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

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Outline

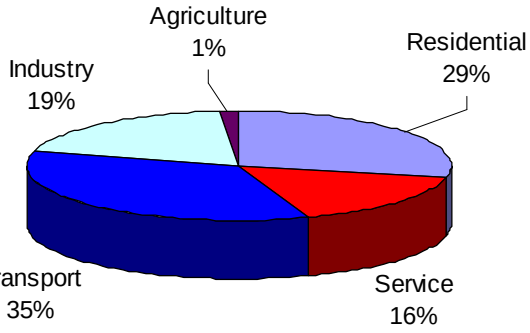
- **Overview of Swiss electricity systems**
- **Swiss TIMES Electricity Model**
  - **Model features**
  - **Input data and key assumptions**
- **Scenario definitions**
- **Results and discussions**
- **Conclusions**

Overview of Swiss energy system

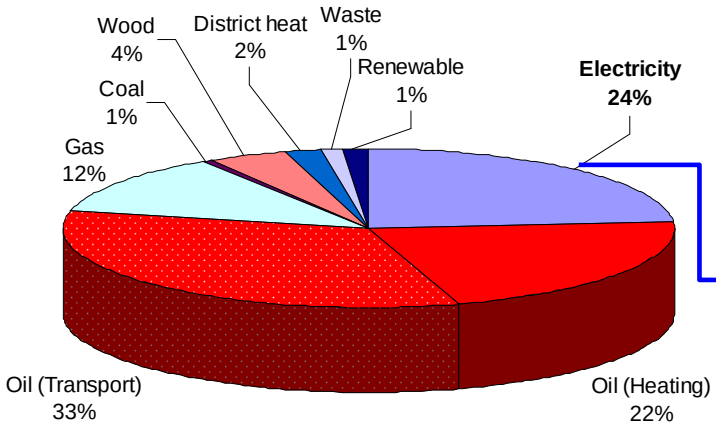
Energy Economy (2009)

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

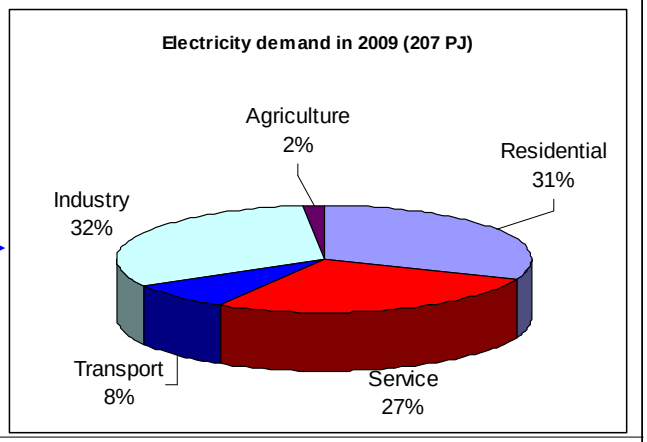
Final energy demand in 2009 (877 PJ)



Final energy demand in 2009 (877 PJ)

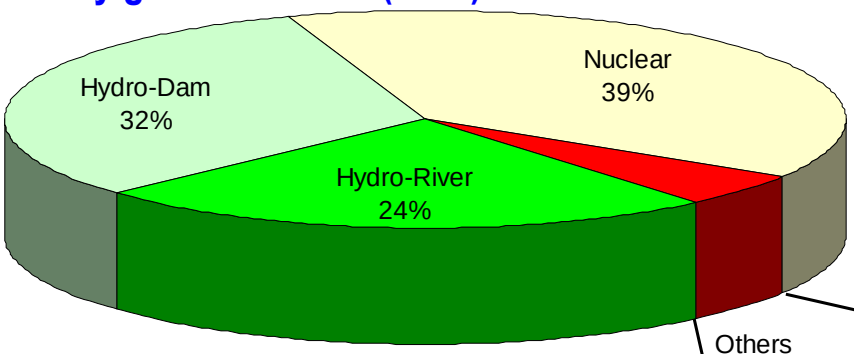


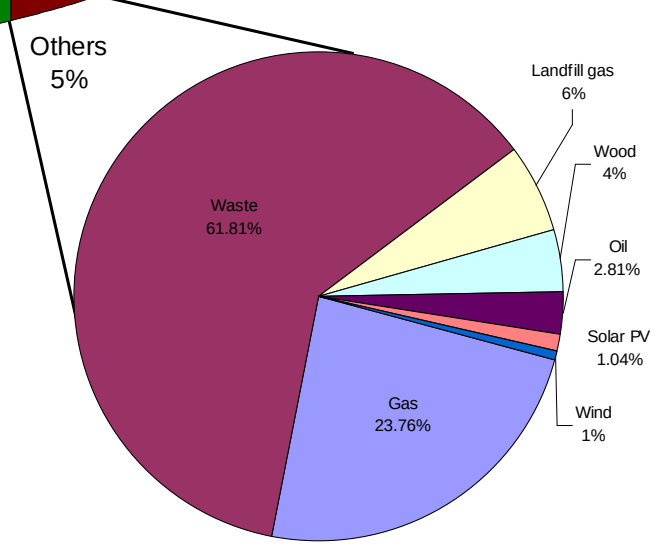
Electricity demand in 2009 (207 PJ)



Swiss electricity system

Electricity generation mix (2009)

