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6th Workshop of SAEE Student Chapter, ETH, 17th Oct 2014

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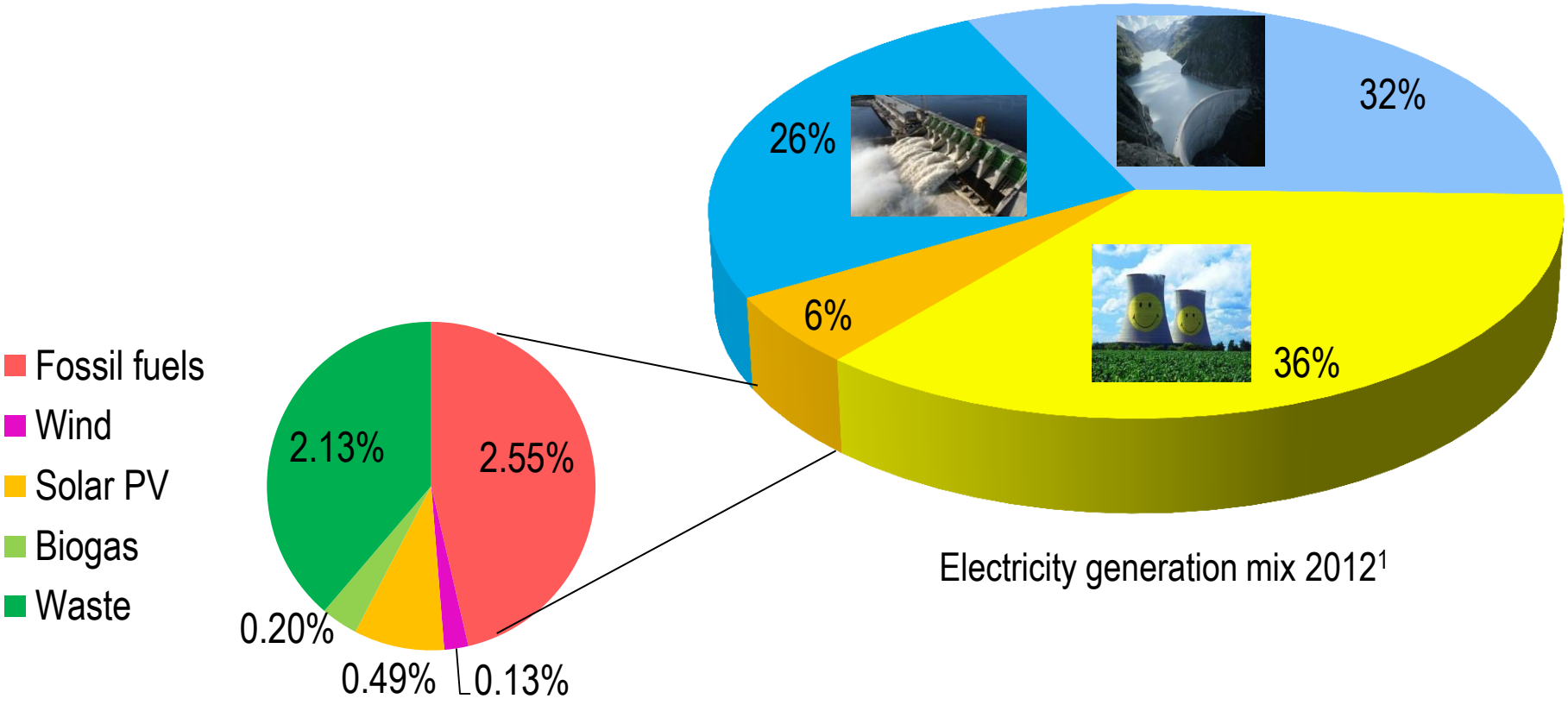
Development of the CROSSTEM model – A tool for analyzing uncertainty in the evolution of the Swiss electricity system

Outline

- Introduction – Background of Swiss Electric system
- CROSSTEM Model
- Motivation – European nuclear phase-out and its consequences
- Scenarios & Key Assumptions
- Preliminary results
- Conclusions
- Model limitations, issues and challenges

Introduction

- Electricity accounts for one quarter of Swiss energy demand
- Large differences in seasonal output, seasonal demand.
- Creates seasonal dependence on electricity import.



1. "Schweizerische Elektrizitätsstatistik 2012", BFE Bern, Okt 2013

Future of Electricity system

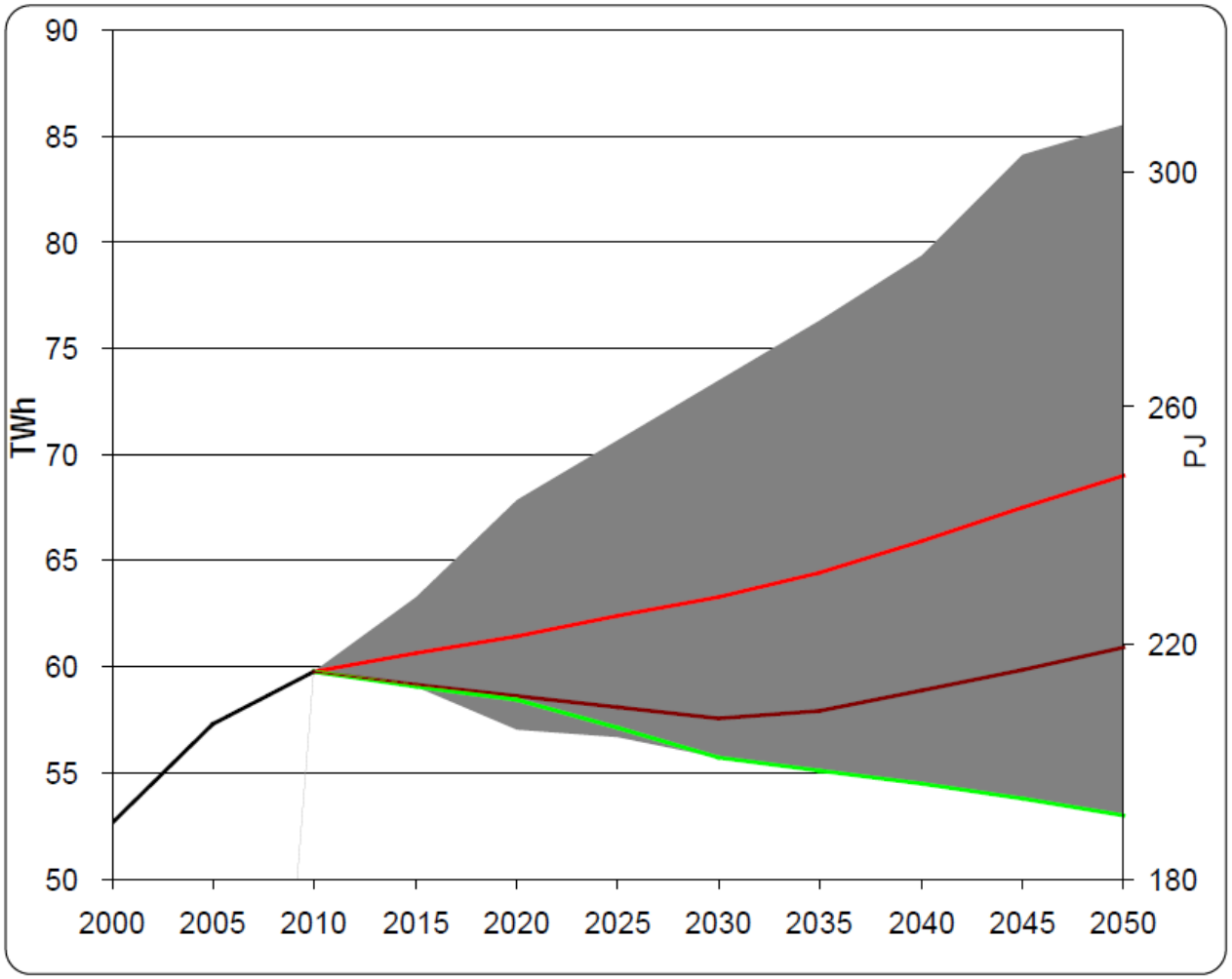
- ***Nuclear phase out*** – No replacement of existing Nuclear power plants at the end of their 50 year lifetime. Last power plant off grid by 2034.

