



# Tackling Energy Security in Europe: the Role of the Electricity Sector

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# Overview

- Motivation and scope of analysis
- Modeling framework
- Scenario analysis
  - i. Scenario definition
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- Conclusions

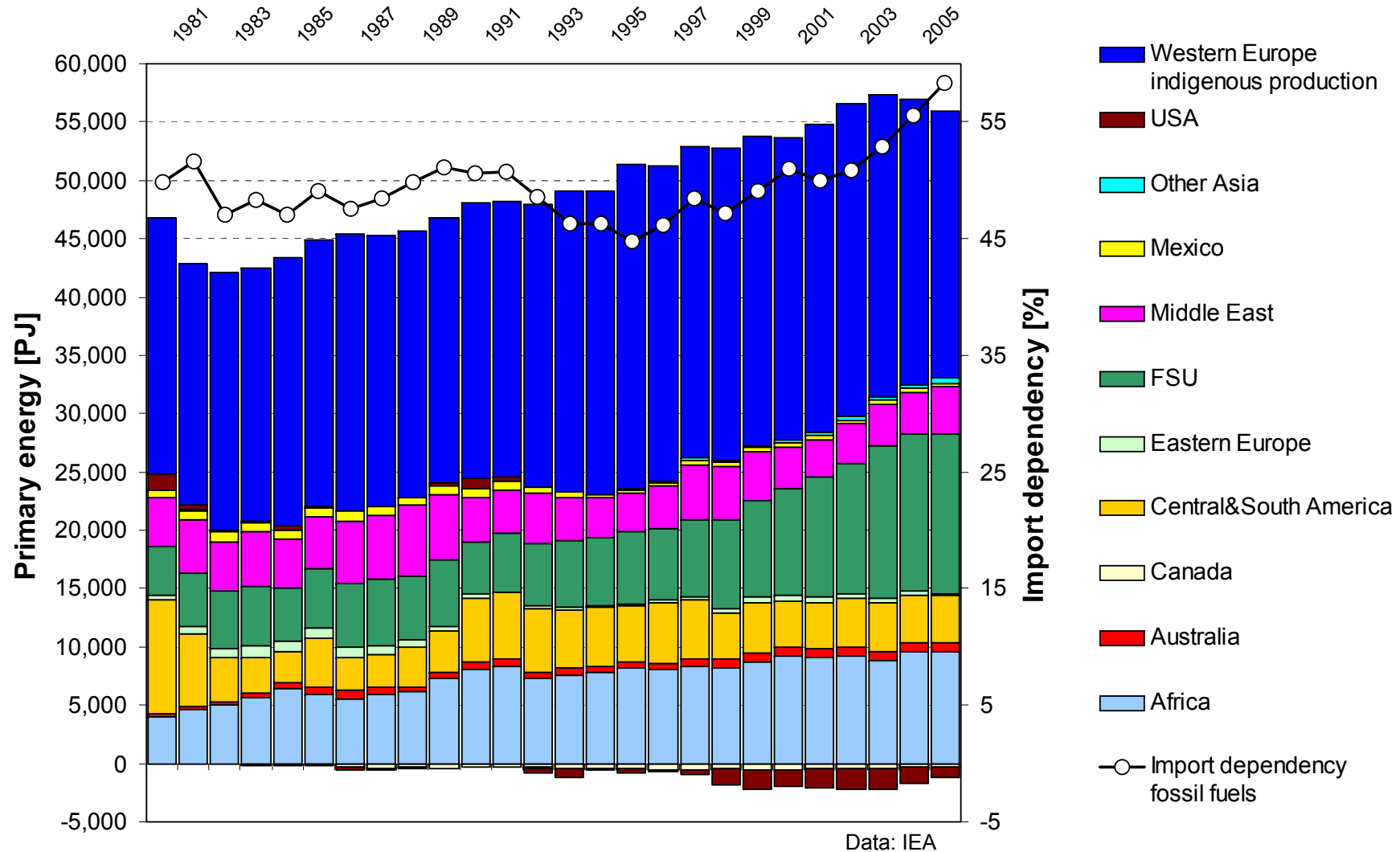


# Aspects of supply security for Western European electricity sector

- **Electricity sector largest consumer of energy imports after transport**
- **Areas of supply security in the electricity sector:**
  - i. Upstream: fuel side
  - ii. Downstream: reliability in the electricity system
- **Factors on the fuel side:**
  - i. Domestic resource situation
  - ii. Share of imported energy carriers
  - iii. Mix of supply countries
  - iv. Transit of energy imports
- **Options in power generation to improve security of supply**
  - i. Efficiency improvements (e.g. CHP)
  - ii. Use of indigenous fossil energy carriers
  - iii. Use of non-fossil energy carriers

