Technological Development in Aluminium Production
- Contributions to Environmental Changes -

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Abstract

Following the discussion of sustainable development the need to develop differentiated rules considering special requirements of products, production processes and industrial sectors becomes obvious. Technical progress is one major aspect in this discussion.

To show the existing potentials for an efficient use of resources in complex production systems analysis and modelling of material flows are appropriate instruments. For this a technology-orientated process chain model has been developed along the material flow of aluminium from mining, smelting, to recycling and disposal.

Differentiating between the maximum and predicted technical potential the impacts of the implementation of modern technical concepts on resource use and emissions are quantified. Based on a scenario approach the 1997 basis is compared with a calculation considering full replacement by newest technologies available today and a further one with regard to reduced replacement in the year 2010, taking financial and market aspects into account. As an example the German packaging industry and its special recycling concept, including material and energy supply and transport has been chosen.

With the technical improvement of the different processes itself, the increase of material efficiency per tonne of produced packaging material and the improvement of the energy supply, three different effects are responsible for the overall results. The quantifications decompose the overall results according to the three effects. Focus is laid on selected emissions.

Introduction

Metallic raw material flows interfere with a large number of sustainability issues. Stakeholders including industry, politics or NGO's are integrated in the discussion to promote the "highest" potential. For more practical purposes there is a need to develop differentiated rules keeping in mind special aspects of products, production processes and industrial sectors. To support this mediation process a scientific instrument has been developed to supply information on complex metal flow systems. This integrated resource management system is a set of tools which are designed to point out existing potentials and to estimate resulting ecological, economical and social effects of various actions.

Technical progress is regarded as a means of creating sustainable production systems by dematerialization or efficiency revolution besides other means as e.g. sustainable demand behaviour. Although technical progress can not be easily quantified, its impacts on resource use and emissions can be evaluated using process chain analysis on condition that information is available on the level of different processes and locations. Furthermore, the concept of technical progress needs to integrate market processes. Therefore, it was differentiated in this paper between the technical potential of full capacity replacement by newest technology (maximum technical potential) and the smaller potential of reduced replacement in 2010 which can be realistically implemented under consideration of financial and market aspects (predicted technical potential) to get reliable projections of the impacts of technical progress.

Using a scenario approach and differentiating between the maximum and predicted technical potential the impacts of the implementation of modern technical concepts on emissions and resource use are quantified. Standing in place of other effects the impact on greenhouse gases is discussed in more detail. A supplementing description concentrating on the impacts on the energy demand can be found in [1].

To reduce the complexity this study exemplarily selects the use of aluminium in the German packaging system. It introduces the concept of technical progress for the production and recycling of aluminium packaging, giving detailed description of expected technical progress on the process levels within the next decade. The approach follows the modelling concept of a process chain analysis [2].

Production and use of aluminium packaging material in Germany

World aluminium demand in 1997 was 30 million tonnes. Germany's share was 8.5% of total, but 30.7% of European metal demand which characterises Germany as one of the big aluminium markets. The overall use of primary and secondary aluminium for production was 2.4 million tonnes, 1.8 million tonnes were semi-finished wrought products and 0.6 million tonnes were casting alloys. Figure 1 shows the share of applications of wrought products in Germany in 1997.

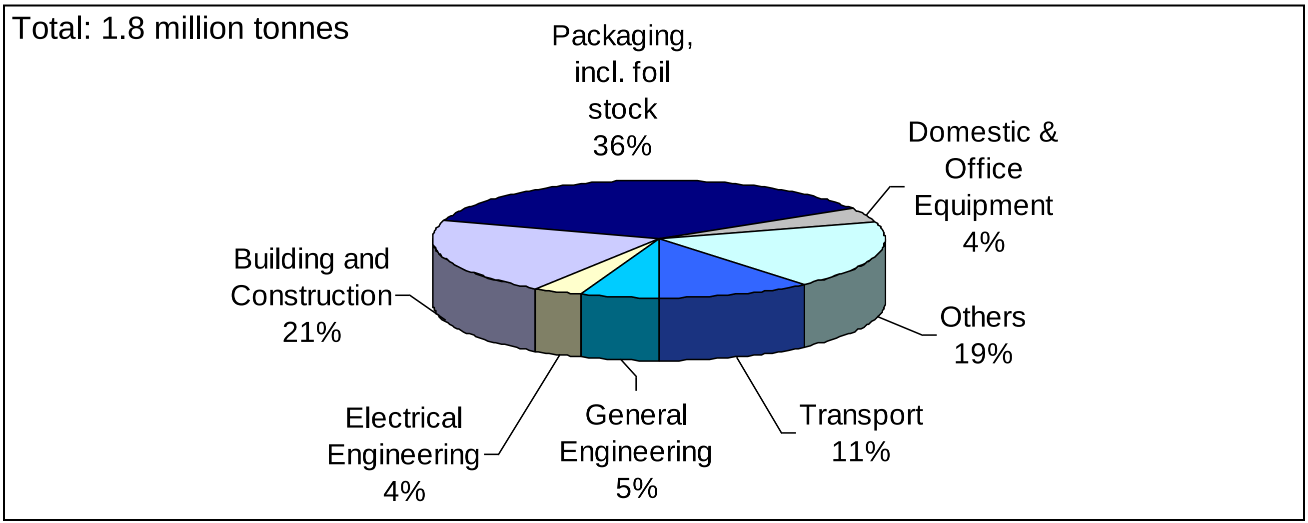

Figure 1: German semi-finished wrought material production for different areas of application

Applications of aluminium as a packaging material are still increasing. The variety ranges from combined coffee-packaging with a low metal content to full aluminium containers. The total German production of packaging material for domestic use and export was 600,000 tonnes which makes it the biggest in Europe with a share of 20% of total rolled products. In Germany itself, with 110,000 tonnes, the packaging sector is the third important end-use sector of semi-finished products behind building and transport.

