PAUL SCHERRER INSTITUT

Case Studies of the Swiss Energy System – Sensitivity to Scenario Assumptions Assessed with the Swiss MARKAL Model

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Introduction

In order to cope with the challenges of climate change and energy security, important decisions related to the Swiss energy system need to be taken during the coming years. Besides the development of energy prices, decisions on climate policies and on the future role of nuclear will have an important impact on the configuration of the Swiss energy system. However, there exists significant uncertainty about how these different issues will be resolved.

In the case of nuclear power, decisions on the construction of replacement plants for Mühleberg and Beznau 1+2 are still pending, thus it is not clear whether any new plants will be built in Switzerland. It is also unclear if the construction of alternatives to nuclear, in the form of other large centralized generation plants fuelled with fossil energy carriers, would receive the necessary public and political support. Thus there are currently major uncertainties about which generation options will be available to meet increasing demands for electricity.

These questions about nuclear power have arisen at a time when it has become increasingly clear that stringent mitigation of climate change is necessary to avoid serious damages to natural and human systems, including agriculture, health, and infrastructure. Thus, it is important to consider future energy transitions that are compatible with a stable climate. Among the policies advocated for responding to greenhouse gas emissions in Switzerland, the relatively ambitious target from the Advisory Body on Climate Change (OcCC) is considered in this work.

Importantly, Switzerland is not self-sufficient in terms of energy and relies heavily on imported fossil fuels, primarily oil for transportation and heating. Accordingly, the options for the energy system in the future may also be affected by international developments that affect energy prices and availability. Recent movements in the price of oil illustrate the high level of uncertainty in this regard.

To understand future options for achieving a sustainable energy system in Switzerland, and to explore these uncertainties, we present here a number of scenarios of the future development of the Swiss energy system out to the year 2050. We include scenarios reflecting different levels of support for nuclear power (see below), in combination with assumptions on climate policy, oil prices and economic development. These scenarios are analysed with the Swiss MARKAL model (SMM), a least cost optimization bottom-up energy system model of the Swiss energy system that provides a detailed representation of energy supply and end-use technologies, including energy efficiency options.

The objective of this work is to show how policy related changes as well as external effects can influence the future Swiss energy system until 2050. The results of this work are intended to support decision making on energy related issues by identifying some of the options for achieving policy objectives, some of the trade-offs between different objectives, and the technologies that may be important for realising a sustainable Swiss energy system.

Method

For this analysis we employ a detailed model of the Swiss energy system to quantify and explore various cases and scenarios regarding the future. The model, key assumptions, and the cases and scenarios are described below.

Energy system model Swiss MARKAL

The energy system model Swiss MARKAL provides a detailed representation of energy technologies of the Swiss energy system. Energy supply as well as the end-use demand technologies are explicitly modelled. New energy technologies that will be available in the future are also represented.

The model identifies the most cost-competitive combination of fuels and technologies to satisfy future energy demands, taking into account technical, policy and external constraints. Secondary benefits (avoiding of external costs) and tertiary effects (innovation) are not modelled.

The Swiss MARKAL model used for this analysis is based on an earlier model developed by Thorsten Schulz in 2007 [1]. Recent developments to Swiss MARKAL include:

- Updates to renewable energy potentials for hydro, wind, solar photovoltaic, and biomass. The updated potentials are described below under general assumptions;
- The addition of new car technologies (including an electric battery car and an advanced hybrid); and
- The addition of a centralized combined cycle natural gas generation technology, and a decentralized combined heat and power (natural gas) powerplant technology.

These and other model developments are important for improving the representation of technology options and renewable potentials for Switzerland over the first half of the 21st century.

General assumptions

A number of important assumptions have been adopted in this modeling analysis, which are summarized briefly below:

- The time horizon of this analysis is from 2000 to 2050.
- Future energy demand is based primarily on future GDP and population assumptions:
    - The GDP projection assumption corresponds to the scenario reported by SECO [2], with GDP increasing by nearly 50 % from the year 2000 to the year 2050.
    - The population projection corresponds to the scenario ‘A-Trend’ reported by the Swiss Federal Statistics Office [3]. It is based on a continuation of recent historical trends and middle values for fertility rates, immigration flows and life expectancy. In the ‘A-Trend’ projection, the population of Switzerland increases from about 7.2 million inhabitants in 2000 to about 7.4 million inhabitants in 2030. Afterwards, the population experiences a slight decline reaching about 7.1 million inhabitants in 2050. Newer scenarios that assume a stronger population growth due to migration of 8.3 million people in the year 2035 were not taken into account for consistency

reasons in this analyses, since they would require a new calibration of the model regarding GDP projection and demand.

- The discount rate used in the analysis is 3%.
- For this analysis we have assumed a maximum hydro electric generation of 36.6 TWh, 4 TWh of wind generation, and 13.7 TWh of solar PV (see ref. [4,5,6]). Geothermal energy from deep hot rock is not taken into account for this analysis because of the high uncertainty of its future potential and public acceptability. For biomass we assume a domestic potential of 103 PJ, with no imports.
- Electricity imports are not modeled to allow us to analyse the implications for the Swiss system independently. That is, we are assuming that Swiss policymakers and society are likely to place an emphasis on maintaining a close balance between domestic electricity supply and demand to support energy security objectives.

The general assumptions above are used in all the scenarios presented in this report.[1] There are of course other possible futures regarding socio-economic development, energy demand, and renewable potentials not covered by these assumptions. Accordingly, the scenario analysis presented here seeks to examine only some of the key policy and external uncertainties, rather than the full range of possible future developments. We now turn to the specific cases and scenarios we present here, and which we use to analyse some of the key policy and external uncertainties.

Cases and scenarios

In this report we make a distinction between 'cases' and 'scenarios'. We analyse four cases related to domestic electricity generation and look at how they react under different scenarios.

The following four **cases** are analyzed in this report:

Case 1: Nuclear replacement

In this case it is assumed that the total capacity of nuclear generation is maintained but cannot exceed the level existing today. We assume an available nuclear capacity of 3 GW over the whole time horizon (equivalent to today's installed capacity).

Case 2: No new nuclear replacement

In this case, existing capacities of nuclear power generation are not replaced at the end of their technical lifetimes. Today's nuclear capacity of 3 GW is available until 2020, at which time Mühleberg and Beznau 1+2 are shut down (leaving a remaining capacity of 2 GW), followed by the shutdown of Gösgen in 2040 (1.17 GW remaining) and finally shut down of Leibstadt in 2045 (0 GW remaining).

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[1] With one exception for energy demand when we examine the impact of a long-term economic stagnation (see below).

Case 3: No centralised fossil power plants + no new nuclear replacement

This case assumes that investment in nuclear and centralized fossil fuel electricity plants is completely prohibited. Options to fulfil the demand are decentralized (particularly combined heat and power production from natural gas) or centralized renewables.

Case 4: Nuclear expansion

With this scenario we analyse the effect of a possible expansion of nuclear capacity, beyond 2025: From 2000 until 2025 the available nuclear capacity is 3 GW, and then is able to expand up to approximately 5 GW by the end of the time horizon.

