Energy Efficiency in Innovative Industries: Application and Benefits of Energy Indicators in the Automobile Industry

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ABSTRACT

In this paper, the application and benefits of energy indicators are discussed focusing on the automobile industry. The need for action to introduce energy indicators in companies' operational energy management is discussed with respect to the new guideline on energy indicators by the German Association of Engineers (VDI). Methodological aspects of determining and comparing energy indicators are shown taking into consideration branch-related characteristics of the automobile industry. The currently available data on energy consumption within the German automobile industry is described and future steps to develop a system of energy indicators and benchmarks are out lined.

Introduction

The new German Guideline on Energy Indicators focuses on comparison and assessment of the energy efficiency of equipment, plants and systems (VDI 2000). It is therefore focusing on the introduction of energy indicators at the company level, complementing the international efforts to implement energy indicators at sectoral and international levels (cf. IEA 1997, Bosseboeuf et al. 2000). The main aim of using energy indicators at the company level is "the technical and economical optimization of the overall process" (VDI 2000). The guideline includes an extensive section on definitions of terms as well as a description of energy indicator applications and methodological aspects. Nevertheless, to develop and implement a system of energy indicators for companies in a particular industrial branch, detailed knowledge of energy technologies *and* branch-related facts are required. To support the application of energy indicators in companies

- the advantages of their use have to be illustrated,
- a selection of suitable energy indicators (including the method of their determination) has to be provided and
- benchmarks of these indicators have to be given to consultants or assigned persons in the companies.

Possible Applications and Advantages of Energy Indicators

Possible applications of energy indicators can be structured as shown in Figure 1. They can be used for analyzing as well as for control purposes and are discussed here for the case of the automobile industry at operational level. In this context, the focus is on the technological aspects which are the basis of a useful economic indicator system.

The development of an operational energy indicator system first requires an analysis of the energy consumption structure of the plant. This leads to higher transparency of the energy flow and makes it possible to distribute costs according to energy consumption in each cost center. Conflicts between cost centers can be avoided when accurate information on cost distribution is available. Reporting of energy costs to the cost centers motivates implementation of rational energy utilization.

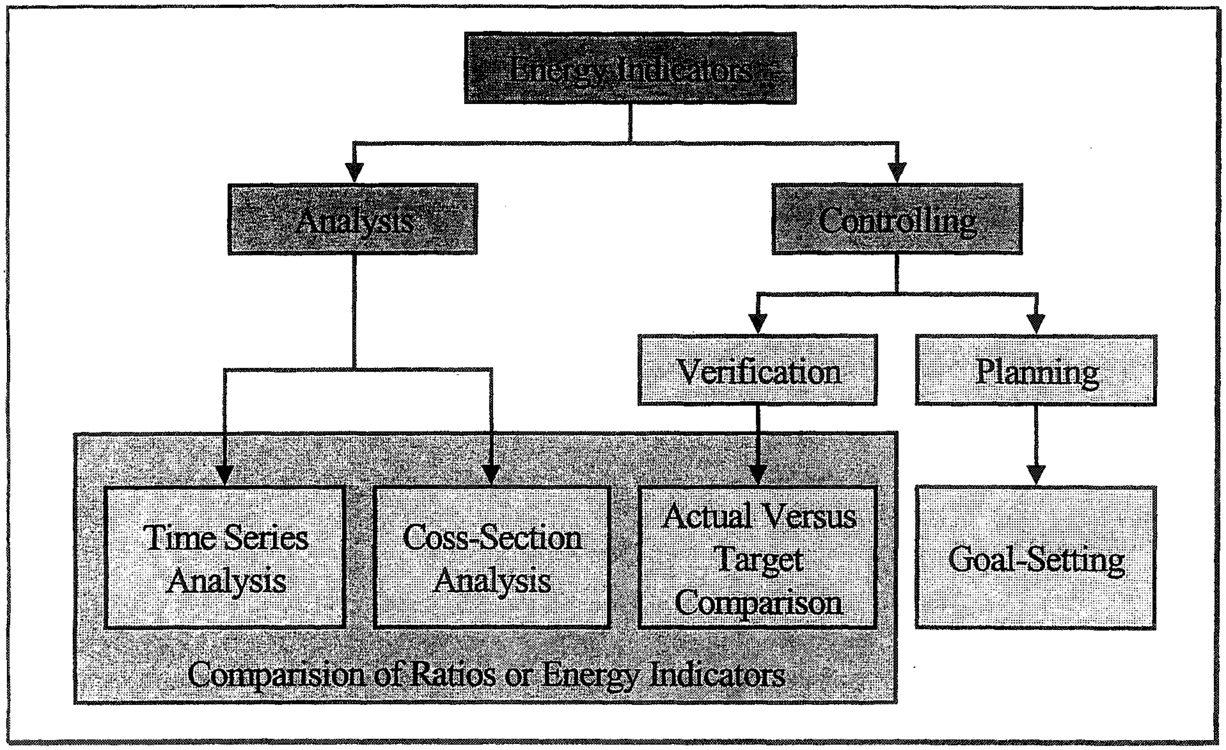

Figure 1. Possible Applications of Energy Indicators (VDI 2000)

