New Energy Externalities Development for Sustainability

Final Report Summary - NEEDS (New Energy Externalities Development for Sustainability)

The ultimate objective of the NEEDS Integrated Project (IP) was to evaluate the full costs and benefits (i.e. direct and external) of energy policies and of future energy systems, both at the level of individual countries and for the enlarged EU as a whole.

From the scientific and technological viewpoint, this entailed major advancements in the current state of knowledge in the following main areas of:

- life cycle assessment (LCA) of energy technologies;
- monetary valuation of externalities associated to energy production, transport, conversion and use;
- integration of LCA and externalities information into policy formulation and scenario building.

An additional, important goal was to increase awareness, acceptability and actual use of externality data in policy formulation, calling for dedicated efforts in assessing stakeholders perceptions, facilitating the access to usable externality data, disseminating and communicating results to all involved stakeholders.

The IP was built as a series of streams, each addressing a specific area of research. Innovation and S&T advancements lied both within each stream and in their overall integration. According to their specific objectives and area of research, the streams were grouped in three main blocks.

The first block corresponded to new developments, updating, enhancement of the current state of the art in the field of energy externalities and includes the following research streams (RS):

1a) LCA of new energy technologies
1b) new and improved methods to estimate the external costs of energy conversion
1c) externalities associated to the extraction and transport of energy
1d) extension of the geographical coverage of the current knowledge of energy externalities.

The second block addresses long term strategies and includes the two following streams:
2a) modelling internalisation strategies, including scenario building
2b) energy technology roadmap and stakeholder perspectives.

The third block focuses on providing input to policy making, dissemination and other communication issues, and includes the following two streams:
3a) transferability and generalisation
3b) dissemination / communication.

A summary of the work performed in the first period by 2 is provided below.

Examination of the candidate set of social criteria and indicators: The initial set of criteria and indicators was re-examined and recommendations for further use of social criteria and indicators were formulated.

Establishment of a preliminary full set of criteria and indicators: A preliminary full set of criteria and indicators, covering economy, environment and social aspects was proposed. Practical constraints were taken into account, including prospects for successful quantification in view of expected inputs from other streams.

Initiation of indicator quantification tasks: Most quantification tasks were in the initial phase but some are more advanced. For economic indicators the focus was on the examination of proposed indicators and establishment of contacts with relevant work packages in streams 1a and 2a. For environmental indicators, the feasibility of country-specific adjustments of generic LCA-indicators to be generated within 1a was addressed and elaborated; such adjustments were considered to be feasible. Extensive internet and literature searches were made for social indicators demonstrating the very limited availability of relevant data. Thus, most of the social indicators will have to be measured by conducting expert interviews.

Definition of requirements and selection of suitable method(s) and tool(s) for multi-criteria decision analysis (MCDA): An extensive review of candidate methods for MCDA was carried out taking into account the requirements.

Case-study based exploration of the acceptability of monetary valuation methods and their potential role in the energy policy making process: The work package was successfully carried out. Several interviews were made with United States and United Kingdom industry representatives. The report demonstrated quite a large variation between the considered countries in the uses of externality valuation in the policy. The existence of official requirements to consider full costs and benefits of proposed regulations and / or official guidelines appeared to be crucial to explain this pattern.

Preparation of survey on externalities and stakeholder database development: A draft of a survey questionnaire on the externality concept, results and uses was prepared and intensely discussed. A stakeholder database was established.

The objective of 2b was to broaden the basis for decision support beyond the assessment of external costs and to extend the integration of the central analytical results generated by other research streams.

For the health and environmental set of indicators, system performance associated with normal operation was considered to be sufficiently well described by the burdens and impacts assessed within NEEDS. However, external inputs were needed for accident risks, not directly addressed by NEEDS.

The objective of work package 7 was to estimate quantitative indicators for severe accident risks for a set of technologies in year 2050 considered within NEEDS.

Risk indicator results were based on PSI's severe accident database ENSAD (Energy-related severe accident database), except for nuclear systems where predictive analyses were performed. The generated risk indicators served as an input to the multi-criteria decision analysis in work package 10. With regard to historical experience, a full update of the ENSAD database up to year 2005 was undertaken with focus on major fossil chains and hydropower, supplemented by the implementation of a simplified PSA approach for the nuclear chain. In contrast, consideration of new renewables was based on accident statistics, literature review and expert judgment
because of limited or lacking historical experience.

Within the framework of PSI's database ENSAD, an accident was considered to be severe if it was characterised by one or several of the following consequences (Hirschberg et al., 1998):
1. at least five fatalities or
2. at least 10 injured or
3. at least 200 evacuees or
4. extensive ban on consumption of food or
5. releases of hydrocarbons exceeding 10 000 (metric) tones (t) or
6. enforced clean-up of land and water over an area of at least 25 km² or
7. economic loss of at least 5 million USD (2000).

Although accidents in the energy sector have been shown to form the second largest group of manmade accidents, their level of coverage and completeness was not satisfactory because they were commonly not surveyed and analysed separately, but just as a part of technological accidents.

Consideration of complete energy chains was essential because accidents not only occur during actual energy production, but in every stage of a chain from exploration to extraction, refining, storage, distribution, and finally waste disposal.

