Measuring the sustainability of products: The Eco-Efficiency and SEEBALANCE® analysis

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Abstract BASF has pioneered the assessment of the sustainability of chemical products and production processes through the development and use of its Eco-Efficiency Analysis as well as SEEBALANCE® analysis. The tools are used by BASF and its customers to assist strategic decision-making, facilitate the identification of product and process improvements, and enhance product differentiation as well as to support the dialogue with opinion makers, NGOs and politicians.
Both Eco-Efficiency Analysis and SEEBALANCE® analysis are comparative methods; the advantages and disadvantages of several alternatives are assessed according to a predefined customer benefit.

1 Introduction

The Eco-Efficiency Analysis uses a Life Cycle Assessment approach with the whole life cycle of a product being considered. Next to the environmental impact, which is assessed based on ISO14040 and ISO14044 norms, all economic factors are taken into account. The SEEBALANCE® also considers social impacts of products and processes.

The finalization of over 450 analyses until today show the wide range of applicability of the methodology. Several examples show, how the methodology can be applied. It helps with its holistic approach to answer questions of sustainability in the fields of R&D, strategy development and marketing. It enables industries along the whole supply chain to improve products and processes for more sustainable solutions.

The multicriterial life cycle based approach in combination with a defined aggregation and summary of single results ends in an easy understandable graph.

Different scenarios can be worked out additionally to support decision-making processes. New developments of the methodology will show additional aspects in the sustainability evaluation.

The Eco-Efficiency Analysis compares the economic and environmental pros and cons of each alternative for defined customer benefit or functional unit over the whole life-cycle. Thus, eco-efficient solutions are those which provide a specific customer benefit more effectively than others from the financial and environmental point of view. The methodology has been validated by the German TÜV Rheinland in 2002 and by the US National Sanitation Foundation (NSF) in 2009.
In this context, SEEBALANCE is the extension of Eco-Efficiency-Analysis by including social factors in the evaluation. They are also life cycle based and give information on social impacts of the different alternatives.

Eco-Efficiency Analysis and SEEBALANCE [1], [2], [3] are useful for:

- Supporting strategic decision-making
- Marketing: communicating with external customers
- Prioritizing R & D activities
- Activities in the field of stakeholder dialog and political decision-making processes

2 Design and preparation of Studies

2.1 First steps and work flow

Every Eco-Efficiency Analysis passes through several key stages. This ensures consistent quality and comparability of different studies. Environmental impacts are determined by life-cycle assessment (LCA) and economic data are calculated using usual business or, in some instances, national economical models. In the SEEBALANCE social impacts are determined by different factors out of statistics for different sectors which are relevant for the defined customer benefit.

The basic preconditions are:

- Products or processes studied have to meet the same defined customer benefit.
- The study should follow a holistic approach by considering economy and ecology in the Eco-Efficiency Analysis and additional social aspects in the SEEBALANCE.

The sustainability evaluation is worked out by following specific and defined ways of calculations:

- Definition of goal and scope
- Definition of customer benefit and system boundaries
- Data collection
- Preparation of a specific life-cycle analysis for all investigated products or processes according to the rules of ISO 14040 and 14044.
- Calculation of total cost from the customer viewpoint.
- Determination of impacts for each single LCA indicator over the whole life-cycle including energy consumption, resource consumption, emissions to all media, toxicity potential, risk potential and land use.
- Calculation of relevance and social factors for specific aggregation and weighting of LCA results
- Determination of relative importance of ecology versus economy
- Creation of an Eco-Efficiency portfolio respectively of final results
- Analyses of weaknesses, scenarios, sensitivities, and business options
- Suggest strategic recommendations

The relevance of each environmental category and also of economic versus environmental impacts is evaluated using national emissions and economic data [4].

The single results are displayed in specific graphs and will afterwards be summarized to an environmental or social fingerprint (SEEBALANCE) in the first step. This step is only a normalization step showing the best and the worst alternatives in the single categories. All other alternatives are ordered relatively to them. The Fingerprint makes it possible to easily visualize the trade-offs between alternatives by clearly showing where certain alternatives performed well and where they had less desirable results. However, to clearly understand which alternative has the overall lowest or highest impacts and thus understanding which impact categories are important in driving the results of the study, an additional weighting procedure is required in order to combine the normalized results reflected in the fingerprints into one single score.