- **Ambitious carbon reduction targets**

- ***Uncertainty in electricity demand*** – The Swiss Energy Strategy 2050 defines possible demand pathways
  - Business as Usual (WWB)
  - Political Measures (POM)
  - New Energy Policy (NEP)

- ***Uncertainty regarding future supply options*** – A combination of gas based generation, renewables and electricity imports are mentioned in SES 2050.

Swiss Energy Strategy 2050 – Demand projections



Demands from BFE, 2012

→ **BFE: Weiter Wie Bisher**

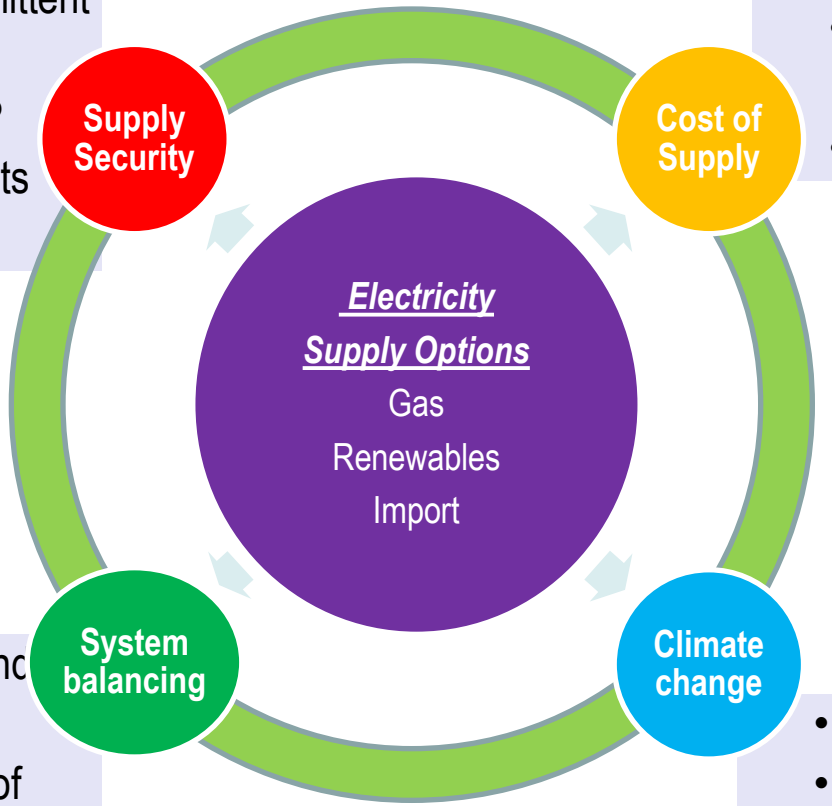
→ **BFE: Politische Massnahmen**

→ **BFE: Neue Energiepolitik**

** "Swiss Electricity Supply Options: Techno-economic Analysis"– Ramachandran Kannan, ENE-NES Colloquium 2013*

Future of Electricity sector – Tradeoffs

Developments in Europe
- Integration of intermittent Renewables
- Nuclear phase-out?
- CO_2 emission targets
- Gas imports



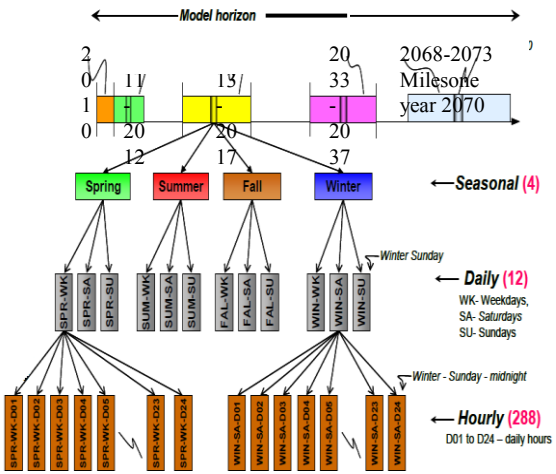
- Cost implications of renewable / low carbon policy
- Revenue from trade

