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The Transformation of the Energy System – Challenges and how to meet them

PT 2/2018

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The current energy system finds itself in the beginning of a transformation process of which until now only targets and fundamental determinants are known. To meet the strategic goal of a medium global warming of under 1.5 - 2 K, a drastic reduction of greenhouse gases until 2050 is necessary. The energy system in the long run will have to work without fossil hydrocarbons: No electricity production based on coal or natural gas, no heating systems and industrial process heat based on mineral oil products or natural gas, no transport based on gasoline, diesel fuel, kerosene. Some industrial processes like production of iron and steel, cement and basic chemical products which are fundamentally dependent on hydrocarbons (coal for steel, naphtha for chemical products) will meet additional challenges.

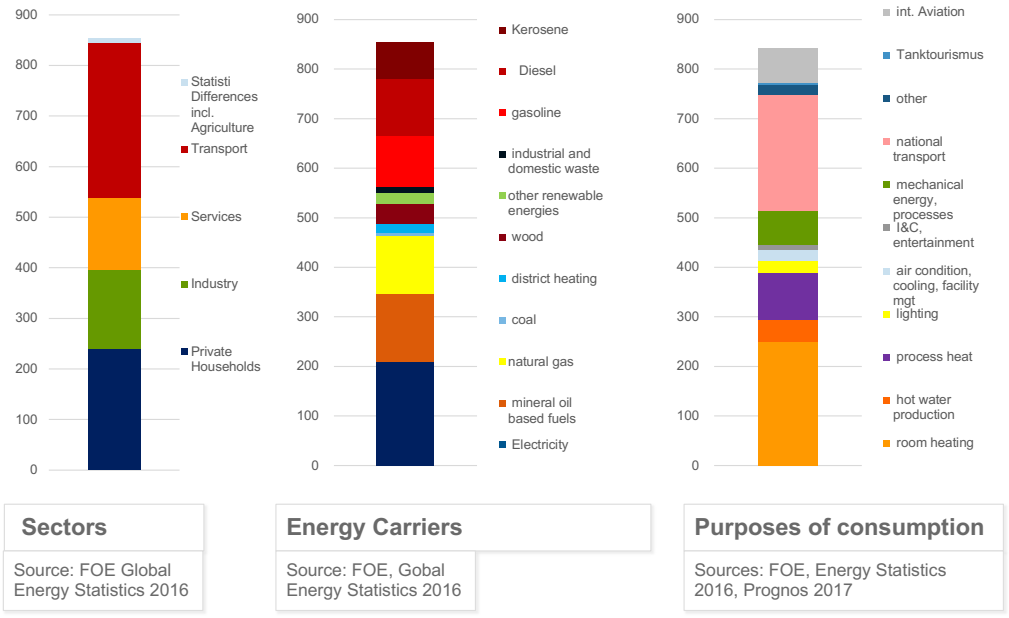
If – for reasonable reasons – electricity based on nuclear fission is no longer admissible and does not provide a „loophole“, all forms of energy utilization as well as production have to change fundamentally and drastically.

In the Swiss energy system more than two thirds of final energy consumption are provided by mineral oil products and natural gas (Graph 1) Switzerland‘s electricity production consists mainly of hydropower (nearly 60 %) and nuclear power (Graph 2). So-called „new“ renewable energies like photovoltaics, solar thermal energy and wind energy contribute up to now only very small amounts of energy in comparison to the overall demand. Part of the energy transition will be the phase-out of nuclear power.
The transformation will necessarily include additional electricity consumption in the mobility and the heat sector.