German aluminium supply is highly dependent on imports. Whereas the proportion of imported bauxite is 100%, the proportion for alumina and aluminium is less but considerably high. Roughly two thirds of primary aluminium supply is imported material. On the other hand the supply of recycled aluminium was mainly covered domestically.

The biggest share of about 56,470 tonnes of aluminium packaging in 1997 was collected together with other light packaging material (LPM) by the Duales System Deutschland AG (DSD). The nearly 2 million tonnes of LPM had an aluminium amount of 28,580 tonnes [3]. Beside that, 21,650 tonnes of bottle closures and 7,000 tonnes of menu plates were recycled separately.

Process chain model

To analyse the existing system of production and recycling of packaging material a process chain model has been developed. Using this model the effects of technical progress on emissions and resources can be quantified by building up a scenario differentiating between maximum and predicted technical potential.

Within the process chain model production, use and recycling of aluminium products is divided into single processes which are represented by technology-specific and location independent modules.

They can be seen as entities of a production system, each of which has specific inputs and outputs of materials, energies, emissions and products taking distinct natural and technical properties into account. The technical status of the various processes is classified into different technology categories. They are old technologies (OT), present technologies (PT), and the newest available technologies (NT) which are already introduced. Furthermore, technical options for future use (FT) are existing.

The production of packaging material starts with primary aluminium production from bauxite (fig. 2). In the cast houses of the smelters unalloyed aluminium is cast directly into rolling slabs for foils. Alloyed aluminium for strip, especially can body and can lid stock, is cast after addition of scrap and/or alloying elements to the molten metal. Latter is also done at remelting facilities of rolling mills which mainly use in-house fabrication and foreign scraps and primary ingots. The following strip production is done by conventional hot and cold rolling. There the foil is reduced down to a thickness of 7 microns for unalloyed material and about 100 microns for AlMgMn-Alloys. For the various aluminium bins, tubes and cans the investigation ends up with the production of alloyed strip for deep-drawing operation.

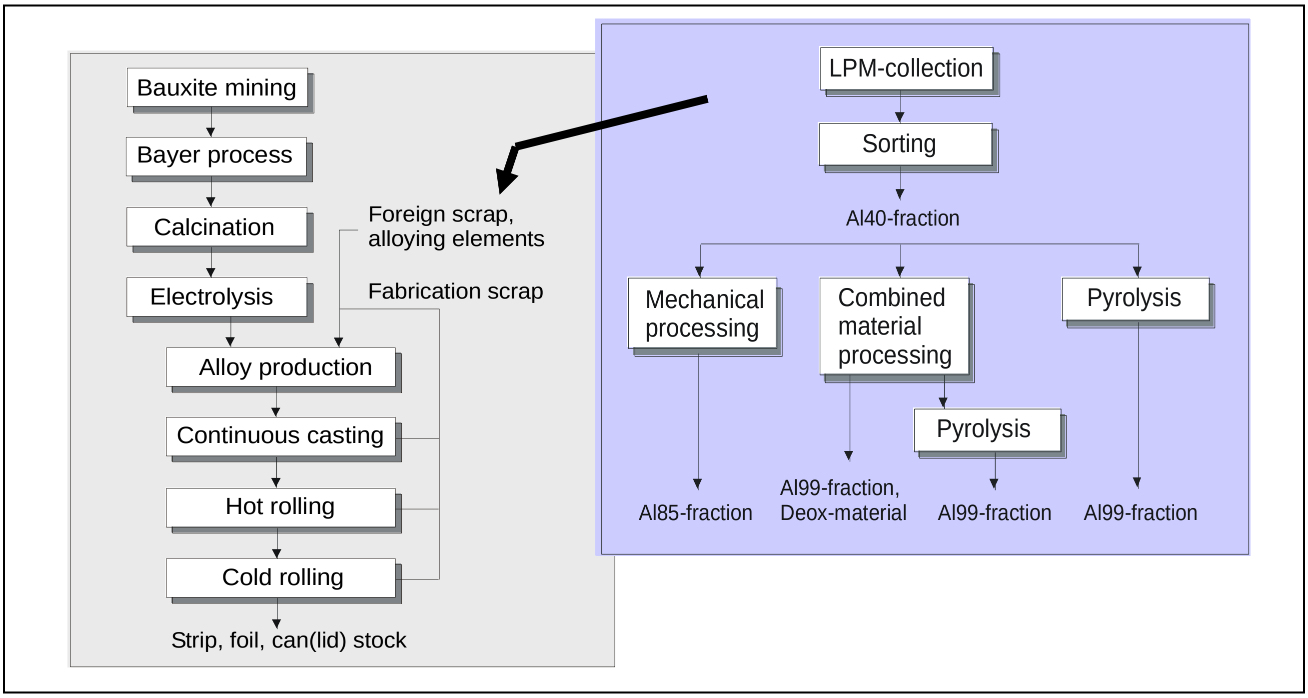

Figure 2: Production and recycling of packaging material

The recycling of LPM can be divided into three levels: collection, processing and remelting. After the collection, the aluminium fraction is separated from the packaging materials in a sorting plant. The received aluminium content of 40% is not high enough and needs further processing for a sufficient metal yield during remelting. Three processing technologies were implemented in 1997 for this. The smallest fraction (10%) was processed in a mechanical plant, 35% were the processing of combined material with a subsequent pyrolysis and the rest (55%) by straight pyrolysis. The obtained scrap has an aluminium amount of 85% and 99%, respectively. From the remelting processes (third level of recycling, included in alloy production) only those are included in the investigated system, which's material is reused for packaging production (fig. 2).

