# Scaling up and scaling out of renewable energy – worldwide and in Switzerland

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## Content

# 1. Renewable energies advancing worldwide

Some investors and media commentators still regard renewable energy as a modest-sized and expensive side-show in the energy sector. That view has it that the “serious” investment activity goes on in conventional energies such as oil and gas, coal and nuclear with the latter being called “cheaper” in terms of economics. However, recent numbers show a different reality.

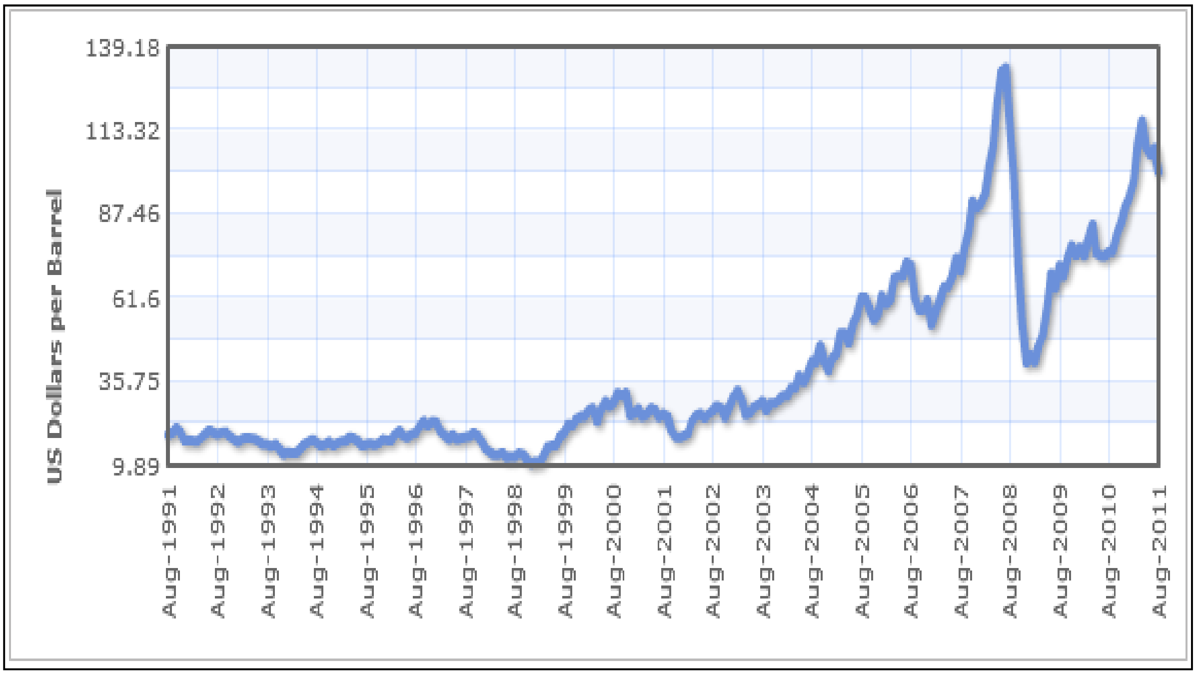



**Figure 1 Crude Oil price 1991-2011** (source: indexmundi)

Over the past 10 years we have seen three significant new trends in world energy markets.

(1) Oil prices rose significantly. They are bound to stay high due to stagnant or declining production rates in a majority of oil countries.

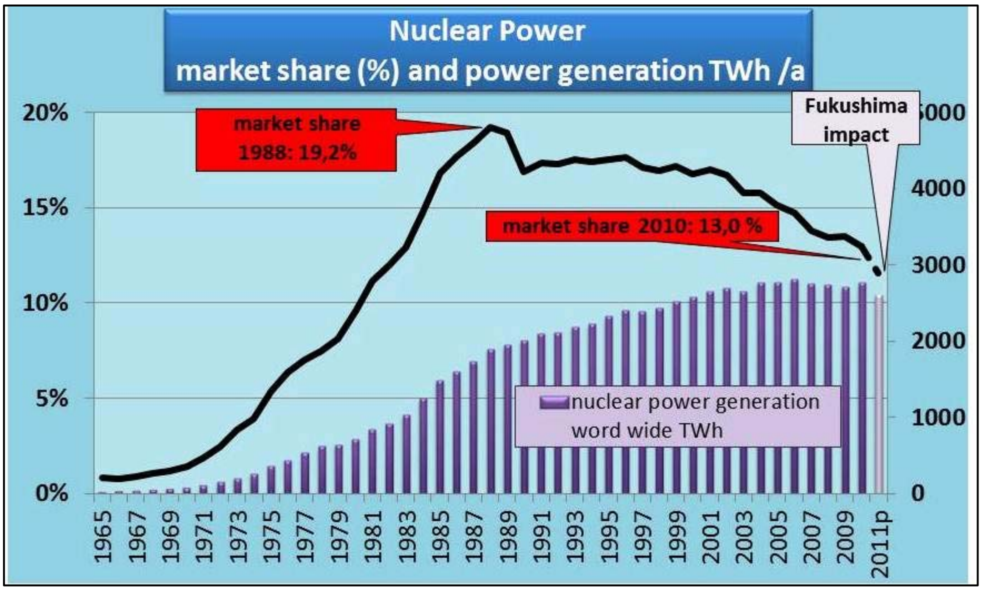



**Figure 2 nuclear power: Market share in the electricity sector and power generation per year in TWh.** Data: BP Statistical Review of World Energy 2011

(2) Nuclear power has lost confidence and market shares in the electricity sector. Nuclear power generation (in TWh) is in decline since 2006 and faces abandonment in a number of nations and by a number of companies such as ABB and Siemens. With shutdowns of reactors in Japan and Germany, and regarding the age of the existing fleet, an overall reduction of nuclear capacities over the next decades is to be expected, despite some additions, mainly in China and India.

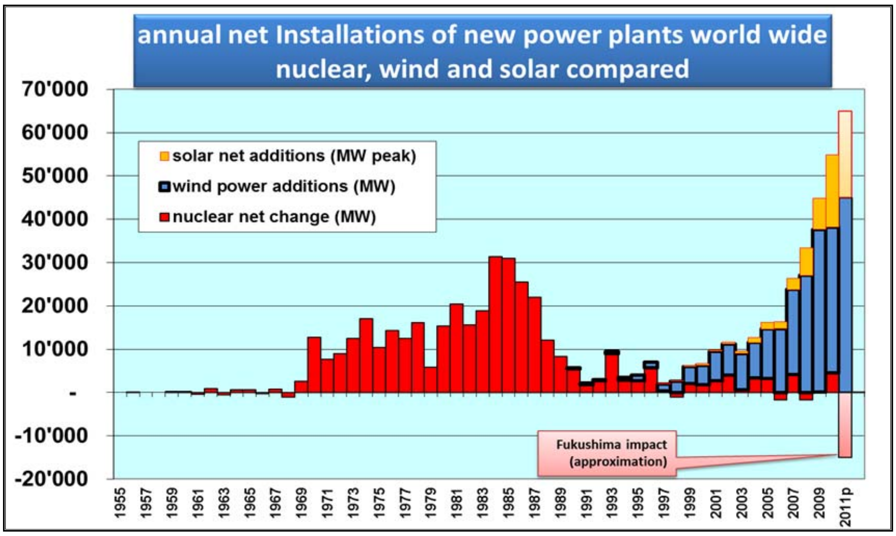
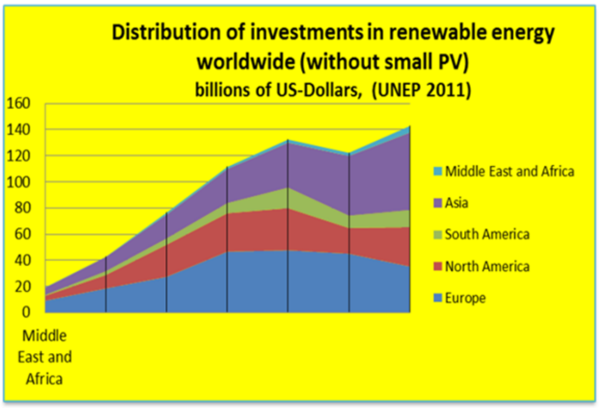



**Figure 3 Annual net Installations of power plants worldwide: nuclear, wind and solar compared** Data: IAEA, Windpower Monthly, PV Status Report 2011)

(3) Within the non-fossil power generation, wind and solar power are on a solid growth path. Their additions exceeded 50 GW in 2010. These technologies have lower capacity factors than nuclear, but their price per kWh is competitive in a fast growing number of applications. Their net annual power contributions now start to exceed what nuclear delivered in many of its best years before Chernobyl. Most important: Wind and solar will

not disappear due to accidents or unexpected cost overruns. They will, day by day, grow cheaper and more attractive.

## Investment Trends



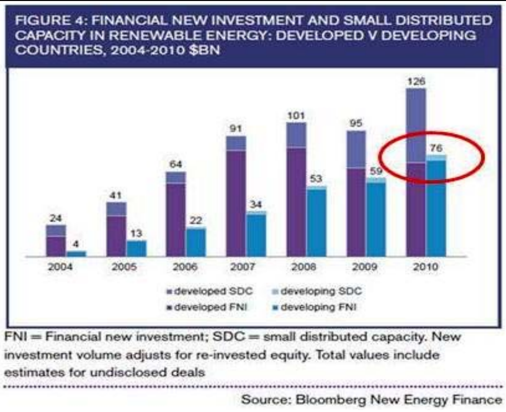




**Figure 4 and 5: Distribution of investments in renewable energy worldwide, developed and developing countries compared (source: UNEP 2011)**

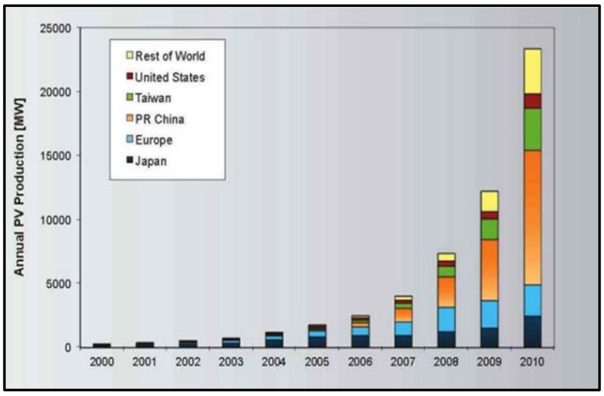
Renewable technologies have high up-front costs; their benefits come with low expenses for operation and maintenance due to free fuel from nature. Since the start of the financial crisis in 2008 financing of renewable energy projects was not an easy task. Despite this negative environment, net investments in renewables, including large hydro, in 2010 rose to $233 billion, while gross investment in the fossil fuel power sector stood at a total of $219 billion.

2010 was the first year in the electric power sector, a UNEP report says, when investments in renewable additions excluding hydro exceeded the investments in fossil fuelled power plant additions.[2]

For some it came as a surprise that a slight majority of renewable power plant investments has shifted to the so called developing countries due to the generally strong power demand there.

## Solar power

When we include small distributed capacities, mainly solar photovoltaics (PV), the developed world still prevailed in renewable investments. But this might change soon, too.



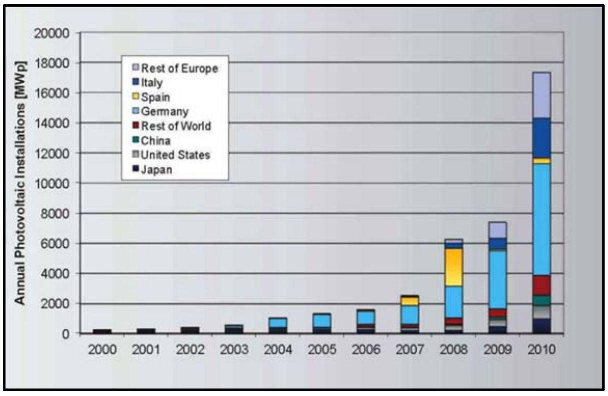




**Figure 6 and 7: Annual photovoltaic production (left) and photovoltaic installations (right) by country.** (Jäger-Waldau: PV Status report 2011)

Growth rates were highest in the solar energy field. Since 2000, total PV production increased almost by two orders of magnitude, with annual growth rates between 40% and 90%. In 2010 a doubling of new installations compared to 2009 has been observed. China and Taiwan together now account for almost 60% of world-wide PV cell production. Main consumption centers were in Europe, mainly Germany and Italy, but this pattern is changing.

