qualitative data

Influence on availability

Operation characteristics

Restrictions on i.a. fuel quality

Influence on other emissions, waste-water, by-products

CO_2 quality

Maturity vs. scale-up requirements, R&D needs and technical risks

Results of the evaluation procedure

Comparison of different CO_2 capture technologies

Effects of CO_2 capture on power generation in comparison to conventional power plants

Capture influence on the European power situation

Chalmers, CERTH/ISFTA*, Vattenfall, RWE Power, Public Power Corporation, Statoil, ALSTOM, Siemens

Objectives – To investigate

- How large-scale introduction of CO2 capture and storage will influence the European energy system
  - electricity cost
  - supply security
  - different CO2 emission scenarios
  - different time perspectives.
- How CO2 capture fits into a portfolio of technologies and on the path towards a sustainable European energy system.
- How CO2 capture technologies fit into future status of the European power plant structure, including regional aspects, power plant age and fuel mix.

*Centre for Research & Technology Hellas / Institute for Solid Fuels Technology & Applications

Deliverables

- Description of scenarios
- A database describing all major European power plants and CO2 storage and transport options
- Model able to calculate cost effective solutions for CO2 free electricity production

4 important tools as basis for analysis

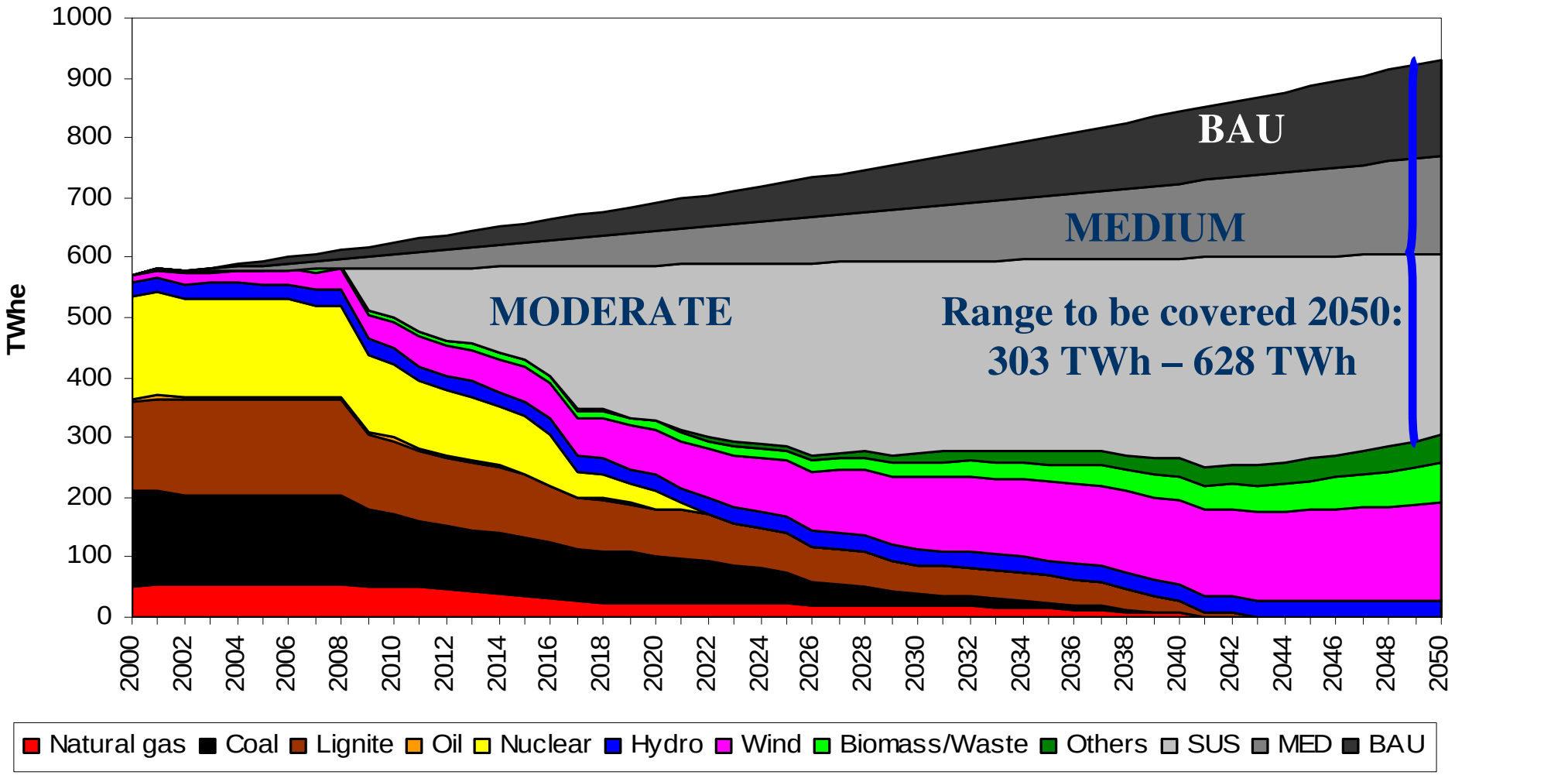
- The Chalmers Power Plant database
- The Chalmers Fuel database
- The Chalmers Storage database
- The Chalmers Member States database

