Nuclear Phase-out in Switzerland

Economic impacts of a complete nuclear phase-out in Switzerland until 2025

Georg Putzi, 06-908-438

FS 11, 08.06.2011

Energy Economics and Policy

Prof T.F. Rutherford

cepe
Centre for Energy Policy and Economics
Department of Management, Technology and Economics

Abstract

The recent nuclear accidents in Japan launched the discussion about the future use of nuclear energy for power generation in a new manner. They showed that nuclear accidents can occur not only due to out-dated unsafe technologies, but can be induced by severe natural disasters. Votes in Switzerland and Germany after the Fukushima accident were consequently characterized by a strong vote gain of the green parties and a loss for economy-based parties. The Swiss social-democratic party (SP) is now preparing a referendum for a premature phase-out of the five nuclear power plants (NPP) in Switzerland. The NPP in Leibstadt is to be the last one to shut down in 2025.

Politicians are discussing what energy supplies could replace the NPP. One possibility would be to build new gas turbine combined cycle power plants (IGCC). This is not convenient with the Kyoto protocol since large amounts of CO_2 would be released. Renewable potentials are affordable, but its conversion technologies are expensive and its power therefore often not competitive. The prices of the renewable power output are therefore 2-4 times higher, affecting the economy by a severe braking effect.

The paper provides an overview of the political discussion about the use of nuclear power. It shows the economic impacts of renouncing nuclear power supply by considering alternative sources as renewable energy and power trading with the surrounding countries. An optimistic scenario for power prices in 2025 shows the price effects. The price is modeled as average price over all supplies. The modeled price is very sensitive upon the price elasticities of the different supply sectors. The assumed elasticity values in this paper resulted in an electricity price of 23 Rp./kWh, i.e. 10 Rp./kWh more than today.

Regarding the inconstancy in time of renewable energies and the lack of available and economically feasible storage technologies leads to the conclusion that fossil thermal power plants would provide a useful bridging supply on the way to renewable energies. Such power plants are less capital intensive than nuclear power plants and are therefore more profitable in short-term views and can start up and shut down fast. These factors underline the competence of fossil thermal power as bridging technology and it is likely that it will be applied in the near future.

Contents

1 Introduction

Nuclear power plants (NPP) in Switzerland have a share of 40% in electricity production (Fig. 1) supplied by five reactors producing 3220 MW (table 1). Their run times are not fixed but depend upon political decisions and all reactors have now running permissions without deadlines (www.nzz.ch; see also Böhringer et al. 2003). Three of them have been in operation since 1971 and should phase out around 2020. This means that Switzerland has either to replace them or find alternative energy sources for a sufficient electricity supply.

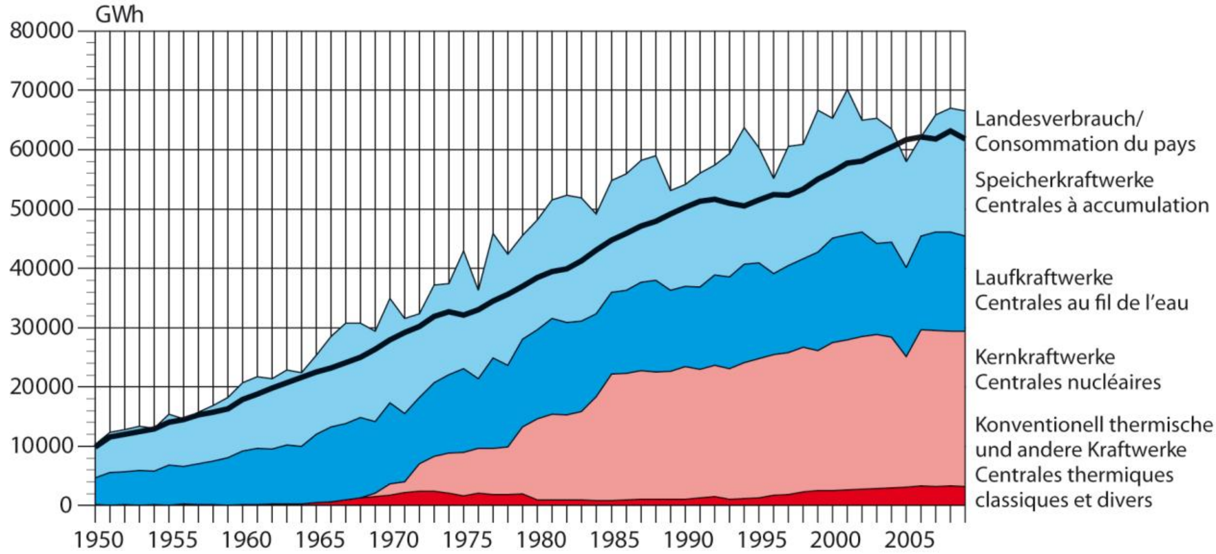

Fig. 1: Composition of the Swiss electricity mix (www.bfe.admin.ch)

Several NPP-operating companies have already submitted project plans for new NPP. Two large (1600 MW) new plants could replace the power output of all operating NPP, but the three largest operators (Alpiq, Axpo and BKW) decided to replace only Mühleberg and Beznau I + II with two new NPP.

In February, a vote in the Canton of Bern about the continuation of the planning for a new NPP in Mühleberg BE showed that a slight majority of the population votes in favor of new NPP. The recent Fukushima nuclear accidents reminded people of the risks NPP can pose. Several European countries including Switzerland and Germany prove now ways to improve the security of the NPP and consider alternative supplies to replace nuclear power. The parliaments of Germany and Switzerland each decided in the last days to follow the nuclear phase-out strategy.