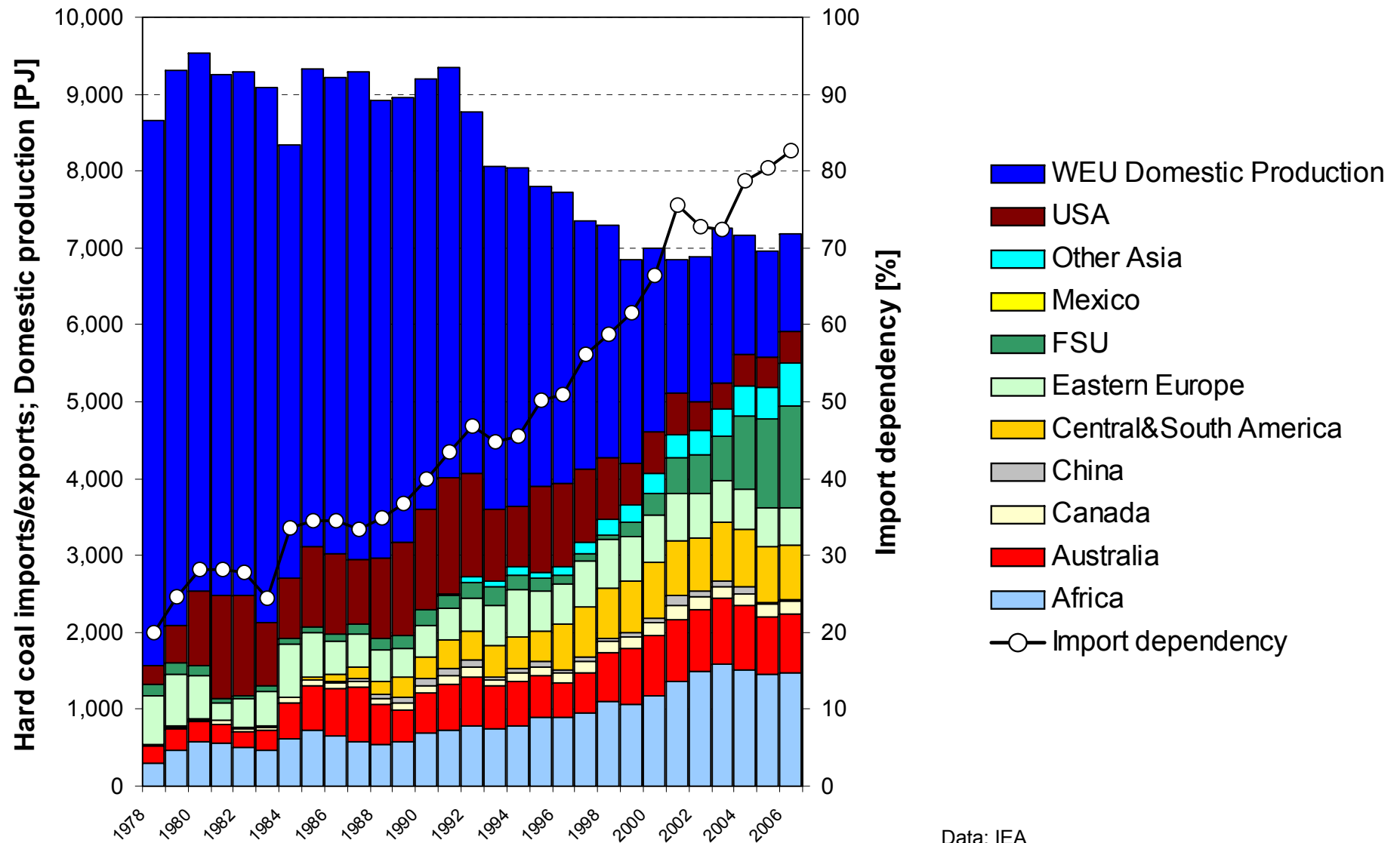


# TPES Supply (Western Europe)





# Hard coal supply (Western Europe)



Data: IEA



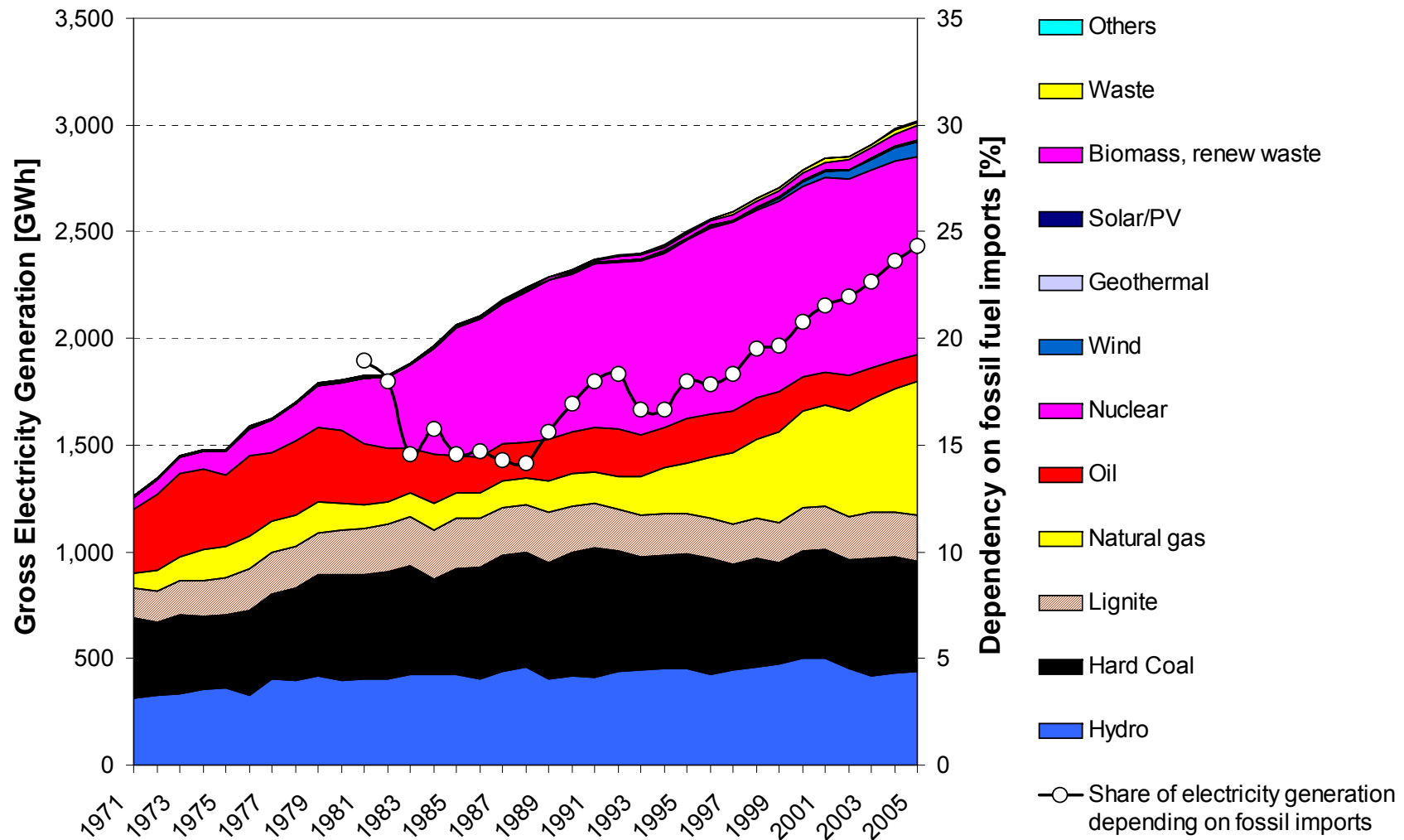
## Resource situation in Western Europe

| <b>Energy carrier</b> | <b>Reserves (end 2005)</b> | <b>Resources (end 2005)</b> | <b>Production 2005</b> |
|-----------------------|----------------------------|-----------------------------|------------------------|
|                       | [EJ]                       | [EJ]                        | [EJ]                   |
| <b>Hard coal</b>      | 34                         | 306                         | 1.3                    |
| <b>Lignite</b>        | 104                        | 809                         | 2.3                    |
| <b>Natural gas</b>    |                            |                             |                        |
| Conventional          | 432                        | 399                         | 10.3                   |
| Unconventional        |                            | 2466                        |                        |
| <b>Oil</b>            |                            |                             |                        |
| Conventional          | 180                        | 386                         | 11.4                   |
| Unconventional        |                            | 214                         |                        |

