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# Cost of ad-hoc nuclear policy uncertainties in the evolution of the Swiss electricity system

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## HIGHLIGHTS

- ▶ Development of a Swiss TIMES electricity model and long-term scenarios analyses.
- ▶ Short-term demand can be cost-effectively met with new investment in gas-fired generation capacity.
- ▶ In the medium and long run, nuclear represents the most cost-effective option.
- ▶ All non-nuclear electricity supply options increase the cost of electricity supply by between 50 and 150%.
- ▶ It is difficult to avoid an increased reliance on imports of gas or electricity.

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## ABSTRACT

About one-third of the Swiss nuclear capacity is due to be retired in the next ten years, creating a short-term supply gap. In addition, the Swiss Federal Council has decided to phase out nuclear power over the longer term by not replacing existing nuclear power plants after retirement. We have analysed possible electricity supply options for responding to these two developments under different conditions using the Swiss TIMES electricity sector model—a least-cost optimization framework. Short-term demand can be cost-effectively met with new investment in gas-fired generation capacity. However, meeting the government's $CO_2$ emission and renewable electricity targets requires an accelerated investment in renewable generation and/or increased reliance on imported electricity. In the medium and longer term, nuclear represents the most cost-effective option. The alternatives to nuclear lead to increased dependence on imported natural gas, seasonal renewables and imported electricity. All non-nuclear supply options increase the cost of electricity supply by between 50 and 150%, and create a range of tradeoffs between supply security and climate change mitigation goal. However, it is expected that an accelerated uptake of end-use efficiency measures and demand side management would reduce future electricity demand, thus reducing the need for some expensive supply options.



## 1. Introduction

Electricity accounts for one quarter of Swiss final energy demand (BFE, 2010a). Currently, most of the electricity is generated from hydro (55%) and nuclear (40%) power plants (BFE, 2010b). Switzerland is self-sufficient in meeting its annual electricity demand, but trades large amounts of electricity, particularly importing cheap off-peak electricity and exporting during peak hours using its large dam- and pumped-hydro facilities (BFE, 2004; 2008; ENTSOE, 2010). About one-third of the country's nuclear capacity is expected to be retired in the next ten years (FASC, 2011; Leuthard, 2011), which is expected to leave a gap between demand and available capacity. Despite the government's target to cap electricity demand at 5% above the level in 2000 (BFE, 2001b), electricity demand in 2011 was already 12% above the 2000 level (BFE, 2010b). Recent longer-term scenario analyses (BFE, 2007a, 2011, 2012b; McKinsey, 2009; ETS 2009; Weidmann et al., 2012; ETH, 2011; VSE, 2012) foresee future annual electricity demand growth between −0.16 and 0.92%, during 2010–2050 (see Fig. 1), indicating that the supply gap is likely to increase in the future. One option to close the supply gap is to invest in replacement nuclear plants. However, there is a high level of political uncertainty regarding this option and nuclear policy has been highly debated (see SAEE, 2010).

The Swiss Federal Nuclear Safety Inspectorate gave a positive assessment on construction of new nuclear power plants in November 2010 (ENSI, 2010). However, the Fukushima Daiichi nuclear disaster four months later triggered large public and political

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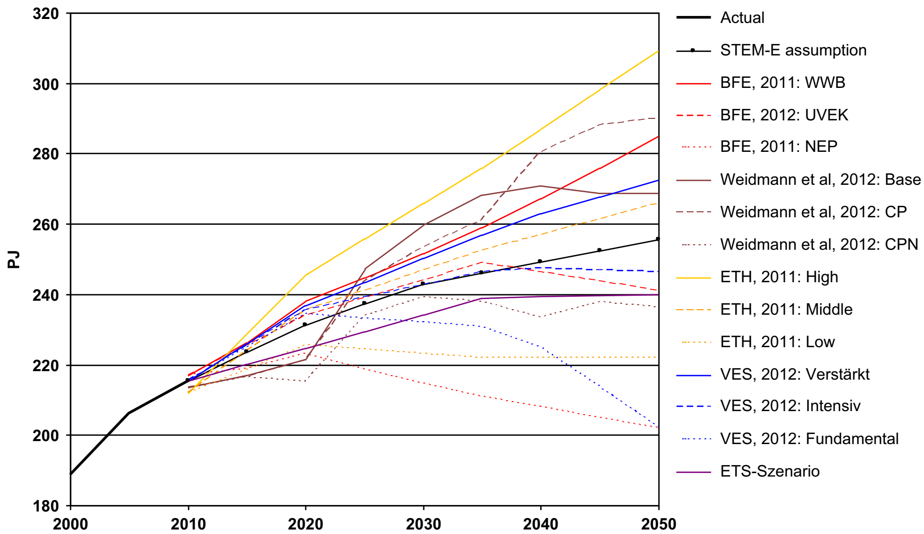


STEM-E: Electricity demand assumed for this paper
In Weidmann et al, 2012, CP - Climate policy scenario and CPN – climate policy scenario without investment in new nuclear
ETS-Szenario is taken from ETS (2009): Tab. 1, page 45.