The efficiency of the recycling system for aluminium packaging in Germany can be described for collection, processing and remelting. Each level of recycling causes losses of metal so that the overall recycling quota (collection, processing, remelting) is 60% and the technical recycling quota (processing, remelting) is 67%.

Beside the production levels shown in figure 2 transportation and energy supplying processes are also taken into consideration as well as the production processes of intermediate products and waste treatment. The end product manufacturing process and also the use phase are important elements in the process chain, which will be included in near future [4].

The scenario "technical progress"

Technical progress is one subject in the discussion of sustainable development which can be evaluated using scenario technique [5]. For the chosen example the changes in material and energy flows due to technical progress and innovation and its impacts on the environment was investigated in a first analysis. To separate different effects the scenario approach is carried out in three steps:

1. The reference case shows the domestic market supply for Germany for **1997** (including import and export of primary aluminium, its pre-products and secondary aluminium).
2. As a second case the maximum technical potential is calculated considering the exclusive application of newest technology (**NT**) for each process of the 1997 structure.
3. In a third case financial and market aspects are taken into account. Looking at **2010** as the target year only a part of existing plants will be replaced by NT. Some plants will be upgraded and others will not be changed at all. This differentiation is not a model result but exogenously determined based on expert information.

The results of all three cases were compared resulting in maximum and predicted potential of technical progress and its impact on the environment in a medium term time frame.

Set of assumptions

To explore a reliable scenario a comprehensible set of the assumptions becomes very important. Following, the main assumptions concerning all calculation steps and the variations within the three cases will be described.

The calculations are based on constant amounts of production and recycling. Therefore, there is no effect of capacity increase. German aluminium supply is highly dependent on imports. The import structure is shown in table 1 distinguishing between direct sources and indirect sources. Latter are those countries which export pre-products to direct suppliers. This import structure is left unchanged for all three cases.

Table 1: Direct and indirect sources of bauxite, alumina and primary aluminium for the German production of packaging material 1997

	Bauxite %	Alumina %	Aluminium %
Australia	14.8	8.5	
Brazil	9.1	7.5	7.5
Canada		2.4	9.0
France		0.4	0.9
Germany		19.9	46.9
Ghana	2.0		
Greece	0.1	0.1	
Guinea	19.0	0.1	
Guyana	8.6		
Iceland			4.4
Ireland		7.0	
Italy		2.9	
Jamaica	30.1	29.4	
Norway			12.0
Russia	11.8	11.8	12.8
Spain		1.4	
Suriname	4.0	3.6	
UK		1.9	6.4
USA		2.1	
Venezuela	1.2	1.2	
direct sources			
Total amount	2,902,000 t	1,230,000 t	637,000 t

The share of secondary raw materials for alloy production was not varied. A mass flow scheme for pure and alloyed aluminium has been created from several statistics, which was extended to single alloy groups. It was found that pure metal is made 100% from primary materials and alloyed metal has a share of 43% of secondary materials (which represents the 1997 average value, excluding in-house scrap from rolling). The same is assumed for the UK and France, imported alloys from the other countries are made of primary metal plus alloying elements.

The energy supply for the various processes is based on the energy carrier mix of the investigated year. Only for electrolysis a special so-called ‘contract mix’ is used. Here, the ‘contracted’ electrical energy supplier of the smelter and its base load mix has to be considered [6].

Beside the case independent assumptions each case has a set of specific assumptions to describe the investigated system. For the NT (full replacement) case, the selection of newest technologies in the different process steps is expressed through the saving of energy and accordingly a reduction of emissions. The modelled levels from bauxite mining to electrolysis consider only one technique.

Additionally, for alloy production, semis production and material processing the material yield becomes another major factor.

The assumptions can be categorised in three main groups. The first group reflects the change of technology itself. Beside that, those assumptions which effect the increase in material efficiency and another considering the energy supply situation can be made out.

Until 2010 (reduced replacement) the technological improvements will be limited realised considering beside possible physical improvements also financial and markets aspects and investment behaviour. Table 2 summaries the main assumption for the three cases.

Table 2: Set of main case-specific assumptions

<table>
<tr><th></th><th>1997</th><th>NT</th><th>2010</th></tr>
<tr><td>Mining</td><td>Base year supplying mines</td><td>Constant bauxite quality</td><td>Closure of some mines</td></tr>
<tr><td>Alumina production</td><td rowspan="3">Base year technology mix of supplying countries</td><td>Only tube-digestion and fluid bed calcining</td><td>10% energy savings, 1% higher yield</td></tr>
<tr><td>Electrolysis</td><td>Only newest PFPB cell technology</td><td>Modernisation, expansion only by NT</td></tr>
<tr><td>Alloy production</td><td>Only modern furnaces with oxygen burners or heat recovery</td><td rowspan="3">Increasing share of newest technology</td></tr>
<tr><td>Continuous casting</td><td rowspan="3">Base year technology mix</td><td>Max slab weights = min fabrication scrap</td></tr>
<tr><td>Hot/Cold rolling</td><td>Lower energy and material demand</td></tr>
<tr><td>LPM recycling</td><td>Only fully automated separation and pyrolysis</td><td>10% of fully automated separation, replacement of mechanical processing</td></tr>
<tr><td>Energy supply</td><td>1997 energy carrier mix</td><td>1997 energy carrier mix, newest conversion technology</td><td>Technical improvement and 2010 energy carrier mix</td></tr>
</table>

For the bauxite mining the calculation bases on long-term supplying contracts. Nevertheless, until 2010 the closure of some mines has to be considered. The bauxite quality remains the same for all cases.