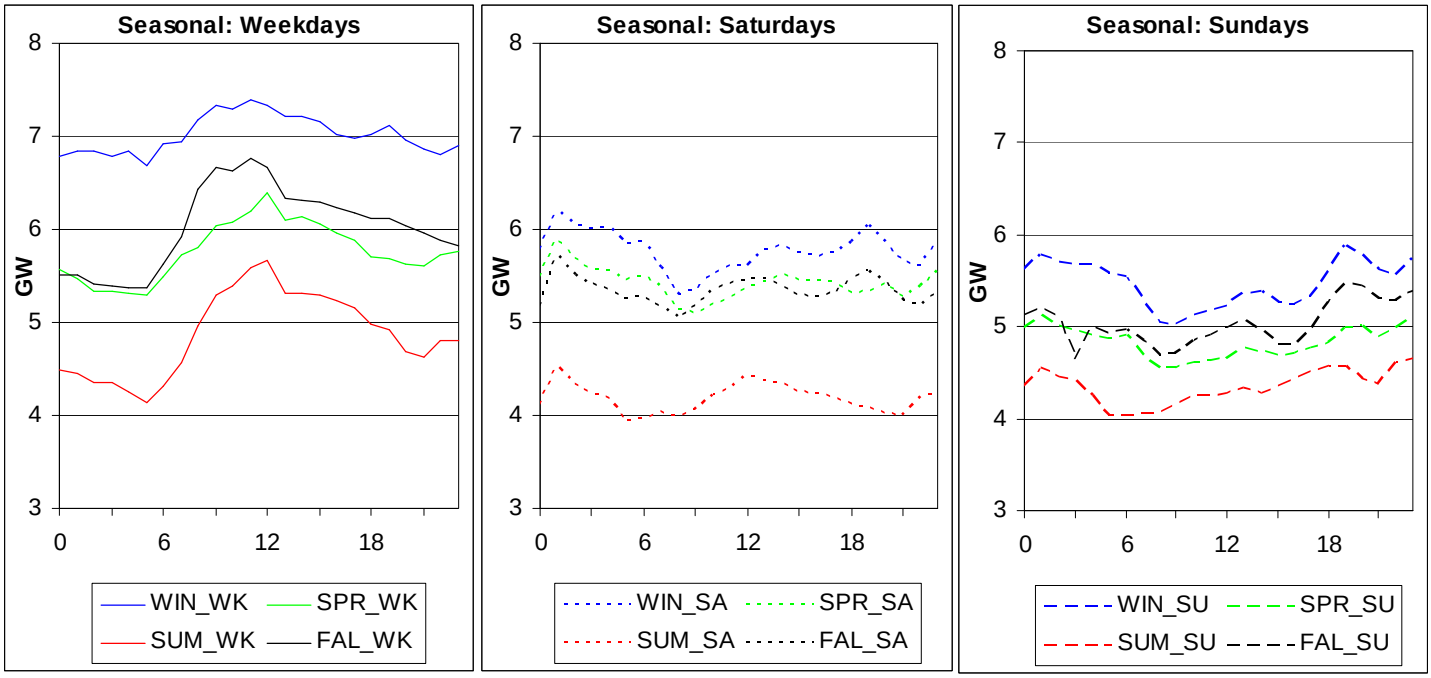




- An annual average growth of 1.3% over the past ten years.
- Self sufficiency in annual electricity generation, but still dependent on imported electricity for seasonal demand.
- Power sector is nearly decarbonised.
- Electricity trading is important in terms of power system balance and revenue (CHF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

Swiss electricity system

Electricity load curves (2008)



Overview of Swiss energy system

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%)

Quelle: EnergieSchweiz, 2010

Swiss electricity system

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.

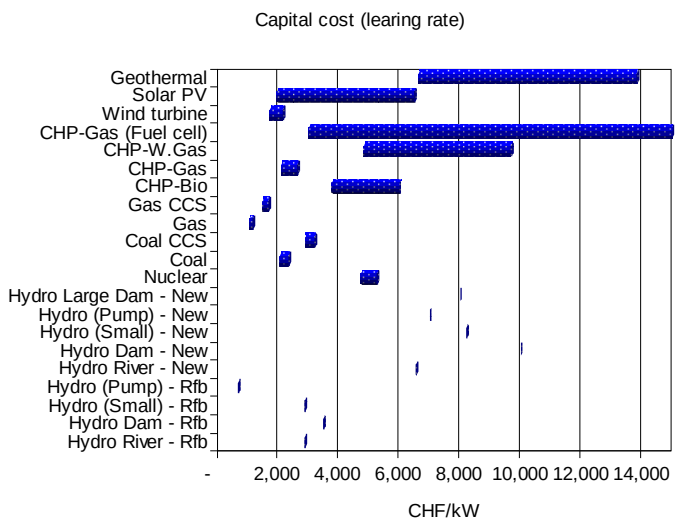
Swiss TIMES electricity model

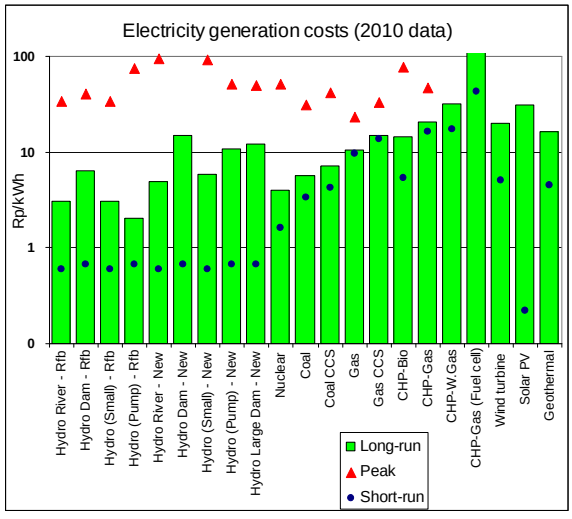
Model features

- 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)