A time series analysis of energy indicators, e. g. of a production plant, can be used

- to provide early indication of operational faults (e. g. leaks),
- as an indicator for preventive maintenance (increasing operational safety),
- for information and motivation of staff or the operational personnel or
- for public information and environmental reports (e. g. European Eco Audit)

As in other areas, targets can be *quantified* and the success, e. g. of energy efficiency measures can be verified by comparing energy indicators before and after the undertaking of a measure. On the basis of energy indicators, planning safety with respect to energy demand and energy costs can be improved for future periods of time.

A cross-section analysis, e. g. of production plants, can indicate potential energy savings. In each automobile company several production plants are in operation for similar purposes, e. g. several paint shops with different or similar technology. A comparison of energy indicators from different production plants enables an assessment of the production methods, e. g. different types of painting or drying processes, whereby a comparison of identical production plants enables monitoring of operations. An analysis of a paint shop by the IER showed that the energy consumption of two identical devices, i. e. the electricity consumption of the air conditioning and ventilation of a Body Top Coat Booth can differ by the factor 2 (Schelle 1997). In cases like this energy savings can be achieved easily and economically by undertaking organizational measures.

A particular type of cross-section analysis is benchmarking (Leven, Weber and Voß 2000). Benchmarking is a systematic procedure with the aim of understanding processes and functions and especially the practices behind them. Partners are chosen specifically who are assumed to be the best of class (= benchmarks). The final aim of a benchmarking project is the adoption of best practices to improve company performance. This means that benchmarking is more than just a comparison of ratios or energy indicators.

Branch-Related Aspects of the Automobile Industry

The development and implementation of a system of energy indicators for a particular industrial branch is only possible when taking into consideration branch-related and energy aspects. Costs and benefits of the energy indicator system can only be optimized in this way. Major relevant facts for the automobile industry in general and the German automobile industry in particular are provided in this section.

The automobile industry is characterized by a low share of energy costs, which is typical for the capital goods industry. In 1997, the gross production value of the German automobile industry could be imputed to related cost categories as follows (Federal Statistical Office Germany 1997):

- materials usage, merchandise, wage work 63 %,
- personnel costs 23 % and
- other costs 14 %.

The cost of energy is included in the cost of materials and amounts to 0.8 % of the gross output. Because of the liberalization of the European energy markets the cost of energy is declining. Therefore, the reduction of energy costs is not the highest priority for the business management, even though the energy costs can amount up to 100 million US $ per year and plant. In view of the costs, personnel and materials are considered to be more important and due to the just in time production, operational safety and quality management are playing an important role.

From a societal and national economic point of view, the automobile industry is however contributing substantially to the gross domestic product (GDP) and is also relevant as far as energy consumption and CO_2-emissions are concerned. The percentage of automobile energy consumption is 7 % of the electric energy and 3 % of fossil fuels consumed by the German industry. In several states of Germany, like Baden-Württemberg, the percentage is twice as high because of the lower share of energy-intensive basic materials industries.

The final energy consumption of the automobile industry is dominated by electricity (45 %) and natural gas (33 %) as shown in Figure 2. While the use of coal and oil has declined in the last decade, the percentage of gas, district heat and especially electricity has increased. In many cases, electricity is produced in co-generation plants either on the production site itself or more frequently in organizationally independent power plants near the site.

Electricity has the largest percentage (approx. 80 %) of energy costs in the German automobile industry (own calculations on basis of industry energy prices (Federal Ministry of Economics and Technology 2000)).

