SIXTH FRAMEWORK PROGRAMME

Project no: **502687**

NEEDS

New Energy Externalities Developments for Sustainability

INTEGRATED PROJECT

Priority 6.1: Sustainable Energy Systems and, more specifically,
Sub-priority 6.1.3.2.5: Socio-economic tools and concepts for energy strategy.

Deliverable n° D14.4 – RS2b
"Analytical overview of the technical and scientific production of the stream 2b"

Due date of deliverable: February 2009
Actual submission date: February 2009

Start date of project: 1 September 2004 Duration: 54 months

Organisation name for this deliverable: Edited by PSI, with contributions from Armines, CESIRICERCA, EDF, GLOBE Europe, HELIO International, IIASA, ISIS and University of Stuttgart

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

1. General objectives

Overall objectives:

The central objective of this Research Stream is 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. The ultimate results of the technology roadmap will include mapping the sensitivity of sustainability performance of technological options to stakeholder preference profiles. Furthermore, within this stream stakeholder acceptance of the external cost concept, results and uses is examined.

Objectives for the reporting period:

- Establishment of the final consensus set of criteria and indicators covering the three dimensions of sustainability, i.e. economy, environment and society. For this purpose a stakeholder survey (II) was conducted.
- Full quantification of the selected environmental, economic and social indicators for four countries, i.e. France, Germany, Italy and Switzerland.
- Multi-Criteria Decision Analysis (MCDA) method development, selection and web-based implementation.
- Performing the actual MCDA ranking of NEEDS technologies based on stakeholder preferences combined with quantitative indicators.

Progress achieved:

- *Establishment of the final consensus set of criteria and indicators.* The results of Survey II showed a strong support among stakeholders for the proposed set of criteria and indicators. A limited streamlining of the proposed set was conducted by eliminating a small number of overlapping indicators. The final set contains a total of 36 indicators, thereof 11 environmental, 9 economic and 16 social. This set was then employed when assessing the sustainability of the technological options.
- *Quantification of economic indicators.* Economic indicators were quantified using primarily inputs from RS1a with some supplements from RS2a. Indicators such as “Direct labour”, “Autonomy of electricity generation” and “Flexibility of dispatch” were generated within RS2b.
- *Quantification of environmental indicators.* Since RS1a generated mostly generic inventories, calculation of country-specific environmental burdens required the extrapolation of these specific technology inventories to the individual situations of the four countries assessed in the project. This resulted in adjustments being made to some of the technologies in order to account for specific wind conditions and solar irradiation, energy resource densities and effects on efficiencies due to average ambient air temperatures; certain technology characteristics were modified according to country-specific boundary conditions.
- *Quantification of social indicators.* Semi-standardized expert phone-interviews were conducted to obtain the expert judgment based data that could not be obtained from other sources, existing datasets or literature research. This is the first time that social indicators had been quantified for a large variety of energy technologies.
- *Quantification of risk indicators.* Some social indicators were quantified based on natural science. Quantitative assessment of severe accident risks based on the extended PSI’s database ENSAD and on Probabilistic Safety Assessment (PSA). Chain-specific and

comparative results were provided for major energy chains. Development and implementation of a qualitative assessment procedure (using ordinal scales) to estimate indicators related to the terrorist threat was successfully carried out.

