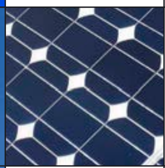
NO. 21 / NOVEMBER 2012

ENERGIE-SPIEGEL

FACTS FOR THE ENERGY DECISIONS OF TOMORROW



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The new Swiss energy policy: Where will the electricity come from?

Politics has set the guidelines: no more new nuclear power plants in Switzerland. That means that 40 % of today's electricity must come from other sources in the future. So much is clear – we must reduce demand and strengthen use of renewable energy. But if this is not enough? Are gas power plants needed? Or should we depend on electricity imports? These and other similar questions are investigated by PSI within the framework of energy scenarios.*

After Fukushima it quickly became clear that the electricity supply of Switzerland in 40 years should look different than today. There should be no more electricity from new nuclear power plants, and the use of sun, wind and biomass should be massively increased. Whether this will be enough to fill the electricity supply gap is certainly questionable, particularly if one looks at the development of electricity demand to date, and considers the predicted increase of the population to 9 million and economic growth of about 50 % by 2050.

Switzerland stands before a great challenge: For a successful transformation of the electricity supply the renewable energy sources must each be built rapidly up to the limits of their usable potentials. And electricity must be used more efficiently – the means for this are available. But if we do not manage to significantly reduce demand, then our foreign dependence will grow. To depend fully on electricity imports is risky in view of security of supply. Above all in winter, when demand is high and the hydro power plants produce less. If gas power plants are chosen, then much natural gas must be imported and gas power plants will produce much CO_2, so otherwise challenging climate policy goals will become even more difficult to achieve.

Even if future development is difficult to estimate, there is evidence that by 2050 electricity will cost at least 50 % more than today.

* Complete background information and further scenario results are available for download: http://www.psi.ch/info/energie-spiegel

What if...?

"Prediction is hard, especially about the future." It's not clear to whom this quotation should be ascribed[1]. What is clear is that it should at least be kept in mind whenever the public is presented with new energy scenarios.

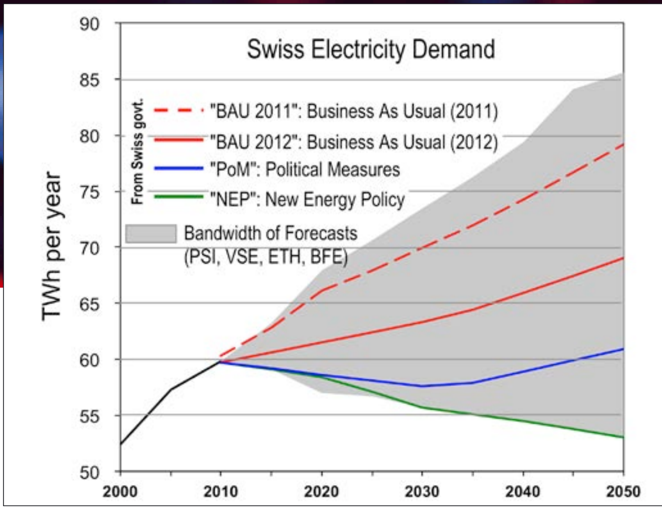

Figure 1: Bandwidth in assumed Swiss electricity demand trajectories to 2050 (Source: Federal Energy Strategy 2050; PSI, Laboratory for Energy System Analysis; VSE; ETH).

No one can predict today how the Swiss energy and electricity supply will look like in the year 2050. That is impossible either by looking in a dark crystal ball, or by complicated modelling – even when this impression is gladly given by predictions of remarkable precision. The uncertainties behind the most important influencing factors are simply too large. Population development and economic growth, the price of oil and other energy carriers, technological development, and international frameworks: these are only some of the influencing factors that cannot be precisely forecast over such a long time horizon. But this does not mean that model calculations are useless. On the contrary, scenarios for energy and electricity supply can answer many "what if" questions. They sketch developments that can be expected under quite specific assumptions and conditions, and show their costs and consequences for the CO_2 balance of Switzerland.

Electricity demand climbed about 14% between 2000 and 2010.

How much electricity will we need?

The level of electricity demand is one of the most important parameters when scenarios are calculated for how our electricity supply could look in 40 years. How demand will develop depends on many factors. And the bandwidth of different forecasts is accordingly broad (Figure 1).

For the Swiss electricity supply it makes a difference whether 50 or 85 terawatt-hours per year are needed – because the potential of individual sources of electricity is limited. This applies particularly to renewable energy sources, whose domestic production cannot be arbitrarily increased.

