



BOOSTING RESOURCE PRODUCTIVITY

by Adopting the Circular Economy



Christian Ludwig and Cecilia Matasci (Eds.)
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Cover

Markus Fischer, PSI

A creative assembly of photographs and symbols representing the importance of establishing a circular economy for solving the trade-off between a healthy environment and a prosperous, but resources intensive, society.

16. THE GUIDELINE SERIES VDI 4800 RESOURCE EFFICIENCY: AN APPROACH FOR INCREASING RESOURCE EFFICIENCY WITH THE AIM OF CONSERVATION OF NATURAL RESOURCES IN THE INDUSTRIAL SECTOR

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Abstract

In 2011, the Association of German Engineers (VDI) started working on a set of guidelines towards increased resource efficiency. These guidelines represent a framework that defines resource efficiency and outlines considerations for the producing industry. A special guideline for SMEs is included as well as guidelines on methodologies for evaluating resource use indicators, such as the cumulative raw material demand of products and production systems.

Resource efficiency, defined here as the relationship between a specific benefit or use and the natural resources that need to be spent or consumed to attain this benefit or use. It can be evaluated by defining a function which expresses the specific benefit and quantifies the resource requirements through a set of indicators (use of raw materials, energy, water, land and ecosystem services including sinks). The results from this also depend on the system boundary parameters and the allocation rules for by-products and waste treatment options. Optimising resource use is possible at all stages of a product's or production system's life cycle chain (raw material extraction, production and manufacturing, use and consumption, and the end-of-life stage).

VDI guidelines are widely accepted across Germany's industrial sector and therefore represent an important means of mainstreaming resource efficiency in this target area. As well as providing a methodological framework, the guidelines describe strategies and measures towards increasing resource efficiency, and they enable industrial producers and service providers to identify potential areas of improvement. The full article presents an overview of the methodology and contents of these guidelines and discusses their impact in achieving absolute reductions in the industrial use of natural resources.

Keywords: resource efficiency, life cycle thinking, guidelines, products and production systems, standardization

Introduction

Resource protection and the efficient use of natural resources are some of the biggest challenges of the 21st century. Therefore, Germany addressed the topic of natural resource efficiency and conservation in its 2002 sustainability strategy (Federal German Government, 2002). The topic of resource efficiency received further strategic grounding on a political level through the "ProgRess" German Resource Efficiency Programme (Federal German Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2012).

The motives to save resources or use them more efficiently are varied and depend crucially on the perspective of the actor. The main focus to significantly increase the efficiency of utilization of natural resources is on the private sector, as this is responsible for a very large share of exploiting and consuming natural resources (Baron et al., 2005). From a corporate perspective, primarily economic objectives are pursued in order to ensure competitiveness in the implementation of resource efficiency measures. Trigger for resource-efficient action are:

- Expected general cost savings (e.g. material and energy cost savings)
- Long-term hedge against rising commodity prices and reduction of dependence on raw materials
- Externally formulated demands and expectations on the company / product.

Research has shown that small and medium-sized enterprises (SMEs) in several sectors of the German economy could potentially achieve savings between EUR 5 billion and EUR 11 billion per year within a timespan of seven years (Baron et al., 2005). In the processing industries, which also carry very high material costs, the potential savings associated with natural resource efficiency are estimated at around 7 percent (Schrüter et al., 2011). Nevertheless, the path towards improved resource efficiency in companies is frequently not followed as consistently as it could be (Schmidt and Schneider, 2010).

A fundamental problem with previous analyses of how businesses can increase their resource efficiency – and thereby achieve the cost savings outlined above – is that the methods and programmes deployed today are almost entirely focused on the operative material flows within a company (“gate-to-gate”). Significantly larger savings goals can be achieved when the entire life cycle of a company’s products and services is taken into consideration (“cradle-to-grave”) (Lang-Koetz et al., 2010; von Geibler et al., 2011; Rohn et al., 2013, 2014). Furthermore, in the context of resource efficiency, there has to date been a lack of unambiguous definitions and guidelines. Similarly, there are currently no nationally or internationally agreed evaluation and calculation methods and procedures to be found in this field. Only once provided with a strong definitional basis will companies be able to develop meaningful resource efficiency strategies to identify and implement specific measures.