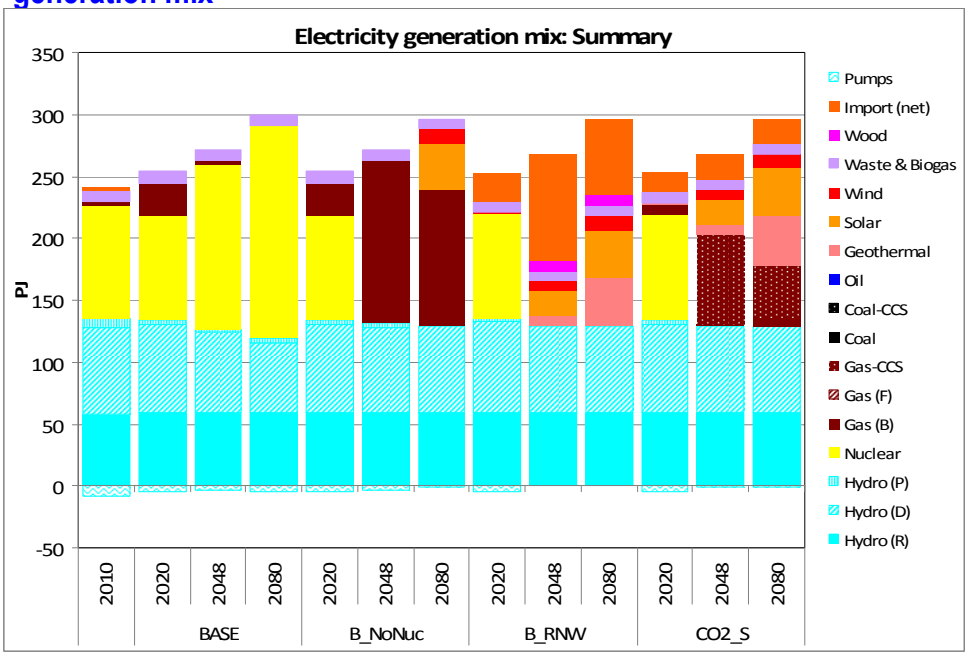
For more details: R. Kannan and H. Turton (2011) *Documentation on the development of Swiss TIMES Electricity Model (STEM-E)*, http://eem.web.psi.ch/Projects/STEM-E.html

Scenario definitions

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_2 emission intensity of electricity (g-CO_2/kWh) to the level in the year 2010. In addition, nuclear investment is completely restricted, but gas with CCS is available.

Results

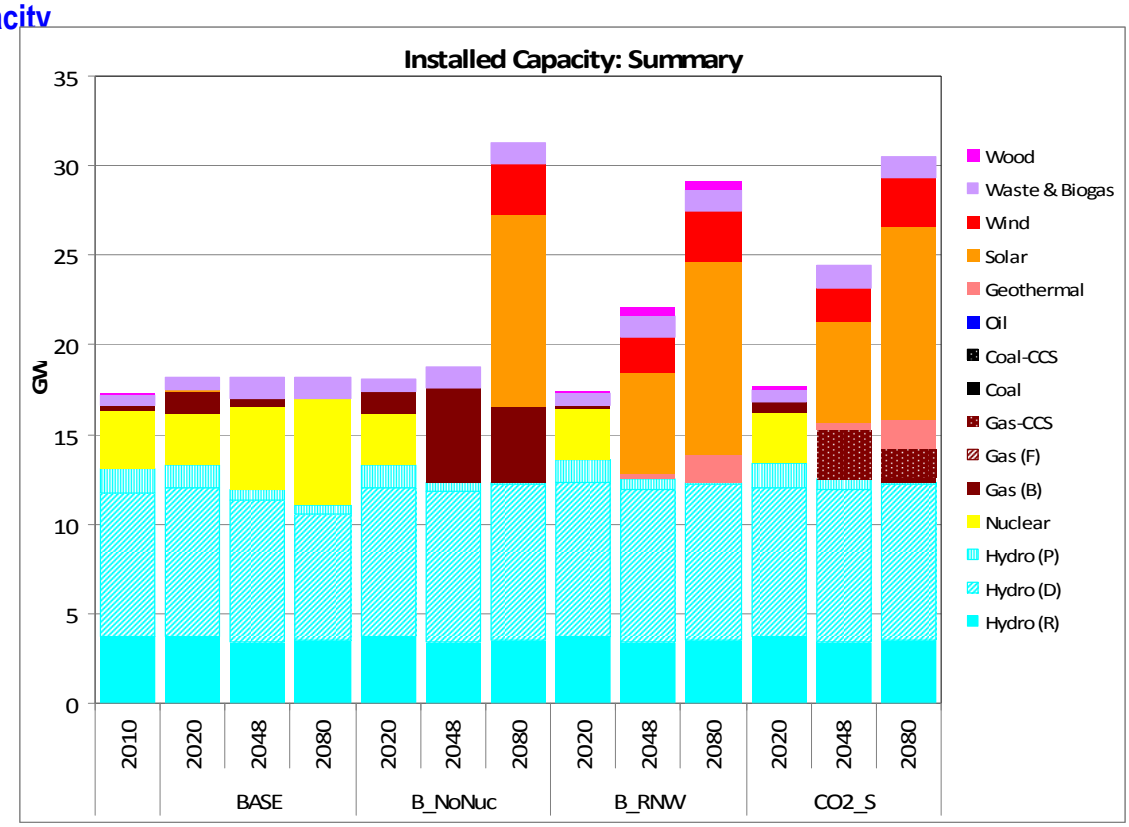
Electricity generation mix



- 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.

