Value chain costing analysis as an approach to evaluate market price volatilities due to changing energy prices

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Abstract

The commercial availability of resources and preliminary products is of essential importance for the industry. One aim of manufacturing companies is to know about structural dependencies in the availability of resources along the entire value chain of their products and to also not only know about environmental impacts of a product but also to have information about the economic life cycle and the value chain. Life Cycle Costing (LCC) is a technique to evaluate the costs of a product over its entire life cycle. Existing approaches give no sufficient answer on how input price alterations in upstream processes influence the value chain costs of materials. But for decision makers, it is crucial to know e.g. at what oil price investments in new materials or the change of feedstock from fossil to renewable become profitable from a life cycle perspective. Therefore, a new approach is suggested, combining LCC and Life Cycle Assessment (LCA). LCA provides the fundamental basis (a functional system model with energy and mass flow balances of all upstream processes) which is enhanced with economic parameters. It basically combines most of the elements of Life Cycle Assessment, environmental Life Cycle Costing according to the method suggested by SETAC and Total Cost of Ownership avoiding restrictions of the respective methods. The paper will describe the procedure of modelling, an exemplary process model and combined static LCA and dynamic LCC results for insulation materials along the value chain of the product. The model is validated using alternating energy prices.
Keywords: energy costs, Life Cycle Engineering, supply chain risks, green procurement, Life Cycle Costing, price sensitivity.

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1 Introduction

The commercial availability of resources and preliminary products is of vital importance for the industry. One aim of companies is to know about structural dependencies in the availability of resources within the entire value chain of their products. Also, forecasting of price developments is of great importance for planning processes. Therefore, an approach that combines and extends the methods of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) and thereby allows identifying the impact of changing energy prices on the selling price of products is presented.

This paper describes the methodological foundation of the method, and then gives a validation for the approach.

2 Method

Within the next section, an outline of the method compared to existing approaches will be explained and the procedure of the developed approach itself will be described. Furthermore, a calculated evaluation of the method is applied.

2.1 Analysis of existing methods and demarcation of the value chain energy cost analysis method

Life Cycle Costing (LCC) is a technique to evaluate the costs of a product over its entire life cycle [1]. However, existing approaches give no sufficient answer on how input price alterations in upstream processes influence the value chain costs of materials. But for decision makers, it is crucial to know about e.g. at what oil price an investment in new materials or the change of feedstock from fossil to renewable becomes profitable from a life cycle perspective.

By combination and further development of existing economic assessment methods, identified gaps are filled according to the goals of this approach. The following table 1 summarizes the essential methodical requirements and the differences of the respective approaches.

The comparison of the existing methods indicates that none of the presented approaches can meet the requirements of the goal of the value chain energy costs analysis method. Previous approaches of LCC such as conventional LCC / TCO [3] or the flowcost accounting [4] are no appropriate methods as they do not consider interactions of companies within the value chain. Further approaches that integrate upstream processes either do not include economic aspects (such as LCA [2]) or focus only on organisational aspects of the value chain (Supply Chain Management, Supply Chain Costing [3]).

Therefore, a new approach for LCC is suggested using the Life Cycle Assessment (LCA) method as the fundamental basis (a system model with energy and mass flow balances of all upstream processes) enhanced with economic aspects. With this, it will be possible to calculate more precisely e.g. the influence of energy price alterations and its influences regarding the value chain of a product considering all upstream processes.

Table 1: Comparison and evaluation of existing methodical approaches.

Description	Life Cycle Assessment LCA [2]	Conventional LCC/ Total Costs of ownership TCO [3]	Environmental-LCC	Flowcost Accounting [4]	GaBi [8]	Supply Chain Management/Supply Chain Costing [3]	Experience Curves [5]
Modelling/ Integration of upstream processes	✓	(✓)	✓	(✓)	✓	✓	(✓)
Energy input per module of the upstream process	✓	x	✓	x	✓	(✓)	x
Costs for the energy input	x	(✓)	(✓)	(✓)	(✓)	(✓)	x
Consideration of margins / surcharges	x	(✓)	x	x	x	x	x
Compounding over the links of the upstream processes	x	x	x	x	x	x	x
Summation / transfer of the sum	✓	(✓)	(✓)	(✓)	(✓)	✓	x
Physical life cycle	✓	x	✓	x	✓	✓	x
Dynamic projection into the future	(✓)	(✓)	x	x	x	(✓)	✓

✓ = component of the method;

(✓) = possible; not up to now, indirect or only applied for some players of the value chain (application for single process modules);

X = not component of the method

2.2 Procedure of the energy cost analysis through a combination of a technical process chain analysis and dynamic cost accounting

The first step is the definition of the technical system and the functional unit, according to the procedure of an LCA study. The functional unit according to ISO standard DIN ISO 14044 [6] is defined as "[...] the quantified performance of a product system for use as a reference unit".

After defining the functional unit of the product system, the next step is to set up a Life Cycle Inventory model corresponding to the LCA procedure. This is based on mass and energy flows for each step of the upstream value chain. The relevant Life Cycle Inventory data must be available in non-aggregated form. The process model should be broken down to the energetic input resources like naphtha, gas or electricity.