With more than 154,000 members, VDI is Europe’s biggest science and technology association, and, next to the German Institute for Standardization (DIN), one of the most important standard organisation in Germany. Given its wide-ranging base of technical expertise, VDI decided in 2009 to embrace resource efficiency as a cross-sectional topic. The objective was to close terminological and definitional gaps by streamlining both the terminology and the basic methods of calculating and evaluating the resource efficiency of products, processes, services and companies. Today, a framework of rules has been devised. To VDI, “resource efficiency” means that all natural resources such as raw materials, energy, air, water and land (soils) are exploited as responsibly and efficiently as possible, and that environmental impact is reduced to a minimum. Any evaluation of resource efficiency can therefore only take place if the deployment of all natural resources is quantified and viewed in context. Quantification is based on a set of indicators, each of which represents a resource category. The indicators are modular; when combined, they form a basis for evaluating the utilization of natural resources.

VDI 4800 Part 1 Resource Efficiency – Methodical Principles and Strategies defines general terms pertaining to resource efficiency. It also provides descriptions of the resource categories, general assessment principles and rules, and recommendations on how to conduct resource efficiency analyses and evaluations. The final version of this VDI standard was released in February 2016 (VDI 4800 Part 1: 2016-02). In-depth profiles of the individual resource categories and their associated indicators and assessment options will follow in further VDI Standards on Resource Efficiency (see Figure 16-1), which will be discussed briefly below.

VDI 4800 Part 2 Resource Efficiency – Evaluation of Raw Materials Demand was compiled for the “Raw Materials” resource group, including Water and Land as Input-materials. This

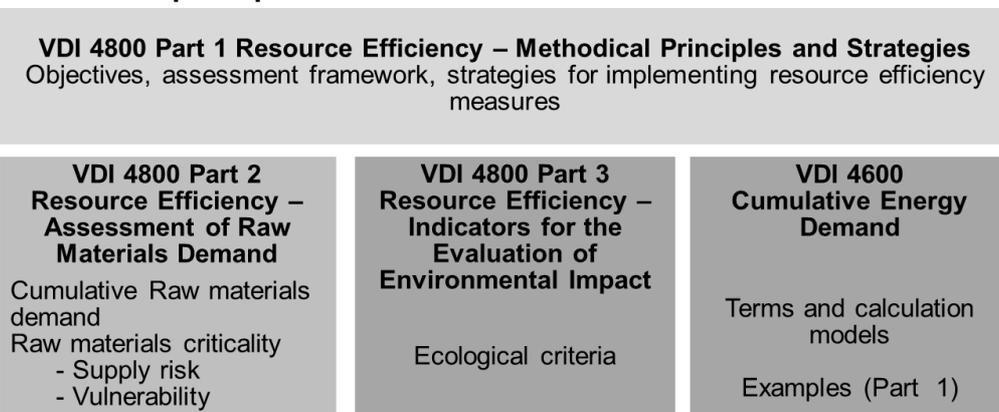
standard describes an assessment model for raw materials including water and land/soil and was released as draft version in March 2016 (VDI 4800 Part 2: 2016-03). In VDI 4800 Part 2 the cumulative raw material consumption (German: kumulierter Rohstoffaufwand, KRA) is accounted in four categories: Construction materials and industry minerals, energy feedstock, metals and biotic raw materials. KRA_{metallic} can be approximated by the inverse of the metal concentration in the respective ores. Other models are provided for assessing the scarcity of raw materials – their so-called criticality. This enables criticality evaluations for abiotic materials (metallic and non-metallic), fossil energy materials, biotic materials, and water and land/soil.

VDI 4800 Part 3 Resource Efficiency – Indicators for the Evaluation of Environmental Impact provides a model for assessing the environmental impact of products, processes and product-service systems as part of a resource efficiency analysis. A set of scientifically valid indicators is proposed that essentially references the sink properties displayed by different environmental media.

The third tier of resource efficiency analysis is VDI 4600 Cumulative Energy Demand, which was first introduced in 1997 and last updated in 2012. This provides guidelines on how to assess cumulative energy demand (KEA) and cumulative energy consumption (KEV). The cumulative energy demand represents the overall expenditure of primary energy (in energy units) arising from, or attributable to, the production, use or disposal of a product or service. This set of indicators forms the basis of evaluation.

In addition, VDI 4801 Resource Efficiency in Small and Medium-Sized Enterprises was released as draft version in February 2016 (VDI 4801: 2016-02).

Methodical principles



Application

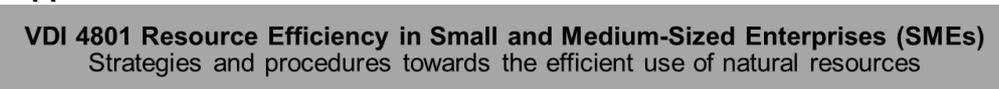


Figure 16-1: Structure of VDI Standard series on resource efficiency analysis (acc. to VDI 4800 Part 1).

