Norway—A Report on TRANSES/GLUE joint research projects

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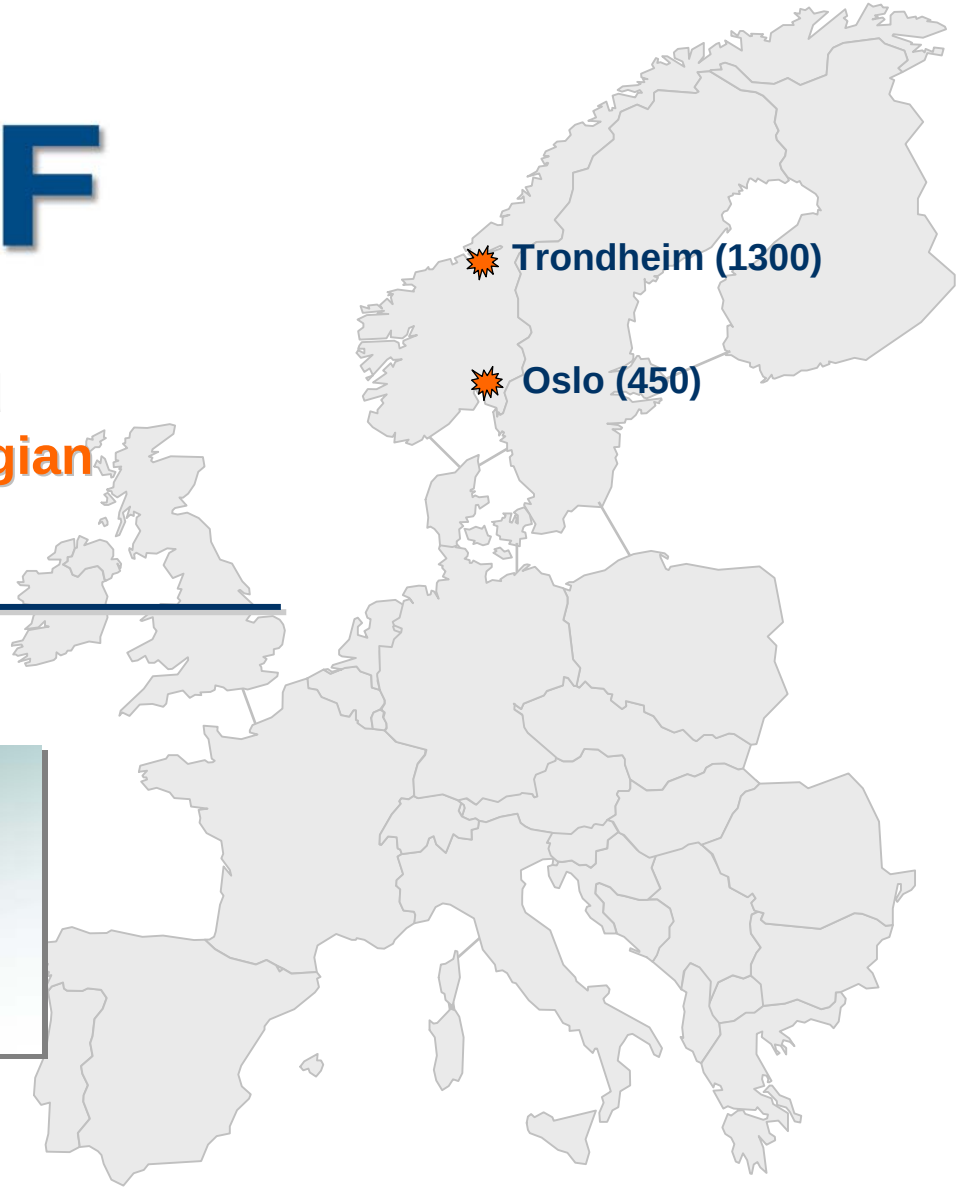
SINTEF

The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology



Established 1950 by The Norwegian Institute of Technology (NTH)

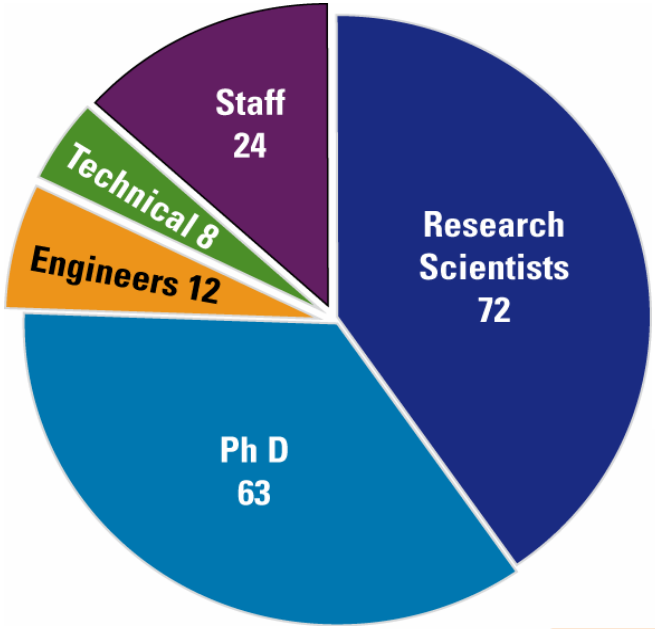
Turnover 2005: $ 300 mill.

Employees: 1.800

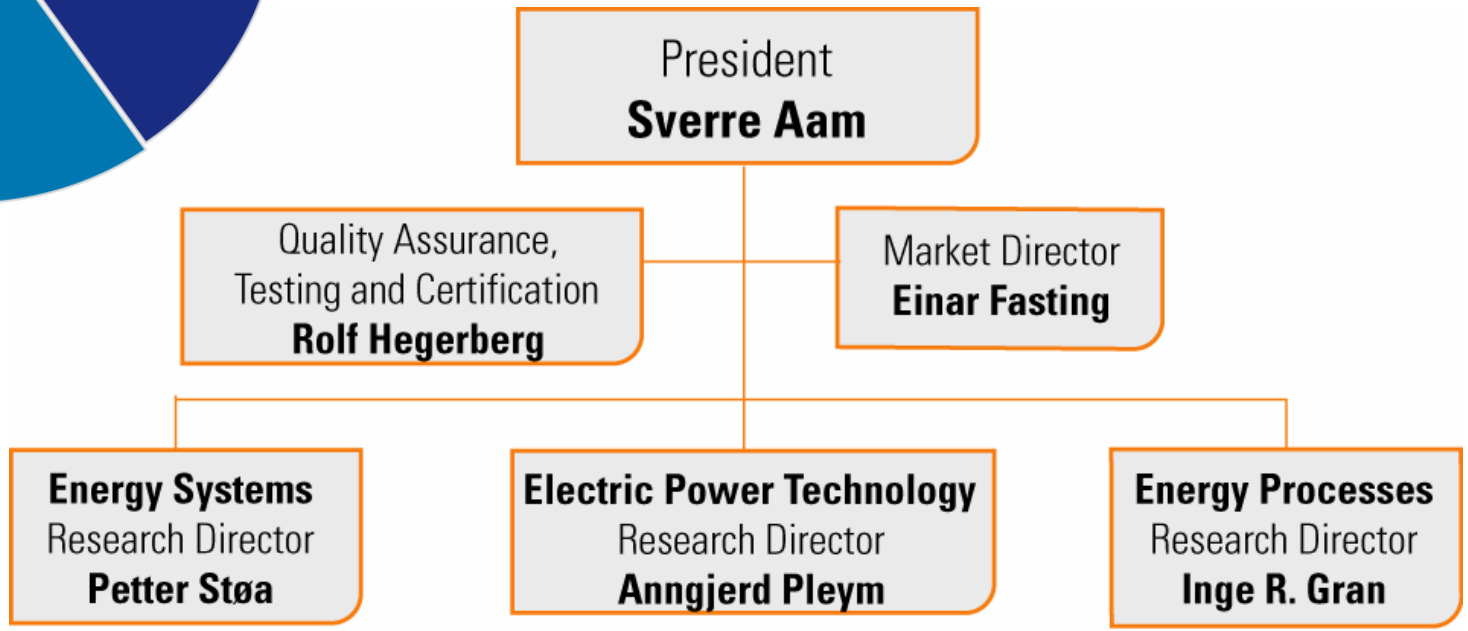
Partnership with NTNU

- **The Norwegian University of Science and Technology (NTNU), Trondheim**
  - 20,000 full-time students
  - 935 Scientific employees
  - 149 PostDoc
  - 731 PhD Students

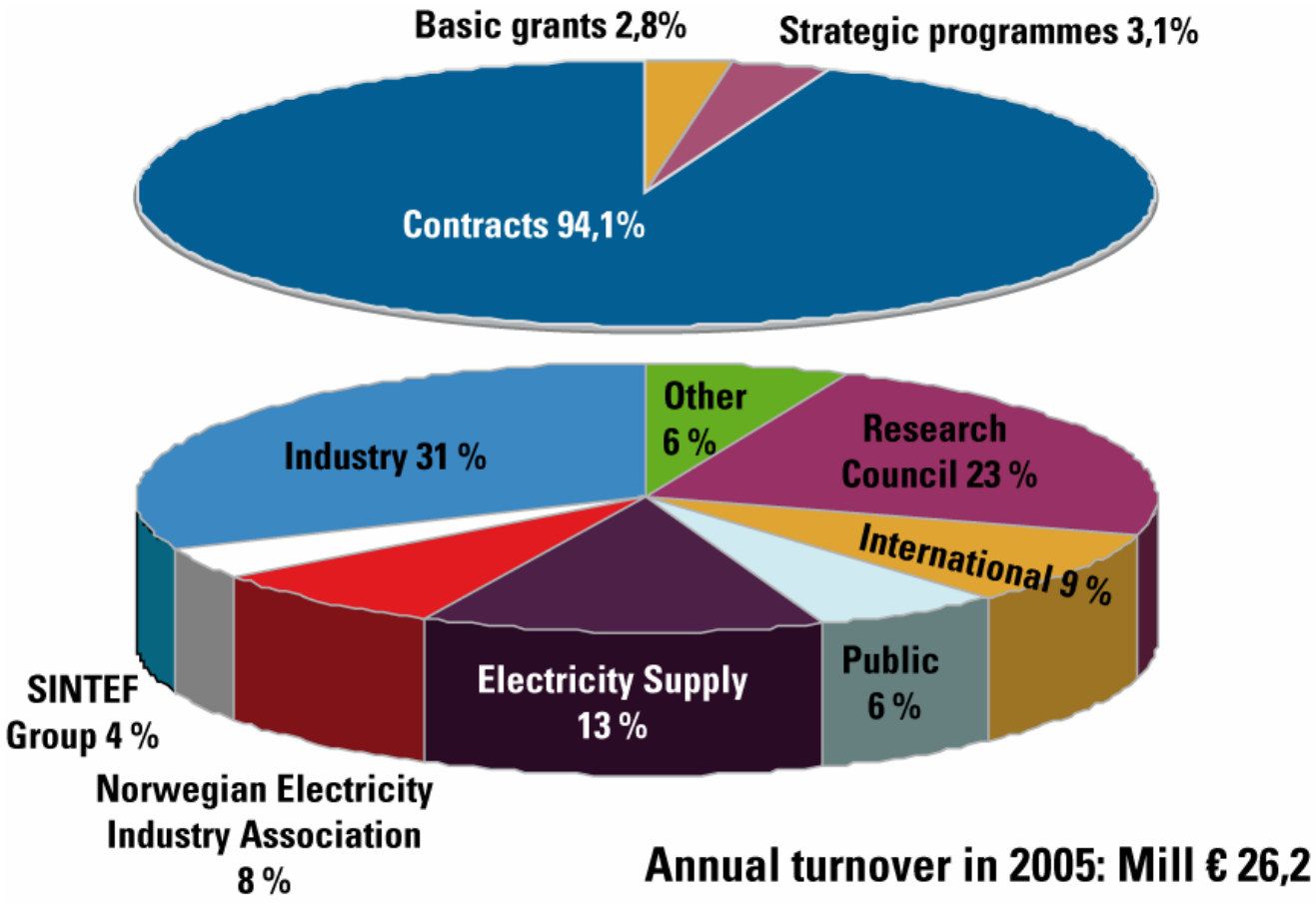
SINTEF Energy Research



Employees (2005): 179
Turnover (2005): $ 35 mill.