- *Sustainability indicator database.* Technology indicator data collected from several streams (RS1a, RS2a and RS2b), were harmonized as necessary and validated. The database on sustainability indicators for future (year 2050) electricity supply technologies with the associated fuel cycles was established. The database includes 36 separate indicators for 26 future technologies (in the year 2050) in four countries, i.e. France, Germany, Italy and Switzerland.
- *MCDA method development.* Over 20 new MCDA methods were developed by IIASA and tested by the PSI team to select one method which was most suitable for the stakeholders invited to the MCDA survey. All developed MCDA methods basically meet the requirements for the use in MCDA within NEEDS. One specific method, considered most suitable by the PSI team, was employed and implemented in the Web-based applications needed for conducting the survey; an interactive MCDA of a discrete choice problem for large number of criteria (over 60) and alternatives (about 20).
- *Web-based implementation of MCDA methodology:* New method(s) for MCDA were developed and tested within a prototype Matlab-based environment, ported to the Web-based application, and adapted for the Web-based survey. The survey was implemented in form of web-based software integrating the technology database, MCDA methodology and stakeholder database.
- *Survey of stakeholder preferences.* Over 3000 stakeholders were invited to the survey, 346 registered to the MCDA site, 160 completed the MCDA. Considering the fact that MCDA is by far more demanding than a traditional survey, the number of completed surveys is satisfactory though somewhat below expectations. Nevertheless, the responses were adequate for drawing concrete conclusions and reaching the project objectives.
- *Sensitivity aspects.* For the main technologies considered in RS1a potential major developments or breaks-through were considered. For each of these developments or breaks-through, the influence on specific sustainability indicators were discussed.
- *MCDA results.* The results of the individual stakeholder preference specifications were analyzed after the multi-criteria analysis survey was closed. The survey results were analyzed to find clusters or groups of individual preferences. The results were compared with the total cost ranking showing distinct patterns. In particular the impact of considering a variety of social criteria was evident.

Table 1: List of Research Stream 2b Deliverables and Technical Papers.

WP N°	**TITLE**	**D/TP n° Other**	**AUTHORS**
3	Final set of sustainability criteria and indicators for assessment of electricity supply options	D3.2	PSI with contributions by partners
4	Additional technological advancements to be considered in MCDA sensitivity analysis	T4.1	CESIRICERCA
5	Final report on economic indicators for sustainability assessment of future electricity supply options	D5.2	EDF and PSI
6	Final report on quantification of environmental indicators for sustainability assessment of future electricity supply options	D6.1	PSI
7	Final report on quantification of risk indicators for sustainability assessment of future electricity supply options	D7.1	PSI
8	Quantification of social indicators for the assessment of energy system related effects	D8.1	University of Stuttgart
10	Final report on indicator database for sustainability assessment of future electricity supply options	D10.1	PSI
10	Final report on sustainability assessment of advanced electricity supply options	D10.2	PSI and IIASA
12	Implementation, evaluation and reporting on the survey on criteria and indicators for assessment of future electricity supply options	D12.3	PSI
14	Analytical overview of the technical and scientific production of the stream 2b	D14.4	PSI with contributions by partners

2. Scientific achievements and policy relevance

Workpackage 3: Establishment of full set of criteria and indicators

TITLE **D3.2: Final set of sustainability criteria and indicators for assessment of electricity supply options**	
WORKPACKAGE N°3	**WP LEADER :** Paul Scherrer Institut (PSI)
CONTRIBUTING PARTNERS	CESIRICERCA, EDF, GLOBE Europe, HELIO International, IIASA, ISIS, University of Stuttgart

Introduction

Establishment of the final set of criteria and the associated indicators was a prerequisite for the implementation of multi-criteria decision analysis (RS2b WP10). The final set consists of environmental, economic and social indicators and defines the scope of the corresponding indicator quantification tasks (RS2b WP5, 6, 7, 8).

A summary report on the full set of criteria and indicators (D3.1) was already available earlier. The criteria and indicators provided in this report represented a consensus within stream RS2b and also reflected feedbacks received from other NEEDS streams. They were implemented within the questionnaire generated in WP12 and were to be subject of Survey carried out in WP12 among a wide range of stakeholders.

Abstract

The results of Survey II (D12.3) showed a strong support among stakeholders for the proposed set of criteria and indicators (see D12.3). There were hardly any specific recommendations on extending the proposed set. Most suggestions for modifications, though still expressed by a minority, went rather in the direction of reducing the overall set. While this view may not be shared by the various stakeholders we opted for a quite limited reductions motivated by streamlining the set through eliminating few overlapping indicators belonging to the social dimensions. The environmental and economic indicators remained unchanged in terms of substance but definitions were improved.

The final set contains a total of 36 indicators, thereof 11 environmental, 9 economic and 16 social. This set was then employed in WP10 and WP12 when assessing the sustainability of the technological options.

The environmental dimension addresses Energetic and Non-energetic Resources (3 indicators), Climate Change (1 indicator), Impacts on Ecosystems (5 indicators), and Wastes (2 indicators).

The economic dimension addresses Impacts on Customers (1 indicator), Impacts on Overall Economy (2 indicators) and Impacts on Utility (6 indicators).