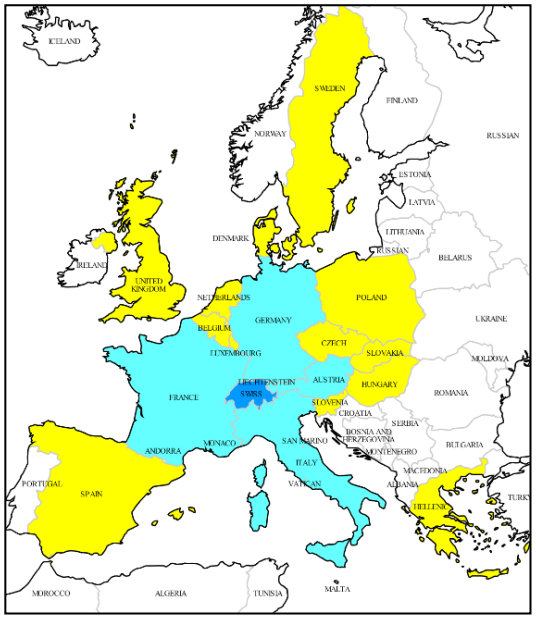
- Balancing supply and demand
- Intermittent nature of renewables
- Electricity imports

- CO2 emission targets
- Expansion of Gas plants

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





TIMES modelling framework

TIMES – **T**he **I**ntegrated **M**ARKAL / **E**FOM **S**ystem

- Technology rich, Perfect foresight, cost optimization framework
- Used to explore a range of parametric sensitivities under a “what-if” framework via exploratory scenario analysis.
- Integrated modelling of the entire energy system
- Prospective analysis on a long term horizon (20-50-100 yrs)
- Allows for representation of high level of temporal detail – load curves
- Enhanced Storage algorithm – modelling of pumped storage systems
- Optimal technology choice – based on costs, environmental criteria and other constraints.

MARKAL – **MARK**et **AL**location

EFOM – **E**nergy **F**low **O**ptimization **M**odel

Motivation – European nuclear phase-out

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[3].

- **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 (?)

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

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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

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Alternative low carbon sources of electricity

- Technical, Economical and Social challenges and uncertainties

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 CH by 2034, DE by 2022. French nuclear fleet can be replaced.

- ***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.
- ***Low CCS scenario (CO2-CCS-L)*** – Lower variant of CCS potentials.
- ***No CCS scenario (CO2-NoCCS)*** – No investment in CCS technology. Free trade allowed in this scenario.

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.

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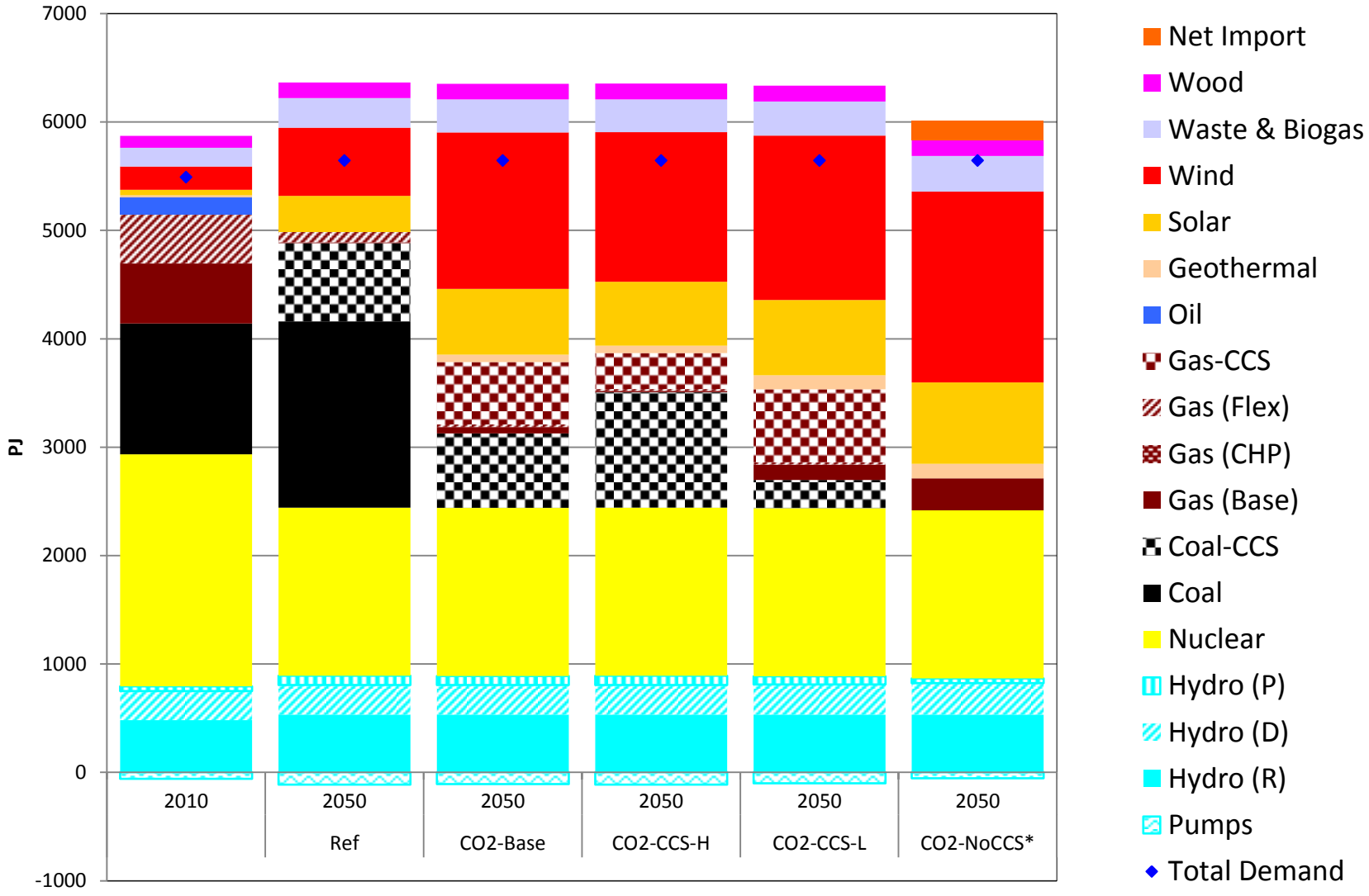
Results