Data: BGR, WEC



# Electricity Generation (Western Europe)



Data: IEA



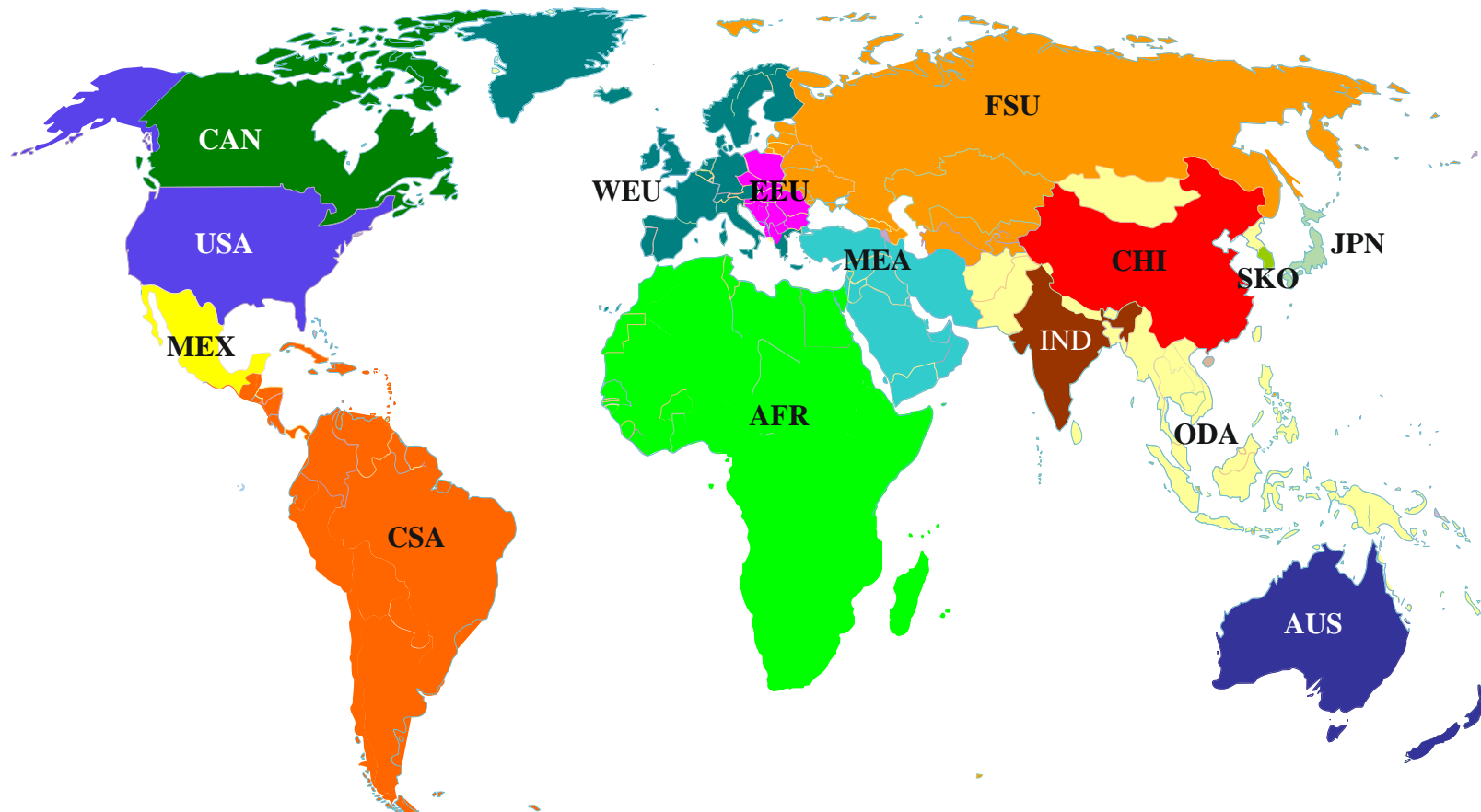
# Analysis framework: TIAM Model

- **TIMES Integrated Analysis Model**
- **Based on TIMES model generator:**
  - i. Developed by ETSAP (*Energy Technology Systems Analysis Programme*)
  - ii. Dynamic partial equilibrium model approach with inter-temporal objective function (perfect foresight) minimizing total discounted system costs
  - iii. Technologically detailed „bottom-up“ model for each region
  - iv. Covering energy flows from the useful energy demand over end-use sectors and conversion sector to the primary supply
- **Time horizon 2000 – 2100**
- **15 world regions with**
  - i. Bilateral trade in hard coal, pipeline gas, LNG, crude oil, petroleum products (distillates, gasoline, heavy fuel oil and naphtha) and bioethanol
  - ii. Global trade in emission permits possible
- **Emissions: CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>**
  - i. Carbon capture and sequestration (power generation and alternative fuel production)
  - ii. Mitigation options for N<sub>2</sub>O and CH<sub>4</sub>
- **Climate module** (3-reservoir model for calculating atmospheric CO<sub>2</sub> concentrations)





# Model regions



15 World regions:

CAN, USA, MEX, CSA (Central South America), WEU (Western Europe), EEU (Eastern Europe), MEA (Middle East), FSU (Former Soviet Union), CHI, IND, SKO (South Korea), JPN, ODA (Other Developing Asia), AUS (Australia+New Zealand)



## Scenario definition

- **BASE** scenario: no explicit security of supply or climate protection policies
- Security of supply scenarios:
  - i. **SQ50**:
    - Reducing share of coal, natural gas and petroleum imports in consumption to 50% for each fuel by 2050
    - Limiting market share of a single importer to 25% of total imports by 2050
  - ii. **TQ50**:
    - As SQ50, but reducing combined share of coal, natural gas and petroleum imports to 50% by 2050
- Variants:
  - i. CO2 reduction scenarios:
    1. **CO2**: Reduction scenario yielding same CO2 emissions levels as in SQ50
    2. **CO2-NOCCS**: excluding CCS
  - ii. **SQ50-NUC**: 50% higher nuclear generation in 2050 compared to SQ50
  - iii. **OG50**: import quotas for oil and gas, but not for coal



## Scenario assumptions

- Population [million]

|       | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
|-------|------|------|------|------|------|------|
| WEU   | 394  | 396  | 397  | 396  | 394  | 391  |
| World | 6409 | 6757 | 7390 | 7942 | 8511 | 9015 |

- GDP growth [%]

|       | 2005-2010 | 2010-2020 | 2020-2030 | 2030-2040 | 2040-2050 |
|-------|-----------|-----------|-----------|-----------|-----------|
| WEU   | 2.0%      | 2.2%      | 2.1%      | 1.9%      | 1.7%      |
| World | 3.1%      | 2.9%      | 2.8%      | 2.6%      | 2.5%      |