Because no complete production numbers of single locations are available for the alumina production process data of different digestion techniques are capacity weighted and related to the missing plants in the various countries. With the supplying structure also unknown country related mixes are modelled. For the NT case only the tube-digestion and fluid bed calcining takes place. Until 2010 a reduction of energy consumption of 10% can be expected by lowering the liquor volume. Also an improvement of the metal yield of 1% seems achievable. The land filling of red mud will only take place in orderly dump sites for both, NT and 2010, cases. The Russian alumina production from nepheline was not replaced in any calculation.

The relation of capacity weighted techniques to country mixes was chosen also for the primary smelters but with the distinction of pure and alloyed aluminium. A fully automated pre-baked cell technology with point feeding, reducing anode effects and consequently emissions, is used for modelling the electrolysis in the NT case [7]. In the 2010 case modernisation by computer control of the cells and the feeding system and by modern point-feeder technology can be assumed.

The alloy production includes remelting and refining and is represented by the 1997 technology mix. It changes completely to modern technology of the various furnace types by implementing oxygen burners or heat recovery systems for the NT case. The share of furnaces with modern technology increases until 2010.

Continuous casting will change to bigger slab weights causing decreasing amounts of fabrication scrap during the whole strip and foil production. In the NT case slab weights of 30 tonnes are assumed for continuous casting. So the amount of fabrication scrap can be minimised. Due to the high throughput of rolling mills for strip and foil stock production, the conventional route via hot rolling has not been replaced by continuous strip casting. Until 2010, beside decreasing metal demand hot and cold rolling itself changes to lower energy and material demand.

The earlier described system for the LPM-recycling will be replaced by fully automated separation and pyrolysis to reach best metal recovery for the NT case. Until 2010 this technique will reach a share of 10% and replaces the mechanical processing entirely.

For the supply of electric power the mix of energy carriers remains equal in the 1997 and NT cases. The implementation of newest conversion technology is assumed. Until 2010 a change in the energy carrier mix for the production of electrical power in Germany is expected. This will have a major impact on the resulting emissions according to the energy supply.

Results

Using the process chain model the changes along the three calculation steps can be quantified. The results allow an analysis in various directions considered in the sustainability discussion. In table 3 some of the major topics can be identified. It shows the most important inputs and outputs per tonne of packaging material. As could be expected, the improvements in the NT case are always bigger than for the 2010 case. Nevertheless the values are different for the various inputs and outputs.

The amount of bauxite necessary for the production will be discussed under the topic 'use of mineral resources'. 13.1% less bauxite is demanded due to higher digestion efficiency and less primary aluminium input for the NT case and 5.1% for 2010. This has also a big effect on the red mud output, the highest solid waste amount of the system. Another discussion concentrates on the recycled content of a product and therefore the relation of primary and recycled aluminium which was considered constant in this scenario. Other topics of interest are the metal yield of the recycled products expressed through the increasing Al-content of recycled LPM.

The major parameter to represent technical progress in the aluminium production however is the energy demand and the connected emissions to air. To reduce the complexity of the subjects in a first analysis focus was laid on the effects on the energy demand, which can be found in [1]. With CO_2 and other greenhouse gases (GHG) being directly connected to the energy discussion this paper concentrates on these emissions. As can be seen in table 3 the reduction potentials for both, the NT and the 2010 case, are relatively high. The various impacts leading to their reduction are discussed now.

Table 3: Calculation results for the material and energy flow due to the production of one tonne packaging material

Input per tonne packaging material	Unit	**1997**	**NT**	Δ	**2010**	Δ
Bauxite	kg	4,554	3,957	-13.1%	4,322	-5.1%
Primary aluminium	kg	1,062	985	-7.3%	1,023	-3.7%
Foreign scrap	kg	239	237	-0.8%	238	-0.4%
Primary energy	MJ	195,968	145,230	-25.9%	165,270	-15.7%
Output per tonne packaging material						
Fabrication scrap	kg	297	225	-24.5%	261	-12.2%
Al-content of recycled LPM	kg	38	48	26.6%	40	4.7%
CO_2	kg	11,491	7,969	-30.7%	9,467	-17.6%
Red mud	kg	2,368	1,871	-21.0%	2,165	-8.6%

The background for a GHG discussion is that various countries committed to limit these emissions. The Kyoto Protocol for example claims a reduction of the four gases CO_2, CH_4, N_2O, and SF_6 and two groups of fluorinated gases (HFC and PFC) of at least 5% below 1990 levels in the commitment period 2008-2012. In Annex B of the protocol the European Union claims the reduction of 8% [8]. This overall target has been distributed on a differentiated basis to individual member states under an "EU burden sharing" agreed upon by the Council of Ministers in June 1998. The target for Germany is therefore 21%. Although this does not refer to any specific industry, it gives an order of magnitude if supposed the reduction would be shared by every industry in the same way.

In addition to these country agreements, industrial sectors in various countries voluntarily committed to reduce GHG. The German aluminium industry participates in two ways. As a member of the German non-ferrous metals industry it committed to reduce specific energy consumption by 22%

until 2005 (base year 1990). In a second voluntary agreement the German aluminium industry in 1997 has announced to reduce perfluorocarbons (PFC) by 50% until 2005 starting from the 1990 figures [9].

