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## Cost of ad-hoc nuclear policy uncertainties in the evolution of the Swiss electricity system

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International Energy Workshop, Stanford

6 July 2011

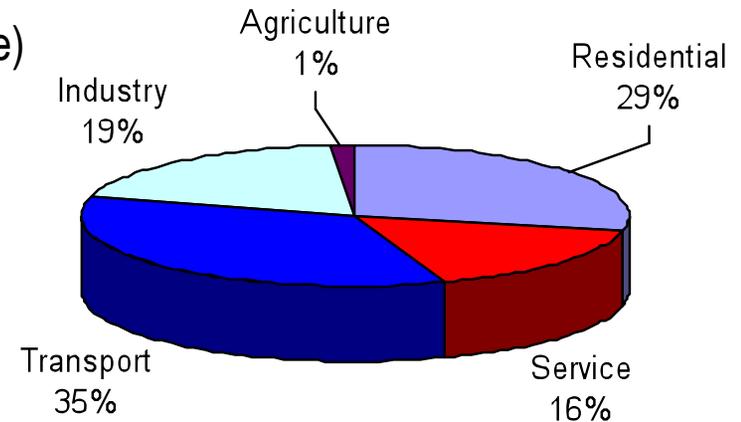
- **Overview of Swiss electricity systems**
- **Swiss TIMES Electricity Model**
  - Model features
  - Input data and key assumptions
- **Scenario definitions**
- **Results and discussions**
- **Conclusions**



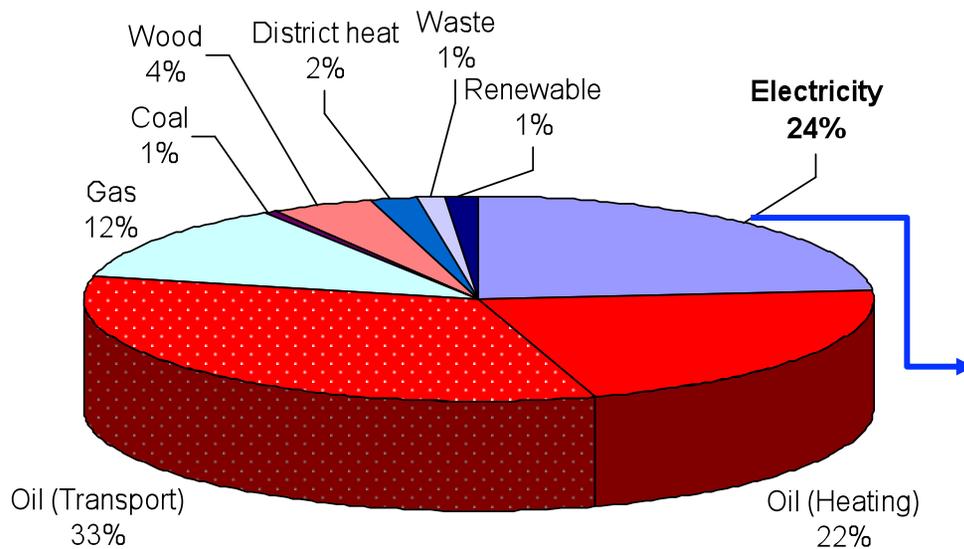
## Energy Economy (2009)

- **Energy expenditure:** CHF 27.1 Billion (5.1% of GDP)
- **Energy import:** CHF 8.7 Billion (4% of import expenditure)
- **Energy import dependency:** 80%

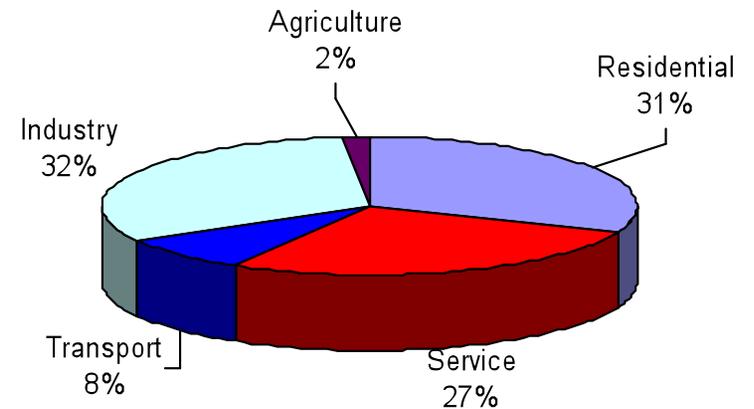
**Final energy demand in 2009 (877 PJ)**



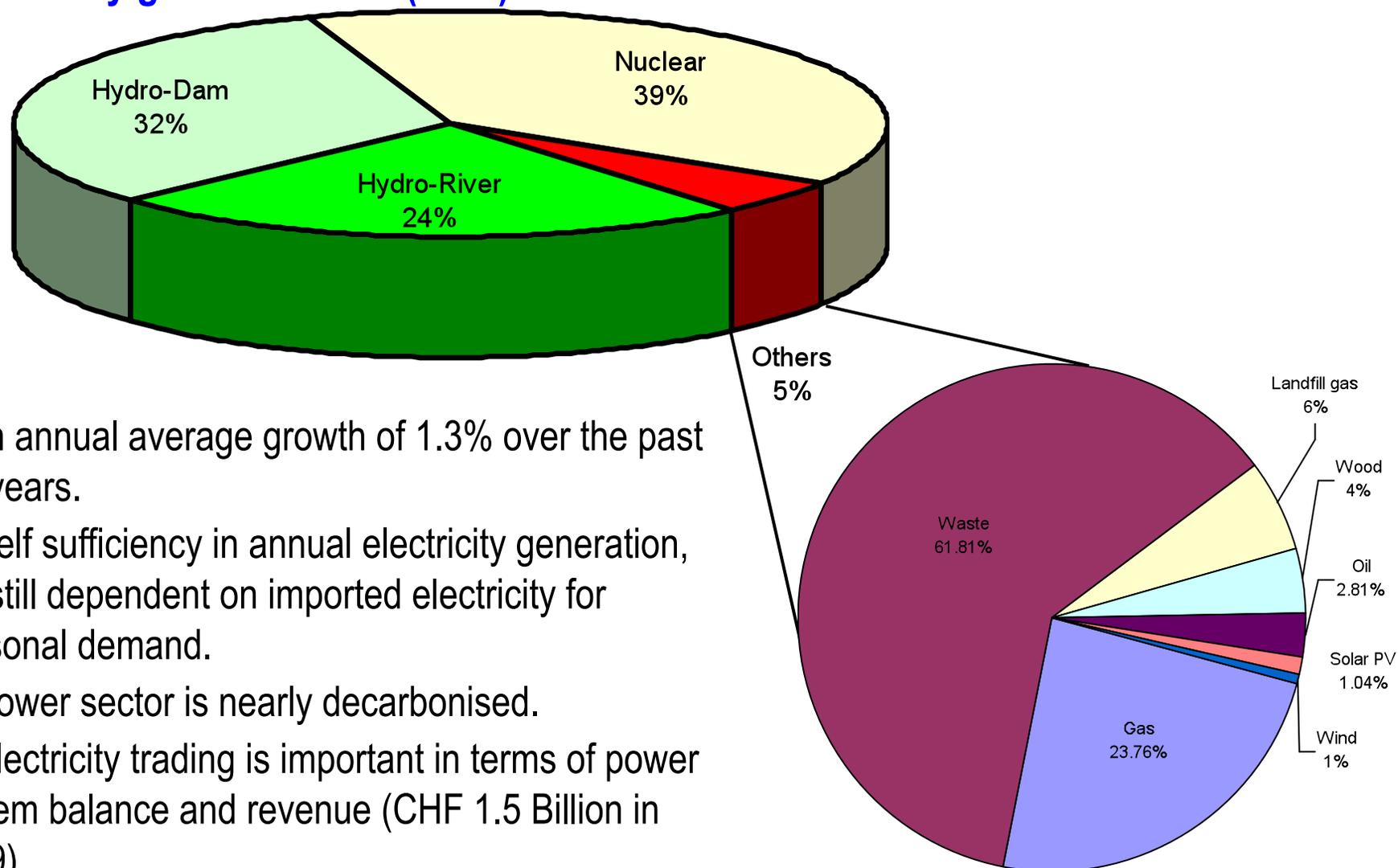
**Final energy demand in 2009 (877 PJ)**