- Import prices

for Western  
Europe

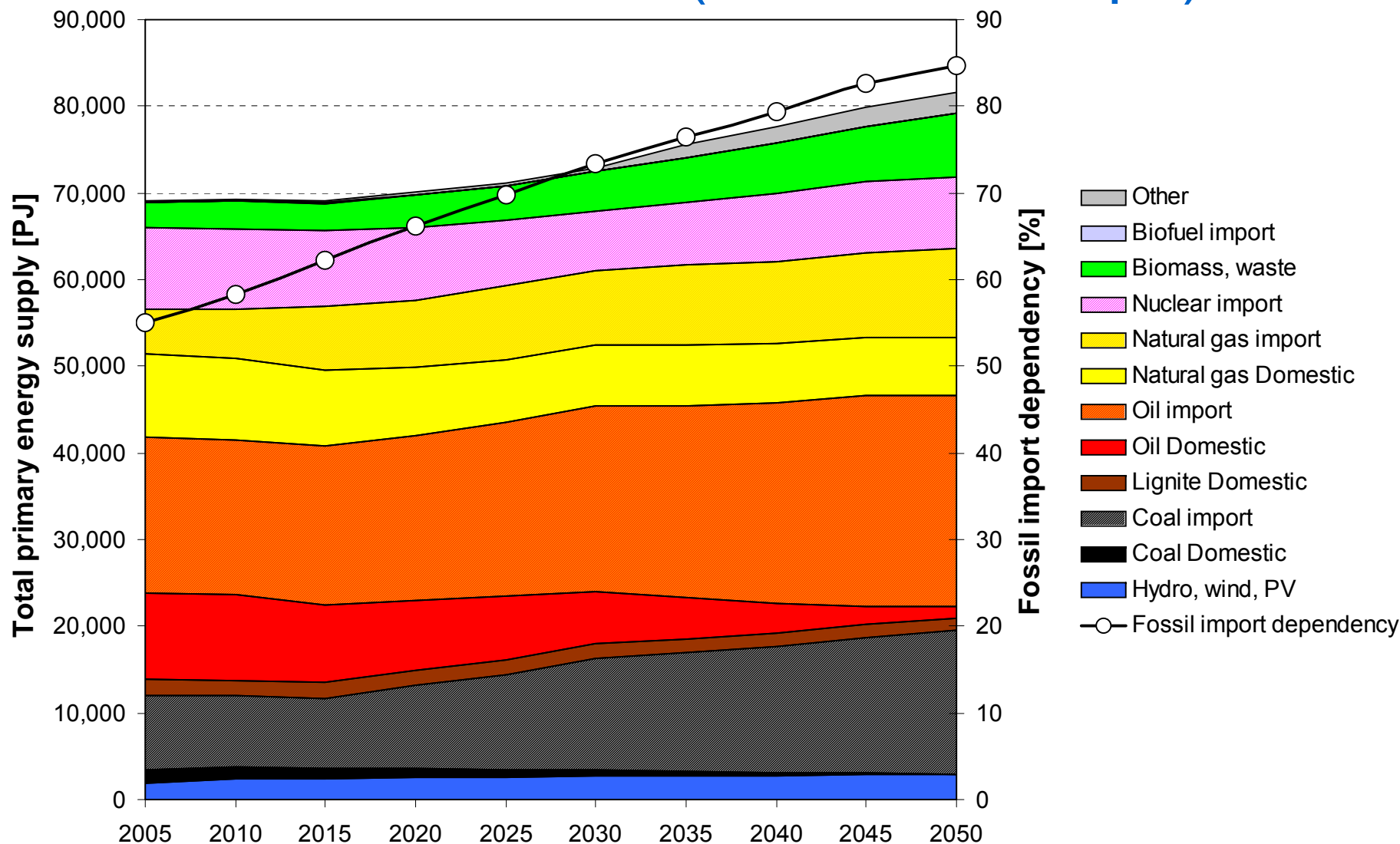
|             |            | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
|-------------|------------|------|------|------|------|------|------|
| Hard coal   | \$2005/GJ  | 2.4  | 1.6  | 1.8  | 1.9  | 2.0  | 2.0  |
| Natural gas | \$2005/GJ  | 8.1  | 7.3  | 7.9  | 8.4  | 8.8  | 9.4  |
| Crude oil   | \$2005/boe | 77   | 51   | 55   | 59   | 61   | 66   |

- Nuclear policy:

- Replacement and expansion only in countries that already use nuclear today
- Phase-out in DE, SE, BE, ES, NL

