Opportunities and Perspectives for Plastics in Coming Fossil Fuel and Solar Energy Scenarios

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1. Introduction

The worldwide production of polymeric materials (i.e., "plastics") in 2004 amounted to 224 million tons (corresponding to roughly to 224 million m^3), compared to raw-steel with 1,060 tons (corresponding to roughly to 133 million m^3). In fact, in terms of volume (i.e., that is what is visibly perceptible) plastics have been outperforming steel since the late-1980s by a factor that now has reached 1.7 (!). Moreover, compared to other material classes such as metals and ceramics, plastics also exhibit by far the highest growth rates over the last decades, a trend which will continue in the foreseeable future [1]. The bright outlook for the polymer industry as a whole, however, is not only related to sheer volume growth of existing plastics products but also reflects the still enormous innovation potential of polymeric materials and polymer related technologies that is unmatched by other more traditional material technologies.

Among the challenges and opportunities ahead for the plastics industry, increasing attention is paid to environmental matters. In addition to production and process related environmental protection measures, many of the environmental activities in the past have concentrated on issues related to plastics waste. However, a much wider perspective integrating economic, ecological, social and not least also technological aspects is now emerging and termed "Sustainable Development," and many efforts of the plastics industry are directed towards a positive contribution. A continuous shift towards Sustainable Development will not only significantly affect the polymer industry but also technology development in general and thus the industry and society as a whole.

In this regard it is well acknowledged that the energy sector is a key sector in any sustainable development scenario for the following main reasons among others. First, on the resource side it is the limited availability of fossil fuels (particularly oil and gas) so that at some point in time the gap between the worldwide energy supply based on fossil fuels and the worldwide energy demand may widen. Second, on the post-use side and as a consequence of the utilization of fossil fuel energy it is the substantial increase in greenhouse gas concentrations (particularly CO_2) in the earth atmosphere that increasingly threatens the earth climate and thus living conditions.

While the transformation of the current fossil fuel based energy system to an energy system substantially to fully-based on renewable resources in the mid- and long-term is at the core of a "true" sustainable energy scenario, there are many open issues and problems to be resolved also technologically over the next decades to support such a transformation process. In the presentation various options and the role of polymeric materials in contributing to such a transformation of the energy system will be explored, providing numerous examples on the innovative use of plastics in this context.

2. Major Aspects and Key Features

For the transformation towards a sustainable energy scenario in the future and to cope with the problem of limited fossil fuel availability, on the one hand, and the threatening consequences of a global climate change, on the other, *two basic guiding principles* may be proposed [2]:

(1) Continuous and significant enhancement in energy efficiency for all energy services (i.e., significant reduction in the energy intensity per service unit), and

(2) Continuous increase in the use of renewable energy resources by implementing an adequate and optimized mix of available technologies.

The latter principle refers to and includes the direct utilization of terrestrial solar radiation by technical systems (i.e., direct solar energy utilization for example via solar-thermal and solar-electrical devices, respectively, such as thermal collectors and photovoltaic cells), as well as the indirect utilization of terrestrial solar radiation by appropriate technologies (i.e., indirect solar energy utilization via wind mills or the energetic use of biomass or biofuels), and other special techniques making use of geothermal energy, water power, wave and tidal power and alike.

Regarding the above guiding principle (1), plastics and polymer based composites have proven in many instances that they contribute significantly to energy savings in a wide variety of applications (e.g., plastic foams for the thermal insulation of buildings, refrigerators etc., weight reduction in vehicles). Recently a comprehensive study on the contribution of plastics products to resource efficiency in Western Europe was conducted [3]. By means of a projection based on a sufficient number of examples, the savings of energy and greenhouse gas emissions achieved by the total market of plastics products (i.e., 38.1 Mt in 2002) were estimated. Considering all substitutable plastics products (i.e., about 81 % of the total market for plastics products) the following results were obtained:

- The total life-cycle energy demand (including production, use and disposal) of all substitutable plastics products amounts to 3.17 TJ/a, whereas the alternative products, needed for a theoretical substitution would amount to 4.19 TJ/a. Hence, plastics products need 1.02 TJ/a less energy. In other words, if plastics products would be substituted to a maximum, the energy demand for the life cycle of these products would increase by 32 % (!).
- In terms of greenhouse emissions, given in CO_2 equivalents and using the existing energy carrier mix, substituting all substitutable plastics products by alternative materials would translate into an increase of 97 Mt/a (increase of 69 % (!) for the relevant product services). To put these numbers into perspective, this compares to about 30 % (!) of the Kyoto reduction target for the EU-15.

