

PAUL SCHERRER INSTITUT PSI

TECHNOLOGY ASSESSMENT

COMPREHENSIVE ASSESSMENT OF ENERGY SYSTEMS – an interdisciplinary framework for sustainable decision-making

The Technology Assessment group is part of the Laboratory for Energy Systems Analysis at the Paul Scherrer Institut, common to its two Energy Departments. It carries on the work of the GaBE Project (Comprehensive Assessment of Energy Systems), whose analysis framework and applications are well established. The goal of Technology Assessment is to help different decision-makers and stakeholders to understand the complex interplay between different energy strategies and to support the decision-making process in moving towards a sustainable energy future. To achieve this goal, energy technologies are analyzed with a comprehensive range of disciplines.

Objective and Scope

State-of-the-art methods and databases enable a quantitative and systematic assessment of energy technologies and energy supply strategies. This objective and consistent methodological framework supports rational decision-making for sustainable development in the Swiss and international energy sectors.

Approach

An interdisciplinary approach integrates a wide variety of research areas (see figure on page 2), including Life Cycle Assessment (LCA), environmental impact and external cost assessment, system modeling, and integrated evaluation based on both the total cost approach and Multi-Criteria Decision Analysis using environmental, economic and social indicators. The integrated framework enables comprehensive studies comparing energy options, for the electricity, heating, and transport sectors.

Vision

In addition to developing, applying and integrating advanced methods, our goal is to present and disseminate our results to the scientific community, policy makers and stakeholders. We apply our knowledge and experience assisting regulators and industry to establish more sustainable energy supply strategies.

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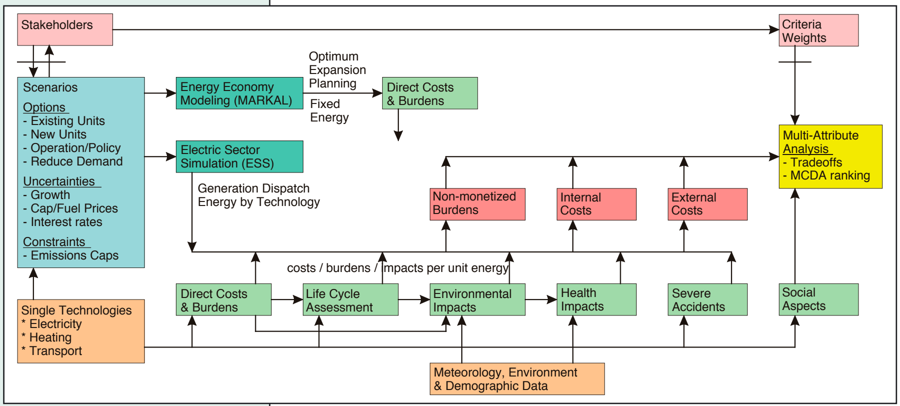


Analytical framework of the GaBE project.

Communication

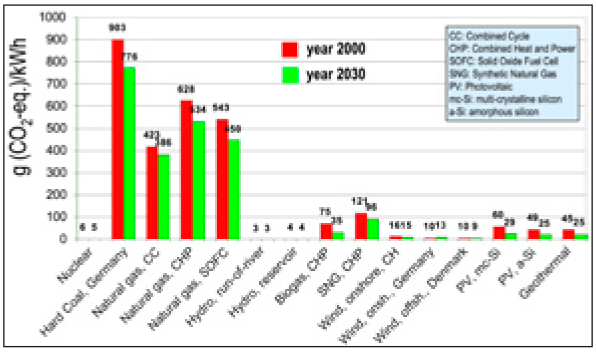
Popular dissemination of scientific results is essential to reach and inform the broad public. Therefore, the project publishes the "Mirror on Energy" (or "Energie-Spiegel") newsletter about every four months as part of its role as an "honest broker" of independent and impartial information within the national energy policy debate.

Life Cycle Assessment

Life Cycle Assessment (LCA) deals with the full spectrum of ways the fabrication of a product or the delivery of a service affects the environment. The Life Cycle Inventories account for all essential material and energy flows occurring during production, operation and decommissioning over the lifetime of every activity.

The GaBE project focuses on the assessment of present and future energy systems, including fossil, nuclear and renewable resources. The full energy chain for each system is analyzed, from raw materials extraction through processing, transport, energy conversion and waste management. This accounts for both direct and indirect burdens to the environment such as emissions to air, water and soil as well as resource and land use. The cumulative results of the inventories allow fair comparison of the wide spectrum of environmental burdens associated with each unit of energy.

