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Intermediate steps towards the 2000 W society in Switzerland: An energy–economic scenario analysis

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Abstract

In the future, sustainable development under the umbrella of the 2000 W society could be of major interest. Could the target of the 2000 W society, i.e. a primary energy per capita (PEC) consumption of 2000 W, be realized until 2050? Various combinations of PEC and CO_2 targets are tested, and the additional costs to be paid by the society are estimated. The assessment is carried out with the Swiss MARKAL model, a bottom-up energy-system model projecting future technology investments for Switzerland. The analysis reveals that the 2000 W society should be seen as a long-term goal. For all contemplated scenarios, a PEC consumption of 3500 W per capita (w/cap) is feasible in the year 2050. However, strong PEC consumption targets can reduce CO_2 emissions to an equivalent of 5% per decade at maximum. For stronger CO_2 emission reduction goals, corresponding targets must be formulated explicitly. At an oil price of 75 $US\$_{2000}$/bbl in 2050, the additional (cumulative, discounted) costs to reach a 10% CO_2 reduction per decade combined with a 3500 W per capita target amount to about 40 billion $US\$_{2000}$. On the contrary, to reach pure CO_2 reduction targets is drastically cheaper, challenging the vision of the 2000 W society.

Keywords: 2000 Watt society; MARKAL; Energy; CO_2; Efficiency

1. Introduction

In the last 50 years, an increasing demand for energy has drastically boosted the consumption especially of oil, natural gas and electricity (SFOE, 2001b). Besides all economical benefits, this high energy consumption also entails several negative aspects. Today, Switzerland is strongly dependent on imported fuels, which are essential for today's lifestyle. Many of those fuels are extracted in politically instable countries such as Iran, Iraq or Saudi Arabia. Looking at the proven oil reserves, by far most of them are located in Middle East countries (BP, 2007). Political tension could increase, and the question could probably be raised "who would be eligible to use these resources".

The recent IPCC report on climate change impacts, adaptation and vulnerability attracts major international attention (IPCC, 2007). The report states: "Negative impacts [for Europe] will include increased risk of inland flash floods, and more frequent coastal flooding and increased erosion … Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses." The effect for Switzerland could be dramatic if action is not taken (OcCC, 2007). In 2002, Switzerland ratified the Kyoto Protocol and committed itself to reduce CO_2 emissions by 10% of the 1990 levels until 2010 (FOEN, 2005). Although the Swiss electricity sector is basically CO_2-free at the moment, other end-use sectors such as the residential and transportation sectors emit significant amounts of CO_2. Additionally, due to probable strong demand increase of electricity, Switzerland is heading towards an electricity gap around 2020 (Hirschberg, 2005). If investments in fossil-based electricity plants should cover this gap, CO_2 is likely to increase

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further. If no measures are taken, fulfilling the Kyoto and additional CO_2 reduction targets will prove unlikely.

Besides possible political tension and climate change issues, the main question of a globally fair-balanced energy consumption arises. The Western world and Switzerland currently use much more energy than the world average. On the one hand, the USA consumes 12 000 W per capita (W/cap), Western Europe 6000 W/cap and Switzerland still 5000 W/cap. On the other hand, in Africa and in some Asian countries the primary energy per capita (PEC) consumption is less than 650 W/cap (Novatlantis, 2004). Overall, about 2000 W/cap is the average worldwide energy consumption. In view of the importance of energy for human development on the one hand, and the material flows associated with any form of energy use on the other hand, a 2000 W society is seen as the long-term goal to achieve a fair and sustainable development (Gutzwiller, 2006; Kesselring and Winter, 1994).

Controversial disputes will be ongoing. The focus could be on reducing energy consumption by increasing the overall energy efficiency. The focus could also be on lowering CO_2 emissions by investing into renewable energy technologies and reducing the fossil import dependence at the same time. It could also be on a combination of targets. Yet one thing is clear: Concrete measures have to be taken if Switzerland wants to contribute to a clean and ecologically sustainable environment. The challenge is to combine measures with a financially flourishing economy. Additional costs to undertake these measures need to be discussed openly.

1.1. The 2000 W society from today's perspective

The vision of a 2000 W society aims at consuming not more primary energy than what corresponds to an average continuous power of 2000 W/cap per capita. This target in units of power (W = J/s) can also be expressed as an annual-energy consumption target of 63.1 GJ per capita and year.

What are the implications of 2000 W/cap from a Swiss perspective? Given a population of 7.2 million for Switzerland (SECO, 2004) and 366 days in the year 2000, 2000 W/cap corresponded to 456 PJ (per year) of primary energy. The Swiss Federal Office of Energy (SFOE) states a primary energy consumption of 1132 PJ (around 5000 W/cap) in 2000 (SFOE, 2001b). Therefore, the Swiss primary energy consumption in the year 2000 was higher than the 2000 W/cap target by a factor of 2.5.

When assessing the feasibility of a 2000 W society for the year 2050, both the population and the economic development must be taken into account. The population projection used in our scenarios correspond to 'A-Trend' reported by SFOS (2001). It is based on a continuation of recent historical trends and middle values for fertility rates, immigration flows and life expectancy. In this scenario, the population of Switzerland increases from about 7.2 million inhabitants in 2000 to about 7.4 million inhabitants in 2030. Afterwards, it experiences a slight decline reaching about 7.1 million inhabitants in 2050. The gross domestic product (GDP) projection used here corresponds to the scenario reported by SECO (2004). The GDP is assumed to increase by nearly 50% from the year 2000 to the year 2050. As a consequence, the realization of the 1.5-fold economic output with 2.5 times less energy implies a decrease in the energy intensity of the GDP by a factor of about 4.

From today's perspective, it is still uncertain if and when the vision of the 2000 W society should be reached in Switzerland. However, it becomes more likely that the formulation of the 2000 W vision will have to include a combination with other targets. The 2000 W/cap goal alone probably falls short of climate protection needs because it does not distinguish between fossil and renewable resources.

In March 2007, the SFOE published the Swiss Federal Energy Research Master Plan for the years 2008–2011 (SFOE, 2007c). This Master Plan, which could be seen as the most prominent but non-binding energy plan, strives for the 2000 W society as a prospective target in the second half of this century. Beside the 2000 W/cap target, the plan also aims at the reduction of CO_2 emission to an equivalent 1 tonne per person and year, similarly to the latest Energy Perspectives report (synthesis report) published in January 2007 (SFOE, 2007a).

In the context of the 2000 W debate, one important issue was missing and is addressed now. What are the additional costs to the society? Furthermore, all studies published before are energy-sector-specific or a combination of energy-sector specific studies. This paper conducts a fully integrated energy-system analysis for the first time. Thereby, the authors link all energy sectors (energy-production and energy-demand sectors) using energy carriers (energy flows) in one modelling framework. The interlinked energy sectors depict the energy system. Using this framework, we impose concrete targets (including a combination of energy and CO_2 targets) for the year 2050, and derive the additional costs necessary for changing the structure and composition of the Swiss energy system.

1.2. Goal of the analysis

The overall goal is the assessment of intermediate steps towards the 2000 W society in Switzerland. Answers are sought for the four main questions:

1. How much can the PEC consumption be lowered until 2050? Is there an upper limit to the PEC reduction potential until 2050?
2. What are the cost-optimal technical choices until 2050? Which sets of technologies are important, in particular for electricity generation, residential heating (including energy-saving measures) and the development of the Swiss car fleet?