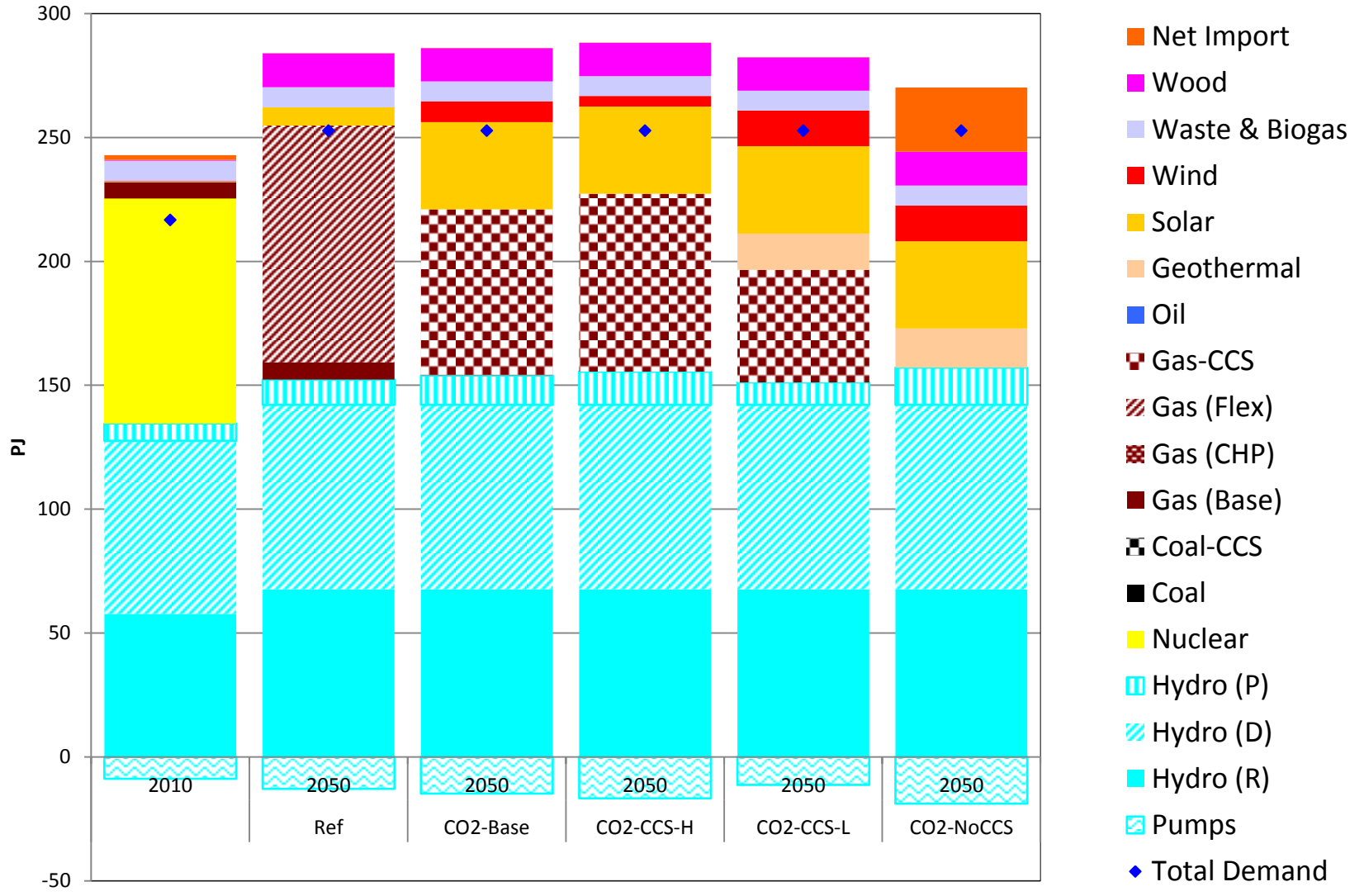
Aggregated Results

Electricity generation mix – 5 countries aggregated



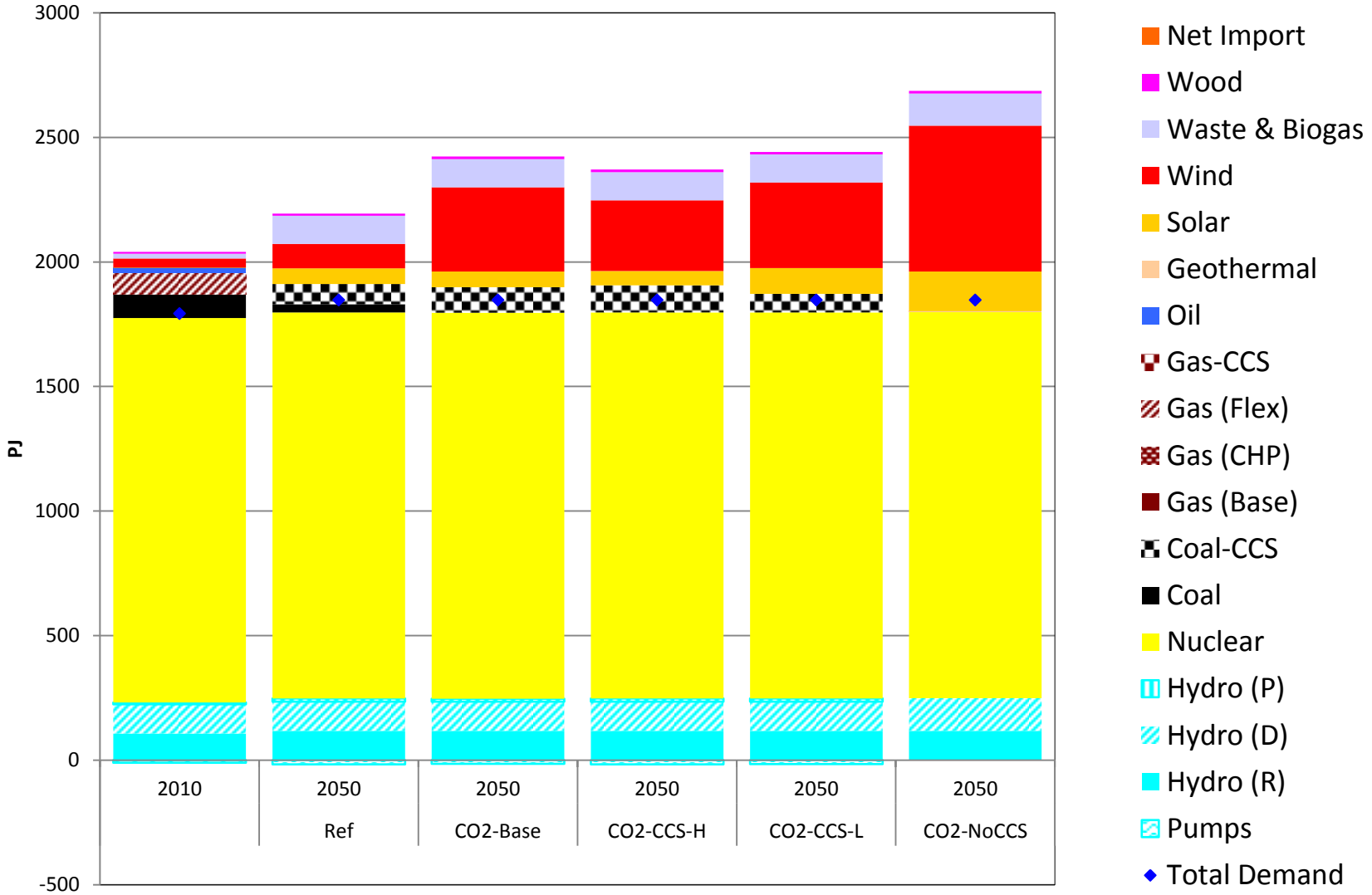
Country wise Results

Electricity generation mix - Switzerland



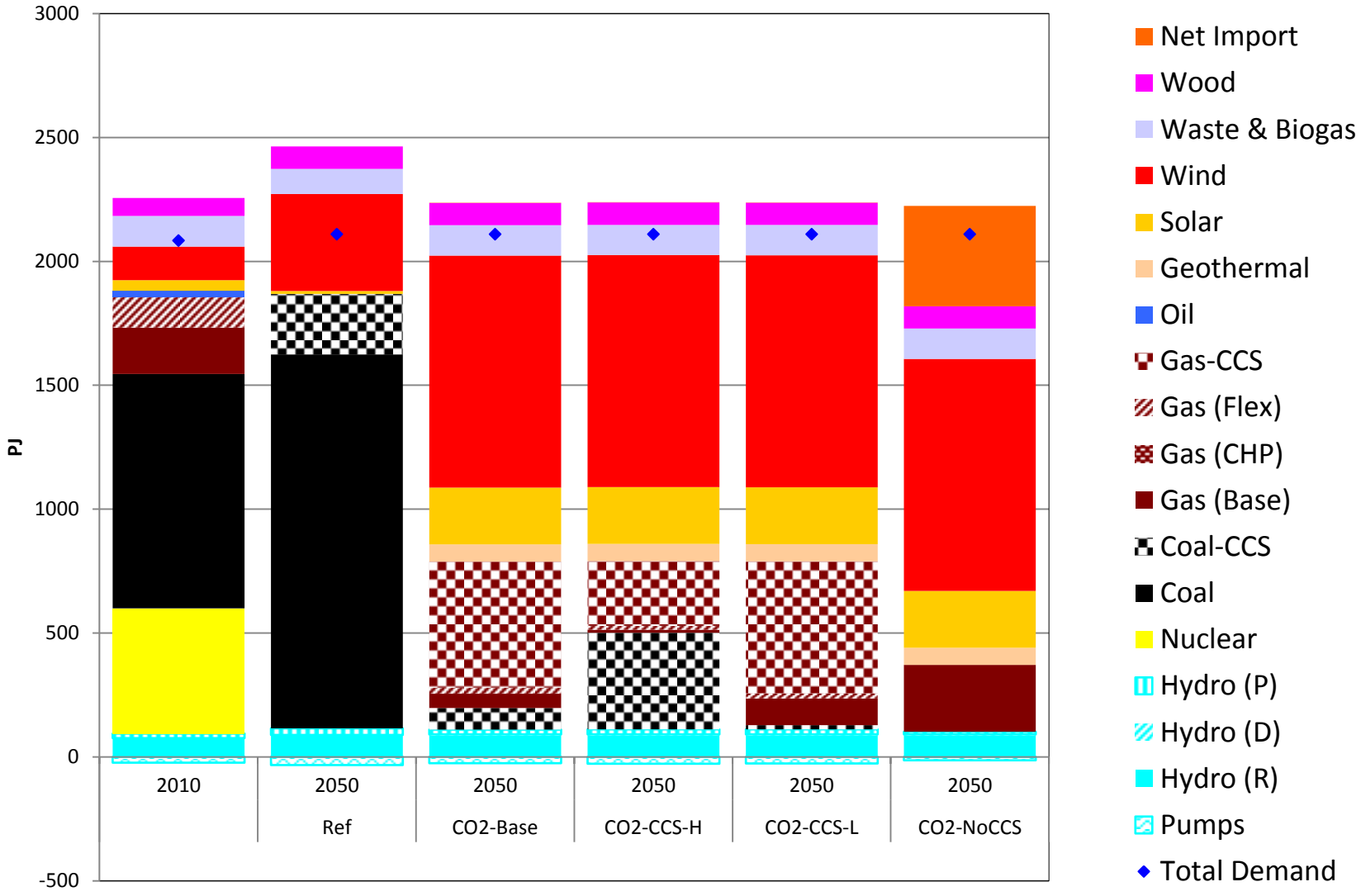
Country wise Results

Electricity generation mix - France