All cases mentioned above are combined with **scenarios** described in the following:

Baseline

For the baseline we assume an oil price of 28 $US\$_{2000}$/bbl in 2000, linearly increasing up to 50 $US\$_{2000}$/bbl in 2050. The price of natural gas is coupled to the oil price (increasing up to 35 $US\$_{2000}$/bbl in 2050). There is no climate policy in the baseline, i.e. no targets for the CO_2 emissions.

High oil price

Under this alternative scenario we assume that the oil prices increase linearly from 28 $US\$_{2000}$/bbl in 2000 up to 200 $US\$_{2000}$/bbl in 2050 (with natural gas increasing up to 140 $US\$_{2000}$/bbl).

Climate policy

We consider the impact of a climate policy that targets a reduction of domestic CO_2 emissions (excluding international air transport and international navigation) by 20% until 2020, and by 60% until 2050 relative to the level of 1990 emissions. These specification follow the recommendation of the Swiss Academies of Arts and Sciences (a+) and the Advisory Body on Climate Change (OcCC).

Stagnation

In this scenario we assume a continuation of the current economic crisis, and examine the implications for the energy system. To simulate the effect of the crisis we assume that demand for energy stagnates (remains unchanged) from 2005 until 2015

In the following sections, results for Cases 1 – 4 are presented and discussed. A complete representation of time-dependent primary energy consumption and CO_2 emissions for all cases, combined with all scenarios, is given in the Appendix.

Case 1: Replacement of nuclear power plants

Results

Baseline

In the baseline scenario (cf. Figure 1) total primary and final energy consumption stay more or less constant. Total CO_2 emissions (Figure 2) decrease slightly over the time horizon, with an increase in CO_2 emissions in the electricity sector and a decrease in the residential and service sector. CO_2 emissions in transport and industry do not change too much over the time horizon. Nuclear and hydro capacities are used up to assumed potentials described above; oil is partly replaced by natural gas. In the road transport sector there is a shift from gasoline to diesel cars. In the service sector liquid fuels are replaced by electricity, and in the residential sector liquid fuels are replaced by natural gas, district heat and renewables.

High oil price

A scenario with higher oil prices shows a slight reduction in primary energy and stronger reduction in final energy. In the middle of the time horizon oil is replaced by gas, and after 2035 we observe a shift from gas to renewables such as wind and solar. In the residential sector the higher oil price promotes efficiency and a much faster shift from oil to electricity than seen in the baseline scenario. After 2030 oil is not used any more in the residential sector and has only very small share in the service sector. There is an increase in efficiency and a switch from petroleum fuels to natural gas in the road transport sector (i.e. cars and trucks). Because of the high oil price, energy saving options and more efficient technologies are used, leading to a lower demand for carbon-intensive oil and thereby causing less CO_2 emissions. Especially in the residential and services sector the share of CO_2 emissions is very small towards the end of time horizon. Relative to the base case, the expensive oil causes high total discounted energy system costs[2], i.e. up to 37% higher compared to the baseline.

Climate policy

When adding a climate policy to the baseline scenario, we observe a shift from fossil fuels to biomass and renewables at the end of the time horizon and a decrease in final energy in the residential sector. Similar to the high oil scenario petroleum fuels are partly replaced by natural gas in the road transport sector (i.e. cars and trucks). The climate policy also promotes efficient cars and hybrids. And at the end of the time horizon first hydrogen cars become attractive. In the residential sector there is a stronger and faster shift from fossil fuels to electricity and renewables. Similar to the high oil price scenario the climate policy promotes efficiency in the residential and services sector. Compared to the baseline, emissions are reduced substantially in the residential and electricity sectors, while the decrease in transport is rather small. One of the reasons for this is that more technology detail and abatement options are represented in the residential sector compared to the transport sector. Unlike in the baseline scenario, there is a strong decrease in residential heating energy consumption because of higher efficiency of end-use demand

[2] The total discounted system costs are the annual discounted system costs accumulated over the time horizon of 50 years.

technologies and the application of energy saving options. The total discounted energy system costs increase moderately (by 4%) relative to the baseline.

Baseline	*High oil*	*Climate policy*

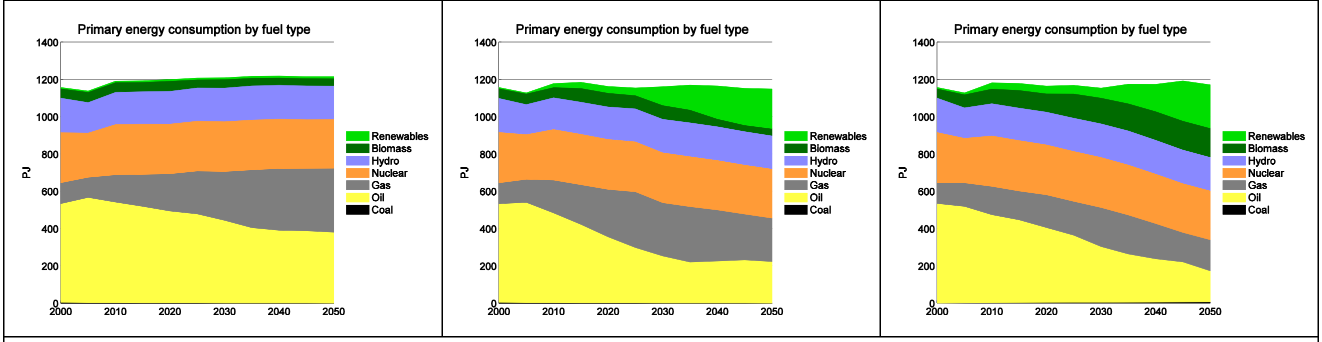


Figure 1*: Primary energy consumption for scenarios baseline, high oil and climate policy*

High oil price + climate policy

If we combine both a high oil price and the climate policy we observe effects of both single scenarios (i.e. high oil price and climate policy). While the climate policy is the dominant influence, we also see a shift to natural gas and biomass similar to that observed in the high oil price scenario. Additionally it is interesting to see that the total primary energy consumption at the end of the time horizon is slightly lower than in each of the single scenarios.

Baseline	*High oil*	*Climate policy*

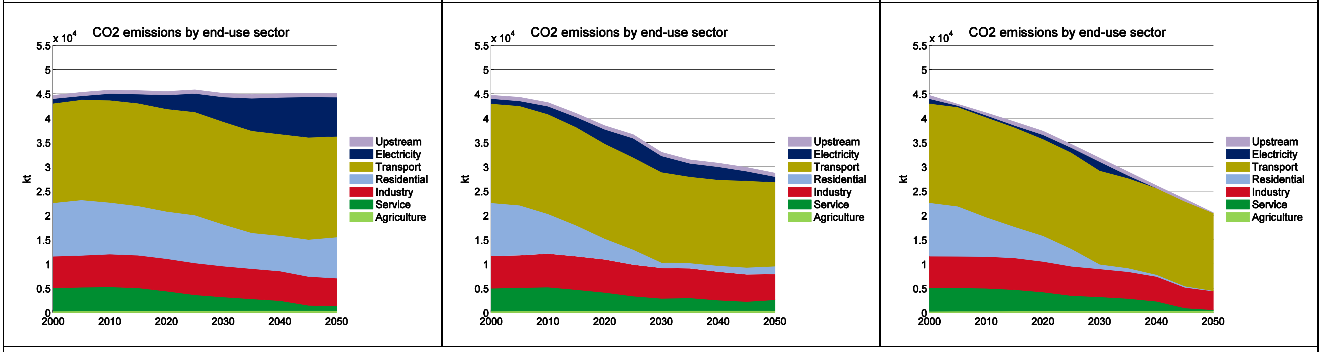


Figure 2*: CO_2 emissions for scenarios baseline, high oil and climate policy*

Stagnation

Assuming that the end-use demands stay constant during 10 years because of a recession we observe that there is a decrease in final energy consumption between 2005 and 2015. This decrease occurs despite end-use demands remaining unchanged because there is some turnover and replacement of old equipment with new more energy-efficient technologies (although investment in energy technology is around 20% lower during the recessionary period). Afterwards the energy consumption slightly increases but remains below the baseline level described above. Total CO_2 emissions decrease during the 10-year stagnation period and then stay more or less constant while the sectoral shares are similar to the baseline scenario.