Results

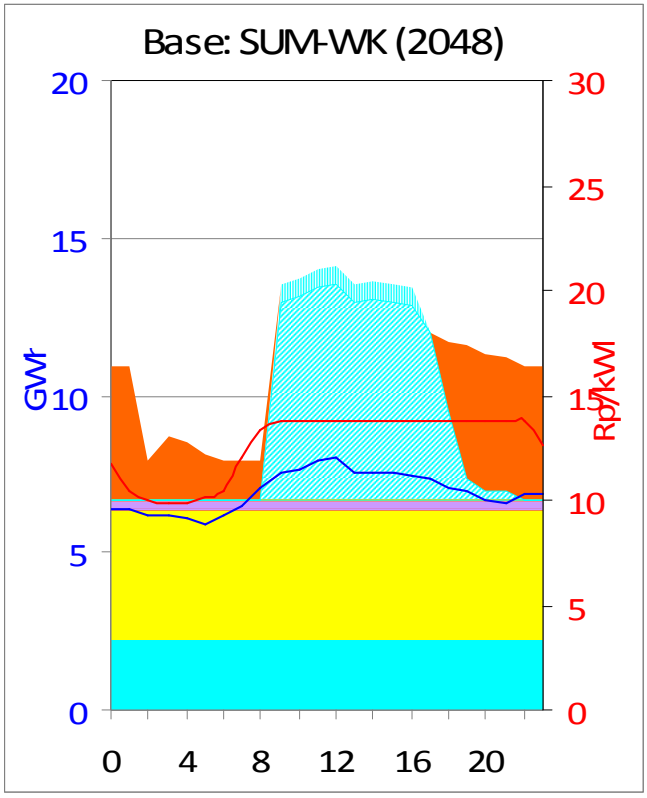
Installed capacity

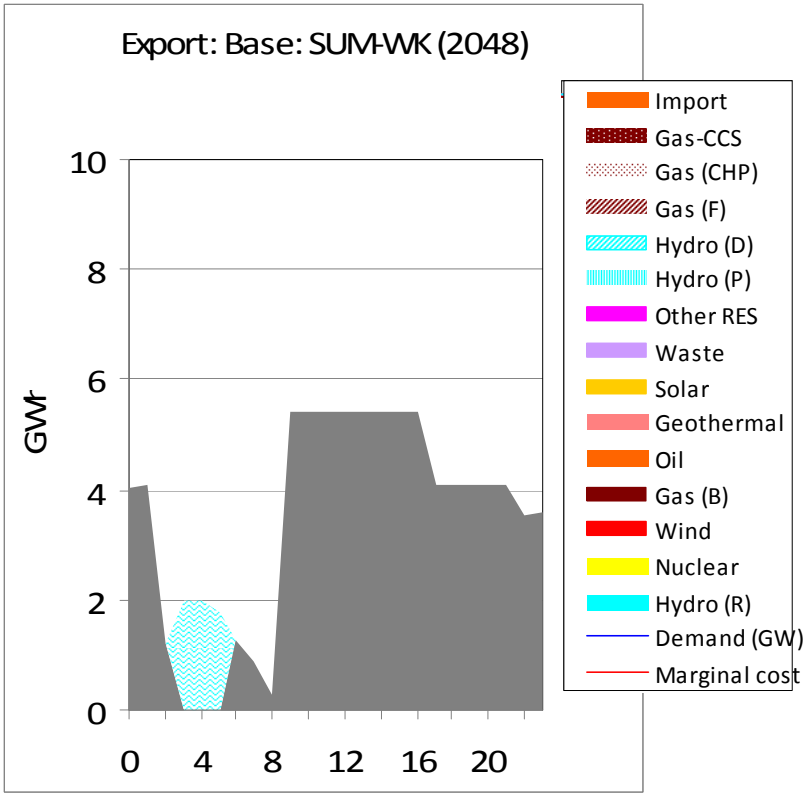


➢Short-duration intermittence is not considered but it is likely that dam hydro could support the management of intermittency.

Results

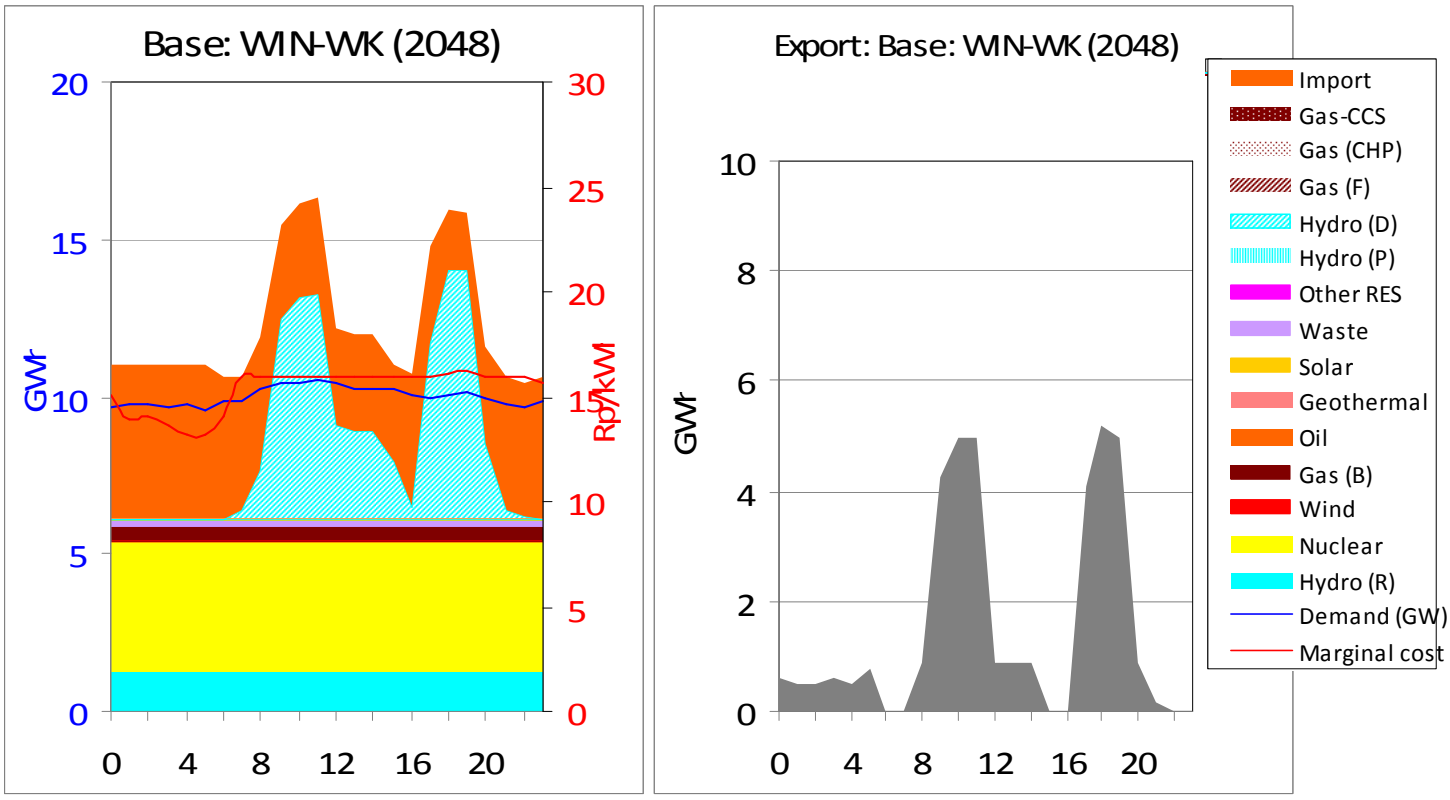
Load curve Base scenario (Summer weekday)