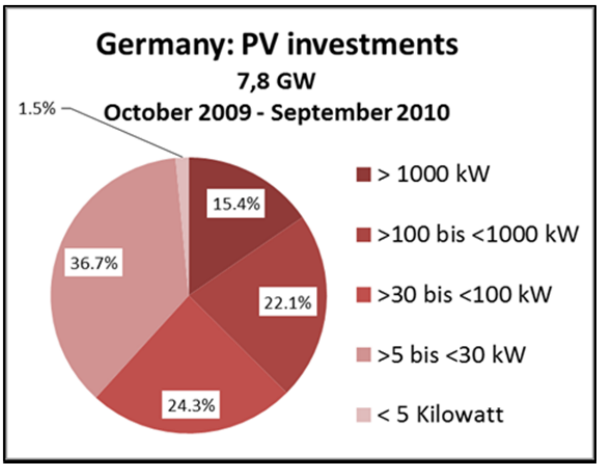
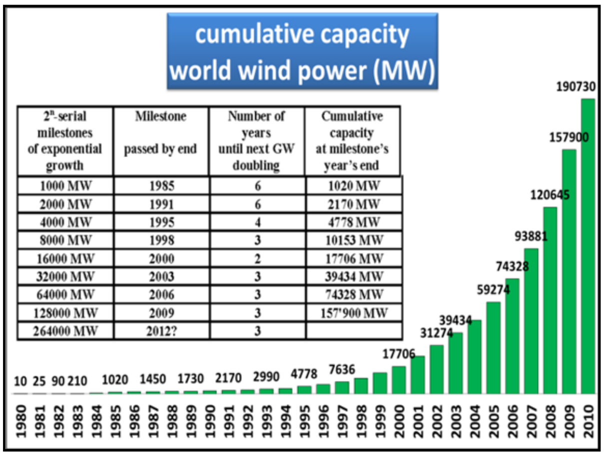



**Figure 8 Distribution of solar investments in Germany (2010/2011)**

In Germany, some 380'000 new solar installations have been constructed in 2010. Almost two third of the new capacities were erected by private households and small enterprises with capacities below 100 kW. Residential PV system prices have decreased by more than 50% over the last three years. The gap between residential rates and cost of PV-generated electricity is closing fast and new markets are evolving.

## Wind power




| $2^n$-serial milestones of exponential growth | Milestone passed by end | Number of years until next GW doubling | Cumulative capacity at milestone's year's end |
|---|---|---|---|
| 1000 MW | 1985 | 6 | 1020 MW |
| 2000 MW | 1991 | 6 | 2170 MW |
| 4000 MW | 1995 | 4 | 4778 MW |
| 8000 MW | 1998 | 3 | 10153 MW |
| 16000 MW | 2000 | 2 | 17706 MW |
| 32000 MW | 2003 | 3 | 39434 MW |
| 64000 MW | 2006 | 3 | 74328 MW |
| 128000 MW | 2009 | 3 | 157'900 MW |
| 264000 MW | 2012? | 3 | |

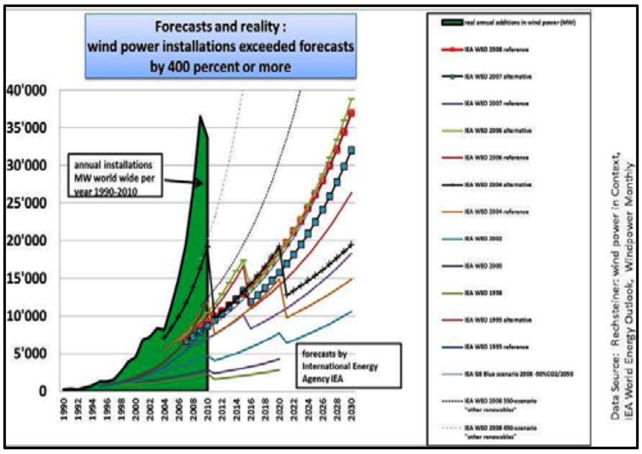



**Figure 9 and 10: cumulative wind capacity worldwide doubling every 3 years (left); Wind power growth exceeding forecasts by the IEA World Energy Outlook (right)**

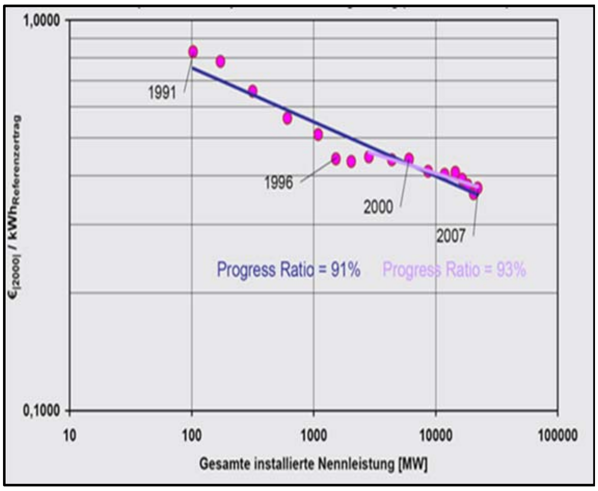
Data: Windpower Monthly, IEA World Energy Outlook

The cumulative capacity of wind power has doubled every two to three years worldwide since 1995. Total wind capacities will grow toward 1100 GW by 2020, predicts leading wind analyst BTM Consult.[3]

Wind power growth rates have exceeded all forecasts by so called energy think tanks such as the International Energy Agency (IEA). The IEA seems to lack understanding of the fundamentals of renewable energy, its learning curves, potentials and advantages. For decades it is telling that oil, coal, gas and nuclear will dominate the energy scene. Billions have been spoiled into research of non-renewable technologies which are the root of exceptional environmental damage. In doing so IEA (and more so IAEA, the Atomic Energy Agency) are clearly accelerating the world's climate, environmental and proliferation risks.

## 2. Success factors of renewables

### Cost reduction factors



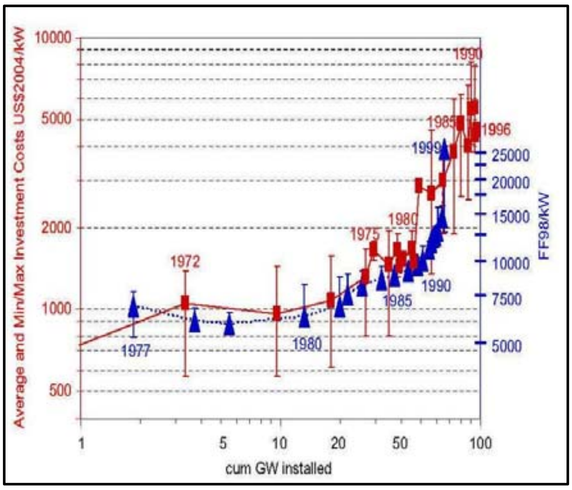




**Figure 11 and Figure 12**: wind power positive learning curve (left), negative learning curve of nuclear power (right): Average and min/max reactor construction costs per year of completion date for US and France versus cumulative capacity completed

Graphs: A. Grubler, Energy Policy, Sept 2010, Fraunhofer IWES: Windenergie Report Deutschland 2010

Year by year, reports such as the World Energy Outlook of IEA fail to recognize the benefits of renewables. Fossil and nuclear energies show cost overruns compared to official expectations due to a decline of fuel reserves, a decline in energy return on energy invested and, in case of nuclear power, due to additional construction lengths and costs and unresolved radioactive waste issues. For nuclear energy a negative learning curve has been observed – and this trend continues with the much hailed European Pressurized Reactor EPR whose cost overruns are to be covered by the French tax payers.[4]

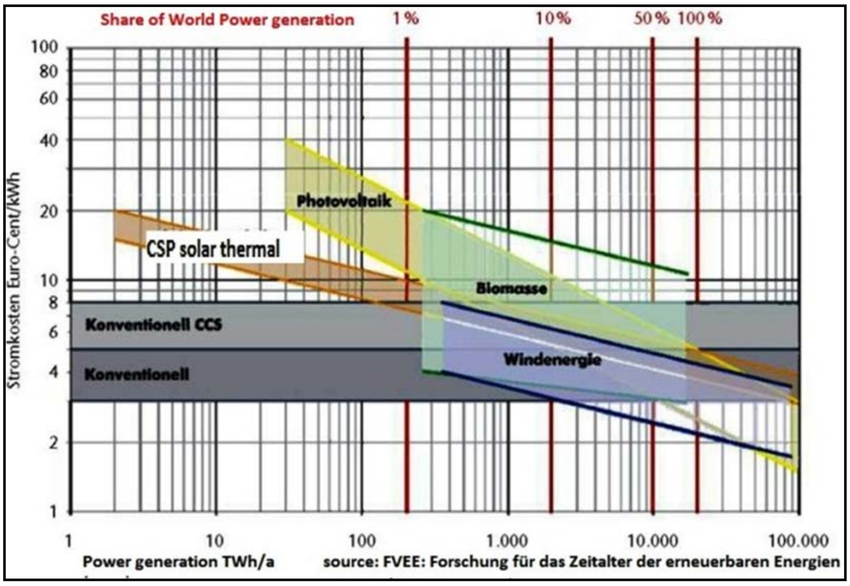



**Figure 13 Learning curves and potentialities of renewable power generation technologies (Source FVEE 2010[5])**

The learning curve of renewable energy goes the other way round and shows a virtuous circle. PV, wind power and other renewable energies are the only ones to offer price reductions, rather than an increase, in the future. The younger a technology the faster its costs can be reduced. With each doubling of cumulative PV installations the price was observed to fall by 15 to 22 percent, [6] while for wind power a reduction between 9 and 17 percent is mentioned.[7]

These reductions show up rather in the long run, while over the short period (such as from 2005 to 2009) generation costs rose temporarily due to rising prices of metals and high demand. Meanwhile wind power is a least cost option competitive with natural gas in many markets – and another price reduction per kWh of up to 40 percent can be expected by 2020.

## Non-cost factors

It would be wrong to see the success of renewables as a question of costs only. Behind the success is more. It is a want for energy security and independence, for new jobs, localized generation, short time construction, local income, technical innovation and protection from fossil fuel price volatility. For wind power, 16 different factors can be identified.[8]

1. The primary energy is cost-free ;
2. The primary energy never runs out;
3. There is an abundant resource creating power independence in many regions of the world;
4. Stable life-cycle-cost can be guaranteed;
5. Wind power is competitive with other new power sources;
6. wind turbines cause no carbon, air emissions nor hazardous waste;
7. No water for cooling is needed;
8. Wind has an energy payback of less than 1 year;
9. There is global, easy access to wind technology;
10. Time to market is very short;
11. Fast innovation cycles prevail;
12. Wind is a young technology, allowing progress on the learning curve and cost reductions;
13. Wind is decentralized power with a non-exclusive structure; it allows small organizations or groups in various places to become a part of the power generation business and to sell it for a profit – very different from the exclusive structure of the oil, gas or nuclear business
14. Distance to consumers is moderate (1-1000 miles);
15. Wind has positive side benefits such as taxes, income for farmers and for remote areas;
16. Wind energy creates know-how and human labor.

Many of these growth factors apply to solar as well. An important advantage of solar is the relief of decentralized generation in times of congested grids.

Renewable energies show a growing versatility in use. Wind power is conquering low wind and offshore areas. A technology leap with higher hub heights, longer blades and better overall efficiencies of turbines is in the works.

Solar energy started with niche off-grid applications. Today we find grid connected installations as main contributors of growth. It started with South sided roofs, but cheaper solar cells start to cover West and East bended roofs and give way to completely new resources and extended power profiles.

Evolutions and revolutions in materials and resource consumption continue. Thinner and more efficient solar cells and inverters are driving material consumption down with unexpected speed. New carbon fibres for rotor blades helped deliver higher capacity factors for wind power.

