Abstract

Material efficiency strategies of energy-intensive materials[1] (Materialeffizienzsstrategien energieintensiver Werkstoffe)

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In the last three decades the R&D-activities in the field of rational energy use have focused on energy conversion aspects such as efficiency improvements of power plants or the reduction of heating losses in buildings. The discussion about sustainable development and the unsolved problem of greenhouse gas emission reduction are now focusing the current debate on material efficiency strategies. Looking at the total system – from material generation over product manufacturing and product use to waste disposal/recycling of products and materials – a relevant energy saving potential can be identified by realising different strategies:

- ***recycling***: compared with the use of primary materials, recycled materials often have a lower specific energy demand, even taking into account the energy use of the recycling process and the transport involved. A high potential of recycling has already been realised for some materials (i.e. for bottle glass the recycling rate is over 80 %), but for others, the numbers are comparatively low (i. e. for aluminium this is around 40 % and around 20 % for synthetic substances). It must also be kept in mind that the material production of energy-intensive materials like aluminium often takes place in countries with low energy prices (like Canada or Australia) and this leads to a corresponding increase of transport with its associated energy consumption.
- ***Material substitution***: in the past, material substitution potentials were analysed using cost and product use criteria. By analysing the substitution potential from the perspective of energy efficiency and climate policy aspects, a relevant energy saving potential can be realised.
- ***Efficient material use***: from the viewpoint of rational energy use, the possibility of reducing the specific material demand is also of importance. For example, the weight of glass packing can be reduced by constructional measures to save energy during the glass production process and the product transport. However, the question of functionality remains a relevant topic.

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[1] Here selected results of a study supported by the Bundesministerium für Wirtschaft und Arbeit German Federal Ministry of Economics and Labour are presented. The authors of the study are: E. Jochem, M. Schön, M. Wietschel, C. Nathani, G. Angerer, M. Ball, F. Marscheider-Weidemann, W. Eichhammer, W. Mannsbart.

- In addition, the ***extension of product life*** or increasing the ***intensity*** of product use (e. g. with car-sharing) may be options for energy saving, but these are not examined in this paper

The effects of the first three material strategies are evaluated in a study focusing on the energy material with the highest energy consumption in Germany. To demonstrate the effects, some examples are presented below.

Lightweight strategies for cars are one of today's most discussed material strategies. For Germany, the transport sector currently has the highest demand for the energy-intensive materials steel (30 %) and aluminium (33 %) of all demand sectors. On top of this, more than 30 % of the final energy demand is consumed in the transport sector and this sector emitted more than 20 % of all CO_2 emissions. These figures demonstrate the energy relevance of this sector. Energy saving strategies can be realised, among others, by lightweight strategies, e. g.:

- **substitution of steel by lower weight materials** like aluminium, magnesium or synthetic materials. For example, 1 kg steel can be substituted by 0.6 kg aluminium (with the same functionality) (see Figure 1). When realising such a concept, however, it must be taken into account that the potential substitutes for steel have a higher energy demand during their production processes than steel . It has to be analysed carefully, therefore, whether this higher energy demand is saved over the drive cycle of the car. Additionally, the different energy demands for material recycling have to be regarded. Therefore, the whole life cycle of a car has to assessed. To do so, a system analysis based on a dynamic approach is made, taking into account such factors as the dynamic development of the average fuel demand of cars, efficiency improvements of drive systems or material production processes, export-share of materials and cars, availability of recycling material,.... . Figure 2 shows that a strong substitution strategy of steel by aluminium leads to an increase of the primary energy demand in the first decades and that the primary energy demand can only be significantly reduced after 20 years. This example demonstrates the complexity of the decision situation.
- **Lightweight steel strategies** by construction material measures. These include part consolidation, functional integration, incorporating feature lines in outer panels and designing inner to support outer panels. For example, in the frameless door design, a thin wall die casting was used as a structural node to connect the upper and lower frame (see also Figure 3). Calculating the total energy demand of the life cycle of all cars as illustrated in Figure shows that the primary energy consumption of this sector can be drastically reduced (see Figure 2).