UVEK minister Doris Leuthard predicted an absolute need of new gas turbine combined cycle power plants (IGCC) in case of a total nuclear phase-out (www.nzz.ch). IGCC are comparatively cheaper to construct and more expensive to run, depending on the international gas prices. The dependence on imports would increase due to a high gas demand. A clear advantage of IGCC is the short starting times. Increasing shares of the intermittant renewable supplies in the electricity mix require higher time flexibilities through a depressed base load but unchanged peak loads. Gas is considered as a transitional solution on the way to a renewable power mix and IGCC are economically feasible in short to mid-term views. But IGCC lead to elevated CO_2 emissions and this paper examines the effect of phasing out all NPP and renouncing fossil fuels like gas as power supply. It assumes that the recently created SP-plebiscite 'Atomausstiegsinitiative' will be accepted and realized. By the 'Atomausstiegsinitiative' demanded phase-out years are shown in table 1. The run times expected by operators are clearly longer and are primarily limited by aging of the power plant.

The following five NPP are currently in operation:

Location	Reactor Type	Power output	Start of operation	Economic phase-out	Premature phase-out
Beznau 1	Pressurized water	365 MW	1969	2024	2015
Beznau 2	Pressurized water	365 MW	1971	2026	2015
Mühleberg	Boiling water	355 MW	1971	2026	2015
Gösgen	Pressurized water	970 MW	1979	2039	2020
Leibstadt	Boiling water	1165 MW	1984	2044	2025

Table 1: NPP in Switzerland

This paper uses a model to show the renewable energies capable to supply the current NPP share and calculates the resulting power prices of the electricity mix in this scenario. Economic aspects hinder renewable energies in replacing NPP in the case of liberalized power markets. NPP require large investment costs but are then very cheap to run and to maintain. Most of the NPP operating countries partly finance the plants. NPP produce the cheapest power in Switzerland (www.elcom.admin.ch). Political measures are necessary to enhance the use of renewable power sources. The economic advantages of nuclear power are not undisputed, because long-term costs are difficult to estimate. Further following the nuclear path will require investment costs from the state. The use of such capital in the development of renewable energies may accelerate their technologic progress and thus lead to enhanced market competitiveness.

Other energy strategies are increasing conversion efficiencies to reduce the amount of necessary primary energy and the application of the costs-by-cause principle to substantially reduce the energy consumption. The reduction in the consumption is presently smaller than the increase due to the gross domestic product (GDP) and population growth and the demand therefore increasing.

2 Policy Backgrounds

2.1 History of Nuclear Power in Switzerland

First experiments on nuclear fission were performed during the Second World War in order to construct nuclear weapons. Those were already ostracized in Switzerland in the 1950s. The rise of peaceful use of the nuclear fission of uranium and plutonium happened fast. The following occurrences have been important considering nuclear power generation in Switzerland (www.global2000.at):

1950s: Ostracism of nuclear weapons. Consideration of nuclear power.

1960s: Planning and construction of NPP and research reactors.

1969: The first commercial NPP in Beznau starts operation.

1969: Partial core melt down in the research reactor in Lucens VD. Before the Japan accident, it was considered the 7th most severe nuclear accident in history.

1970s: Begin of the concerns about the use of uranium as a power source.

1975: Construction of a new NPP in Kaiseraugst was stopped after strong protests from environmental activists.

1977: Switzerland signs the international nuclear non-proliferation treaty.

1986: The Chernobyl accident stirs the world. Fuel rods melt down, releasing radioactive material into the environment.

1988: NPP projects in Graben and Kaiseraugst were abandoned after enduring protests against it.

1990: A ten year moratorium for the construction stop of new NPP was decided in a plebiscite.

1990: Failure of the security system in Leibstadt. Fast shut down was broken, but the reactor could be shut down slowly by the driving rods.

1992: Two people die after argon releases in Beznau.

1998: Slow retreat from nuclear energy decided by federal assessment.

1999: Switzerland signs international comprehensive nuclear test ban treaty

1999: A new law obligates the NPP operators to pay for the processing and storage of radioactive wastes.

2000: CO_2-emission law gives new hope and perspectives to nuclear supporters.

2003: Refusal of the plebiscites ‘Strom ohne Atom’ (SOA) and ‘Moratorium plus’ (MOP). The MOP had mentioned another ten year construction stop for NPP, while the SOA scenario proposed a nuclear phase-out until 2015.

2005: New NPP law was passed, opening the way for constructions.

2007: Decision of the federal assessment to replace the running NPP by new ones.

2007: AXPO project for a NPP replacing the ones in Mühleberg and Beznau submitted.

2008: ALPIQ project for a new NPP close to the one in Gösgen submitted.

2008: Zürich City passes a law for retreating from nuclear power.

2011: A tsunami in Japan leads to nuclear accidents in several reactors of the Fukushima NPP.

2011: Germany phases out its 8 oldest NPP.

2011: Austria proves an international complaint against Switzerland amongst other nations accusing the danger the NPP pose in their neighborhood.

2011: Creation of the 'Atomausstieggesetz' in Switzerland.

2.2 Alternative supply policy

The easiest and cheapest way to replace NPP is to install IGCC (no potential limits, well established technology, and independent on outer factors as weather). Energy supply by gas turbines leads to a failure of the CO_2 emission reduction goals. The efficiencies are larger than achievable efficiencies for renewable energy technologies (except hydro plants). And the electricity price is smaller due to low gas prices at the moment, smaller construction costs and higher efficiencies.