Better cell efficiencies and tracking systems conserve scarce areas in densely populated regions. In terms of land use, solar and wind are more efficient than biomass and hydro, exceeding the former in terms of land economies by an order of one or two. Solar and wind can be used on non-sensitive areas that are less in demand than agricultural or wet lands.

A number of new wind farms have been reported to deliver power for 5-6 US Cents per kWh.[9] These plants offer additional benefits when the official lifetime of 20 to 25 years can be extended at reasonable costs.

## 3. Switching to renewables – the Swiss Situation

### The Challenges of Renewables

Renewable energies use local resources which fluctuate along local conditions. They rely on sites with prolific energies such as rivers, solar light, wind at certain speeds, geothermal heat or biomass and waste. Renewables have a regional face. Transportation and trade are possible, but more on a regional than a world market level. While use of non-renewable energies is relying on extraction of stored chemical energy, storage of renewable heat and electrical power has a price in terms of energy losses and costs.

Developing renewable energies means to combine local and regional flows rather than stocks. Daily and seasonal flows should approximate demand and they can be optimized by transportation and storage. This optimization is not an easy task, even more in an environment of fast falling prices. Regional frameworks and master plans are needed for regional exploitation and transport, including regulatory rules for non-equal resource qualities, storage management and back-up power. The one dimensional merit order of conventional power plants is dysfunctional when must-run facilities have to be integrated and absorbed by a fluctuating demand.

The overall management of this might look a complex affair. But once basic rules are defined such as priority access, transportation cost allocations, storage, back-up duties and a smarter grid with flexible rates; it can work more robust than the conventional system with its supply risks and its environmental hazards. And – last but not least let's be aware that renewables such as hydro and biomass have been on service to manage non-renewables for a long time.

The challenges for the switch to renewables include

- Fair remuneration for non-polluting power
  - Coverage of investment costs and risks over a facility's life time
  - Integration of high, medium and low profile supply avoiding windfall profits
  - Stability of regulatory frameworks for cost reduction of the manufacturing industry
- access to the grids and grid extensions
  - free, non-discriminating access to grids and consumers with priority for nonpolluting power
  - Interconnection of different weather zones and technologies
  - Transparent grid codes
- Grid and backup management
  - Creation of new transportation lines for power and heat
  - Forecasting of demand and supply
  - Storages for short, medium and long term backup (biomass, hydro, batteries)
  - Creation of intra-day and intra-hour markets for power exchange
  - Fair compensation of idle back-up capacities
  - storing fossil fuels as "lenders of last resort"
- environmental care
  - minimizing environmental impacts while mobilizing natural resources by incentives and regional planning obligations

- Fair and sensitive planning of renewable energies and grids with a 100% approach in mind
- Protection of rare species, natural rivers, exceptional landscapes

## The Swiss and the European energy play

Let us discuss these issues in a short case study for Switzerland.

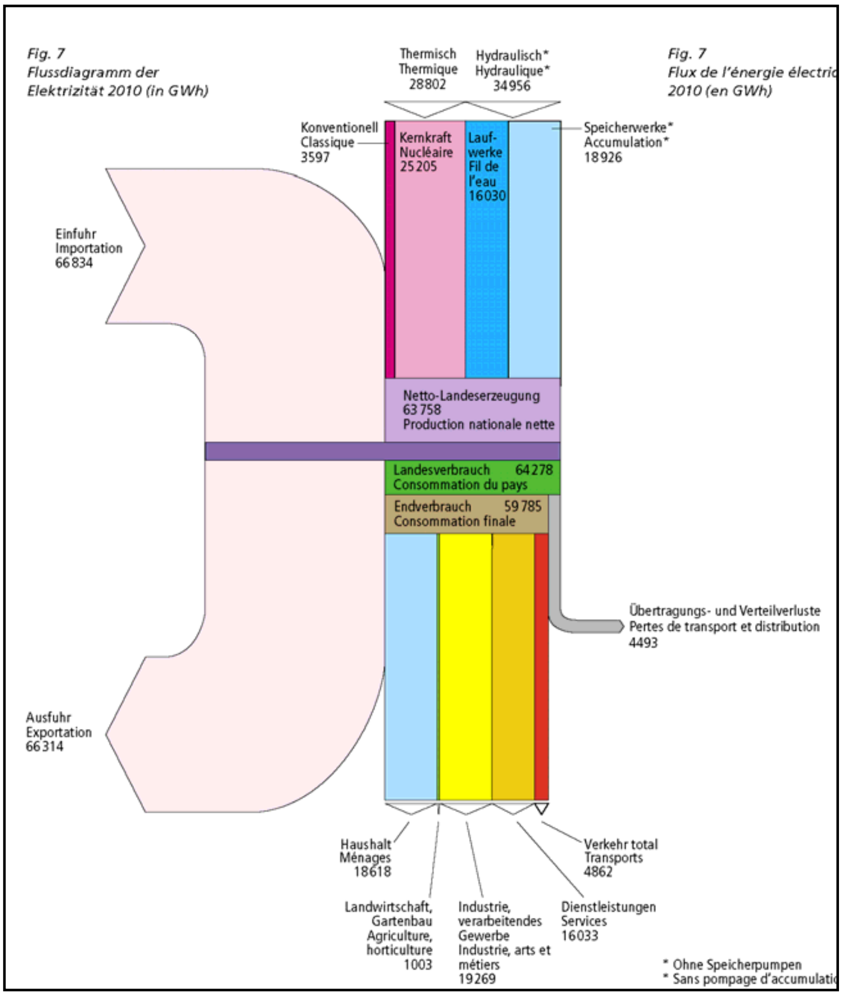



**Figure 14 Swiss power generation and power trade (2010, Swiss Federal Office of energy)**

The Swiss power generation is dominated by hydro with 56% of power domestic generation. Some 38% of power came from nuclear with the rest from new renewables and CHP (combined heat and power). Power transits exceed the national annual consumption of electricity.

For its hydro power Switzerland became an important hub for power transits and peak power due to the large hydro dams in the Swiss mountains.

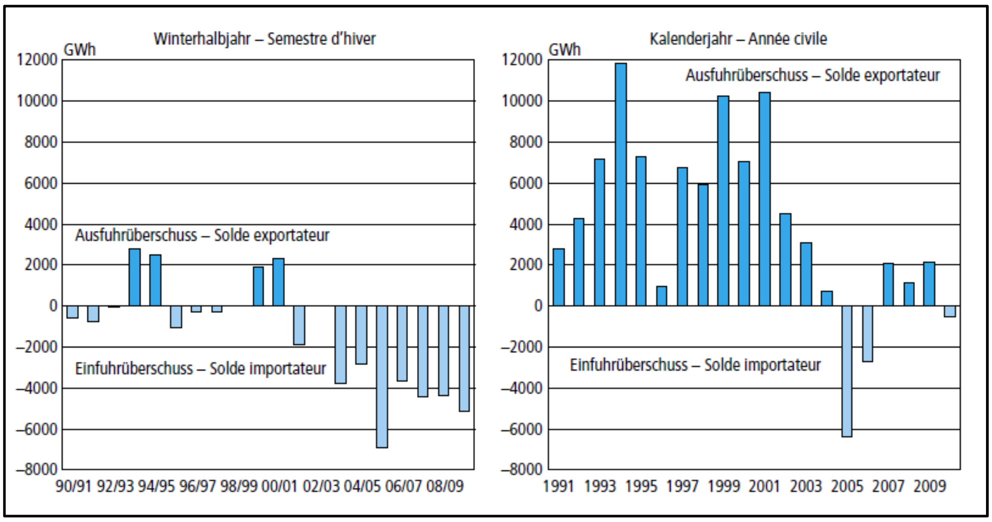



**Figure 15 and 16 electricity balance during winter time (Oct.-March, left) and dwindling annual net power exports 1991-2010 (right)**

For decades Switzerland had excess capacities and excess production of electricity due its hydro base and early expansion of nuclear (1969-1984). Meanwhile excess capacities have dwindled to zero due to the missing efficiency policy and a lack of new power supply. Switzerland started to be a net importer of electricity. Security of supply is not in danger, however, because Switzerland is part of a huge intra-European power exchange.

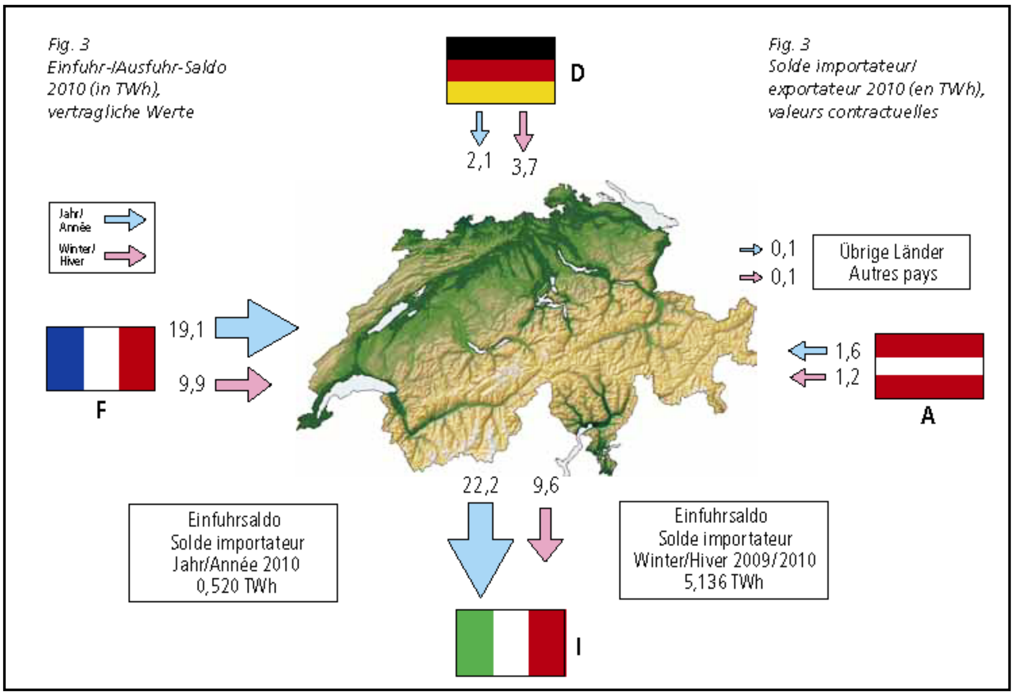



**Figure 17 Swiss net power exchanges with its neighbours (2010)**

Excess power supply from France and Germany traditionally is delivered to Italy. Peak power is also delivered towards France in exchange for base load from nuclear plants. Stored and pumped hydro is the backbone of the Swiss power trade which generates a net profit of up to more than 2 billion CHF per year for the domestic power sector.

## European energy policy

The Swiss energy policy is strongly influenced by its European neighbours. Today the European Union is the partner to be addressed. The European Council endorsed a binding target of a 20% share of renewable energies in the overall EU energy consumption by 2020 together with 20% better efficiency and 20% $CO_2$-reductions. The 2009 EU-Directive on the "Promotion of the Use of Energy from Renewable Sources" indicates the overall percentage of renewable energies for the different Member States.