Case 2: No replacement of retired nuclear capacity

Results

Baseline + no nuclear

Assuming that there is no investment in new nuclear capacities, the decline in nuclear generation is offset by additional electricity generation from natural gas. Use of other energy carriers remains much the same as in the case where nuclear technologies can be replaced. Total primary energy consumption decreases over the time horizon (Figure 3), primarily because of the higher thermal efficiency of the natural gas generation compared to nuclear. The replacement of nuclear by natural gas for electricity generation results in higher CO_2 emissions at the end of the time horizon.

By comparison, the baseline of Case 1 presented above (i.e., where nuclear can be replaced) shows more constant primary energy consumption over the time horizon, with less use of natural gas and a slight decrease in CO_2 emissions (as seen in Figure 1). Forgoing the nuclear option results in slightly higher energy system costs (0.5%).

High oil price + no nuclear

A scenario that combines no investment in nuclear with the high oil price, results in a shift from oil to natural gas, renewables, and biomass. The high oil price makes energy efficiency options more cost-effective, leading to lower primary energy demand. In the residential sector, in addition to lower demand (particularly for heating) we also see a stronger shift to electricity and renewables compared to the no nuclear scenario with regular oil price. The lower heating demand indicates better efficiency and the use of energy saving options in the residential sector (heat pumps, insulation…). Similar to the high oil price scenario where nuclear technologies are replaced over the time horizon, we observe a switch from oil to natural gas in the road transport sector (Figure 4). The combination also promotes deployment of energy efficiency technologies, leading to a reduction in total primary and final energy demand. The increasing energy efficiency and the fuel switch lead to a decline in total CO_2 emissions compared to the “baseline + no nuclear” scenario, although the replacement of nuclear by gas for electricity generation still leads to an increase in CO_2 emissions by 2050. As expected, the effects of fuel switching and the increase in energy efficiency are much stronger in the high oil price scenario than in the scenario with the lower oil price.

Baseline	*No nuclear*	*No nuclear + climate policy*

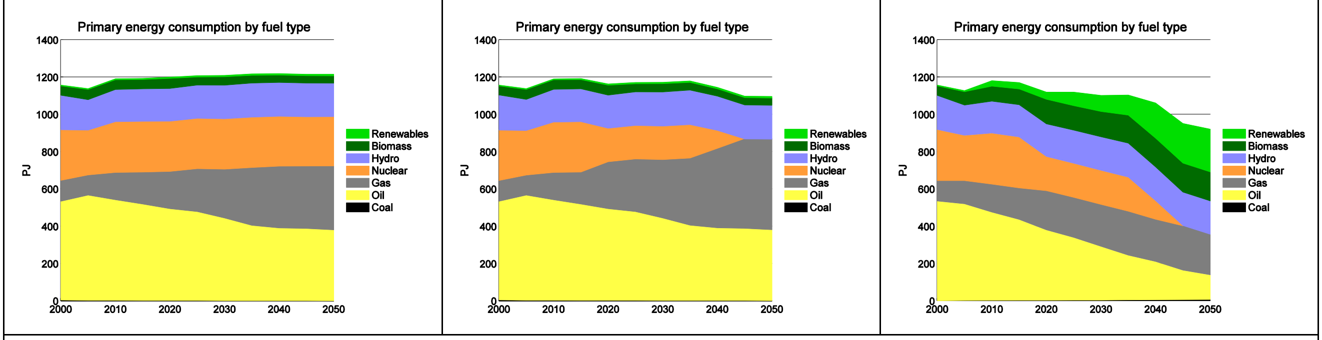


***Figure 3**: Primary energy consumption for scenarios baseline, no nuclear and climate policy + no nuclear*

Climate policy + no nuclear

The scenario that combines the climate policy and no new investment in nuclear generation shows a strong decrease in primary and final energy consumption, because the climate policy promotes additional energy efficiency and a shift from oil and gas to renewables and biomass. In the road transport sector, gasoline and diesel are replaced by natural gas, by hybrids, and by hydrogen and electric propulsion (see Figure 4). CO_2 emissions in the residential sector are strongly reduced through the deployment of heat pumps and energy efficiency options. The additional total system cost of the climate policy is now quite high, rising above 8% compared to the Case 1 baseline (and 4% compared to the Case 1 climate policy scenario).

