LCM in chemical industry: Best available pathways of quantifi able stepstowards sustainability

Martin Baitz[1,*], Anna Braune[1] and Johannes Partl[2]

[1]PE International AG, Leinfelden-Echterdingen, Germany

[2]PE CEE Nachhaltigkeitsberatung & Software Vertriebs GmbH, Vienna, Austria

*m.baitz@pe-international.com

Abstract The chemical industry is a key player towards sustainable products due to two reasons: It uses substantial amounts of energy and resources to produce its products and its resulting products help to save energy in suitable applications. Most of the public assumes the chemical industry is consuming a lot of energy and is causing environmental problems. The benefit of chemical products is often unknown in public and even in expert circles and the chemical industry often hardly tries to quantify it in a reliable way. The chemical industry has different options with varying relevance to improve the environmental and fossil energy performance of its products: 1. Reduction of energy demand. 2. Implementation of renewable energy sources. 3. Switch to non-fossil material. 4. Improve the quality of the products for savings in applications. 5. Improve the EOL of chemical products by adequate secondary uses. But which is the best for whom?

1 Introduction

No innovation is possible without life-cycle thinking and management. From a life cycle view different improvement approaches can be chosen within the chemical industry.

Whether or not one is better than the other is of course a question of the actual product, technology, region and supply chain of the respective situation. After 20 years and thousands of life-cycle projects - with direct or indirect involvement of products of chemical companies - four basic conclusions hold always true:

1. Analyze and model as precise as needed, as simple as possible
2. General answers on specific questions tend to be generally wrong
3. Real technology data and models are decisive and the one and only alternative
4. Relevancy is a perfect advocate of professionalism

Following these basic rules enables a proper LC result as deliverable from the engineering side and a proper and well informed decision context from management side.
In the following different approaches to identify promising pathways according to the specific situations are discussed. If a path is chosen randomly or only methodology driven, without indications about its technical relevance in the specific case, a lot of effort may end up in irrelevant or even contra productive measures [1]. The environment would be irrelevantly improved or even harmed, and economic and social implications maybe negatively influenced.
The society needs advanced chemicals towards more sustainability, if we consider wealth as protection goal. The pathways towards sustainability must be identified and followed individually, while technical implications must be well understood.
Therefore the pathway towards more sustainability must be undertaken in cooperation with pro-actively acting industry, based on proper technological data and best practice methods.
Chemical industry should not waste effort and money to bet on fuzzy horses and must define its individual best way or the best compromise; based on reliable and quantifiable facts.
Suitable technical understanding of the process as well as region- and supply specific upstream chains supported by best practice methods concerning the life-cycle approach, a modern software enabling scenario calculation on basis of technical parameters and a consistent industry-borne database are the way successful chemical companies apply life-cycle-management today.

2 Realistic assessment of benefits and burdens of chemical products

The reduction of energy demand is the classical approach and is already done since decades and often very largely implemented. If energy reduction measures are already applied at existing modern technologies and constantly maintained relevant further reduction potentials probably need “breakthrough or new technologies“.
Suitable examples are steam crackers, which are in average considerably old but optimized to a maximum.
The implementation of renewable energy sources can be quite simple to reach, by changing the energy supplier, if the energy is bought. If own power plants exists the switch to biomass power plants may bear topics like fuel supply and trade-offs regarding positive effects on release of greenhouse gases (GWP) and fossil

energy but possible shift of burdens into other environmental issues such as release of nitrifying and acidifying substances into water bodies, soil or air, contributing to acid rain and over-fertilization. This aspect is very case specific and hardly to answer in general. [1]
Taking ethanol from Brazil as an example it may help to improve European GWP and fossil energy impacts, but will surely produce massive trade-offs locally due to emissions from field burnings.
The switch to non-fossil resources as feedstock for the chemical products bear comparable effects of positive impacts on GWP and fossil energy but possible shift of burdens into NP and AP. Further it must be carefully checked if the quality of the final product stays constant. [1]
Sole improvement of the carbon balance without considering and limiting trade-off in other impacts is not an option, otherwise we should e.g. consider to remove catalytic converters from cars and stop off gas treatments like DeNOx or desulfuration units and we should shut down waste water treatment plants. It gets clear that this would be no option.

The improvement of quality/property of the chemical products that these can save secondary energy in their respective (mobile or energy consuming) applications, is a rather new topic in analysis of the chemical process networks and most likely a promising one. [1]
The quantification of the saved GWP and (fossil) energy impacts of chemistry on the society is not simple, if realistic and defendable figures are aimed. Chemicals are most often further assembled or used as a part of the total system to get products of a certain quality and performance.
However structured and adequately simple approaches can be used to quantify such benefits realistically. Most important is that the approach in not too general and can cope with realistic and specific scenarios.
How to ensure easy communication while maintaining the capturing of all relevant effects? By communicating main decision pillars and sketching the holistic framework in which the decision was drawn.
Reality is complex and proper decisions are complex. Decisions must be drawn knowing all relevant aspects, so the decision may always be a well informed "best compromise". Welcome LCM in the real world.