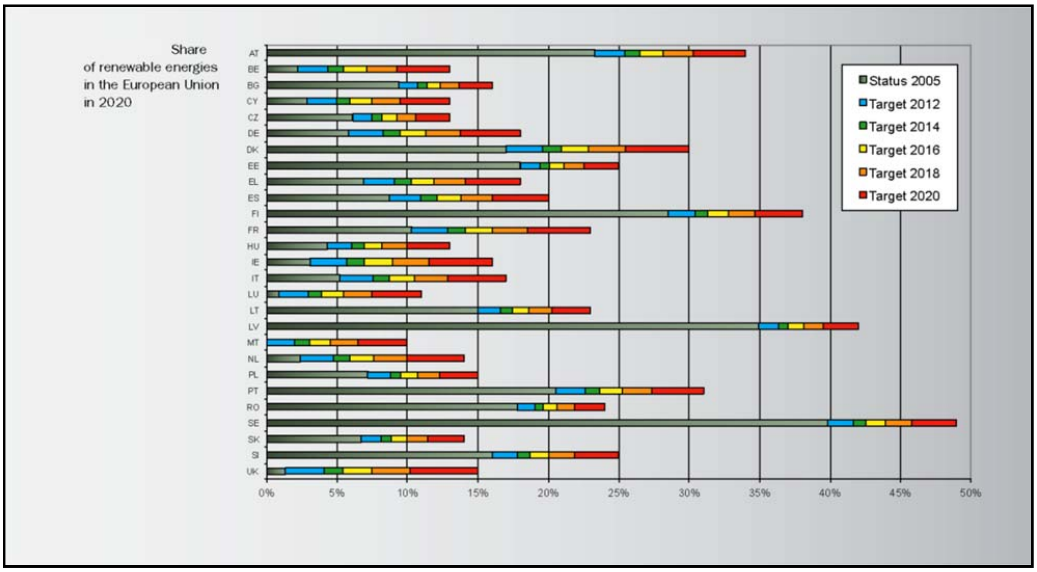



**Figure 18 additional renewable shares in the EU-27 according to the National Renewable Energy Action Plans (NRAPs)**

The decision on what kind of technologies is left to the Member States who by 2010 notified their National Renewable Energy Action Plans (NRAPs). Based on these Member States' plans, renewable energy should at least constitute 37% of Europe's electricity mix by 2020.

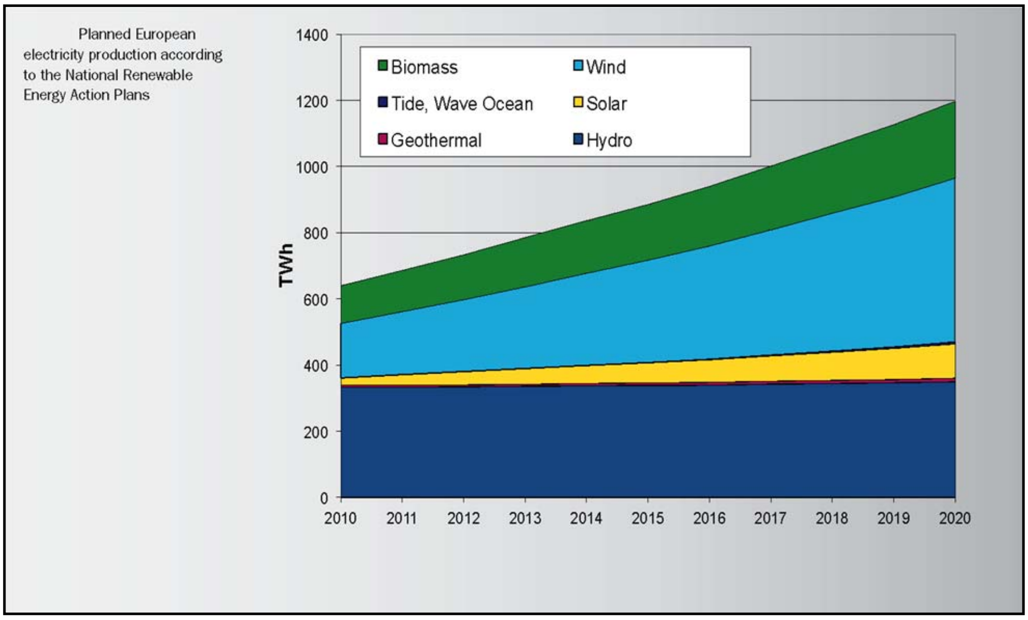



**Figure 19: European power production along National Renewable Energy Action Plans**

A majority of additional power generation in Europe will be produced by adding wind power with a peak during winter time. The additions of solar PV may exceed actual NRAPs mainly in Southern Europe, due to steep price reductions. An equilibrium of summer and winter additions is possible.

The EU called for a priority of renewable energy and priority to renewable electricity investments.[10] Renewables show fluctuations in daily, seasonal and regional terms. Multiple, flexible, smaller scale distributed forms of electricity generation need different grid and market design rules compared to traditional large, centralised power sources. The fast extensions of solar and wind within the Common Market could push Switzerland into a more pronounced role of storage and backup supply. Hydro storage facilities will find a new role, with solar power from the South and wind power from the North instead of nuclear and coal power from France or Germany, as anticipated by Swissgrid.

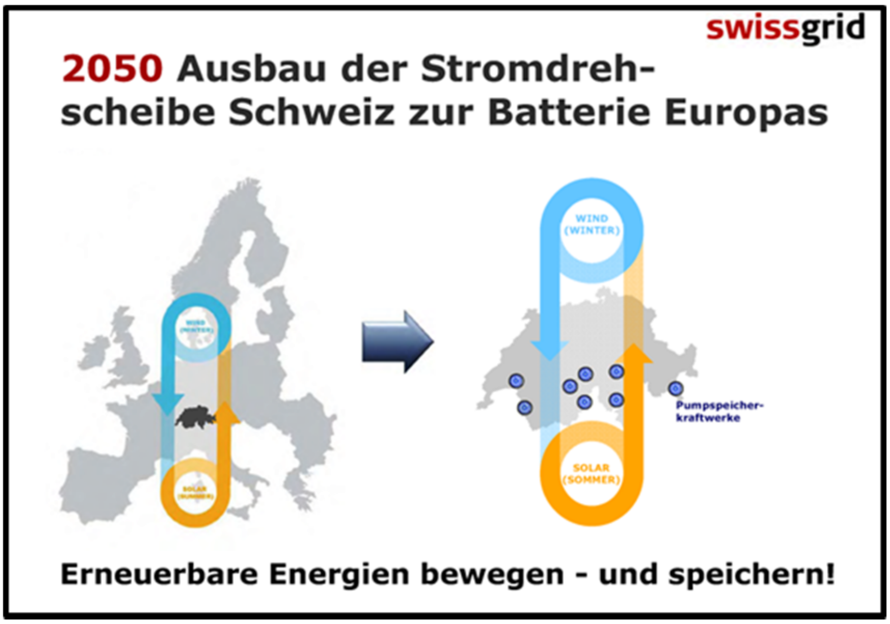



**Figure 20 The Perspective of Swissgrid (national grid operator): Swiss hydro storage as a European battery: integrating solar from the South and wind power from the North**

Since 2007 Switzerland is in talks over an energy treaty with the European Union. Switzerland is looking for free access and integration in the European power markets and grids. The EU made it clear that it expects Switzerland to adopt the market and environmental rules as for member states on equal footing.

## Additional demand and nuclear phase out

New renewables such as solar are the favourite choice of many Swiss people. In the Swiss policy environment however they could not grow due to the blockade of the nuclear industry who dominated Swiss power policy for a long time. Nuclear power was cross subsidized through cheap hydro power for decades, and some CHF 3 billion additionally came from state subsidies.

After Fukushima however, the Swiss Government proposed a new energy policy with a step-by-step nuclear phase out. The existing nuclear fleet would be closed at the end of its lifetime. Both chambers of the Parliament have confirmed this new course.

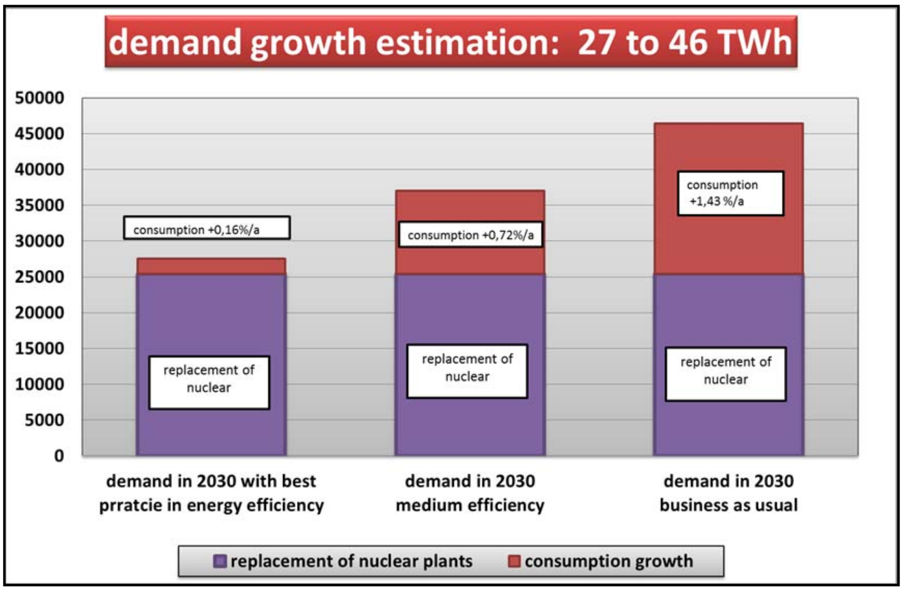



**Figure 21 additional demand in Switzerland due to the nuclear phase out and various demand growth scenarios**

Leaving nuclear power and reducing $CO_2$-emissions toward zero create a strong new demand for non-fossil electricity. To replace nuclear supply, some 25 TWh is needed. And then, general growth of power consumption has to be matched within a range of close to 0 TWh to up to 20 TWh, additional demand, depending on efficiency policy enforcement.

While there are tremendous efficiency potentials such as insulation of old buildings, solar thermal collectors instead of electrical boilers and replacement of electrical resistance heaters and out-dated appliances of all kinds, no stringent efficiency policy can be observed yet in Switzerland. Additional demand is to be expected from replacements of oil and gas fired heaters and from a switch from gasoline to electric cars.

With efficiency policy staying at a low profile, final power consumption could well grow from 60 TWh toward 80 TWh in 2030. With an active efficiency policy though, consumption may be stabilized or even reduced.

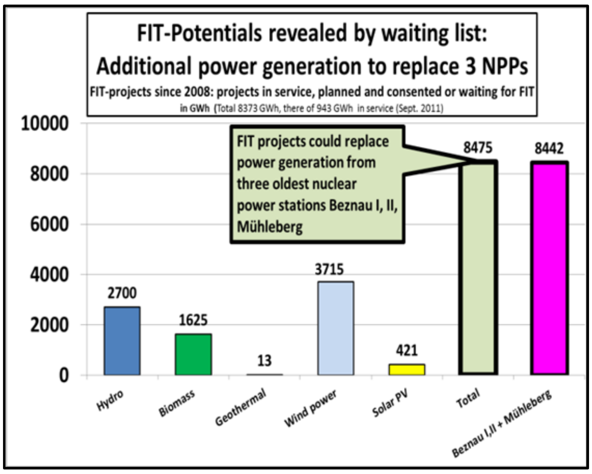
An even higher additional demand has to be planned when some 2.5 GW Swiss power participations and purchase agreements (PPA) in France are to be substituted. These capacities today form the power base for power trade, peak power upgrades and power transits to Italy. Many of these contracts will be expired by 2030 or earlier. For

- replacement of domestic nuclear,
- matching demand growth and
- to have a production base to continue power trade and transits,

A new power generation base of some 30 to 60 TWh corresponding 40-100 percent of actual domestic supply must be created. Not all of these investments have to be placed within Swiss borders because much of this power would serve Switzerland's neighbours and is not planned for domestic consumption.

# 4. Renewable Potentialities and Seasonal Flows

## Power sector liberalization and Feed-in-Tariffs (FIT) in Switzerland



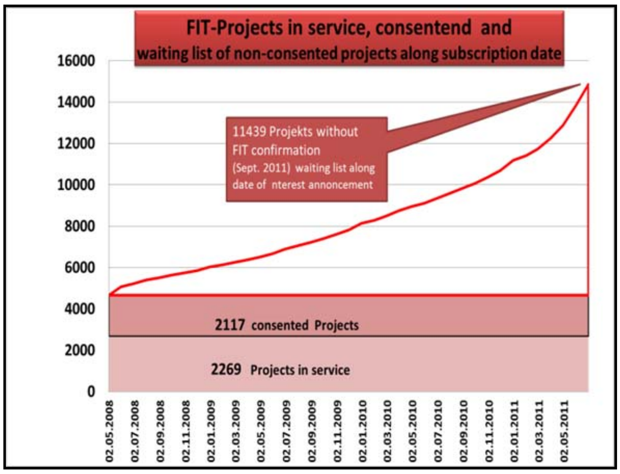




**Figure 22 Feed-in-tariffs driven investments could contribute 8,3 TWh within only three years after FIT-introduction (Swissgrid)**
**Figure 23 consented projects and growing waiting list (data: Swissgrid)**

The Swiss electricity sector has been liberalized in 2008 with free choice of delivery for consumers exceeding 100 MWh annual consumption. In the same legal framework feed-in-tariffs (FITs) have been introduced with a maximum (capped) feed-in-fee at 0.9 Swiss cents per kWh consumed, corresponding an annual budget of some CHF 450 million.