Example **German power generation 2000-2050**

(Phase out of existing plants according to Power Plant database)

RES generation 2050:

Wind: 164 TWh Biomass: 65 TWh Hydro: 29 TWh Geothermal/Solar (Others): 45 TWh

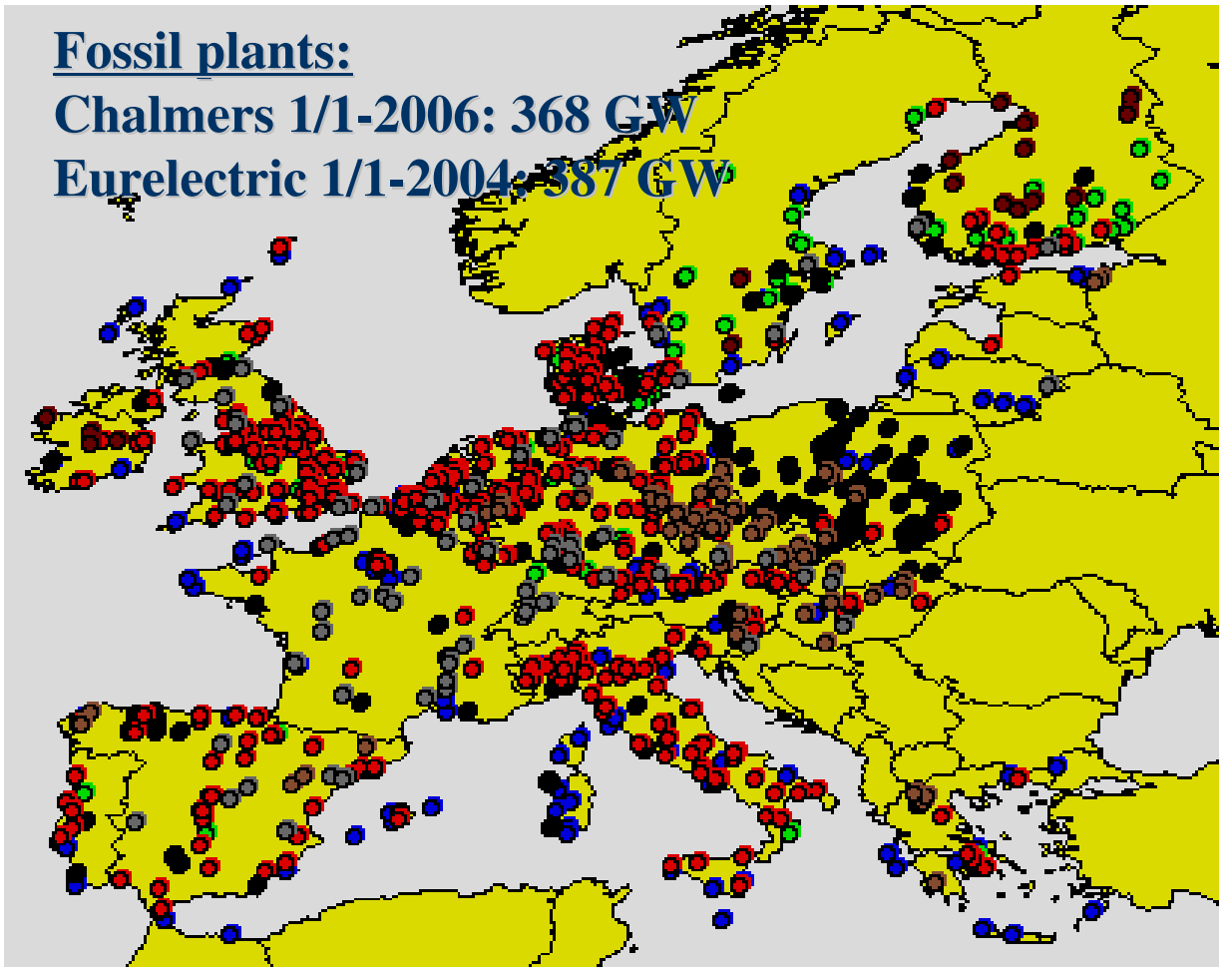


Basic scenario parameters (up to 2050)

- Growth Rates power generation
  - Historic trends
  - Population
  - Fuel prices
  - GDP
  - Technological
- Nuclear
- Renewables including new emerging technologies
- Coal versus gas
- Storage
- Imports

EU thermal plants by fuel

(operating and reserve units – status Jan 2006)

