PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

14th IAEE European Energy Conference, Rome, 31st Oct 2014

Rajesh Mathew Pattupara, Kannan Ramachandran
Paul Scherrer Institute, Switzerland

Exploring uncertainties in CCS – De-carbonization of the power sector & country-wise opportunities

Outline

- Introduction – European nuclear phase-out and its consequences
- CROSSTEM Model
- Scenarios & Key Assumptions
- Results
- Conclusions
- Model limitations, issues and challenges

European Nuclear phase-out - Background

- **Low carbon pathway for electricity** – EU Roadmap 2050

- **"Nuclear Renaissance"** – Switzerland and France to continue with its nuclear program. Italy to have 25% of net generation from nuclear by 2030. Germany to extend life times of existing plans[1].

- **Fukushima Accident** – Socio-political consequences

- **Nuclear phase-out**
  - Germany by 2022
  - Switzerland by 2034
  - Italy to continue with its nuclear moratorium
  - France to reduce share from 75% to 50% by 2025 (?)

1. http://www.world-nuclear.org

.

European Nuclear phase-out - Background

- **Alternative supply options –** Germany substituting nuclear power with coal based generation → 43% (2010) to 52%(2013)

- **Green house gas (GHG) reductions** – Complete de-carbonization of power sector by 2050

.

Alternative low carbon sources of electricity

- Carbon Capture and Storage (CCS) and Renewables

- Technical, Economical and Social challenges and uncertainties

Literature review – Other modelling frameworks

Lohwasser, R. and R. Madlener (2012). "Economics of CCS for coal plants: Impact of investment costs and efficiency on market diffusion in Europe." Energy Economics **34**(3): 850-863.

Viebahn, P., et al. (2012). "Integrated assessment of carbon capture and storage (CCS) in the German power sector and comparison with the deployment of renewable energies." Applied Energy **97**: 238-248.

Selosse, S., et al. (2013). "Fukushima's impact on the European power sector: The key role of CCS technologies." Energy Economics **39**: 305-312.

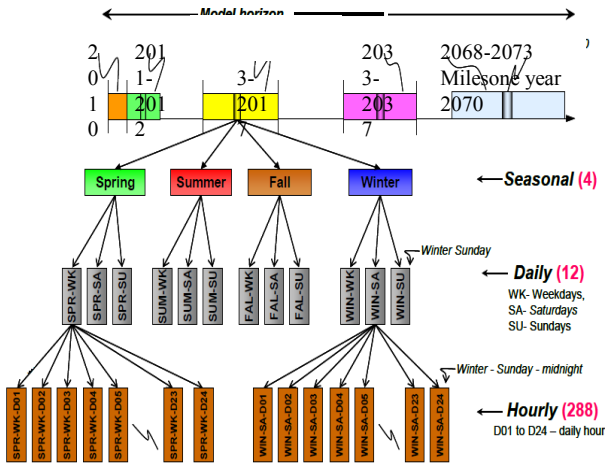
Kjärstad, J., et al. (2013). "Modelling Large-scale CCS Development in Europe Linking Techno- economic Modelling to Transport Infrastructure." Energy Procedia **37**: 2941-2948.

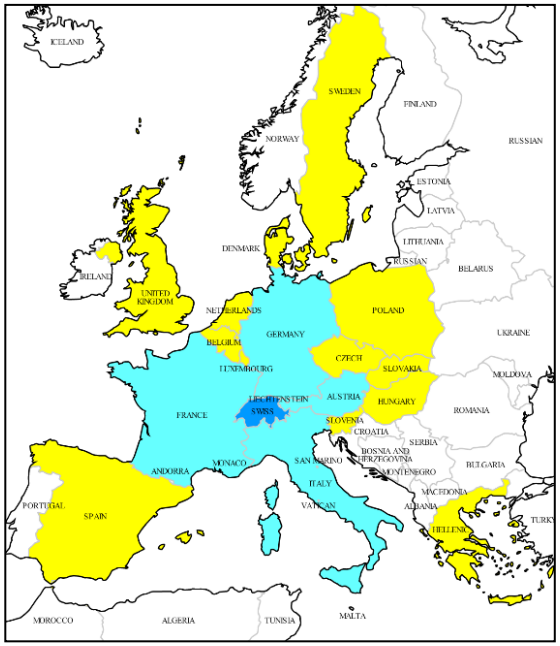
Lohwasser, R. and R. Madlener (2009). Simulation of the European Electricity Market and CCS Development with the HECTOR Model, E.ON Energy Research Center, Future Energy Consumer Needs and Behavior (FCN).

Martinsen, D., et al. (2007). "CCS: A future CO2 mitigation option for Germany?—A bottom-up approach." Energy Policy **35**(4): 2110-2120.

CROSSTEM Model

- **CROS**s border **S**wiss **T**IMES **E**lectricity **M**odel
- Extension of the STEM-E model to include the four neighbouring countries
- Time horizon: 2010 – 2070
- An hourly timeslice (288 timeslices)
- Detailed reference electricity system with resource supply, renewable potentials and demands for 5 countries
- Calibrated for electricity demand and supply data between 2000-2010
- **Endogenous** electricity import / export based on costs and technical characteristics





Research Questions

- How can these countries decarbonise their power sector ?
- What would be the role of CCS ?
- How can countries with higher CCS potentials help in the decarbonisation of the neighbouring countries ?

Scenarios

2 basic scenarios and 3 CCS scenario variants selected for Analysis

- ***Reference Scenario (REF)*** – Nuclear policies of 5 countries implemented. No CO_2 emission targets. Nuclear phase-out in Switzerland by 2034, Germany by 2022. France has the option to invest in nuclear.

- ***CO2 reduction scenario (CO2-Base)*** – REF scenario with a cap on the total CO_2 emission from electricity generation is applied across all regions. Level of decarbonisation to reach 60% of 1990 levels by 2030, 95% by 2050.