A prominent example for easy and general communication is a factor 3 : 1 in GWP and energy savings (three times more CO2 and energy saved, than caused and consumed by chemical products). This can be adequate for portfolio of products of a company, but it is as well very easy to reduce it to absurdity, if looking on specific cases. So specific answers for specific products are needed to

communicate product specific results sincere: e.g. factor 1,5 : 1 in one case and factor 1 : 6 in another case.
And if a chemical turns out to have a factor of 0,5 : 1 (hence more burden caused than saved) two approaches can be followed: Firstly to follow most promising environmental optimization approaches or alternatives using the already gathered information. Secondly strength and positive aspects can be checked and communicated (e.g. higher security for a user) by accepting the higher CO2 burden. Moreover even factors like 0,5 : 1 can be justifiable in a positive way, if not the overall environmental performance is the main driver of sustainability, but maybe very important social implications or single but important human health aspects (accepting that the environmental aspect is second priority in this specific case). [1]

3 Options to improve the status quo and key drivers

From Life cycle view different improvement approaches can be chosen.

1) Approach: Reduction of energy demand due to energy efficiency measures like optimized catalysts, energy recovery measures, closed circuit technologies, by-product use and off-heat recovery measures.

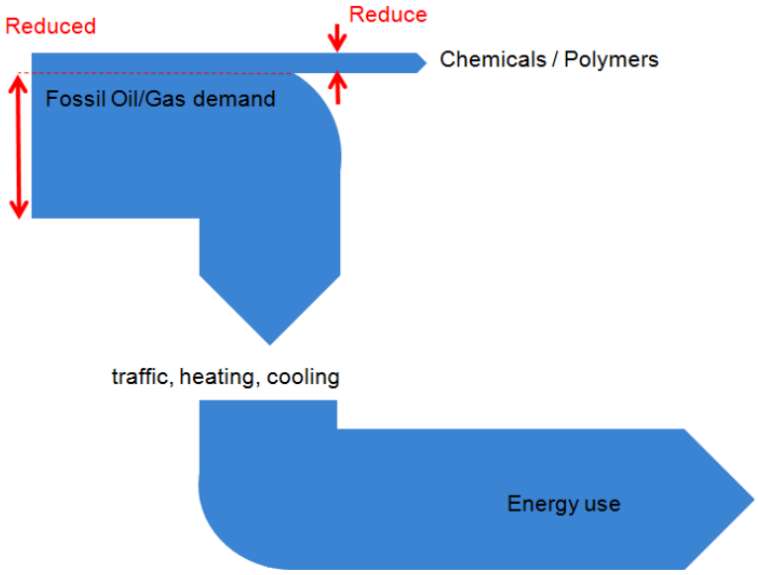


Fig.1: Reduction of energy demand due to energy efficiency measures [1]

Effect: Less fossil energy consumption and less CO2 impact in chemical/polymers industry.

Whether the measure is relevant or efficient is a matter of the viewpoint. For a single company it can be attractive, but due to the limited relevance of resource use in chemical industry compared to fuel and heating use it may not solve the overall problem.

2) Approach: Implementation of alternative or renewable energy sources (new technologies, contracts with renewable electricity suppliers, own biomass power plants)

Effect: Less fossil energy consumption and less fossil CO2 impact in energy supply for chemical/polymers industry.

3) Approach: Switch to alternative or non-fossil resources as feedstock for the chemical products (like sugar beet based ethanol as source to produce ethylene)

Effect: Less fossil energy consumption and less fossil CO2 impact in upstream supply chain for chemical/polymers industry.

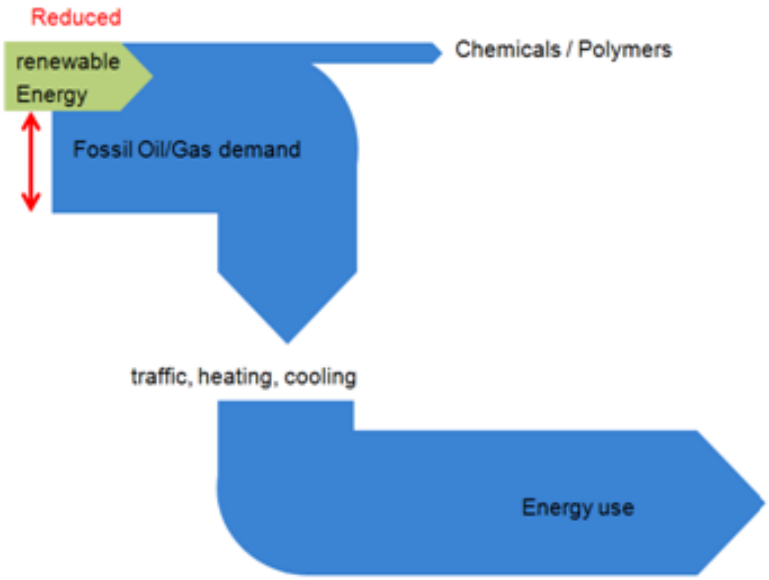


Fig.2: Implementation of alternative or renewable energy sources or non-fossil resources as feedstock [1]

The switch to green electricity is most likely beneficial, if supply continuity is given. Whether measures of renewable feedstock are relevant or efficient depends on the kind of product and the needed technical quality aspects. If the life-time and performance indicators in the use phase can be maintained and the relevance of recyclability is rather low, it might be a good choice if the process efficiency is not relevantly reduced.