No nuclear	*No nuclear + high oil*	*No nuclear + climate policy*

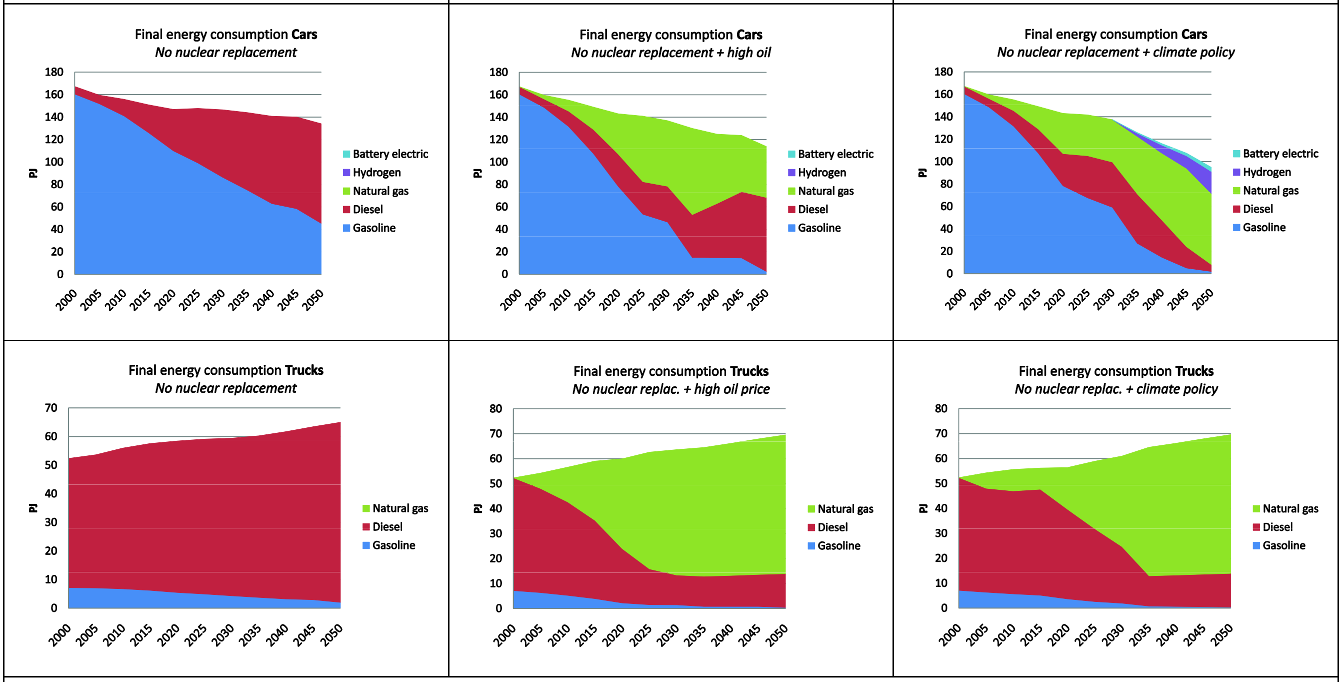


***Figure 4**: Final energy consumption in road cars and trucks sectors for scenarios no nuclear, no nuclear + high oil, and no nuclear + climate policy*

High oil price + climate policy + no nuclear

The implications of not replacing nuclear capacities do not vary significantly with the oil price. However, these implications are different for scenarios with and without the application of a climate policy. For climate policy scenarios, the inability to replace nuclear capacities leads to a stronger reduction of primary energy, particularly oil, and a switch from gasoline and diesel cars to highly efficient cars. In other words, when a large-scale source of CO_2-free electricity is not available, much more abatement action is required elsewhere in the energy system.

Case 3: No replacement of retired nuclear capacity / centralized fossil generation not available (no centralized production)

Results

Baseline + no centralized power stations

Total CO_2 emissions are more or less constant over the time horizon, and roughly similar to the baseline scenario. Compared to the case where centralised fossil power plants are available, however, CO_2 emissions are much lower especially in the second half of the time horizon. This occurs because fossil fuels are almost entirely eliminated from the electricity generation sector. This leads to lower electricity output compared to other cases, partly offset by some additional generation from biomass, wind and solar. Direct use of oil and gas continues for longer in other sectors—due to the lower total generation of electricity—but in net terms total CO_2 emissions are lower in this scenario compared to Case 2. The lower availability of electricity also results in more energy efficiency, and the net effect is constant emissions. The discounted energy system costs are 2% higher compared to the baseline of Case 1.

High oil price + no centralized power stations

As oil becomes expensive, the residential sector invests in efficiency technologies and reduces its fossil fuel use. As seen in the cases where centralised fossil and nuclear capacity is replaced, the high oil price forces the energy system to switch to renewables such as wind and solar. Overall CO_2 emissions decrease, and energy system costs due to the impact of high oil prices rise to the extent similar to the 'no nuclear' case.

Climate policy + no centralized power stations

At the end of the observation period, almost no fossil fuels are used in the residential sectors, while industry and services continue to use some oil and natural gas. In the car sector liquid fuels are replaced by natural gas, hydrogen and battery vehicles, and in the truck sector natural gas is replacing diesel trucks towards the end of the time horizon. The costs are comparable to the corresponding scenario for Case 2, but the achieved CO_2 reductions are lower, since natural gas is replaced by biomass and renewables for electricity.

High oil price + climate policy + no centralized power stations

This is the most demanding of all considered scenarios. There is hardly any change compared to the scenario with standard fossil fuel prices: As there are no alternatives, industry and service sector have to continue using oil and gas, with the overall system costs rising accordingly.

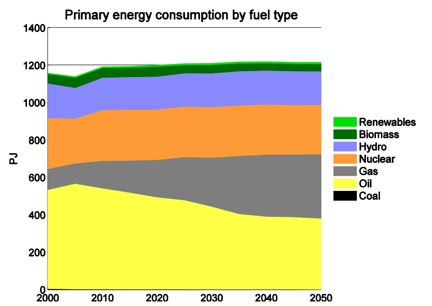
Case 4: Nuclear expansion

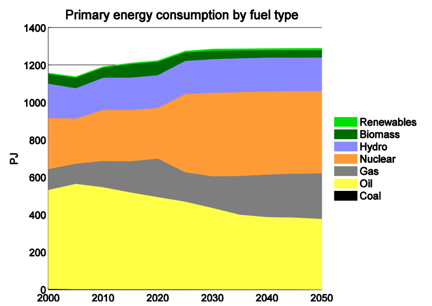
Results

Baseline + nuclear expansion

In a scenario where we assume nuclear capacity is allowed expand, generation from nuclear power plants increases accordingly, indicating that nuclear remains a cost-effective technology option under the assumptions used here. In the year 2020 when additional nuclear capacity is deployed, natural gas for electricity generation in combined cycle power plants is replaced, reducing total primary demand for this fuel (Figure 5). This leads to a decrease of CO_2 emission in the electricity sector, whereas the emissions in the end use sectors do not change significantly (Figure 6). As expected the transport sector is not affected by the additional electricity production since battery and hydrogen cars are not attractive under the conditions assumed for this scenario (which includes cheap oil and no climate policy).

Baseline	*Nuclear expansion*	*Nuclear expansion + climate pol.*





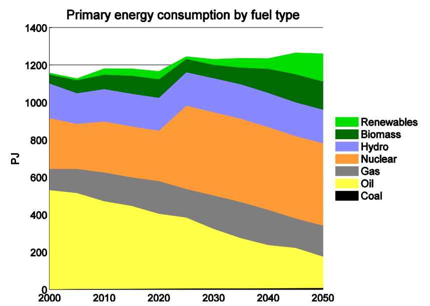
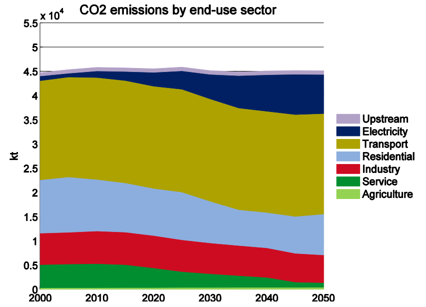


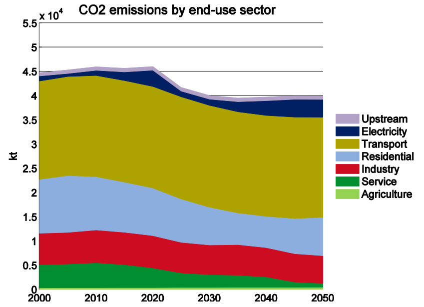
Figure 5*: Primary energy consumption for scenarios baseline, nuclear expansion, and nuclear expansion + climate policy*

Baseline + nuclear expansion + climate target

When adding a climate target to the nuclear expansion scenario we observe that total primary energy consumption is on a similar level as for the scenario without a climate target, but renewables and biomass are replacing oil and gas. Again electrification takes place in the residential and services sector but not in the car sector, where oil-based fuels are widely replaced by natural gas. The addition of the climate target increases total discounted system costs by around 3% (relative to the nuclear expansion scenario without climate target).