The Swiss federal government expects development (Figure 1) based on specific conditions – but demand that declines almost immediately, and by 2050 is significantly below the current level (the New Energy Policy, or "NEP"), can only be implemented by massive, fast acting controls and savings measures. And not just in Switzerland, but in coordination with international action. The measures now under review in Switzerland within the framework of the Energy Strategy 2050 would produce demand in 2050 around the current level (Political Measures, "PoM"). Without these measures (Business As Usual, or "BAU") demand would continue to increase. The current business-as-usual forecast ("BAU 2012") is significantly more optimistic than just a year ago ("BAU 2011"). For comparison, demand grew about 14% between 2000 and 2010.

How realistic it is that the demand grows no further, or that in 2050 even less electricity is needed than today, remains to be seen. Current expectations are that in 2050 there will be 9 million people living in Switzerland, the economy will grow by about half, and electricity will increasingly replace fuel in the growing transport sector (see Figure 2).

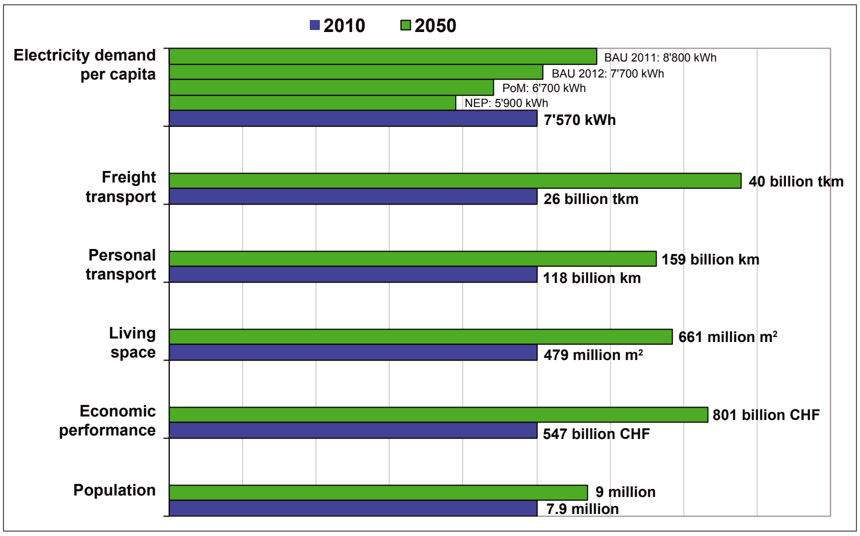

Figure 2: Development of various Swiss parameters to 2050, according to federal forecasts.

[1] Karl Valentin, Mark Twain, Winston Churchill (among others)

Gas power plants or electricity imports?

Domestic renewable resources will only suffice if, thanks to new energy policies, we can get by with much less electricity than today – despite a growing population and economy. Otherwise there needs to be a Plan B.

PSI has calculated various supply scenarios for the three current demand forecasts shown in Figure 1. How can this electricity demand be covered most economically, and what will be the consequences with regards to costs and CO_2 emissions? To answer this question PSI has used a cost minimization model for the next 40 years (see box on the insert page). The conclusion: No matter how high the demand may be in 40 years, the electricity supply for Switzerland will still pose a challenge if the climate policy goal of a 60% CO_2 reduction by 2050 is maintained and no new nuclear plants are built.

Boundary conditions

Figure 3 shows the results of the model calculation if the electricity demand can be held at about the current level (the "PoM" forecast in Figure 1). Three scenarios were analyzed: in the first ("Gas") the electricity imports and exports were required to balance over each year, while in the second ("Import") net imports were allowed, but no gas power plants. In both cases new nuclear plants were not allowed. The third scenario represents a reference case with conditions corresponding to before Fukushima ("REF"). Here new nuclear plants were allowed, but annual electricity imports and exports were required to balance.

Renewables at their limits

The scenario "Gas" shows that a combination of flexible gas power plants, photovoltaics and wind energy is the most economical solution, if annual electricity imports and exports must balance. Seven large gas power plants would then be required in the year 2050.

In the scenario "Import" without gas power plants more electricity can be imported, at most barely a fifth of the annual demand. The potential of all the new renewables – photovoltaics, wind, wood and geothermal – will then be fully exhausted. But that is not enough: much electricity must still be imported, above all in winter (see insert, Figure 7).

Because nuclear electricity costs the least, nuclear plants together with pumped storage hydro displaces the gas power plants and renewables in the third scenario ("REF").