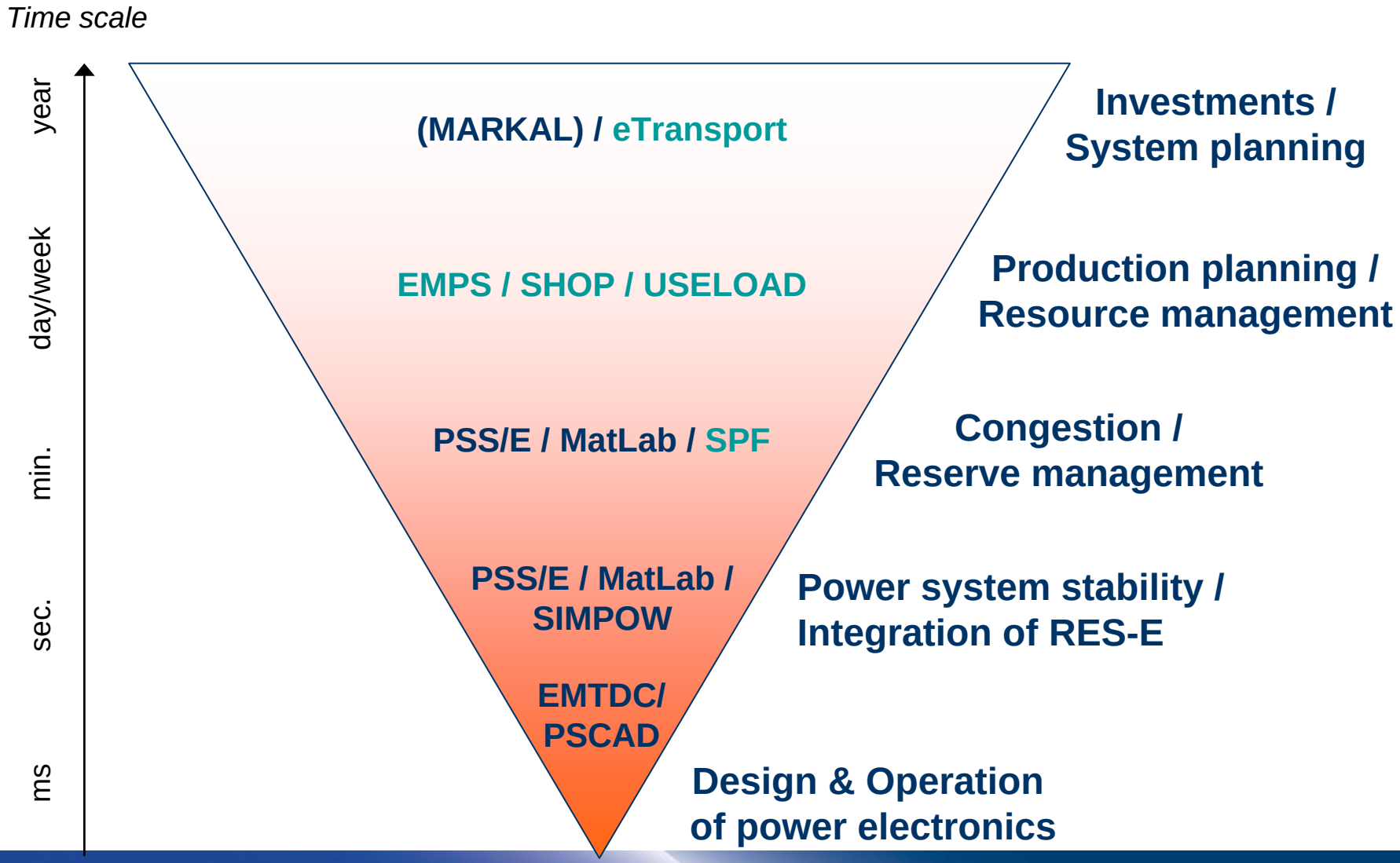


Sources of funding



Annual turnover in 2005: Mill € 26,2

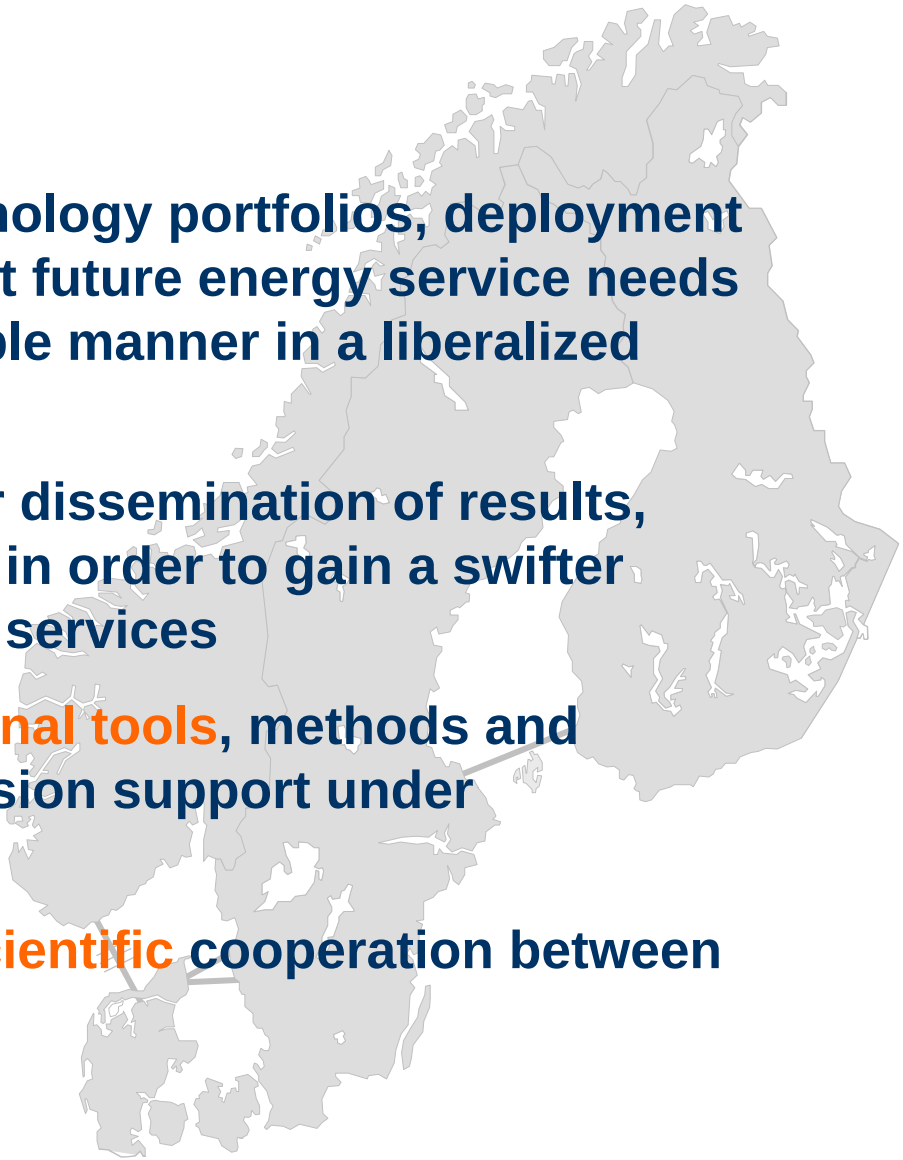
Energy system analysis at SINTEF Energy Research (~60 pers.)



TRANSES –
Transition to Sustainable Energy Services in Northern Europe

A joint research program
NTNU / SINTEF / MIT / Chalmers
2004 – 2007

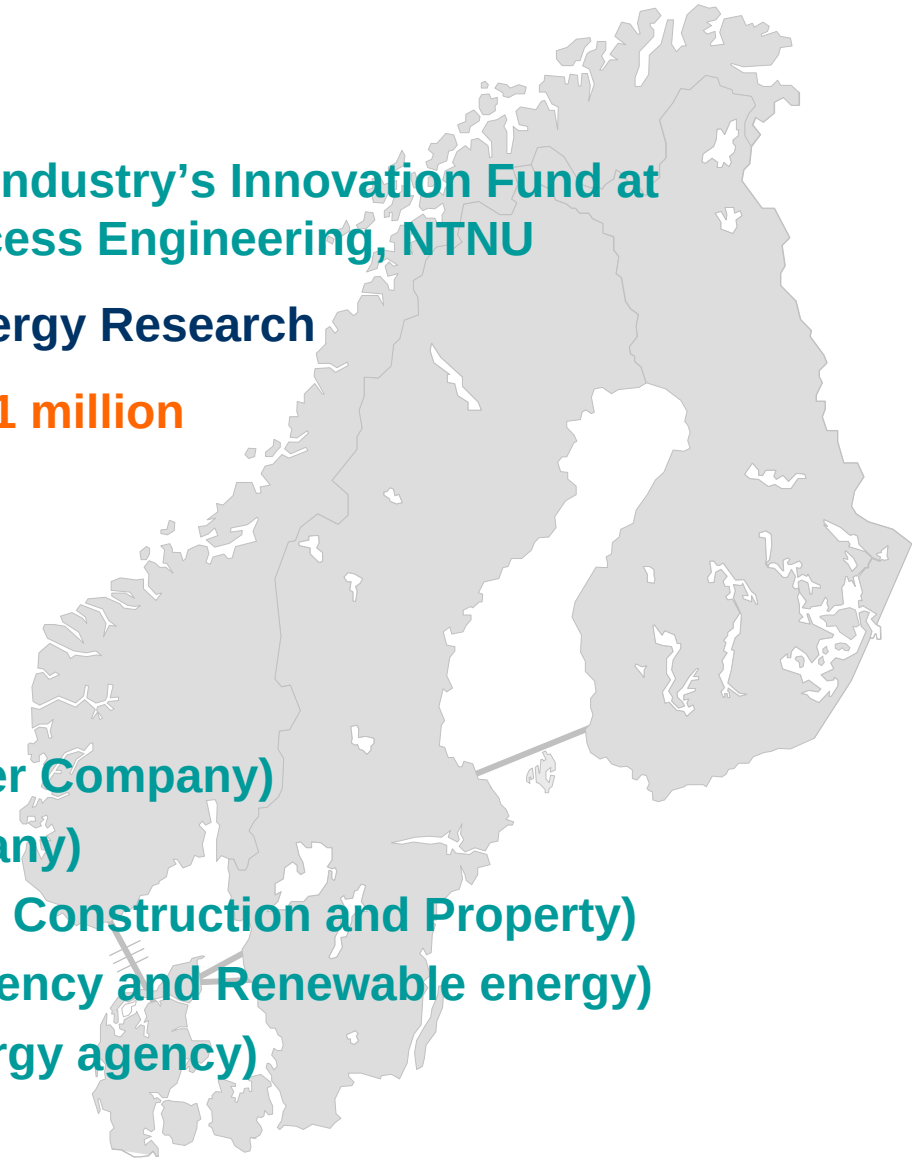
TRANSES Objectives



- **Outline and evaluate** likely technology portfolios, deployment paths and policy options to meet future energy service needs in a cost-effective and sustainable manner in a liberalized energy market environment
- **Create an international arena** for dissemination of results, dialogue and exchange of ideas in order to gain a swifter transition to sustainable energy services
- Provide a toolbox of **computational tools**, methods and databases for analysis and decision support under uncertainty
- **PhD education** and **long-term scientific** cooperation between the institutions involved

TRANSES Sponsors

- Project idea created by Hydro, The Industry's Innovation Fund at NTNU and Dept. of Energy and Process Engineering, NTNU
- Project management by SINTEF Energy Research
- Current budget (2004-2007): USD 2.1 million
- Current sponsors:
  - Hydro
  - Statoil
  - Norske Shell
  - Statkraft (Norwegian State Power Company)
  - Statnett (Norwegian Grid Company)
  - Statsbygg (Directorate of Public Construction and Property)
  - Enova (Agency for Energy efficiency and Renewable energy)
  - NVE (Norwegian Water and Energy agency)
  - ...



Scientific partners of TRANSES

- Dept. of Energy and Process Engineering, NTNU
- Dept. of Electrical Power Engineering, NTNU
- Dept. of Architectural Design, History and Technology, NTNU
- SINTEF Energy Research
- The Laboratory For Energy and the Environment (LFEE) at MIT
- Institute for Energy Technology (IFE)
- Programme for Sustainable Development (Prosus), UiO
- Dept. of Energy Technology, Chalmers
- SINTEF Materials and chemistry
- ....