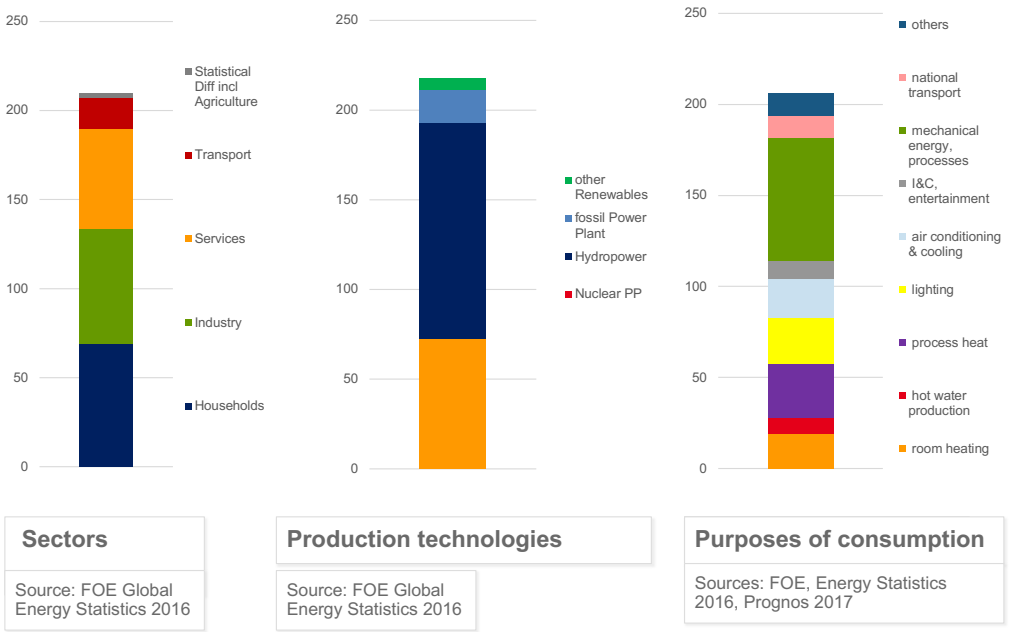
The future energy system will have to decrease the use of fossil-carbon-based fuels and increase the use of renewable sources drastically. (Graph 3)

Limits are found mainly due to potentials of alternative and renewable energy sources: Most of the „alternative“ energy sources are derived from solar radiation (solar, wind, biomass, partly also hydropower and wave energy) and are harvested on surfaces with limited energy density. Especially sustainably produced biomasses as energy carriers are sought after – and compete directly with the food chain, material use and ecological needs – meaning that under an overall perspective they are rather scarce.

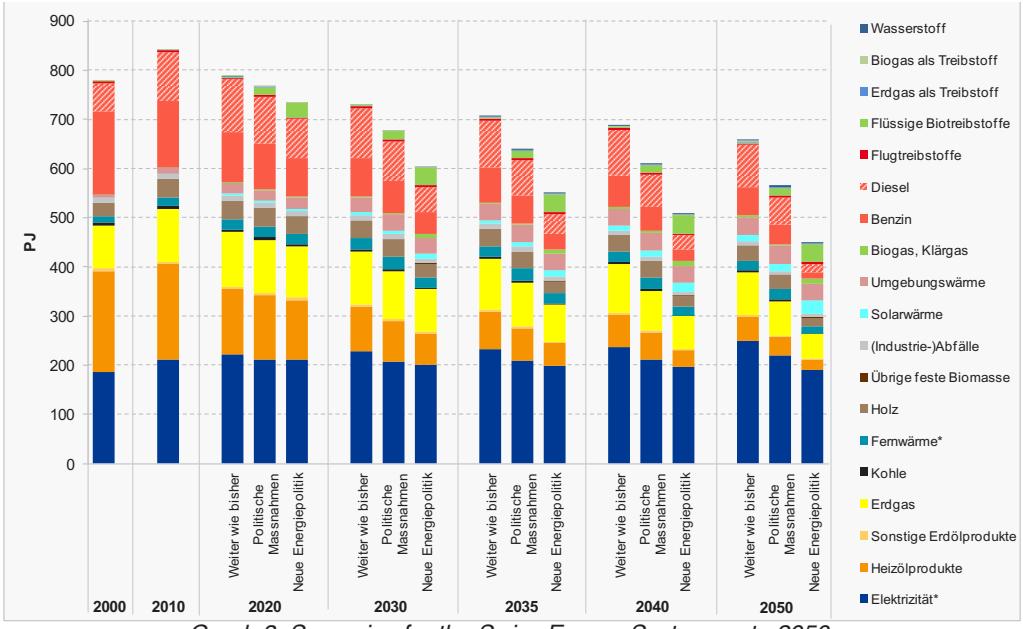
The regional and temporal structure of energy use and energy production – especially electricity production – will change which in turn will call for developments in the infrastructure as well as the relationships between acteurs (i.e. „prosumer“ – combined consumers and producers) and business models for production as well as for services. (Graph 4)



Graph 1: Final Energy Consumption in Switzerland 2016 – by sectors, carriers and consumption purposes, in PJ