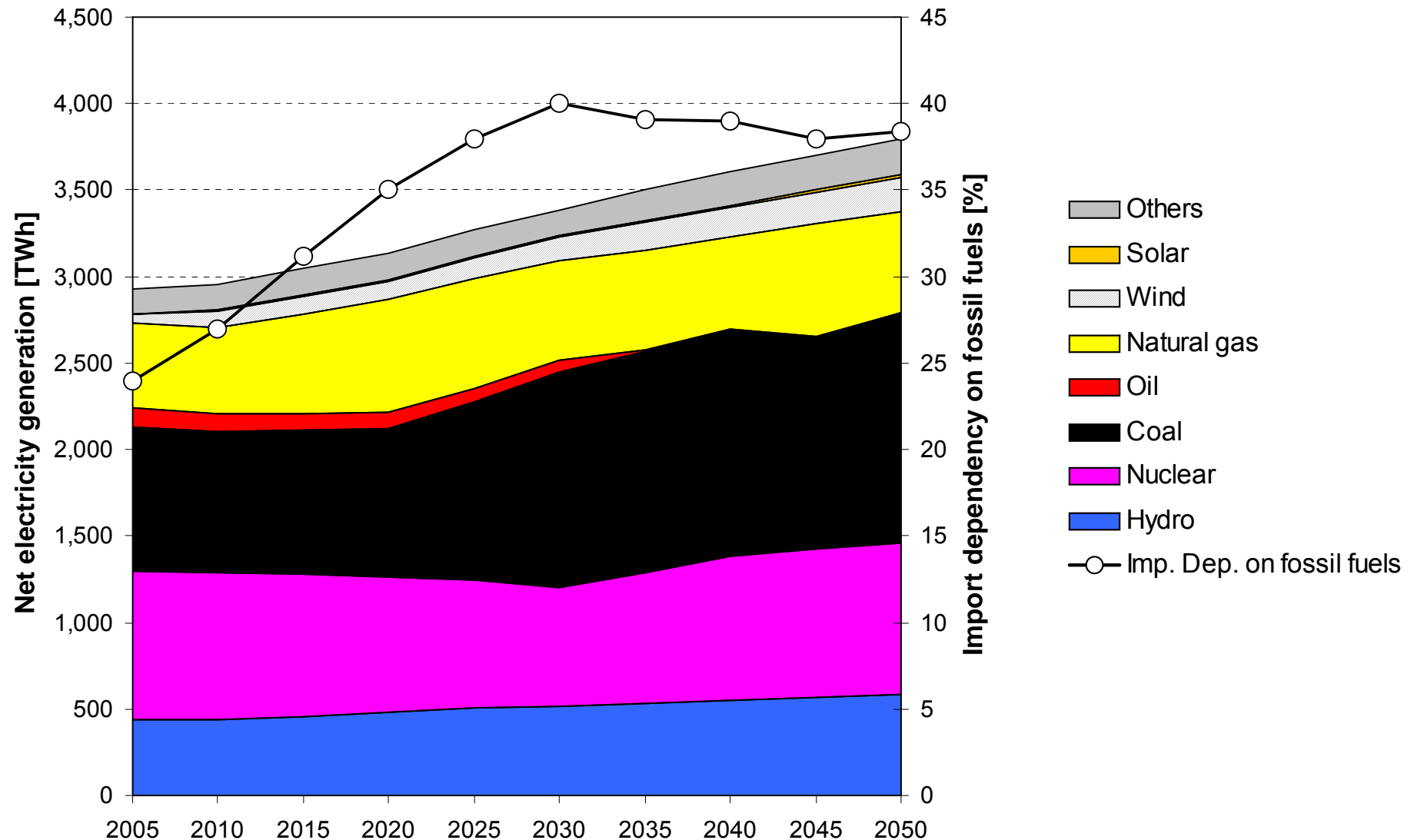


# TPES in BASE scenario (Western Europe)



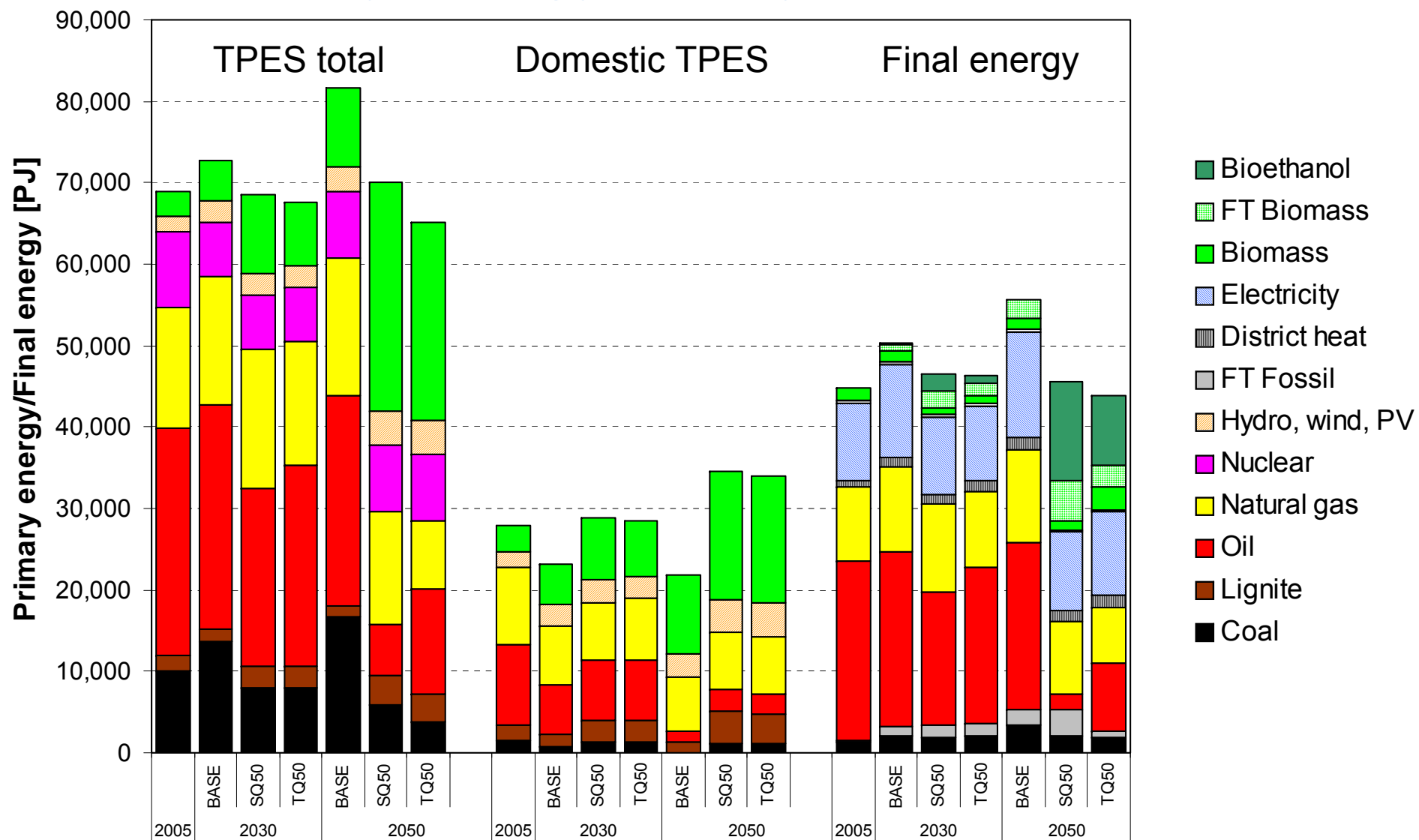