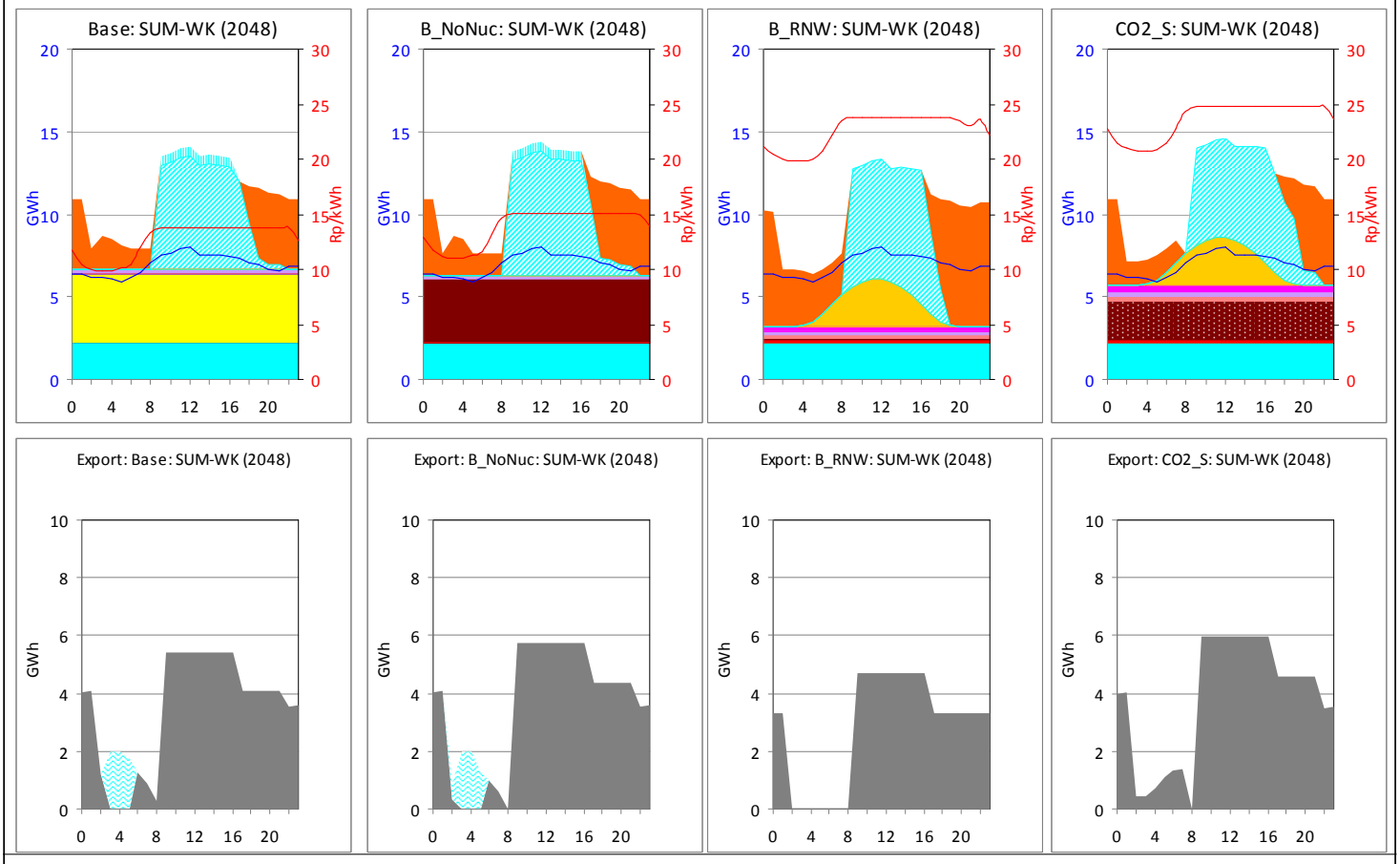
Results

Load curve Base scenario (Winter weekday)