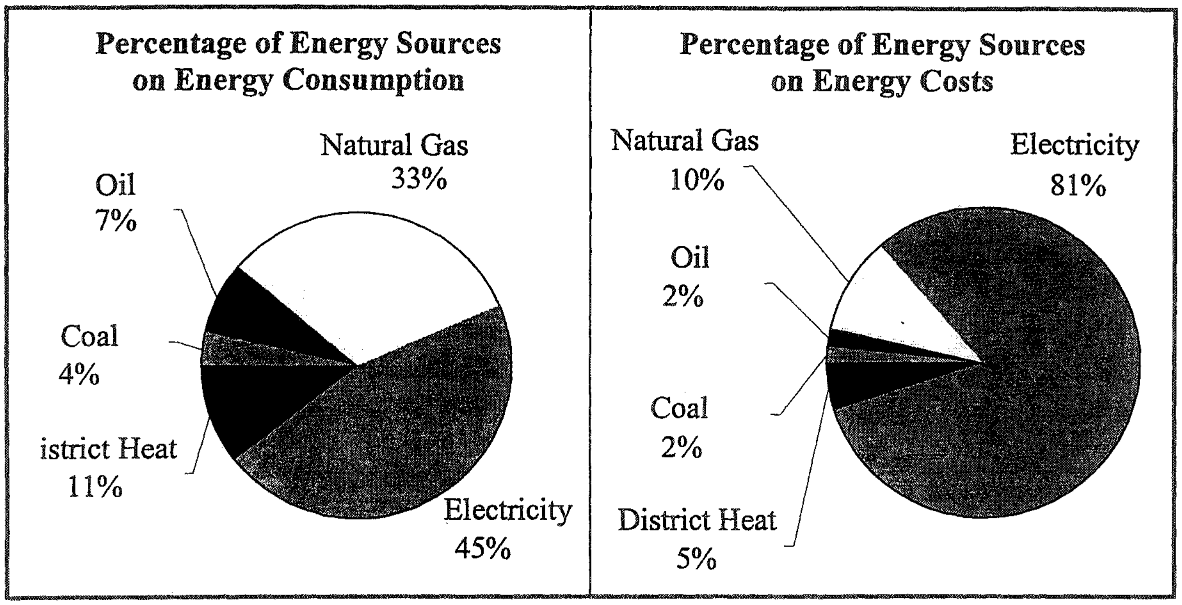

Figure 2. Percentages of Energy Sources for Energy Consumption and Energy Cost in the German Automobile Industry in 1995 (AG Energiebilanzen 1995)

Most of the electricity (approx. 30 to 50 %) is used in the paint shop. Bodywork, assembly and stamping plants (if present) are also significant electricity-consuming cost centers. Heat consumption is equally divided between space heating and process heating. Most of the fossil fuels or heat (50 to 60 %) is demanded by the paint shop, especially for heating of plating tanks, for air-conditioning and thermal oxidation of VOC-components within the exhaust air. In addition, the energy used for supplying compressed air represents a significant share of the final energy consumption.

Application of Energy Indicators – Methodological Aspects

The German guideline provides indications on the treatment of the following methodological aspects:

- kind of plant or system,
- size and capacity utilization of the plant or system,
- system boundaries,
- meaningful reference values,
- quality and further aspects.

The implications of these aspects for the case of the automobile industry are discussed.

Kind of Plant or System

The production sites of an automobile company are usually organized in a production network, in which assembly plants and manufacturing plants or combinations of both exchange parts. Assembly plants usually contain at least the cost centers bodywork, paint shop and assembly line. A small number of production sites contain a stamping plant where also pressed parts for other assembly plants are produced. In manufacturing plants, engines, axles, plastic or cast parts (gray iron or light metal) etc. are produced. Consequences of the low homogeneity and the varying depth of production of the sites are significant influences on the energy consumption structure and on several energy indicators.

Size and Capacity Utilization of a Plant or System

Due to the significant percentage of space heat and other energy consumers, which are relatively independent from the production output (e. g. lighting, air-conditioning), the capacity utilization has to be reported with energy indicators related to the production output.

System Boundaries

The definition and reporting of temporal and spatial system boundaries are essential when determining and comparing energy indicators. Periods of time when a plant or parts of it are modified for producing a new automobile type or model can not be compared with periods of time with full capacity utilization.

Technical equipment, e. g. a furnace for heat treatment, can only be compared with others if the operational conditions (e. g. capacity utilization rate, heating up or cooling down process) are the same or at least similar.

In view of spatial boundaries, energy conversion and the use of technical gases, e. g. oxygen in furnaces, have to be taken into consideration. Especially a power production plant within the system boundary "fence of the production site" has to be taken into account. The influence of this is shown in Figure 3 on the ratio of the final energy consumption per number of produced automobiles of 17 German sites.