**Fig. 1.** Swiss electricity demand outlook.

concerns over the safety of existing (and any new) nuclear reactors. As a result, on 25 May 2011 the Swiss Federal Council decided to gradually phase out nuclear energy as part of its new energy strategy (FASC, 2011; Leuthard, 2011). Debates are also underway for an early closure of the existing nuclear reactors. The final steps in this decision process are not concluded, and may ultimately face a public referendum. However, even assuming a reversal of the Council's decision, it would still be expected to take about a further 10–15 years until any new nuclear power plants could enter into operation, and projects could still face opposition and further referendums at various stages. Therefore it will be necessary to fill the supply gap without nuclear in the near term (through to 2025), irrespective of decisions regarding the future of nuclear, and possibly in the medium and longer term as well.

The nuclear uncertainties and alternative supply options have been analysed in various studies (BFE, 2001a, 2007a, 2011; Schulz et al., 2008; Ochoa and Ackere, 2009; McKinsey, 2009; ETS 2009; Axpo, 2010). In all these studies, a combination of natural gas combined cycle plant or combined heat and power (CHP) generation, imported electricity[1] and renewables has been proposed. Some of these analyses were short-/medium-term focused and ignored long-term implications (such as technology lock-in, emergence of new technologies) (e.g., BFE, 2001a, 2007a; Ochoa and Ackere, 2009). In almost all these analyses, the electricity supply balance was considered at the annual or winter seasonal level. However, Switzerland experiences large differences in seasonal electricity demand and, as a consequence of the large contribution from hydroelectricity, seasonal electricity output. Moreover, Switzerland is highly integrated into the European electricity grid, and engages in extensive diurnal and seasonal trading. In the future, new renewable technologies with intermittent and seasonally variable output (such as solar and wind), or CHP systems with seasonal operation may also play a role. Therefore, understanding possible technology transition pathways for the Swiss electricity system over the medium and long term requires sophisticated analytical tools that can also account for seasonal and diurnal variations in energy demand and supply. Existing analytical tools are not able to respond to this need and therefore we are developing a Swiss TIMES electricity systems model (STEM-E) which explicitly depicts plausible pathways for the development of the electricity sector, while dealing with intertemporal variations in demand and supply. The development of this model and its underlying assumptions and methodology are described elsewhere (Kannan and Turton 2011).

To understand the potential economic tradeoffs of the uncertainties associated with nuclear and various alternatives, we analysed a number of scenarios and sensitivities of the long-term evolution of the Swiss electricity system using STEM-E. For the present paper[2], we present one baseline scenario and three ad-hoc scenarios exploring the contribution of non-nuclear alternatives in the future Swiss electricity system and their cost implications. Section 2 provides an overview of the model, its key assumptions and limitations. Section 3 describes a set of four scenarios which are analysed and presented in Section 4. In Section 5, the results are discussed from a policy perspective and Section 6 draws key conclusions.

## 2. An overview of Swiss TIMES electricity model

The Integrated MARKAL EFOM System (TIMES) is a technology-rich cost-optimisation modelling framework (Loulou et al., 2005). The objective function of the model seeks to minimise the discounted system cost over the entire time horizon. TIMES is a perfect foresight model, i.e., the participants in the system have *perfect* inter-temporal knowledge of future demand, technology, policy, etc. Hence, TIMES determines cost-optimal energy system evolution under a given set of input assumptions.

The Swiss TIMES electricity Model (STEM-E) is a single-region model, covering the entire Swiss electricity system from resource supply to end use. STEM-E has a century-long time horizon (2000–2110) in 14 unequal time periods with an hourly[3] diurnal resolution.

[1] There are long-term electricity import contracts with France, which are often described as virtual power plants. But they expire in stages from 2016 (Axpo, 2010; IEA, 2008).

[2] An earlier version of this paper was presented at the 2011 International Energy Workshop held at Stanford University, USA (Kannan and Turton, 2011a).

[3] The 8760 h of a year are aggregated at four seasonal (winter, fall, spring and summer), three daily (weekdays, Saturdays and Sundays) and 24 h levels, and thus represented in 288 hourly time steps ($4 \times 3 \times 24 = 288$).