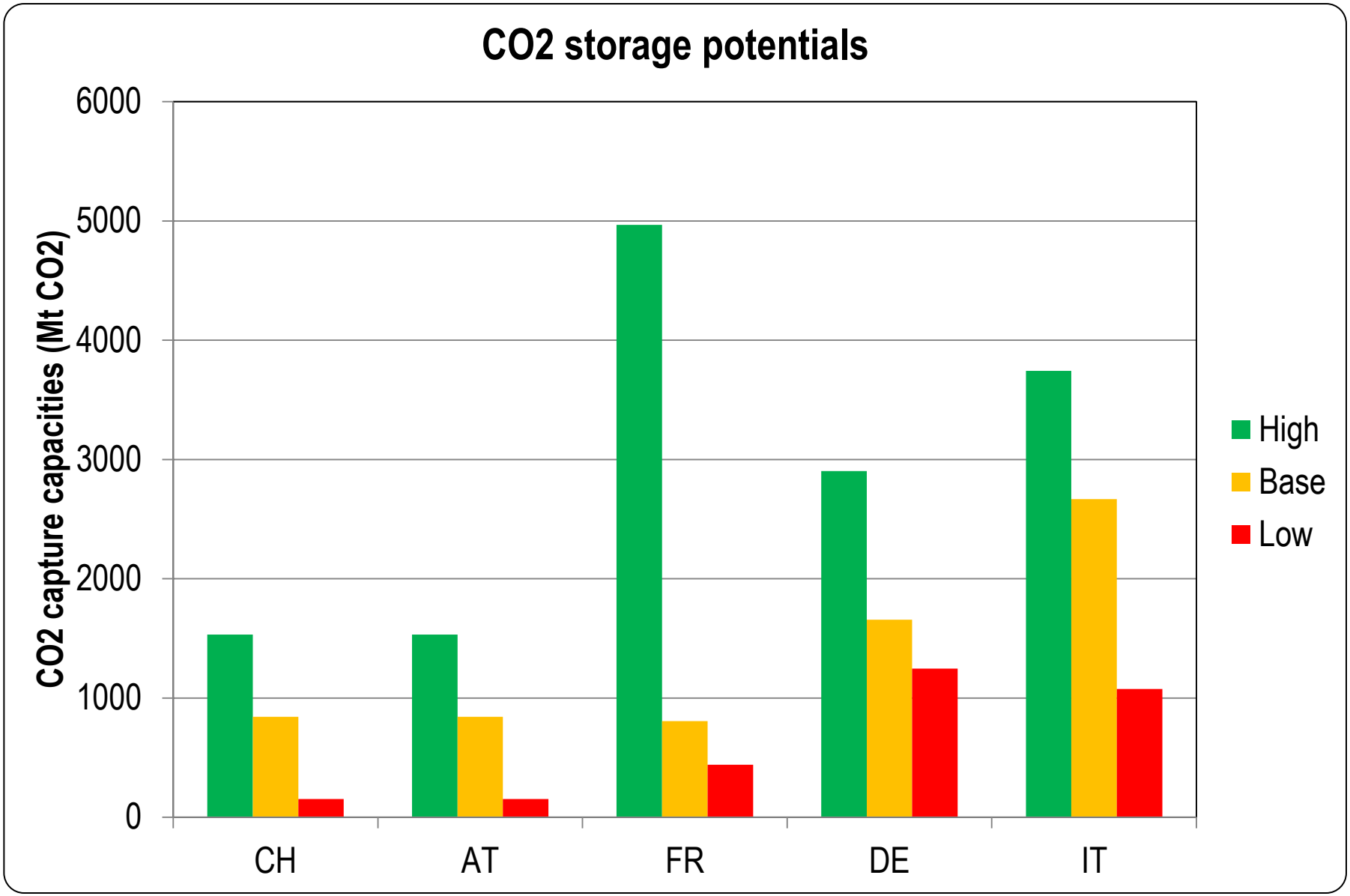
CCS Scenario variants

- ***High CCS scenario (CO2-CCS-H)*** – Upper variant of CCS potentials. (Aquefiers + Hydrocarbon fields)

- ***Low CCS scenario (CO2-CCS-L)*** – Lower variant of CCS potentials. (Hydrocarbon fields only)

- ***No CCS scenario (CO2-NoCCS)*** – No investment in CCS technology. Free trade allowed in this scenario.

CCS Scenario variants



Key assumptions

Input Assumptions

- **Electricity Demand** – EU Trends to 2050 (Reference scenario), BAU demands for CH (SES 2050)
- **Trade with "fringe regions"** – Historical limits applied
- **CO2 price** – European ETS prices implemented (SES 2050, Bfe)
- **Fuel Prices** – International fuel prices from WEO 2010.

