Resource efficiency potential analysis as tool for life cycle management

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Abstract

The paper describes the resource efficiency analysis of technologies, products and strategies as an important criterion for life cycle management. Using the results of the task 1 of the project “Material Efficiency and Resource Conservation” (MaRess) it is shown how the life cycle wide resource use of technologies, products and strategies can be calculated and how their resource efficiency potential can be quantified on a national level. The project MaRess started with a literature- and expert-based identification process, in which 21 topics were chosen to be assessed in terms of their resource efficiency potential. To assess the life cycle wide resource use, the material footprint has been applied as a reliable indicator. With one concrete example it is shown how the resource use of specific applications can be analysed. Additionally a conclusion of the overall project is given. The results of the paper show that resource efficiency can be used as a basis for life cycle management, thus resulting in a remarkably lower natural resource use.

1 Introduction

It has become obvious that a life cycle perspective is essential when considering sustainability aspects. However, there are several ways to assess the life cycle impacts of processes, goods and services regarding various impact criteria. One central sustainability aspect is the use of natural resources. Present resource use leads to ecological, economical and social problems but despite of increasing prices for natural resources during the past 30 years the global consumption of natural resources is still growing [1]. Resource efficiency is already on the political agenda (EU and national resource strategies) but there are still remarkable knowledge gaps concerning the effectiveness of measures promoting resource efficiency in different fields.

Therefore, identifying resource efficiency potentials within resource intensive sectors is crucial. This paper describes the methodology of a resource efficiency potential analysis that can be used as an easy-to-apply tool for life cycle management. The paper is based on results from a joint effort of 9 German research institutions for assessing resource efficiency potentials in the framework of the German project "material efficiency and resource conservation" (2007-2010) [2].

2 Methodology

One goal of the project was to identify and assess appr. 20 topics for increasing the resource efficiency in Germany. The methodology used is described in this section.

2.1 Selection process

First of all, measures increasing resource efficiency have to be identified. The measure should be applied in a resource-intensive sector to reach the best possible saving effect. In this project topics where categorised in technologies, products and strategies. At the beginning a desk research and a survey was made. The survey had the aim of enriching and broadening the overview from the desk research with further products and technologies. It was addressed to experts from university and non-university research institutes and organisations but also to associations, initiatives and companies. As a first result the technologies, products and strategies identified were collected in a pre-evaluation list.

In the second step, a first internal evaluation of the pre-evaluation list took place. The evaluation consisted of a general evaluation according to the qualitative criteria resource input, resource efficiency potential, and economic relevance. Based on this evaluation process a first evaluated list of measures was made (Top 250 topics).

The third step was the criteria-based evaluation by experts. On this basis, a ranking was performed for the evaluated measures. The ranking was discussed, revised and validated by additional experts. The selection of the final measures to be analyzed was done by experts from different universities and companies according to a qualitative evaluation based on existing data. The criteria were defined as follows:

1) Other than natural resources-related environmental impacts,
2) Feasibility,
3) Economic relevance,
4) Communicability,
5) Transferability.

As result of the selection process, the final list of measures to be analysed (Top 21 topics) consisted of resource-intensive sectors with possible technologies, products and strategies than can be used to reduce resource consumption. The selected measures cover a broad field of relevant technologies, products and strategies in the fields of energy supply and storage, Green IT, transport, foodstuffs, agricultural engineering, design strategies, lightweight construction and "utility instead of possession".

2.2 Calculation of resource use

For each measure of the final list an example of a specific technology, product or strategy was identified. The example had to be a possibly more resource efficient technology, product or strategy to be compared to the current status. The resource use was quantified on the basis of the material footprint according to the MIPS concept [3,4,5]. MIPS means the life-cycle-wide "Material Input Per unit of Service". MIPS allows estimating the input oriented environmental impact potential of a product used for providing a specific service or benefit. The material input (MI) is measured in kilograms or tonnes of material (incl. energy carriers). The unit of service (S) has no predefined dimension. It depends on and must be defined in each individual case. The following categories of resources are accounted separately: biotic (or renewable) raw materials, abiotic (or non-renewable) raw materials, water, air, and earth movement in agriculture and forestry (incl. erosion). MIPS can be easily calculated by using existing material intensity data. Material intensity data relate all material inputs (material and energy which are necessary for the manufacture of goods or for the provision of a service) to a mass unit of resources per unit of input (e.q. kg/kg or kg/kWh).