The technical model is then extended with economic quantities, such as costs for material and process energy for every process step as well as the product selling price. Data sources used for this are described in detail in section 2.3.
To provide a stable basis, data from a year with slight price fluctuation has to be used. Thus, prices from 2009 were used to set up the static model, since energy prices (oil and naphtha price, gas price, electricity price) fluctuation was relatively low in this period.

Processes which take place within the organisation underlie a special analysis interest. It is possible to depict the functional dependence in maximum detail by using manufacturer-specific data, thus providing the opportunity for a very explicit analysis. According to classic cost accounting theory, the following costs are identified:

+ Direct material costs
+ Direct energy costs
+ Direct manufacturing costs
+ Overhead costs
= Production cost per unit
+ Selling, general and administrative costs
= Original costs
+ Profit margin
= Product selling price

Direct manufacturing costs are mainly wages directly corresponding to the manufactured product.

Investment costs are usually included in the overhead costs. Within investment decisions, with the goal of a certain return on investment, the realistic possibility to realise this return rate, is a decisive factor. Therefore, it is recommended to identify investment costs for one product- or process-specific analysis based on the produced functional unit and to integrate those costs with a reference to time according to the projected life span. The production costs and other, nonspecific overhead costs accumulate to the original costs. Those, together with the profit margin, result in the products selling price.

To analyse upstream processes where no detailed information is available, a surcharge margin has to be calculated. The margin is determined by the data from Life Cycle Analysis and price databases. The margin in this method contains overhead costs as well as the profit margin and is defined as:

$$\text{Margin} = \text{sales price} - \sum \text{material costs} - \sum \text{energy costs}.$$

Depending on the availability of data, the margin can be further subdivided. This can only be done with additional information.

In a next step, the margin is related to the direct material and energy costs, in order to identify the percental mark-up. Based on these assumptions, it is possible to identify the direct cost basis and the margin for every process step. The product selling price is then calculated with the formula:

$$\text{Product selling price} = (\text{Direct material costs} + \text{Direct energy costs}) * (1+\text{margin})$$

The functional linking serves the creation of a mathematic model alongside the value chain. Thereby, the separately analysed process steps are combined over the entire value chain. The final prices of preliminary products are at the same time the material costs of the following process step (Input costs). Consequently, there is a functional mathematic relationship along the value chain for used substances (mass balance), energies (energy balance) as well as costs and prices (economic balance).

The up to date static model is complemented with variable costs for the energetic inputs naphtha, gas and electricity. Therefore, the product price p depends on the prices of the energetic input resources:

$$P(t) = (P_{Naphtha}(t); P_{Electricity}(t); P_{Gas}(t))$$

The developed method can for example further be used for

- Evaluation of expected cash flows to calculate net present value;
- Determination of the energy costs share of the product price to evaluate the dependence on resources and supply guarantee;
- Comparison of product prices subject to variable energy costs: Comparing the “Break-Even-Point” of product alternatives based on different feedstock.

2.3 Data requirements

A general need for all simulation tools and models is the availability of input data. For this method, both LCA and LCC data is required. The specific requirements for data are described in the following.

2.3.1 Technical and environmental data requirements

LCA models are in principle system models of the life cycle of a product or parts of the life cycle like the value chain of the production phase. Each process step requires a mass balance and energy balance model, which is called unit process according to ISO standards [6, 7], to describe physically the production process as single steps in the value chain. Combining the respective mass and energy balances of singles processes of the value chain of the respective production phase then describes the whole production process, starting with the extraction of raw materials. This kind of modelling requires knowledge of all upstream processes including detailed knowledge of process specific materials and energy carriers. These data requirements are normally handled by using databases like GaBi [8].

2.3.2 Economic data requirements

For the creation of the value chain energy cost analysis model, price and cost data along the entire value chain are required. Most important are the prices of all physical inputs (materials and energy carriers). Also, selling prices for all pre-products along the value chain should be known, since those market prices are input prices on the next higher level of the value chain. Based on the sum of input costs for a product and the selling price, the margin is calculated. If information on input prices and the margin of all upstream processes is available, a functional composition for the entire value chain can be made.

Economic information for materials and energy carriers can be gained from various price databases. Here public available information was chosen for energy carrier prices. On a national German level the German Ministry of Economics and Technology (BMWi) [9] provides long term price data for energy carriers like crude oil, natural gas and electricity both for industrial and private customers.

On a European level Europe's Energy Portal [10] provides current energy price ranges for each European country, for private customers and for industry.
Price data for Germany for a bulk of traded goods are available by the German statistics office (destatis) [11]. On a European level EUROSTAT provides import and export prices of traded goods in Europe [12]. Special prices and additional information like volatility, average prices and price ranges for specific sectors like the plastics industry are provided by commercial database providers such as KI Web [13], which offer price information for most commercial thermoplastic polymers and its most important pre-products.

Further information, like labour costs, ROI factors or average overhead costs can be gained (if available) from branch specific reports, for example the report of the chemical industry in Germany [14].