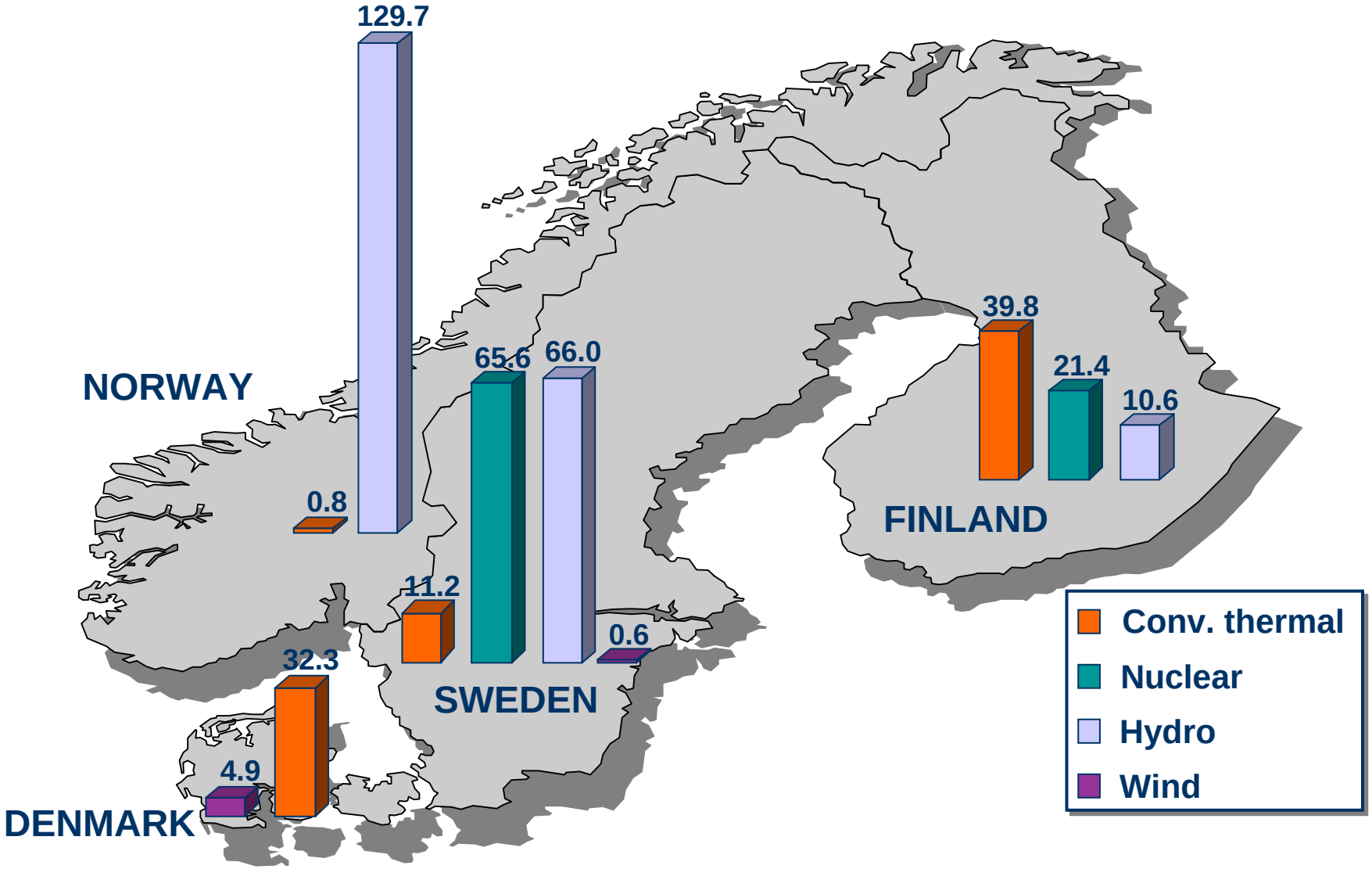
NTNU

MIT

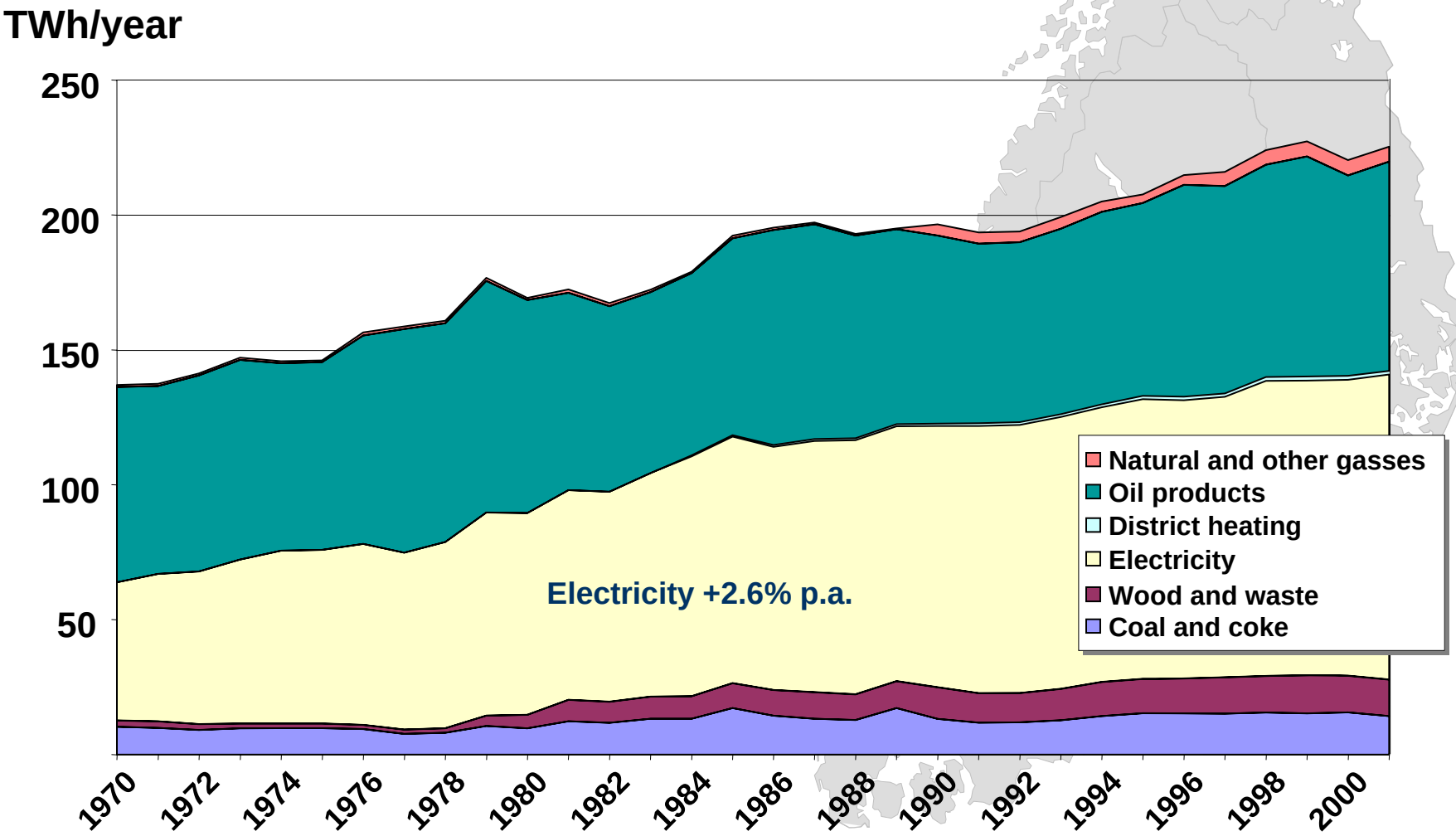
SINTEF

IFE

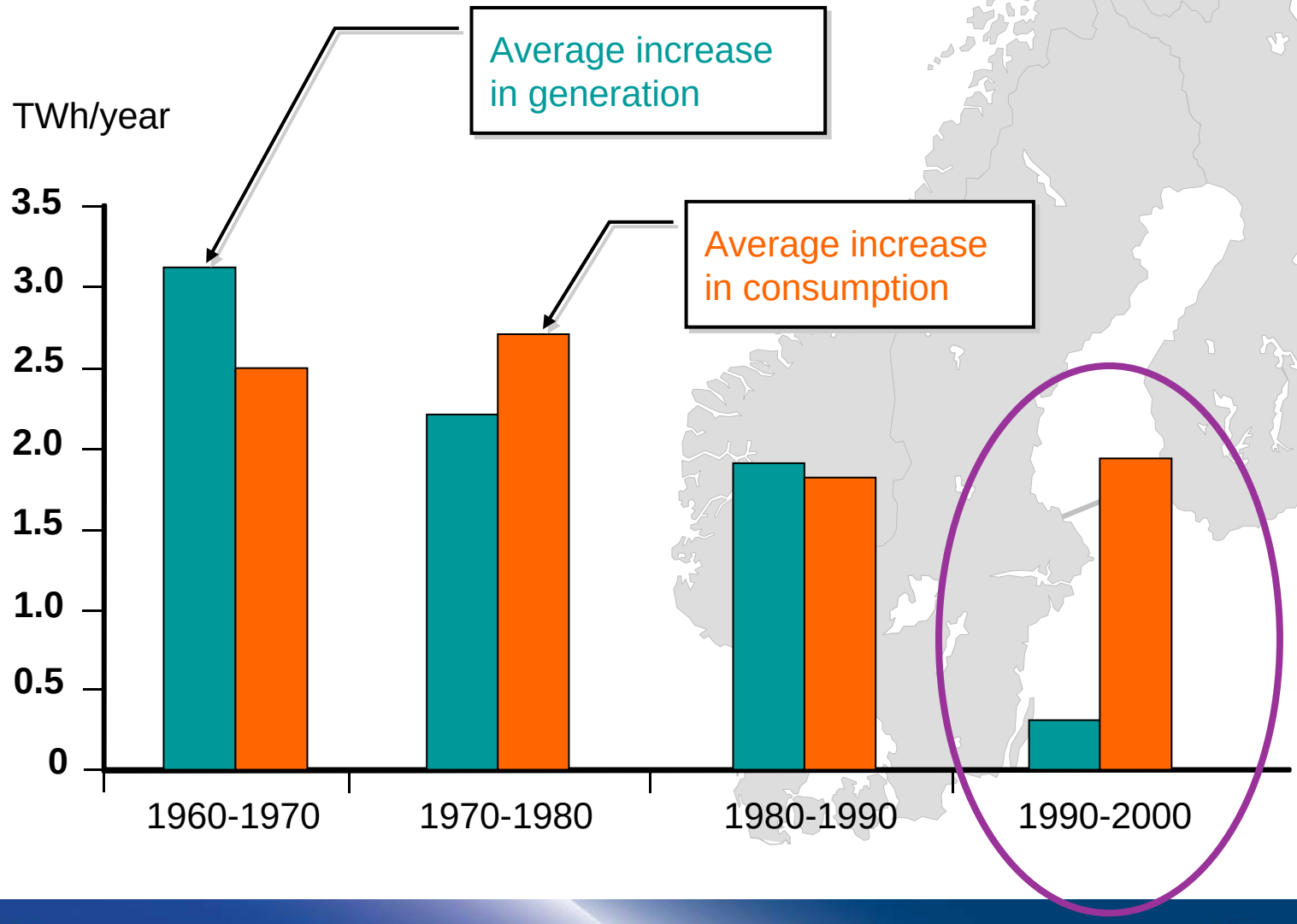
Electricity Generation in Nordel 2002 (TWh)



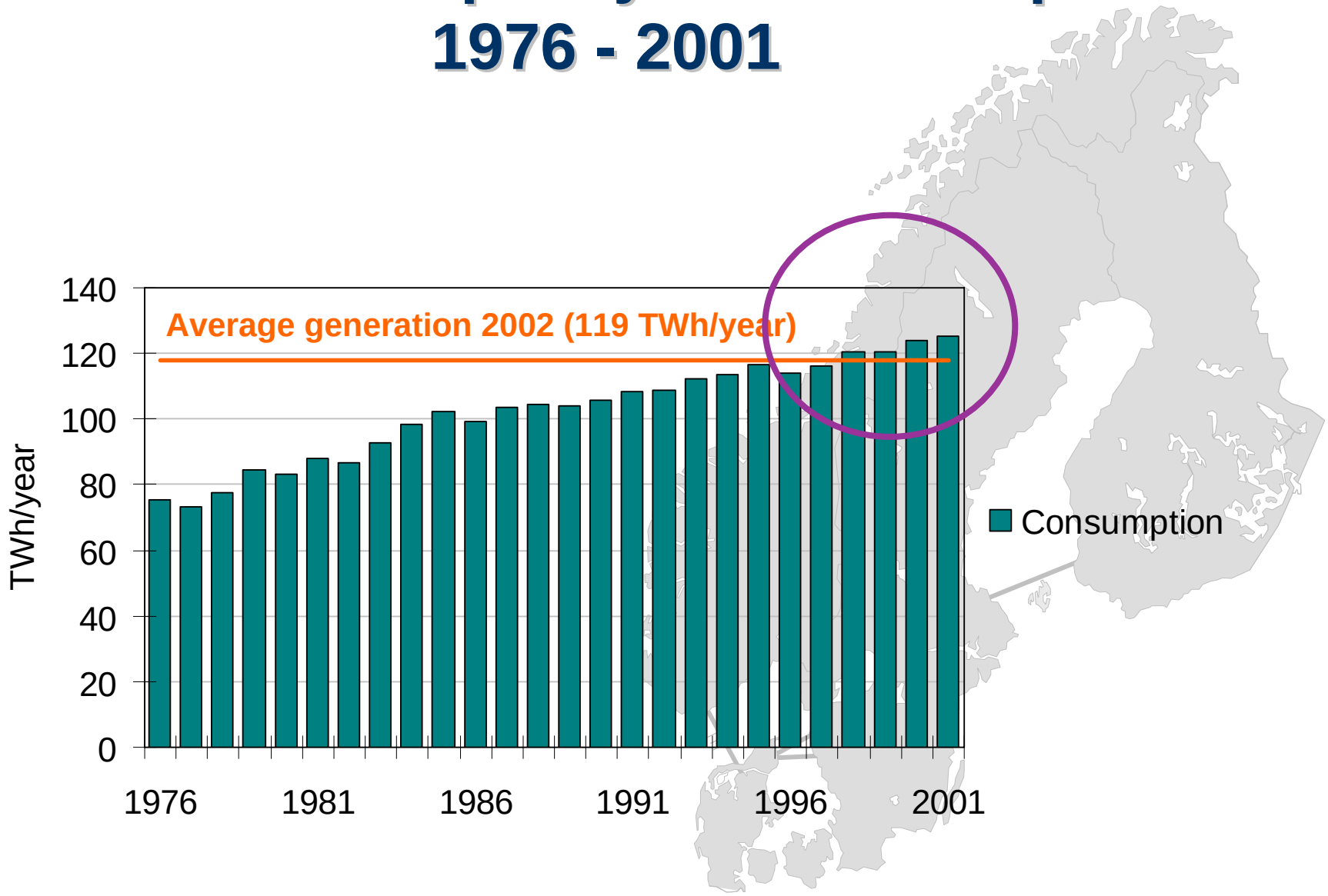
Total energy consumption in Norway 1970 - 2001



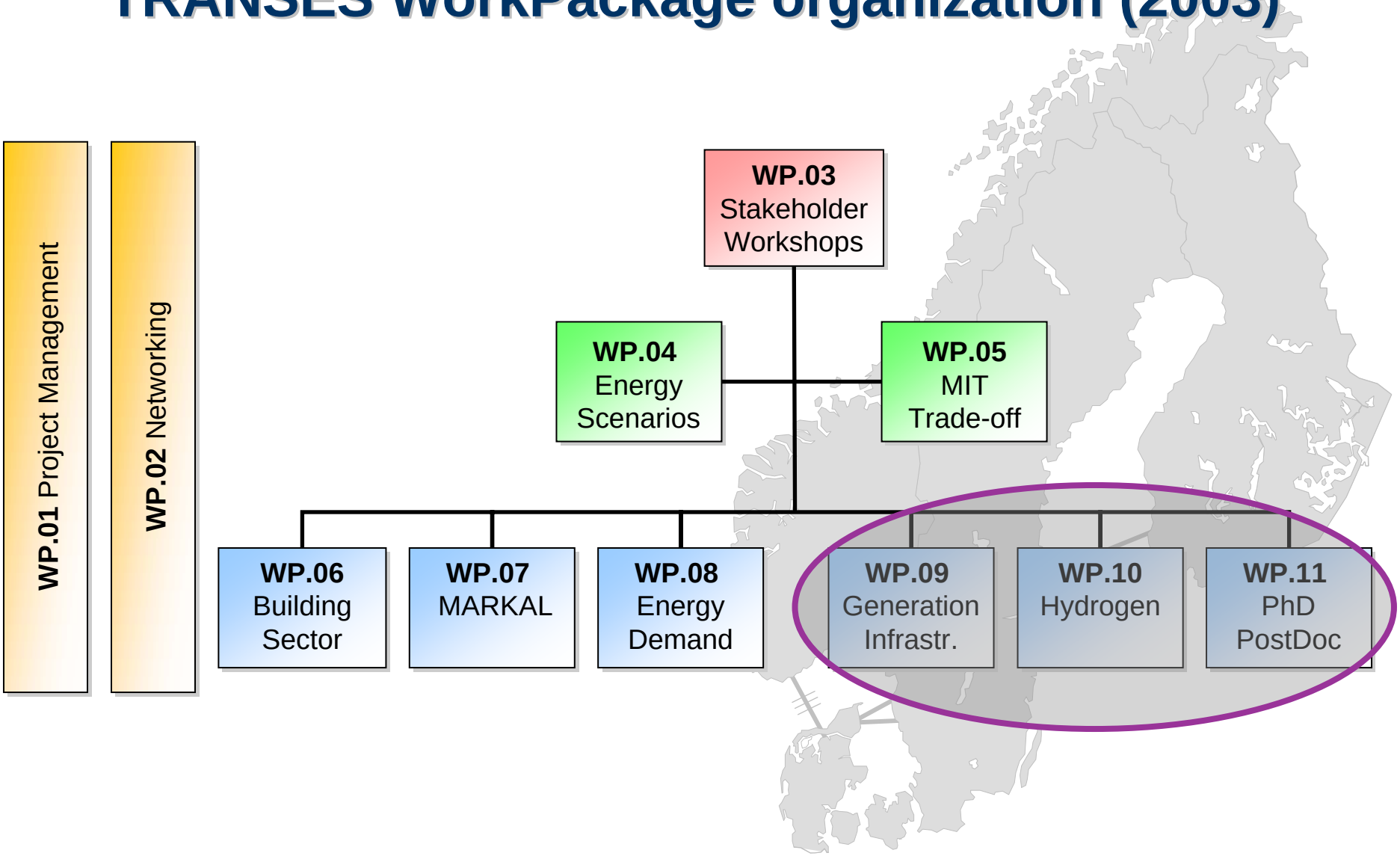
Annual increase in generation and consumption 1960 - 2000



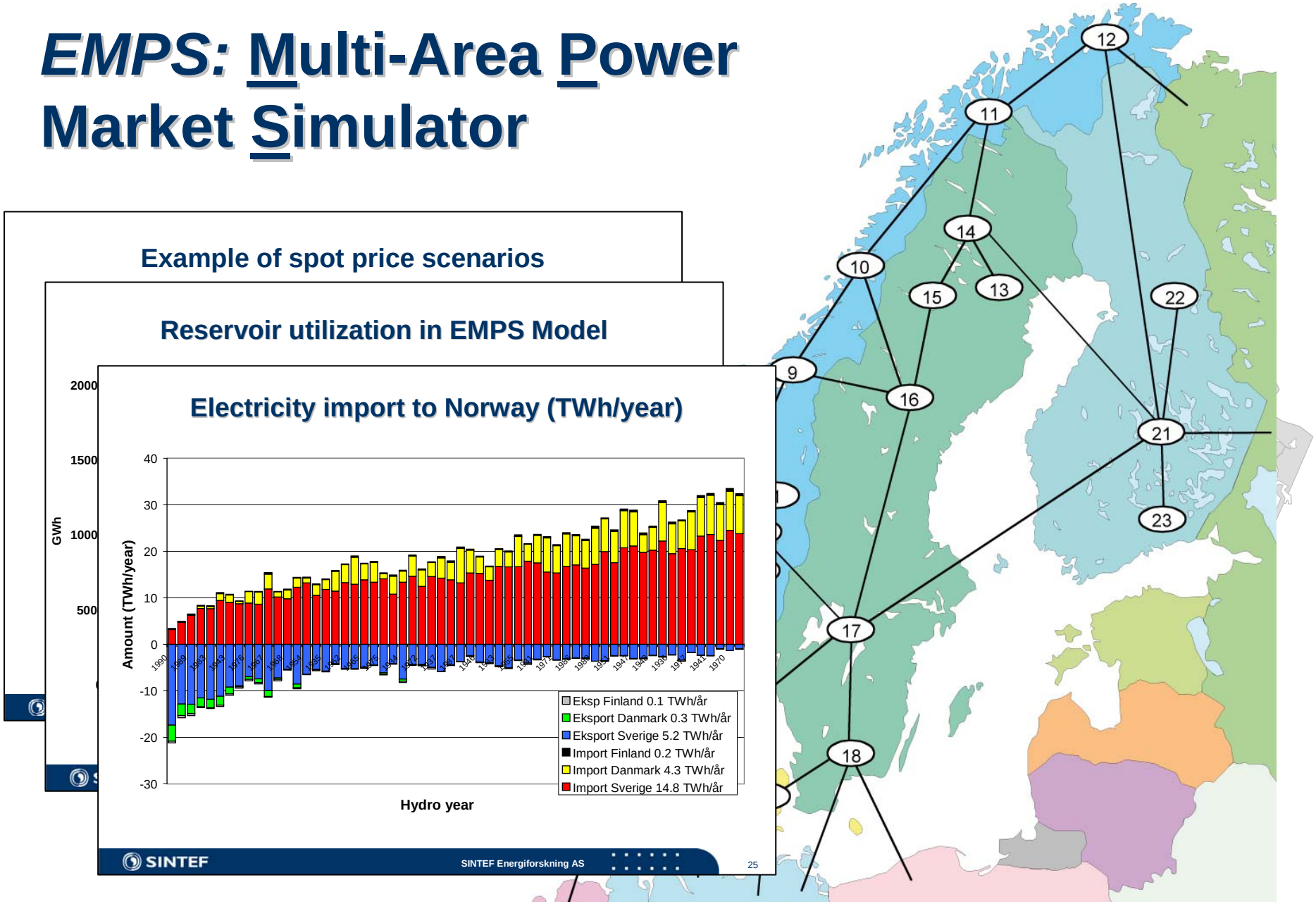
Generation capacity vs. consumption 1976 - 2001