Finally, the social dimension addresses Security/Reliability of Energy Provision (3 indicators), Political Stability and Legitimacy (2 indicators), Social and Individual Risks (9 indicators) and Quality of Life (2 indicators).

The report D3.1 was updated to reflect the above results of Survey II. The resulting deliverable D3.2 replaces thus D3.1.

Structure

The report provides a short background to the selection of the indicators, referring to the work carried out in the preceding periods. The core of the report is constituted of the descriptions of the selected criteria and indicators, including definitions and comments on the intended quantification. The changes based on Survey II are documented and the final set is provided.

Conclusions

The final set of criteria and indicators to be used in the comparative sustainability assessment for future technologies evolved from the research tasks and the feedback provided by stakeholders through a dedicated survey. The basic structure uses the three pillars of sustainability, i.e. environment, economy and society. Within these three dimensions there are four hierarchical levels. The final set contains 11 environmental, 9 economic and 16 social indicators (among the latter 12 are directly connected to ecology).

Workpackage 4: Extended technology characterization and prospective advancements

TITLE **T4.1: Additional technological advancements to be considered in MCDA sensitivity analysis**	
WORKPACKAGE N° 4	**WP LEADER:** CESIRICERCA
CONTRIBUTING PARTNERS	EDF, PSI

Introduction

The report identifies and examines credible improvements of technological characteristics of future electricity supply options beyond those considered in RS1a. These advancements may be considered in future sustainability evaluations and may provide relevant input for corresponding sensitivity studies.

Abstract

The reference technologies analyzed in MCDA were defined in RS1a. Implementation of these technologies is subject to uncertainties. First, the development path could show to be different than assumed. Second, the future technology performance could exhibit other characteristics than those derived in the present project. Third, alternative technological options that were not analyzed within NEEDS, could be prioritized in the future.

The report examines two types of changes in comparison with the reference development, i.e. relatively limited changes of some basic characteristics such as dimensions or efficiencies as well as major technology breakthroughs.

The technologies considered are: fuel cells, wind offshore, solar PV, solar thermal and nuclear. The impact of the above mentioned types of changes on sustainability indicators have been explored and evaluated

Structure (organization of the work)

The technologies were examined by researchers familiar with specific options. A detailed analysis would require substantially higher resources.

Conclusions

The report identifies and evaluates changes of characteristics as well as possible break-throughs for a number of technologies addressed in NEEDS. On a case-by-case basis the impacts on sustainability indicators are examined. These impacts may be substantial. The findings should be followed-up by more detailed analysis and need to be considered in MCDA sensitivity cases.

Workpackage 5: Quantification of economic indicators

<table>
<tr><td colspan="2" align="center">TITLE
D5.2: Final report on economic indicators for sustainability assessment of future electricity supply options</td></tr>
<tr><td>WORKPACKAGE N° 5</td><td>WP LEADER: EDF</td></tr>
<tr><td>CONTRIBUTING PARTNERS</td><td>PSI</td></tr>
</table>

Introduction

Economic criteria play a key role in assessing the sustainability of generation technologies, especially as higher costs are often traded against gains in the areas of environmental and social indicators. Economic criteria are not limited just to the cost of generation, but also to risk and operating characteristics that can have economic impacts on the generator, customers and society as a whole.

Abstract

The report addresses the process of combining economic data from other Research Streams and independently developed economic results to produce a range of quantitative and qualitative economic indicators. In particular Indicators such as “Direct labour”, “Autonomy of electricity generation” and “Flexibility of dispatch” were quantified within this task as they haven’t been analyzed by other streams. The indicators have been produced for each of the four countries used in the NEEDS assessment; France, Germany, Italy and Switzerland, using modifications related to country-specific boundary conditions. The values generated were used in the MCDA-assessment reported in deliverable D10.2.

Structure (organization of the work)

The final report is organized as follows, reflecting the organization of work:

- Introduction
- Description of economic indicators, including a brief description of indicator requirements, an overview of the indicators chosen, general methodology, data scenarios and sources, and country-specific adjustments.
- Brief listing of the NEEDS technologies and their characteristics necessary to understand the indicator results, as well as links to references for more complete technology documentation.
- Detailed presentation of indicators, any necessary discussion of indicator-specific methodology, graphical representation of the results, and discussion of any patterns based on technology, energy source or country.
- Overall discussion of the economic results and their contribution to Research Stream RS2b.