3 Model validation

Based on the newly developed method, an LCA based economic price model of Expanded Polystyrene (EPS), which is mainly used for insulation and packaging applications, was set up. This price model is validated to check its accuracy.
The following Figure 1 shows a simplified model of the production value chain of EPS. It comprises all relevant upstream processes including the steps where energy carriers enter the system.

EPS and Polystyrene (PS) are polymerised from styrene, which is based on the fossil feedstock oil. The share of fossil feedstock dominates the used materials and energy carrier within the value chain of the production.

To validate the model, a retroactive forecast, based on historic energy and product prices, is carried out for the product "Expanded Polystyrene". The data used as a basis for the static model is from 2009, most of it being taken from destatis [11] foreign trade statistics and KI-Web (synthetic materials and preliminary products) [13]. After the static model was set up, average energy prices for every month in 2008 and 2009 were used as input prices, while other prices remained fixed. While 2009 saw a quite constant oil price rise from 0.23 €/kg in January to 0.36 €/kg in June and then prices quite constantly fluctuating around 0.36 €/kg until December, 2008 was a year with very volatile oil prices. Starting with 0.44 €/kg in January, prices peaked at 0.62 €/kg in July, only to drop to 0.21 €/kg in December. This offers the opportunity to validate the model both for quite constant and volatile surrounding conditions.

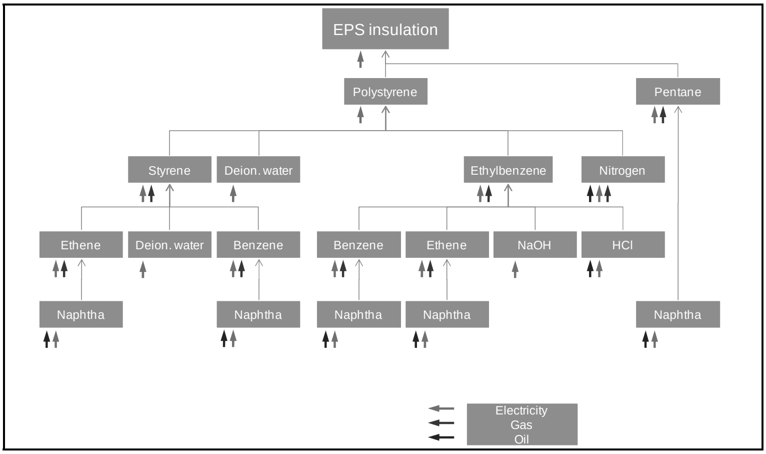

Figure 1: Simplified flow chart of the production of polystyrene foam EPS including input of energy carrier.

The calculated product price based on varying energy prices showed a mean variation of less than 5% over the assessed two-year period, compared to the market price of the product.

When comparing the real market price with the simulated price, it was found that there was a lag between them. A phase-postponement of one month of the naphtha price (t) to the resulting product price (t) resulted in an improvement of the mean deviation from about 5% to about 3% in average. This is due to temporary delayed transmission of the price variation. It shows that the approach is working as a basic principle and generates accurate results.

The simulated and actual market prices for this period are shown in Figure 2.

It can be seen that the forecasted prices depict the actual market prices quite accurate and follow all market price trends. This shows that the approach is working as a basic principle.

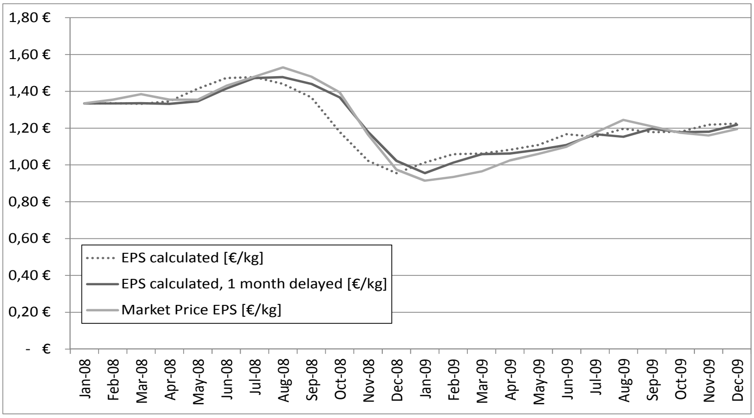

Figure 2: Validation of the economic model for EPS.

4 Conclusions

With the value chain energy cost analysis method, an innovative approach is developed that allows calculating the influence of energy price alterations more precise, taking into account the whole upstream value chain. This method combines the deep process knowledge of the environmental Life Cycle Assessment method with economic information to create a new procedure for a more detailed knowledge of where and in which intensity energy prices influence product prices along the products value chain.

An exemplary model was set up for German boundary conditions and prices and was evaluated with real market prices from 2008/2009 for Expanded Polystyrene by varying naphtha, electricity and gas price monthly. The modelled mean prices show a very high precision compared to real market prices of the product. The deviations mean value for the examined 24 months-period is about 2.9%. Due to its ability to potentially create relatively precise predictions of a product price depending on energetic input prices, this method is an innovative enhancement of existing Life Cycle Costing approaches.

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