2.3 Potential analysis

The potential analysis was performed by comparing the material footprint of the resource efficient option assessed to the one of the current status option. To calculate the overall resource saving potential of the resource efficient option, the resource consumption was scaled up to a national level.

Besides quantifying the material inputs during the whole lifecycle and potentials for the resource efficiency, measures for action should be discussed in order to show how these potentials could be reached.

A problem here is to consider rebound effects: For example the use of efficient technologies might result in lower prices and higher consumption, which can lead to negative side effects such as an overall increase of resource consumption. To regard further aspects than resource consumption and to include possible rebound effects in the analysis, the five qualitative criteria used for the final selection in the earlier process (see 2.1) were assessed on a qualitative basis.

3 Example: Analysis of wind energy

The energy sector is one of the most important sectors in terms of resource consumption and thus also for increasing resource efficiency [6]. As a consequence, renewable energies were one of the fields identified within the selection process as described in 2.1. To give an example of a potential analysis made in the project the analysis of the first German offshore wind farm (OFFWF) “alpha ventus” and a fictious onshore wind (ONWF) farm based on [7] is described in this section.

3.1 Technology analysed

At present, wind energy is the major renewable energy source for electricity generation in Germany, having supplied about 39 TWh/a in 2009 [8]. The amount is expected to triple by 2030 [9], which is mainly due to climate change policy goals in Germany. Beside cutting greenhouse gas emissions, increasing resource efficiency is a key strategy for environmental politics of the German government [10]. In this context the question arises, which amount of natural resources wind farms consume, especially when built offshore. Therefore, an analysis of the resource use of an offshore and onshore wind farm and their resource efficiency potential is shown. As offshore wind farm the German OFFWF named „alpha ventus“ was used in the calculations. In addition, an analysis of a fictitious ONWF with the same number of turbines and the same amount of installed power (60 MW) as „alpha ventus“ was conducted.

3.2 Material Inventory and calculation of resource use

Masses and basic construction materials as well as the energy consumption of the wind farms over the whole life cycle were collected. Beside the wind turbines, the offshore transformer station and the power cable to the grid connection point were analysed. As system border the point of connection to the inland high voltage power grid was chosen.

The material inventories (weights and types of constructions and components) were mainly provided by the specific manufacturers. In case of missing manufacturing data, estimations of experts and literature data of existing life cycle studies such as [11,12] were used.

Based on the material inventories collected, the amounts of energy, transport distances and the material intensity data available [13], the overall resource consumption of the specific system was calculated.

3.3 Results of the resource efficency potential analysis

The abiotic raw material consumption of the OFFWF (177 kg/MWh) is about twice as high as the demand for the ONWF (87 kg/MWh). Water and air consumption between the ONWF and OFFWF differ less: The OFFWF requires 826 kg of water per MWh and 9.1 kg of air per MWh, while the ONWF needs 626 kg and 7.9 kg, respectively. The reason for the higher resource requirements of the OFFWF is mainly due to the undersea energy cable that connects the wind farm with the onshore power grid.

To show the influence of a growing energy production of wind energy on the resource consumption for the German power mix, a scenarios was generated. In this scenario the part of wind energy for electricity generation grows from 6.6% (year 2008) to 17.2% (offshore 5.4%), as assumed in the scenario of the German Ministry for the Environment [6]. The electricity generation through coal is reduced to the same amount (-10.6%). Apart from this the power mix stays equal as in 2008.

By comparing the results with the resource consumption of the German power mix, it becomes obvious that the wind farms analysed are very resource efficient: The "scenario wind" induces a reduction of 25% with abiotic materials. Also the inputs in the resource categories "water" (-11%) and "air" (-22%) are lower (s. Fig. 1). Also the qualitative assessment criteria showed the advantages of wind power.