PSI's highly comprehensive database ENSAD utilised merged and harmonised historical data from a large variety of information sources. Therefore, ENSAD could be considered superior compared to single database approaches that were also often limited concerning geographic area, time period, and energy chains included.

For the assessment of severe, energy-related accident risks within the NEEDS project, external database inputs relevant for ENSAD were reviewed with respect to suppliers, scope, update frequency, acquirement costs etc.

The ENSAD database allowed carrying out comprehensive analyses of accident risks that were not limited to power plants but cover full energy chains. Such a broader perspective was essential because for the fossil chains accidents at power plants play a minor role compared to the other chain stages. Furthermore, identification of weak links in an energy chain, potential improvements and effective measures on the technical or regulatory levels required deep knowledge of events, their possible causes, dimensions and relationships.

For the NEEDS multi-criteria analysis (MCA), a database comprising a set of 36 separate indicators for 26 future electricity generation technologies (in the year 2050) in four countries (i.e. France, Germany, Italy and Switzerland) was established. For the risk indicators the following country differentiations apply.

For the calculation of indicators for the nuclear chain a more specific site definition was required so that indicators like potential fatalities from an accident could be calculated.

Some technologies were eliminated from the technology set in certain countries because they were not considered viable alternatives due to resource limitations. Due to high summer temperatures, thermal efficiency was assumed 3 % lower in Italy, as compared to the three other countries. This affected the results for hard coal and centralised natural gas technologies.

Within the environmental dimension of the NEEDS criteria and indicator set, two indicators addressed ecosystem impacts in the event of severe accidents:
1) Hydrocarbons: This indicator quantified large accidental spills of hydrocarbons to the environment, which could potentially damage affected ecosystems. It considered severe accidents only. The applicability of this indicator was restricted to the oil chain. However, in the final NEEDS technology set no technology using oil as fuel was considered.
2) Land contamination: This indicator quantified land contaminated due to accidents releasing radioactive isotopes. The land area contaminated was estimated using probabilistic safety analysis (PSA). This indicator was restricted to the nuclear electricity generation technology chain.

Within the social dimension of the NEEDS criteria and indicator set, there were two indicators assessing the risk from severe accidents and three indicators estimating the risk of terrorism:
1) Accident mortality: This indicator was based on the number of fatalities expected for each kWh of electricity that occurred in severe
accidents with five or more deaths per accident for a particular electricity generation technology chain.

2) Maximum fatalities: This indicator was based on the maximum number of fatalities that were reasonably credible for a single accident for a particular electricity generation technology chain.

3) Terror potential: This indicator estimated the potential for a successful terrorist attack on a specific technology, based on its vulnerability, the potential damage and public perception of risk.

4) Terror effects: This indicator concerned the potential likely consequences of a successful terrorist attack. The criterion implicitly addressed the aversion towards low-probability high-consequence accidents.

5) Proliferation: This indicator represented the potential for misuse of technologies or substances present in the nuclear electricity generation technology chain, based on both their presence and the risk of such misuse or diversion.

For the evaluation and ranking of possible terrorist attacks on technology-specific infrastructure elements in the energy sector, three indicators were established under the criterion ‘terrorist threat’, namely terror potential, terror effects and proliferation. Subsequently, qualitative procedures were developed to provide a ranking and relative importance of terrorist threats on energy related technologies and systems.

The evaluation was performed by assigning three indicators to each technology:

1. potential of attack;
2. likely potential effects of a successful attack: expected number of fatalities (on- and off-site);
3. proliferation: potential for misuse of technologies and substances (within the nuclear chain).

The numerical results demonstrated that fatality rates were lowest for nuclear, intermediate for new renewables and highest for fossil technologies, whereas for maximum consequences nuclear and new renewables were reversed, while fossil technologies remained intermediate.

The ENSAD database contained comprehensive historical experience of severe accidents in the energy sector allowing for detailed and quantitative technical comparisons of a wide range of aspects of severe accident risks. ENSAD was:

1. continuously maintained to ensure accurate functionality and proper operation;
2. regularly updated to keep up with the demand for timely availability of growing historical experience; and
3. extended in scope to broaden its range of application and to enable tailored studies for a variety of stakeholder groups and their specific needs.

Calculated risk indicators in work package 7 included large accidental spills of hydrocarbons (oil chain), land contamination due to the release of radioactive isotopes (nuclear chain), accident mortality based on expected fatality rates (all chains), and maximum consequences based on the most deadly accident (all chains).

Risk indicators led to valuable insights and conclusions, but above all they provided essential input to the NEEDS MCA for the sustainability assessment of a defined, future (year 2050) set of electricity generation technologies. Within MCA actual indicator values were combined with stakeholder preferences resulting in a technology ranking, which in an iterative process could be modified by balancing tradeoffs and compromises between risk indicators and in relation to all other sustainability indicators, as well as among the three sustainability dimensions. The MCA results could support stakeholders assess and understand the sustainability performance of current and / or future energy supply technologies, and they could also contribute to decisions on / formulation of energy policies at different spatial scales and for different technology portfolios.

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