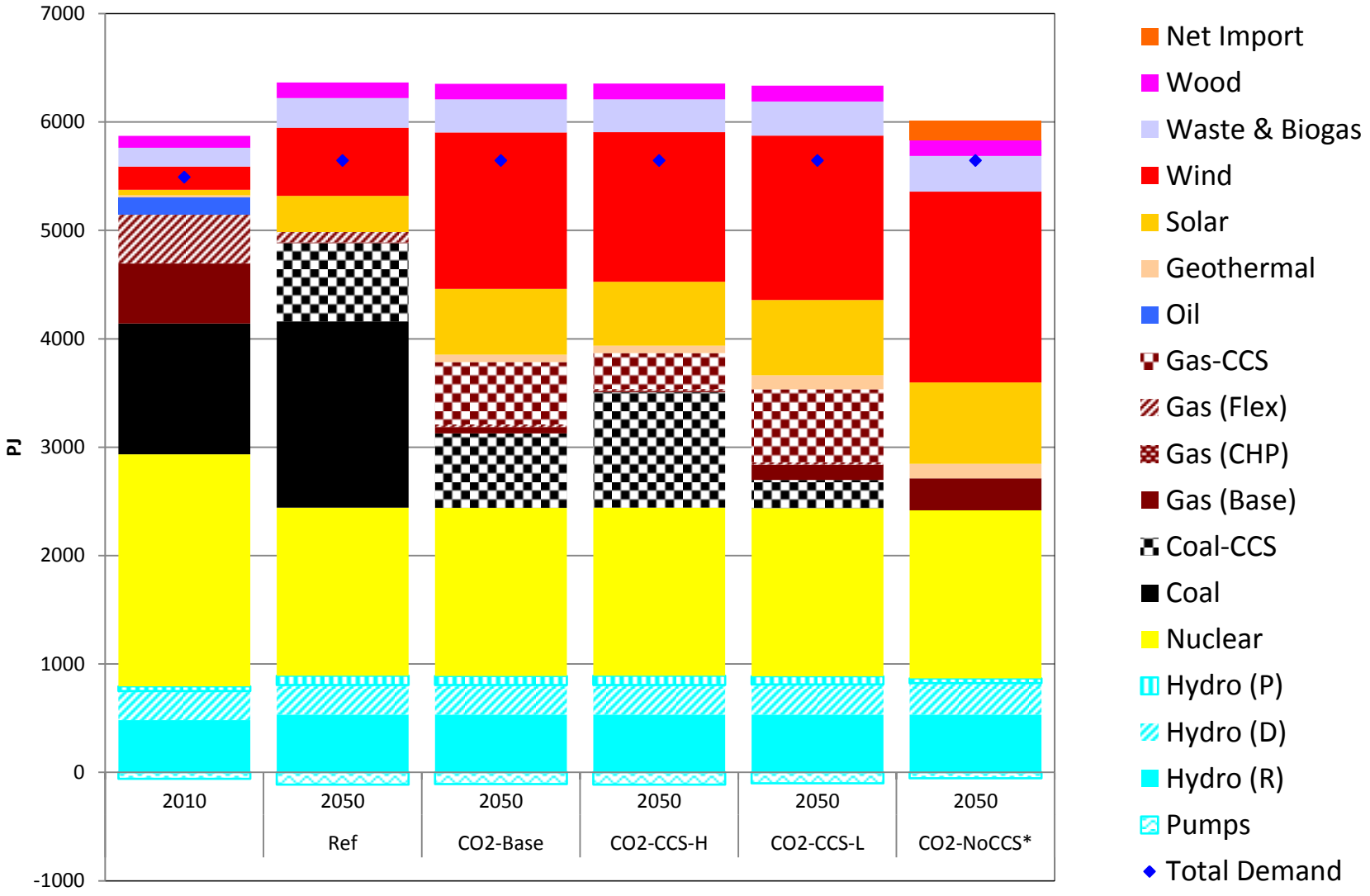
Methodological Assumptions

- **Copper Plate regions** – No transmission and distribution infrastructure within each country. Interconnectors between regions, with no trade loss.
- **Endogenous trade limits** – Based on historical trends. Net importers cannot become net exporters and vice versa. Not applied to NoCCS.

.