Figure 1: Material composition of an average car in Germany for different scenarios *(2000-frozen: current situation; 2030-steel: realising all options of steel light construction; 2030: realising the maximum substitution of steel by aluminium)*

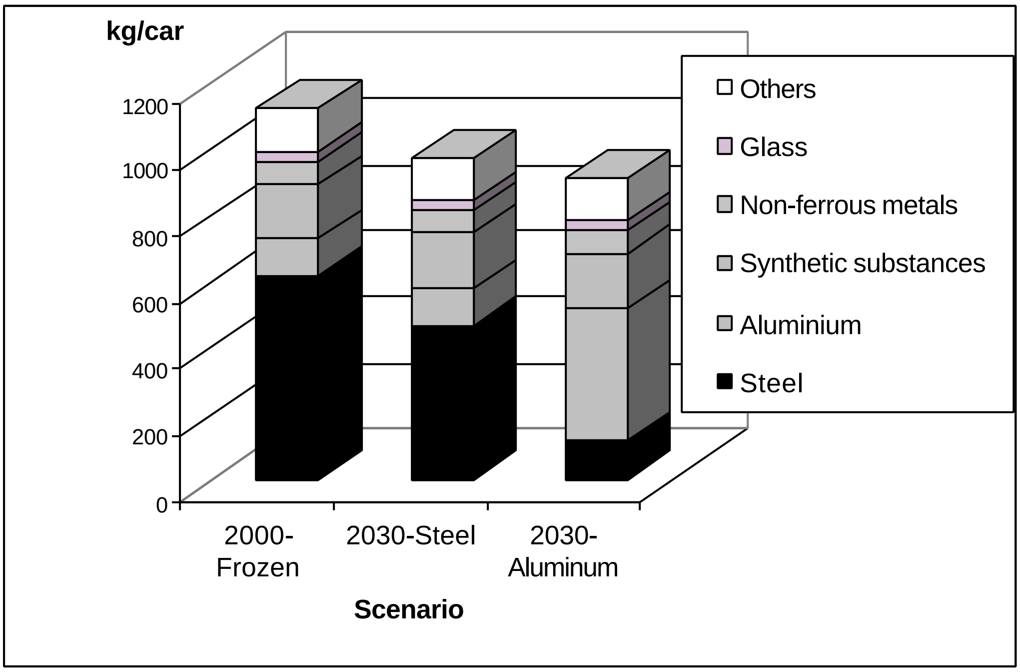


Figure 2: Development of primary energy demand in Germany in the car sector *(results of a model simulation)*

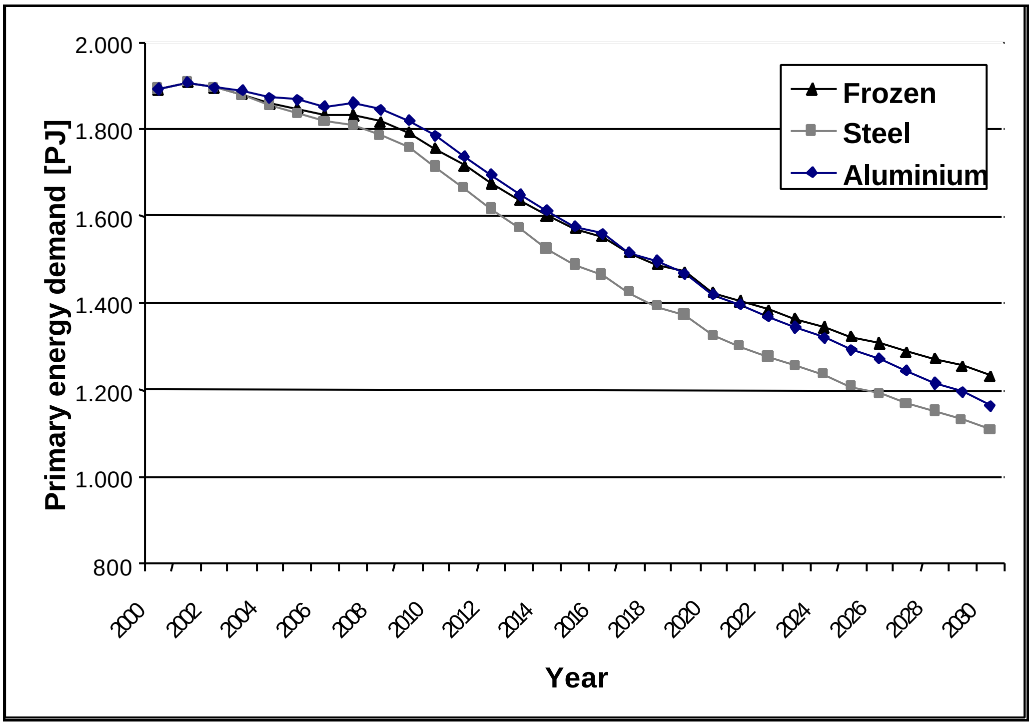
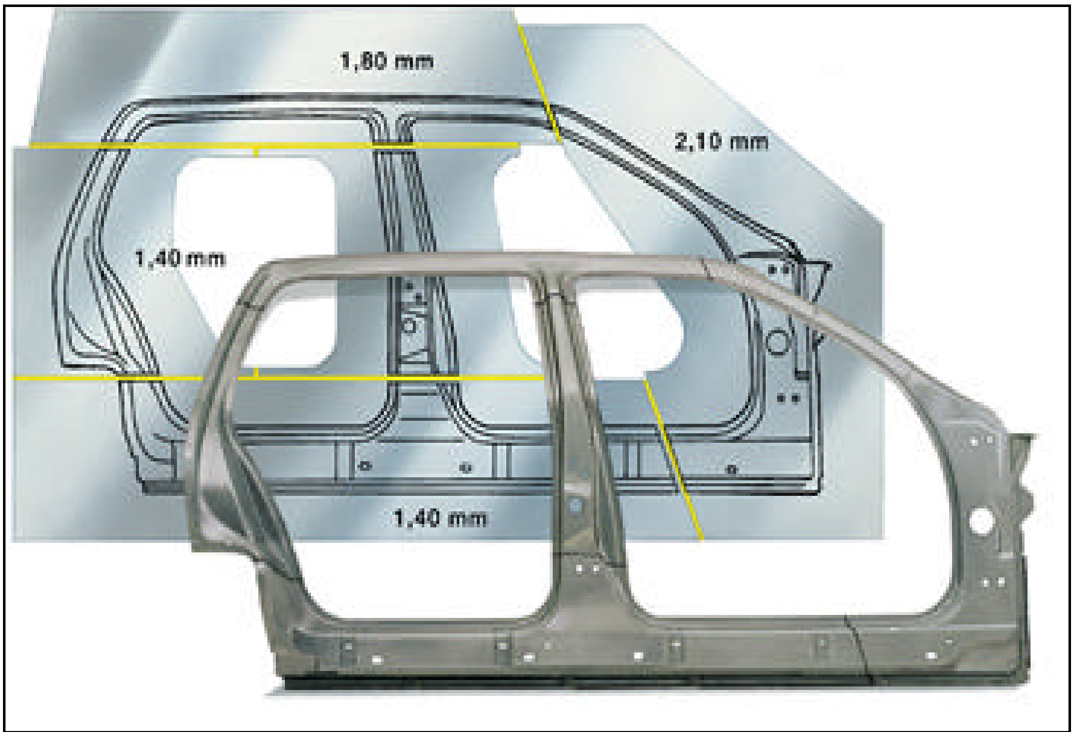