The plants with own power production (displayed as hatched columns) show a higher energy consumption per automobile and deviating shares of electricity and fossil fuels. Therefore previous conversions in the energy chain have to be taken into consideration either by using the primary energy use (or more precisely the consumption of exhaustible energy resources) as indicator or by modifying the system boundaries in a way that the power plant is outside the boundaries.

Meaningful Reference Figures

The determination of energy ratios as an essential form of energy indicators is possible by using many different reference figures, e. g. number of employees, heated space or produced parts. If however, there is only a minor relation between the reference figure and the energy consumption, the use of such an indicator is not advantageous.

For example, a reference figure for specific energy consumption ratios, which is often used due to ease of availability, is the total number of employees in a company. Figure 3 shows clearly the inaccurate conclusions, which can be derived if only this indicator is looked at. Plants with a high specific final energy consumption per employee are particularly efficient regarding the specific final energy consumption per vehicle (with one exception). Reasons for this are in particular the high productivity per employee but also the low depths of production in these plants. In fact, these are mostly new plants with correspondingly higher building and equipment energy efficiency, but limited also mostly to assembly lines, bodywork and paint shops.

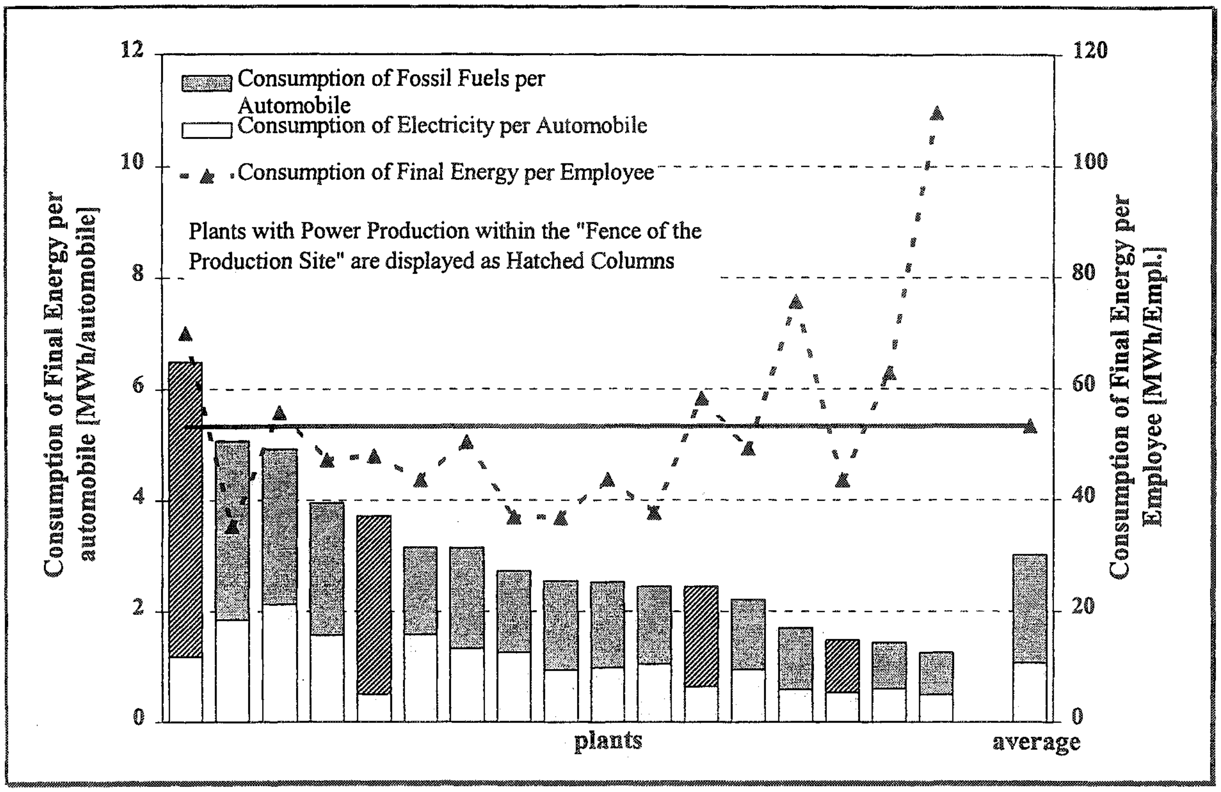

Figure 3. Final Energy Consumption per Automobile of 17 German Bodywork and Assembly Plants

In this case, the total number of employees is therefore not suitable as a reference figure. The production output or the production surface area would be more adequate, later especially due to the high percentage of energy consumption which is not directly dependent on the production output. However such information is not publicly available, and also some automobile companies were not willing to answer such questions when approached with a corresponding questionnaire.