In the following the paper does not claim to be a monitoring report. Neither the scope packaging material, the spatial system boundaries nor the base and target years of the scenario cover the system considered in the commitments. Nevertheless it's important to calculate emissions reduction potentials for a defined example.

The total CO_2 emissions per tonne packaging material was nearly 11,500 kg in 1997 and is about 8,000 kg and 9,500 kg for the newest and 2010 realised technique, respectively (fig. 3). The highest CO_2 production is in all three cases due to the carbon consumption during smelting. To a much lesser extent the Bayer-digestion and the alumina calcination are responsible for the amount followed by the cold rolling, electrode production (including coke and pitch production for pre-baked and Söderberg cells), hot rolling and the alloy production from primary and secondary material. The effects of the other processes, such as transport, soda or lime production, bauxite mining or red mud treatment can be neglected.

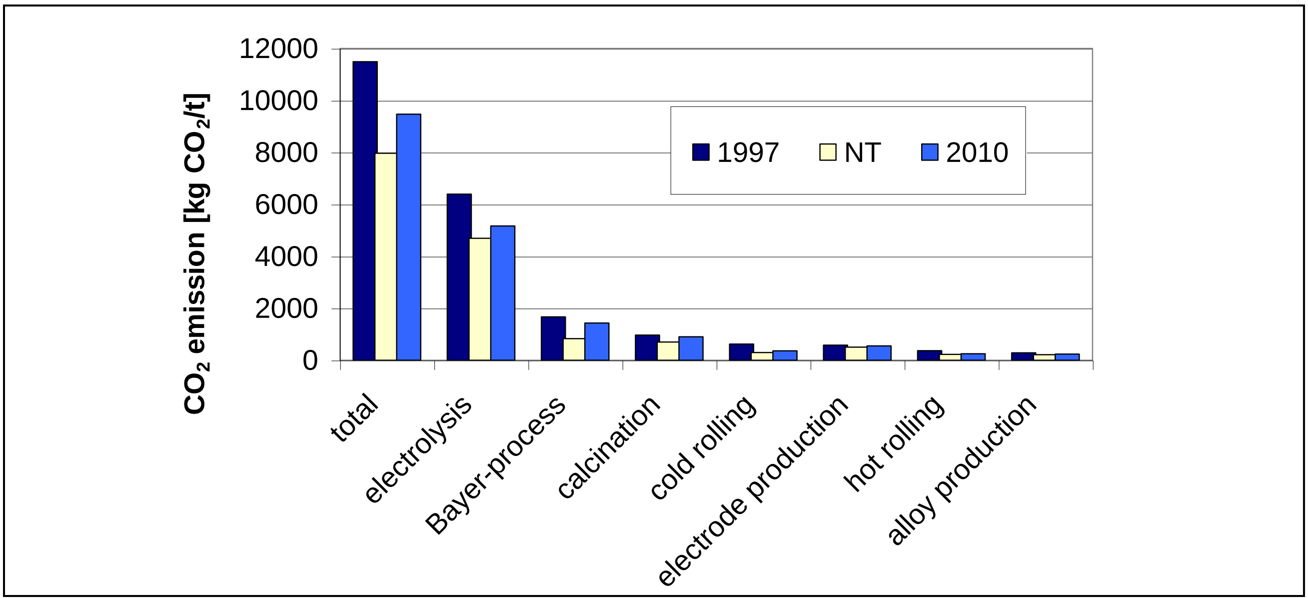

Figure 3: CO_2 emissions of the scenario calculations per tonne of packaging material

It is common in the CO_2 discussion to differentiate between process and energy induced emissions [10]. Typical process induced CO_2 emissions of the aluminium industry are those generated during electrolysis. More interesting for the discussion about technical progress is the differentiation between those CO_2 emissions which can be determined by the aluminium industry itself (Al-industry), by selection of technology or handling of the processes, and those emissions related to the supply of energy (energy supply), shown in figure 4. Latter cannot directly be determined by the aluminium industry.

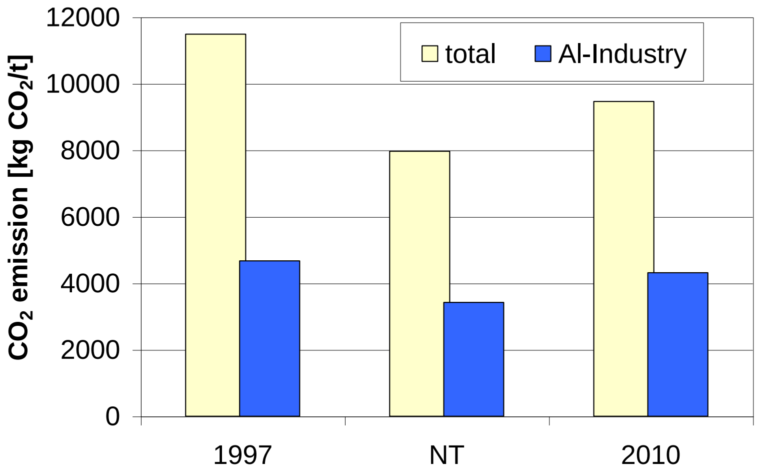

Figure 4: Comparison of total and Al-industry determined CO_2 emissions per tonne of packaging material

As mentioned above the commitments are often country related and can differ between them. Therefore it is interesting where the emissions occur. Figure 5 shows the reduction potential of CO_2 emissions. Beside the total reduction potential (entire system incl. energy supply) the potential of the aluminium industry in Germany and the potential of the metal supplying countries are considered. It can be seen that the technical reduction potential of the export countries (32%) is higher than the German one (17%). Compared with the average imports the German aluminium system has already undertaken big efforts to reach a high technical and environmental standard. Nevertheless, less than half of the possible potential in Germany is likely to be reached until 2010, whereas only a third will be reached by the other countries included in the investigated system. The reduction in Germany and supplying countries will reach about 7% until 2010 with regard to CO_2 emissions.