# Electricity generation in BASE scenario



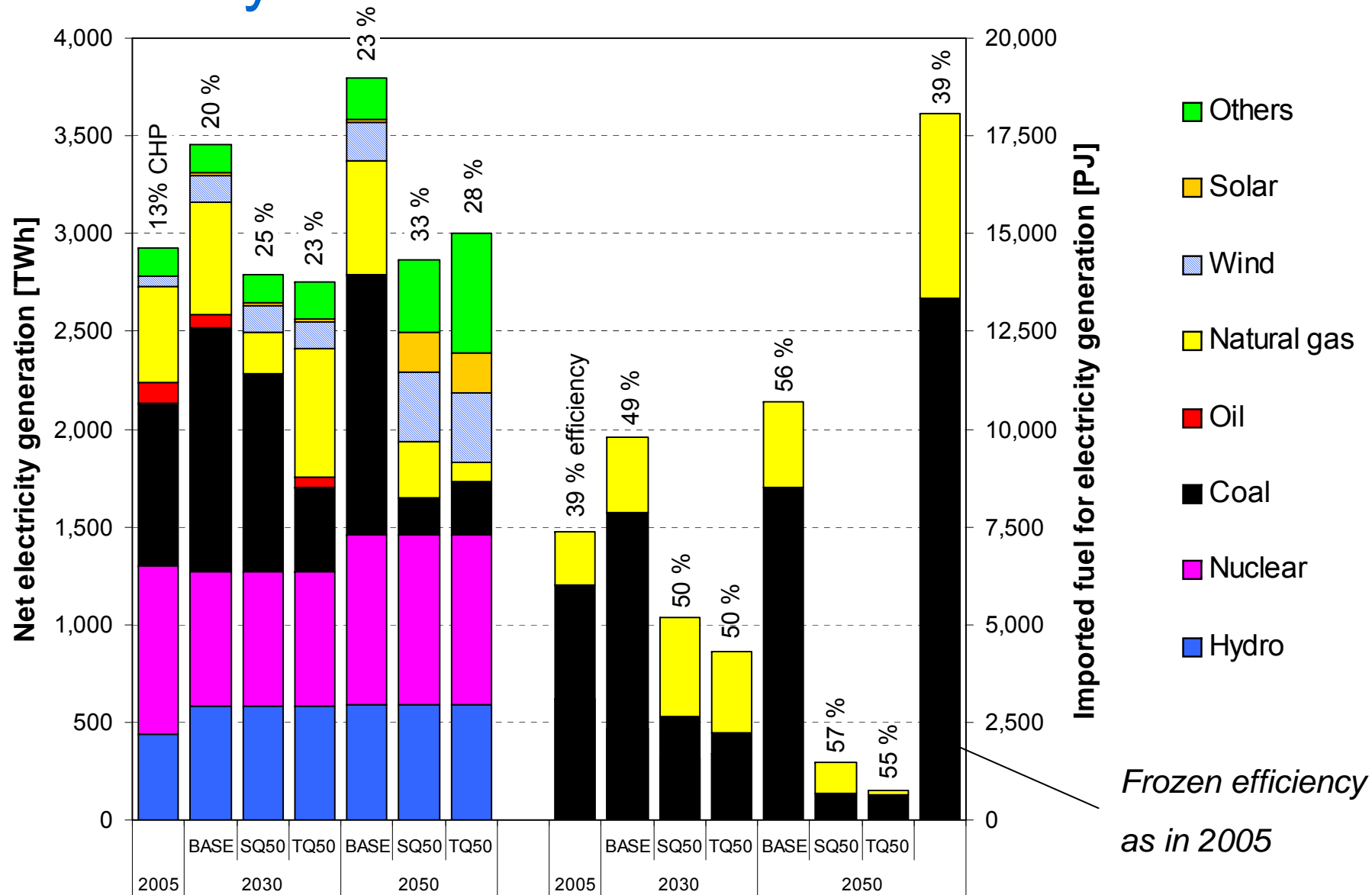


# Total primary energy supply



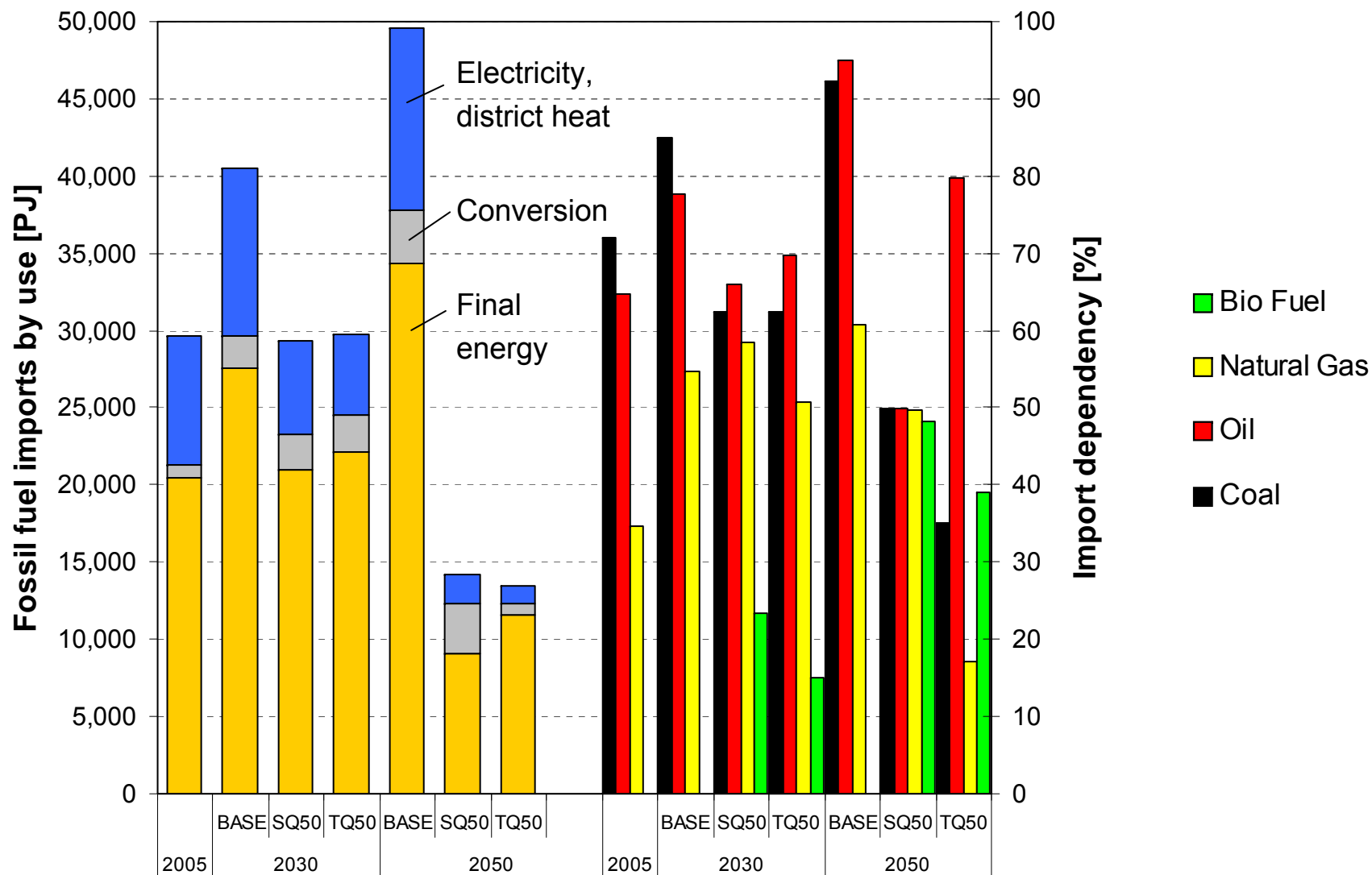