**Electricity demand in 2009 (207 PJ)**

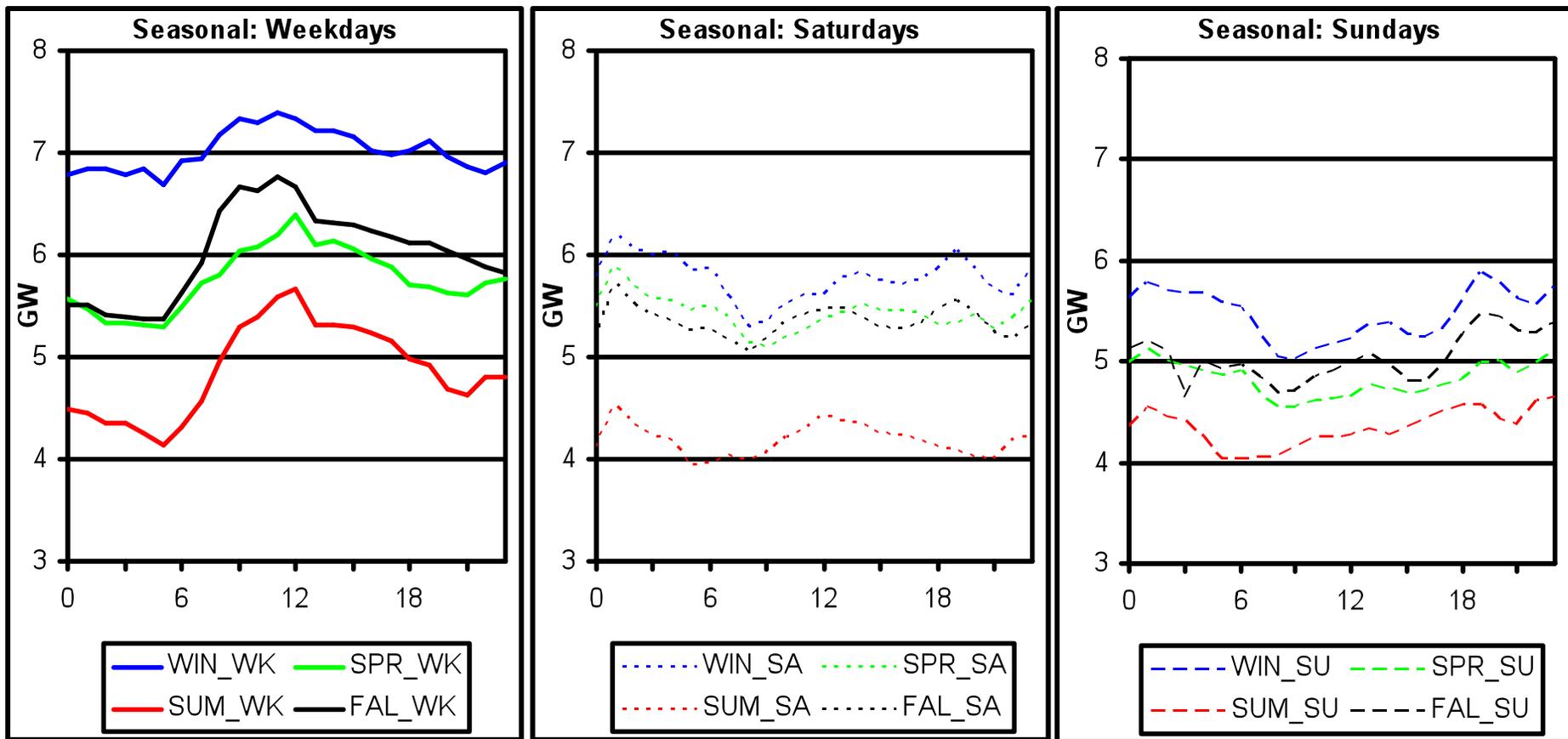


## Electricity generation mix (2009)



- An annual average growth of 1.3% over the past ten years.
- Self sufficiency in annual electricity generation, but still dependent on imported electricity for seasonal demand.
- Power sector is nearly decarbonised.
- Electricity trading is important in terms of power system balance and revenue (CHF 1.5 Billion in 2009).

## Electricity load curves (2008)



## 2010 energy policy targets: status as of 2009

- Fossil fuel reduction target of 10% from 2000 level: **-1.3%** ☹️
- Carbon reduction targets of 10% from 1990 level: **-2.7%** ☹️
- Cap the growth in electricity demand to < 5% from 2000 level: **+14.4% (2010)** ☹️
- Renewable electricity production of 1% from 2000 level (0.5 TWh): **+0.46 TWh** 😊

- |   |   |
|---|---|
| 1 | Solar power (2.7%)                                  |
| 2 | Biomass (12.8%)                                     |
| 3 | Wind energy (1.4%)                                  |
| 4 | Proportion of renewable energy from waste (73.8%)   |
| 5 | Proportion of renewable energy from drainage (9.3%) |

- Renewable heat production of 3% from 2000 level (3 TWh): **+3.37 TWh** 😊

- |   |   |
|---|---|
| 1 | Solar power (3%)                                    |
| 2 | Ambient heat (20.5%)                                |
| 3 | Biomass (55%)                                       |
| 4 | Proportion of renewable energy from waste (19%)     |
| 5 | Proportion of renewable energy from drainage (2.5%) |

## Challenges and uncertainties

- Retirement of the exiting nuclear reactors and filling the supply gap: The Swiss Federal Nuclear Safety Inspectorate gave a positive assessment on construction of new nuclear power plants (Nov. 2010). After the Fukushima nuclear disaster, the Swiss Federal council has suspended plausible new nuclear option (May 2011).
- Ambitious carbon reduction targets: 60-80% by 2050.
- Large seasonal and diurnal variation in demand.
- Renewable electricity – Limited resources and high variability in availability.
- Uncertainties in future growth of electricity demand.
- Imported electricity - Security and availability concerns in light of climate policy in cross-bordering countries.
- Role of long term electricity trading - Uncertainty in development of electricity market in neighbouring countries under a low carbon economy.

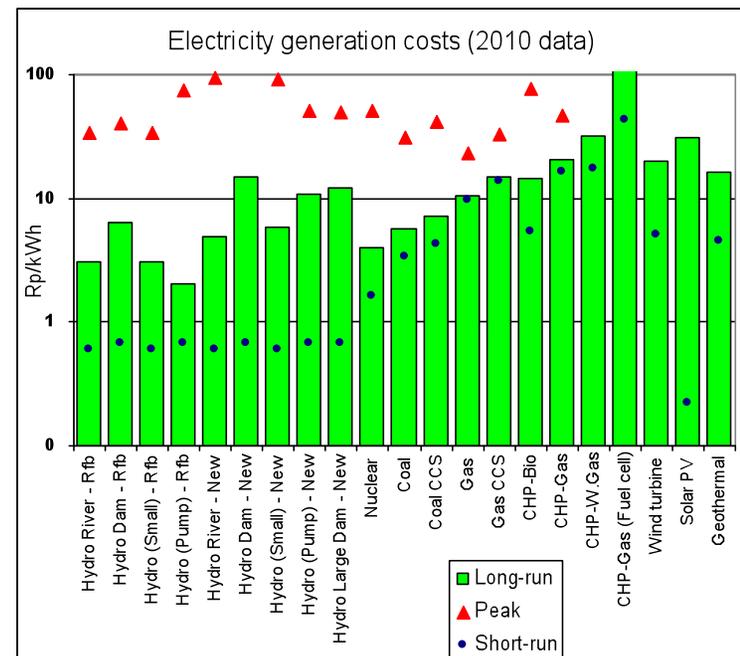
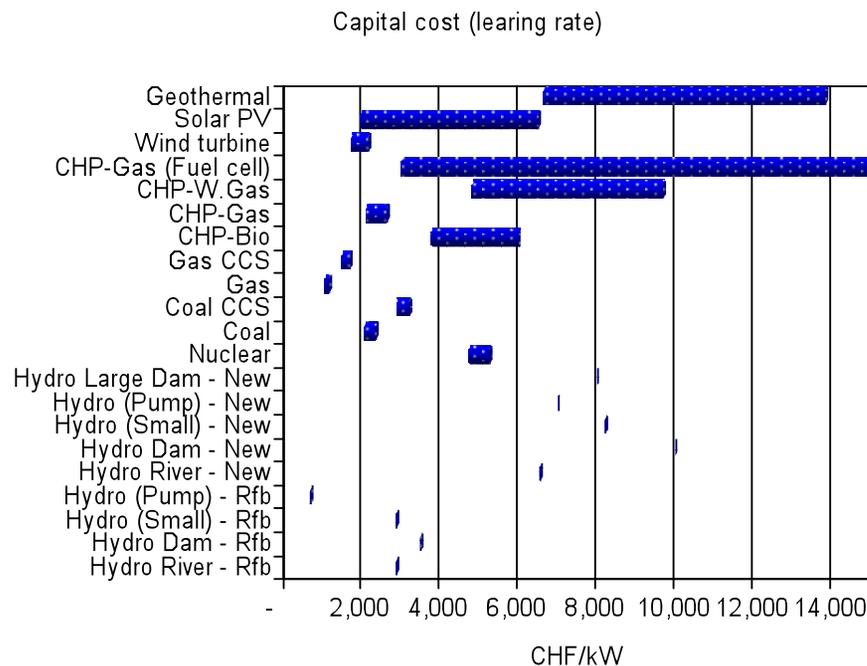