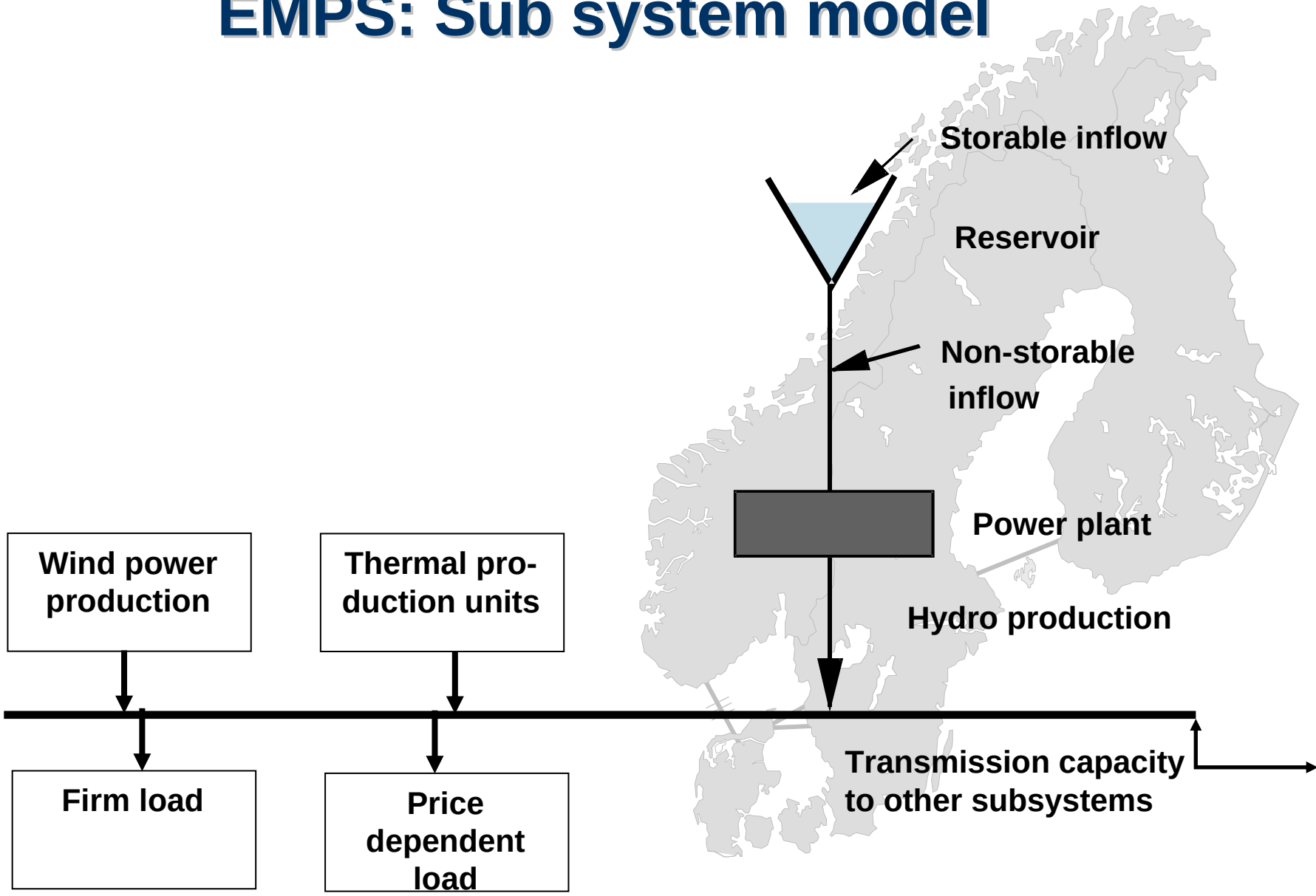
TRANSES WorkPackage organization (2003)