From the first day after FIT-introduction, thousands of investors registered projects for a FIT compensation. Within a few months the official budget cap was exceeded. New installations for wind, solar, biomass, small hydro and geothermal power generation were put on a waiting list which stood at 11'500 projects in September 2011.

Many house-owners and thousands of private investors are demotivated by the evolving waiting-list bureaucracy. Thousands who already have grid connection and standardised accountability and who, last but not least, are looking for neighbourhood pride and an intrinsically decentralised PV-energy-system are heavily frustrated about the FIT-cap. This blockade was just another victory of the nuclear industry who insists that renewables may not match power demand on its own.

### The potentials

In reality Switzerland has huge potentials of renewable energies.

- Today some 37 TWh or 55 % of the 66 TWh gross generation are produced by hydro.
- The estimates of photovoltaic power potentials on roofs and façades vary from 18 TWh to 31 TWh. These numbers would exceed 50% of actual consumption. Additional power could come from covering infrastructures such as roads and barrier lakes with solar panels.
- Wind power with a penetration level like in Germany (72 kW/km$^2$) could easily deliver another 10 % of consumption, and an additional 10% could be derived from power generation from biomass.

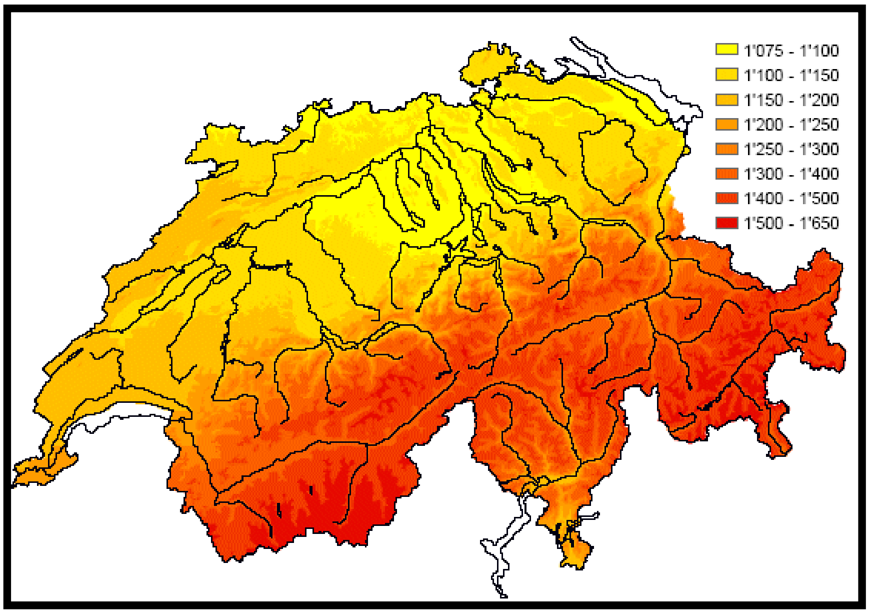



**Figure 24 Swiss solar insolation map (Federal office of Energy)**

Net costs and yield of solar PV depends on the locations where installations could be mounted. On high altitude and the Southern locations of the Alps solar insolation can rise to the same as in Spain and generation costs are reduced.

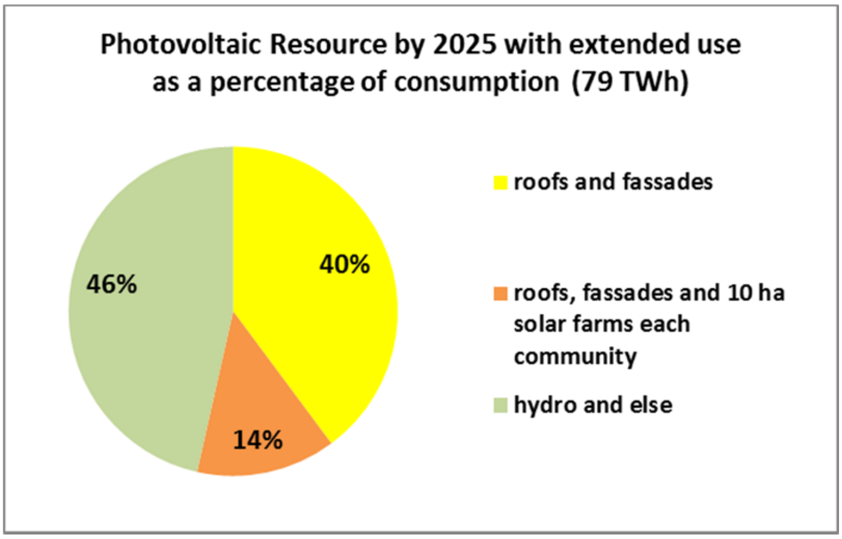
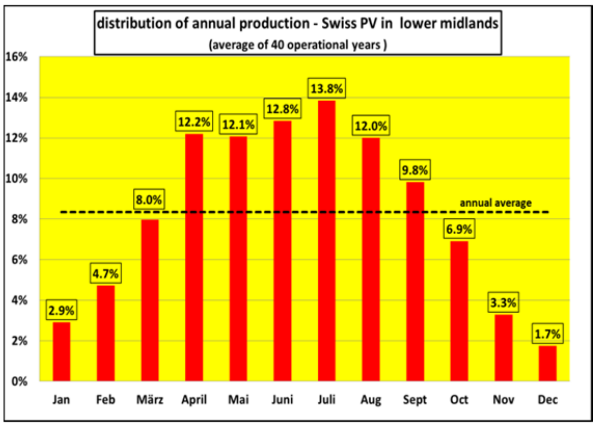



**Figure 25 power composition within a purely solar/hydro scenario**

If we would use all Swiss roofs with >80% of maximum insolation, some 45% of actual final electricity consumption could be covered. If additionally each Swiss community would be responsible for another 10 hectares of solar farms each somewhere in the country, the solar share could grow toward 60% of power consumption. However this scenario had to fit seasonal demand in winter and spring time.



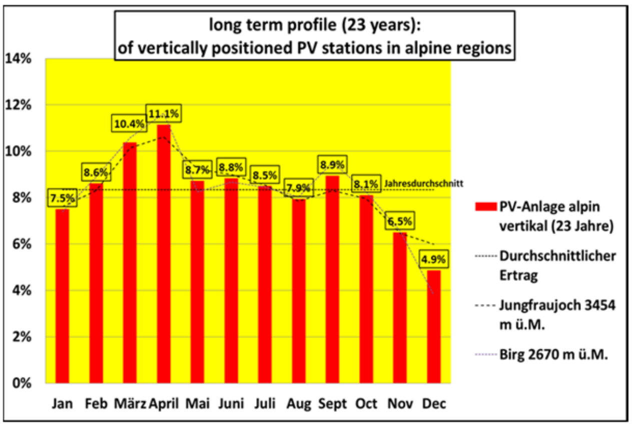




**Figure 26 Specific monthly profile of lowland rooftop solar panels**
**Figure 27 Specific profile of alpine solar panels with vertical (façade-like) positioning**

Alpine locations not only show a higher production than lowland locations. They also show a remarkably diverted production profile: a first peak from February to Mai and a second peak in September/October. Cold temperatures and snow lift productivity and create these remarkable spring and autumn peaks in contrast to the summer peak of lowland solar.

## Matching Seasonal Demand

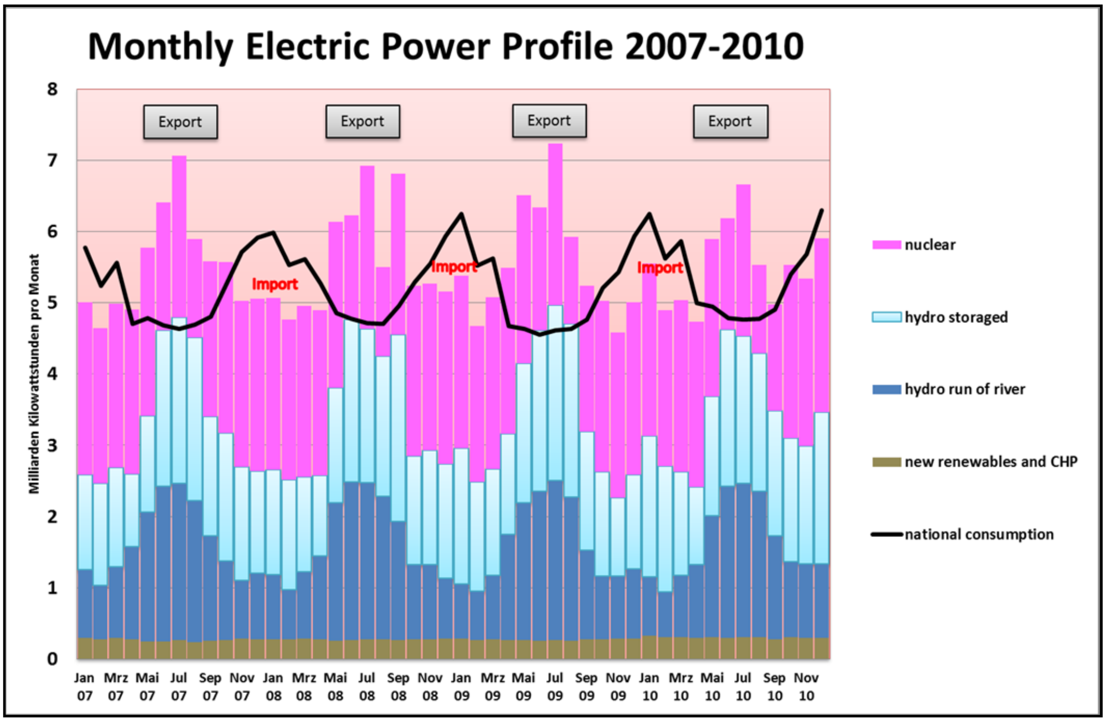



**Figure 28 Monthly Composition of Swiss power generation and consumption 2007-2010**

An important question is: how much additional power is needed in which season?

- Switzerland is almost self-sufficient in renewable power production during the summer months when hydro is most prolific and most of nuclear production is exported.
- In wintertime up to 20 % of monthly consumption have to be imports. The closure of nuclear plants would widen this gap toward 50 percent or more, without a more efficient use and a renewables build out.