## Model features

- Single region model with 2000-2100 time horizon and an hourly timeslice
- Calibrated to 2000-2010 data

## Key Parameters

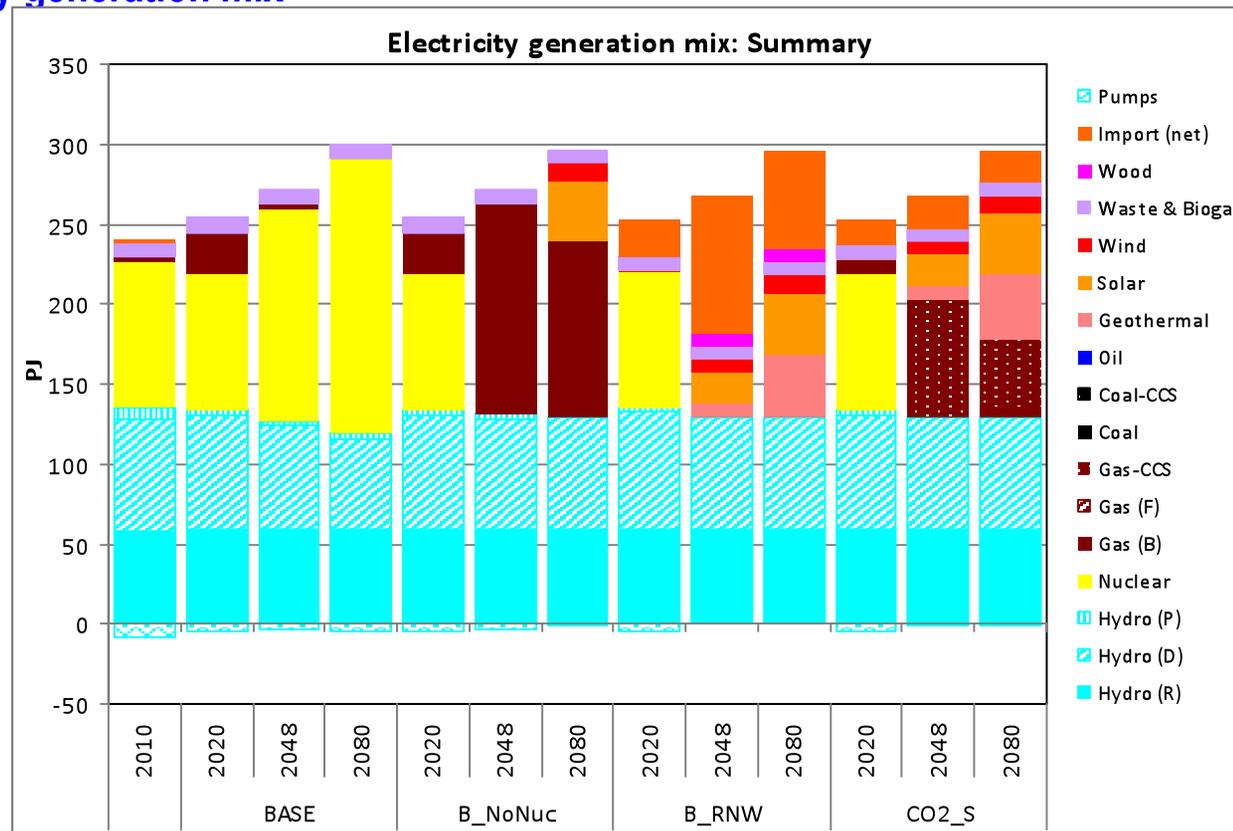
- Electricity demand growth: 0.7% (2010-2020); 0.4% (2020–2035); 0.27% (2035...).
- Discount rate 3% (slightly higher than the long term yields from confederation bounds)



For more details: R. Kannan and H. Turton (2011) *Documentation on the development of Swiss TIMES Electricity Model (STEM-E)*, <http://eem.web.psi.ch/Projects/STEM-E.html>

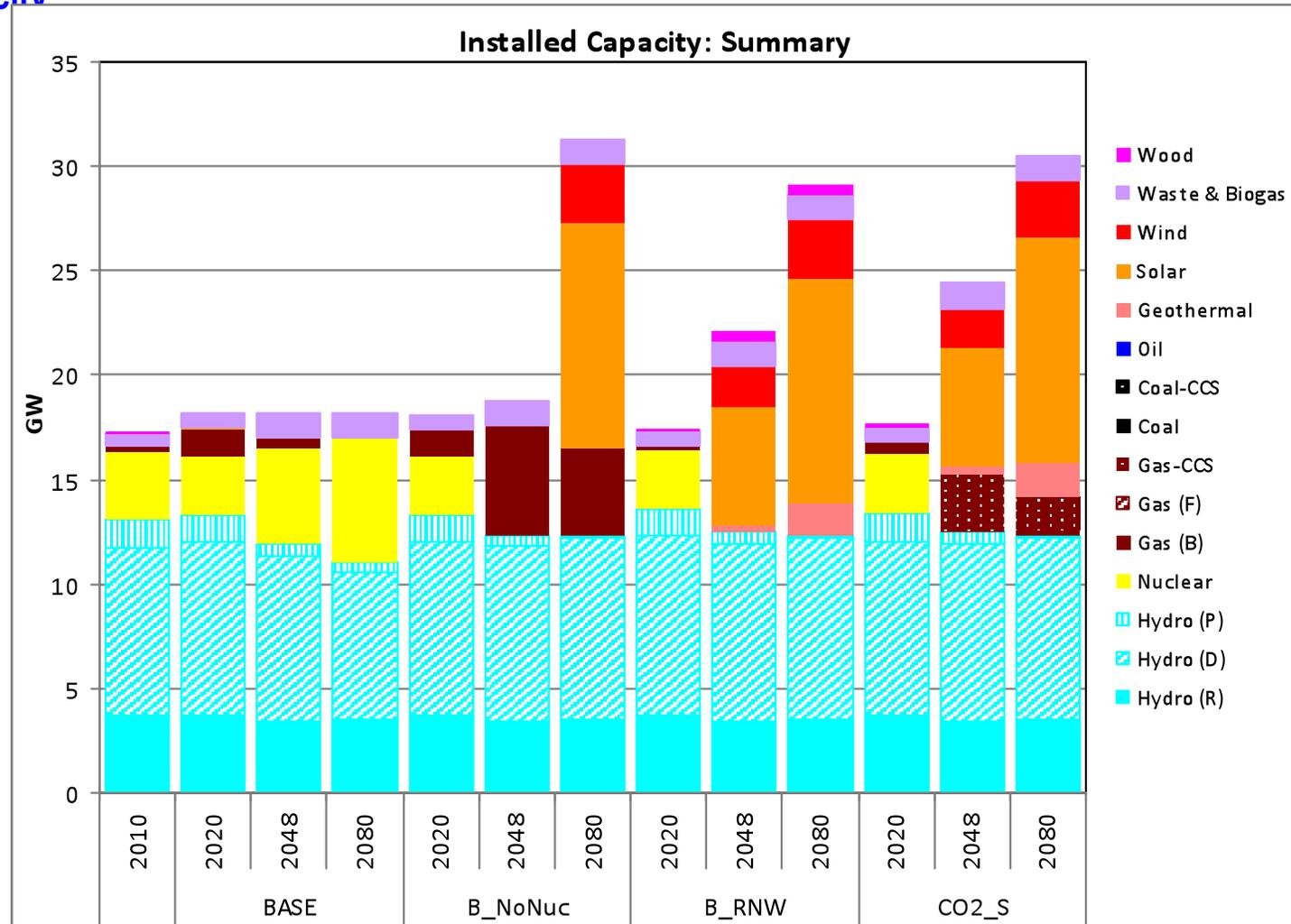
- 1. Base scenario (Base)** – Self-sufficiency in electricity supply. A constraint is introduced in such a way that annual exports and imports are required to be balanced but the timing of electricity trade is left unconstrained.
- 2. No nuclear scenario (B\_NoNuc)** - No new investment in nuclear plants, but operation of the existing nuclear plants can continue till the end of their 50 years lifetime.
- 3. Renewable scenario (B\_RNW)** - Nuclear and gas-fired power plants are restricted. Since Swiss renewable resources are assumed to be not fully adequate to meet the demands, the self-sufficiency constraint is relaxed so that net imports can account for up to 35% of the electricity demand.
- 4. Carbon stabilization scenario (CO2\_S)** – Capped CO<sub>2</sub> emission intensity of electricity (g-CO<sub>2</sub>/kWh) to the level in the year 2010. In addition, nuclear investment is completely restricted, but gas with CCS is available.