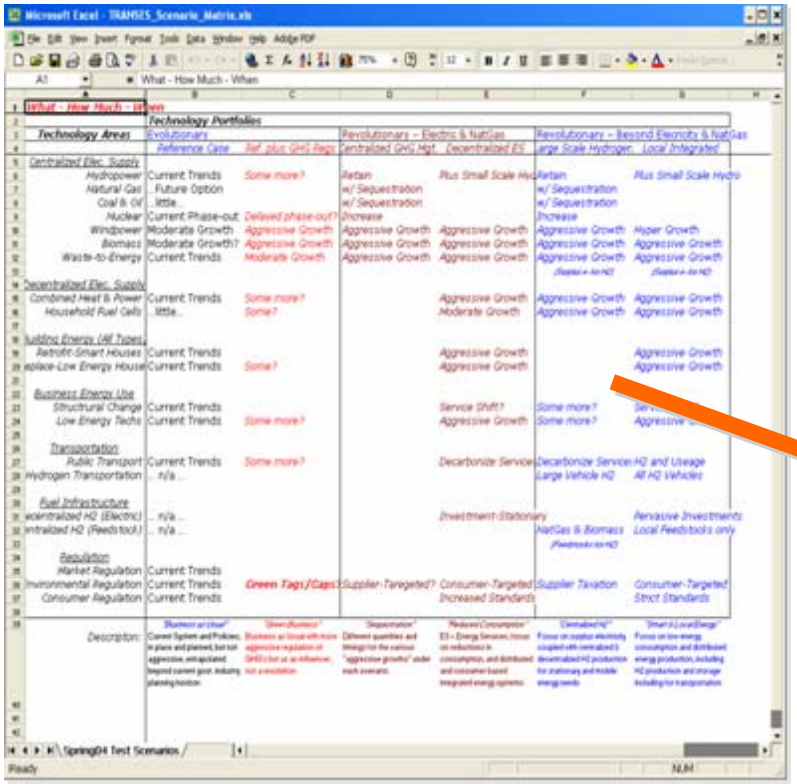
EMPS: Multi-Area Power Market Simulator

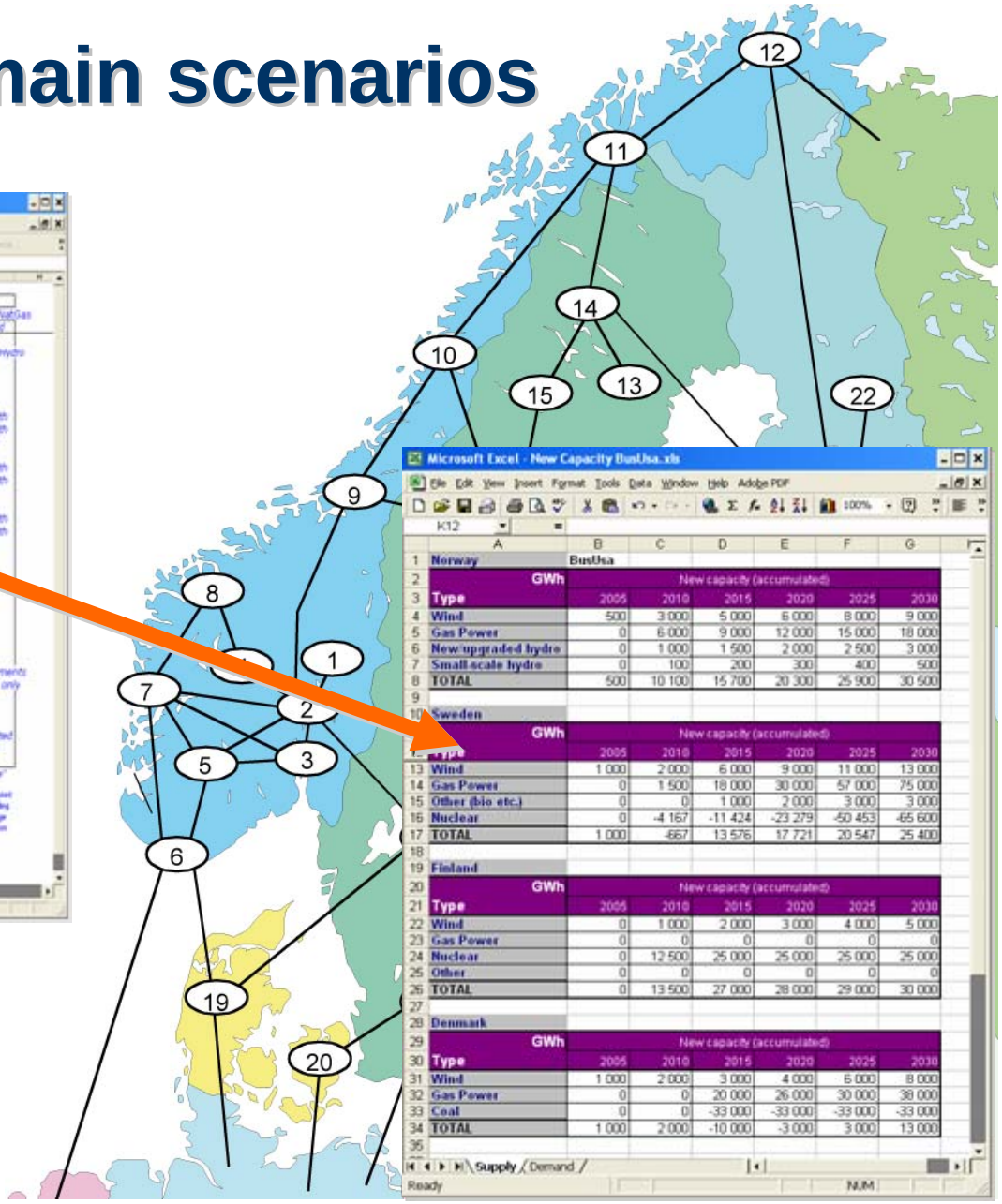


EMPS: Sub system model



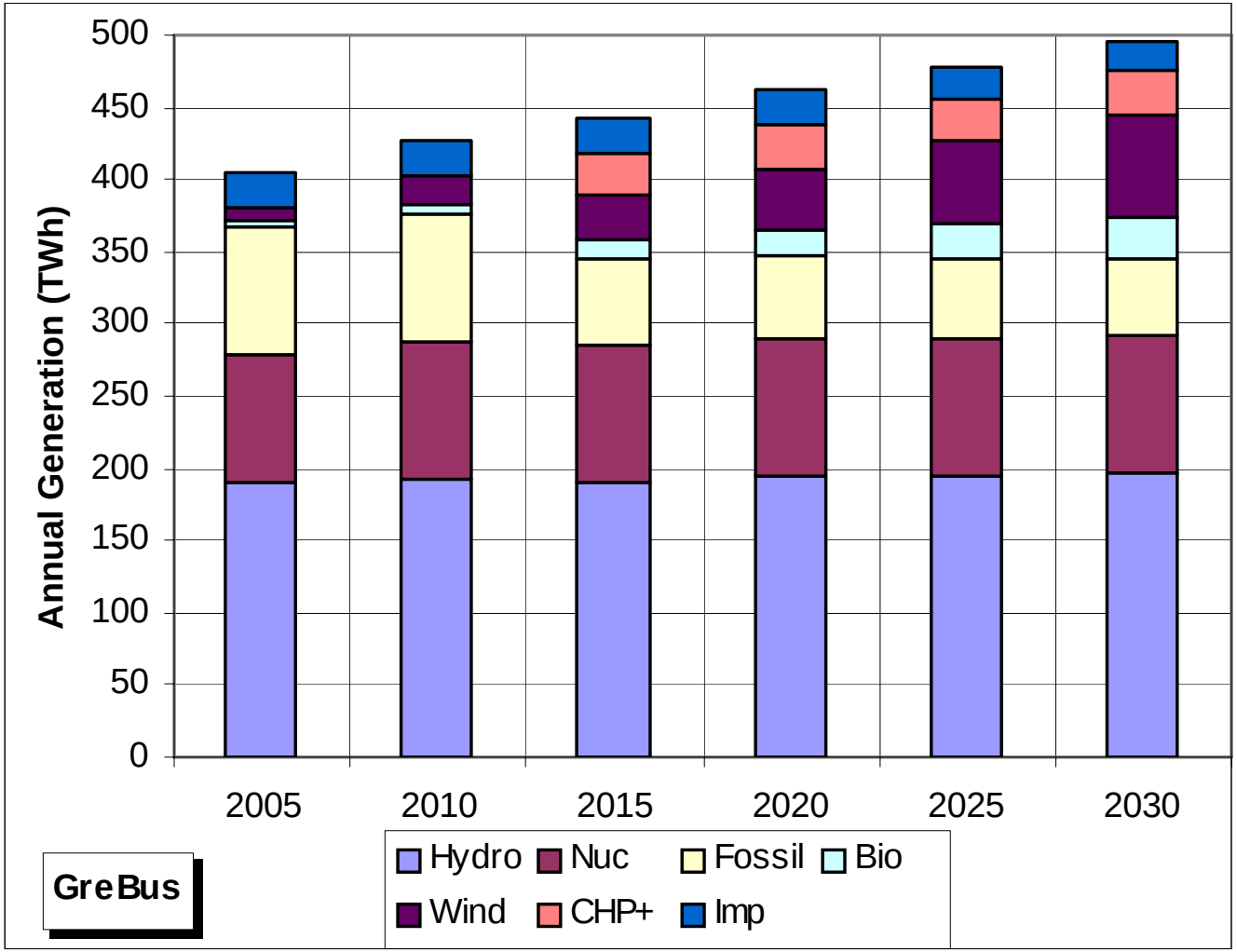
2004: Outlining main scenarios



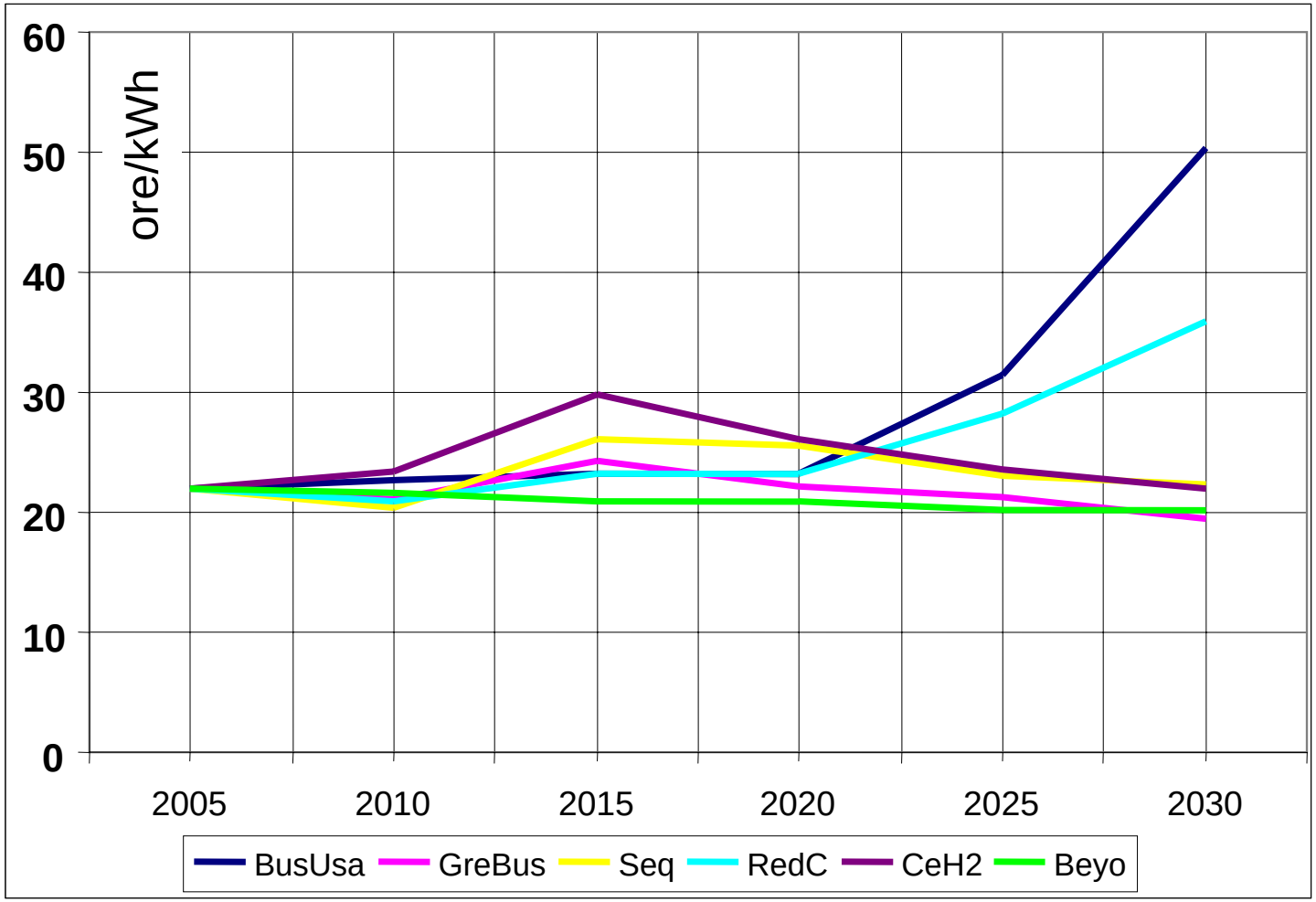


Generation Capacity – GreenBus

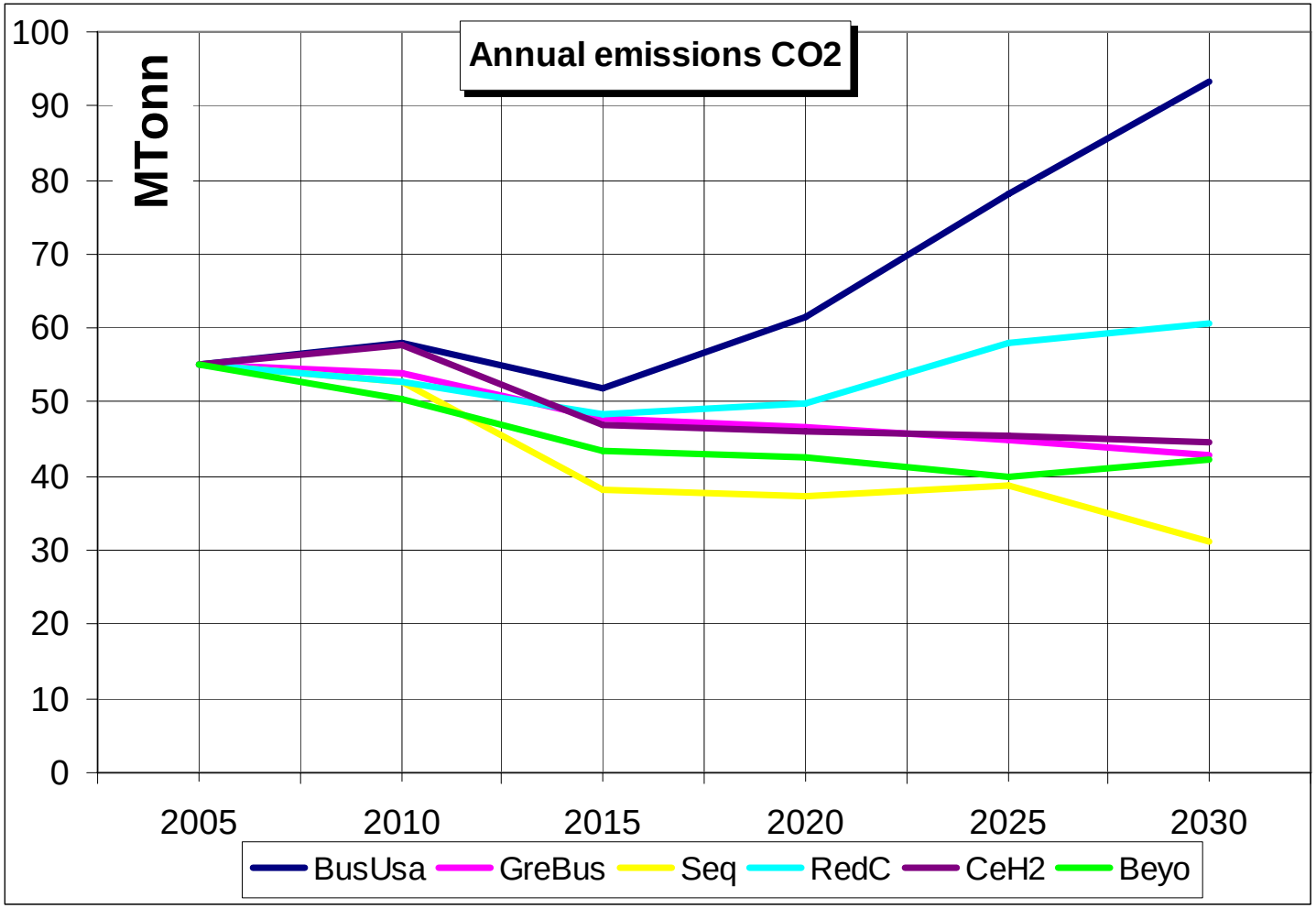
NordPool area



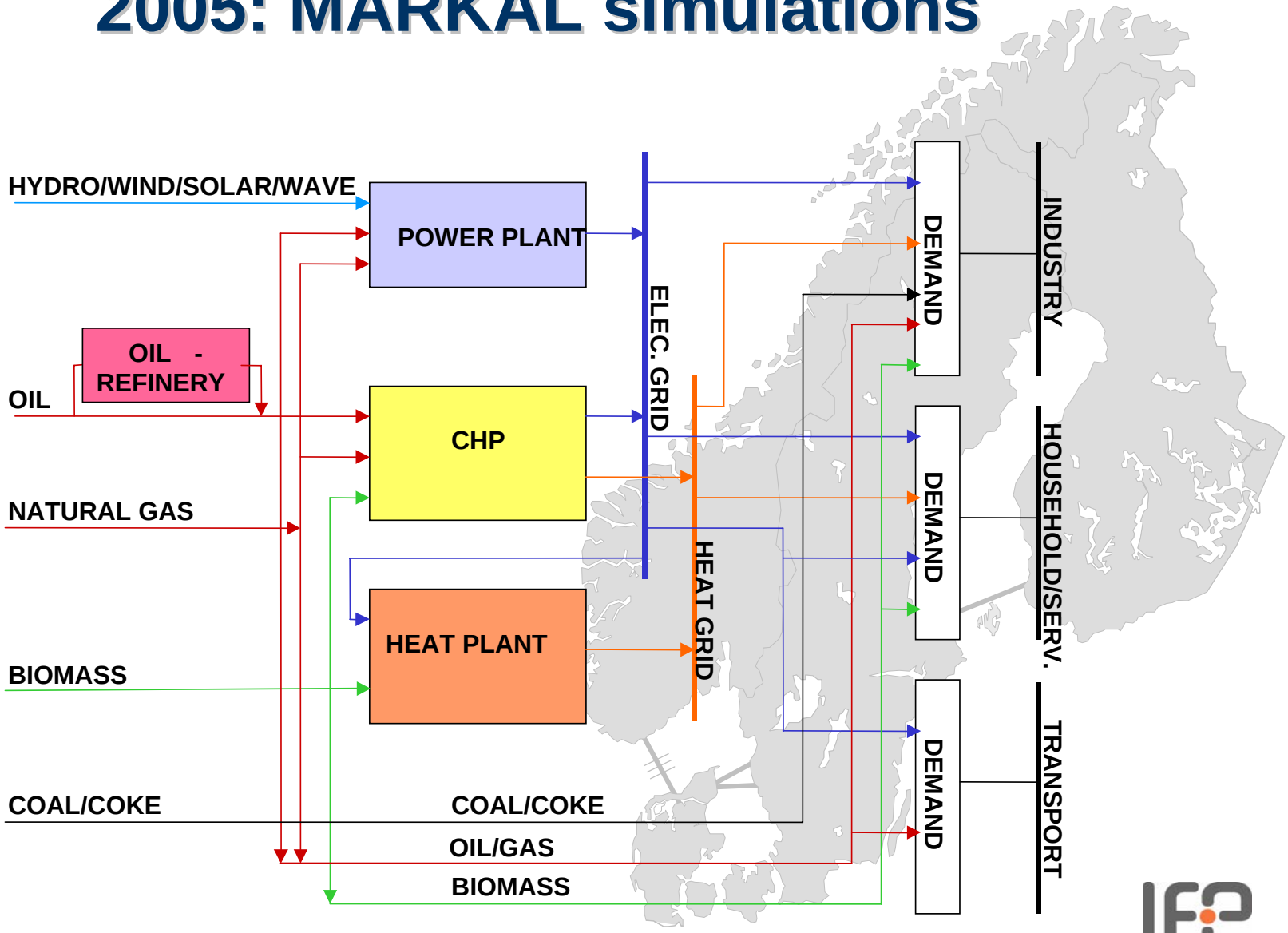
Power prices (excl. investments)
Norway



CO_2 emissions
Nord Pool Area

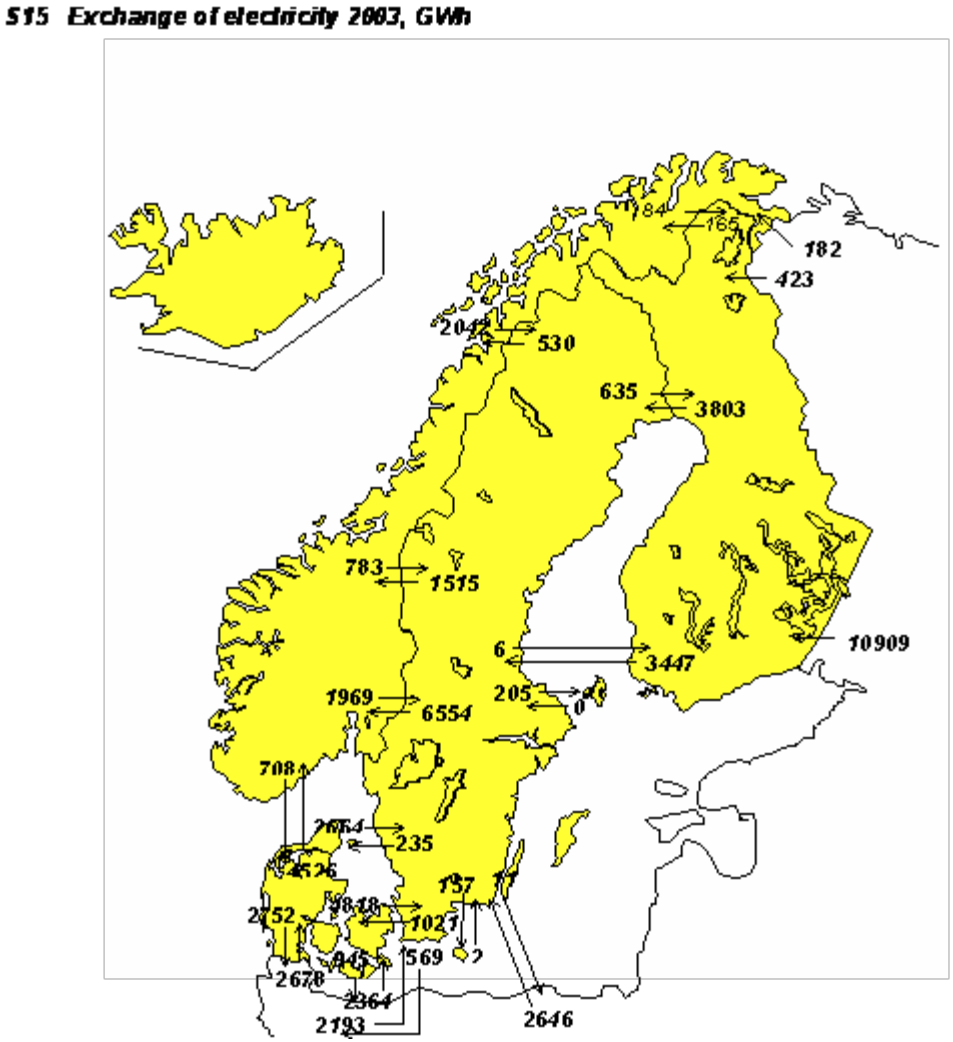


2005: MARKAL simulations



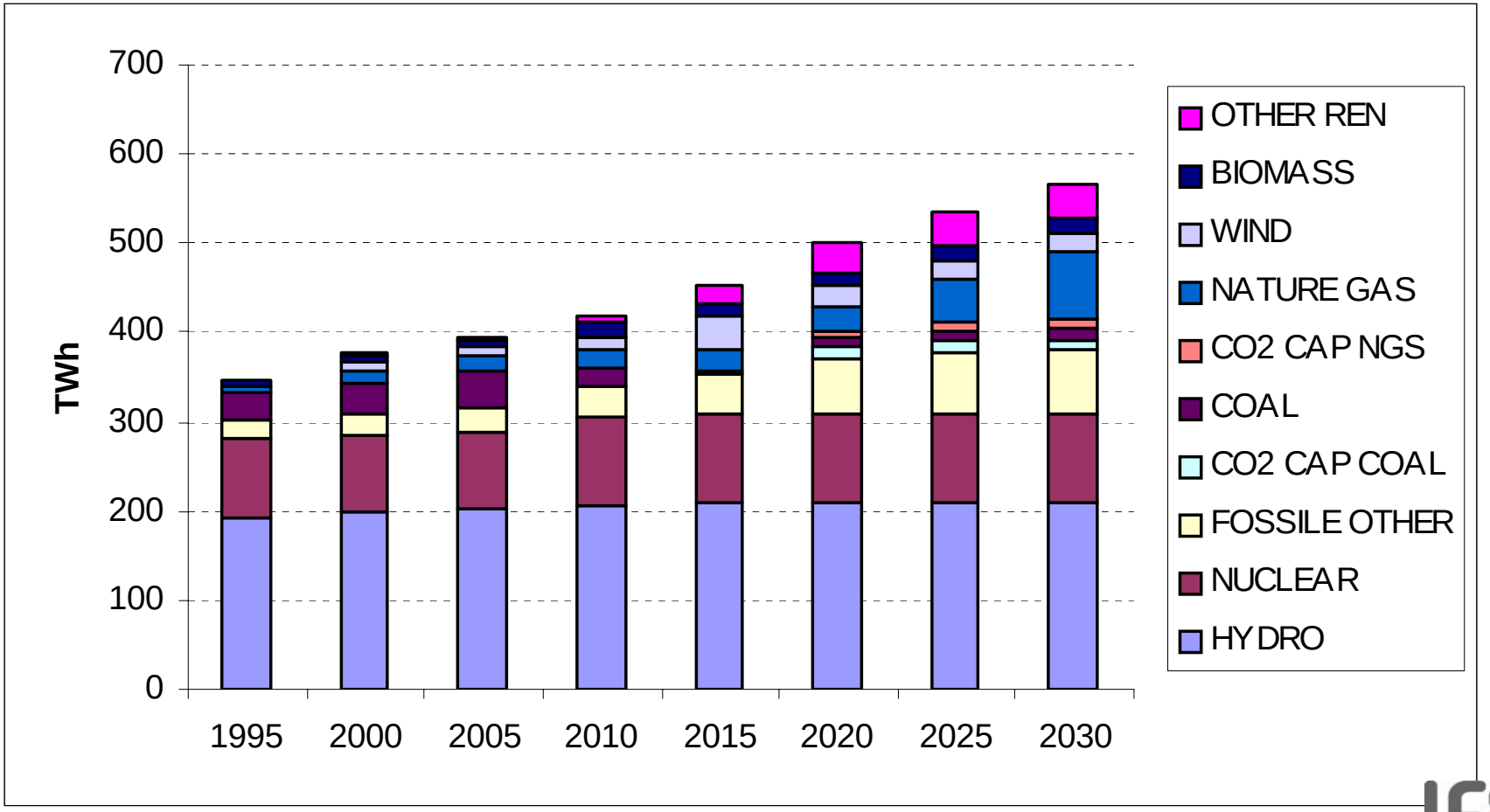
Structure of the Nordic model

(Electricity trade in Nordic countries 2003, source: NORDEL)



- 4 national models (el and heat) linked by electricity grid
- Fossil fuels common for the Nordic market (equal price)
- RES specific for each country