Results

Load curve Summer weekday



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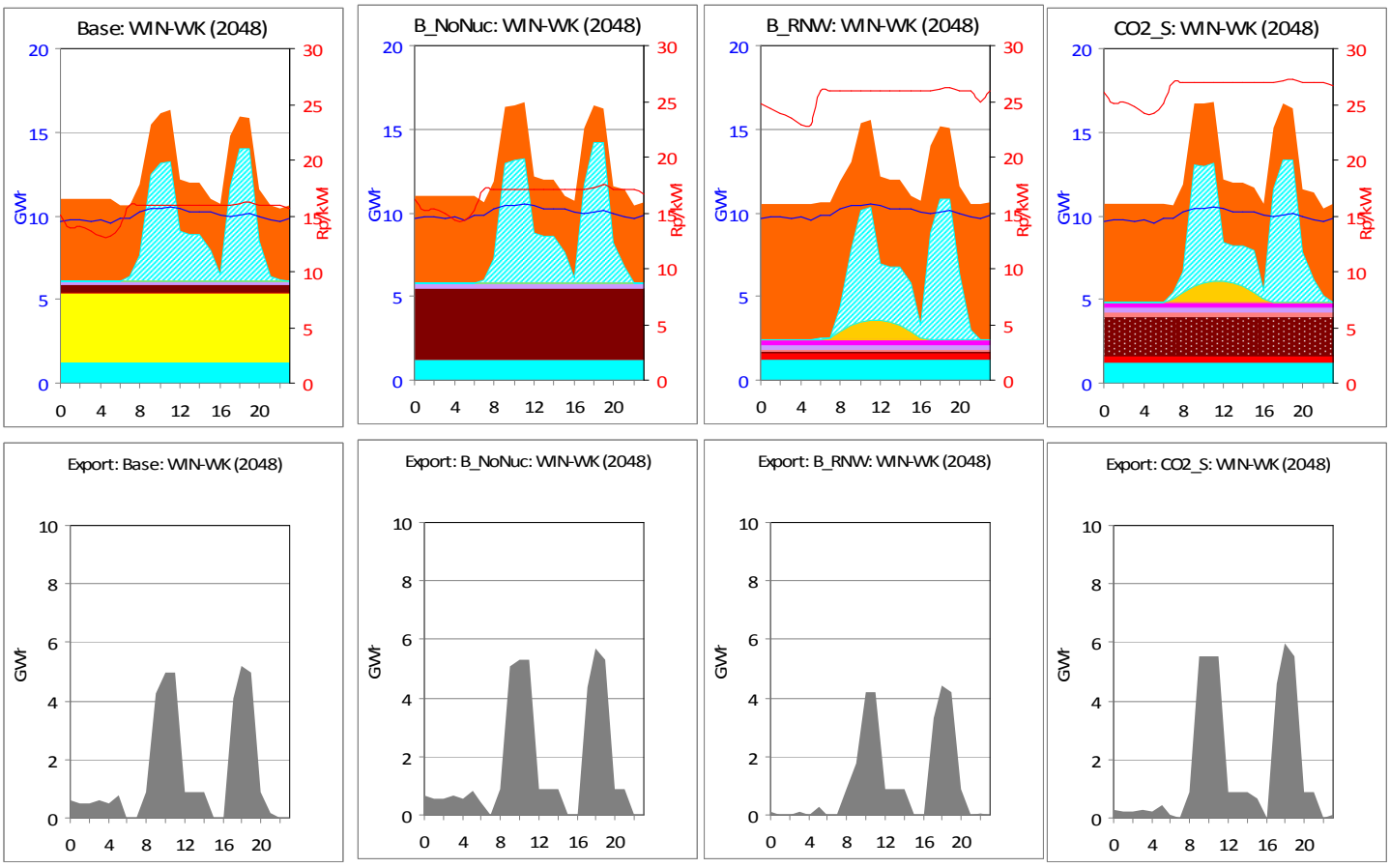
Results