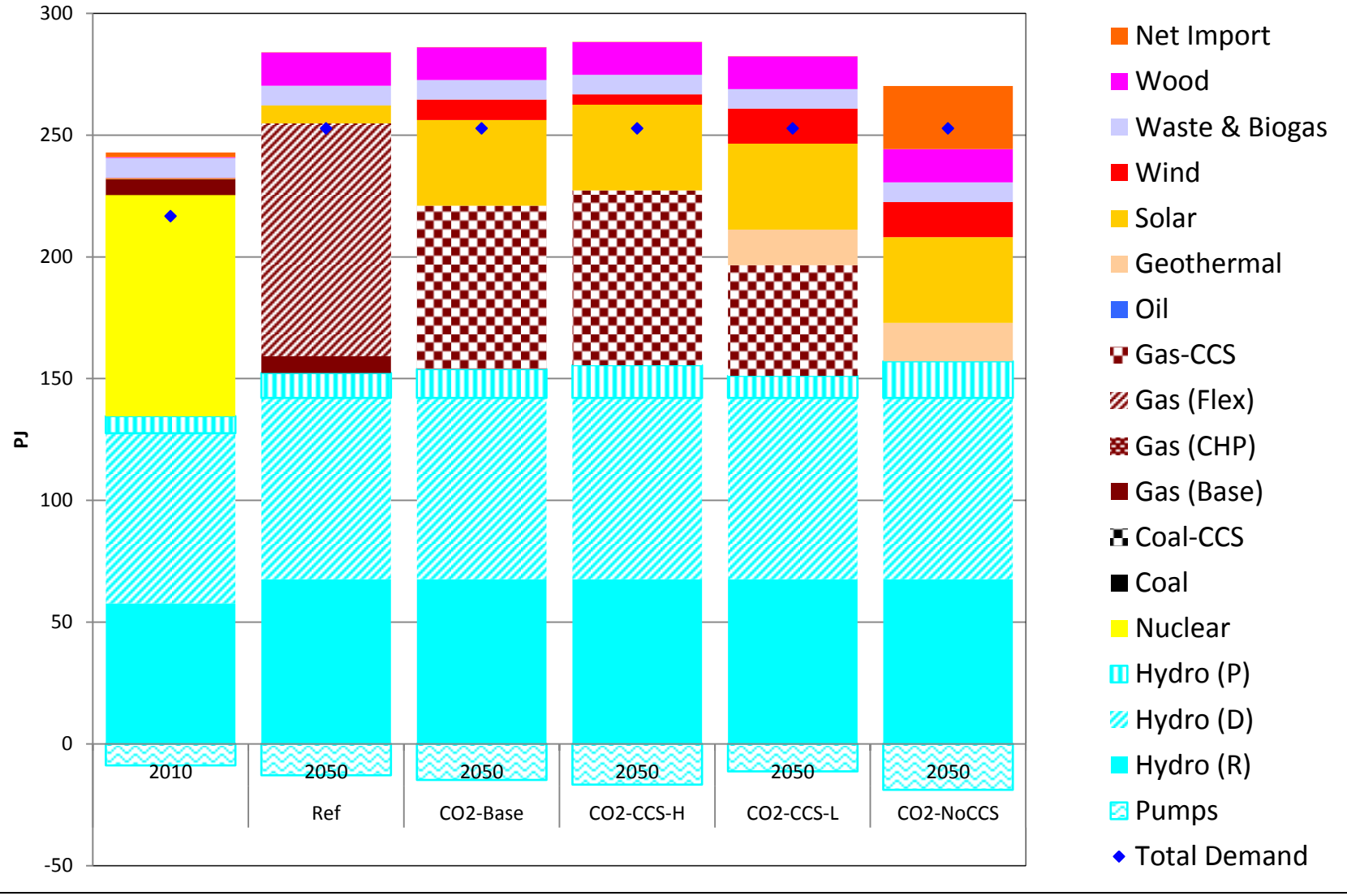
Aggregated Results

Electricity generation mix – 5 countries aggregated



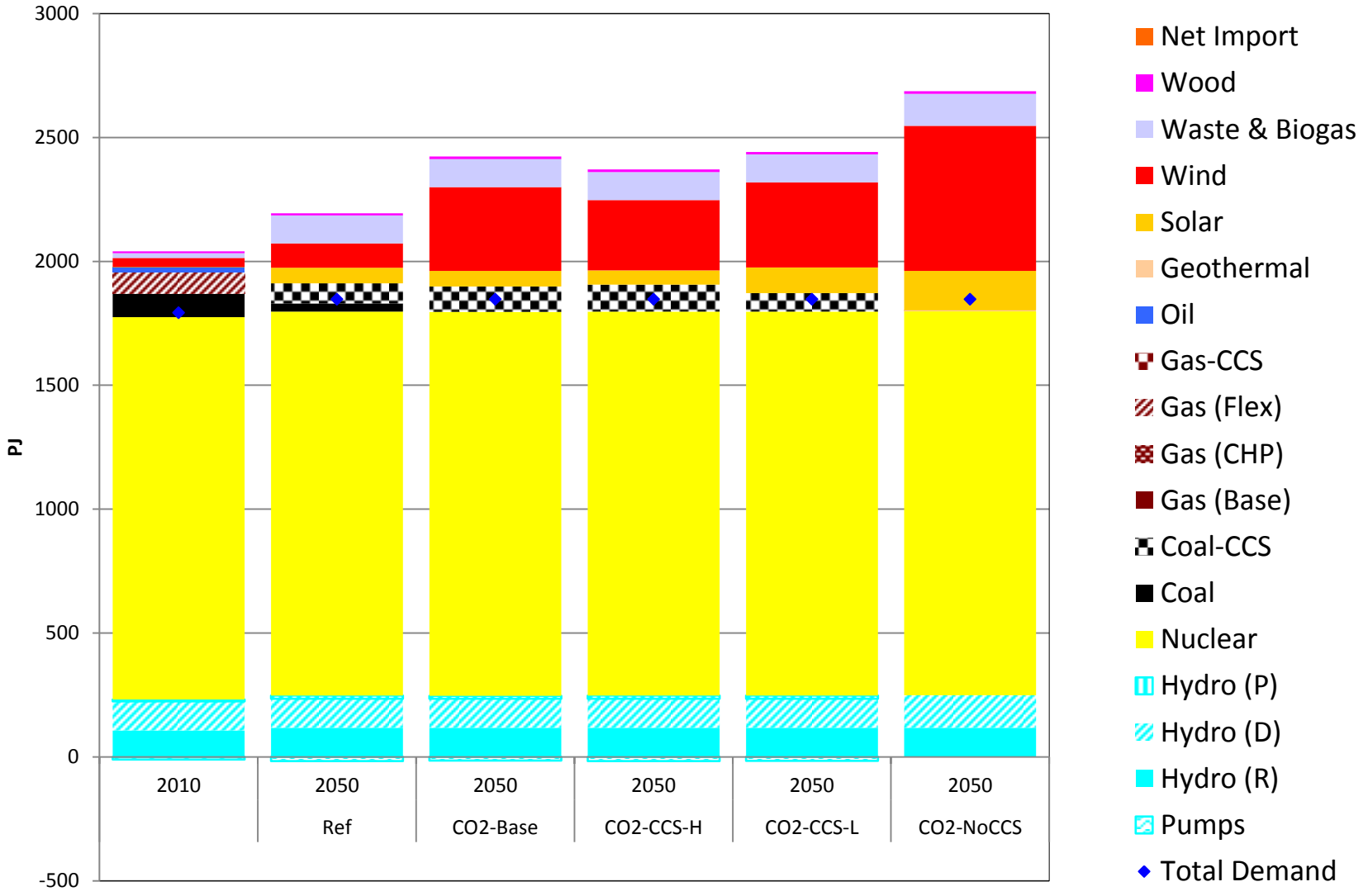
Country wise Results