Conclusions

This report reviewed the economic indicators, including indicator requirements, data scenarios for assumptions, data contributors and the differentiation of the indicator assumptions between countries. It also very briefly reviewed the 26 different technologies contained in the NEEDS analysis, and referred the reader to other reports for further descriptions and full characterization. The report has then presented the nine individual economic indicators. A brief description of each indicator and the associated methodology used was then followed by a graph of the indicator results and discussion of the performance based on different technologies, energy resources and countries.

The generated indicators capture the economic strengths and risk of nuclear, the generally good performance of coal and lignite in most economic categories (their real weaknesses lie more in the environmental areas). Natural gas units are particularly good in fast response, moderate in capital and average cost, and quick to build at moderate cost. Most of their flaws have to do with the gas fuel – foreign dependence, fuel cost and hence dispatch cost. Renewables in general have a number of real strengths – employment, domestic and renewable energy sources, and low unit costs and construction times. Biomass differs from solar and wind chiefly in fuel costs and hence dispatch costs and fuel price sensitivity. Overall, it can be said that the economic indicators have been successfully quantified and succeed in measuring the economic criteria that were established.

Workpackage 6: Quantification of environmental indicators

TITLE **D6.1: Final report on quantification of environmental indicators for sustainability assessment of future electricity supply options**	
WORKPACKAGE N° 6	**WP LEADER:** Paul Scherrer Institut (PSI)
CONTRIBUTING PARTNERS	

Introduction

The main objective of this report was to provide estimated of the criteria and resulting indicators used to assess the potential environmental impacts of each technology, as well as to display the results for each of the four countries used in the assessment; France, Germany, Switzerland and Italy.

Abstract

The country-specific environmental burdens associated with the power generation are calculated using Life Cycle Inventories (LCI) established within RS1a of the NEEDS project. Certain technology characteristics are modified according to country-specific boundary conditions.
Calculation of the potential impacts arising from the complete technology chains (production and use of fuel; construction, operation and decommissioning of power plant; handling of waste; transport of fuels, materiels; etc.) was conducted using Life Cycle Inventories established within RS1a. The ecoinvent database (data v1.3) was used as source of background LCI data (ecoinvent 2006). Cumulative LCA results per kWh electricity produced (in the ecoinvent format, i.e. with a list of more than 1000 elementary flows) were the basis for the calculation of all environmental indicators. Since RS1a generated mostly generic (and in some cases site-specific) inventories, calculation of country-specific environmental burdens required the extrapolation of this specific technology inventories to the individual situations of the four countries assessed in the project. This resulted in adjustments being made to some of the technologies in order to account for specific wind conditions and solar irradiation, energy resource densities and effects on efficiencies due to average ambient air temperatures. The country-specific environmental burdens (basis for the quantification of the environmental indicators) were calculated using the SimaPro v7.1 LCA software.

Structure (organization of the work)

The report firstly gives a review of the characteristics required of an indicator to support a clearly defined and necessary criterion in the environmental as well as the overall sustainability assessment. It then goes on to present an overview of the environmental impact indicators, together with an explanation of the structuring of the criteria hierarchy employed in the assessment. A description of the technologies considered in the assessment is also given in order that the impacts resulting from the energy chains of each technology can be more easily related to specific characteristics. Finally, a more concise description of each indicator followed by the graphical illustration of the results for each of the four countries is provided together with an interpretation of the predominant observations.

Conclusions

This report gives a review of the procedures used in selection of the environmental impact indicators as well as the Life Cycle Assessment (LCA) methodologies employed for their assessment within the NEEDS Integrated Project. The basic characteristics of the 26 technologies and associated energy chains have been described. These were defined as being appropriate in 2050 according to “realistic/optimistic” development scenarios and the assessment methodologies were applied according to the various specific characteristics relevant to the four countries of Switzerland, Italy, Germany and France.

The environmental assessment showed that the nuclear technologies cause relatively very low impacts for most of the indicators. The Generation IV, European Fast Reactor (EFR), has significant advantages over the European Pressurized Reactor (EPR) since its recycling capabilities greatly reduces the quantity of high level radioactive waste needing long-term underground storage.