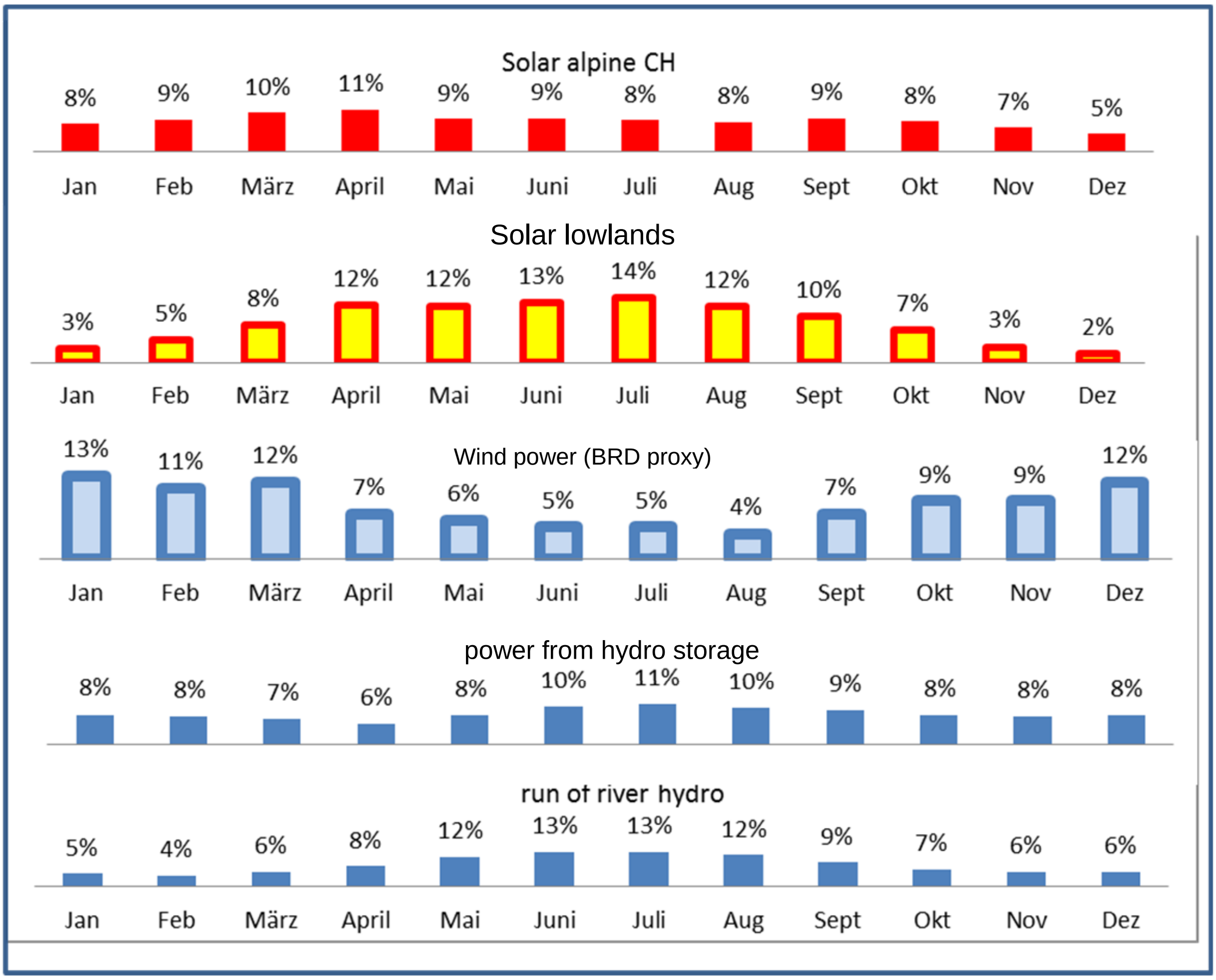



**Figure 29 monthly power profiles of solar, alpine solar, hydro and wind power**

We find a number of possibilities to fill this gap with renewables. A combination of different power sources can deliver solid contributions during summer and winter time:

- solar from rooftop and alpine locations
- domestic and European wind energy,
- run of river and flexible stored hydro,
- CHP and biomass/biogas and waste
- BAT efficiency
- Geothermal generation

Wind power complements solar and run of river remarkably good in a seasonal perspective. Solar power comes always as peak power supply because demand peaks during daytime. Wind power from Northern Europe is mainly winter power. And as has been shown, alpine PV has its peaks in spring and autumn, complementing solar power from rooftops in a seasonal perspective.

For the high demand in winter and for the low run-of-river profile during winter and spring, the Desertec perspective is less an option for Switzerland. New access to the North Sea, where a huge fleet of some 150 GW will be constructed by 2030 is more important, including with North-South grid extensions.[11]

# 5. Approaching 100 percent renewable power and beyond

Based on official studies from government and industry sources, some 185 TWh of additional generation sources, including efficiency, can be identified as possible power sources by 2030, depending on planning and permission rules, incentives and regulatory frameworks.[12]

Three strategies for matching domestic demand and international trade

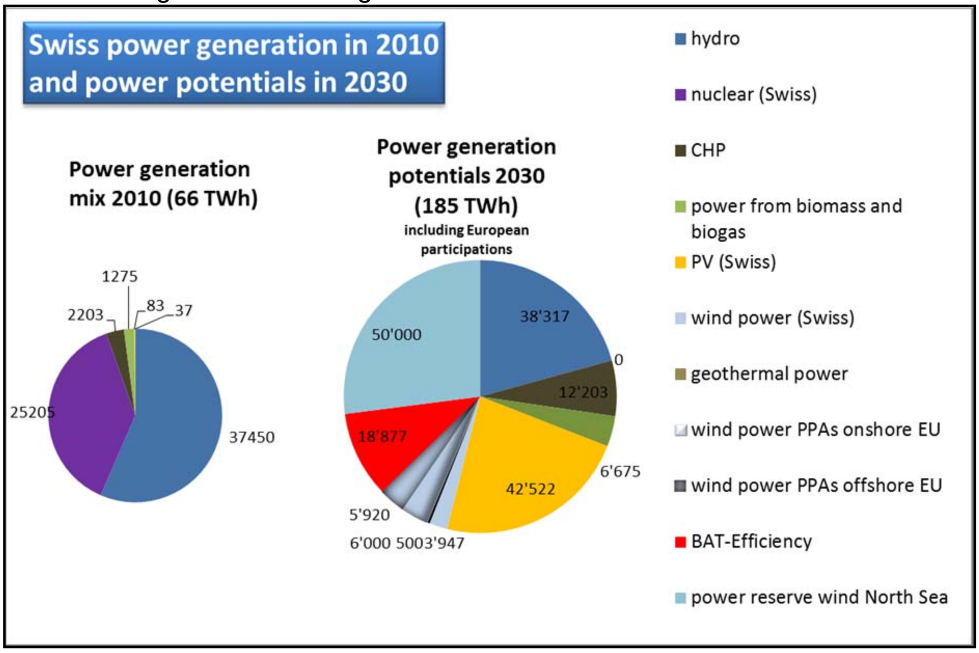



**Figure 30 possible power sources up to 2030**

Based on this inventory of possible generation, three different strategies are derived. Two of them are purely renewable and one is a combined renewables-and-gas-CHP strategy where gas could be fossil natural gas or synthetic methane derived from excess solar and wind power. They each combine domestic efficiency and domestic renewable resources with European renewable capacity build out in a very specific manner.

Swiss gross power generation stood at 66 TWh in 2010. The power demand trend would mea that demand could grow toward 85 TWh or more by 2030 with efficiency as neglected as for the last 20 years. However with a strong efficiency policy, power demand could be stabilized at 70 TWh, replacements of fossil heaters and new electric cars included. Then there are 25 TWh of nuclear participations and power purchase agreements (PPAs) in France to be replaced. This gives a maximum overall demand of some 110 TWh in 2030 – trade, deliveries for hydro storage and a power reserve for additional demand included.

Excess wind power during winter and excess domestic solar and hydro during summer will be used for power trade and to keep peak power storages full. Buying on the European market will be optimized along European market prices and it will depend on actual storage levels also; a strong power trade base also may serve as a reserve cushion and enhance security of supply. Each of the three strategies is able to deliver some 112 TWh of power replacements. Each of them can fulfill the domestic demand and the production base for trade. But they do in a very specific manner each.

1. The **solar & and efficient** strategy is based on a BAT (best available technology)-approach for appliances and power consumption of any kind, combined with solar rooftop and solar alpine power extensions, strong hydro, some wind, some biomass/biogas power and very little gas-CHP.

2. The **continentally integrated strategy** is looking for security of supply by connecting with the vast and cheap power resources of the European Common Market. It is based mainly on least cost imported wind power based in Western and Northern Europe and combines this with existing domestic hydro and, to a lesser extent, with rooftop solar, some domestic biomass and wind power and a business-as-usual efficiency policy.
3. **The domestic generation strategy with gas** is based on a purely domestic power generation based on solar PV, medium efficiency policy and mandatory cogeneration of natural gas and oil for domestic heaters with more than 1 MW capacity. This third strategy is partially non-renewable but it could later turn to a more renewable share with domestic heaters relying on synthetic methane derived from excessive solar or wind power.

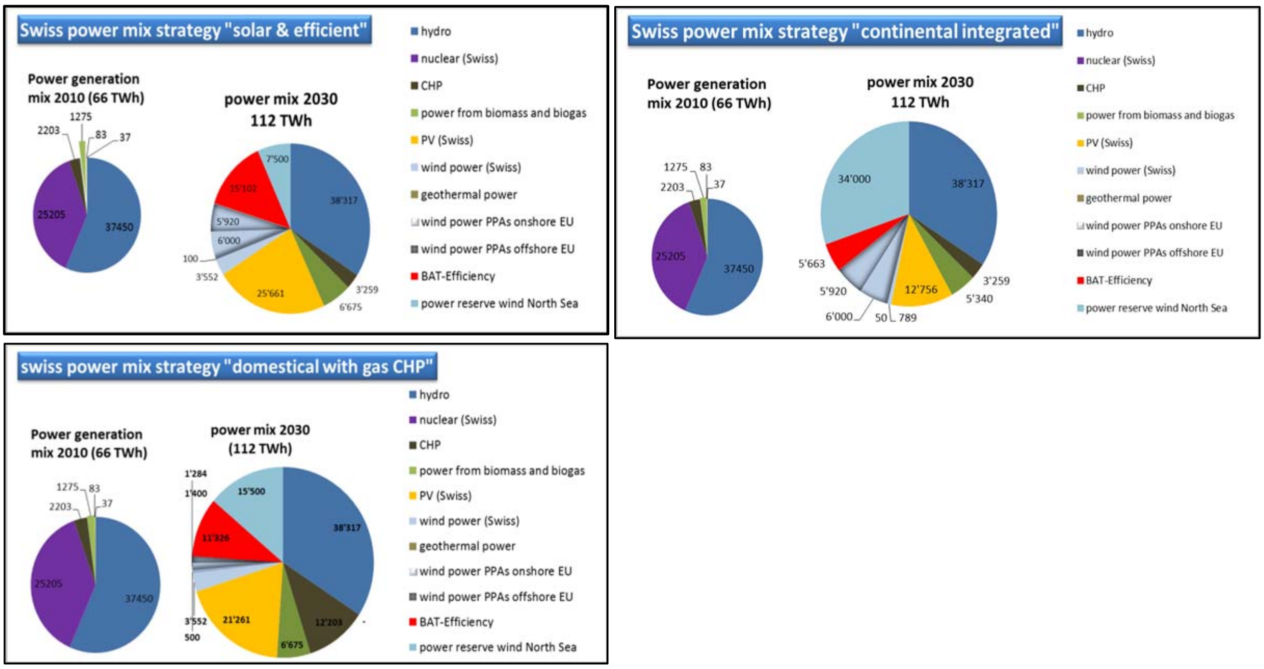
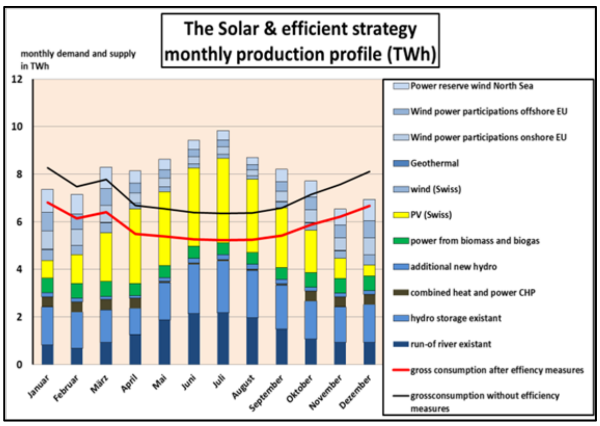



**Figure 31, 32 33: Three different power mixes for matching Swiss power demand**

All three strategies deliver a robust security of supply. But the mixture of sources varies along imports and exports and seasons as well.