And if the electricity demand turns out differently? Figure 4 shows the same three scenarios with the same assumptions as before for only the year 2050, using all three of the demand forecasts shown in Figure 1.

If the demand goal of the new energy policy ("NEP") is reached, then Switzerland can avoid gas power plants and net electricity imports. Full use of the renewables will suffice averaged over the whole year, but as now electricity must still be imported in winter.

If the demand is higher than today (BAU 2011 and 2012), then there will need to be either more gas power plants or higher imports. If the same amount of electricity as today were still to come from nuclear plants, then additional gas plants and electricity from photovoltaics and wind energy would still be required.

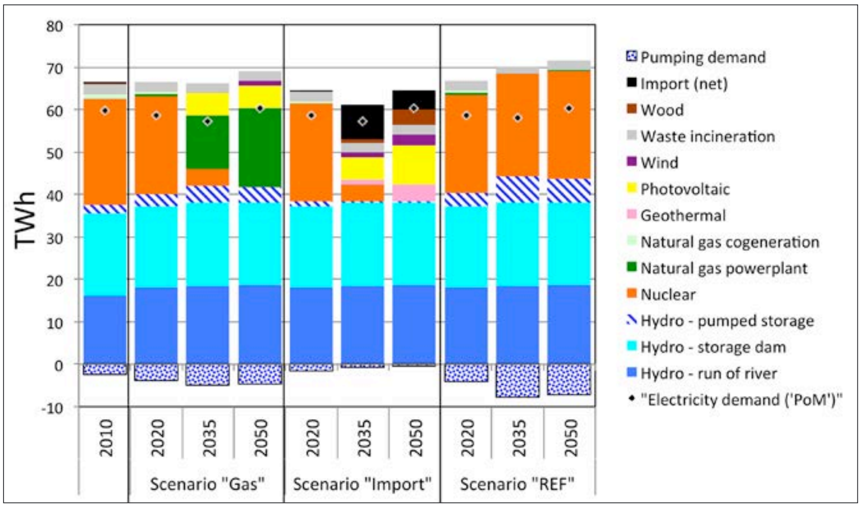

Figure 3: Swiss electricity supply in three scenarios to 2050 with different conditions, based on "PoM" electricity demand forecast.

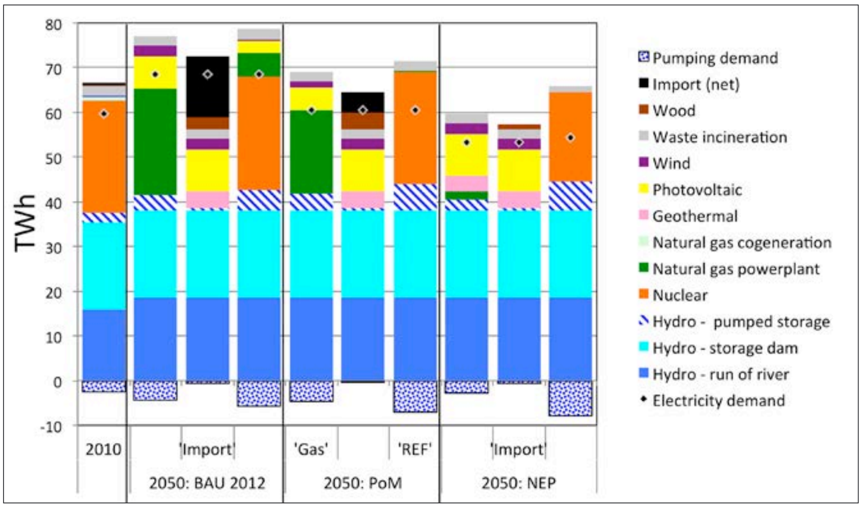

Figure 4: Scenarios for Swiss electricity supply in the year 2050 for different energy demands (equals gross production minus use in pumped storage plants).

"The price of electricity will be about 30% higher in 10 years."

From your point of view how will electricity demand develop in the next decades?
On the basis of population and economic growth, as well as new electricity uses like heat pumps, household appliances, electric mobility, etc., the electricity demand will continue to grow. Axpo is counting on a growth of electricity demand of about 1 percent per year until 2040, with near-term growth being more significant and then weakening over the long-term.