However the supply with non-fossil feedstock in industry scale is still not efficient for many renewable feedstock pathways and bears drastic tradeoffs if primary crops or fruits are used; hence proper agricultural by-product use is essential but limited.

4) Improve the quality/property of the chemical products and resulting parts that those can save more secondary energy and CO2 in their respective (mobile or energy consuming) applications than initially consumed.

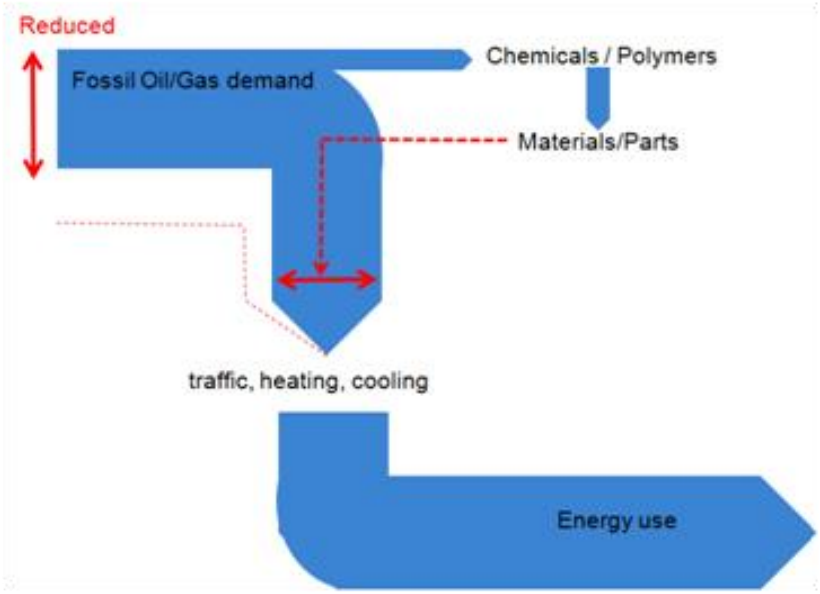


Fig.3: Improve the quality/property of the chemical products [1]

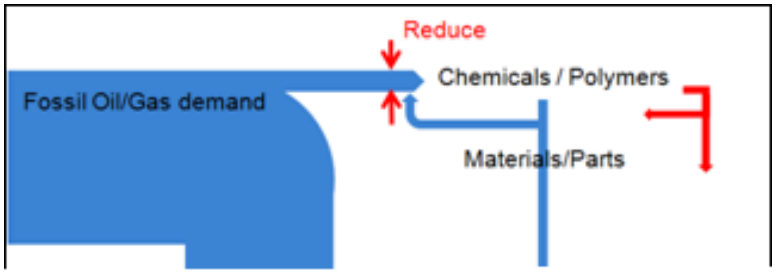
Effect: Less fossil energy consumption and less fossil CO2 impact in downstream use of products made from chemical/polymers industry.

The improvement of the quality or performance of chemicals or polymers can have positive effects on the overall sustainability performance of products, but is not easy to be quantified realistically. In many cases an "invest" of slightly higher energy use or emission release in (e.g. more complex) production may pay off several time in application by reducing weight, improving durability or environmental performance indicators due to secondary consumption improvement.

Even if the quantification is not trivial, the justification for a relevant contribution is comparatively easy; taking chlorine as an example. If the chlorine industry would be closed down, many organic chemicals and polymers and many pharmaceutical products would fade out. For some products alternatives would exist, some of comparable quality, some of less quality and performance and some of dramatically bad performance and secondary effects. For some products simply

no alternative to chlorine exists and e.g. a long lasting building material would disappear or even worse a medicine product would die out; greener industry but bad luck for the patient. However it is always worthwhile to know the relevant consequences, therefore "informed decisions" is the key word..

5) Improve the EOL of chemical products by adequate secondary uses (either material recycling to reduce primary material needs in chemical industry or energy recycling to reduce primary energy need in other industries)



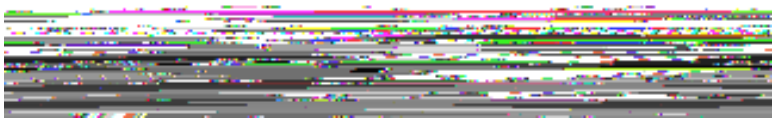


Fig.4: Improve the EOL of chemical products

Effect: Less fossil energy demand and less fossil CO2 impact due to less primary material needs in chemical industry and/or less primary energy needs in other industries.

The effect of recycling can be very promising or badly disappointing. The reason is not varying quality or ability in the recycling processes, but the value of avoided primary production.

Polyolefin's are at the very beginning of the chemical network and are comparatively simple to produce, therefore used as mass polymer in many consumer products and often heavily contaminated in or after use. Therefore recycling measures are demanding and compete with a primary product of comparatively low value.