## Electricity generation mix



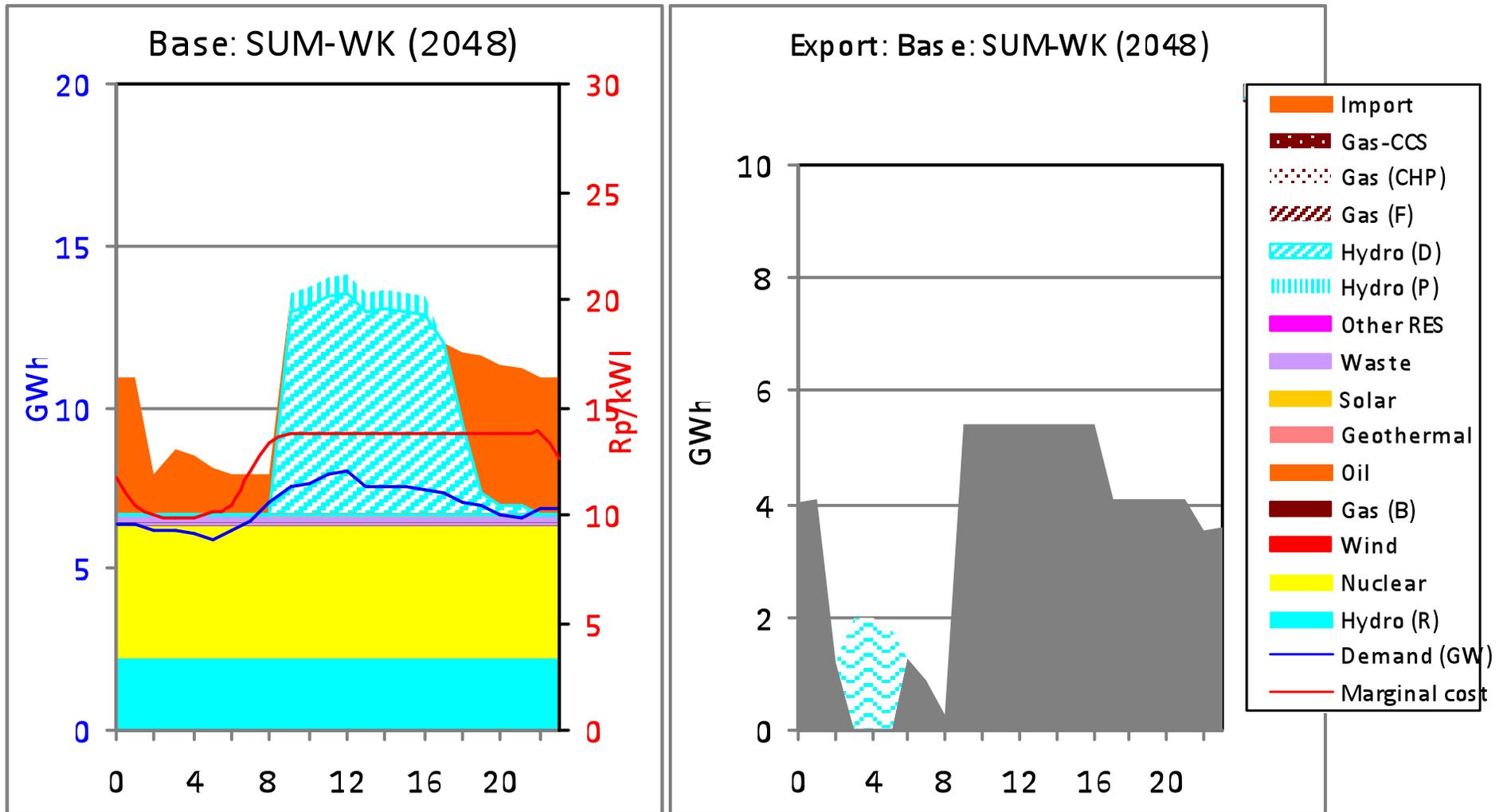
- Gas-based generation represents the most cost-effective **non-nuclear** alternatives but undermines long-term carbon reduction targets.
- For **low carbon and non-nuclear**, imported electricity is required between 10-35% of the demand.
- Imported gas/electricity would increase concerns about supply security, particularly in winter when gas demand is also high for heating applications.