Therefore, in the second step they are aggregated to environment and social axis positioning the alternative with the highest and the lowest burden relatively on a summary axis (Figure 1). This weighting process involves incorporating both relevance factors with societal weighting factors. The relevance factors help put into context how important or significant an environmental impact is for each individual Eco-Efficiency Analysis. The relevance factors calculated are unique for every study and depend on the specific results of the study and on which region of the world the study applies. Advantages of this approach are that high burdens or unwanted impacts are more heavily weighted than relatively low ones and changes in society's view relative to each individual impact category can be included.

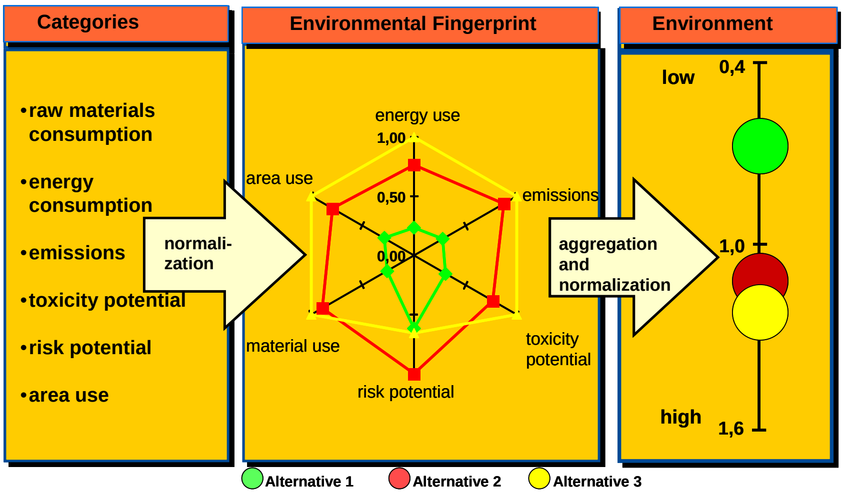

Fig.1: **From single indicators results via the environmental fingerprint to aggregated axis**

2.2 Case study for heating systems

The reason for carrying out the study is to compare alternative systems for providing space heating and hot water for domestic buildings (detached houses, new developments), examining both renewable and non-renewable fuels. The Eco-efficiency Analysis (EEA) was based on the ASUE study (ASUE: Arbeitsgemeinschaft für sparsamen und umweltfreundlichen Energieverbrauch

e.V. Germany: Comparison of heating costs in new developments, 2009); the EEA study examines a subset of the systems in the ASUE study and adds some additional heating systems.
The goal of the Eco-efficiency Analysis is to compare the different alternatives for their environmental and economic advantageousness as of now and in the near future:

- Established commercially available technologies based on
  - fossil fuels (gas or fuel oil condensing boiler both with additional solar water heating, district heating block heat and power plant)
  - Renewable sources (wood pellet boiler, split logs boiler)
  - New commercially available technologies (brine-water and air-water heat pump, micro combined heat and power Stirling engine)
  - New, not yet commercially available technologies (fuel cells).

The functional unit (customer benefit) of this EEA study is the provision of space heating and hot water for a single-occupancy detached house (floor area 150m2) during one year, corresponding to annual space heating requirements of 7,500 kWh/a and annual hot water requirements of 1,875 kWh/a [p. 6]. The reference flows of space heating and hot water are provided by the following alternatives:

1) Natural gas condensing boiler combined with solar thermal hot water;
2) Fuel oil condensing boiler combined with solar thermal hot water;
3) Split logs boiler;
4) Wood pellet boiler;
5) Brine-water heat pump (powered by grid electricity);
6) Air-water heat pump (powered by grid electricity);
7) Natural gas-fed micro combined heat and power (CHP) Stirling engine;
8) Natural gas-fed mini CHP fuel cell (SOFC);
9) Natural gas-fed mini CHP fuel cell (PEMFC);
10) District heating block CHP

The calculation of the energy requirements per heat and hot water output was performed in accordance with the applicable standard DIN 4701–10 (as in the ASUE study). Different life spans were assumed for the systems, discounting emissions and costs accordingly. It was shown that the results are not particularly sensitive to the life span assumptions.

The life cycle inventory uses basic data on energy carriers and materials from acknowledged life cycle databases (Ecoinvent, Boustead).
All in all, these data are deemed suitable for compiling the life cycle inventory (LCI) of this product system in accordance with ISO 14040 and 14044.