An overall distinction of the fossil fuelled technologies was shown to be far less clearly possible according to the indicators used. Concerning the application of CCS technologies, the large reductions in GHG emissions from the entire energy chains of fossil fuelled technologies was shown to be counteracted in a number of other indicators due to the reduced efficiencies of the power plants and, specifically for the post combustion and IGCC technologies, the pollution effects of the CO_2 separation mechanisms.

Solar thermal, solar PV and wind perform well, with only very few indicators reflecting significantly larger impacts; specifically the depletion of metal resources (with the exceptions of PV thin film and solar thermal) and, to a lesser extent, ecotoxicity and the production of chemical wastes.

Workpackage 7: Quantification of risk indicators

<table>
<tr><td colspan="2" align="center">TITLE
D7.1: Final report on quantification of risk indicators for sustainability assessment of future electricity supply options</td></tr>
<tr><td>WORKPACKAGE N°7</td><td>WP LEADER: Paul Scherrer Institut (PSI)</td></tr>
<tr><td>CONTRIBUTING PARTNERS</td><td>EDF</td></tr>
</table>

Introduction

This report builds on the earlier technical interim report (T7.1).

The objective of the report was to estimate quantitative indicators for severe accident risks for a set of technologies in year 2050 considered within NEEDS. The generated indicators were to be used within MCDA-applications for four countries, i.e. France, Germany, Italy and Switzerland.

Abstract

The present study within the NEEDS framework reviewed and substantially extended the knowledge on major accidents related to energy conversion activities, both in terms of technologies taken into consideration (covering fossil, hydro, nuclear and new renewables) and calculation of indicator values for current and future technologies. Based on the results for the individual energy chains the comparisons of selected accident indicators were carried out.

Within NEEDS, the ENSAD database has been first reviewed and consolidated as per year 2000, and then a total of 3024 new accident records for the period 2001-2005 have been added. Of these 2601 were attributable to the energy sector, of which 508 resulted in five or more fatalities.

Quantitative assessment of severe accident risks based on ENSAD and PSA data was supplemented by expert judgment for some of the new renewables. Chain-specific and comparative results are provided for major energy chains. Risk indicators were specifically calculated for the NEEDS technology set to be used in Multi-Criteria Decision Analysis (MCDA) of WP 10.

For the nuclear chain the simplified Level III Probabilistic Safety Assessment was fully implemented for two advanced designs and the selected sites. It builds on the estimated source terms and site characteristics.

Development and implementation of a qualitative assessment procedure (using ordinal scales) to estimate indicators related to the terrorist threat was successfully carried out.

Structure (organization of the work)

In the first part of the report the methods and approaches used are described, followed by the overview of the current state of ENSAD. In the second part the results obtained for each energy chain are reported; this included the relevant indicators.

Conclusions

This study demonstrates that the comprehensive historical experience of energy-related severe accidents available in ENSAD can be used as a sound basis for quantifying the corresponding damages. However, analyses should be complemented by a PSA approach when full chain risks are dominated by the power plant stage or when availability and applicability of historical experience is strongly limited, as it is the case for Western nuclear power plants.

Calculated risk indicators in WP7 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). For the terrorist threat three indicators were estimated, namely the potential for a successful attack (all chains), the potential likely consequences of a successful attack (all chains), and the proliferation of technologies or substances present in the nuclear electricity generation chain.

Comparative evaluations showed substantial numerical differences between the different energy chains and country groups analyzed. Expected fatality rates were lowest for western hydropower and nuclear power plants. Among fossil chains, natural gas exhibited the lowest risks followed by coal and oil, whereas LPG performed worst. When comparing country groups, energy-related accident risks are distinctly lower in the OECD and EU 27 countries than in non-OECD countries. Differences between OECD and EU 27 are mostly quite small, thus the more statistically robust estimates obtained for OECD countries can also be considered representative for the EU 27. Results for maximum consequences showed that very low accident frequencies can be associated with very large numbers of fatalities, as it is the case for hydropower in non-OECD countries and for hypothetical nuclear power plant accidents based on site-specific, simplified PSA.