- Major electricity and heat production technologies harmonised
- Model years: 1995 – 2035

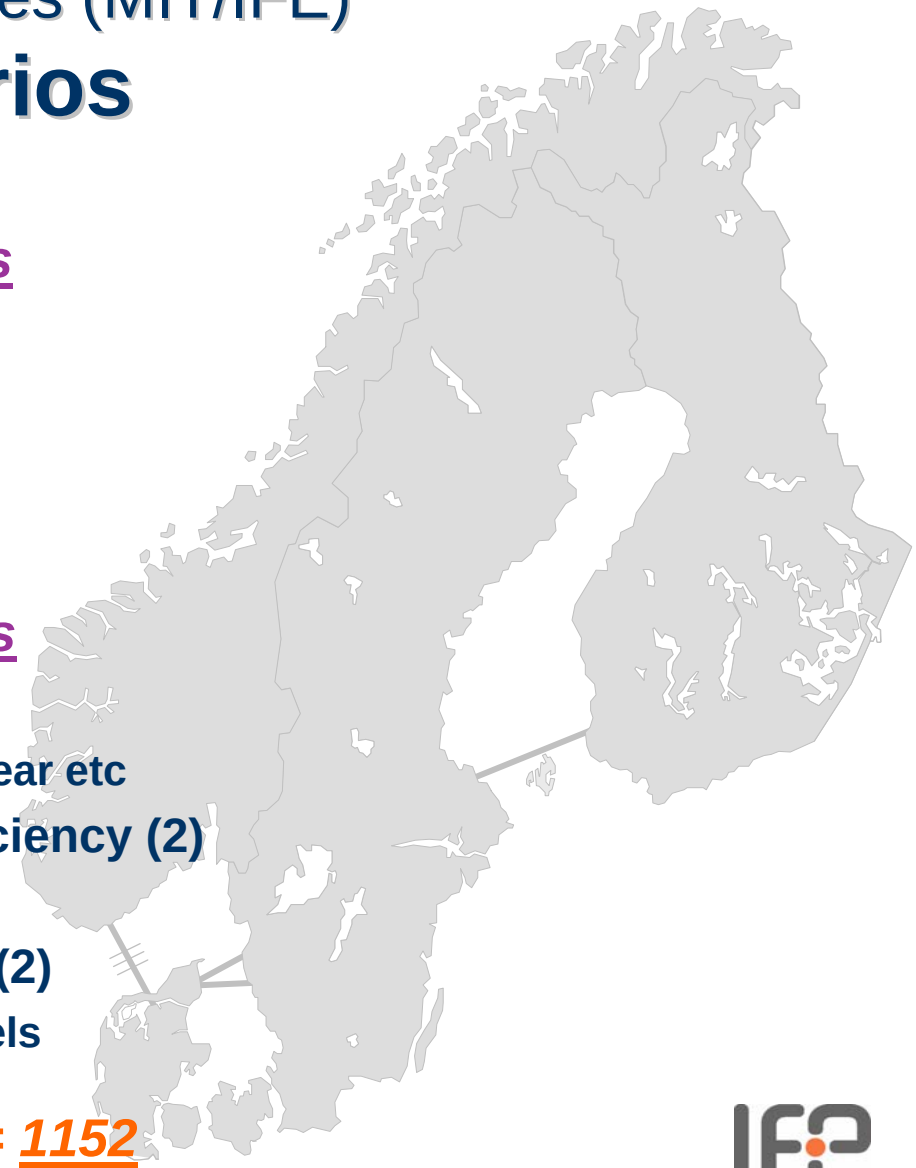
Markal: Electricity production scenarios



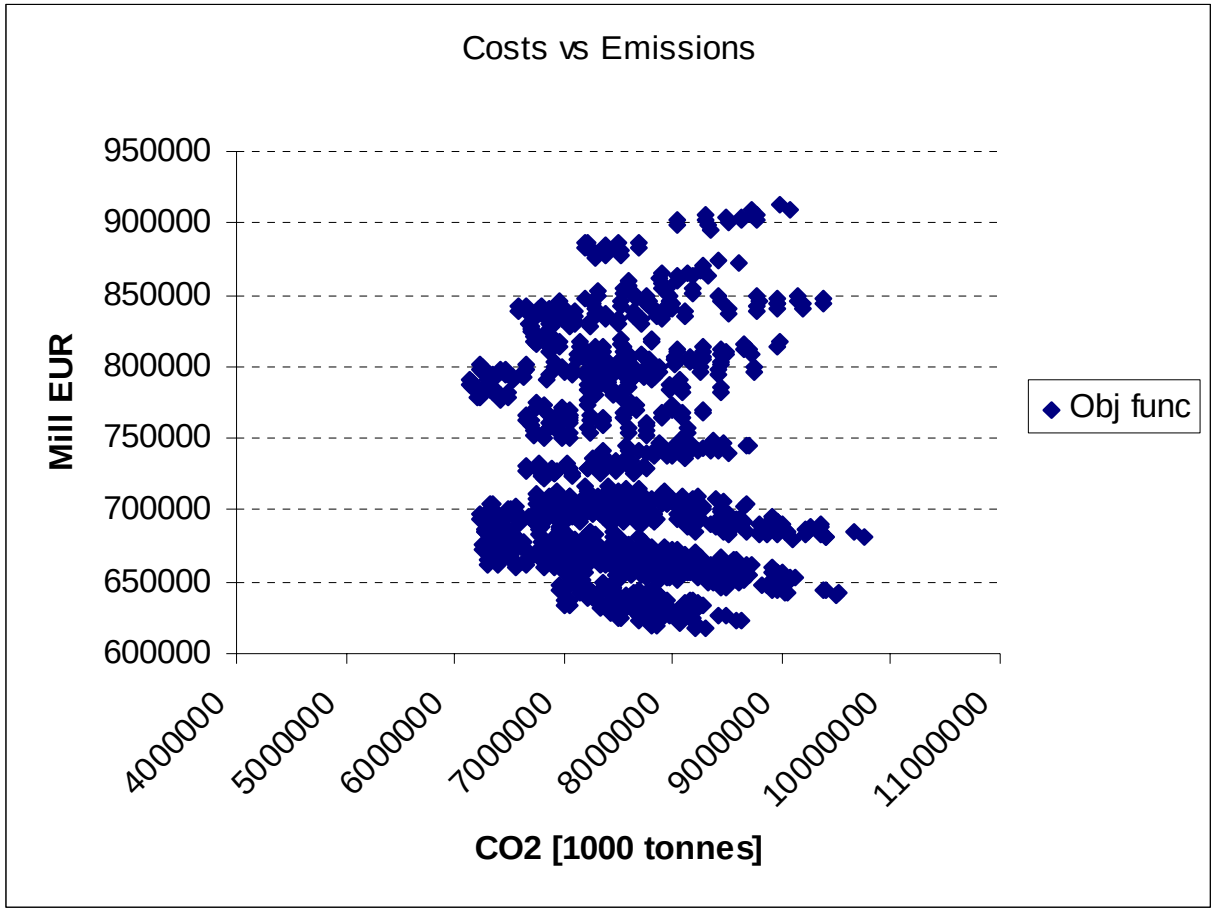
2006: Multiple scenario strategies (MIT/IFE)

From 6 to 1152 scenarios

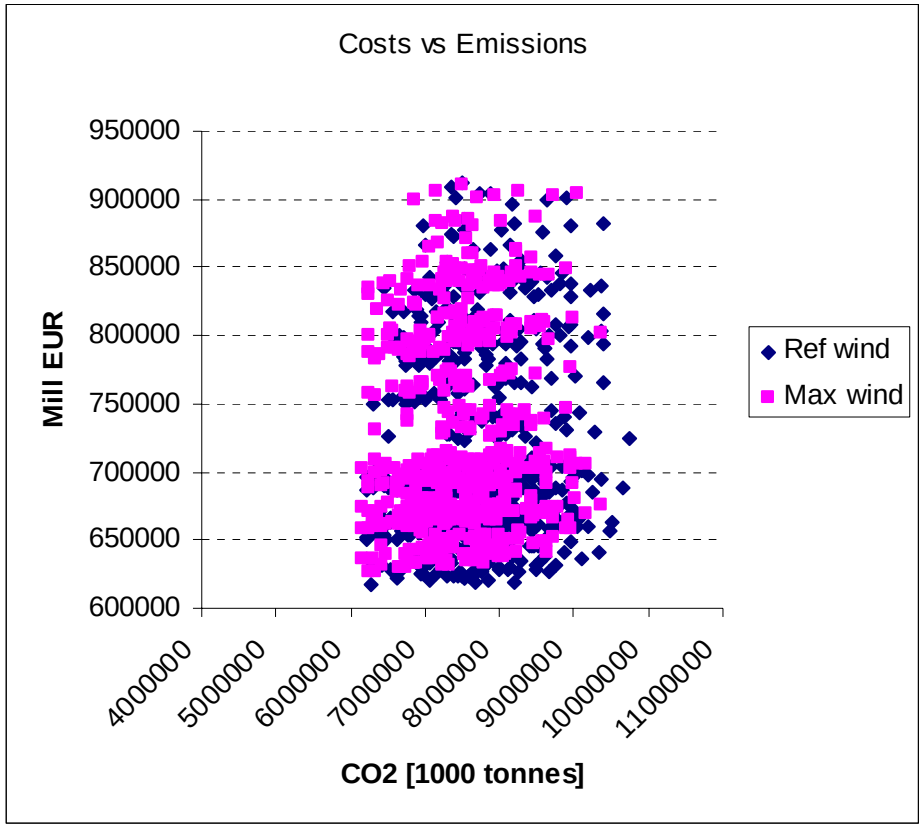
- 2 x 3 x 2 x 2 = *24 unique Futures*
  - Energy Demand Growth (2)
  - Fuel Prices (3)
  - CO2 Taxes (2)
  - European Electricity Prices (2)
- 12 x 2 x 2 = *48 unique Strategies*
  - Electricity Supply (12)
    - Renewables, Hydro, CCS, Nuclear etc
  - Non Transportation Heat & Efficiency (2)
    - Biomass, End-Use Efficiency
  - Alternate Transportation Fuels (2)
    - Conventional, Hybrids & Biofuels
- *Total no. of scenarios: 24 x 48 = 1152*



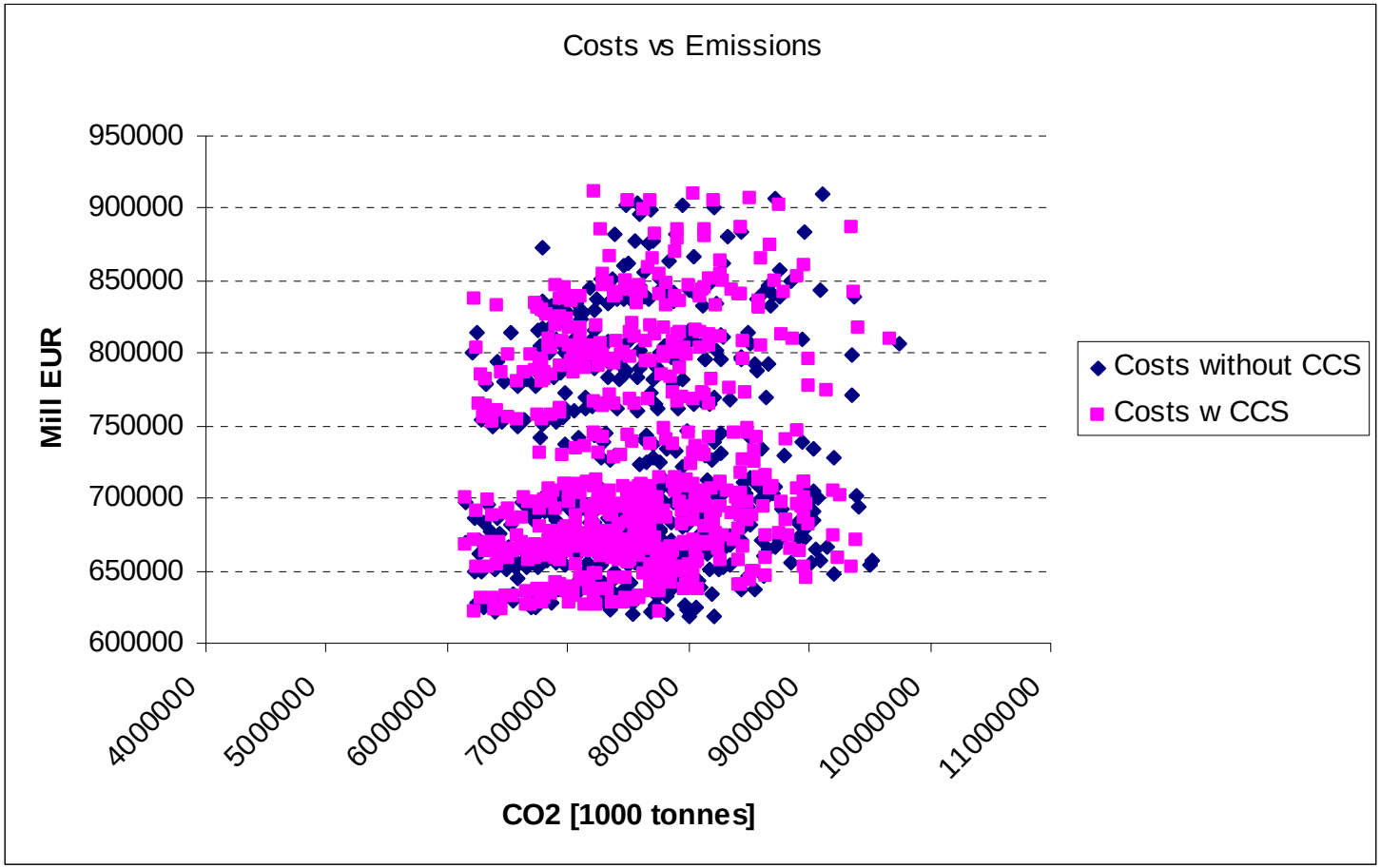
Total costs vs emissions (1152 total)