Terminological definitions

One of the biggest challenges faced in compiling the VDI 4800 series of guidelines was that the concept of resource efficiency can be defined in many different ways. In a discursive process involving all the relevant stakeholders, a shared understanding of the term was negotiated and courses of action for day-to-day operations were outlined. The VDI committee

was always guided by the overriding goal to conserve natural resources in order to protect the livelihoods of current and future generations. The sum of these objectives informed VDI's terminological definitions:

The VDI 4800 series of guidelines describe the term "efficiency", as the relationship between a specific use or benefit and the effort or expenditure required.

The VDI 4800 Part 1 provides a general definition for "resources", which is as the means that are used or deployed for a system or process, as well as a specific definition, which narrows the range of these means to the area of natural resources. In the VDI standard, "natural resources" are those resources that are part of nature, such as renewable and non-renewable primary raw materials, environmental media and ecosystem services. Implicitly excluded here is the commercial deployment of human resources and capital assets.

VDI 4800 Part 1 defines "resource efficiency" as the relationship between a specific benefit or use and the natural resources that need to be spent or consumed to attain this benefit or use. The definition of "benefit" was largely informed by the ISO Standard on Life Cycle Assessment (DIN EN ISO 14044:2006-10). For an analysis of resource efficiency according to VDI 4800 part 1, the benefit must be defined and quantified as the numerator of the equation. This is done as follows:

- Benefit and effort must refer to the same reference object and be determined completely by it. The reference object can be a product or service, a bundle of products and services, an organisation, e.g. an enterprise, or a process.
- The benefit is generated by the function of the reference object (e.g. the product or service), which usually can be described and quantified technically. Methods of life cycle assessment refer to this as a functional unit. Such a technical quantification is to be preferred over others because it is more reproducible.
- In case of multiple products or services or for organisations, the benefit results from the sum of the performance of these reference objects. It may happen that this performance cannot be aggregated and quantified with the help of technical parameters, or that it contains benefit components that are impossible to be described technically. In these cases, the benefit can be quantified in a different way, e.g. with the number of users of a service or with economical parameters such as an organisation's turnover. However, the benefit must still be quantifiable, and benefit and cost parameters must still be congruent. For example, turnovers achieved with financial operations must not be counted in if the cost relates only to production.

The life cycle concept

The use of natural resources can only be adequately assessed through a life cycle analysis. In this respect, the VDI standard at hand again complies with ISO Standard 14040 on Life Cycle Assessment. In most cases, this will require a company to account for the original extraction of the raw materials that end up being used in its manufacturing processes; this is commonly referred to as a "cradle-to-gate" analysis. In cases where the consumption and disposal stages of a product's life cycle also require resources (such as energy), a full-scale "cradle-to-grave" approach is necessary.