Risk indicators led to valuable insights and conclusions, but above all they provided essential input to the NEEDS MCDA for the sustainability assessment of a defined, future (year 2050) set of technologies.

Workpackage 8: Quantification of social indicators

<table>
<tr><td colspan="2" align="center">TITLE
D8.1: Final report on quantification of social indicators for sustainability assessment of future electricity supply options</td></tr>
<tr><td>WORKPACKAGE N°8</td><td>WP LEADER: University of Stuttgart</td></tr>
<tr><td>CONTRIBUTING PARTNERS</td><td>Helio International</td></tr>
<tr><td colspan="2">Introduction

The aim of this work was the quantification of the social indicators formulated in WP2 of Stream 2b and adapted by WP3 of Stream 2b. The quantification of indicators was done for four selected countries: France, Germany, Italy and Switzerland. It should be noted that some social indicators were quantified in other work packages within RS2b (primarily WP7), based on natural science. These indicators were not explicitly addressed in D8.1.</td></tr>
<tr><td colspan="2">Abstract

In order to meet the needs of the NEEDS-project, the set of social indicators selected by the project had to be quantified within the financial and time constraints of the NEEDS-project. To deliver reasonably robust data for all the energy technologies, a series of large representative surveys would have been the optimal methodological approach. This optimal solution exceeded by far the financial constraints of WP8. As an applicable compromise, the research team decided to conduct semi-standardized expert phone-interviews to gain the data, which could not be obtained from other sources, existing datasets or literature research. A semi-standardized questionnaire was developed and translated into English, French and German. The questionnaire covered a total of 14 item batteries each pertaining to different indicators. The indicators were grouped into four thematic blocks.

1. Security and reliability of energy provision

2. Political stability and legitimacy

3. Social and individual risks

4. Quality of life

The quality and reliability of expert interviews depends on the quality of the selection process. In order to obtain an optimal solution, a databank including the address data of possible interview candidates of the four selected countries was set up. The interview candidates were selected by asking the following questions:

1. Who has relevant knowledge?

2. Who is most likely to give precise information?

3. Who is most likely to give relevant information?

4. Who of the potential informants is most likely to be available?

Ultimately a total of 60 experts were contacted for the survey 13 in Germany, 11 in Switzerland, 25 in Italy and 11 in France. Of those 35 volunteered to be interviewed Of the final sample 10 respondents hailed from Italy, 9 from Germany, 10 from Switzerland and 6 from France. The total response rate was 58.3 %.</td></tr>
</table>

The inputs obtained from expert interviews were used for the quantification of social indicators that were used in MCDA.

Structure (organization of the work)

The report first examines possible sources of indicators. In the second part the expert interviews are covered. This is followed by the evaluation and discussion of indicators.

Conclusions

Due to the lack of earlier relevant research on quantitative indicators for the social dimension of energy systems, most of the social indicators for the assessment of energy systems were measured by conducting expert interviews. Two indicators were measured directly by asking the respective stakeholders.

This is the first time that social indicators had been quantified for a large variety of energy technologies. As an innovative project, WP 8 delivered a first benchmark. But a broader empirical basis is desirable and should be pursued in the future.

Workpackage 10: Evaluations and analysis integration

<table>
<tr><td colspan="2" align="center">TITLE
D10.1: Final report on indicator database for sustainability assessment of future electricity supply options</td></tr>
<tr><td>WORKPACKAGE N°10</td><td>WP LEADER: PSI</td></tr>
<tr><td>CONTRIBUTING PARTNERS</td><td></td></tr>
<tr><td colspan="2">Introduction

A fundamental part of the MCDA evaluation framework is the establishment of a set of criteria and indicators to be used for the evaluation, and the creation of a database of indicators that actually embody the indicators that have been established. A separate report (D3.2) has provided an overview and description of the criteria set and associated indicators selected for use within NEEDS for the evaluation of electricity generating technologies and the associated fuel cycles. The present report describes how the indicators were collected from other Work Packages, completed with calculations within the present Work Package, combined into a database embodied in spreadsheet form and exported to the partner institution (IIASA) hosting the online web survey for the purpose of establishing stakeholder preferences.</td></tr>
<tr><td colspan="2">Abstract

The database includes 36 separate indicators for 26 future technologies (in the year 2050) in four countries, i.e. France, Germany, Italy and Switzerland.