Baseline	*Nuclear expansion*	*Nuclear expansion + climate pol.*





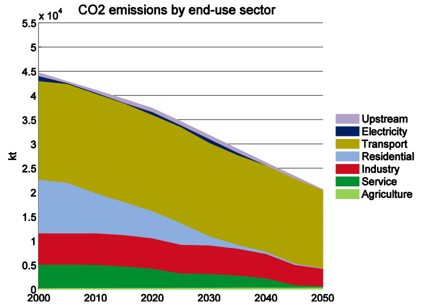


Figure 6*: CO_2 emissions for scenarios baseline, nuclear expansion, and nuclear expansion + climate policy*

Comparison of Cases 1-4 – Survey on power generation

Surveying the results presented in the preceding sections, the following conclusions can be drawn.

- High oil prices generally give rise to strongly increased energy system costs (by as much as 100% at the end of the modeling period). Use of oil and, to a lesser extent, also of gas is reduced relative to the baseline scenario. This effect of high oil prices leads to some similar outcomes as in the climate policy scenario, resulting in a decrease in CO_2 emissions of about 40% in 2050. As the oil price is, in contrast to federal climate policies, an exogenous factor over which Swiss policymakers have little influence, we take note of this effect, but concentrate on the endogenous factors in the following paragraphs.
- For the high oil as well as for the climate policy scenarios we observe that heating in the residential sector is largely achieved without fossil fuels, and electrification in the services sector supports increasing energy efficiency. Renewables, in particular biomass, wind and solar photovoltaics take a larger share in the primary energy mix (cf. Figure 4).
- The climate policy target increases energy system costs typically by 5-8 % if investment in nuclear power remains an acceptable option, corresponding to 0.3-0.5 % of projected GDP in the 2040-2050 period. If nuclear is not available the discounted system costs increase by 20-30%, corresponding to 1-2 % of GDP.
- In all scenarios hydro and nuclear appear to be among the most cost-effective generation options, and are deployed up to the assumed available potential (in the case of hydro) or the policy limit (in the case of nuclear).
- If nuclear power is not available after the retirement of the currently operating nuclear power plants, the electricity generation is replaced by gas combined cycle plants, in the absence of climate targets. As a consequence, CO_2 emissions rise after 2030.
- In order to achieve the OcCC targets in the case where nuclear power is not available, primary energy demand is reduced due to strong efficiency measures in the transportation, residential and services sectors. Biomass combined heat and power as well as centralized natural gas electricity generation contribute more important shares.
- If neither replacement of nuclear power nor centralized fossil generation plants are available (Case 3), electricity production is reduced and there is a shift to biomass power plants and some wind and solar energy. Energy system costs rise by 4-5 % towards the end of the observation period, relative to the baseline of Case 1.
- Efficiency options such as heat pumps in the residential sector and electrification in the services sector are scarcely adopted if neither nuclear nor other centralized generation options are available, as a consequence of the limited availability of electricity. Fossil fuels continue to be used throughout the economy.
- In the climate policy scenarios where centralized fossil power plants are not available we observe that centrally produced electricity from biomass and from wind turbines and solar photovoltaics (see Figure 7) are used to drive heat pumps in the residential sector, whereas gas is employed for industry. In transportation, electrification occurs only scarcely due to limited availability of electricity. Energy system costs rise by 15-20% compared to the baseline of Case 1.

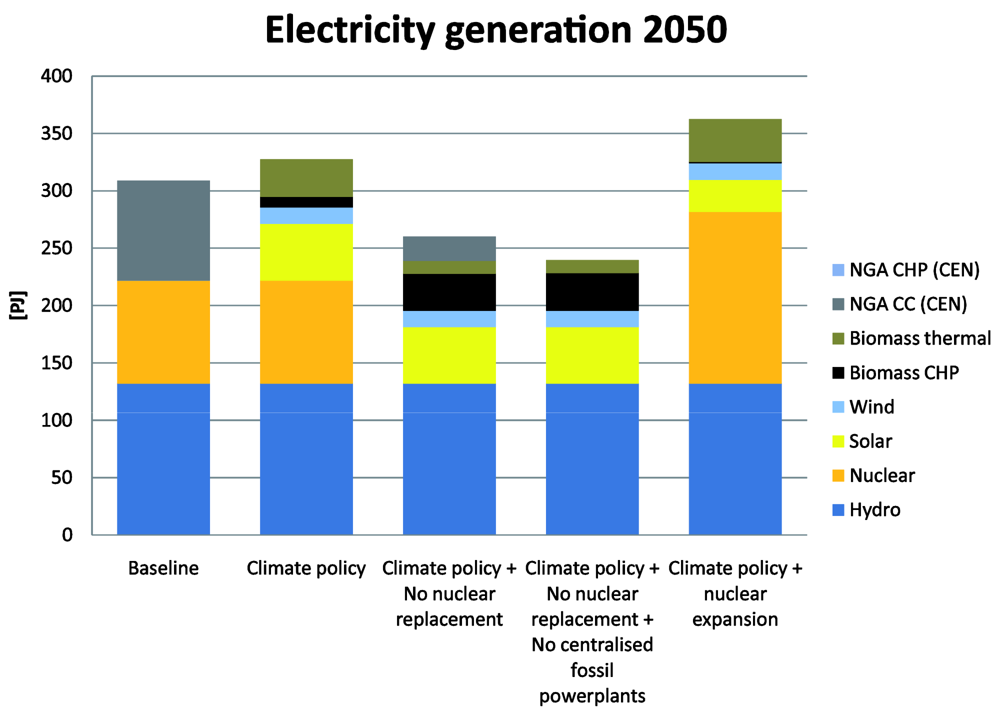


***Figure 7**: Electricity generation in the year 2050 for four selected scenarios, with standard assumptions for the development of the oil price.*

Summary

A number of conclusions can be drawn from this analysis:

- Ambitious climate policies are feasible under a range of future technology scenarios. However, the cost of achieving these targets is higher with restrictions on nuclear. Strong support will be needed for renewable energy technologies such as solar photovoltaic and wind to achieve these targets.

- Coping with high oil prices leads to a similar level of abatement as ambitious climate policies up until 2030. In other words, abatement action is likely to reduce vulnerability to oil price shocks.

- High fossil prices and climate policy targets force the residential sector to forgo fossil fuels, and to invest in heat pumps and energy efficiency options instead. We also observe that electrification is taking place in the residential and services sector for the high oil price and the climate policy scenario.

- In the road transport sector we observe a shift from oil to natural gas as soon as climate policies become relevant or the prices oil based fuels rise. In cases where nuclear capacity cannot be replaced, “ultra-efficient” vehicles are required to meet the climate target.

- Overall, the analysis indicates that the development of the energy system in Switzerland is highly sensitive to the outcome of a number of unresolved policy uncertainties, including the available generation options (particularly nuclear) and climate policy. To ensure that private decision makers in businesses and households are able to develop and deploy necessary technology options for a sustainable future, clear and timely policy decisions are needed.