The environmental inventories are also used in the estimation of impacts and associated external costs. The environmental profiles are an essential input to the implementation of Multi-Criteria Decision Analysis (MCDA).

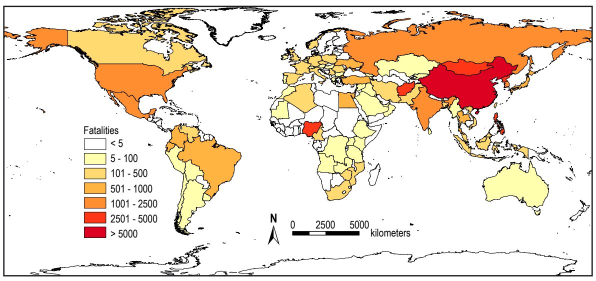


Greenhouse gas emissions per unit of electricity from current and future (year 2030) electricity supply systems (technologies implemented in Switzerland, unless otherwise noted).

Risk Assessment

Severe accidents are a very controversial topic in public perception and energy politics. The database ENSAD (Energy-related Severe Accident Database) at PSI comprehensively covers severe, energy-related accidents and their technical aspects. Complete energy chains are considered because accidents can occur in every stage of the chain. Rare events are analyzed using Probabilistic Safety Assessment (PSA).

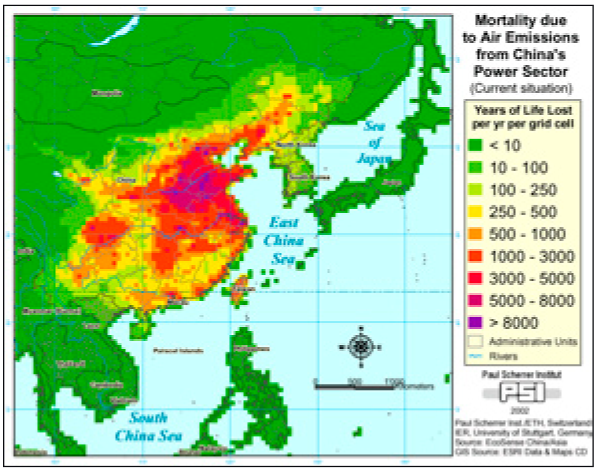
The results based on ENSAD show that energy-related risks in the industrialized countries of the OECD are significantly lower than in the medium or less developed non-OECD countries. This is due to differences in the technologies used, safety standards and the general safety culture. The most accident-prone areas in non-OECD countries are the upstream stages of the fossil energy chains and hydro power. Expected fatality rates are lowest for western hydropower and nuclear power plants; however the maximum credible consequences can be very large.



Individual countries are shaded according to their total numbers of severe accident fatalities in fossil energy chains for the period 1969–2000.

Environmental Impact Assessment and External Costs

Polluting activities can damage people, goods and/or nature. These burdens are often imposed on society and not fully borne by the polluter. From the polluter's viewpoint, the damages are "external." In general, an externality is an effect on a populace or the environment that is caused by another party that does not include, or internalize, the effect in its own accounting. Negative externalities are called external costs, and positive externalities are called external benefits.



Years of Life Lost (YOLL) due to air emissions from China's power plants.

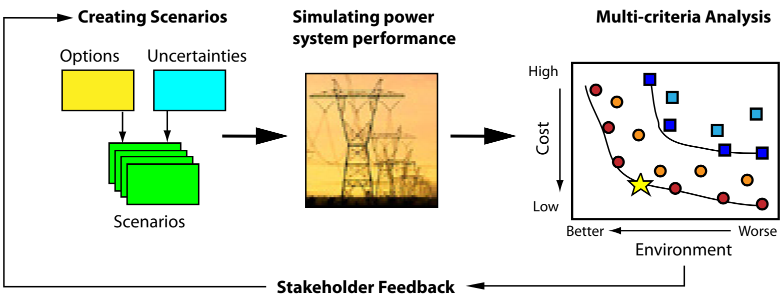
The Impact Pathway Approach (IPA) consists of:

1. Estimation of emissions.
2. Estimation of changed pollutant concentrations.
3. Estimation of impacts on receptors like humans, animals, plants etc. For example this includes health effects in terms of mortality expressed in Years of Life Lost (YOLL).
4. Valuation. The external cost method uses monetization to value the impacts.