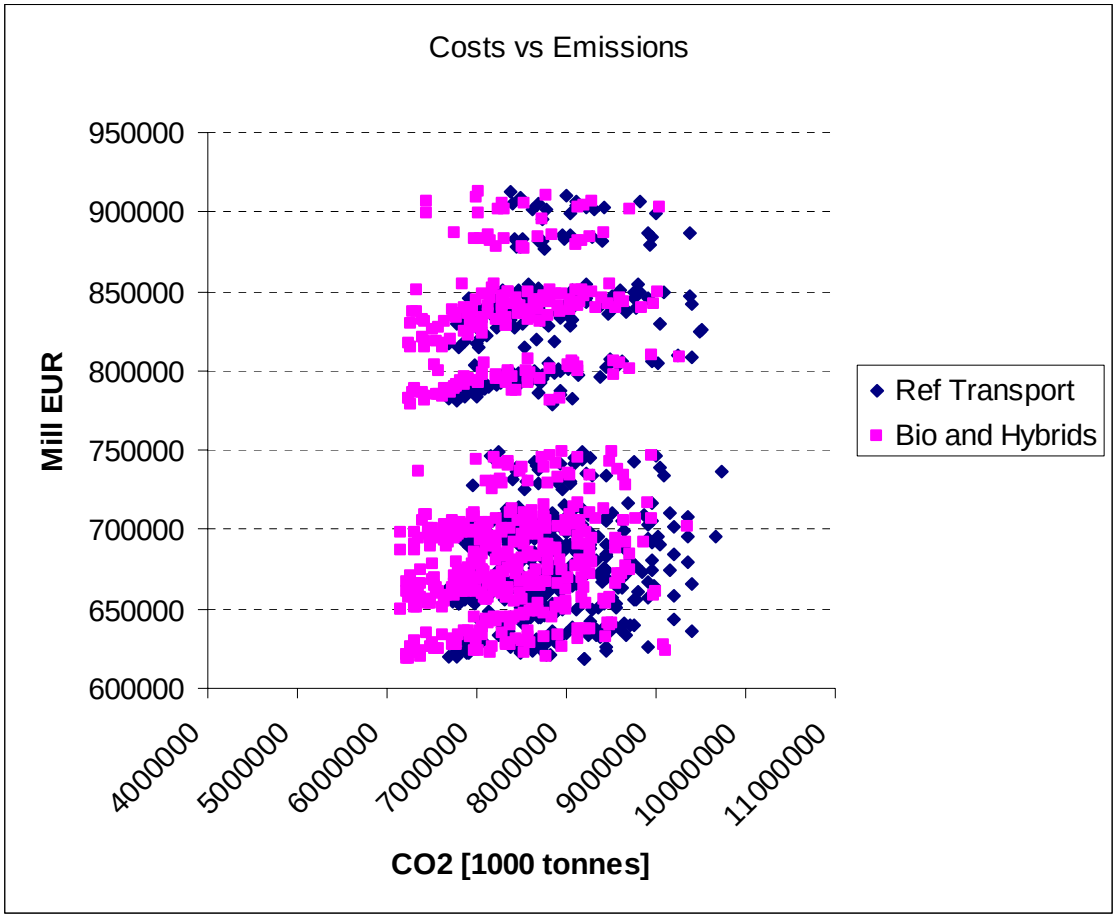
Wind power costs vs emissions



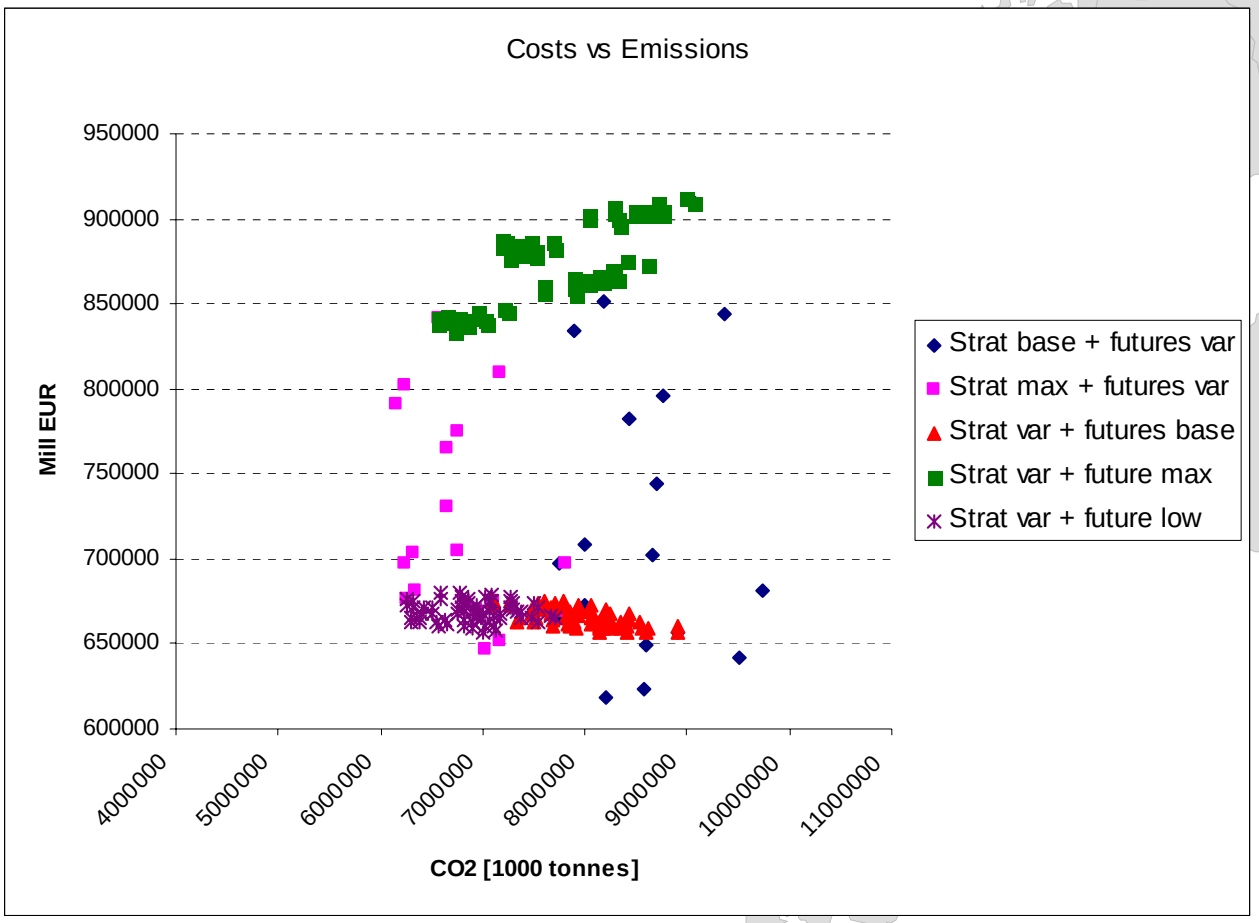
CCS costs vs. emissions



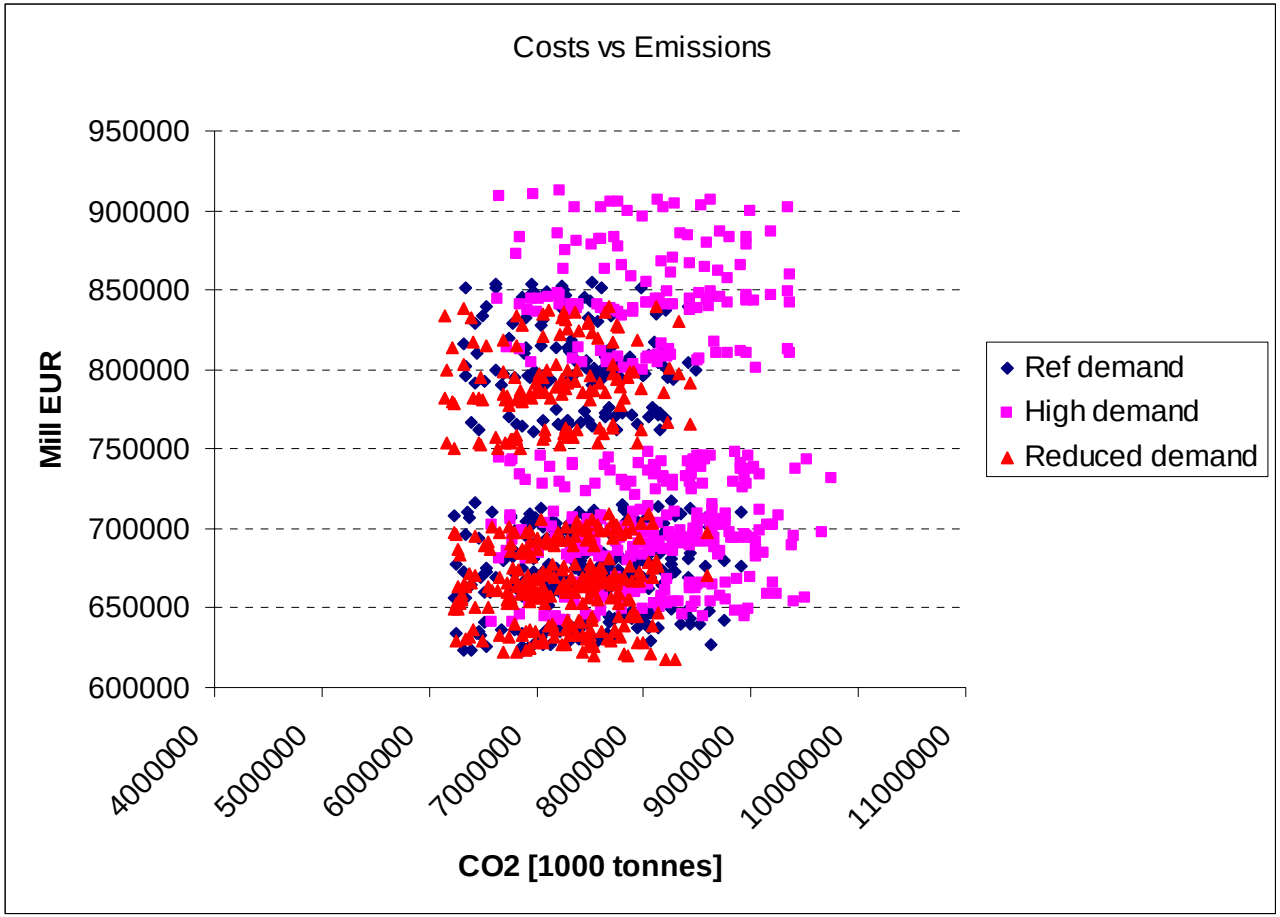
Transport


Costs vs Emissions
950000
900000
850000
800000
750000
700000
650000
600000
Mill EUR
4000000
5000000
6000000
7000000
8000000
9000000
10000000
11000000
CO2 [1000 tonnes]
Ref Transport
Bio and Hybrids

Total costs vs emissions



Demand

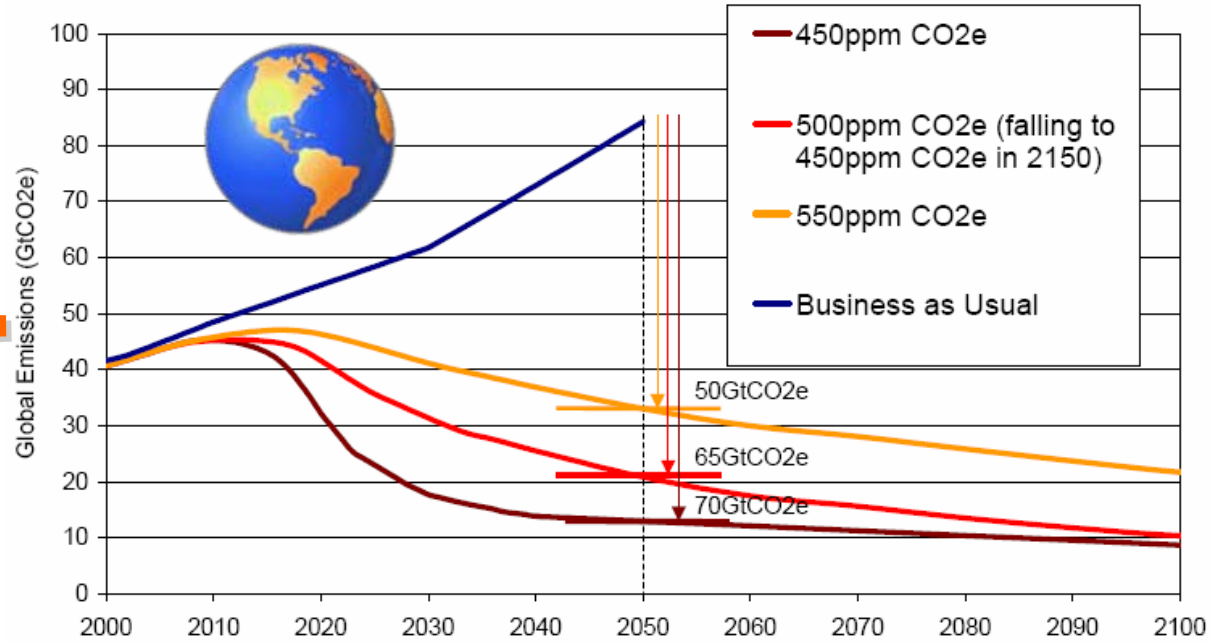

Costs vs Emissions
950000
900000
850000
800000
750000
700000
650000
600000
Mill EUR
4000000
5000000
6000000
7000000
8000000
9000000
10000000
11000000
CO2 [1000 tonnes]
Ref demand
High demand
Reduced demand