# Electricity Generation





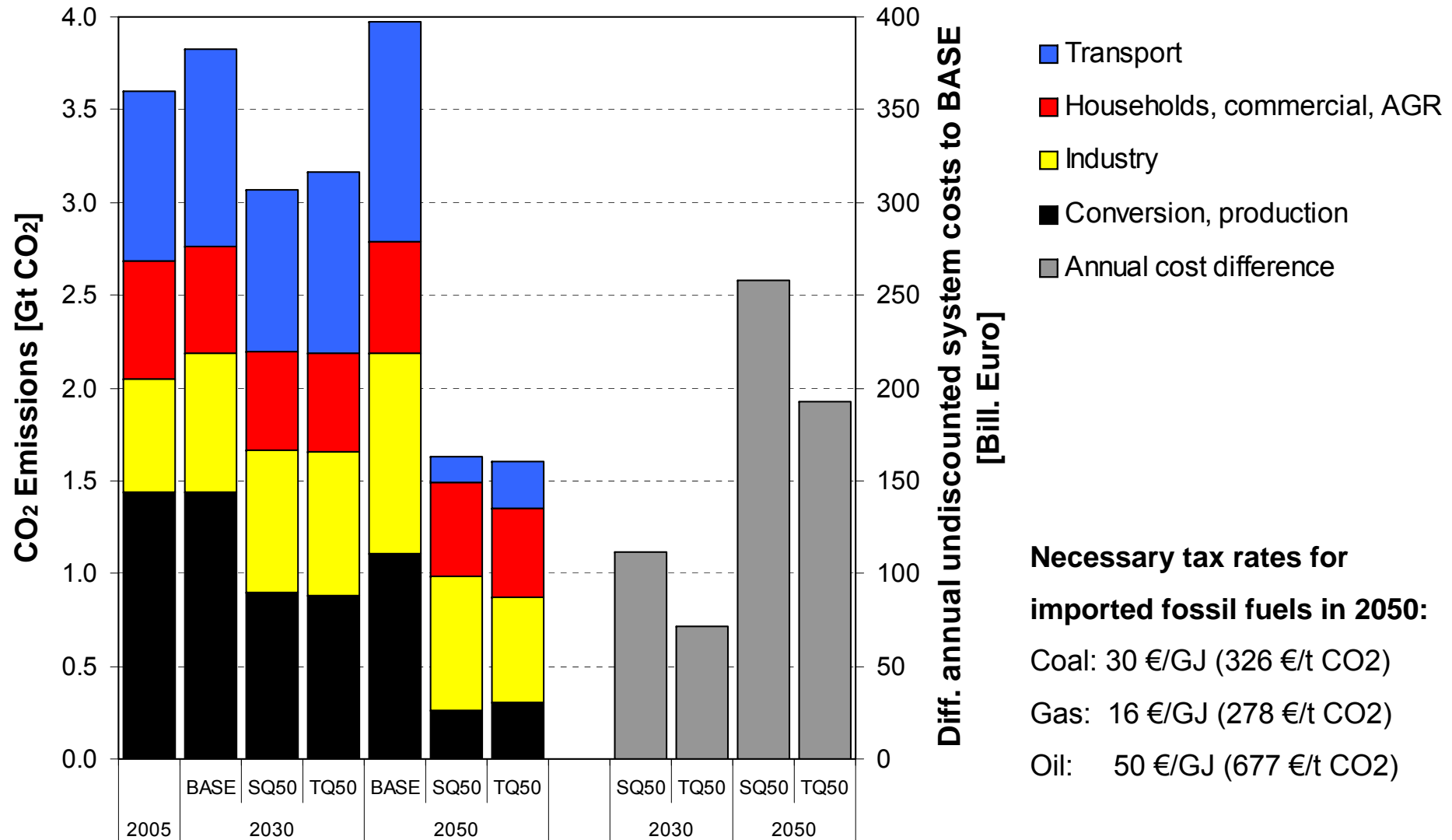
# Net energy imports and import dependency