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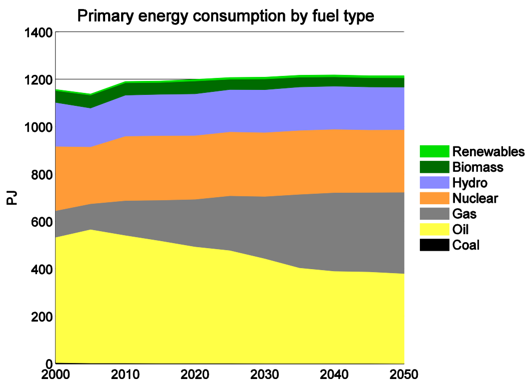
Appendix

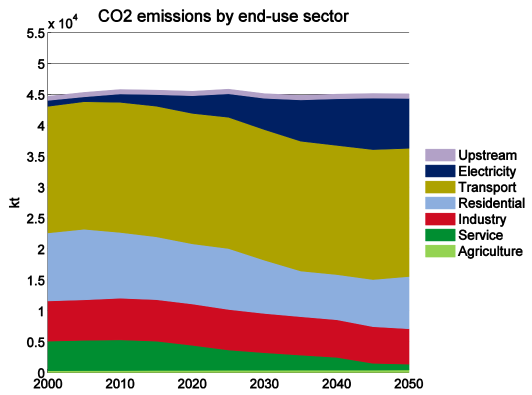
The figures for primary energy consumption and CO_2 emissions of the scenario analyses realised with Swiss MARKAL are illustrated in the table below. The abbreviations in the left columns are explained below:

BASE	Baseline scenario
BH	Baseline + high oil price
BO	Baseline + climate target (OcCC)
BOH	Baseline + climate target (OcCC) + high oil price
BS	Baseline + stagnation in demands due to 10 years recession
BN	Baseline + no nuclear replacement
BON	Baseline + climate target (OcCC) + No nuclear replacement
BOH	Baseline + climate target (OcCC) + high oil price
BOHN	Baseline + climate target (OcCC) + high oil price + no nuclear replacement
BNC	Baseline + no nuclear replacement + no centralized fossil power plants
BONC	Baseline + climate target (OcCC) + no nuclear replacement + no centralized fossil power plants
BHNC	Baseline + high oil + no nuclear replacement + no centralized fossil power plants
BOHNC	Baseline + climate target (OcCC) + high oil price + no nuclear replacement + no centralized fossil power plants
BE	Baseline + nuclear expansion
BOE	Baseline + climate target (OcCC) + nuclear expansion

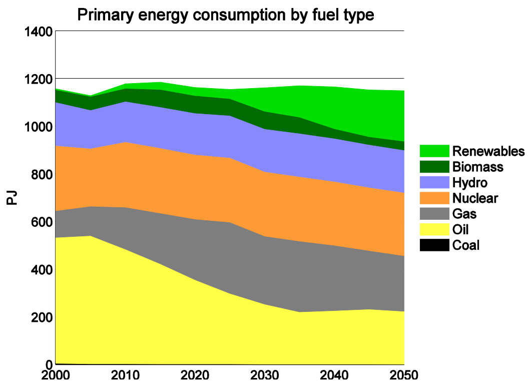
PRIMARY ENERGY CONSUMPTION (P.A.) | TOTAL CO_2 EMISSIONS (P.A.)

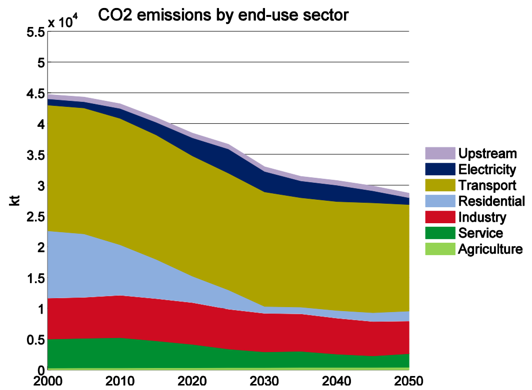
BASE



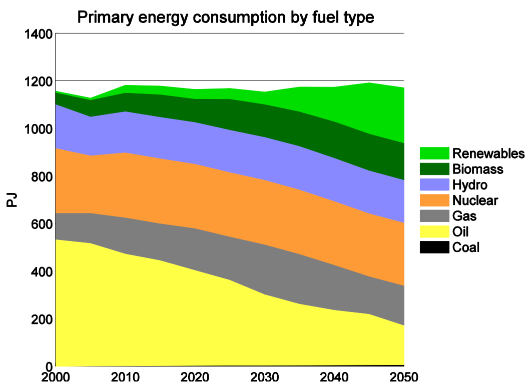


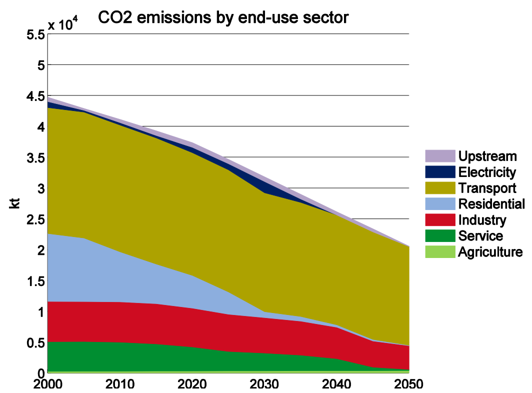
BH





BO





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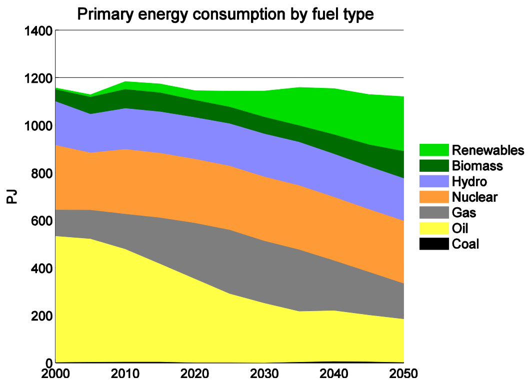
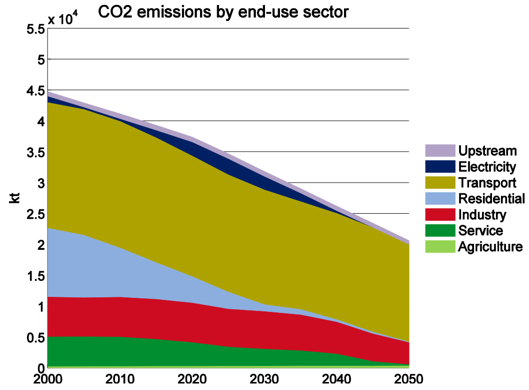
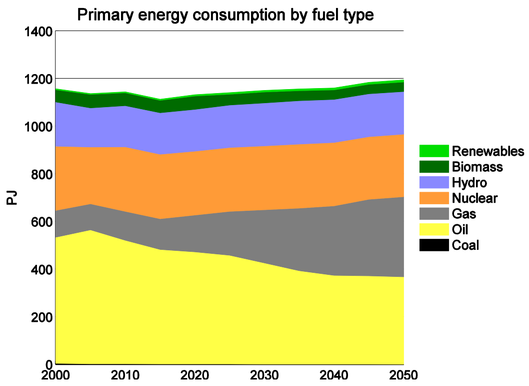
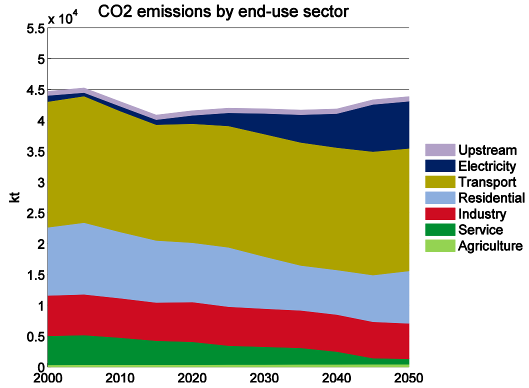