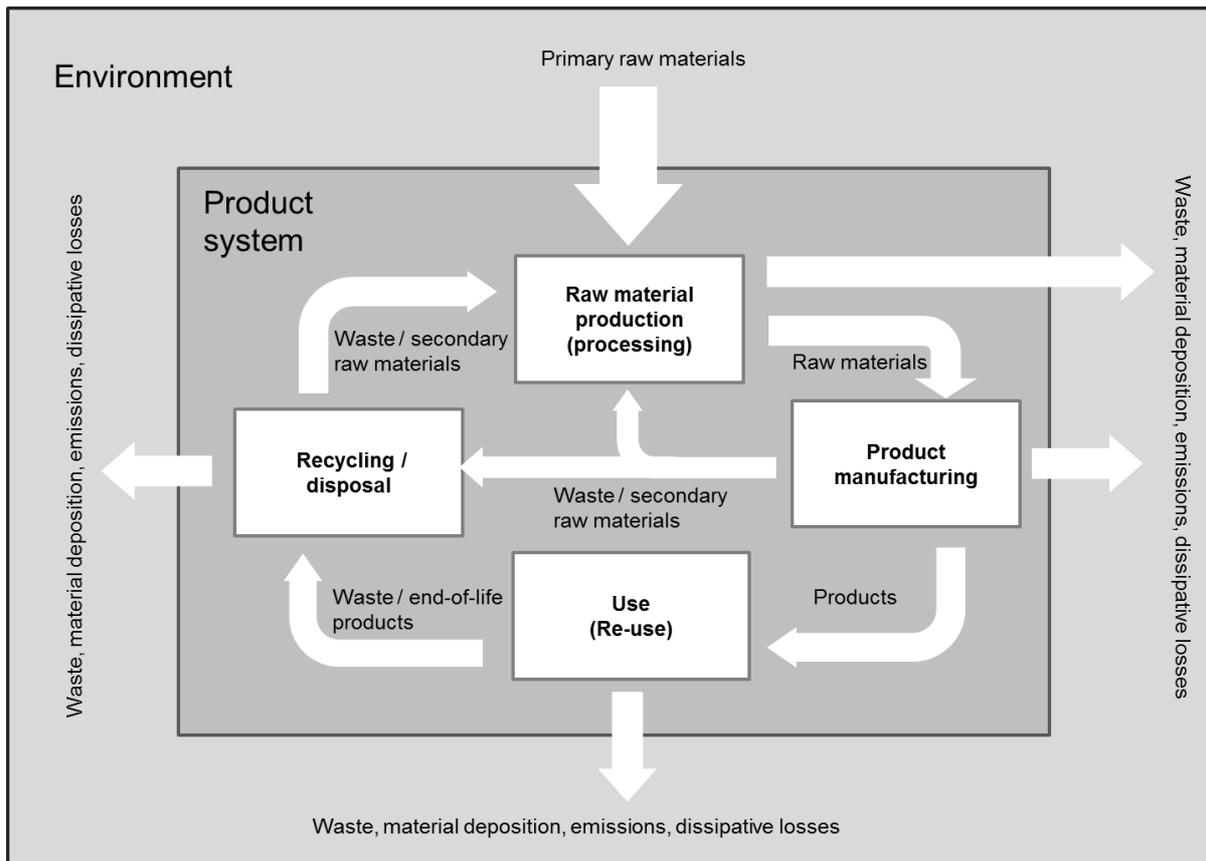


Figure 16-2: Resource use across a product life cycle (from VDI 4800 Part 1).

The life cycle concept becomes particularly relevant when the deployment of natural resources is understood to not only include the extraction of raw materials from their natural environment but also the role of environmental media as sinks. In this context, the storage of waste, the emission of harmful substances, and the use and transformation of land and soils can all be viewed as uses of natural resources. Factors such as these occur right throughout a product's life cycle, i.e., as part of the supply chain, during its use or consumption, and during its disposal. The only way to adequately address all of these stages is through a full cradle-to-grave life cycle assessment.

Implementation for products and processes

Targeted implementation of strategies and measures towards increased resource efficiency in companies requires that the involved parties receive suitable support in three main areas.

- (1) A systematic approach that focuses on relevant operative aspects of the company as well as product life cycles requires methodical support.
- (2) Due to the wide range of applicable strategies and measures, conceptual support may also be necessary.
- (3) In addition, operationalisation requires systematic support for the involved parties' specific actions and processes. This applies particularly to small and medium-sized enterprises.

The first two of these areas are described in the VDI 4800 methodological series, in which also practical examples are included. The third area is described in VDI 4801 - Resource Efficiency in SMEs.

Product and process development

Methodical product and process development forms the basis for a comprehensive optimisation of products and processes across their life cycle. Figure 16-3 shows the connections between the Product development process chain and the Product Life Cycle process chain. These connections are elemental to the development of resource-efficient product systems.