2008 ->
(GLUE) / LinkS

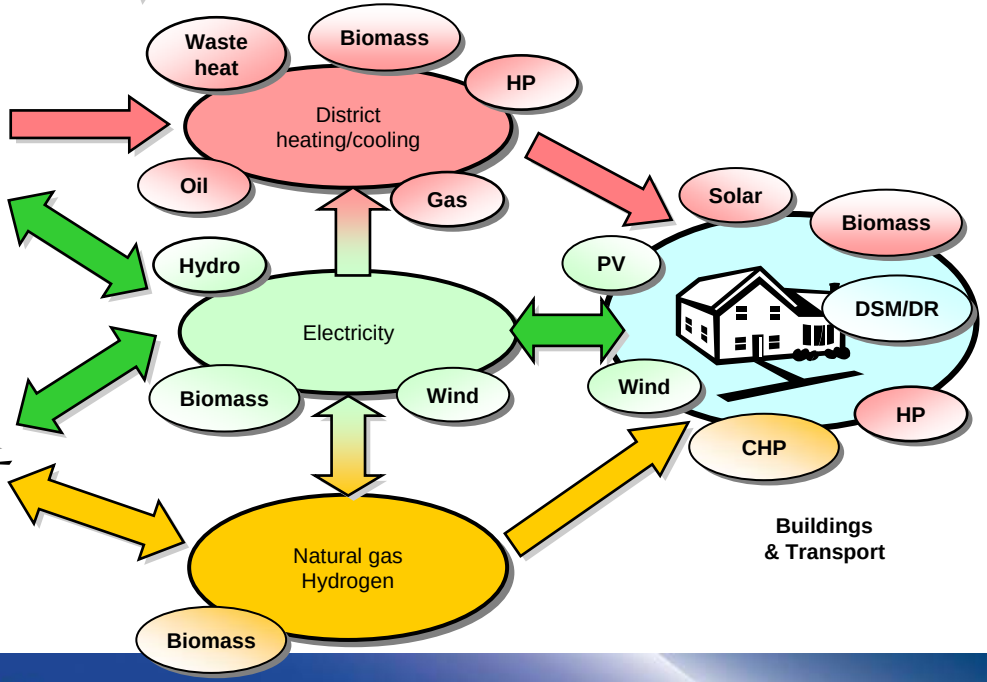
Linking Global and Local Energy Strategies

Joint research program
DoE – OED
UMCP – NTNU
JGCRI/Battelle - SINTEF

Understanding regional impacts of climate targets



Industry
&
Centralized
energy supply



Main objectives

- Find optimal investment strategies in local energy systems from a global perspective but utilizing regional advantages
- Analyze and suggest policy recommendations and instruments supporting a sustainable development of regional energy systems based on regional differences in technology, economy and resources
- Analyze how a given region can contribute to specific emission and climatic targets (e.g. stabilization of atmospheric concentration of CO2 at 550 ppm) in terms of technology
- Analyze how projected climate changes will influence the future development of a regional energy system with increasing share of renewables, both in the demand and supply sectors

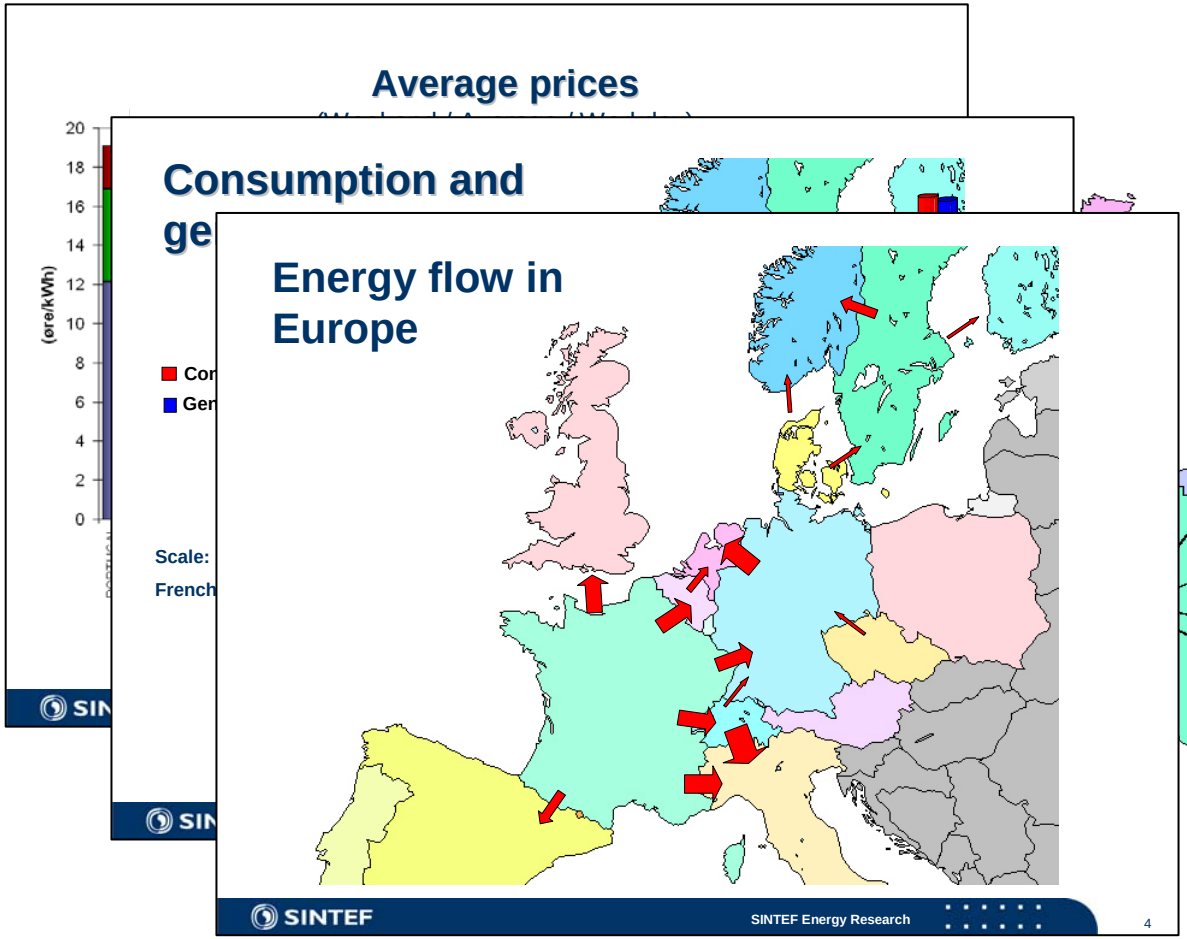
The project will deliver 4 PhD candidates and 10-15 international publications

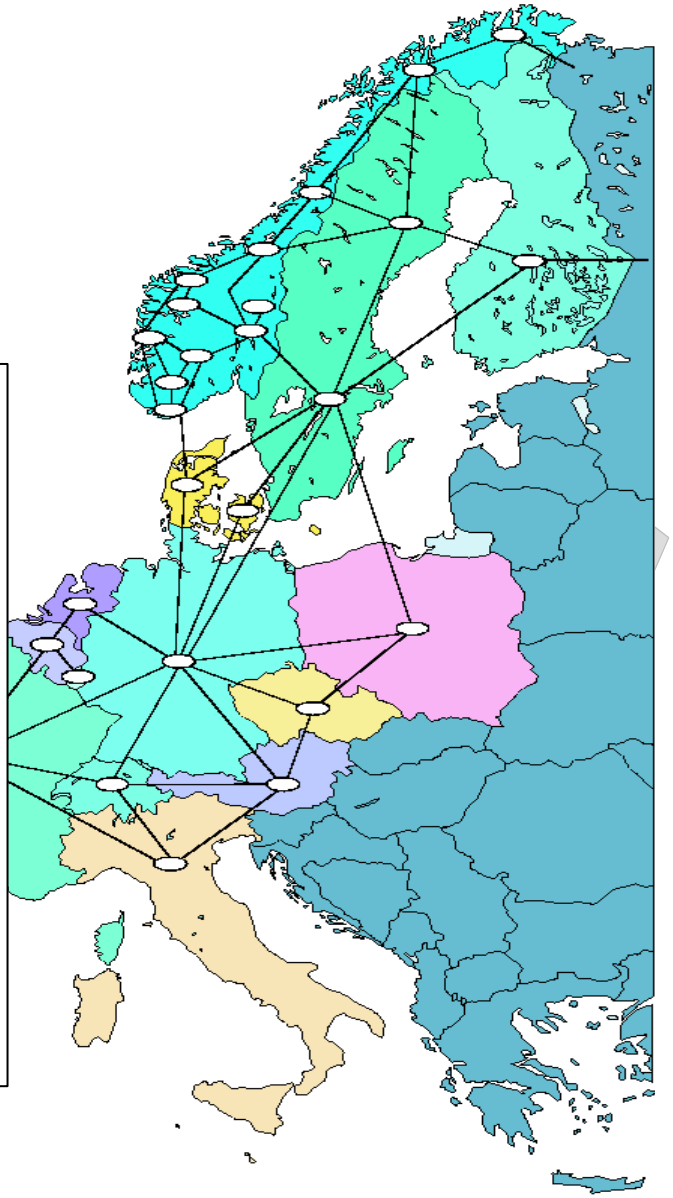
Improve existing studies by

- including stochastic elements in both supply (wind, hydro, solar etc) and demand (temperature etc)
- considering integrated markets of electricity, gas and emissions quotas
- considering uncertainty and risk
- geographic distribution of investments, resources and markets
- including physical infrastructure of electricity grids, gas networks etc
- analysing and giving recommendations with respect to regional governance and policy instruments
- handling different perspectives of business actors vs. governments; corporate vs. socio-economic?

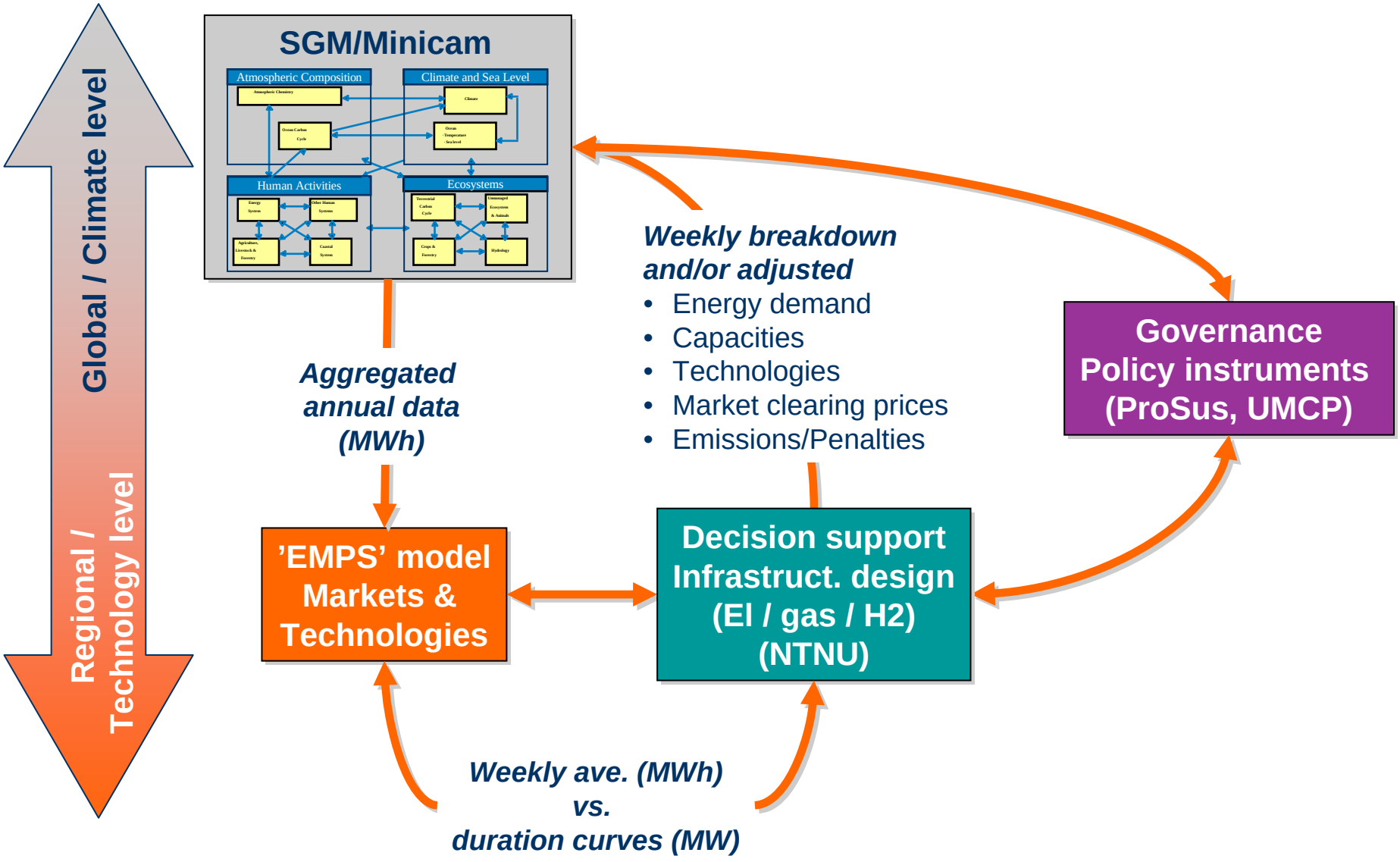
- *Ref. to IEA Energy Outlook 2006, Stern Report etc.*

EMPS model of Europe





Main feedback loops



Top-down data transfer

SGM/Minicam

2020 2025 2030 2035 2040 2045

For each 5-year timestep:

- Investments
- Energy demand (MWh)
- Capacities/Technologies (MWh)
- Climate trajectories (?)
  - temperature?
  - precipitation?
- Quota markets (?)
- Emissions / Emission constraints?

- 70 climatic years
  - precipitation
  - temperatures

- Marginal production cost
- Inter-area transmission capacities
- Generation capacities (MW)

'EMPS' type model

- **operational**
- **static**

Regional analysis

- 70 climatic years
  - precipitation
  - temperatures

- Marginal production cost
- Inter-area transmission capacities
- Generation capacities (MW)

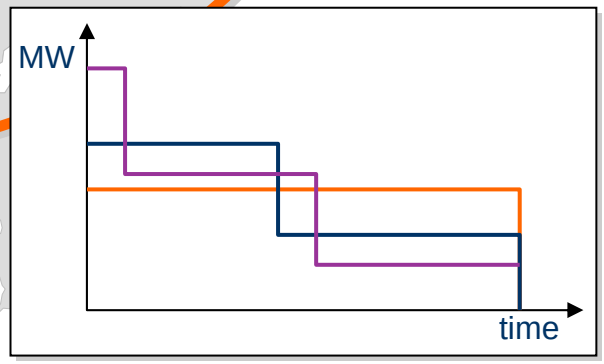
'EMPS' type model
- **operational**
- **static**

MW capacity vs.

MWh generation

Decision support/ Investments (NTNU)

For each 5-year time-step, and quantity portfolio; a stochastic outcome per sub-area per week:
- Energy market clearing price
  - including curtailment cost
- Operation profiles of technologies
- Energy demand
- Emissions / penalties
- 52-104 weeks



Bridging 'engineering' and 'policy implementation

GOVERNANCE MODEL
¨Classic" social science methods

IMPACT MODEL
¨Classic" engineering models
EMPS / SGM

PREFERENCE MODEL
Advanced decision support methods

Recommendations for local/regional technology options and policy instruments

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