Primary energy consumption by fuel type
PJ
0
200
400
600
800
1000
1200
1400
2000
2010
2020
2030
2040
2050
Renewables
Biomass
Hydro
Nuclear
Gas
Oil
Coal


CO2 emissions by end-use sector
x 10^4
kt
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
2000
2010
2020
2030
2040
2050
Upstream
Electricity
Transport
Residential
Industry
Service
Agriculture

BS


Primary energy consumption by fuel type
PJ
0
200
400
600
800
1000
1200
1400
2000
2010
2020
2030
2040
2050
Renewables
Biomass
Hydro
Nuclear
Gas
Oil
Coal


CO2 emissions by end-use sector
x 10^4
kt
0
0.5
1
1.5
2
2.5
3
3.5
4
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5
5.5
2000
2010
2020
2030
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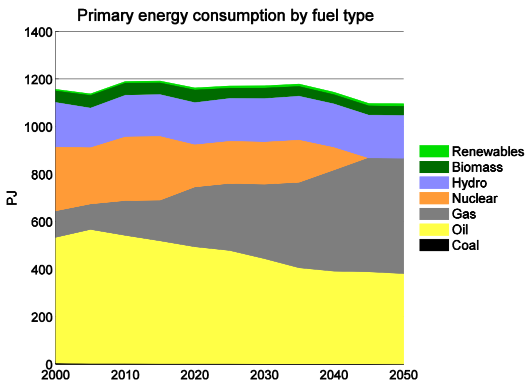
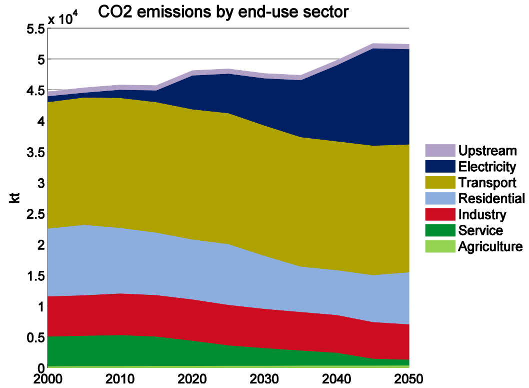
2050
Upstream
Electricity
Transport
Residential
Industry
Service
Agriculture

BN


Primary energy consumption by fuel type
PJ
0
200
400
600
800
1000
1200
1400
2000
2010
2020
2030
2040
2050
Renewables
Biomass
Hydro
Nuclear
Gas
Oil
Coal


CO2 emissions by end-use sector
x 10^4
kt
0
0.5
1
1.5
2
2.5
3
3.5
4
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5.5
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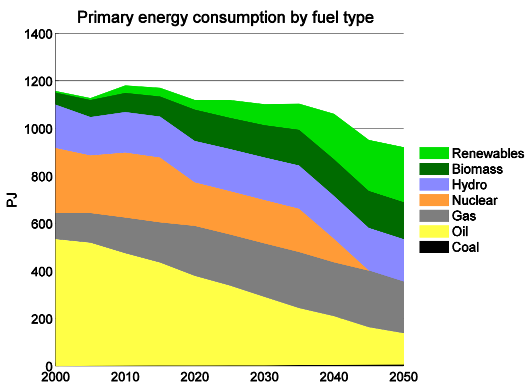
2040
2050
Upstream
Electricity
Transport
Residential
Industry
Service
Agriculture

BON


Primary energy consumption by fuel type
PJ
0
200
400
600
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1400
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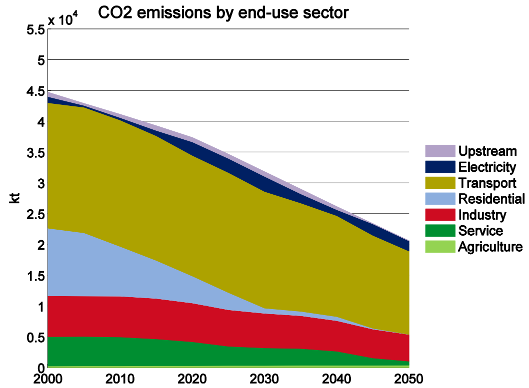
Nuclear
Gas
Oil
Coal


CO2 emissions by end-use sector
x 10^4
kt
0
0.5
1
1.5
2
2.5
3
3.5
4
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Upstream
Electricity
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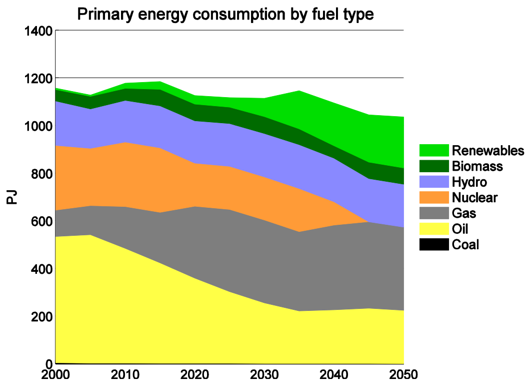
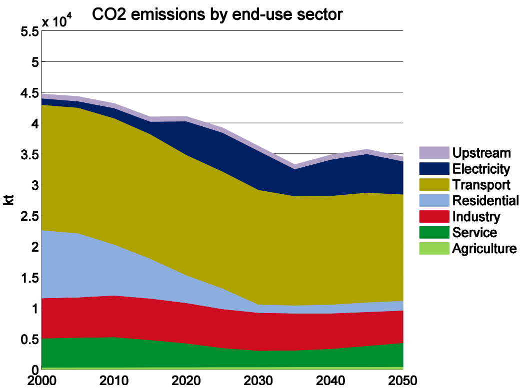
Industry
Service
Agriculture

BHN





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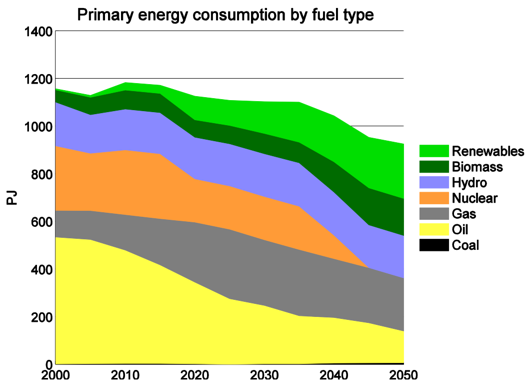