## Installed capacity

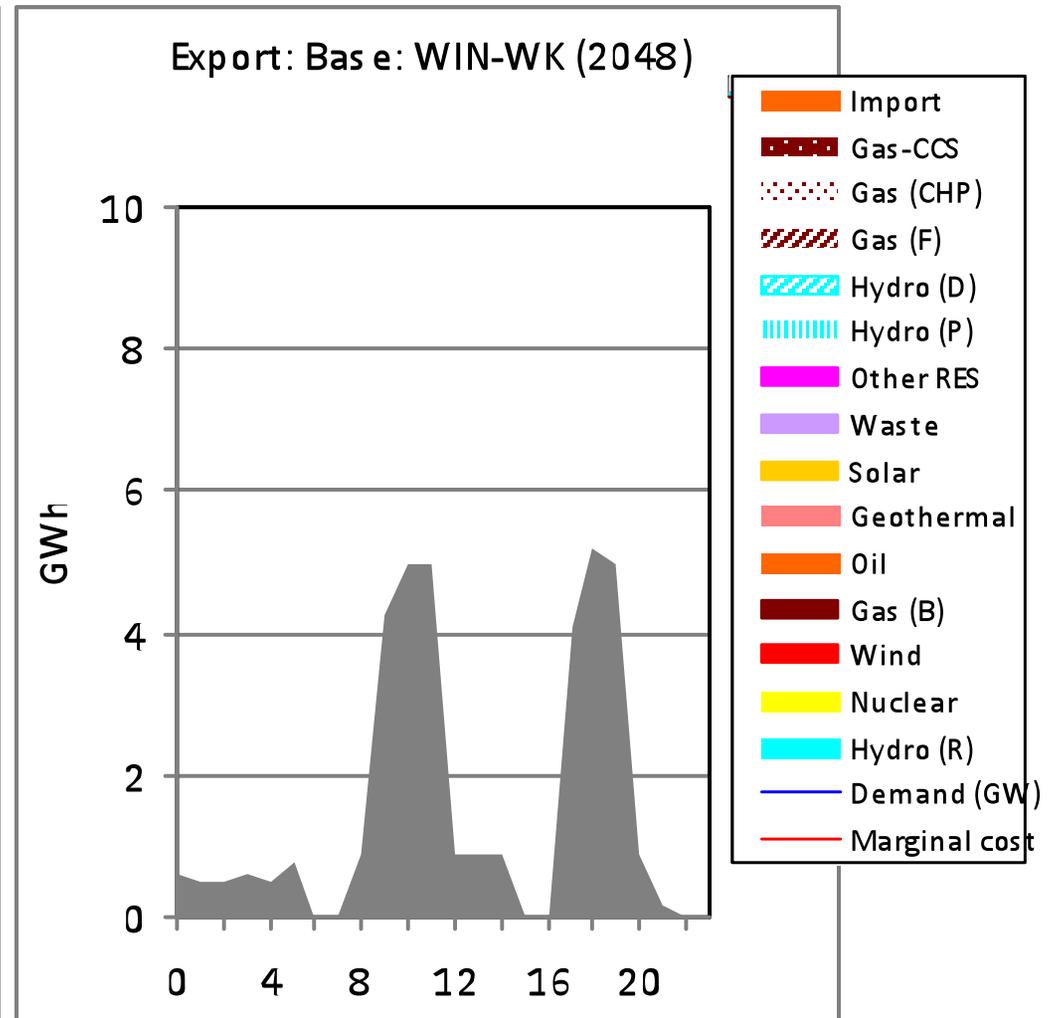
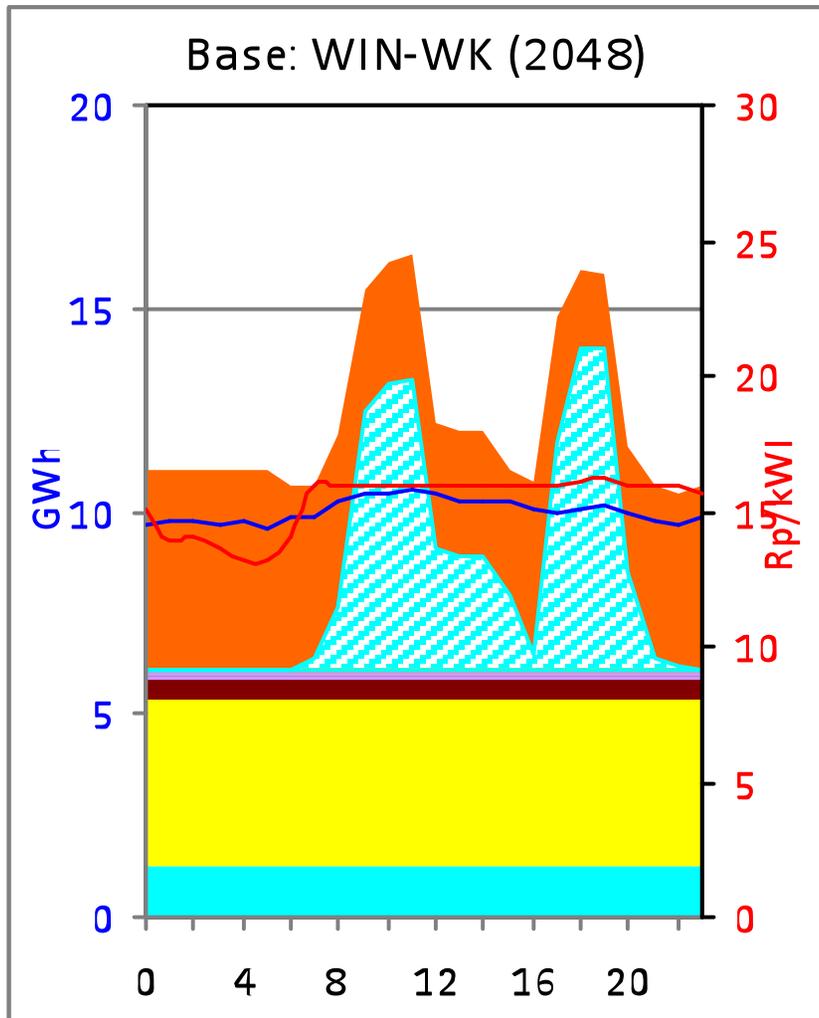


➤ Short-duration intermittence is not considered but it is likely that dam hydro could support the management of intermittency.

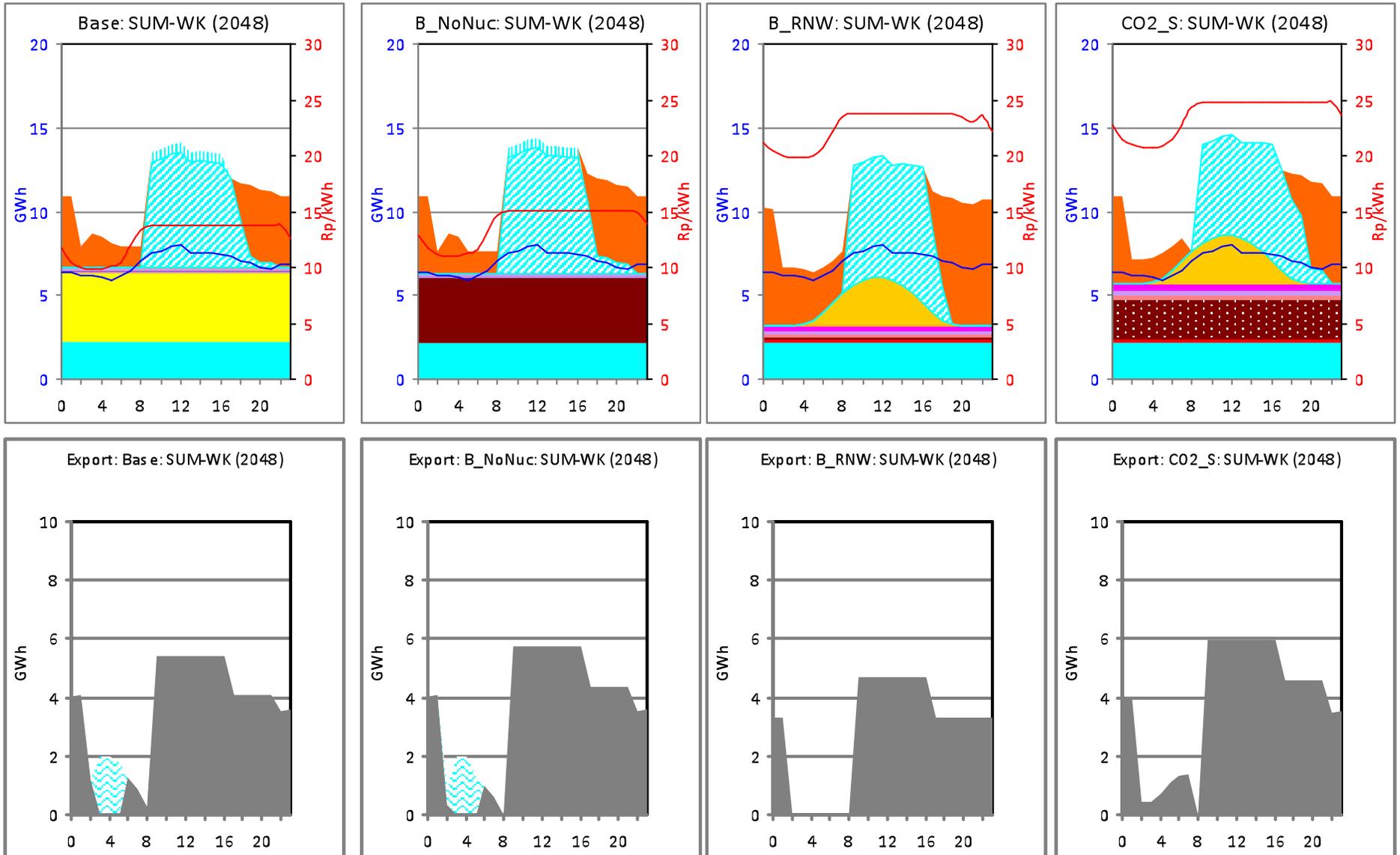
## Load curve Base scenario (Summer weekday)



