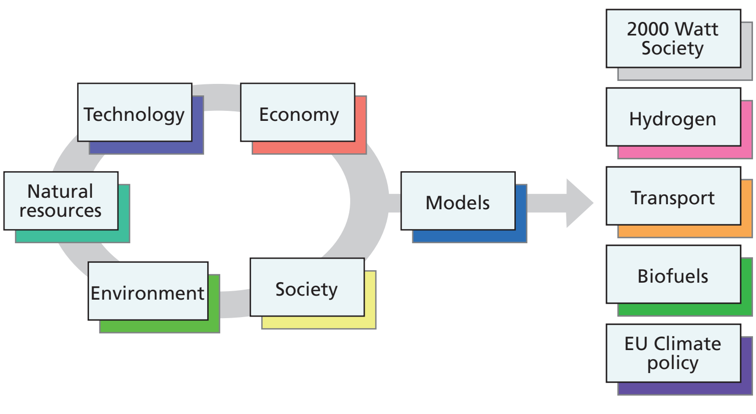
ENERGY ECONOMICS – understanding transitions to a sustainable energy system

The world today is confronted with a number of significant challenges related to the supply and use of energy. Foremost is the need to provide access to affordable and secure energy services throughout the world, while protecting the environment. Responding to these challenges is a key element in achieving a sustainable energy system.

The Energy Economics group (EEG) at PSI, as part of the Laboratory for Energy Systems Analysis, contributes to understanding of energy technology development and identifies policy strategies towards the realisation of sustainable energy systems at the Swiss, European and global levels. Energy system development and technology change are explored and analysed by using scenarios developed with detailed energy-system models. These scenarios present a range of "what if" future descriptions of the world, that help to identify potential challenges, interactions and implications associated with different pathways of economic and social development, technological change, resource availability and policy.



EEG uses models of *technology*, the *economy, resources*, the *environment* and society to study energy issues

The energy-system models used to develop these scenarios include a technologically detailed representation of current and potential future technologies such as hydroelectric generators, windfarms, solar photovoltaic systems, nuclear power stations, and natural gas turbines – including their performance, cost, commercial potential, speed of diffusion and so on. The models are then used to determine the combination of technologies and resources that can supply energy demand into the future at the least cost under different sets of policy goals.

EEG has recently used these techniques to understand the "2000 Watt Society" concept in Switzerland, the deployment of new fuels such as hydrogen and biofuels in the transport sector, and options for mitigating climate change by reducing greenhouse gas emissions, among others.

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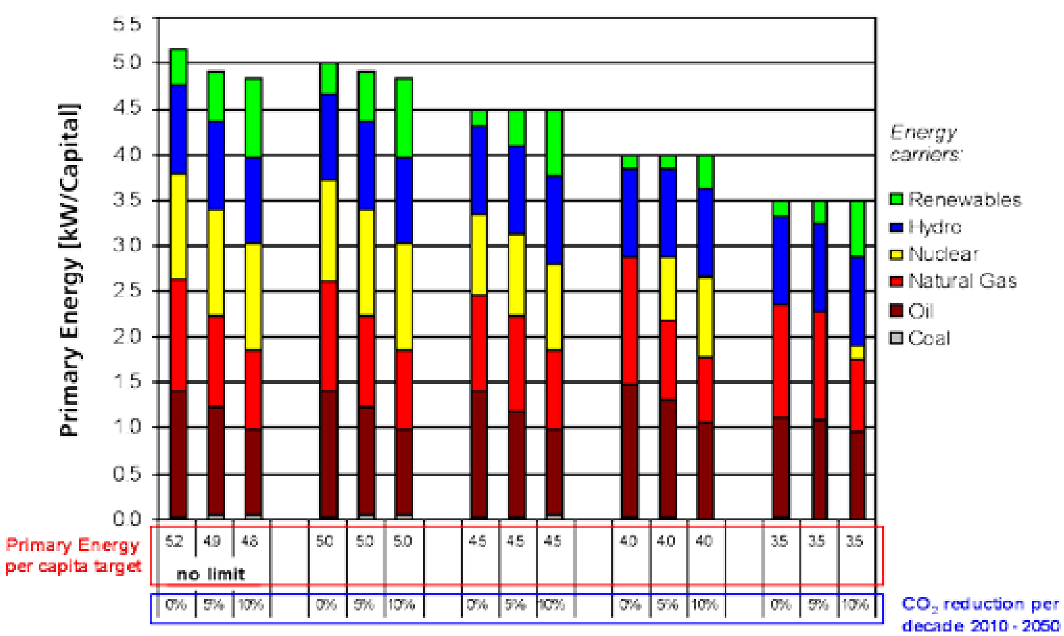
2000 Watt Society in Switzerland

Energy economics research at PSI has recently looked at the realisation of a **2000 watt society** in Switzerland — that is, a society where average annual per capita energy demand is equivalent to roughly 63 gigajoules (ie., 2000 watts for 8760 hours per year). EEG's analysis indicates that it is not so much the level of the target, but rather the choice of energy sources and technologies that is critical for reducing greenhouse gas emissions, increasing energy security and avoiding other negative impacts.