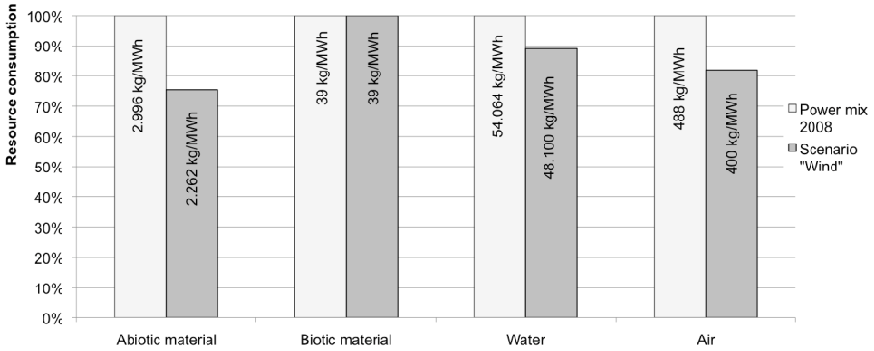

Fig.1: **Resource efficiency potential through an increased share of wind energy within the German power mix [4]**

4 Conclusions

Considering growing global energy consumption as well as the pressure to reduce resource consumption and climate gas emissions, an increasing capacity of wind energy offshore and onshore can be recommended for Germany. From a producer's or consumer's point of view, purchasing wind power can be recommended in order to reduce life-cycle wide resource consumption and environmental impacts.

In general, the results of the MaRess project show that the resource efficiency potential analysis is a reliable tool to identify measures for life cycle management. As assumed during the selection process, substantial resource saving potentials were identified for most of the 21 measures selected [2]. Based on the results possible recommendations for the selected fields of action were drawn up (see Tab. 1).

In many cases, the resource efficiency potentials calculated go hand in hand with other aspects of sustainability. However, the resource potential analysis may also open up new perspectives. For instance the use of electric cars was proved to reduce abiotic resource consumption only in a scenario based on wind power use but not under the prevailing German power mix [2].

Especially when estimating rebound effects it is important to note that resource efficiency is only one of many criteria in the scope of a sustainability assessment [14]. However, the results of the qualitative analysis were depending on existing literature and aquiring data for the cases studied would have been laborous in comparison to the resource efficiency potential analyses performed.

Overall, many challenges of a potential analysis can be deduced to fundamental problems of data availability, especially of life cycle data. There is great need for integrating the resource perspective in existing life-cycle databases to ensure a quick and easy application of the MIPS indicator as an essential part of a resource efficiency potential analysis.

Tab.1: Overview of the 21 measures analysed and the related field of actions [12]

Fields of action and assigned potential analyses
Cross-sectional technologies and enabling technologies: "Door openers" for resource efficient applications • Resource efficiency in grey water filtration using membrane technologies • Comparison of direct and indirect storage for electric vehicles • Resource efficiency potential of energy storage – resource efficient heat storage • Resource efficiency potential of insulation material systems
Renewable energies facilitate substantial resource savings • Resource efficiency potential of wind and biomass power • Resource efficient large-scale energy production: potentials of Desertec • Resource efficient energy production by photovoltaics
The growing ICT market needs a careful resource management • Green IT: Resource efficiency potential of server based computing • Green IT: Resource efficiency increase with ICT – comparison of displays • Resource efficiency potential of recycling small electric and electronic appliances by recoverage from household waste using an RFID labelling of primary products
Food – both production and consumption need to be considered • Resource efficiency potential in food production – Example: Fish • Resource efficiency potential in food production – Example: Fruits • Resource efficiency potential in food production – Example: Vegetables • Resource efficiency potential of intelligent agricultural technologies
Traffic – Infrastructure bears higher resource efficiency potential than drive systems • Assessment of resource efficiency potential in freight traffic • Resource efficiency potential of electric vehicles
Integrating resource efficiency into product development • Consideration of resource efficiency criteria in product development processes • Resource efficiency potential of the implementation of light-weight construction • Resource efficiency potential of high-strength steel
Resource efficiency-oriented business models: product-service systems require rethinking • Resource efficiency potentials of new forms of "using instead of possessing" in assembly facilities • Resource efficiency potential of production on demand

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