Quality and Further Aspects

Aspects such as product quality and weather conditions have also to be taken into consideration when comparing energy indicators. The paint quality of a luxus class automobile is higher, prolonging the painting procedure compared to the case of a compact car. Therefore, also in the first case the painting procedure will mostly be more time- and energy consuming.

Costs for Determining Energy Indicators

The *cost* of determining energy indicators must be in acceptable proportion to the expected *benefit* for the company. Costs are incurred particularly through data recording and processing (measurement equipment, personnel etc.). A decision concerning the scope of data recording can be made on the basis of a monetary evaluation of energy flows. For example, it could be decided to record all flows of energy worth more than 10,000 US $ per year (Flanagan, Menzler and Theweleit 1999). Thereby preferably not market prices for energy should be used for valuation, but internal energy costs, including charges for equipment, maintenance etc.

Currently, several meters for electricity are installed in automobile plants, but in the case of space and process heat often only one meter per factory building. Yet, for compressed air mostly only one meter per site is installed, despite compressed air being a particularly energy-intensive energy carrier.

The *data available* on plant level vary significantly in the automobile industry. The energy supply structure is relatively transparent in new production sites in comparison to older sites. The short innovation cycles in the automobile industry result in frequent changes to the production plants. Although implementation of new equipment in existing sites is in principle advantageous for energy efficiency, time or financial restrictions are often an obstacle to energy efficiency improvements. The required adaptation of the supply structures and the additional aggregates, e.g. ventilation systems, to the new conditions is only partly performed due to reasons of time and cost. To avoid large investments, measures are also carried out, which lead to an inconsistent connection of energy-consuming devices, e.g. connection of a radiator to a process heat network. This makes it more difficult to allocate energy-consuming devices to meters and to determine meaningful and useful energy indicators.

Selected Energy Indicators for the Automobile Industry

Under these conditions, the following types of energy indicators are particularly useful for the automobile industry:

- general energy indicators,
- indicators for cross-cutting technologies,
- product-related energy indicators.

Important general energy indicators are notably the final energy consumption per plant or per heated space, differentiated by energy carrier. This should in any case be determined over time, to allow general performance monitoring.

Among cross-cutting technologies especially space heat has to be considered, since it is rather easily accessible to benchmarking within the automobile industry and beyond. Also the energy consumption per compressed air volume, depending on pressure level, is highly relevant from a cost side and allows for meaningful benchmarks.

Besides, however, product-related energy indicators are of particular interest. Here, the production output, i. e. the automobiles or parts produced, should be favored for use as a reference figure for energy consumption. The reason for this is that the aim of most companies is the production of goods using a minimum of resources (costs and consumption). The main aim is therefore optimization of the specific energy consumption (or costs) per output.

An important energy indicator for evaluation of energy efficiency of bodywork and assembly plants is therefore the *energy consumption for production of a automobile.* This ratio can be determined on the basis of useful energy, final energy or/and total consumption of exhaustible energy resources (primary energy).

To be able to compare these energy indicators with other plants, the aforementioned aspects of method must be taken into consideration and important facts must be specified with the energy indicator. Examples of these are

- depth of production or the cost centers of the production site,

- technological aspects, e. g. the paint system applied, or
- the environmental protection level, e. g. VOC emissions.

An improvement in comparability can be achieved by using the output-related energy indicators at the level of single cost centers of plants. The depth of production and the exchange of components in the production network are less influencing the results in this case. Determination and comparison of such energy indicators appear to be important in particular in energy-intensive centers i. e. bodywork, assembly, paint shop and stamping plant.

In this way, the manufacturing sites could be compared with each other despite a non-homogeneous production structure due to an energy indicator comparison at center (or single plant) level.

Outlook

This paper describes the status quo of the energy utilization and the corresponding data available in the automobile industry. Fundamental aspects of method have been discussed and attempts for a branch-related energy indicator system have been outlined. However, to enable a broad implementation of energy indicators suitable for comparison in the automobile industry, further steps are necessary with respect to

- development of an energy indicator catalog including definitions for enhancing the comparability of individual energy indicators,
- ascertaining of a data base of comparable energy indicators within a company or at branch level (e. g. in cooperation with the manufacturers' association) and
- continual updating of the data base.

Publication of companies' internal data poses a possible obstacle in the case of a branch-wide investigation. Yet, an independent organization or research institute could collect and assess the data and could make this available to the participating plants in an anonymous form.

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