But only renewable energy sources can provide a sustainable power supply. Swiss government pays back the feed-in tariffs for renewable power to the producers as a subsidy, of which the consumer has to pay a part (makes 2% of the electricity price). The price difference between renewable power and mix power must by law not exceed 0.6 Rp./kWh. For 2011 the electricity price difference will be 0.45 Rp./kWh (www.elcom.admin.ch).

Solar power is most expensive. Many suppliers offer pure solar electricity for a price of about 70 Rp./kWh above the mix price. The investment costs for solar panels are high. Yet they profit from the cheap electricity prices, since the production steps require large amounts of energy. The electricity payback time is with currently available technologies around 2 years. Increasing electricity prices after the nuclear phase-out will increase the cost payback time of solar cells, again increasing the solar power price. Wind and biomass power are less affected by this coherence.

There are further cantonal and communal support measures for renewable energy supplies. They will be necessary in the future to keep the price on an acceptable level for the consumer. Some Cantons subsidize households to install PV cells on large roof tops.

The competition of thermal power (nuclear and fossil) will fade out with the above described scenario. The average power price will rise continuously until 2025.

2.3 Power Prices

The power prices consumers pay are composed of three parts: (www.immergenugstrom.ch)

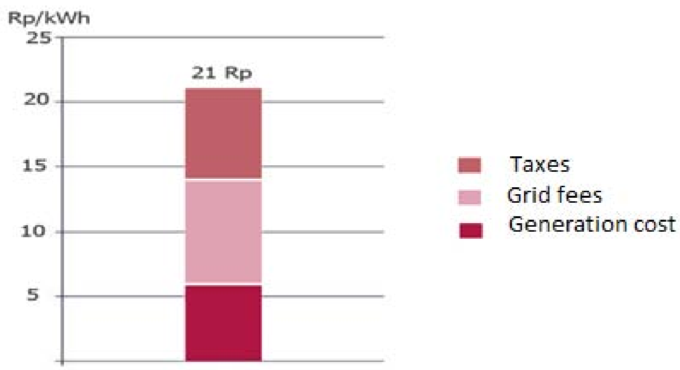

Table 2: Composition of the power price

Table 2 shows the price composition for households. Taxes and grid fees are legally regulated with industrial and private categories.

The variation in taxes and grid fees as well as the different compositions of the electricity mix is responsible for the cantonal distribution of the prices (Fig.2). The prices are generally low in the east and higher in the west (www.elcom.admin.ch).

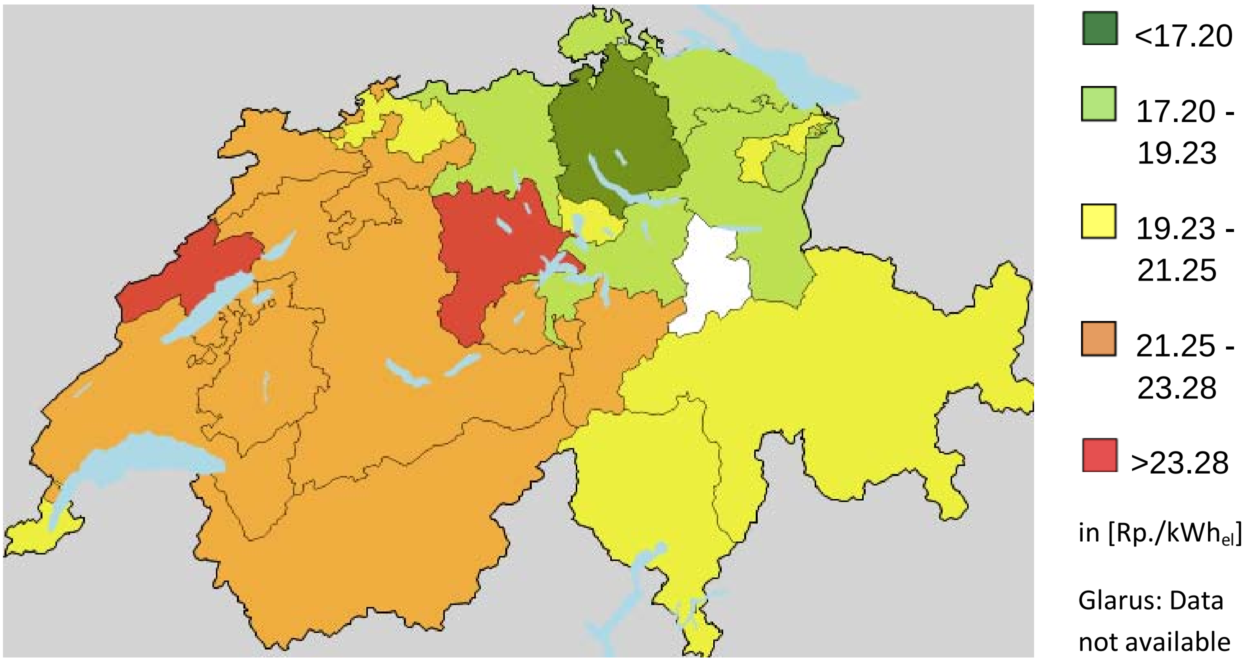

Fig.2: Electricity price distribution by Cantons

In exporting and importing power, only the generation costs are paid. The average export price 2010 was 7.65 Rp./kWh. The import price was at 5.6 Rp./kWh (www.bfe.admin.ch, electricity statistics). It is lower because Switzerland buys the low price excess power from French NPP during nighttime to pump up water into the storage lakes of pumped hydro plants (PHP). Electricity is generated during daytime and sold to Italy at higher prices. These prices exclude taxes and grid fees and represent international trading prices (see www.ompex.ch). In the model, the prices are extrapolated to private consumer prices to compare them with the Swiss power mix prices.