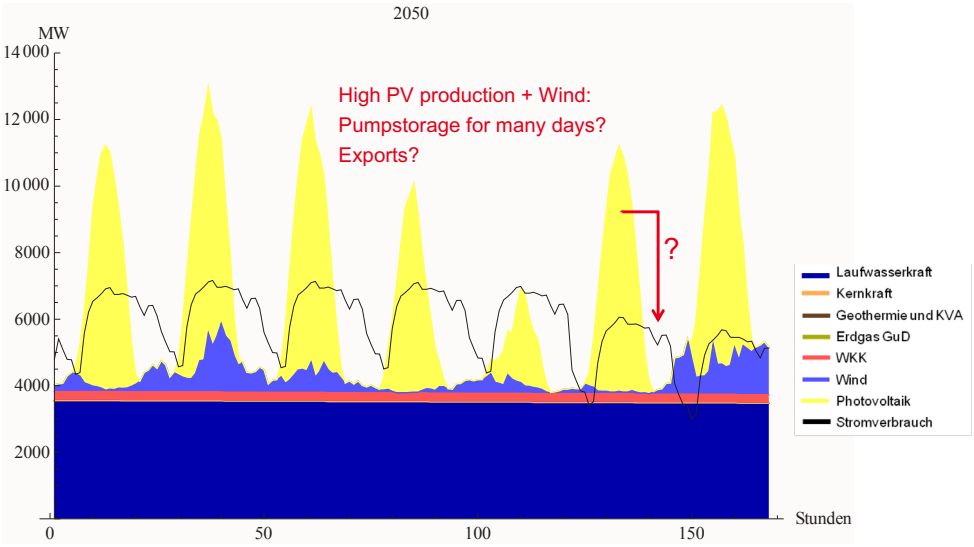


Graph 2: Electricity (net consumption) in Switzerland 2016 – by sectors, production technologies and consumption purposes, in PJ



Graph 3: Scenarios for the Swiss Energy System up to 2050: Final Energy Consumption by energy carriers, in PJ. Source: Prognos (2012)

Example End of may, 2050: options for dispatch



Graph 4: Near-Carbon free Scenario for Switzerland 2050: electricity demand and production, dispatch options for hydropower in one week in summer, in MW. Source: Prognos (2012)

Especially in the transport sector technology shifts as well as organisational shifts are needed. Several alternative technologies are in different states of development which will lead to interesting technological competitions with open results.

Future energy use will need strongly increased efficiency (technologies) to meet the limited potentials of renewable energy sources specificyally as well as in absolute values. Fortunately, this is a „no-regret-option“ and an enabler for more technology openness with respect to different renewable and technological solutions. The ratio of electricity in the energy mix will be increased as well as that of biomasses. Electricity will be produced mainly from renewable sources, and numerous technologies for storage, flexibility and transformation in storable energy carriers will (have to) be developed. If the decarbonisation targets are very ambitious, probably significant capacities for production of synthetic renewable energy carriers will have to be established in countries with favourable production conditions – leading to new imports.

International flows and dependencies of raw materials will change („from oil to lithium or cobalt“).

Expectably yet unknown or only experimentally understood technologies will occur that may have the pivotal role of „game changers“ (e.g. direct biological or catalytical production of hydrogen via algae and sunlight, electricity storage technologies with minimum use of rare metals…) – which may facilitate the transformation but as well lead to stranded investments due to structural change.

The transforming as well as the transformed system requires new digital solutions and business models to guarantee for efficient and stable operating procedures. These are connected with numerous security issues which have to be included in the system development.

The transformation of the energy system is a complex task that interweaves technological as well as societal and economic requirements and developments.

Prognos AG has explored the necessary transformation processes in Germany and in Switzerland in detailed energy system scenarios and presents the main results as well as open questions – especially interesting ones for practical physicists (and a few for theoretical ones). Crucial fields of development are material sciences (e.g. for storage and energy transformation technologies), system controlling and regulation technologies and digital as well as other „material“ and infrastructure-related safety and security technologies.

References (inter alia):

Prognos AG, infras AG, Energieperspektiven für die Schweiz bis 2050, im Auftrag des Bundesamts für Energie, Bern, 2012

BCG, Prognos AG, Klimapfade für Deutschland, 2018, im Auftrag des BDI, Berlin