Looking in more detail at the findings of EEG's analysis, only intermediate steps towards a 2000 watt (W) society are possible during the first half of the 21st century, with a target of 3500–4000 W feasible and realistic by 2050. The implications of these targets for the energy mix are shown in the figure below. Importantly, even these intermediate steps are associated with a considerable transformation of the Swiss energy system and deployment of new technologies. Key contributors could include energy conservation in buildings, heat pumps, advanced passenger cars and biofuels.

However, as mentioned, a 2000 watt vision alone is not sufficient to induce the full reductions in greenhouse gas emissions anticipated under Swiss law, meaning that additional or alternative targets and incentives are needed. Realising more stringent greenhouse gas reduction targets is likely to require an extensive use of conservation and efficiency improvement measures together with renewables and nuclear energy. The impact of emissions targets is also shown in the figure below. Another important issue is the amount of energy used elsewhere in the world to make imports for Switzerland. This 'grey energy' is so far not included in this analysis. More information on this study is available under "Publications" at http://eem.web.psi.ch/.

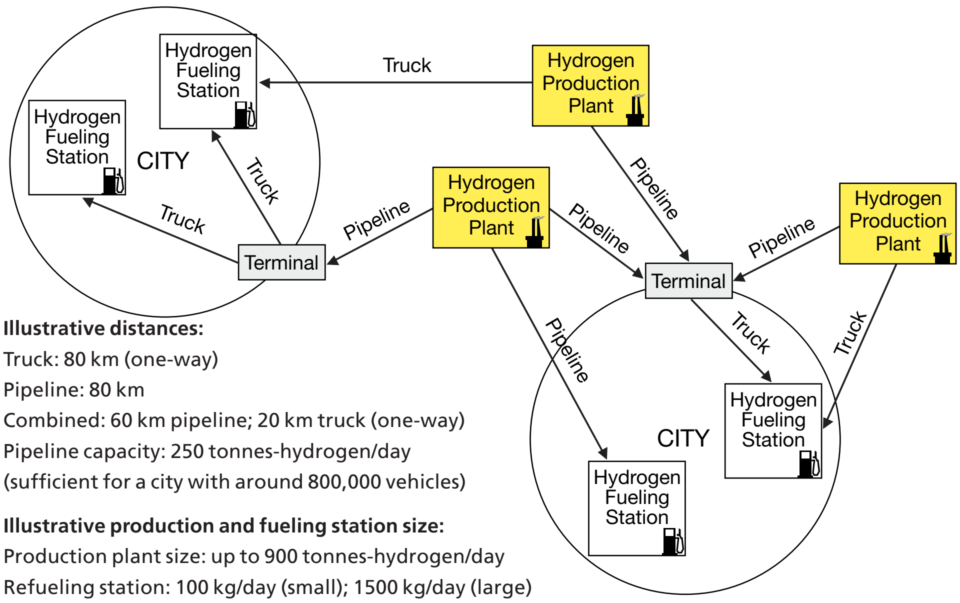
Energy system development under intermediate targets towards a 2000 W (2 kW) society



Alternative fuels in transport

The continuing use of petroleum fuels in transportation represents a significant threat to long-term sustainability – particularly in terms of climate change and energy security. In the future, a number of possible alternatives more suited to a sustainable energy system may emerge, such as biofuels and hydrogen. EEG researchers are closely analysing the prospects for alternative fuels and advanced engine technologies in personal transport over the 21st century, in terms of economic competitiveness, climate change mitigation potential, and energy security characteristics. This is being pursued through the application of Life Cycle Assessment (LCA) approaches and energy systems modeling tools with a detailed representation of alternative fuel production and distribution technologies, covering the extensive range of fueling options, in addition to transportation technologies. An illustration of options for delivering hydrogen – one future alternative fuel – is shown in the figure below. This analysis is ongoing, but has already identified possible increased roles for hybrid drivetrain and fuel cell technologies for realizing a more sustainable energy system (more at http://eem.web.psi.ch/).