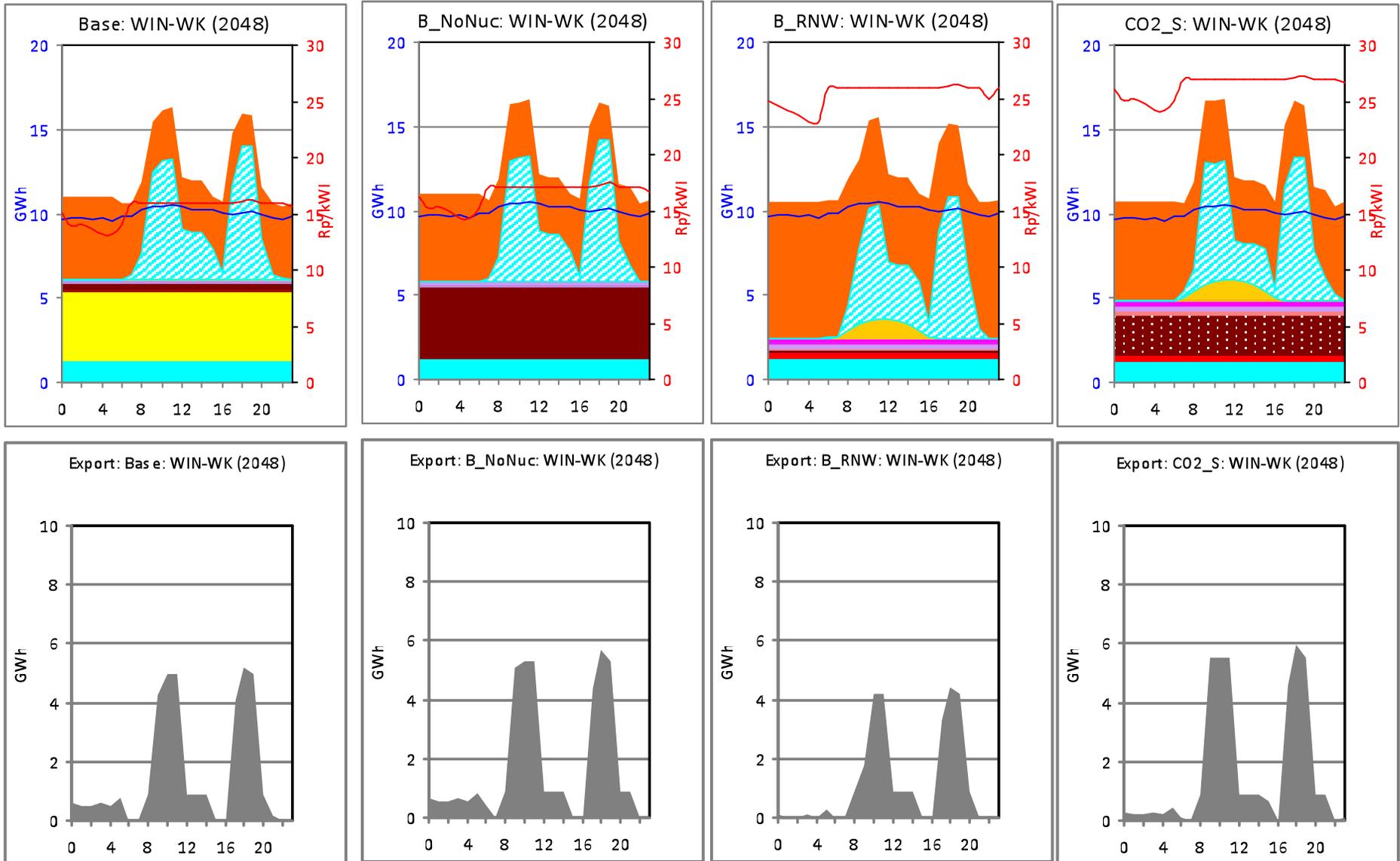
## Load curve Base scenario (Winter weekday)