The price elasticity of the power supply is fairly small. The shutdown time of NPP is large and it is not cost-effective to do it in low-price periods. The prices can even become negative, i.e. NPP pay PHP to consume their power in order not to shut down the power plant. The single phase-out time is set during low load times in summer when one NPP after the other shuts down for maintenance.

PHP and IGCC cover peak loads. PHP need to pump up water with French nuclear power during low price periods in the night. Its capacity during high price periods is limited by the storage volume of water.

The price elasticity of the demand is also small. Sectors like industry, transport and agriculture rely on electricity and cannot relinquish it for elevated prices. High electricity prices slow down the economy.

The following graph shows a qualitative schematic diagram of the price/demand/supply relationship in Switzerland (Fig. 3):

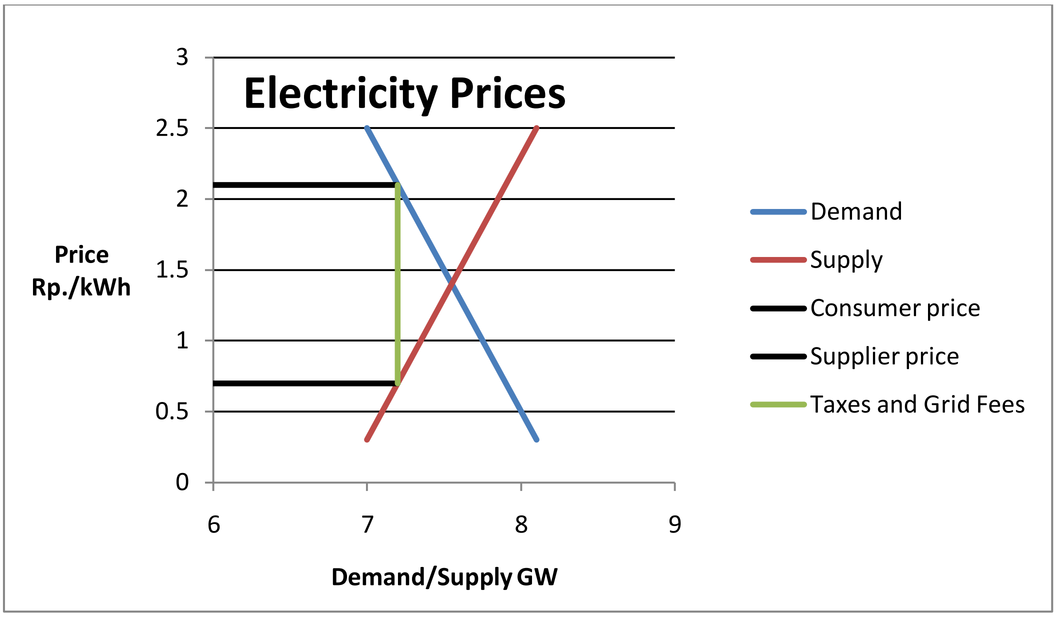

Fig. 3: Price versus demand/supply: Overview of elasticity of demand and supply, and taxes.

The feed-in tariff for renewable energies has an effect on the tax and grid fees. It diminishes the supplier price and elevates the consumer price. The taxes are thus higher.

3 Power Price Model for the Phase-Out Scenario

Forty percent of the Swiss electricity supply must be substituted to achieve a complete nuclear phase-out. Additionally, the electricity demand will further increase, since the lift due to growth in GDP and population growth is not yet fully balanced by efficiency increases (Fig.4).

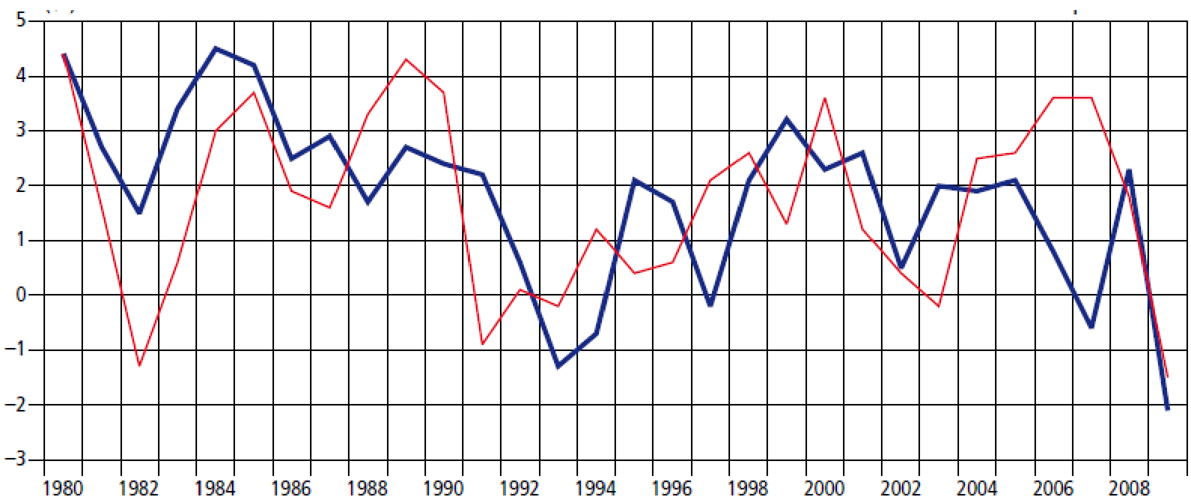

Fig. 4: Change in electricity demand in the past 30 years (www.bfe.admin.ch).