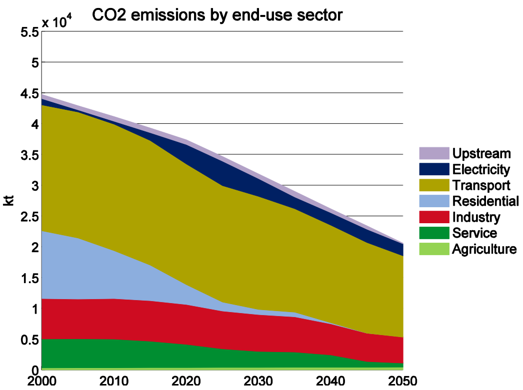

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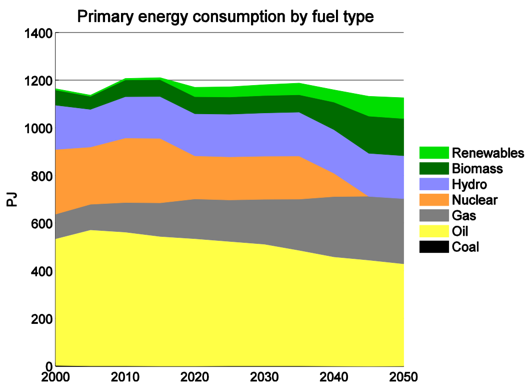

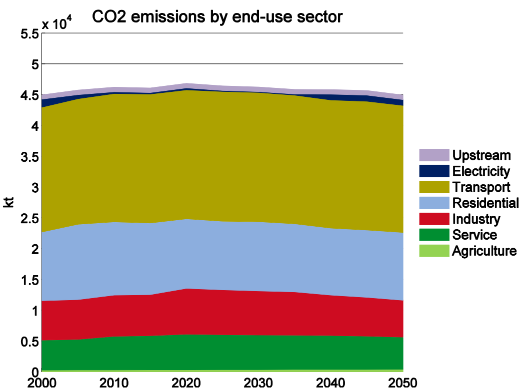

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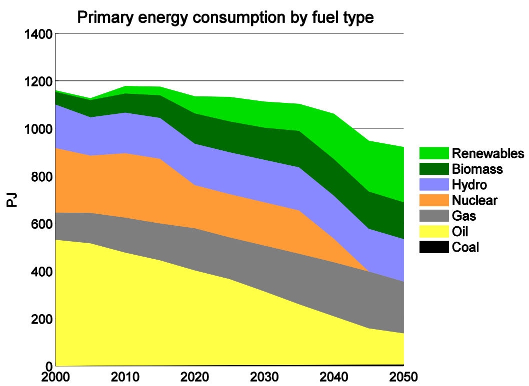
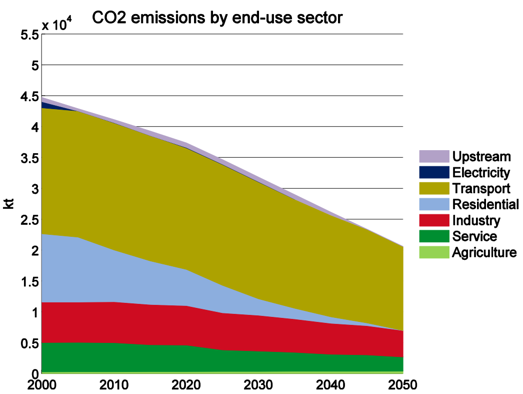
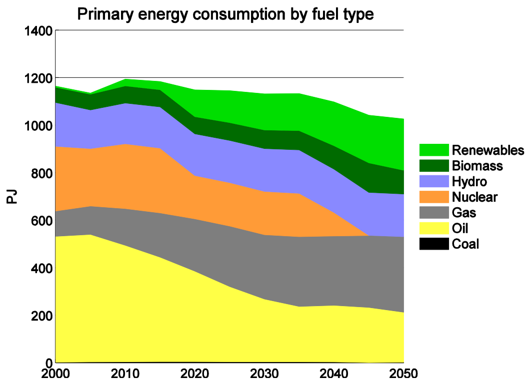
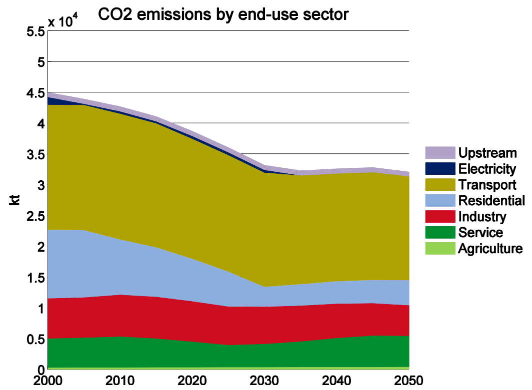
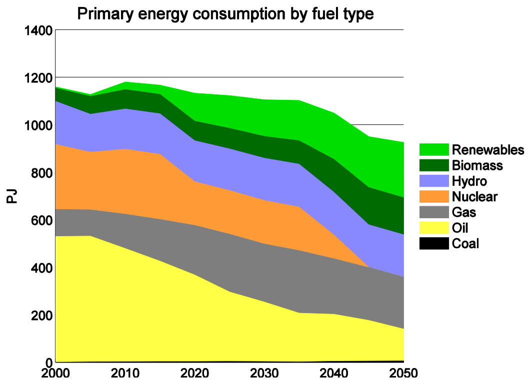
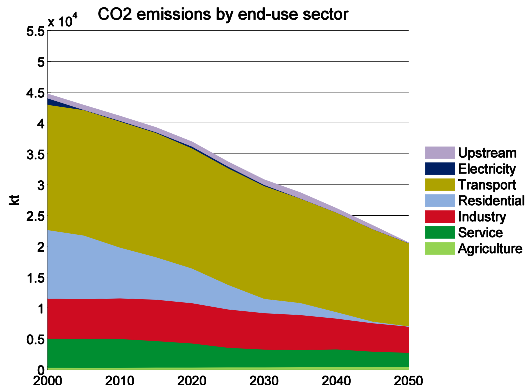
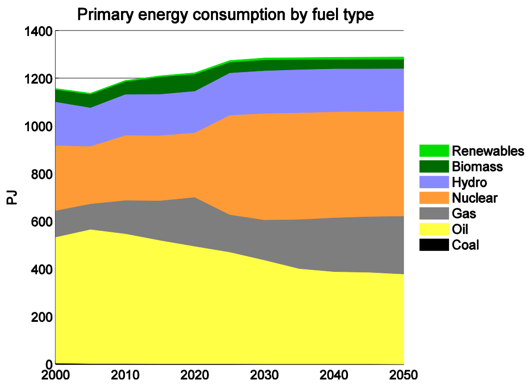
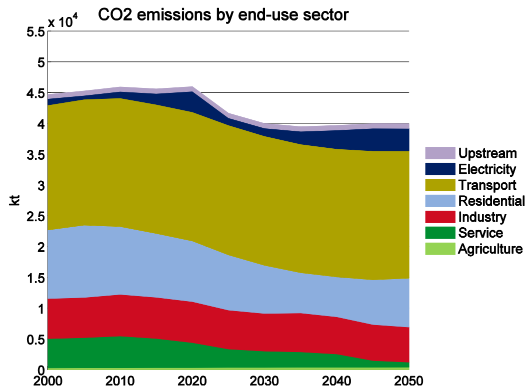




BHNC		
BOHNC		
BE		
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