Electricity generation mix - Switzerland



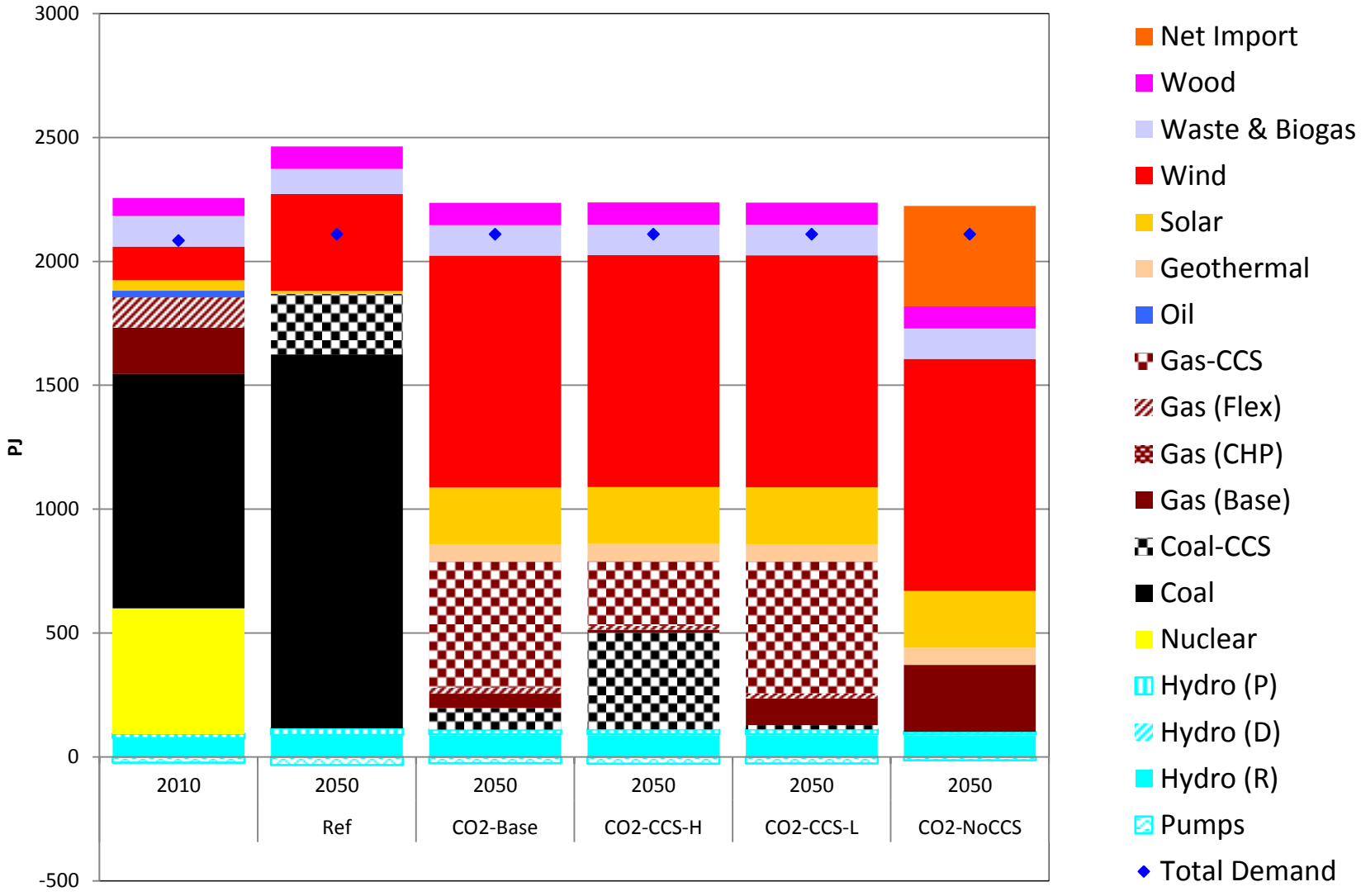
Country wise Results

Electricity generation mix - France



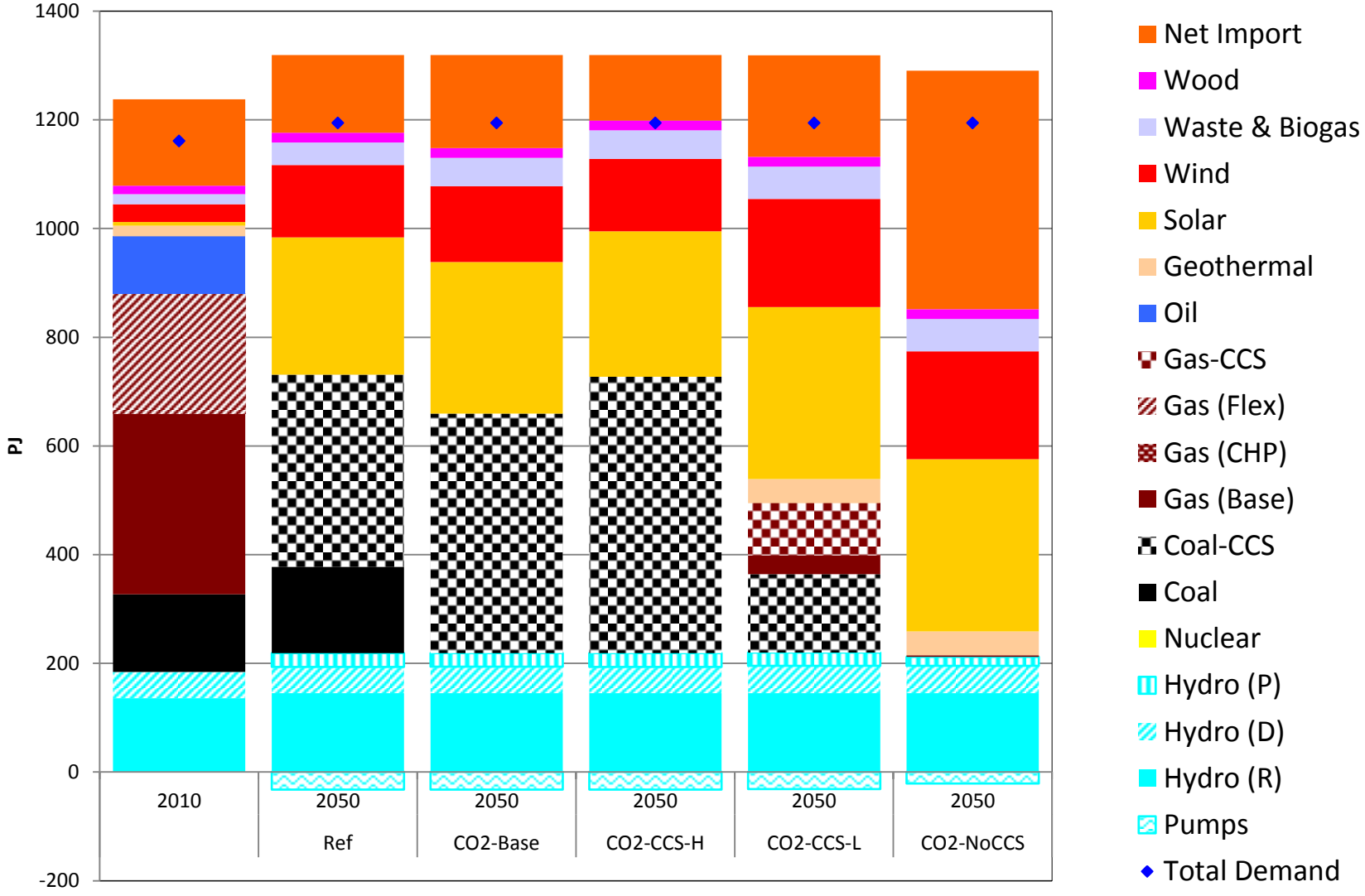