Load curve Winter weekday



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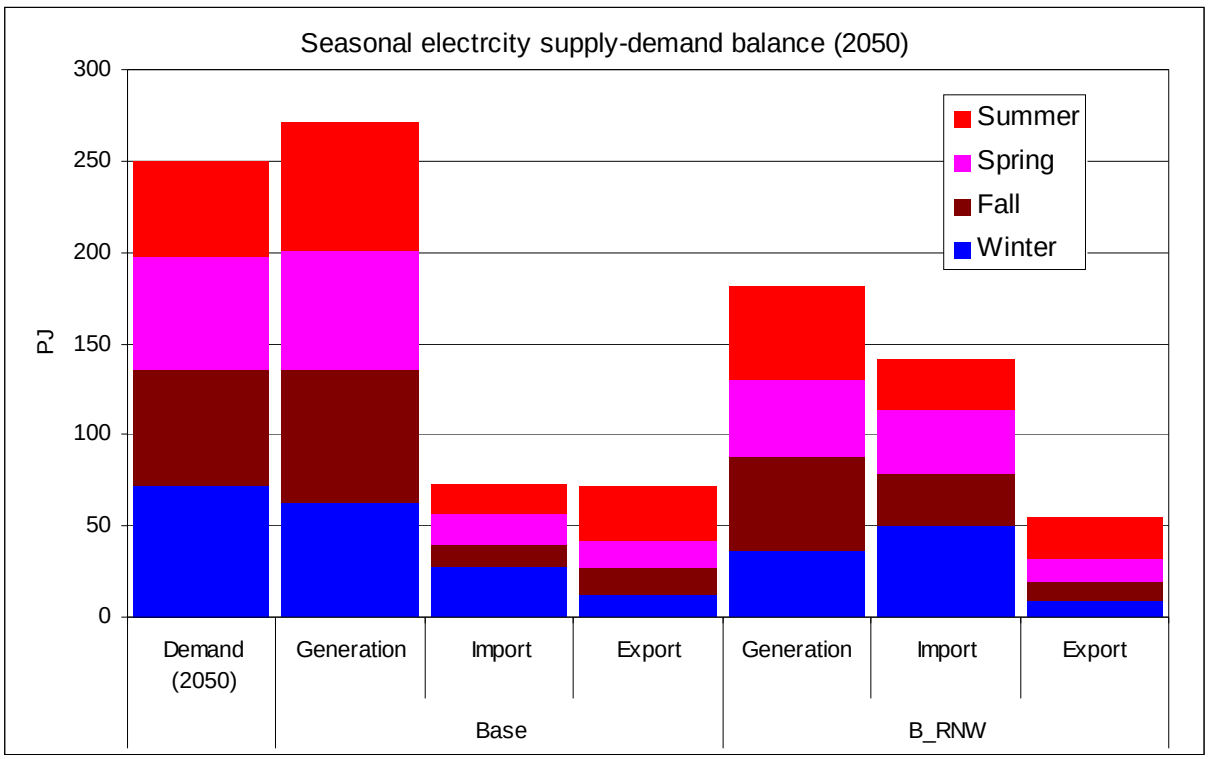
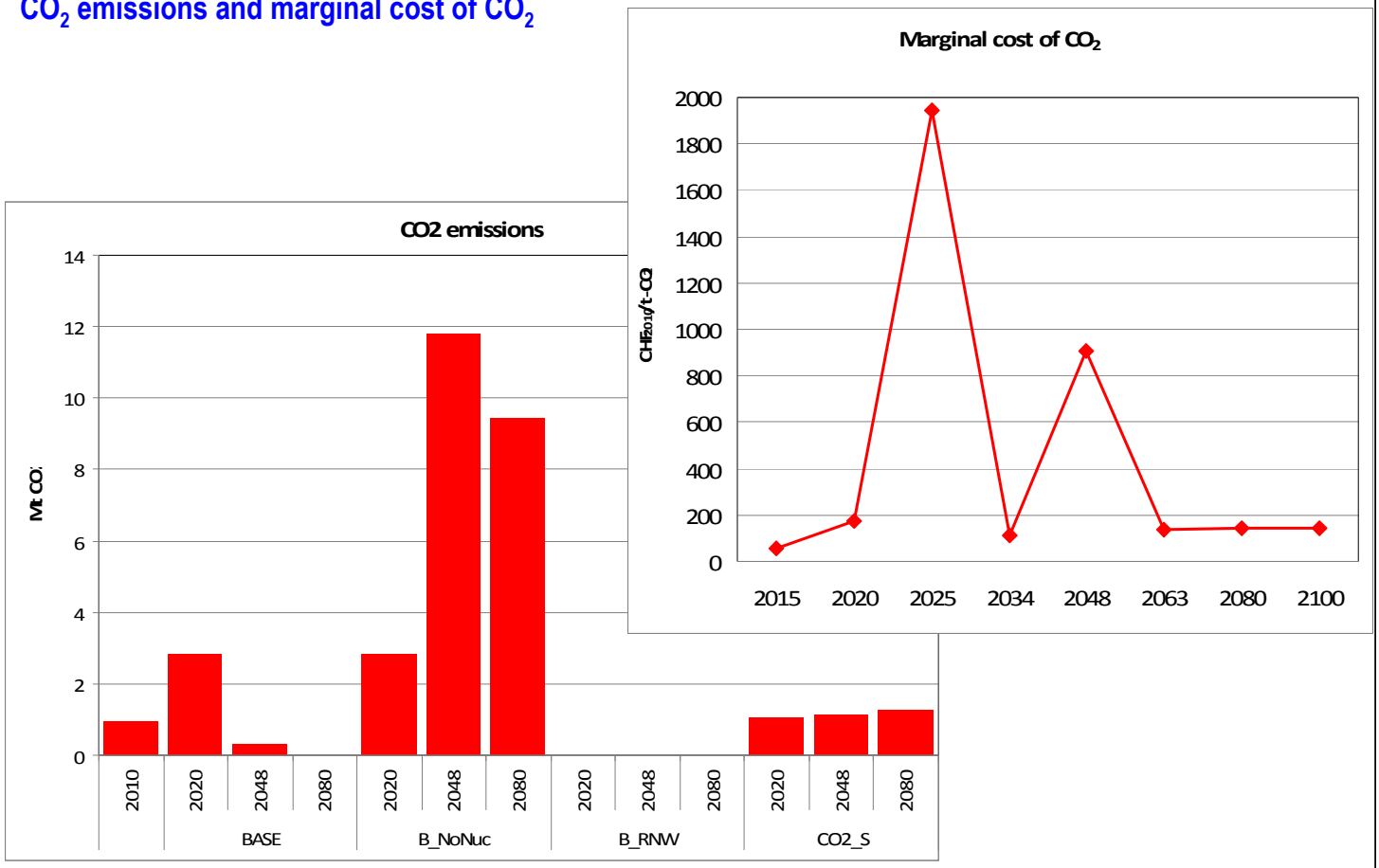
Results