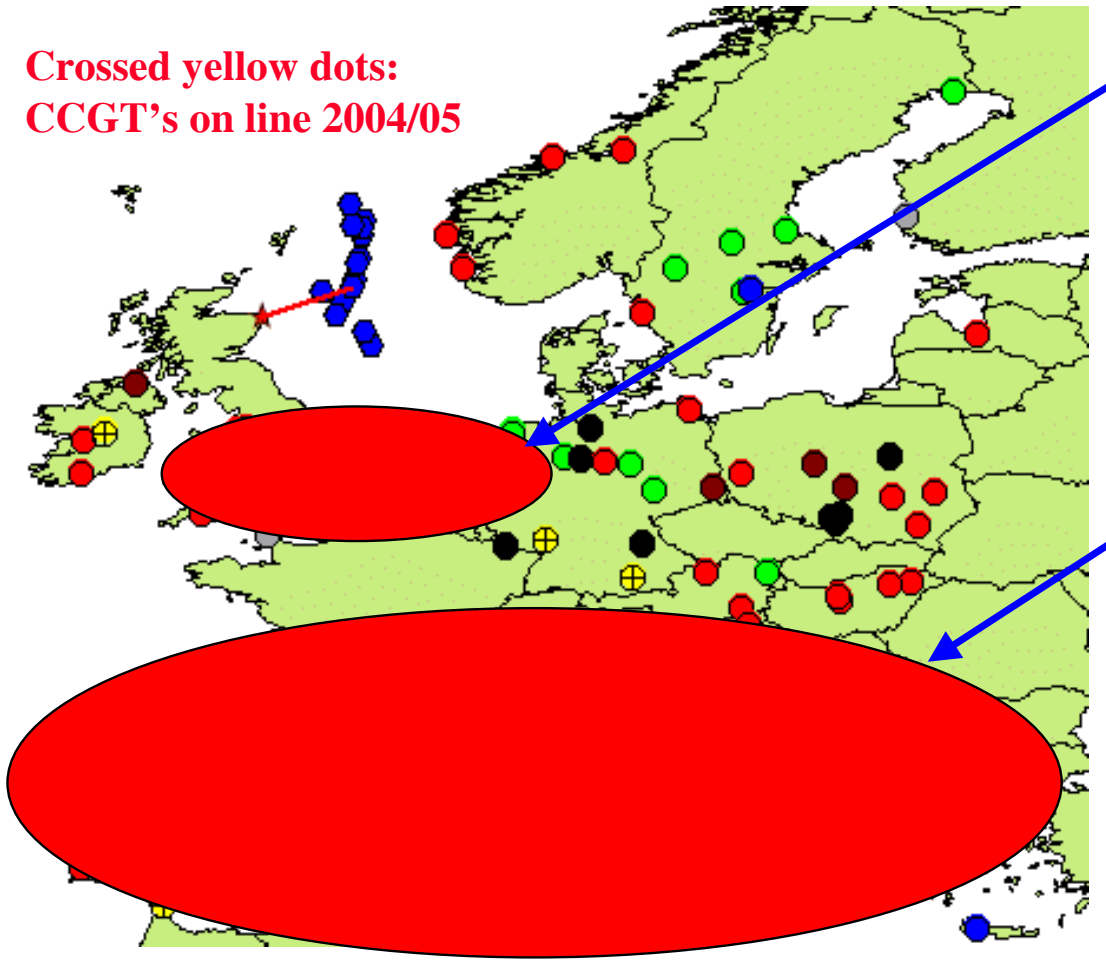


- Coal (black): 714 units, 127 GW
- Lignite (brown): 262 units, 52 GW
- Gas (red): 736 units, 126 GW
- Oil (blue): 551 units, 63 GW
- Biomass/waste (green): 157 units, 5 GW
- Peat (dark brown): 28 units, 2 GW
- Nuclear (grey): 147 units, 130 GW

Source: Chalmers Power Plant Database

Distribution Planned Plants by fuel EU-25

(same colour code as previous slide, includes bio/peat)



- Northern Gas Zone: Declining production and;
  - ~ 4 GW gas installed 2004/05
  - Another 10-12 GW feasible by 2010
  - Implying 11-17 bcm incremental demand*
- Southern Gas Zone - Increasing demand
  - ~ 9.5 GW gas installed 2004/05
  - Another 30 GW feasible by 2010
  - Implying 30-42 bcm incremental demand*

Source: Chalmers Power Plant Database

***57-80% Capacity factor**
60% efficiency, 40 MJ/m3

For each Member State (EU25 covered), the following is defined

- An assumption in growth rate in power demand over the projection period
- Application of a high but realistic penetration of renewables (based on country specific targets or best available projections from recent EU projects and other investigations)
- Phase out of nuclear plants as announced by utilities/authorities
- Phase out of fossil plants after pre-defined years of operation
- Investing in sufficient new fossil capacity to cover the remaining of the projected demand, i.e. projected demand subtracted with what is covered by generation from nuclear and renewables.

Then, these are aggregated to EU 25 level, resulting in an overall scenario with respect to generation, CO2 emissions and power generation cost.

A scenario with CO2 capture will be compared with a corresponding scenario for which this is not employed

Model

The model which is a simulating model with an overall objective function of matching supply of gross electricity production with demand on a yearly basis over the time period studied.
The model outputs are:

- Power plant mix for each of the EU-25 member states over next 50 year period.
- Cost data, e.g. electricity generation cost, system cost and/or CO2 avoidance cost.
- CO2 emissions.