Electricity demand will increase further

How do you see the federal energy strategy, above all regarding the development of electricity demand and the potential of renewable energy?
Axpo fundamentally supports the federal energy strategy, which along with the long-term exit from nuclear power also calls for the strengthened promotion of new renewable energy and energy efficiency. Axpo, which is already today the largest Swiss producer of electricity from renewable energy, has made it a goal to more than double production from renewable resources by the year 2030. On the basis of limited potential, and furthermore the expected resistance to specific projects, this growth will largely be achieved outside Switzerland. The federal council expects a reduction in electricity demand from the year 2020. In our view this is not realistic.

Where do you see risks in this new energy strategy, and what required conditions must the federal government create for a successful transformation?
Now as before, many assumptions depend upon developments that are hard to estimate from today's viewpoint. Therefore you should not build on any one option today that you must depend upon in every case tomorrow. Axpo will remain active in the design of Switzerland's energy future. We emphasize our belief that the people must be involved in energy-political decisions and policies. Far reaching measures with corresponding economic consequences for the people should absolutely require a public vote.

How can Axpo be sure that you can fulfill your duty to supply power in 25 years and more? Will electricity imports play a role?
It is Axpo's job to continue to provide a secure and sustainable electricity supply in its service area. In January 2012 we have begun to implement our new strategy. With this strategy we want to be able to react flexibly to unforeseeable developments, above all by means of an ever-broader production and supply portfolio. Imports will play an increasingly important role in the future.

Under what conditions would Axpo invest in gas combined cycle power plants?
With today's CO_2 regulations, economic operation of a gas combined cycle plant in Switzerland is hardly possible. The plants produce significant CO_2 emissions that must be compensated for 100 % in Switzerland. In the case that the legal and economic conditions are someday right, then gas combined cycle plants could be an option. The chief precondition would be the entry of Switzerland into the emissions trading system of the EU.

What electricity prices can customers expect in 25 years?
It is clear that electricity imports will play a larger role according to the federal council's Energy Strategy 2050. This will bring higher grid costs, based on the large needed investments. And we must assume that taxes to subsidize the new renewable energy sources will be higher. So we must expect the electricity price to climb on the order of 30 % in the next 10 years alone.

Heinz Karrer has been Chief Executive Officer (CEO) of Axpo Holding AG since 2002. Until September 2007 he was also CEO of Axpo AG (then NOK). Karrer was previously in corporate management at Swisscom AG, director of Ringier Schweiz, and a member of the Ringier AG management, as well as managing director and board member of Intersport Holding AG.

Reducing electricity demand is a political goal. Does Axpo see it as its responsibility to contribute to reaching this goal? Will corresponding business models be developed?
Axpo remains committed to a secure, sustainable and competitive supply of electricity. The demands of the economy and society must be kept in mind. Axpo will work more strongly on energy efficiency in the future, both in our own plants and also with our customers.

Impressum

Energie-Spiegel is the newsletter of PSI for the comprehensive analysis of energy systems (Projekt GaBE). Contributions to this edition come from Kannan Ramachandran, Hal Turton and Stefan Hirschberg.

ISSN-Nr.: 1661-5107

Circulation: 15 000 copies in German, 4 000 French, and 800 English. Prior editions are available as PDFs (D, F, E) at: http://gabe.web.psi.ch/

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Energy systems analysis at PSI: The goal of energy systems analysis at the Paul Scherrer Institute in Villigen is to analyze present and future energy systems in a comprehensive and detailed way, considering in particular health, environmental and economic criteria. On the basis of Life Cycle Assessment (LCA), energy-economic models, risk analysis, pollution transport models and finally multi-criteria decision analysis, it is possible to compare different energy scenarios to create a basis for political decision-making.

In cooperation with:
ETH Zurich; EPF Lausanne; EMPA; Swiss Federal Office of Energy (SFOE), swisselectric research; World Energy Council (WEC); Massachusetts Institute of Technology (MIT); European Union (EU); International Energy Agency (IEA); Organization for Economic Cooperation and Development (OECD).

CO_2 Emissions, Costs and Security of Supply

Without new nuclear power plants, the risk of nuclear accidents in Switzerland falls away. But the new energy policy is not free. It will be noticeable in our household budgets and in the Swiss CO_2 budget. And electricity or gas imports could mean a less stable electricity supply.

If we cannot get by with significantly less electricity than today, then abstaining from new nuclear plants will mean importing natural gas or electricity from abroad. Both are more risky, from the point of view of security of supply, than importing fuel elements for nuclear plants. Germany will likely also depend upon electricity imports in the future. But as a strategy for all of Europe this will not work. And countries like Russia and Iran could turn out to be undependable suppliers of natural gas.