The present report focuses on the process of combining and extending results obtained and documented in a number of Work Packages within RS2b, which in turn profited from a variety of experiences with criteria and indicators, accounted for in the literature. The focus is on presenting the requirements and process of creating the NEEDS sustainability database for future generating technologies.

There are reasons why the indicator values may vary between the four different countries. These reasons fall into the four different categories: resource availability, resource quality, thermal efficiency, and aspects related to the environment. Whenever necessary suitable country-specific adjustments were implemented.</td></tr>
<tr><td colspan="2">Structure (organization of the work)

The report first discusses data requirements from the point of view of functionality and practicality. Next country differentiation is discussed along with special adjustments of social indicators and the results obtained for all indicators are presented. Apart from all numerical results summary descriptions of NEEDS technologies are provided.</td></tr>
<tr><td colspan="2">Conclusions

The NEEDS database is an essential step in combining the technology analysis contributions from many different NEEDS participants and passing them along to the NEEDS multi-criteria analysis effort. It also serves the role of summarizing these contributions in one place, and making them readily available to the NEEDS stakeholders and general public for information and discussion.</td></tr>
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The design and execution of the database in its spreadsheet format has fulfilled the basic design requirements, and is well suited to future revisions and dissemination.

Workpackage 10: Evaluations and analysis integration

TITLE **D10.2: Final report on sustainability assessment of advanced electricity supply options**	
WORKPACKAGE N°10	**WP LEADER: PSI**
CONTRIBUTING PARTNERS	**IIASA**

Introduction

The ultimate goal of this Research Stream 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. The ultimate results of the technology roadmap include mapping the sensitivity of sustainability performance of technological options to stakeholder preference profiles.

Abstract

This report provides the overall summary of the process of carrying out a comprehensive and detailed assessment of sustainability of technologies of interest, as employed in this research stream. The elements of this process included the following steps:

- Establishment of criteria and indicators (with stakeholder input)
- Quantification of the technology- and country-specific indicators
- Establishing the indicator database
- Analysis of MCDA requirements
- Development of MCDA method(s) meeting the requirements
- Testing and adapting the method(s)
- Selection of the most suitable MCDA method
- Development of a web-based user interface for conducting the stakeholders preference survey and for running the MCDA
- Eliciting stakeholder preferences along with individual MCDA
- Analysis of the results of MCDA including comparison with total costs

The steps are described in the report. Results are analysed and commented.

Structure (organization of the work)

The report provides the motivation for developing and implementing the analytical framework used in RS2b. All steps within the process are described and illustrated. MCDA results are provided and commented.

Conclusions

A comprehensive framework for evaluating sustainability of electricity supply technologies including the associated fuel cycles has been developed, implemented and applied. Stakeholders were actively involved in various stages of the process.

In the final step, carrying out MCDA with stakeholder preference inputs, over 3000 stakeholders were invited to the survey, 346 registered to the MCDA site, 160 completed the MCDA. Considering the fact that MCDA is by far more demanding than a traditional survey, the number of completed surveys is satisfactory though somewhat below expectations. Nevertheless, the responses were adequate for drawing concrete conclusions.

The individual preference profiles have a decisive influence on the MCDA-ranking of technologies; this influence is particularly pronounced for technologies which have a highly differentiated profile, i.e. show top performance on a number of indicators but also weak relative performance on some other. Such technologies may be controversial; nuclear energy is the most pronounced example having these features. Thus, given equal weighting of environmental, economic and social dimensions and emphasis on the protection of climate and ecosystems, minimisation of objective risks and affordability for customers, the nuclear options are top ranked. On the other side, focusing on radioactive wastes, land contamination due to hypothetical accidents, risk aversion and perception issues, terrorist threat and conflict potential, the ranking changes to the strong disadvantage of nuclear energy. This emphasizes the need of further technological developments towards mitigating the negative impacts of these issues.

The ranking of fossil technologies highly depends on the emphasis put on the environmental performance, which in relative terms remains to be a weakness, more pronounced for coal than for gas. Renewables show mostly a stable very good performance, based on highly improved economics. Still emphasis on the economics along with flexibility and availability of stochastic renewables, and health effects of biomass technologies, leads to some shifts towards lower ranking.