The technical use of renewable energy sources as the sun and wind is underdeveloped at the moment, except that hydro power is nearly fully exploited. Dietrich et al. 2010 estimated the remaining potential of wind, sun, biomass and small hydro plants. The total expansion potential exceeds the amount of power presently supplied by NPP. The economic drawbacks of renewable energies prevented their breakthrough so far. Solar cells require high investments and energy-intensive production steps as well as precious metals making the electricity price from PV cells around 3-4 times higher than nuclear power.

The scenario assumes that the use of renewable energy potentials is raised linearly with time and fully exploited until 2025 (within 14 years). The installed capacity of the renewable power supplies is therefore given by (S = Installed supply):

$$S_i(t) = S_0 + \frac{S_{pot} - S_0}{14} * t \tag{1}$$

Nuclear power supply diminishes after each NPP phase-out as described in Table 1. That leads to an unbalanced supply/demand ratio. Possible demand excess until 2025 will be covered with imported power.

The following replacement supplies are included in the model (Tab. 3) (Schulz et al. 2008; Dietrich et al. 2010):

Power Sector	Presently Installed Capacity [MW]	Estimated Potential [MW]
Solar	21	1563.93
Wind	0.33	456.62
Biomass	273.74	3266.11
Water	4330.48	4581.6
Thermal	3264.15	Inf.
Total	**7890.17**	**9868.3**

Tab. 3: The potentials of renewable power sectors.

The potential for solar power is based on available roof tops for PV cells. Only technically feasible potentials are considered and not theoretically possible power extraction. For biomass, a sustainable potential is taken from Steubing et al. 2010, which is particularly important for the use of wood. The wind potential is as seen quite small in Switzerland due to a lack of sufficient wind velocities. Additional single wind turbines of 2800 MW could be installed beside the wind parks (Schulz et al. 2008), but its grid connection would be economically unfeasible and this potential will not be included in the model.

The total exploitable potential exceeds the presently installed power capacity including NPP. The model assumes complete installation of the wind, biomass and small hydro plants potentials and coverage of the difference to the power demand with solar PV panels. Many research projects investigate the increase of PV cell efficiencies and the use of cheaper construction materials avoiding precious metals as photo-absorbers. It is therefore reasonable to wait with major installations.

Geothermal power is not considered here, although its potential is quite large considering the heat flux through earth's crust. Japan and Iceland use it because both are located in tectonic active zones where the hot region from the lower earth crust rises towards the surface. No similar tectonic zones occur in Switzerland, the best places for geothermal energy use are in the region of Basel. A fracture zone in the tectonic plate below leads to elevated heat flux rates, yet the bore holes have to be as deep as 5000m for a sufficiently efficient power plant. A pilot project triggered several minor earth quakes in December 2006 and January 2007. Public acceptance decreased abruptly and the geothermal community leading the pilot project decided to investigate of the geologic circumstances more thoroughly, and then continue the project under safer conditions. The future of geothermal power is therefore ambiguous and potential power plants excluded from the model.

The electricity prices of a certain supply sector are modeled as a function of the resulting average electricity price (because of the use of it for the technology fabrication) and of the total installed capacity of each supply sector (due to higher efficiencies in large power plants and the technologic progress due to enhanced research.

Tab. 4 shows the response of the supplies on these factors:

Supply Sector:	*Response to Average Power Price [ε]*	*Response to Total Installed Capacity [η]*
Small Hydro Plants	0.1	0
Wind Power	0.1	0.0004
Solar Power	0.8	0.008
Biomass	0.05	0.0003

Table 4: The responses of renewable power prices to electricity mix prices and capacity.

The power price of each supply sector is then calculated as following (C is the total installed capacity of supply sector i):

$$p_i(t) = p_{i,0} * \left(1 + \varepsilon \left(\left({p(t-1)}/{p_0} \right) - 1 \right) - \eta \left(\left({C(t)}/{C_0} \right) - 1 \right) \right) \quad (2)$$

The initial prices from 2010 ($p_{i,0}$) are taken from www.aee.ch and www.naturemade.ch and presented in the model in the appendix.

The response of the supply to the power price is completely neglected by the model, because there is no additional capacity that could be taken into operation in mid-term views (PHP production is increased during short-term price peaks, but limited by the available water volume if regarded over a year).

The demand is modeled as a function of population and GDP growth and the average power price. Continuing growth rates extrapolated from the past 30 years are assumed for GDP and population (www.swissinfo.ch).

The following demand responses are presumed for the model (Tab. 5):

Demand response to:	*Symbol in the equation:*	*Assumed response value:*
Population growth	x	0.3
GDP growth	y	0.3
Average Power price	z	0.2

Table 5: Demand growth and elasticity

The demand is calculated as following (D=Demand; X=Population (# of inhabitants); G=GDP):

$$D(t) = D_0 * \left(1 + x * \left(\left({X(t)}/{X_0}\right) - 1\right) + y * \left(\left({G(t)}/{G_0}\right) - 1\right)\right) * \left(1 - z\left(\left({p(t-1)}/{p_0}\right) - 1\right)\right) \quad (3)$$

Feed-in tariff is applied to all newly installed power plants. Only the hydro plants remain from the presently installed generation capacity. They have today a share of about 57%. The electricity price is finally calculated as one average price:

$$p_{mix}(t) = \sum_i (p_i(t) * S_i(t))/D(t) \quad (4)$$

4 Results

The energy demand will increase with GDP and population. Fig. 5 shows the modeled demand:

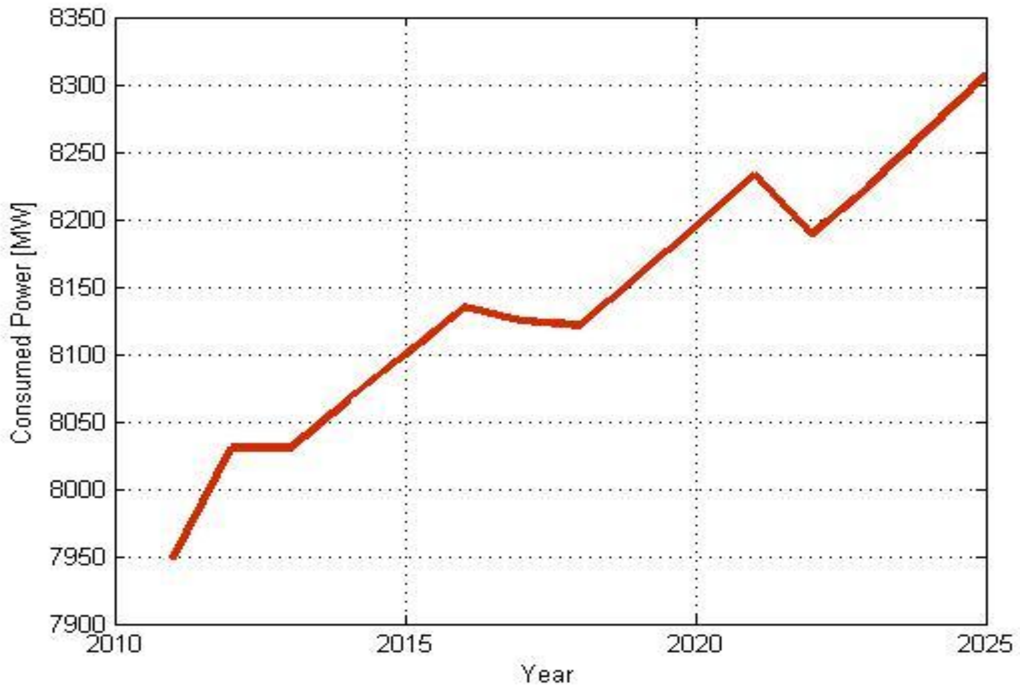

Fig. 5: The energy demand of Switzerland until 2025

An … n the beginning while the NPP are only phased out upon reaching the year indicated in table 1.

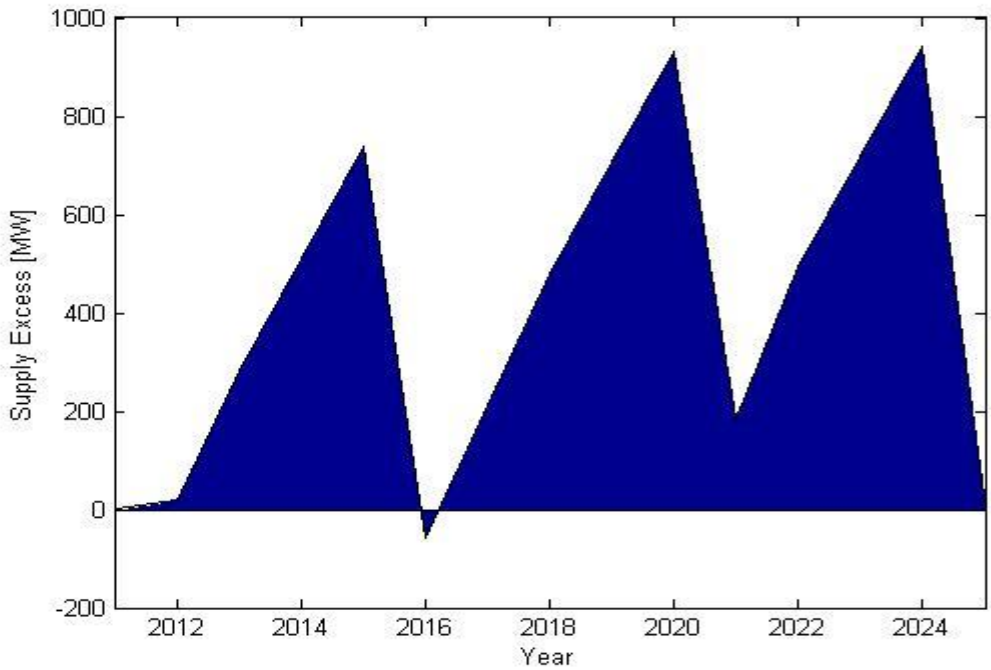

Fig. 6: Excess supply during the NPP phase-out time.

Excess supply is either sold to the surrounding countries or used to fill up the storage lakes of pump water plants. In the price calculation in the following, it is assumed that the excess demand is sold at the modeled price and that this value is subtracted from the electricity price.

Fig.7 shows the resulting average electricity prices with the chosen model parameters:

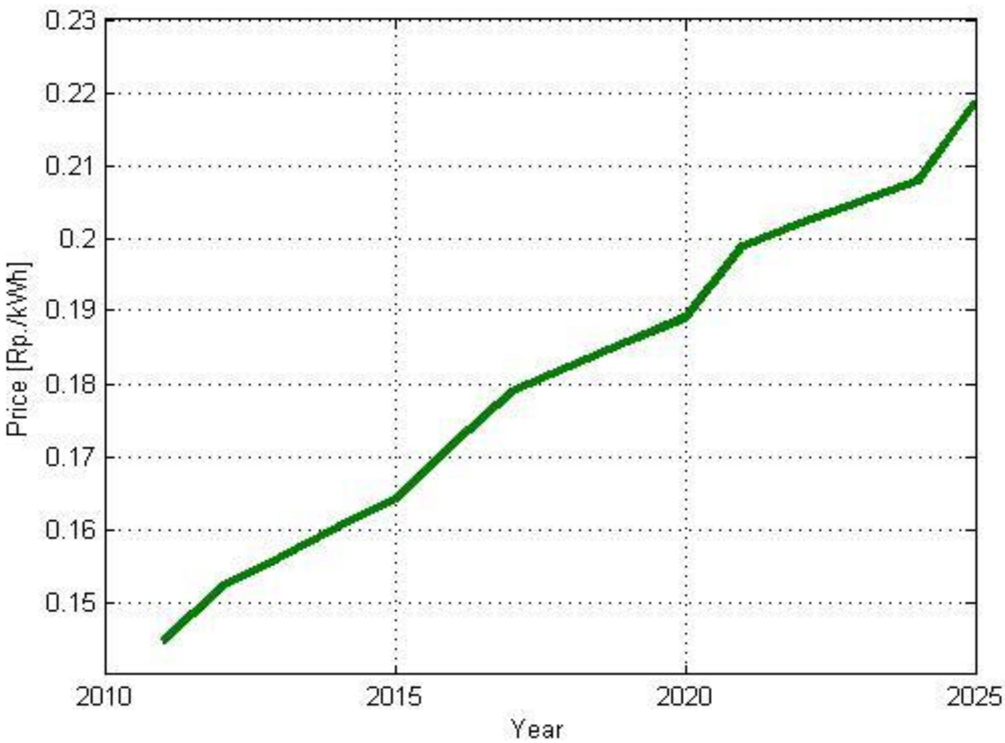

Fig. 7: Average electricity price after a phase-out of all NPP in Switzerland

5 Conclusion

This paper shows a rather optimistic power price scenario for the case of phasing out all NPP. It implies that the sustainable potential of wind, sun and particularly biomass can be fully exploited until the year of the entire nuclear phase-out. The aim of the model is to demonstrate the economic advantages of nuclear power and the impact of renouncing it in the future. The model calculated the effect on the electricity price for private consumers, which is increased strongly. But this is just one consequence of a premature nuclear phase-out in Switzerland.

The power from NPP is sold as cheap as the electricity mix price including hydro power, nuclear power and IGCC power. The reasons for low nuclear power prices are low operation and maintaining costs and the long lifetime of NPP. The resulting price curve has the steepest slopes around the phase-out years of the NPP (2015, 2020 and 2025), indicating the price lowering effect of nuclear power. The flattening of the curve after 2015 and after 2020 occur due to the demand response to the elevated prices.

The prices will also reach higher levels than in this model since the excess supply is here sold and the revenue of this trade subtracted from the power price.

Long-term economic effects of nuclear power are debatable. Aspects like the rebuilding of the NPP and future costs for radioactive wastes are difficult to calculate. Most of the NPP built worldwide are partly financed by their states, subsidizing the operators and thus reducing the electricity price. New NPP contribute very little to the amount of jobs created; the number of employees per kW is fairly small. Increasing environmental protection, uranium prices and safety expectations may also raise the price of nuclear power in the near future.

Opponents claim that the money for new NPP should better be invested in renewable technologies. As seen in the model, the transposition will lead to an abrupt increase in electricity prices, affecting the economy drastically.

The demand will decrease further with elevated prices, because the mid-term price elasticity of the demand is larger, overall moving households to reduced consumption. The state is in this scenario obliged to enhance the development of the mentioned new technologies, what accelerates their improvement. Larger aggregates can work more efficiently, will produce more power and lot of new jobs would be created. New developed technologies can be exported, to countries trying to reduce their CO_2 emissions and the own dependence on imports (uranium, NPP technology) declines. All those effects are machineries for the economic growth and the CO_2 balance would be lowered strongly in the electricity sector.

The short-term effects of a premature nuclear phase-out will doubtlessly have negative economic effects. The mid-term economic effects may nonetheless be positive. The time length and severity of the occurred nuclear disasters and the complexity of the radioactive waste problem make the need of a change in supply technologies inescapable. It might be favorable to start early.

6 References

6.1 Literature

Böhringer C., Müller A. and Wickart M., 2003. *Economy impacts of a premature nuclear phase-out in Switzerland: An applied general equilibrium analysis.* **Schweiz. Zeitschrift für Volkswirtschaft und Statistik.** Vol.139, pages 461-505.

Dietrich P., Kaiser T. and Wokaun A., 2010. *Das inländische Potenzial der neuen erneuerbaren Energien in der Schweiz.* **Vision erneuerbare Energien.** Bulletin 9/2010.

Dittmar M., 2009. *The future of nuclear energy: Facts and fiction.* **Institute of particle physics ETH Zürich.**

Energie Trialog Schweiz, 2009. *Energie-Strategie 2050, Impulse für die schweizerische Energiepolitik.* **Grundlagenbericht.**

Hirschberg S. and Dones R., 2005. *Sustainability aspects of current and future electricity supply systems.* **Chimia**. Vol. 59, pages 887-893.

Schulz T.F., Kypreos S., Barreto L. and Wokaun A., 2008. *Intermediate steps towards the 2000 W society in Switzerland: An energy–economic scenario analysis.* **Energy Policy**. Vol. 36, Is. 4, pages 1303-1317.

Steubing B., Zah R., Waeger P. and Ludwig C., 2010. *Bioenergy in Switzerland: Assessing the domestic sustainable biomass potential.* **Renewable and Sustainable Energy Reviews.** Vol. 10, Is. 8, pages 2256-2265.