Country wise Results

Electricity generation mix - Germany



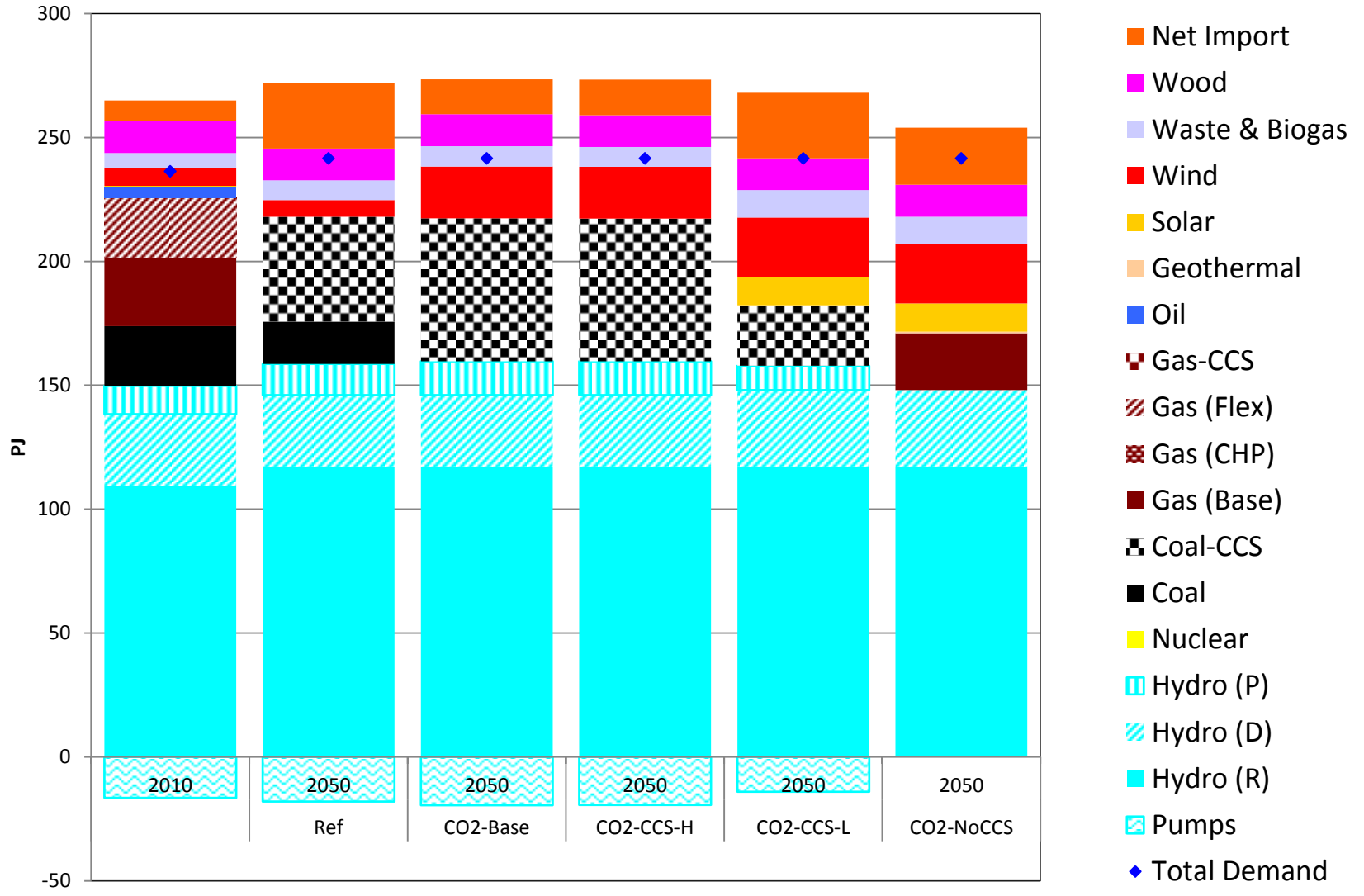
Country wise Results

Electricity generation mix - Italy