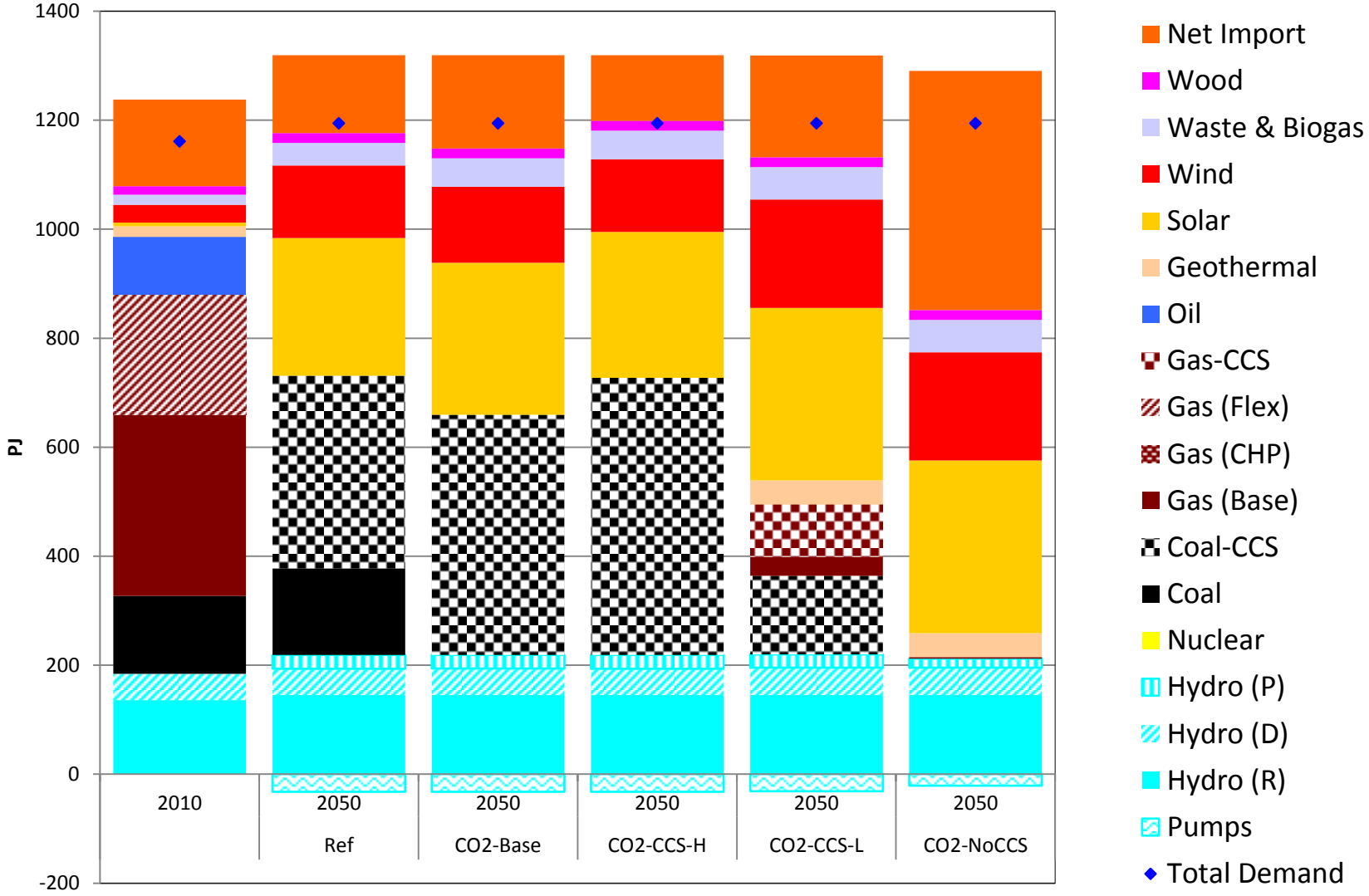
Country wise Results

Electricity generation mix - Germany



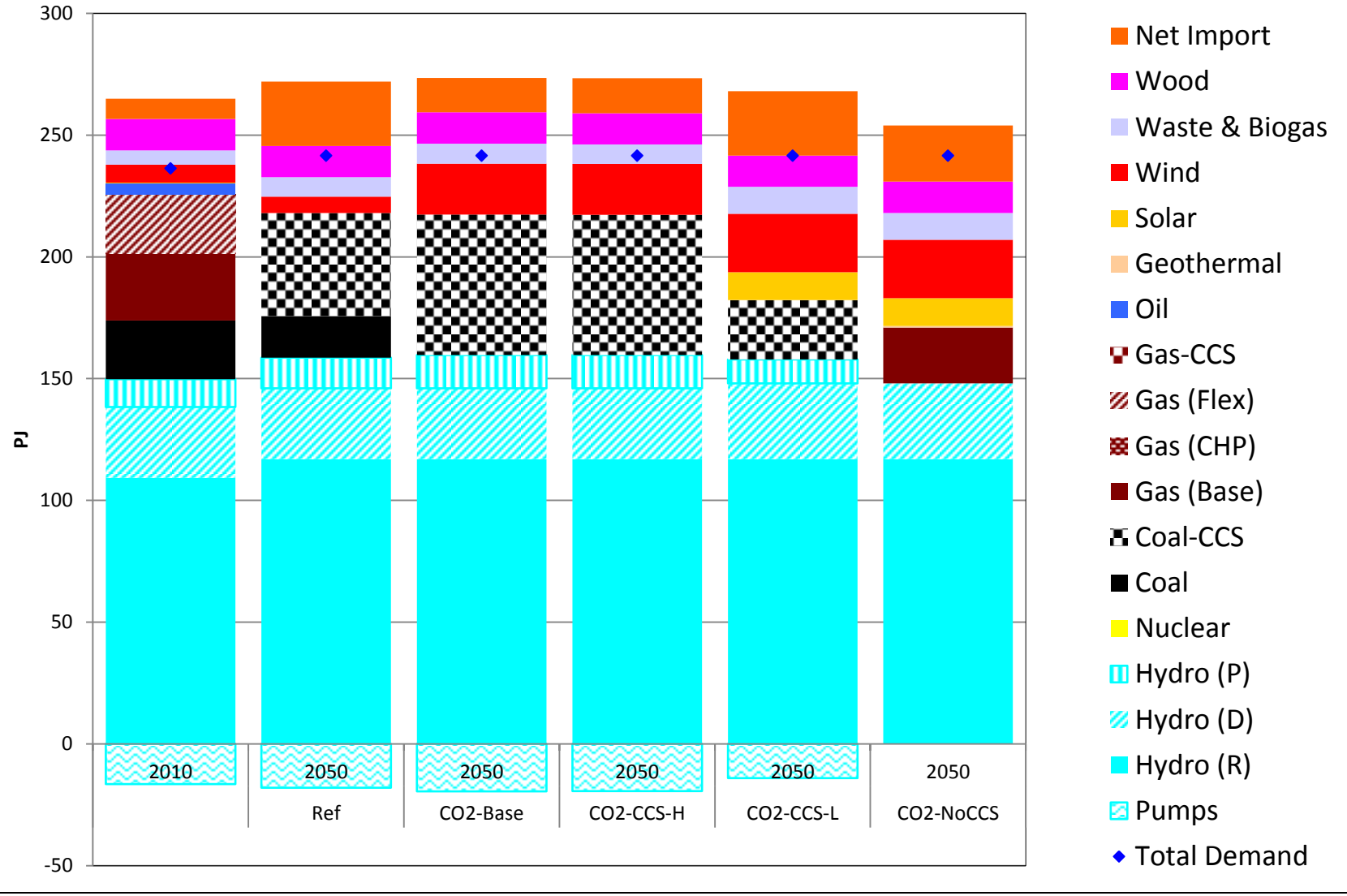
Country wise Results

Electricity generation mix - Italy



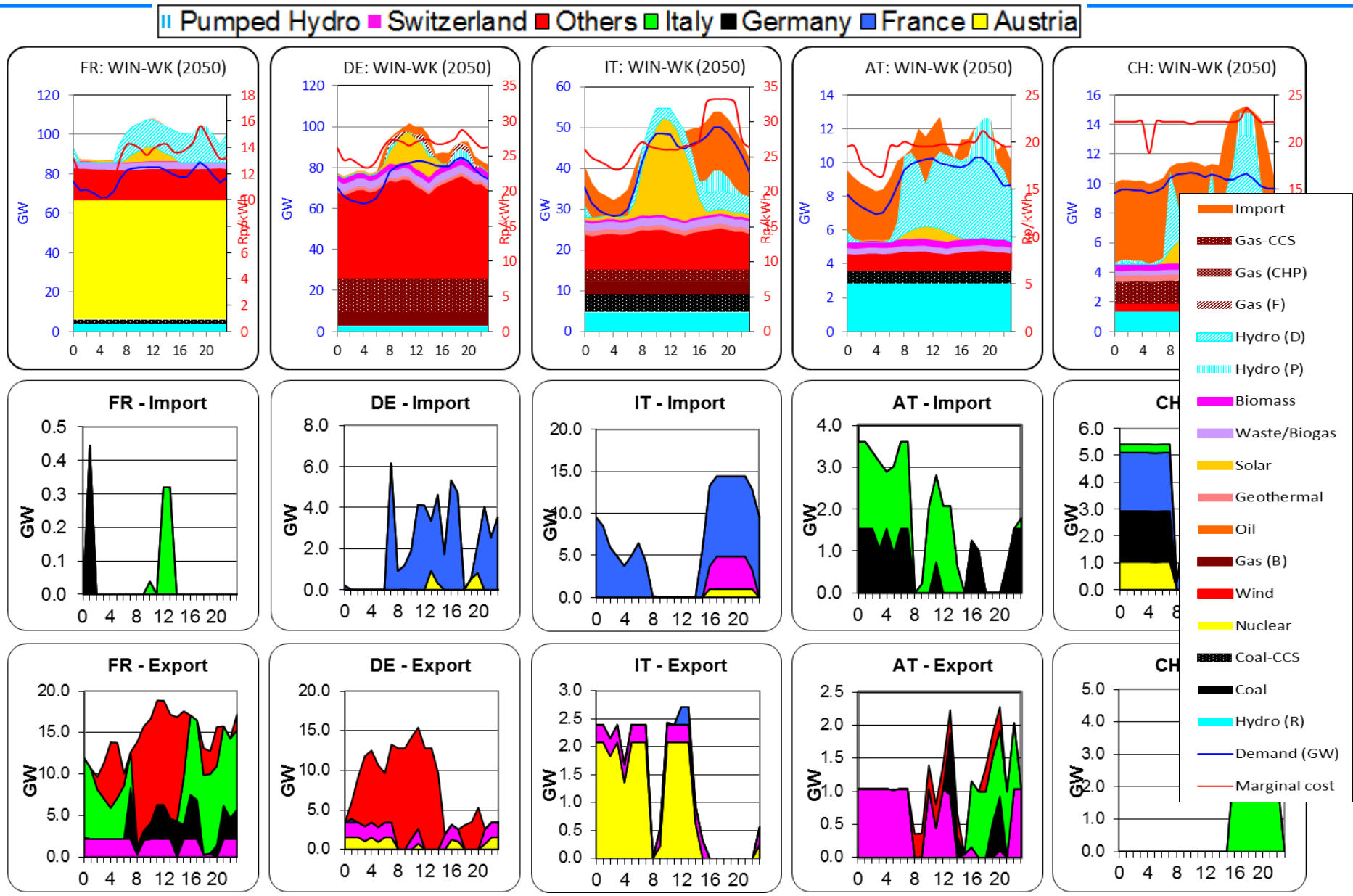
Country wise Results

Electricity generation mix - Austria

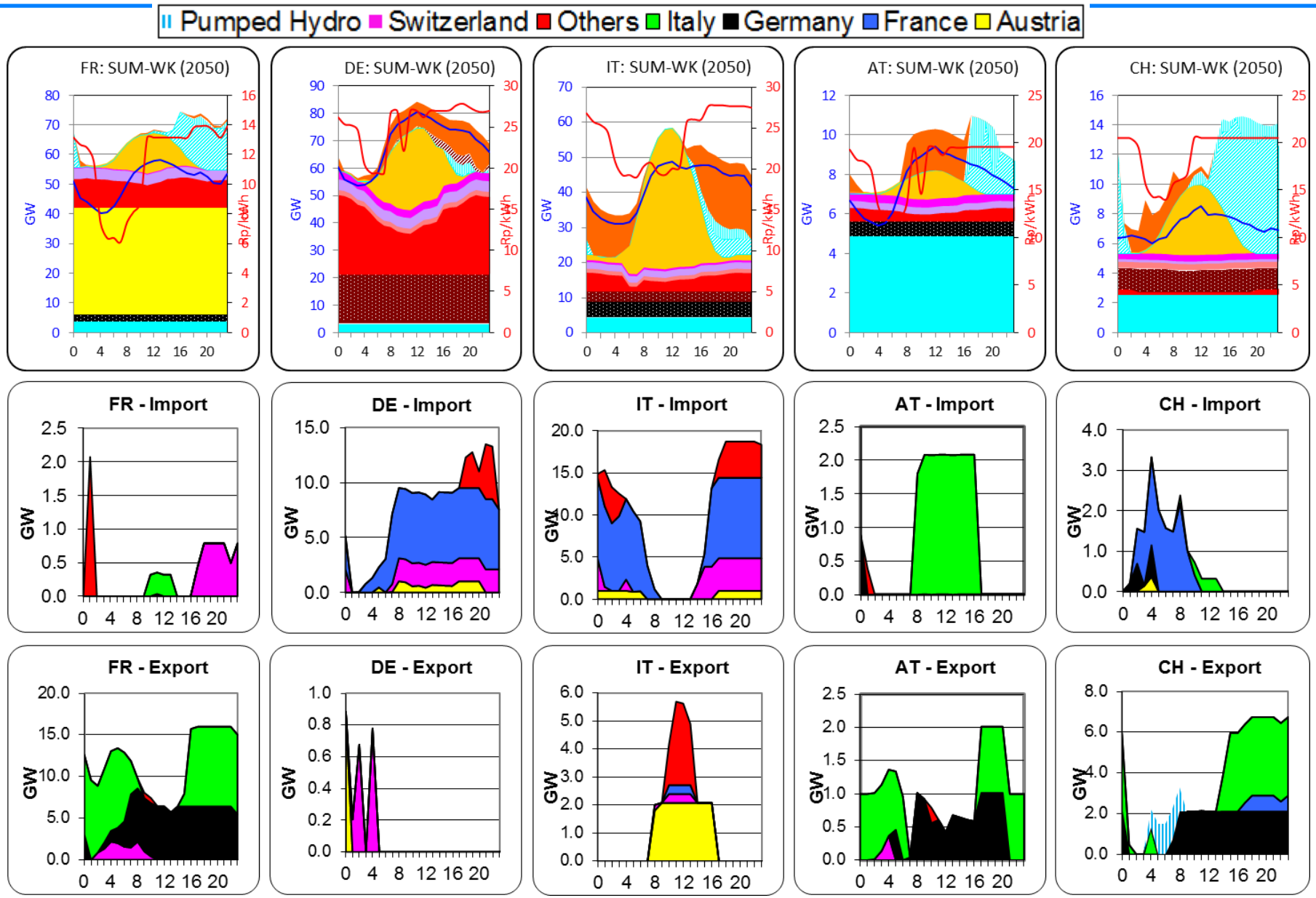