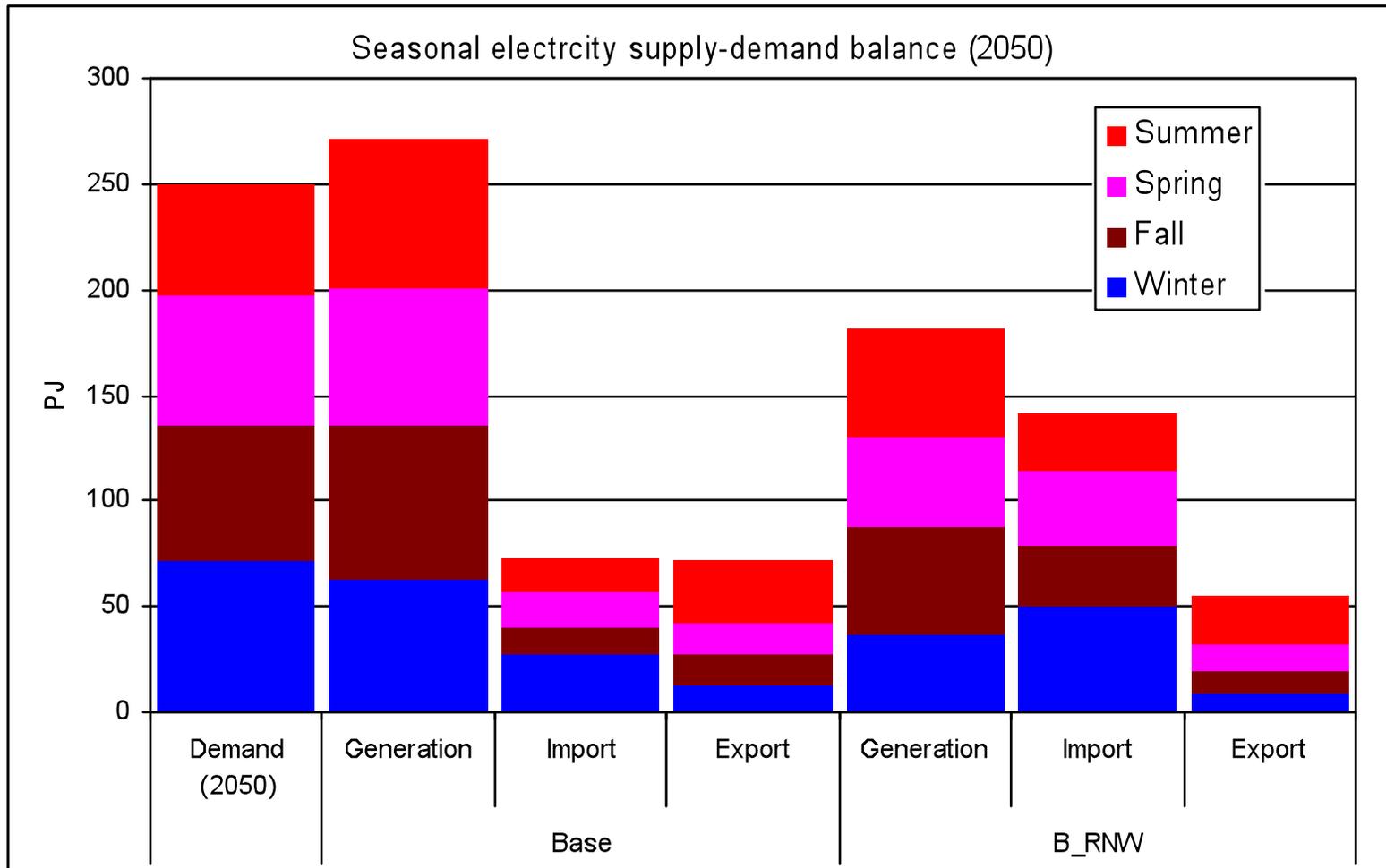
## Load curve Summer weekday



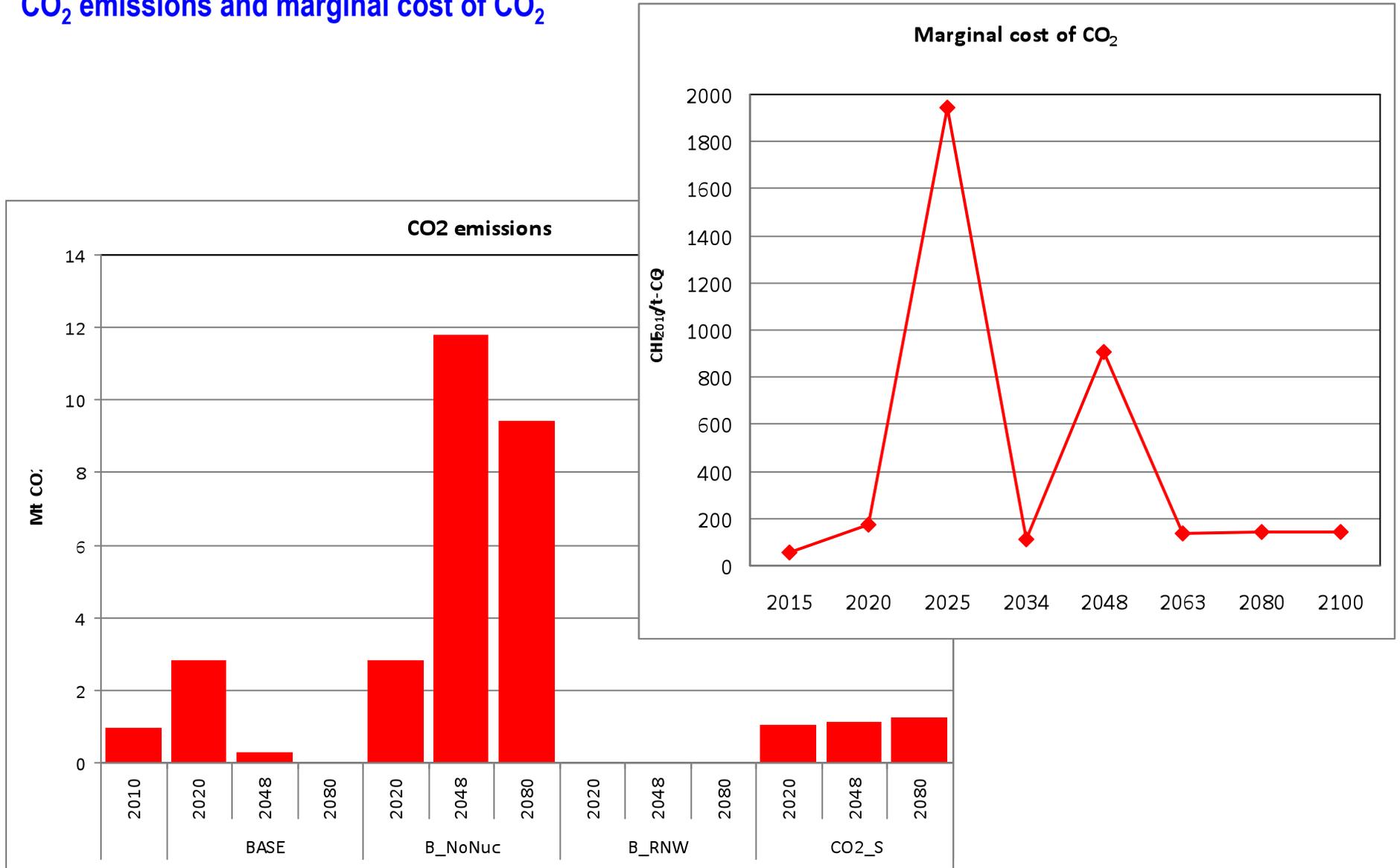
## Load curve Winter weekday



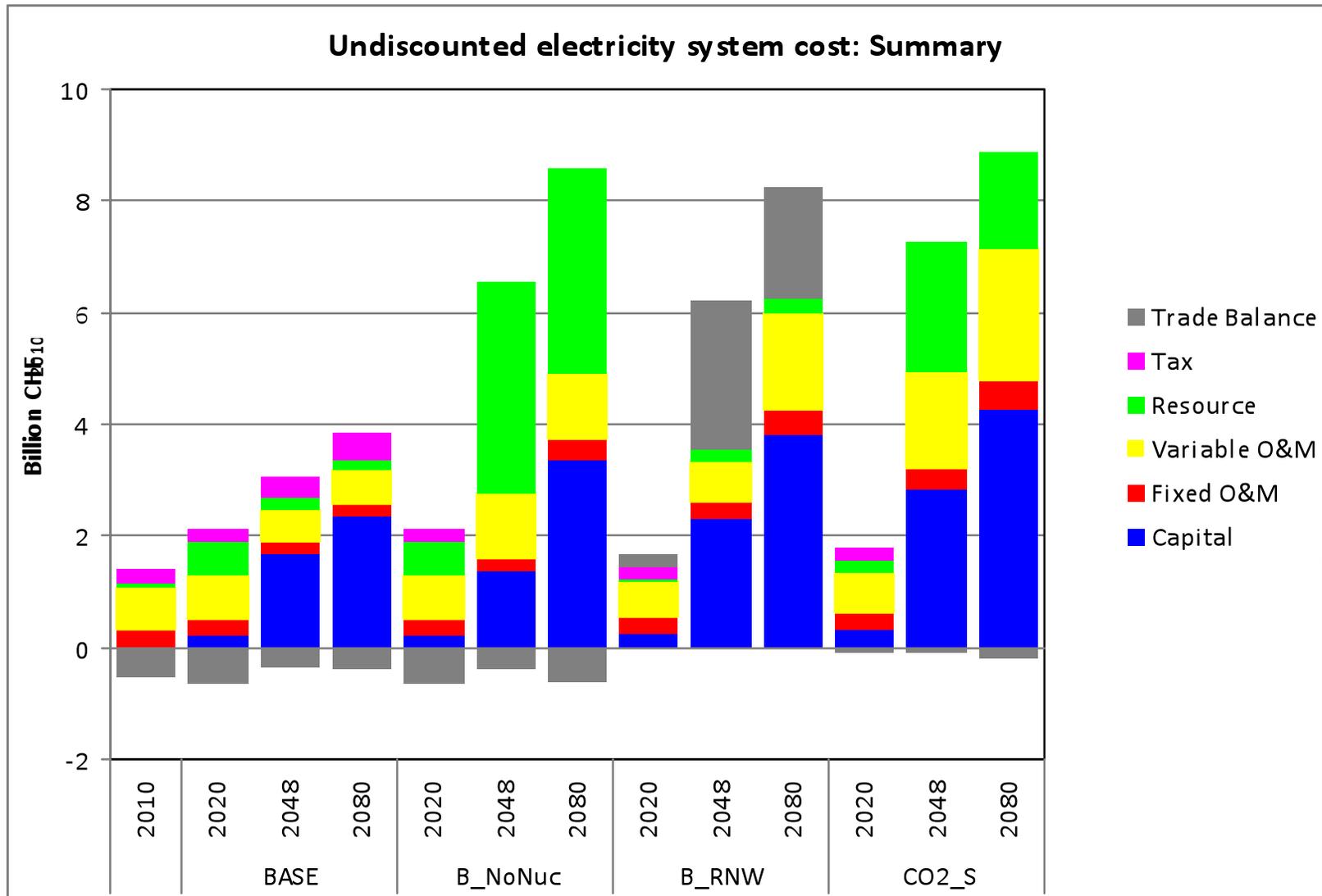
## Seasonal electricity supply and demand balance