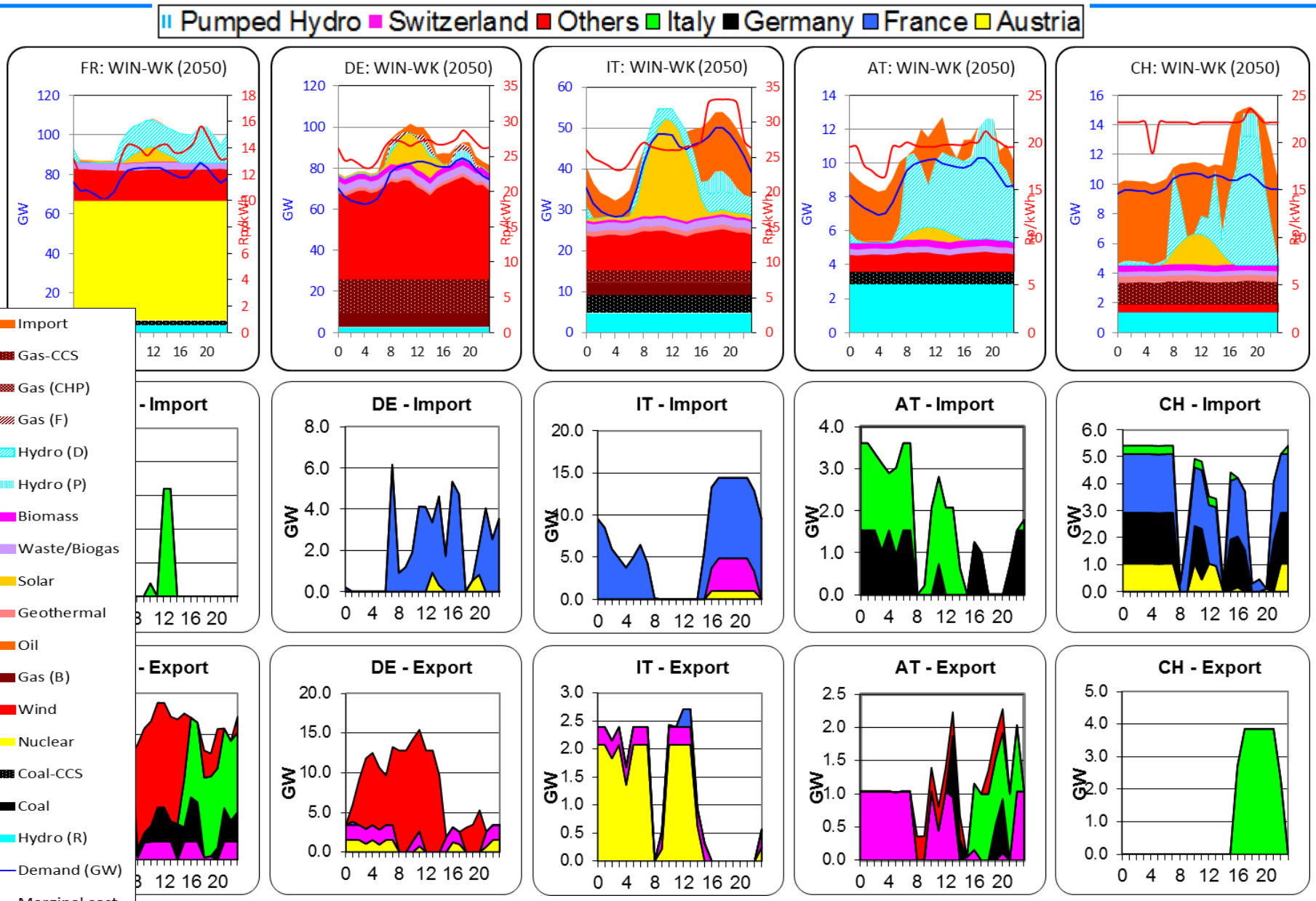
Country wise Results

Electricity generation mix - Austria

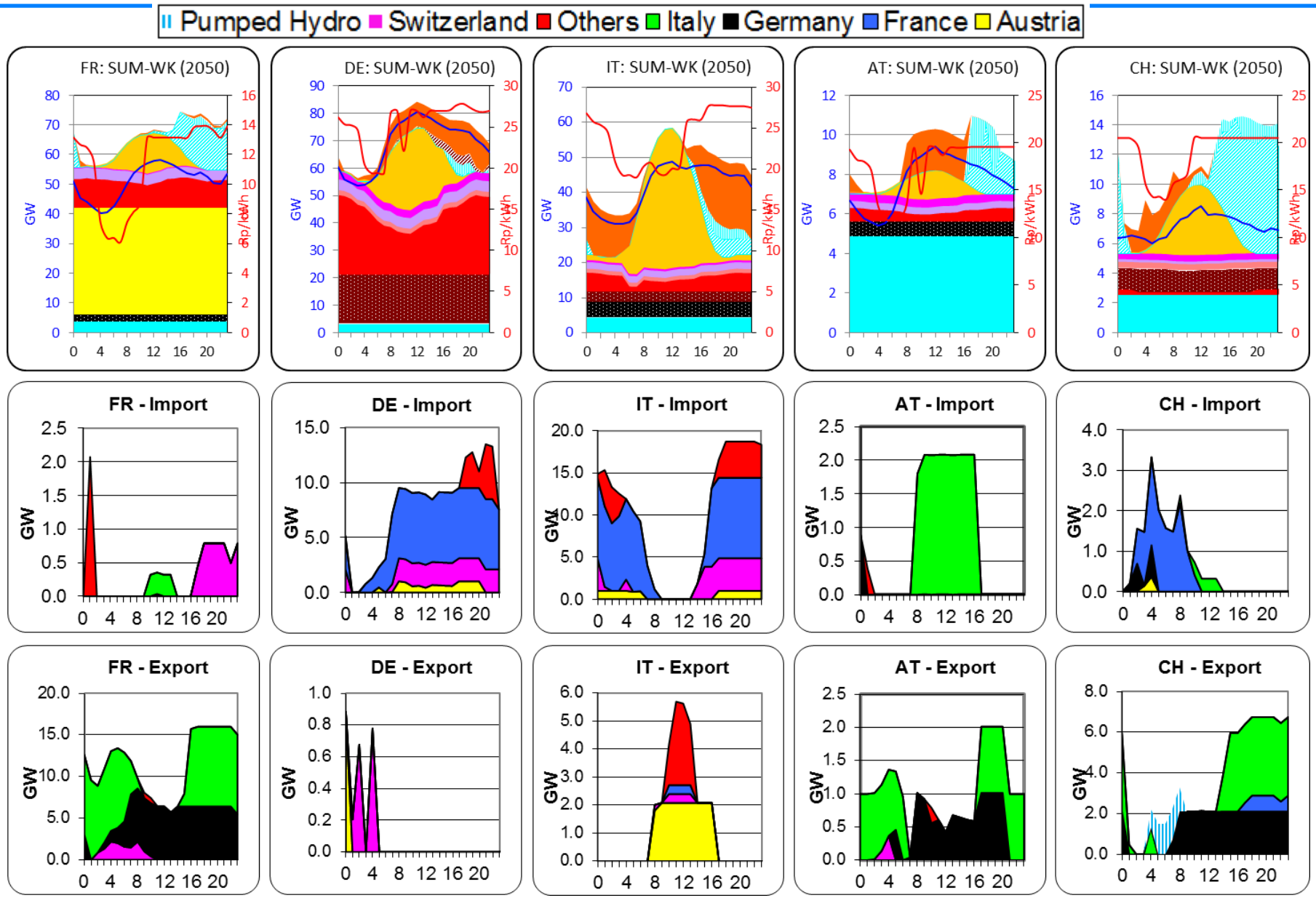


Load Curves

Load Curve – Winter Weekday 2050 (CO2-CCS-L)