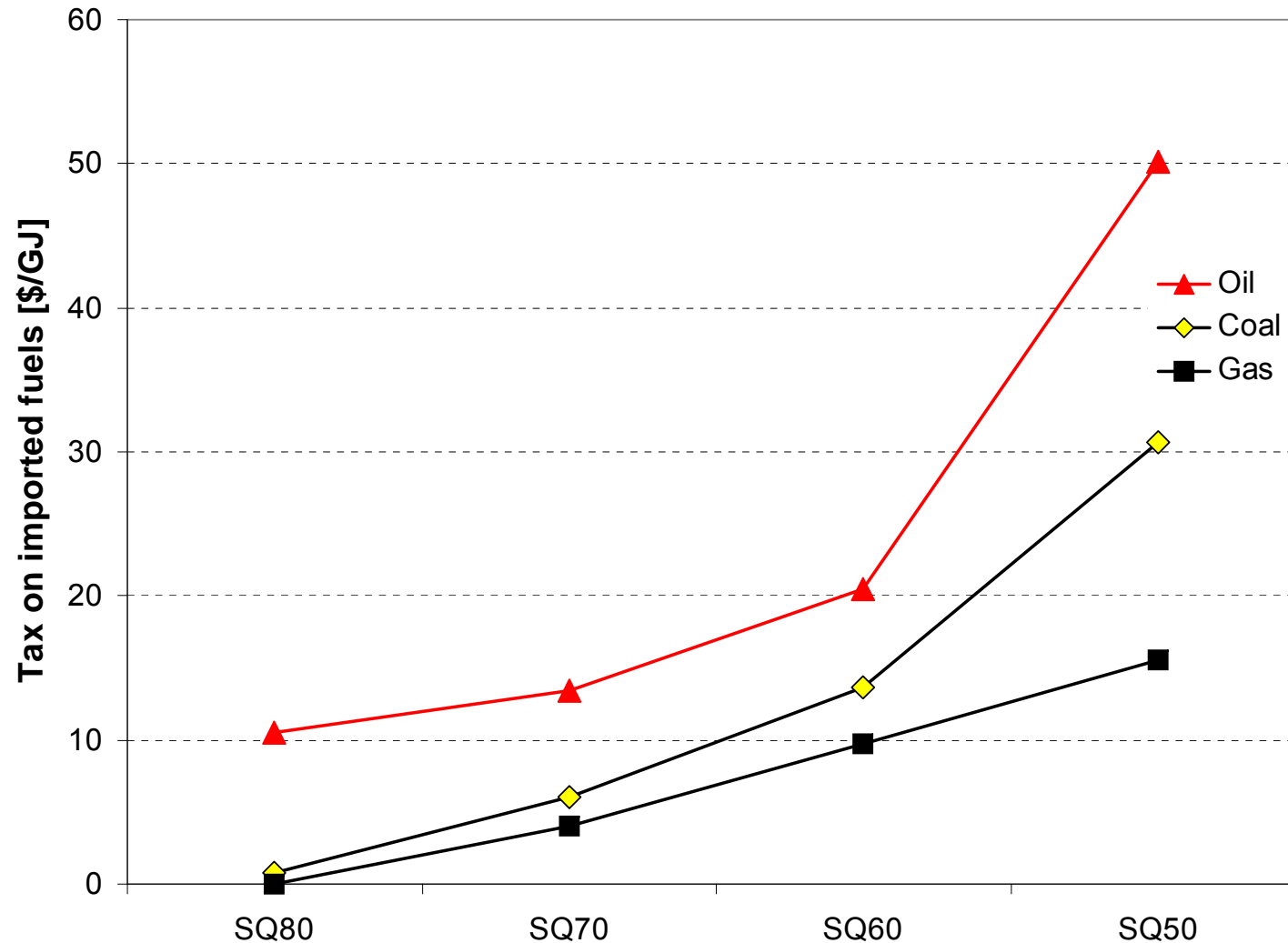


# CO<sub>2</sub> and cost implications



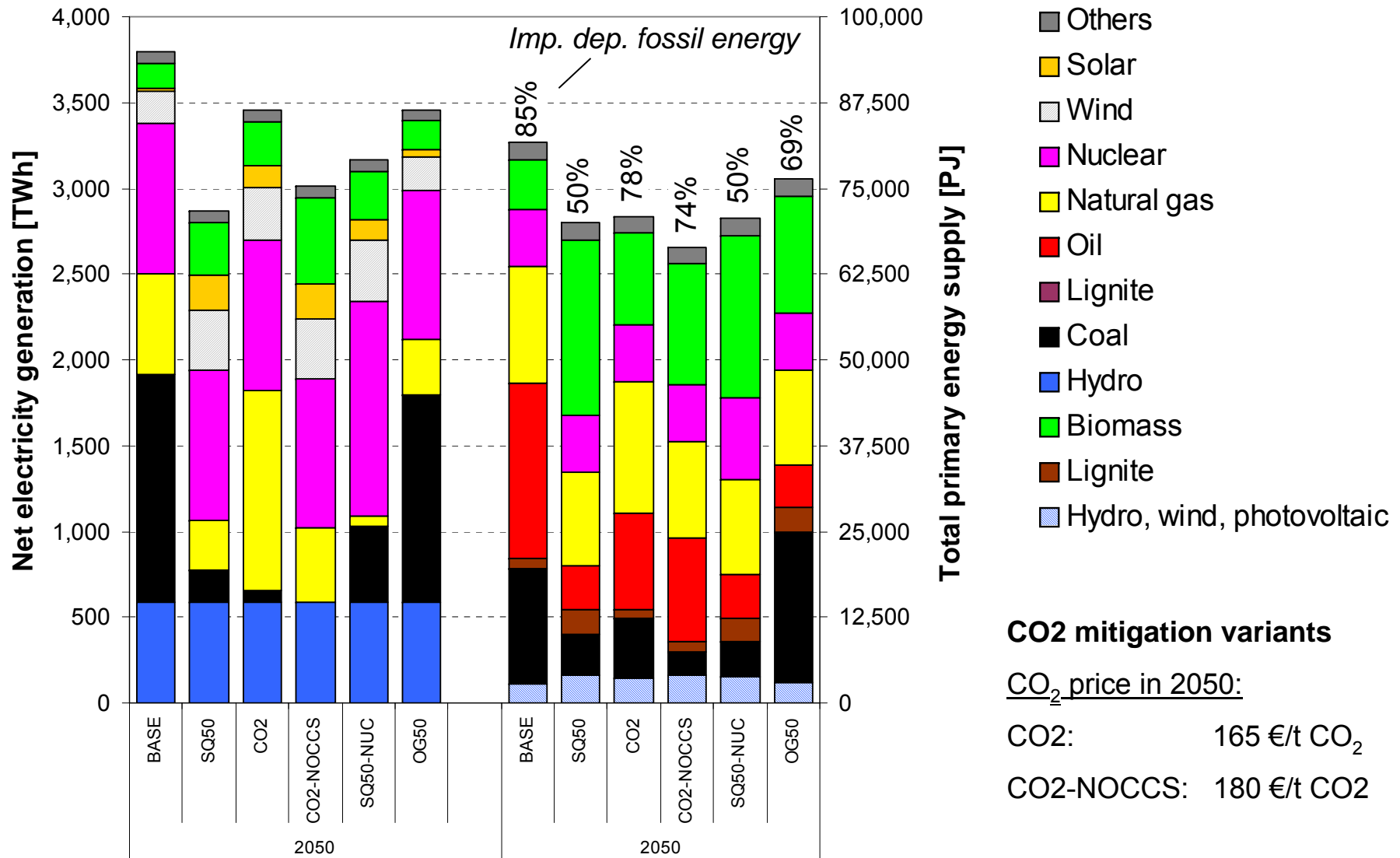


# Sensitivity of tax on quota level





# Variants





# Conclusions

- **BASE scenario** without taking any explicit security of supply measures:
  - i. Imported dependency of TPES on fossil fuels expected to increase from 55% in 2005 to 85% in 2050.
  - ii. Dependency of electricity generation on fossil imports increases from 25% to 38% in the same time frame
- Measures to reduce import dependency (**SQ50** scenario):
  - i. End use sectors: energy efficiency, biofuels in transport  
-> Fossil import dependency of final energy demand reduces to 24%.
  - ii. CO<sub>2</sub> emission can be halved, however, at high costs compared to pure CO<sub>2</sub> mitigation target.
  - iii. Electricity generation: plant efficiencies (already in BASE), CHP, Renewables (58% in 2050)  
-> Fossil import dependency of electricity drops to 7%.
- Flexibility in import quotas (**TQ50**):
  - i. Reduced use of imported coal and especially natural gas in power generation to allow higher dependency on oil for transportation.
- **Variants:**
  - i. CO<sub>2</sub> mitigation targets reduce fossil fuel use in power generation (if CCS is not available), but to lower degree in other sectors
  - ii. Nuclear in combination with hydrogen can be in option to reduce oil use in transport.
  - iii. Quotas only on oil and gas (OG50) increase coal imports being used to produce CTL fuels for transportation.