Workpackage 12: Organisation and management of the surveys

<table>
<tr><td colspan="2" align="center">TITLE
D12.3: Implementation, evaluation and reporting on the survey on criteria and indicators for assessment of future electricity supply options</td></tr>
<tr><td>WORKPACKAGE N°12</td><td>WP LEADER: PSI (during this period)</td></tr>
<tr><td>CONTRIBUTING PARTNERS</td><td>ISIS, IIASA, EDF, HELIO International, University of Stuttgart</td></tr>
</table>

Introduction

Within Work Package 12 (WP12) of RS2b the survey questionnaire on sustainability criteria and indicators (in the following referred to as "Survey II") collected and analysed feedbacks from a large variety of stakeholders to obtain a consolidated and harmonized set of criteria and indicators to be used for the sustainability assessment of electricity production technologies.

Abstract

The questionnaire of Survey II has been designed to explicitly assess stakeholders' acceptance of the proposed set of sustainability criteria and indicators to be used for the assessment of electricity production technologies. The questionnaire consists of a total of 60 question assigned to five sections:

1. Stakeholder profile (5 questions + 1 question for language selection)
2. Feedback on individual indicators (40 questions)
3. General feedback on the indicator set (5 questions)
4. Socio-demographic and personal questions (4)
5. Feedback on the questionnaire (5)

Survey II resulted in an overall response rate of 9.7%, i.e. 275 completely filled in questionnaires could be analyzed. In conclusion, the criteria and indicator set proposed within NEEDS found a wide acceptance among stakeholders, with only few individual indicators considered controversial. Some minor modifications of indicator descriptions were applied. Finally, the outcome of Survey II provided timely input for the establishment of the Multi-Criteria Decision Analysis (MCDA) survey.

Structure (organization of the work)

The report provides a detailed account of the survey. This includes details of the questionnaire, organisation of the survey and analysis of the results.

Conclusions

The following conclusions were drawn:

- The response rate of 9.7% was at the lower end of the expectations.
- The complexity and extent of the survey were rather demanding.

- The number of qualified people in the stakeholder database showed substantial variation among countries.
- Participants were mostly highly qualified and educated, but there was an over-representation of the category Researcher/Academia, however when comparing individual response rates of stakeholder categories this was less distinctive.
- In general the indicator set proposed within the NEEDS project found a wide acceptance.
- Only few individual indicators were considered controversial, and only what concerns their necessity, but not their relevance or dimension assignment.
- A quite strong minority (44%) of participants opted for fewer indicators; i.e. in the range of 20.
- Most participants were residents from Switzerland, and to a lesser extent from Germany, whereas France and Italy were substantially less represented.
- Overall, the survey confirmed that the proposed set of indicators is comprehensive and accurate for the sustainability assessment of energy technologies. Therefore, only few indicator descriptions were slightly modified to increase the level of clarity and understanding, but only one indicator – namely “Work Quality” – was eliminated.

3. Conclusions

RS2b demonstrated the feasibility of indicator-based sustainability assessment for current and future technologies and has the potential to guide in a structured manner the debate on the future energy supply and support informed decisions.

The main achievements of RS2b include:

- Pioneering work on the establishment and quantification of technology-specific social indicators.
- Establishment of the full set of sustainability indicators covering environmental, economic and social dimensions, with strong support from the engaged stakeholders.
- Quantification of the full set of sustainability indicators and establishment of a corresponding database for four countries.
- Development of new MCDA methods and web-based MCDA implementation.
- Application of MCDA with a variety of stakeholders, demonstrating the merits of the process, strengths and weaknesses of the analyzed technologies, and the unavoidable impact of stakeholder preferences.

The implementation was done for electricity generation technologies including the associated fuel cycles. Improvements of the consistency of the indicators and more robust quantifications of some of the “soft” social indicators are desirable and feasible. Furthermore, the extensions of the scope to include heating technologies needs to be pursued. The same approach can also be applied to the current and future mobility options. Eventually, the sustainability evaluation of alternative energy scenarios could be undertaken based on the indicators for specific technologies. The geographic scope of the evaluations can also be extended much beyond the current applications covering just four European countries.