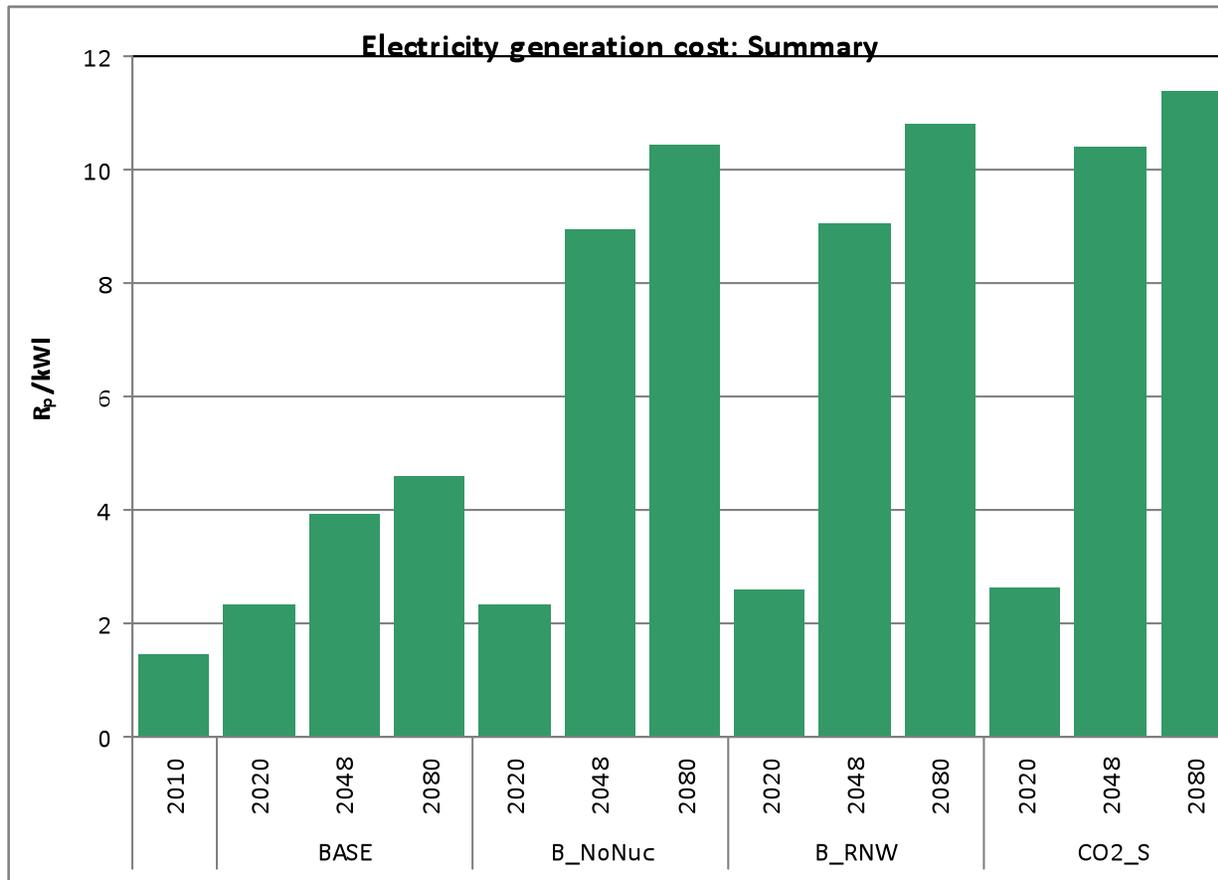
## CO<sub>2</sub> emissions and marginal cost of CO<sub>2</sub>



## Undiscounted electricity system costs



## Average cost of electricity supply



- With nuclear, average cost of electricity is 4-5 Rp/kWh while the marginal cost of electricity supply at an hourly level rises to 17 Rp/kWh in winter.
- In the non-nuclear options, average cost of electricity doubles (highly sensitive to the gas price & capital cost reduction in renewable technologies).

## Short-term (through 2025)

- Independent of decisions on new nuclear plants, there is a need for new supply in the short-term.
- Support for the continued operation of existing nuclear and hydro plants remains important under all cases.
- The most cost-effective short-term supply option is new gas combined-cycle power plants.
- Realising CO<sub>2</sub> reduction targets requires considerable investments in non-hydro renewables, incurring high cost.

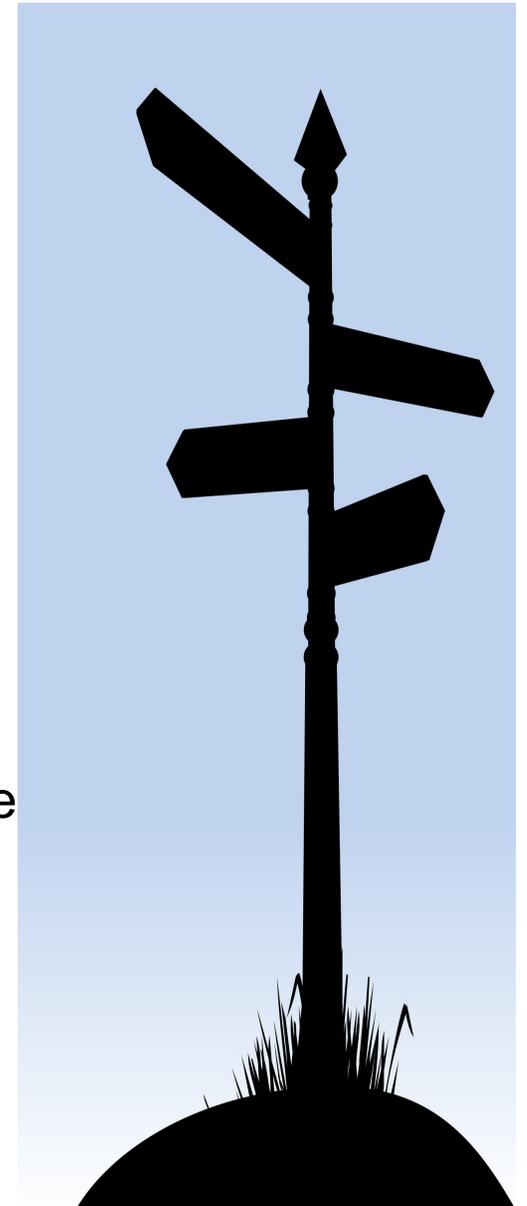
## Medium and long term

- Nuclear is the cost-effective technology options and favourable to a low carbon policy.
- For a low carbon and non-nuclear policy, large investment in renewable or CCS is inevitable, which would double the electricity cost.
- In any options, import of gas or a net import of electricity is required.
- Swiss energy system would still rely on imported electricity for seasonal demands.

## Policy implications

- Non-nuclear option incurs high cost with some tradeoffs between supply security and climate policy.
- An increased dependence on imported natural gas or electricity, raising supply security concerns. There are needs to develop or enhance policy approaches supporting energy security.
  - Developing strategic reserves of natural gas and diversifying supplies.
  - Reinforcement of interconnection capacity, expanding energy storage potential and negotiating long-term contracts with reliable partners.
- Deployment of capital intensive renewable technologies requires high capital outlays.
  - Financing the necessary capital investment shall be addressed.
  - Create an appropriate investment climate that reduces (or shares) some of the risks associated with new technologies.
- Large-scale deployment of CCS is not fully demonstrated. Importantly, potential carbon storage sites are yet to be fully characterized in Switzerland.

- Within STEM-E
  - A **comparison** between the hourly STEM-E model and an aggregated timeslice model.
  - Implementation of other policies, e.g. feed-in tariff, electricity surcharge, .....
  - Sensitivities on electricity demand variance, ...
- Extension of **STEM-E** to other sectors – A **whole energy systems model** (on going and funded by Swiss Federal Office of Energy).
- **CROSSTEM** (*Swiss + 4 regions*) – inclusion of four **cross bordering counties' electricity systems** (to be kicked off and funded by Swiss Federal Office of Energy).



## **Energy Economics Group**

### **Laboratory for Energy Systems Analysis**

**General Energy Research Department & Nuclear Energy and Safety Research Department**