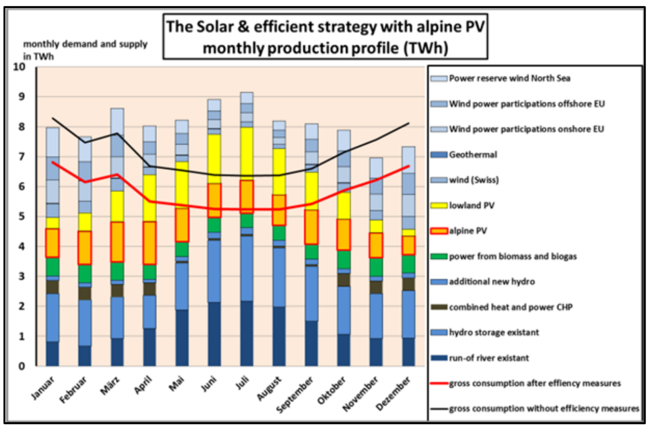




**Figure 34 the "solar & efficient" (left) and Figure 35 the "solar&efficient alpine" strategies in a monthly perspective**

## The “solar&efficient” strategy

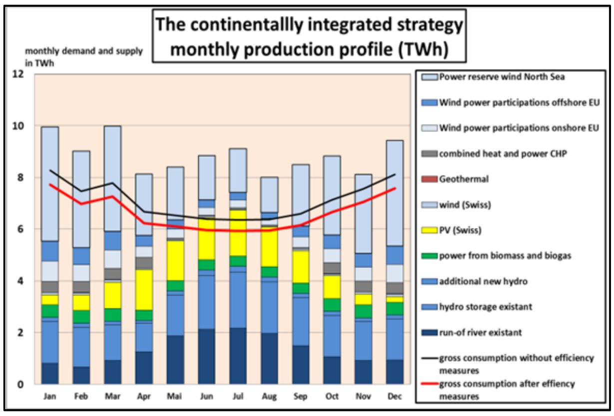
Better efficiency of electricity consumption plays a varied role in each strategy. There are hundreds of thousands inefficient electrical resistance heaters, millions of old inefficient motors and other appliances to be replaced by better systems over the next two decades.

In the solar & efficient strategy these efficiency sources are realized in a strict manner with mandatory best-in-class admissions to market, incentive fees and rebates, and an acceleration of modernization in the housing sector.

The graphs above show a mixture of BAT efficiency and a purely rooftop PV strategy (left). It delivers a very strong summer peak with much of the PV power generation exported from Mai to August, compensating for wind power imports during winter. A 100% domestic supply based on renewables may be approached during six out of twelve months

The graph on the right side shwos the power mix when half of PV installations is placed in alpine locations. The result is a more even distribution of solar power generation over the year and a much stronger contribution during the cold period, especially from February to May. A 100% domestic supply based on renewables can be achieved during seven out of twelve months with the remaining (small) winter demand satisfied by onshore and offshore wind power participations throughout Europe.

## The continentally integrated strategy



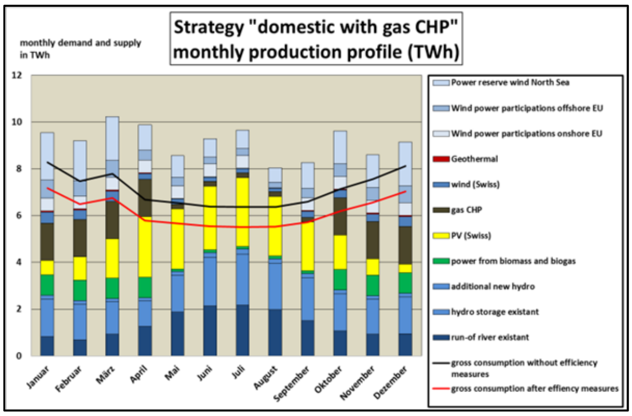




**Figure 36 the “continentally integrated” strategy (left) and**
**Figure 37  the “domestic with gas-CHP” strategy (right)**

The **continentally integrated strategy** follows the idea to earn renewable energy where it is most prolific. Solar power from the South would mix with wind power from all over Europe, combining locations of cheapest generation costs. Additional costs are to be expected however from building additional grids or grid upgrades necessary for fluctuating power regimes. A comprehensive European “Supergrid” is discussed within the European Union. It is technically feasible with High Voltage Direct Current (HVDC) technology.

But the overall cost of such an integrated strategy with needed redundancy of power lines might not be cheaper than a more localized or regional approach with PV and wind power from second or third best locations. Therefore a more modest grid extension, focused on really existing power generation comes in at much lower costs.

For this second strategy a huge capacity of wind turbines would be acquired by Swiss power distributors, regionally dispersed from Northern, Western and Eastern Europe, using also the power lines from shut down nuclear power and coal facilities.

From wind power we may expect periods with excessive power supply during winter. For domestic demand, Swiss power distributors could buy cheap European wind power during windy times and they would rely on their domestic must-run-facilities and stored hydro and biomass during periods with low winds. In the summer time direct supply would come from run of river and solar PV while wind power and power imports would feed the trade base and hydro storages.

### The “domestic with gas-CHP” strategy

The “domestic with gas-CHP” strategy is pushing efficiency more ambitiously and it would rely on gas CHP instead of wind power. In the medium term natural gas may be replaced by biogas and synthetic methane.

We expect that alpine solar power soon will be competitive in Switzerland. While the parliament seems not yet ready to recognize these potentials, some of the German and Swiss solar companies with world class products could deliver new low cost pilot installations which could revolutionize the local perception of these resources in the mountains. This could also have a strong influence on legal frameworks and give way to better compensation rules for solar PV such as compensations based on local irradiation and a more dynamic development of tariffs and volumes.

## Domestic power capacities exceeding domestic demand

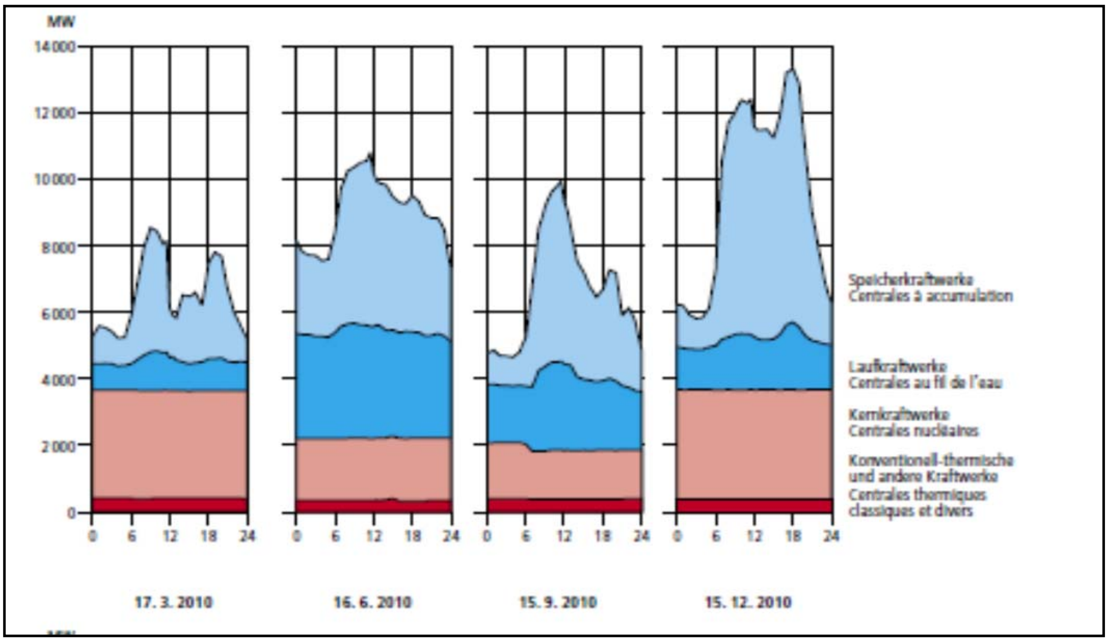



**Figure 38 Swiss power generation profile, four Wednesdays, different seasons**

For daily and seasonal fluctuation management, barrier lakes, flexible power from biomass and waste are available already today in excess. A power generation capacity of 16 GW compares to a maximum monthly load of between 8 and 11 GW – whereof a variable part is also used to feed hydro pumps and exports.

Timing biogas generation, CHP and power from barrier lakes are the cheapest flexibility available, with no or very low energy losses and costs for matching demand. Pumped hydro however comes at loss. The power-to-power-efficiency is around 80 percent which still is considerably good compared to other technologies and they will serve for integration of solar and wind energy. Therefore the hydro pumped storage capacities are expanded independent of the domestic strategy.

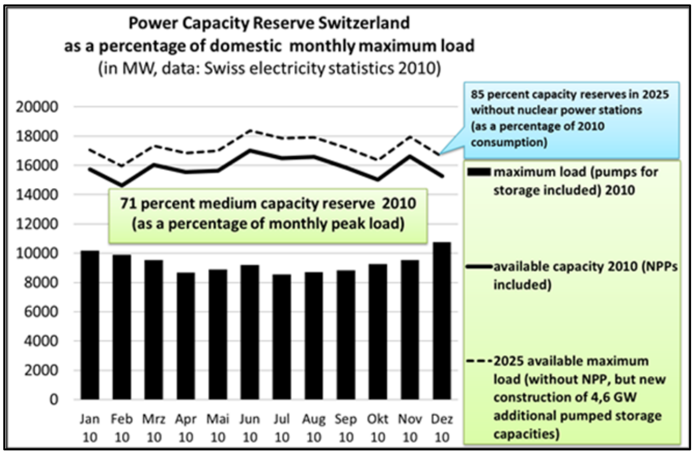



**Figure 39 power capacities (GW) exceeding power demand by some 70 percent now and by 125 percent in 2030**

Additional generation should match bulk load in seasonal and daily terms more or less. The backup question for cloudy or non-windy days is not really critical in Switzerland because stored hydro power is a huge joker who can match fluctuating supplies over the short and medium term easily. In fact we today find a domestic capacity exceeding domestic maximum load by some 70 percent.

More stored capacity will come due to the additional construction of some 4-6 GW pumped hydro facilities and they will compensate for nuclear shutdowns. Many of these facilities are in construction now and will be ready by 2020 or earlier. They will help matching fluctuations of wind and solar as long as the seasonal profile stays intact. In fact: it is the additional wind turbines and solar panels which will increase energy security. The hydro system will just deliver the micro-matching of demand and supply, and for purely domestic demand it would not be needed to expand much.

The result will be that Switzerland will have an overall hydro capacity that will exceed maximum load by some 85 percent or 8 GW in 2020 or 2030. And then there will additionally coming online some 10 to 20 GW of PV, 0.4 to 1.9 GW of wind power, 1.1 to 1.3 GW of power from biomass and waste and – depending on the strategies – up to 12 GW of European onshore or offshore wind power and/or up to 2.7 GW combined-heat-and-power (CHP), with wind and solar power non-dispatching but in its bandwidth easy to estimate and forecast.

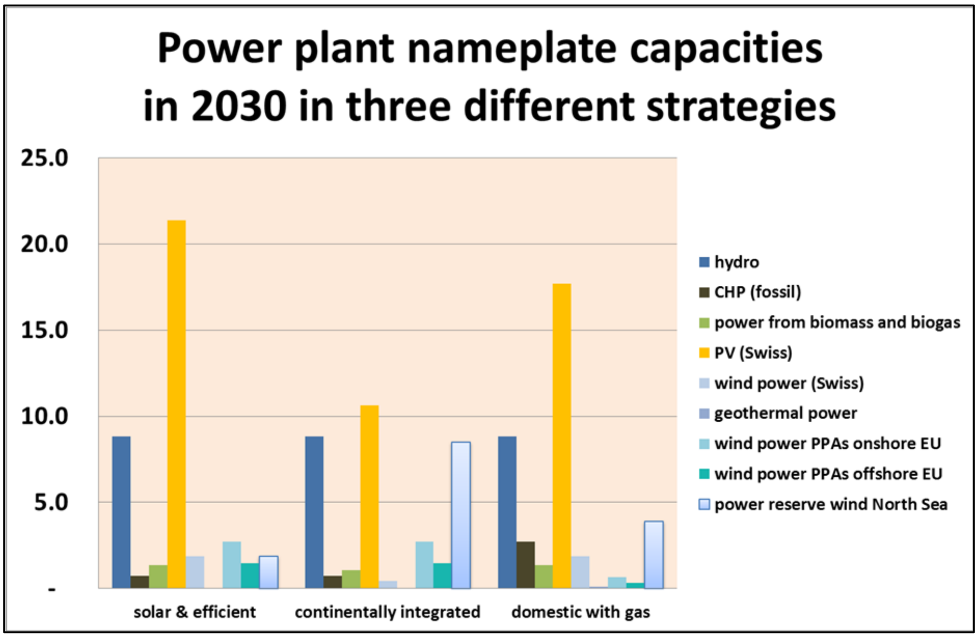



**Figure 40 power capacities in 2030 along the three scenarios**

For additional hydro capacities, new constructions are mainly necessary in terms to pump capacities and high pressure water pipes; a change of barrier lake dimensions is barely needed. The power management of the existing facilities will change though.