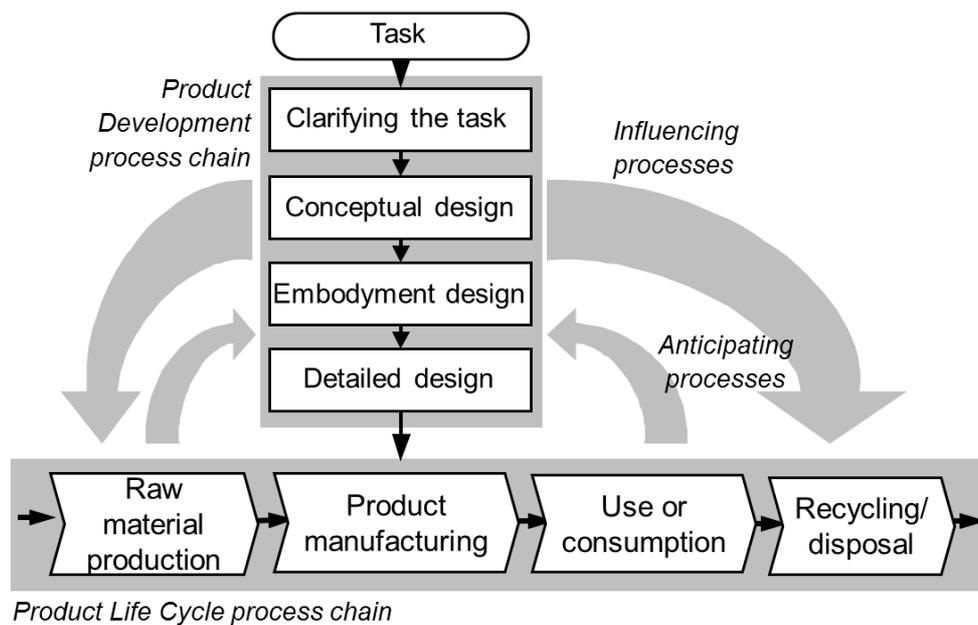


Figure 16-3: Product development and product life cycle processes (adapted from Abele et al., 2005).

The product development process defines functions, methods, types, physical contours and working materials. This is where decisions about technical, economical and ecological product properties are made, and with them decisions about production and recycling processes. Around 85 percent of the production costs are specified at this stage (Ehrlenspiel, 2007). In essence, the same parameters can be applied to resource deployment. Comprehensive measures towards increasing resource efficiency therefore need to address the product development process.

Product characteristics and processes and their associated resource use are defined across all stages of the product development process. As a general tendency, however, the initial stages of Clarifying the Task and the Conceptual design are more relevant in this regard than the later stages of Embodiment design and Detailed design. It should also be noted that the influence of product development could vary significantly across the individual life cycle stages. While the manufacturing processes are directly controlled by the company, use and disposal-related processes are much less controlled. This is due to the increasing timespan between product development and process implementation, but also due to the behaviour displayed by the product users and consumers.

Strategies towards increasing resource efficiency

As well as providing foundational principles for the development of resource-efficient products and processes, the VDI standard at hand is also intended to provide conceptual support in finding suitable solutions. For this, the relevant strategies are conveyed via descriptions, measures and examples. The strategies are structured according to their effect on the product or production process. The VDI standard outlines 14 product-related strategies that can lead to an increase in resource efficiency. These include substitution of materials, light-weight designs, fitness for purpose, miniaturisation, reparability and user/consumer behaviour. In addition, 23 strategies related to the production process are described. Examples include reduction of production volume, reduction of planned losses, efficient energy supply, cascaded use and product documentation.

Each strategy identifies those sections of the company that need to be addressed for it to be successful (e.g., product development, factory scheduling, process planning, purchasing/acquisition, production, sales). In addition, the affected life cycle stages are listed (raw material production, product manufacturing, use and/or recycling/disposal). Lastly, the strategy indicates if there is any need for exhaustive life cycle analyses.

Resource efficiency in small and medium-sized enterprises

The previous chapters discussed how companies can deploy the VDI 4800 to evaluate as well as optimise their products and processes according to the state of the art, thereby including the various life cycle aspects of these. The assessments required for this can be very elaborate and need to be carried out by trained experts. As experience has shown, such a level of expertise is generally not available to SMEs. At the same time, SMEs are generally not willing to finance the outsourcing of expert life cycle assessments. As SMEs are a significant target group, VDI developed a standard on the application level, VDI 4801 – Resource Efficiency in SMEs. Depending on their market position, operating conditions, production methods, product range and development structure companies can be provided with a range of different strategies and measures.

With VDI 4801 “Resource Efficiency in SMEs”, then, small and medium-sized enterprises can achieve a number of resource efficiency increases without having any in-house expertise in this area. The VDI 4801 guideline also represents a great starting point for companies to comprehensively optimise their products and processes in accordance with VDI 4800.

Conclusion and outlook

In conclusion, the creation of the VDI 4800 standard series represent the first published guideline set for companies and consultants to calculate, assess, evaluate and optimise the resource efficiency of processes, companies and products throughout their life cycles according to a standardized framework of principles. This serves as a basis for achieving the private sector resource efficiency and conservation targets outlined in the introduction of this article. Exactly to what extent and how soon the VDI standard will contribute to an absolute reduction in resource exploitation and consumption cannot be reliably predicted at this stage. This will require supplementary evaluations during the standard’s implementation. Implementation will require further supporting measures within Germany, i.e., suitable funding programmes and political frameworks – such as the current revision of the German Resource Efficiency Programme, ProgRes II (BMUB, 2015).

Looking beyond Germany, it will be very interesting to see how a series of guidelines such as this, and also the results projected here, may be able to be adapted across Europe and beyond, and how they may contribute to international regulations and standards. Certainly, the creation and publication of a nationally coordinated standard is an important first step towards further European and global dialogue on resource efficiency.