Options for a hydrogen fueling infrastructure network: pipeline; combined pipeline+truck (liquid/gaseous hydrogen); and truck only (liquid/gaseous).



Illustrative distances:
Truck: 80 km (one-way)
Pipeline: 80 km
Combined: 60 km pipeline; 20 km truck (one-way)
Pipeline capacity: 250 tonnes-hydrogen/day
(sufficient for a city with around 800,000 vehicles)

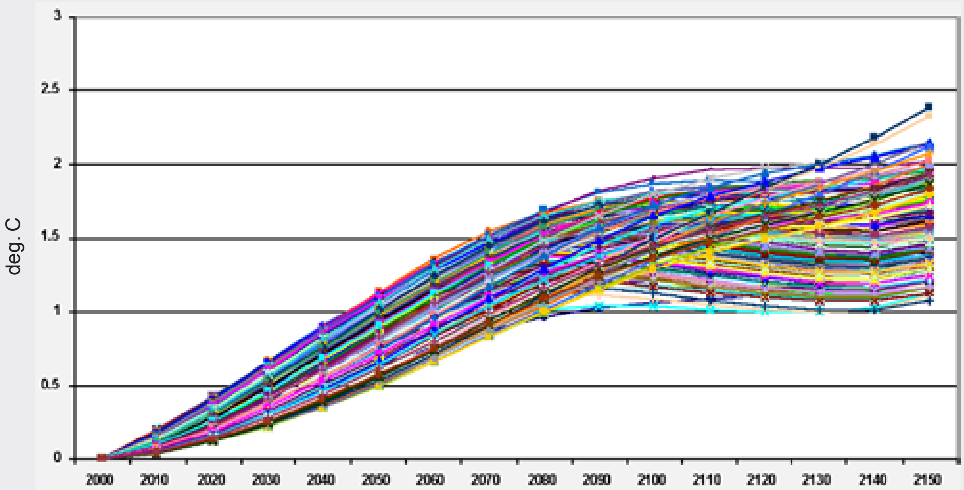
Illustrative production and fueling station size:
Production plant size: up to 900 tonnes-hydrogen/day
Refueling station: 100 kg/day (small); 1500 kg/day (large)

Reducing global greenhouse gas emissions

One of the goals of the European Union is to limit any increase in global temperature from climate change to no more than 2°C (relative to pre-industrial levels). To analyze the prospects for reaching this target, researchers at PSI have conducted a **scenario analysis** accounting for uncertainty about climate science, socio-economics and energy sector developments. Following the Stern Review, this analysis also incorporates estimates of the potential cost of climate change damage, facilitating a cost-benefit analysis comparing mitigation costs with avoided damage from climate change across a large

number of scenarios. The results in terms of optimum temperature change for one set of scenarios is illustrated in the figure below. The analysis also illustrates some of the important considerations for achieving ambitious global temperature targets, such as the EU's 2° goal, including the need for early actions and a strong willingness to pay to avoid catastrophic damage. Find out more under "Publications" at: http://eem.web.psi.ch/.

Scenario simulations: temperature change results from a cost-benefit analysis of mitigation and climate damage costs.



Each line in the figure represents a different scenario, illustrating some of the uncertainty.

Examples of research partners

- Centre for Energy Policy and Economy, ETH Zurich
- Department of Economics, University of Bern
- Sloan Automotive Laboratory, Massachusetts Institute of Technology
- Economics and Environmental Management Laboratory, Ecole Polytechnique Federale de Lausanne
- Enerdata, France
- Fraunhofer Institute for Systems and Innovation Research, Germany
- LEPII-EPE, University Pierre-Mendes, France
- Institut für Energiewirtschaft und Rationelle Energieanwendung, University of Stuttgart, Germany
- International Energy Agency (IEA), Paris
- International Institute for Applied Systems Analysis, Austria
- Politecnico di Torino, Italy
- Potsdam Institute for Climate Impact Research (PIK), Germany
- Technical University of Lisbon, Portugal
- Tyndall Centre for Climate Change Research, Cambridge Centre for Climate Change Mitigation Research, United Kingdom
- University College Dublin, Ireland
- Wageningen University, Netherlands

Examples of project activities

- Adaptation and Mitigation Strategies (European Commission)
- Before a transition to hydrogen (Alliance for Global Sustainability)
- Energie Trialog Schweiz
- Exploring Energy Technology Perspectives (Energy Technology Systems Analysis Programme of IEA)
- National Centres of Competence in Research (NCCR) Climate (Swiss National Science Foundation)
- New Energy Externalities Development for Sustainability (European Commission)

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