Fig. 3: Lightweight strategy using tailored blanks* (source: ThysenKrupp)



* *(Tailored blanks: strips of varying thicknesses and strengths, cut to custom sizes (blanks), and welded together to form a single "tailored" blank that is pressed as a single unit to form a component. Advantages: weight reduction., cost saving, increased material utilisation, improved corrosion resistance, less press tooling required)*

Looking at car recycling, one interesting point can be identified. The amount of synthetic materials is relevant (see Figure 1), but so far material recycling of these substances has not been realised to a significant extent. The material recycling of synthetic substances in cars is very ambitious because up to150 different types of synthetic materials are used in one car and around 2000 different synthetic substances are used in the German car industry.

Another example demonstrating the relevance of harmonisation is the product development of sheet-glass (i.e. windows of cars and houses). Sheet-glass production is a cost-intensive, high-temperature and energy-intensive process which requires absolute purity of the input materials. Due to the fact that every manufacturer has his own top-secret dispensing, it is hardly impossible to install a direct recycling process using secondary material as input material for the sheet-glass process.

Looking at the study, the following overall conclusions can be drawn:

- today, material efficiency strategies save more than 150 PJ and it would be possible to save 800 PJ up to the year 2030, which is around 5 % of the total primary energy demand of Germany (see Table 1).
- In many cases, recycling materials have a lower specific energy demand compared with primary materials.
- A further increase of recycling depends on realising
  - the cost reduction of recycling processes,
  - improvements of scrap metal purity,
  - quality checks for recycling materials,
  - harmonisation of products and reduction of material numbers,
  - increasing the ease of disassembly and dismantling of products.
- In many cases, lightweight strategies represent a very important option to reduce the primary energy demand due to the energy savings made during the product use.
- Material efficiency strategies have to be a part of an efficient and cost-effective energy and climate policy.

Table 1: Energy saving due to material efficiency strategies

Material/Application	***Today's saved primary energy demand per year***	***Potential of the primary energy demand saving in 2030***
Steel	65	92
Aluminium	9	67
Lightweight cars	47	124
Concrete	11	?
Glass	8-10	48
Polymerics	14	304
Bitumen	29	12
Paper	21	142
Total	> 150	Around 800