Consequences for Climate Policy

With an approximately level electricity demand in the year 2050 (forecast "PoM" in Figure 1), depending completely on natural gas generation would mean seven new gas power plants, which would result in as much additional natural gas needing to be imported as is used today for heating and industry. This would produce around six million tonnes of CO_2 more per year (Figure 5, scenario "Gas" in the middle). In comparison to the current Swiss emissions of around 40 million tonnes of CO_2 per year that is an increase of about 15 %. These new emissions from gas plants would place an additional hurdle in the path of the target of a 60 % CO_2 reduction by 2050. Compensating domestically for these additional emissions would be expensive. One solution could be so-called "carbon capture and storage," meaning that CO_2 from power plants is caught and permanently stored underground (see box). Whether this can be realized in Switzerland is still unclear.

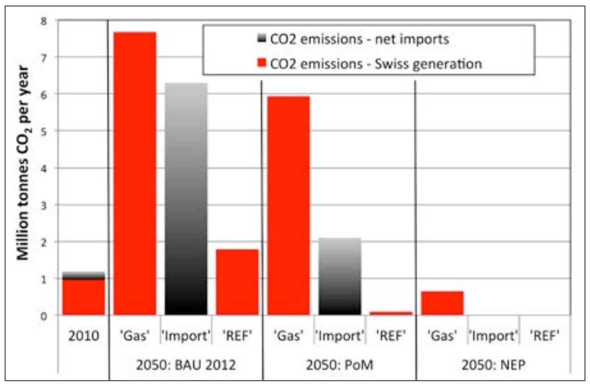

Figure 5: Direct greenhouse gas emissions from the Swiss electricity supply per year, depending upon the development of the electricity demand (compare with Figure 1).

With an import strategy (scenario "Import"), the CO_2 emissions depend on the composition of the imported electricity. With electricity demand following the "PoM" forecast, the range of CO_2 emissions can be from zero to 2 million tonnes per year. This bandwidth is based on the range from "CO_2-free" electricity from renewable sources or nuclear energy up to the CO_2 content of the current average electricity mix in the EU. Whether CO_2 is produced in Switzerland or abroad makes no difference for the climate. However the "gray" emissions of these imports would not count on the Swiss CO_2 balance sheet, but rather on that of the countries where the power originates.

Replacement nuclear plants (scenario "REF") would cause hardly any CO_2 emissions.

If the demand grows as in the BAU 2012 forecast, eight new gas plants would be needed in 2050, or higher electricity imports, and the CO_2 emissions would also climb.

«**Carbon Capture and Storage**» describes technologies that can remove CO_2 emissions from power plants or cement manufacturing plants. The CO_2 is compressed and injected in appropriate geological structures at depths of at least 1000 m. The CO_2 remains stored there and does not contribute to climate change. A possible implementation in Switzerland is investigated in the CARMA project with the participation of PSI: http://www.carma.ethz.ch/

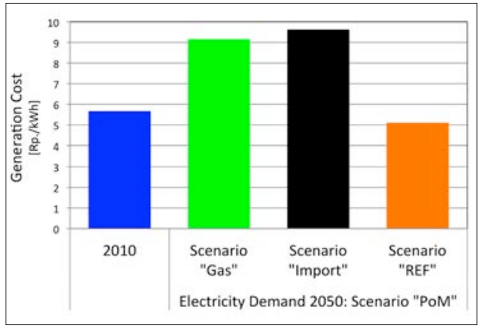

Figure 6: Generation cost of a kilowatt-hour of electricity in the three scenarios on average in the year 2050. The profits from electricity trading are included here.

Economic Consequences

Even if it is difficult to predict how much the generation of a kilowatt-hour will cost in 40 years, it will be considerably more than today (see Figure 6). In the "Gas" and "Import" scenario the average production costs are almost twice as high as today. The uncertainties behind the assumed costs of natural gas and electricity imports as well as nuclear power plants and new renewables up to 2050 are large. And these costs have a decisive influence on the results of the scenarios. With the current assumptions (see table on the reverse side of this insert) avoiding replacement nuclear plants results in additional costs of about 60 billion francs alone for the electricity supply until 2050, if demand follows the "PoM" forecast. This is not including the costs that could result from grid expansion.

The costs for the electricity supply would be less if the electricity demand decreases, as assumed in the "NEP" forecast. But then there would be higher investments necessary in electric efficiency measures in the residential, industrial and transportation sectors. The theme of the overall energy supply until 2050 will be addressed in one of the next issues of the Energie-Spiegel.