Weidmann N., Turton H. and Wokaun A., 2009. *Case studies of the Swiss energy system – Sensitivity to scenario assumptions assessed with the swiss MARKAL model.*

6.2 Webpages

www.aee.ch, Swiss renewable energy agency: Ecologic electricity

www.bfe.admin.ch, General information about Swiss energy supply and consumption.

www.elcom.admin.ch, Power prices raw data by Swiss electricity commission.

www.energietrialog.ch, Energy strategies in Switzerland.

www.globat2000.at, Information about NPP in Europe.

www.iea.org, Energy statistics by country for the entire world.

www.immergenugstrom.ch, Political comments on energy use in Switzerland and power prices.

www.naturemade.ch, ecologic electricity from renewable technologies

www.nzz.ch, Articles about Economy and Policy and e.g. public statements from ministers.

www.ompex.ch, International power trade agency

www.swissinfo.ch, Information about Switzerland

Appendix

The matlab code of the model:

```
% Nuclear Phase-out in Switzerland
% A paper for the lecture 'Energy Economics and Policy'
% By Georg Putzi
% 20.04.2011

% Electricity price model for the scenario of a total nuclear phase-out
% and no new fossil fuel power plants

% Powers in MW: H=Hydro, S=Solar, B=Biomass, W=Wind, N=Nuclear, G=Natural
% gas, im=import, ex=export, E=total electricity demand

% pop=population of Switzerland in Mio., GDP = BIP in Bio. CHF

% Prices pH, pS, ..., in Rp./kWh. They are the prices for private consumers
% includ. taxes and grid fees.

ds=1;
s=15;

time=[1:ds:s];
```

```
H=zeros(1,length(time));
S=zeros(1,length(time));
W=zeros(1,length(time));
B=zeros(1,length(time));
N=zeros(1,length(time));
E=zeros(1,length(time));
ES=zeros(1,length(time));
im=zeros(1,length(time));
ex=zeros(1,length(time));
pop=zeros(1,length(time));
GDP=zeros(1,length(time));
pH=zeros(1,length(time));
pS=zeros(1,length(time));
pW=zeros(1,length(time));
pB=zeros(1,length(time));
pN=zeros(1,length(time));
pim=zeros(1,length(time));
pex=zeros(1,length(time));

H(1)= 4331;
S(1)= 21;
W(1)= 0.33;
B(1)= 274;
N(1)= 3162;
G(1)= 103;
im(1)= 66800/8.76;
ex(1)= 66300/8.76;
pop(1)=7;
GDP(1)=130;
E(1)=H(1)+S(1)+B(1)+N(1)+G(1)+im(1)-ex(1);

pH(1)= 0.20;
pS(1)= 0.96;
pW(1)= 0.41;
pB(1)= 0.40;
pN(1)= 0.21;
pG(1)= 0.21;
pim(1)= 3.5*0.056;
pex(1)= 3.5*0.0765;
p(1)=(pH(1)*H(1)+pS(1)*S(1)+pW(1)*W(1)+pB(1)*B(1)+pN(1)*N(1)+pG(1)*G(1)+pim(1)*im(1)-
pex(1)*ex(1))/E(1);

a=0.1;
c=0.8;
d=0.008;
e=0.1;
f=0.0004;
g=0.05;
h=0.0003;
x=0.3;
y=0.3;
z=0.2;

for t=2:1:length(time)
pop(t)=pop(1)+0.15*(t-1);
GDP(t)=GDP(1)+1.7*(t-1);
u(t)=(1+x*(pop(t)/pop(1)-1)+y*(GDP(t)/GDP(1)-1));

H(t)= H(1)+(4582-H(1))/14*(t-1);
W(t)= W(1)+(457-W(1))/14*(t-1);
B(t)= B(1)+(3266-B(1))/14*(t-1);
if t <= 5
    N(t)=N(1);
elseif t>5 && t<=10
    N(t)=2135;
elseif t<=14 && t>10
    N(t)=1165;
else
    N(t)=0;
end;


if t==1
    G(t)= G(1);
else
```

```
    G(t)=0;
end;

E(t)= E(1)*u(t)*(1-z*(p(t-1)/p(1)-1));
q=E(15)-H(15)-W(15)-B(15)-S(1);
S(t)= S(1)+q*(t-1)/14;

%ES=Excess supply
ES(t)=(H(t)+S(t)+B(t)+N(t)+W(t)+G(t))-E(t);

if ES(t)>0
    im(t)=im(1)+(70000/8.76-im(1))/14*(t-1);
    ex(t)=ex(1)+(70000/8.76-ex(1))/14*(t-1)+ES(t);
else
    im(t)=im(1)+(70000/8.76-im(1))/14*(t-1)+ES(t);
    ex(t)=ex(1)+(70000/8.76-ex(1))/14*(t-1);
end;

pH(t)= pH(1)*(1+a*(p(t-1)/p(1)-1));
pS(t)= pS(1)*(1+c*(p(t-1)/p(1)-1)-d*(S(t-1)/S(1)-1));
pW(t)= pW(1)*(1+e*(p(t-1)/p(1)-1)-f*(W(t-1)/W(1)-1));
pB(t)= pB(1)*(1+g*(p(t-1)/p(1)-1)-h*(B(t-1)/B(1)-1));
pN(t)= pN(1);
pG(t)= pG(1);
pim(t)= pim(1);
pex(t) = pex(1);

p(t)= (pH(t)*H(t)+pS(t)*S(t)+pW(t)*W(t)+pB(t)*B(t)+pN(t)*N(t)+pim(t)*im(t)-pex(t)*ex(t))/E(t);
end

Y=2011:2025;
figure(1)
plot(Y,p)
xlabel('Year'); ylabel('Price [Rp./kWH]')

figure(2)
area(Y,ES)
xlabel('Year'); ylabel('Supply Excess [MW]')

figure(3)
plot(Y,E)
xlabel('Year'); ylabel('Consumed Power [MW]')
```