Seasonal electricity supply and demand balance



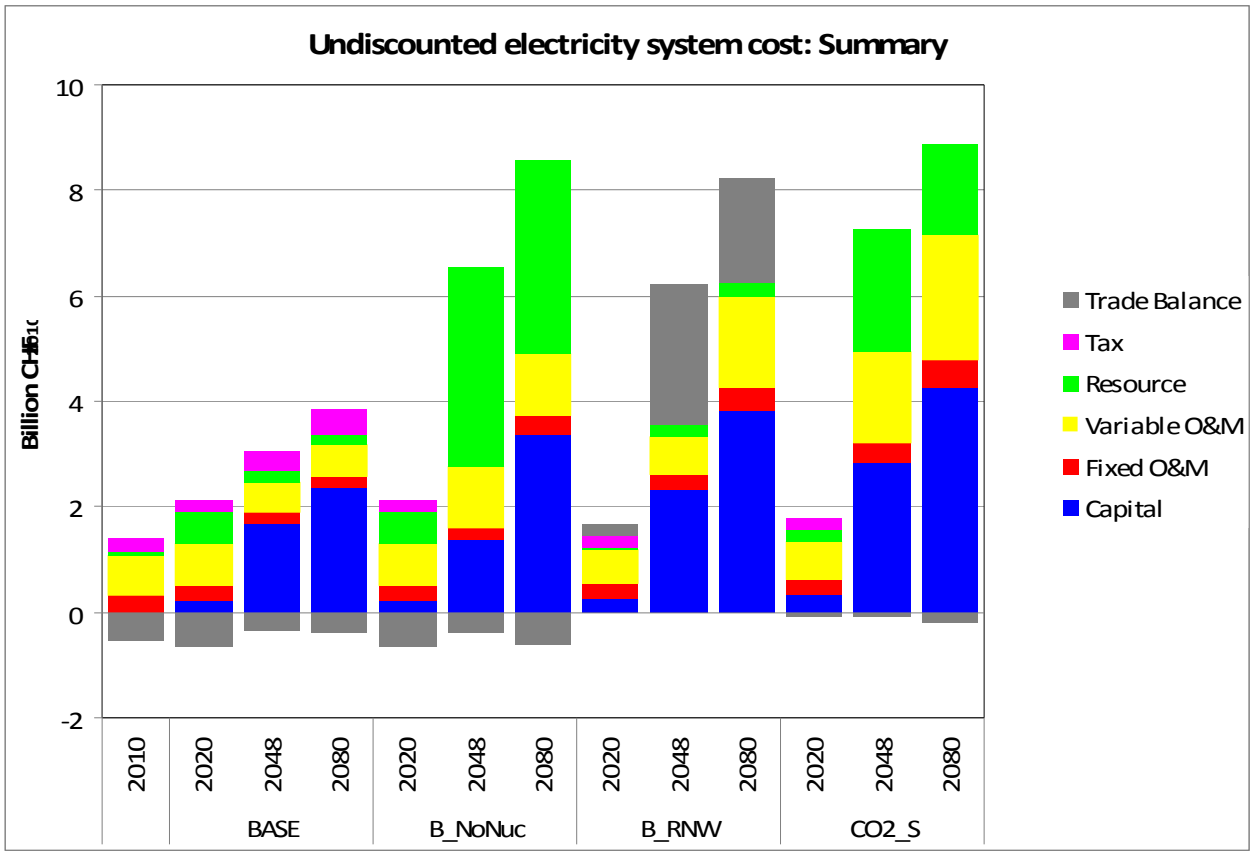
Results

CO_2 emissions and marginal cost of CO_2



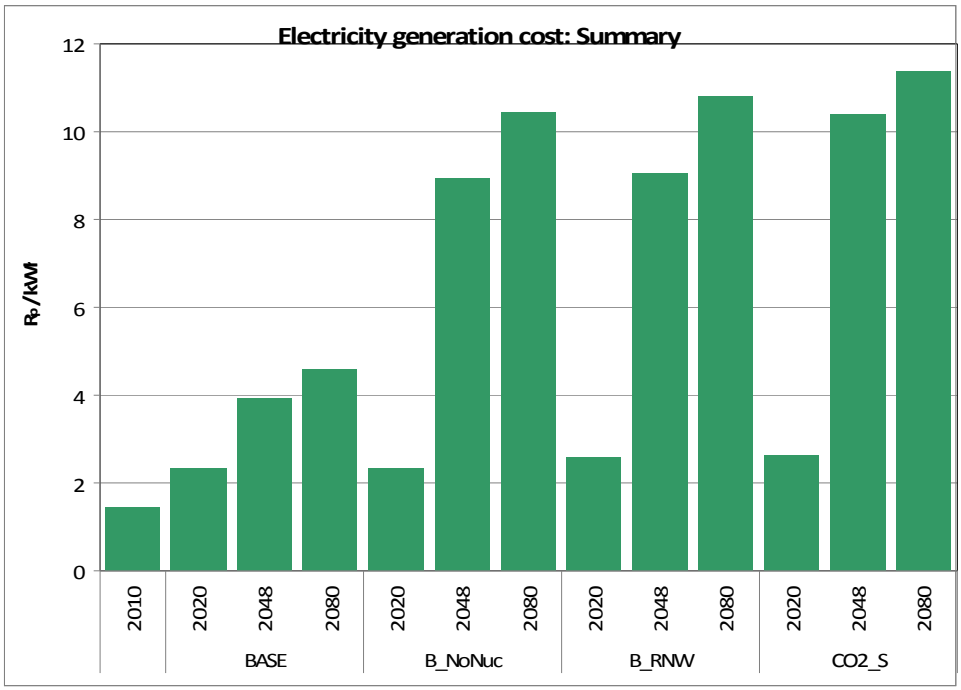
Results

Undiscounted electricity system costs



Results

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).

Conclusions

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 shot-term supply option is new gas combined-cycle power plants.
- Realising CO_2 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.

Conclusions

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.

Future direction

- 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).

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