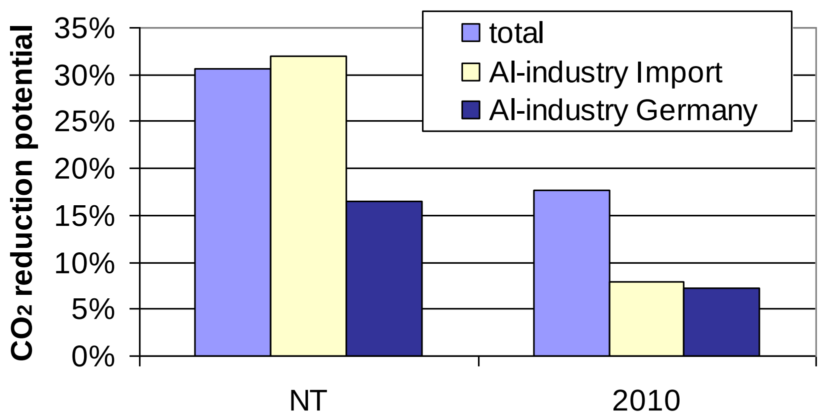

Figure 5: Reduction potential of CO_2 emissions per tonne of packaging material determined by the Al-industry, differentiating between the locations of occurrence

Other GHG than CO_2 important for the aluminium industry are the perfluorocarbons (PFC) and methane (CH_4). All GHG are commonly expressed by their global warming potential (GWP) in

CO_2-equivalences. In this paper the GWP (100) is used. Although CF_4 and C_2F_6 have a small amount their GWP (100) is rather high, with 6,300 CO_2-equivalences for CF_4 and 12,500 CO_2-equivalences for C_2F_6 [11].

In figure 6 the reduction potential of the German packaging production sector separated for the GHG expressed in CO_2-equivalences is shown. The possible reduction due to a total capacity replacement is more than 45%. The predicted reduction is estimated to just more than 20%. As before, also in this diagram it is differed between those emissions which can be determined by the aluminium industry and those emerging during the supply of energy. The reduction potential of the CO_2 gases is mainly determined by the energy supplying industry. Also the CH_4 emissions occur mainly in the energy supply processes (here mainly natural gas supply), whereas the PFC emissions occur exclusively in the electrolysis process. Latter have a high reduction potential.

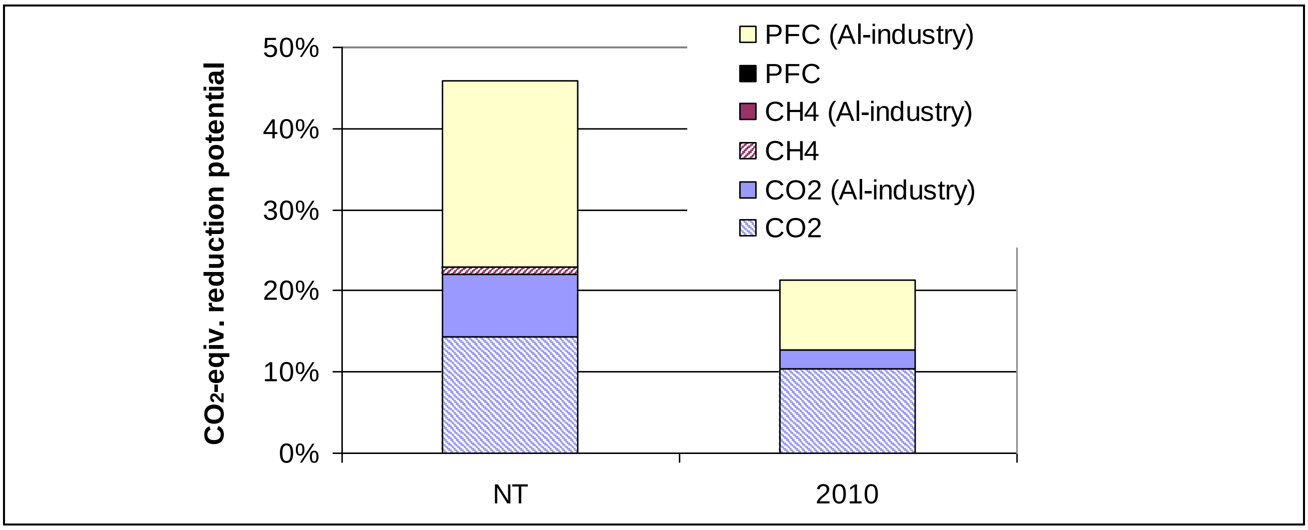

Figure 6: Reduction potential of greenhouse gases separated to Al-industry determined and total amounts

Nearly half of the reduction in both cases, NT and 2010, is reached by the decrease of perfluorocarbons. As they occur only in one process it is obvious, that the electrolysis process has the biggest share of the overall reduction potential. With about 74% of the overall reduction potential (fig. 7) it plays a dominating role. In the NT case the Bayer-process has the second highest share of the overall improvement whereas until 2010 the changes in the cold rolling processes will have a bigger influence on the reduction. Similar it is for the calcination and hot rolling processes. Where the first has a share of about 4% for the NT calculations, latter will have a higher influence in the 2010 case. Again, the other processes are not shown. With respect to the GHG emissions the electrolysis becomes the process where even a moderate effort in process improvement will have a major influence on the entire system.