2.3 Case study results

Systems based on natural gas as the natural gas condensing boiler combined with solar thermal hot water and the district heating block CHP resulted the more eco-efficient solution.
The CHP Stirling engine and heat pumps were found to be less eco-efficient due to higher costs and similar (or, only slightly lower) environmental impacts. Fuel cells were considered to offer potential in case of future cost reductions. The split logs boiler was found to perform somewhat less eco-efficient than the above. The study concluded that the worst alternatives from an eco-efficiency point of view are the fuel oil condensing boiler (with solar thermal hot water) due to environmental impacts, and the wood pellet boiler due to capital costs. The result is shown in an Eco-Efficiency Portfolio in Fig. 2. The whole study was checked with a peer review worked out by the German DEKRA.

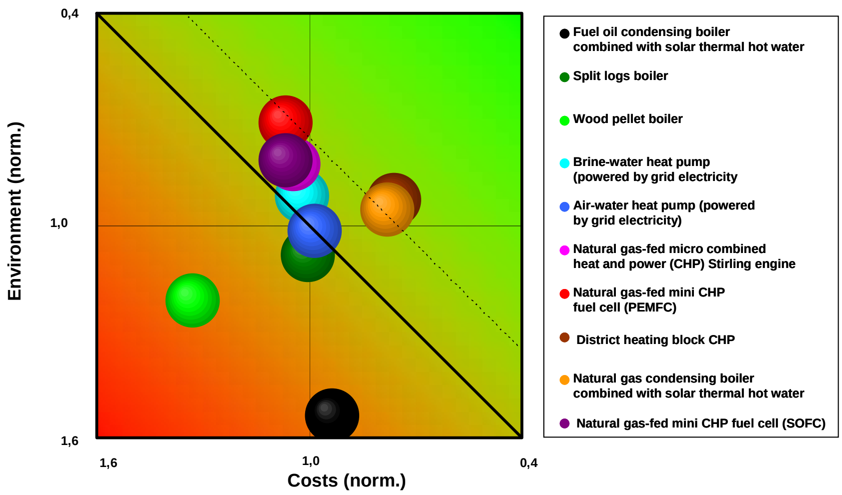

Fig.2: Eco-Efficiency Portfolio of heating systems in Germany

3 SEEBALANCE Method, assessing several social impact categories

3.1 Methodology

The SEEBALANCE®, an instrument that includes an assessment of a product's social impacts in addition to the economic and environmental ones is an innovative tool which aims is to unify and quantify the performance of all three pillars of sustainability with one integrated tool for product assessment. The social impact is assessed by several evaluation categories representing different stakeholders. Assessed are indicators such as the number of jobs and the number of working accidents occurring during production. Special advantages or risks during the application of the products are also taken into account. The social indicators are summarized in a social fingerprint, similar to the ecological indicators.

For the SEEBALANCE® it is necessary that all social indicators have a quantitative relation to the production volumes (e.g. "occupational diseases per kg product"). With this format it is possible to relate all inputs of the ecological life cycle assessment to the social indicators. Therefore different statistical databases are combined to relate social indicators to production volumes.

This so-called sector assessment is based on the "Nomenclature générale des activités économiques dans les Communautés Européennes" [short: NACE] that classifies all industries into different branches. All products can be linked to these NACE codes over the product classification list [CPA= Classification of Products by Activity]. The numbers for the official statistics in Europe [see **Fehler! Verweisquelle konnte nicht gefunden werden.**] are often stored in this format. The NACE codes classify the industries into different branches for this region (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). ISIC, the International Standard Industrial Classification can be used for worldwide analysis.
Social impacts are - as described before - determined on the basis of five stakeholder groups: consumer, employee, national community, international community, and future generations with different subcategories.
Weaknesses and potentials driving social impacts can easily be identified for the indicators representing a given stakeholder. As in the Eco-Efficiency analysis results are calculated first for each indicator. The individual indicators per

stakeholder are subsequently aggregated via the weighting factors to form the overall value for the stakeholder. The calculated impacts of the stakeholder are normalized with respect to one another, the least favorable alternative being assigned a value of one and the other alternatives lying between zero and one. This method is used for all other stakeholder groups of the social impact axis. These stakeholder issues are aggregated with the weighting factors.

3.2 Examples

The study for heating systems was designed only for an Eco-Efficiency Analysis. The next step to the SEEBALANCE was not worked out so far with this example. To give an idea how the SEEBALANCE method works, another study will be introduced. It was a study that was prepared in the development process of REACH to show how a Socio-Economic Analysis can be applied. In this example to alternatives for the production of an electrical motor for washing machines were evaluated. One alternative uses a wire coating process that needs specific solvents and ends in a so-called enamelled wire. Enamelled wire is an important component of almost all electrical devices. A major field of application is the use in small motors, for example in household machines such as washing machines, dishwashers, refrigerators, etc. The other alternative that was considered, uses a different construction and winding technology for the production of the motor. In this case, there was no wire coating needed, but the life time of the motor was reduced.