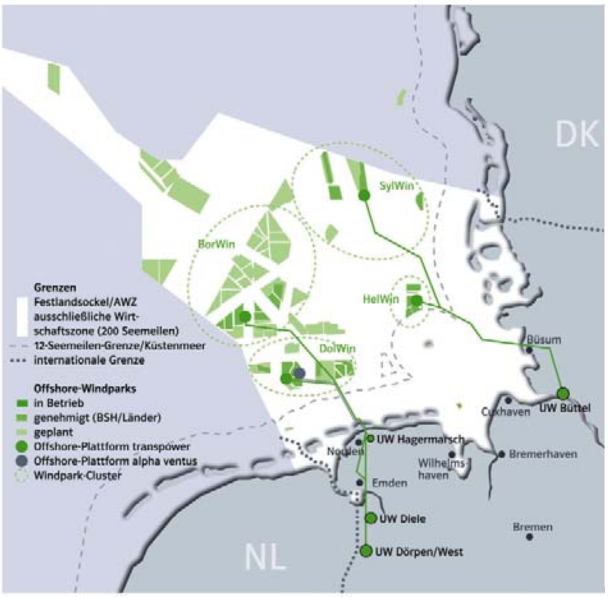
From a seasonal one-fill/one-empty-cycle per year observed in most naturally filled storages, pumped hydro facilities will adapt to daily and weekly assessments of wind and solar power with much shorter infill and emptying cycles. Daily and weekly water fluctuations do not need the huge dimensions of seasonal storages. Smaller amounts of water within a system of fast reactions will satisfy demand.

The hourly moments of in-fill and consumption may change also. With PV production growing rapidly, more stored power could be consumed on cloudy days and in the morning and evening times when solar contributions drop low.

And then we have to remember that there is a huge capacity of old or mothballed fossil fuel stations, gas and coal mainly, dispersed all over Europe. They will play a role of “last reserve” providing additional security for “just-in-case-situations”.

Taken all this together means that we have huge capacity extension for new energy generation and enough dispatching capacity. In years with normal hydrological conditions Switzerland will extend its role as a peak power source for neighbouring countries.

## Reinforcing power grids



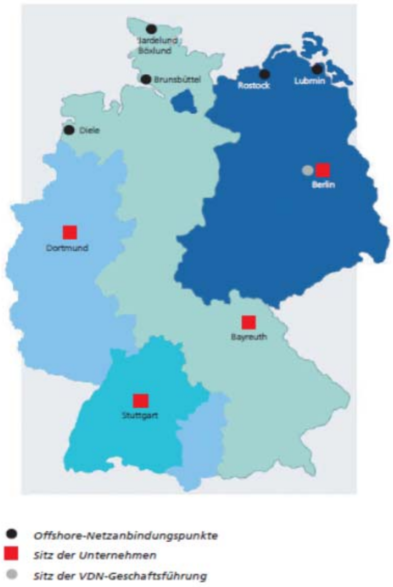




**Figure 41 The "Transpower Offshore GmbH" Conception for the extension of offshore transmissions systems by clusters in the North Sea**
**Figure 42 German Power control areas (2010)[13]**

Due to the steady expansion of wind power, an important aspect of the new power landscape will be the extension of power grids. New HVDC lines now are realized in Northern Germany and the North Sea. The power from new wind farms is collected in clusters with, four hubs connecting these with the onshore grid, DolWin, HelWind, BorWin and SylWin regions.

The main grid bottlenecks for a scale up of wind power are located within Germany though, and not in Switzerland itself. There are bottlenecks towards France also where the nuclear companies still have priority access for transnational grid connections, hindering renewable generation to be brought to Switzerland on equal footing.

In principle Switzerland is well connected with Europe, the sum of connections between 6.6 and 7.7 GW corresponds almost to the daily average load. The "inofficial" physical connection with the European has a capacity of 28.5 GW, but cannot be used to that extent due to domestic bottlenecks on each side of the border.

| NTC Net transfer capacity | For Imports | For Exports |
|---|---|---|
| Austria | 296 | 1200 |
| Germany | 1104 | 4000 |
| France | 3000 | 1100 |
| Italy | 1660 | 1405 |
| Total connected capacity of Switzerland | 6060 | 7705 |

**Figure 43 net transfer capacity (August 2011) between Switzerland and its neighbours**

The closure of nuclear plants will give way for more wind and solar power transports. There are domestic grid congestions within Switzerland, too. But these problems can be resolved over the

2010-2030 periods. New action plans are worked out and political majorities for the necessary decisions are there.

New thinking is necessary in many aspects, also with grids. Today we find the national grid management Swissgrid reinforcing a number of small bottlenecks. For the future though we think that a power transit and storage nation such as Switzerland should use direct current lines that stretch from Hamburg to Milan and further (North-South), and from Spain through Switzerland to Eastern Europe.

With excess capacity of hydro storage power in each moment of the year Switzerland will not need fossil fuel back-ups for domestic demand. New gas power stations are the proposition though of the old oligopolistic power companies. They already gained political support in weakening $CO_2$-restrictions for gas plants. A worst case result could become the continuation of nuclear risks for decades and an increase of $CO_2$-emissions through gas plants, with no renewables at all.

On the long run though, gas prices will rise due to the scarcity of gas and of oil where demand from the automotive sector will be difficult to sytisfy. With EU natural gas production dwindling since 2001, new gas plants could be a major strategic fault. New nuclear has no future in Switzerland anyway due to the lack of public support and the binding law that foresees an referendum for new nuclear installations.

To build new gas plants would mean to create new problems though – with Switzerland missing its Kyoto goal – and new price risks from an exhaustible fuel would be foreseeable for consumers. It would increase supply dependence from external sources.

Wind power onshore is competitive today. Solar power from rooftops will be competitive within the next five years. Beyond environmental aspects the renewable strategies bring more security in terms of delivery of supply and security against price risks. And it may have a better price/cost ratio too in the medium term.

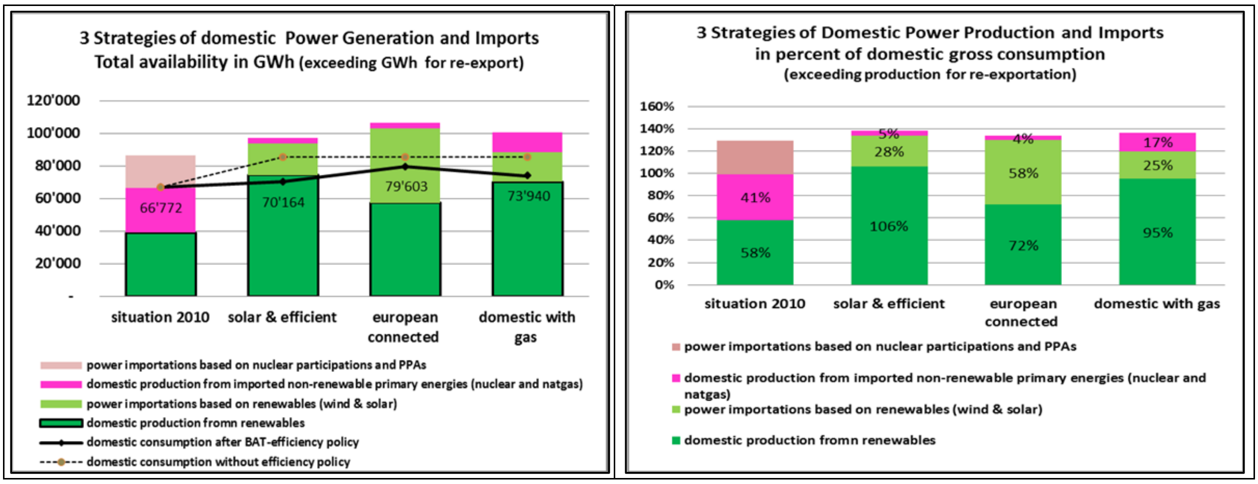



**Figure 44 and 45 Three strategies: domestic generation, imports and domestic consumption with and without efficiency policy**

Supply risks are small because

- The **solar & efficient strategy** delivers a 100% security of supply due to more domestic generation. The risks to buy wind power in the winter are reduced because wind power will be excessive during that season, and for non-windy days enough stored hydro power will be available.
- The **continentally integrated strategy** relies on power from friendly neighbours, based on commercial long term treaties and rules. Wind power instead of natural gas on such a

legal ground means avoiding dependence and price risks from crisis regions such as the Middle East.

In politics there still is resistance against an overall renewable energy strategy. There is a lack of risk consciousness in Switzerland. And the nuclear and natural gas companies like to play the game of killjoy, still hindering renewables. But there is hope.

Switzerland is a federally structured country. Many municipalities and local power companies are looking to grow decentralized renewable power. With power generation costs for PV and wind falling rapidly, a majority of people will favour renewables in the future. The nuclear hopes of academic experts and right-wing parties might become ever more elusive due to the lack of public support and due to the fast of lower cost renewables.

To be successful however, some necessary legal conditions must be created, in priority the lifting of the cap for Feed-in-Tariffs which is legally hindering expansion. More necessary conditions to be fulfilled are shown in the Figure below:

| Technical and Regulatory Imperatives | solar & efficient | Continentally integrated | domestic with gas |
|---|---|---|---|
| Priority permission for solar roofs, façades and landscapes (the latter limited to < 1%) | x | x | |
| north-south grid over Europe | x | xx | x |
| feed-in tariffs for renewables and/or gas CHP | xx | x | xx |
| best available practice for new appliances | xx | | x |
| natural gas power plant or CO2-restrictions or taxes | x | x | x |
| | | | |
| dangers and risks | | | |
| gas price | | | ! |
| dependency from neighbours | | ! | ! |
| costs of European grid extensions (minor for Switzerland) | | (!) | |
| cost of PV expansion | ! | | |
| additional cost of CHP expansion | | | ! |
| permission for landscape use | ! | (! mainly North Sea) | |
| advanced CO2-compensation measures | | | ! |

**Figure 46 must-haves and risks of the three different strategies**

There are also some risks, but with the price of PV in free fall, these risks will disappear very fast and the benefits of these new technologies will start to dominate the discussions. Grid congestions and power plant expansions have to be mastered though by a more favorable permission system.

Environmental care is important however. With the instrument of feed in tariffs (FIT) there are ways for environmental conditioning and for fine tuning of the power mix. The unique success of this system in Germany, adopted now by such giants as China, India and Japan, are proof enough for the way to go. FIT give access to energy for everybody, they make projects bankable and give access for local power supply. FIT are part of the game for a secure, responsible and affordable energy system without unacceptable risks. FIT are superior to any quota system. The latter are complicated, urge investors to pay a high risk premium and would block innovative technologies and access for all kind of investors as well.

## New horizons for domestic power industry within international cooperation

Traditionally the power industry in Switzerland was very strong. Much of this knowledge has been lost due to the strong focus on nuclear energy. In the shadow of the German renewable expansion new companies such as Meyer Burger and Sputnik have emerged, and older ones such as ABB started to deliver new solutions for power transmission and else. They today operate on a world market level. An extension of domestic renewable investments would boost employment and added value in Switzerland at the expense of energy imports and fossil fuel dependence.

Beside the switch for renewables, Switzerland's main international task will be that of a battery for peak power with many old or upgraded facilities in the Swiss mountains. We don't know yet how fast offshore wind energy costs will come down. Offshore could turn to be a least cost option within a decade or so, too. With onshore wind and solar, complemented by biomass and hydro, we expect that Europe's power demand can be satisfied in an innovative, environmentally safe, sensible and affordable manner.

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[1] Dr. Rudolf Rechsteiner (1958, economist) was a Member of the Swiss Parliament (1995-2010). He today works as an independent consultant for his company (re-soultion.ch) and as a lecturer on energy at universities of Basel, Bern and ETH Zurich. He also is member of the Board of Industrielle Werke Basel (IWB), the canton of Basel utility.

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