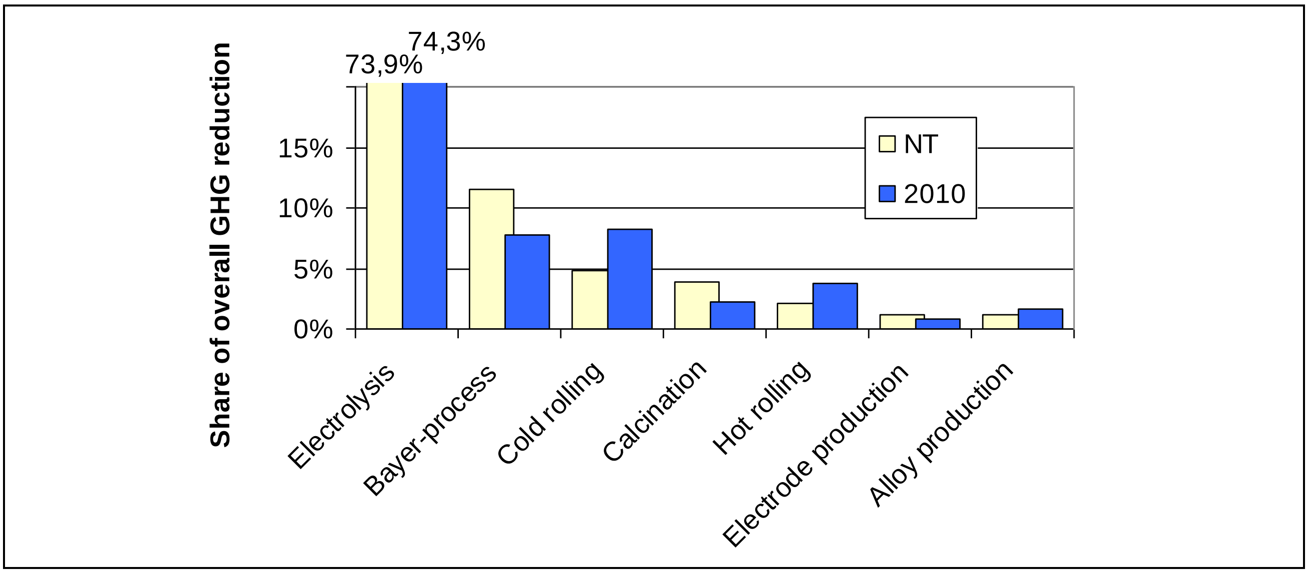

Figure 7: Share of overall GHG reduction according to the different processes per tonne of packaging material

The improvement of every process step are achieved by three main effects, the technical variations of the aluminium production processes, increasing material efficiency per tonne produced packaging material and improvement of the energy supply. In figure 8 these three effects and their influence on the primary energy demand is shown [1]. It can be seen, that the entire improvement in primary energy demand in the case of newest technology (NT) is 26% and that in the year 2010 16% can be realised. Beside the dominating part of technical improvement for the exclusive use of newest technology it is shown that in 2010 the part of energy supply improvement increases significantly. In addition to technical improvements of the energy conversion the expected changes of the energy carrier mix for electrical power supply in Germany generate a major influence of the energy system. The average conversion efficiency of the national grid increases from 31.5 to 43.1%.

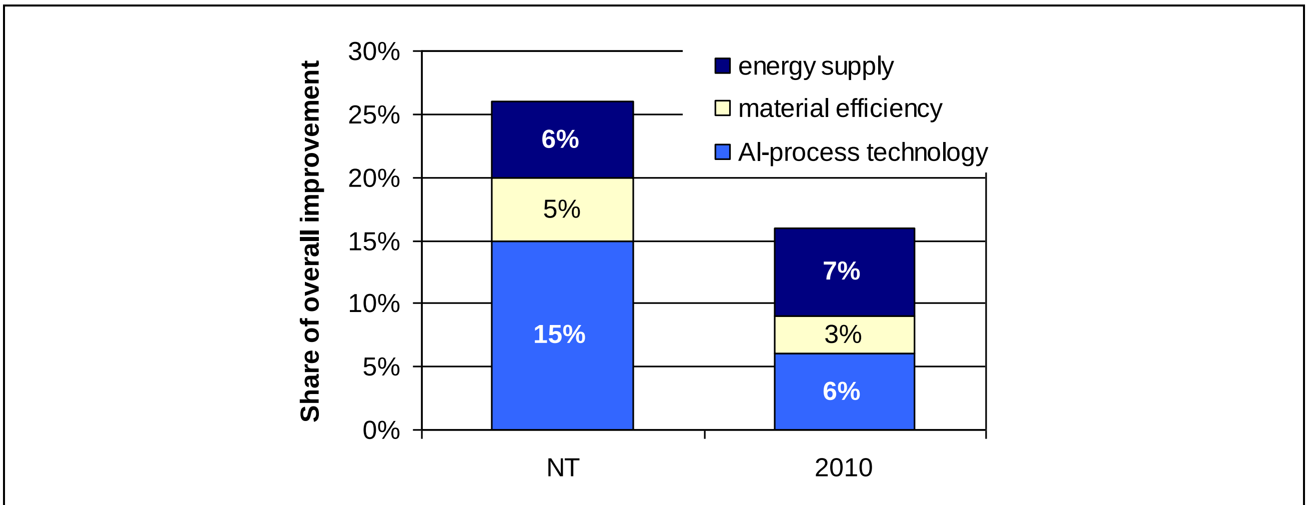

Figure 8: Share of overall primary energy saving for full replacement (NT) and reduced capacity replacement (2010) [1]

With CO_2 and CH_4 emissions mainly connected to the energy supply and the PFC emissions only connected to the electrolysis process the share of the three effects will differ from those of the primary energy savings. As stated before, the reduction potential of GHG emissions for full replacement (NT) is more than 45%. The changes of processes which could be done by the aluminium industry itself would cause a reduction of 34%, plus 4% due to an increasing material efficiency following out of that. The improvement of the energy supplying industry would add another 7%. Less than half of the maximum technical reduction potential is likely to be achieved until 2010 (fig. 9).