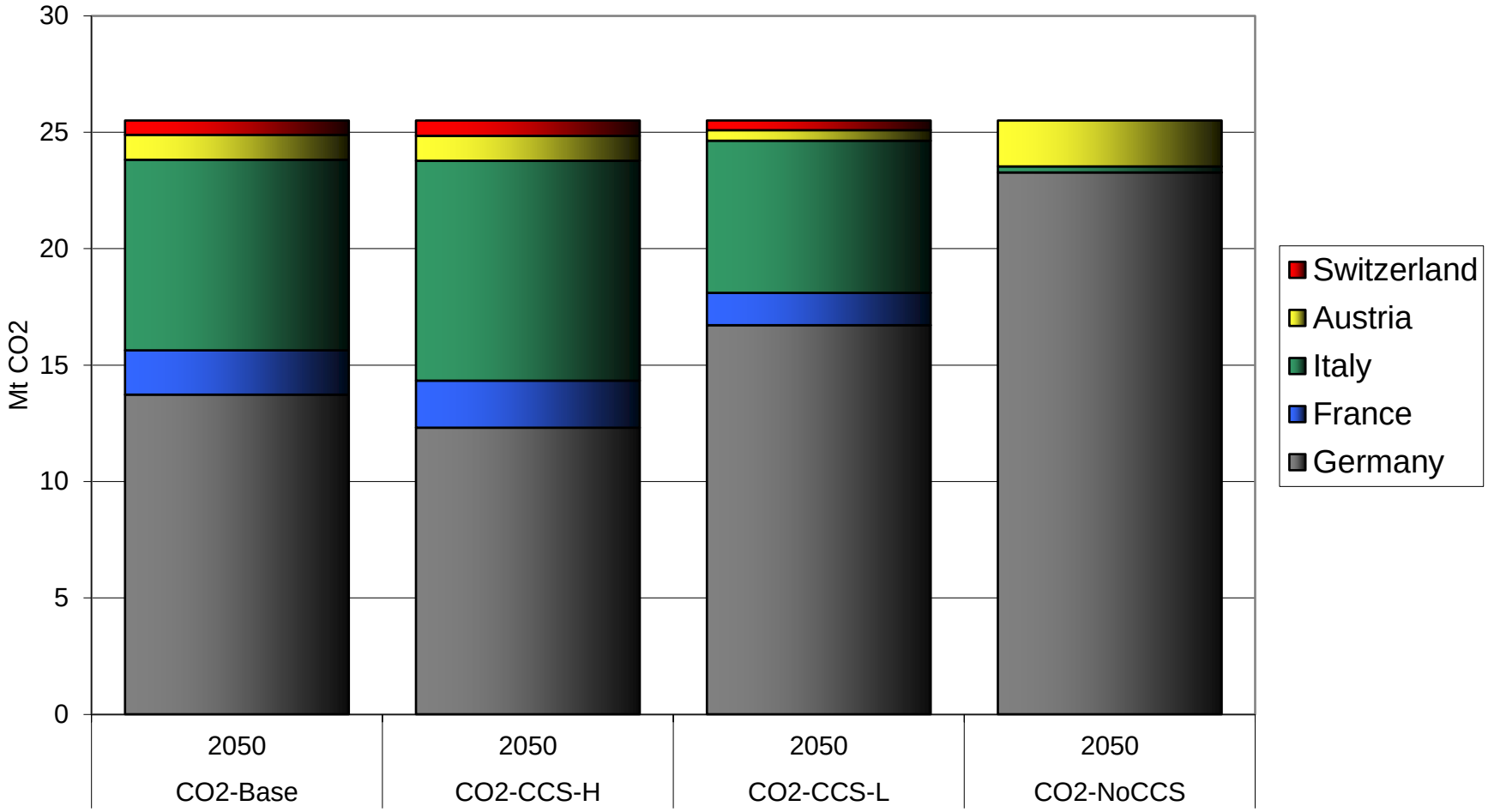


Load Curve – Summer Weekday 2050 (CO2-CCS-L)



CO2 emissions

CO_2 emissions – Regional disaggregation



Conclusions

- Possibilities for alternative low carbon electricity generation pathways for the five countries has been explored.
- Sensitivity of various CCS potentials analysed.
- High potentials favour Coal based CCS plants, low potentials prefer Gas based.
- Renewable technologies preferred over Gas based generation wherever plausible
- Decarbonisation of the power sector is plausible, but significant investments necessary in both renewable technologies as well as CCS.
- CO2 targets achievable without CCS as well, but high impetus on cross border trade – Market liberalization.

Model Limitations

Limitations & Uncertainties

- CROSSTEM is not a pure dispatch model.
- Modelling of representative days – Overall simplifications
- T&D infrastructure not explicitly modelled.
- CO2 transport across countries not modelled
- Trade with fringe regions – Inclusion of surrounding countries
- Model assumes perfect information, perfect foresight, well functioning markets and economically rational decisions – Optimal solution for 5 countries together, not for each country

Thank you for your attention !!!

PAUL SCHERRER INSTITUT

Energy Economics Group

Laboratory for Energy Systems Analysis

General Energy Research department & Nuclear Energy and Safety Research Department