The case study therefore evaluates socio-economic benefits and drawbacks of the substance used as solvent in wire enamels to produce winding wire for the use in a small motor in washing machines compared with the different construction of the motor.

3.3 Results

The results of the evaluation of employment for both the scenario that uses the wire coating technology and the alternative scenario that does not use this technology are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** as number of employees.

Per user benefit – using the washing machine over 10 years – 46% more people are employed in the wire coating scenario than the alternative scenario. In the wire coating scenario, production of the enamel and using it for the coating of copper wire creates jobs that are lacking in the response scenario. Compared to the motor production, only few people are employed in this sector per user benefit. Therefore, the production and use of the enamel only has a small effect on employment. In the alternative scenario, a second motor has to be produced, which increases the number of people employed per user benefit considerably. This example considers only one social criterion, the summary of all of them showed overall advantages for the alternative of wire coating.

<table>
<tr><th colspan="2"></th><th>Result of sector assessment</th><th colspan="2">Wire coating scenario</th><th colspan="2">Alternative scenario</th></tr>
<tr><th colspan="2">Module / social impact</th><td>Employees (No./1 million kg)</td><td>Quantity (kg/UB)</td><td>Employees (No./1 million UB)</td><td>Quantity (kg/UB)</td><td>Employees (No./1 million UB)</td></tr>
<tr><td colspan="2">Production of CMR substance</td><td>6.95</td><td>0.058</td><td>0.4</td><td>0</td><td>-</td></tr>
<tr><td colspan="2">Binder production</td><td>3.31</td><td>0.105</td><td>0.23</td><td>0</td><td>-</td></tr>
<tr><td colspan="2">Diluent production</td><td>1.84</td><td>0.029</td><td>0.05</td><td>0</td><td>-</td></tr>
<tr><td colspan="2">Copper wire production</td><td>12.34</td><td>0.574</td><td>7.1</td><td>1.15</td><td>14.19</td></tr>
<tr><td rowspan="2">Coating of wire</td><td>(per) kg wire</td><td>68.55</td><td>0.145</td><td rowspan="2">10.14</td><td rowspan="2">0</td><td rowspan="2">-</td></tr>
<tr><td>(per) MJ electricity</td><td>0.07</td><td>2.9232</td></tr>
<tr><td colspan="2">Lubricant</td><td>3.89</td><td>0.029</td><td>0.11</td><td>0</td><td>-</td></tr>
<tr><td colspan="2">Motor production</td><td>13.04</td><td>5.22</td><td>68.08</td><td>10.44</td><td>136.17</td></tr>
<tr><td colspan="2">Replacement of motor</td><td>68.55</td><td>0</td><td>-</td><td>0.0001</td><td>0.01</td></tr>
</table>

Tab.1: Employment rates as social factor

The single results of all three dimensions of sustainability can be displayed in three single fingerprints which can be aggregated as described in the Eco-Efficiency Analysis methodology to separate aggregated data sets. The three summarized data axis can be summarized in an overall result (Fig. 3).

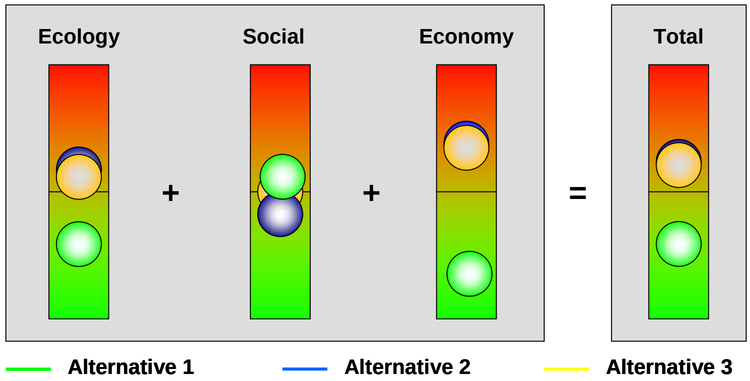

Fig.3: Display and aggregation of all three pillars of sustainability to a final result

3.4 Conclusion

A final result is needed because decision-making processes need clear and easy understandable information. In a typical sustainability evaluation, there are often huge ranges of single data which can not be understood in a defined objective way without the help of a methodology that aggregates all the information to a final result by using defined algorithms.

4 References

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