The GHG emission reduction which can be determined by the aluminium industry will reach 17% points from 38% possible. In contrast to the increasing significance of the energy supplying sector in the primary energy reduction, the share of GHG emission reductions will decrease from 7% to 5%.

The expected change in the energy carrier mix for Germany, which results in an higher efficiency of the national grid, results in an increase of GHG emissions. This is mainly due to the higher percentage of gas fired power plants. Their high efficiency is overcompensated by the increasing CH_4 emissions during the supply of the gas.

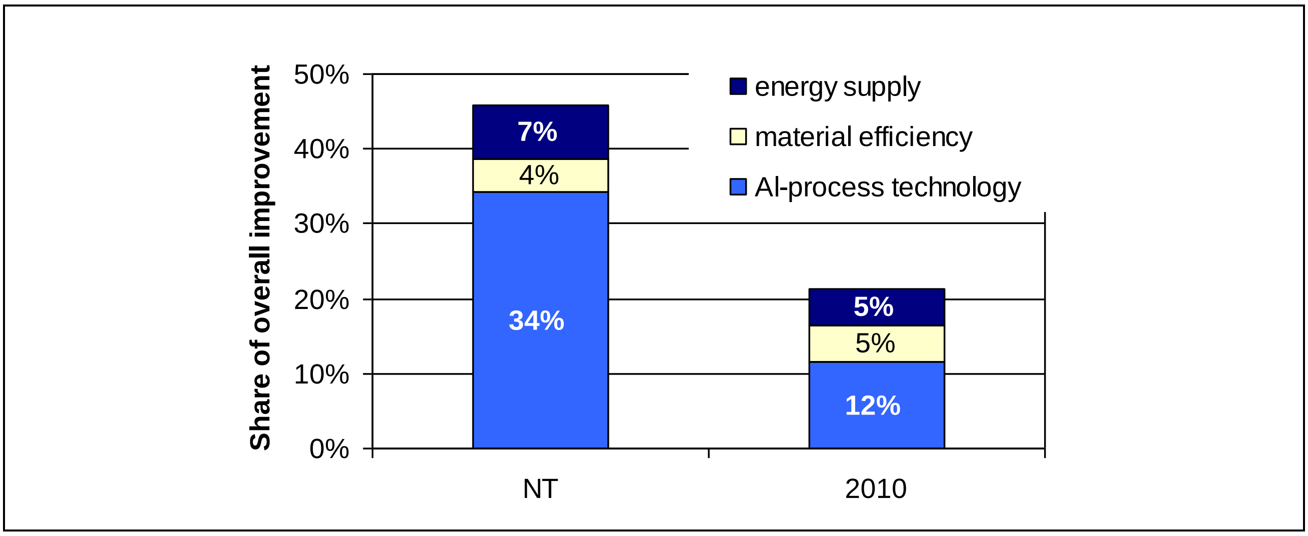

Figure 9: Share of GHG reduction for full replacement (NT) and reduced capacity replacement (2010)

These results are representative for a variety of possible calculations in the field of environmental impact assessment which can be determined from the existing data base. They also show the various facets of the sustainability discussion. An improvement in the energy reduction does not automatically leads to a reduction in emissions as well. To support the discussion the process chain model can be used, to analyse the complex material flow.

Conclusions

Technical progress has an influence on a variety of topics which are related to the sustainability discussion. In this analysis focus was laid on the reduction of greenhouse gases. It was differentiated between the maximum technical potential already achievable with today's known technology and the predicted potential implemented within the next decade. To reduce the complexity of the entire system the German packaging sector was chosen as a first example.

The greenhouse gases occurring in this system are CO_2, CH_4, CF_4, C_2F_6. The maximum reduction potential of newest technology (NT) is 45%, whereas 21% are likely to be realised until 2010. Looking at the improvement in more detail, it is of interest to differ between the actors who can determine the changes necessary for reduction in the system. To differentiate between the 'responsible' sectors is important to prevent double counting in the monitoring of reduction targets. It was differentiated between those determined by the aluminium industry itself and those related to the supply of energy. From the 45% maximum potential 38% points can be determined by the aluminium industry, the rest is due to the supply of energy. In the 2010 case 17% are depending on the changes in the aluminium industry.

Reduction commitments are often country related. Therefore, it must be analysed where the emissions occur. It was shown, that the predicted CO_2 reduction in Germany (2010) is nearly as high as that of the exporting countries of the system (7%) although latter have a much higher maximum technical potential (27%). The main reason can be seen in the already high technical and environmental standard in Germany. Nevertheless only half of the maximum potential will be reached until 2010.

The various process steps have different impacts on the overall reduction potential. The electrolysis process has a dominating part in this. Even a moderate success in the process improvement will change the entire system significantly.

The comparison of primary energy and greenhouse gas emission reduction potentials shows, that within the same system changes can have different effects. A more energy efficient technology might have higher GHG emissions if efficiency increases are accompanied by different energy mixes. For a widespread discussion about sustainable development other aspects such as other emissions, the use of mineral resources, or recycling concepts have to be investigated closely and integrated, too.

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