Electric Sector Simulation

The cumulative impacts of the electrical power system depend upon how the system evolves over time in its physical composition, and also very importantly upon how we choose to operate the system. The Electric Sector Simulation (ESS) method analyzes many specific scenarios over time, optimizing the operation of existing and future plants. Each scenario uses a fixed strategy composed of available options (e.g. new generation technologies, fuel choices, or efficiency programs), combined with uncontrollable uncertainties (e.g. demand growth, fuel prices, or regulatory changes). Electric sector strategies concern multiple stakeholders, so no single strategy for expansion and operation is ever optimum because stakeholders disagree on how to balance conflicting objectives. For this reason, the ESS method analyzes (simulates) several thousand scenarios, calculating many different indicators for multi-criteria assessment. If multi-criteria tradeoff analysis is not sufficient to assist stakeholders in selecting their preferred strategies, then the ESS group can use multi-criteria decision analysis methods to assist stakeholders.

The ESS method is complementary to the Energy Economic Modeling (EEM) performed by the EEM group within LEA, which models the full energy sector, optimizing system expansion strategies using a single, least-cost criterion for a limited number of future scenarios. In both the ESS and EEM cases, key modeling results are used by other GaBE efforts.



Framework of ESS analytic modeling.

Sustainability Assessment

The sustainability evaluation of current and future energy technologies may use the total-cost approach, and/or Multi-Criteria Decision Analysis (MCDA), taking into account ecological, economic and social aspects.

Total costs can be controversial, but they do include the economic and environmental effects of the various energy options. Internalization of external costs increases the relative competitiveness of renewables and nuclear. Renewable technologies have the highest potential for technological improvements and thus cost reductions. Nuclear power has the lowest total costs both now and in 2030.

Total costs lead to a clear ranking of technologies, but provide a limited representation of social aspects whose broader consideration may affect ranking of nuclear. Social factors are better represented in Multi-Criteria Decision Analysis. Depending on stakeholder preferences, MCDA can lead to a different technology ranking than total cost, and is therefore used to provide an alternate aggregated sustainability indicator.

Main environmental, economic and social criteria within MCDA for sustainability assessment.

Criteria	
ENVIRONMENT	ECONOMY
Resources	Impact on customers
Climate change	Impact on the overall economy
Impact on ecosystems	Impacts on the utility
Wastes	
SOCIAL ASPECTS	
Security/reliability of energy provision	
Political stability and legitimacy	
Social and individual risks	
Quality of life	

Examples of completed and current projects

Authorities/Regulators:
- Energy perspectives 2035/2050: new renewables and new nuclear technologies: potential and costs (SFOE)
- ecoinvent: the world's leading multi-sectoral LCA database
- Severe accident risks in the energy sector (SFOE): severe accident database (ENSAD) and PSA

Industry:
- Sustainability assessment of current and future electricity supply technology portfolio (Axpo)
- China Energy Technology Program (CETP): integrated assessment of sustainable energy systems in China (ABB)
- Energy perspectives and CO_2-reduction potentials in Switzerland until year 2010 (FOGA)
- Comparative risk assessment of natural gas (SVGW)
- LCA for gas technologies in France (Gaz de France)
- LCA of electricity generation options (Alstom)
- Perspectives of future electricity and heat supply strategies for Switzerland (VSE)

European Union (EU) and other international organizations:
- Security of energy supply (SECURE, EU)
- Externalities of Energy: NEEDS, Externe-Pol, New-Ext (EU)
- Nuclear energy risks and benefits in perspective (OECD/NEA)
- Sustainability of electricity supply technologies under German conditions (ILK)

Examples of GaBE research partners

(science, industry, authorities, organizations):
- Centre for Energy Policy and Economics (CEPE, ETHZ)
- EMPA
- ESU-Services
- Laboratory of Energy Systems (EPFL)
- Swiss Federal Office of Energy (SFOE)
- Swiss Federal Office for the Environment (FOEN)
- Electric Utilities (Axpo, VSE, Swiss Nuclear, Atel)
- Gas industry (VSG, SVGW)

- École Nationale Supérieure des Mines de Paris (France)
- Fondazione Eni Enrico Mattei (FEEM, Italy)
- International Institute for Applied Systems Analysis (IIASA, Austria)
- Joint Research Centre (JRC) Petten (The Netherlands)
- Massachusetts Institute of Technology (MIT, USA)
- Mediterranean Energy Observatory (OME, France)
- Tokyo University (Japan)
- Tsinghua University (China)
- University of Bath (UK)
- University of Stuttgart (Germany)
- International Atomic Energy Agency (IAEA, Austria)
- Organisation for Economic Co-operation and Development (OECD, France)
- ABB Corporate Research
- Alstom
- Electricité de France (EDF)
- Gaz de France (GdF)

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