Load Curves

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

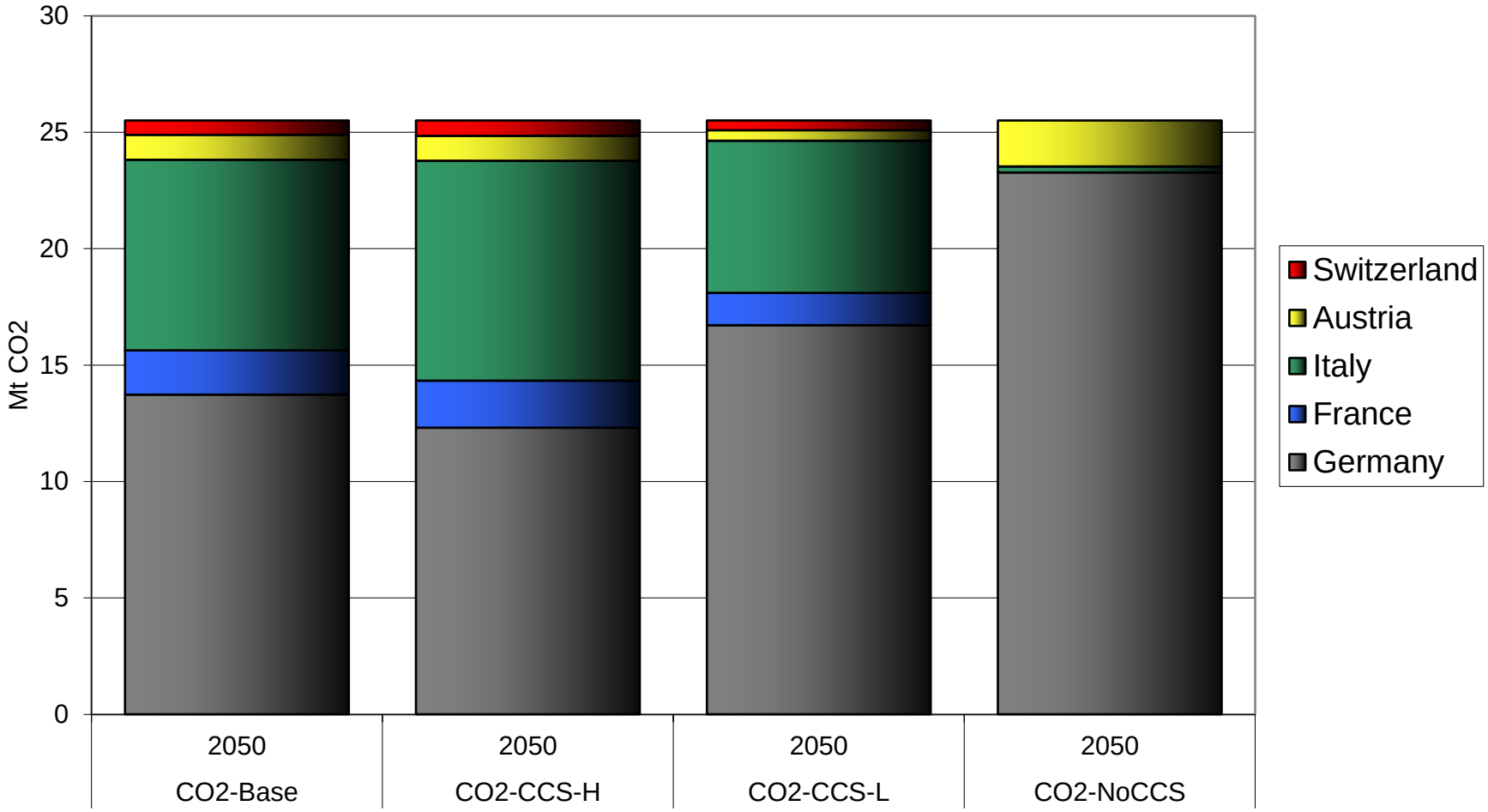


Load Curve – Summer Weekday 2050 (CO2-CCS-L)



CO2 emissions

CO_2 emissions – Regional disaggregation



Conclusions

- Model of the electricity system of Switzerland and its neighbouring countries over a long term horizon combined with dispatch aspect achieved.
- Effects of surrounding country developments on the Swiss electricity system have been demonstrated.
- Possibilities for alternative low carbon electricity generation pathways for the five countries has been explored.
- Sensitivity of various CCS potentials analysed
- Decarbonisation of the power sector is plausible, but significant investments necessary in both renewable technologies as well as CCS.

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 not modelled
- Trade with fringe regions
- 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 !!!

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