Summer and Winter, Day and Night

To have enough electricity for the whole year is one thing. But is there also enough in winter, when all the heaters are running and the sun is hidden behind the clouds? Whether winter or summer, the middle of the night or holidays: electricity demand and production fluctuate strongly.

For scenarios of future electricity to give a realistic picture, the daily variations in demand and production must be considered. For example, photovoltaics deliver power only during the day, and more in summer than in winter. Demand is also somewhat higher in winter. And exactly as supply and demand change, the prices for imports and exports also change with the days and the seasons. The PSI model considers all these circumstances (see box and table).

Lots of Water and Sun in Summer, Little in Winter

Electricity demand and generation for a typical weekday in summer and winter are shown Figure 7, for both the "Gas" and "Import" scenarios in the year 2050.

In the summer evenings and during the nights, cheap electricity is imported in both scenarios (black surface). The daily photovoltaic generation (yellow) is also clear to see with the much higher production during the summer. The hydro reservoir plants (light blue) produce during high demand and when electricity is expensive. In summer, most storage generation can be exported and bring financial profits.

In winter, imports are also needed during the days due to the smaller production of photovoltaic and hydro power. In the import scenario without gas power plants these imports are significantly higher: up to two thirds of the demand must be imported over many hours due to the lower base load capacity available in Switzerland.

Hydro reservoir plants can also be used to compensate for the production lacking from photovoltaics during nights and bad weather, or from wind turbines during calm weather. But doing so of course reduces the profits from power exports.

Potentials and Costs of Electricity Generation for 2050 in the TIMES-Model for Switzerland

	Generation cost [Rp./kWh]	Generation potential, assumed as possible by 2050 [TWh/a]
Natural gas combined cycle	15.4	flexible
Nuclear	5.9	Zero in the scenarios "Gas" and "Import" ~25 in scenario "REF"
Hydro	14 (new powerplants)	38.3
Photovoltaic	10.3	9.7
Wind	14.5	2.6
Geothermal	16.5	4.4
Wood	8.9	3.8
Electricity imports	16.4 (ave.) 8.5–22.7 by time of day	Max. 17 % of demand in "Import" scenario
Natural gas (fuel cost)	6.7 Rp. per kWh natural gas	

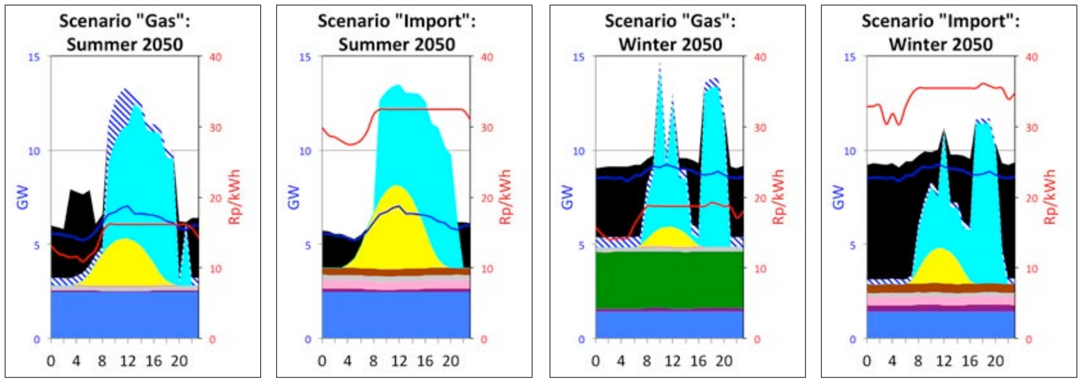

Figure 7: Daily electricity supply and demand curves for the scenarios "Gas" and "Import" for 2050 (left: summer; right: winter). The blue line stands for the demand, and the red for the production cost of an additional kilowatt-hour. The differently colored surfaces show the electricity produced from the different technologies and imports. The production must be around 7 % higher than the demand to cover losses in the electricity grid. If the production is more than 7 % higher than the blue line, the electricity is exported. The colors for the technologies are the same as in Figures 3 and 4.

The "Swiss TIMES Model"
has been developed at PSI for analyzing scenarios of Swiss electricity supply. It finds the most economical system for the supply of electricity under given boundary conditions.
To optimize the whole system, the properties of each technology are considered, e.g. costs, availability and flexibility. The time resolution of the model is one hour, so that daily variations in demand and production can be well modeled. The model includes weekdays, Saturdays and Sundays for each of the four seasons. Electricity can be imported and exported at any time.