As to guiding principle (2) it is certainly also true that polymeric materials are already in use for various solar energy components (e.g., glazings and transparent insulation, piping, thermal storage tanks, sealants and encapsulation materials). However, so far polymer engineering and science based innovative concepts have not yet been considered adequately in product development and applications of solar energy components and systems. Thus there is still a huge potential for further innovations in the future. These include polymeric materials for solar-thermal applications (novel polymeric glazing materials, thermotropic solar control materials, improved transparent insulation materials, polymeric solar absorber and heat exchanger materials) and solar-electrical applications (organic solar cells and new encapsulation materials). Moreover, as evidenced in the past by developments in numerous industrial sectors (e.g., electrics and electronics, automotive and aviation, general machinery, building and construction, packaging) a high potential for innovative advancements by the proper integration of polymeric materials is also to be expected for solar components and systems. Due to the wide range of properties that may be realized by polymeric materials combined with their cost efficient and highly flexible processability and the high potential or multi-functional integration, the advantages related to the use of polymers in solar components and systems include functional improvements, systems cost reductions and - last but not the least - more design freedom to meet the esthetic demands of architects and end-users. Finally, as a result of their property profile which may be tailored to specific requirements and applications together with their low density (light weight), polymeric materials “use less to do more”, thus in this case too contributing to resource preservation.

In view of the continuously and most recently even significantly rising prices for crude oil, one further aspect deserves commenting. After all, fossil fuels are the basic raw material resource for essentially all of the plastics produced worldwide. First, only about 5 % of the oil consumption is used for producing plastics. The vast majority of the oil resources (more than 80 %) is used for purposes related to energy supply of vehicles and transportation systems, buildings, industrial production processes and alike. Although some negative effects on the plastics industry by high oil prices or even continuing oil price increases may not be totally excluded, in the mid- and long-term, however, higher oil prices are expected to have an overall positive effect on the polymer industry. This assumption is based upon the premise that high oil prices will force industry and the society at large towards developing and implementing more efficient technologies on a broader scale, driven perhaps by renewable resources in the long run. Due to their low density coupled with the tremendous potential for tailor-made specific material property profiles and for combining structural and functional material performance attributes in one material system, existing plastics but also plastics yet to be developed will outperform all other material classes in the endeavour to capture markets even in a high oil price scenario.

3. Conclusions

As to the opportunities and perspectives for plastics in coming fossil fuel and solar energy scenarios the following conclusions may be summarized:

- Plastics and composites still exhibit an *extraordinary innovation potential*, unmatched by other material classes. The technical and economic success of plastics and composites is based on characteristic features of these materials, such as:
  - Material properties and performance profiles that can be varied widely and can be tailored to specific needs,
  - Excellent and highly flexible processability with a high potential for part and function integration,
  - Superior economic efficiency and reduced ecological and environmental impact compared to solutions with other material classes.
- Plastics will play a major role in the transformation process from the fossil fuel based energy system to a predominantly renewable energy system, both in the field of energy conservation and in the field of energy supply via solar technologies. Polymeric materials offer an extraordinary *high potential for innovative advancements in solar energy technologies on the component and systems level*. Goals and prerequisites for broad market acceptability are improved functionality, enhanced cost effectiveness, guaranteed quality and performance, and last but not least attractive design.
- While energy prices, in particular *oil prices*, will continue to be rather volatile in the years to come, over the past decades the plastics industry has proven to be rather robust against oil price changes and increases. In fact, compared to other material industries, the plastics industry has continuously improved its market position. Hence it is hypothesized that in the mid- and long-term, **any oil and energy price will be good for the plastics industry**. Even more so, **the higher the oil price, the better for the plastics industry**, unless oil prices reach a level that causes a major economic disruption.
- As a final hypothesis and for various reasons, in the transformation towards global Sustainable Development *the interests of the oil-gas industry and the solar industry will converge*.

4. References and Bibliography

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Speaker’s Biography

Professor Reinhold W. Lang graduated from the University of Leoben (Austria) in 1978 with a “Diplomingenieur” degree (M.S. degree) in Polymer Engineering and Science. From 1979 to 1984 he attended the Graduate School at Lehigh University (Bethlehem, USA) and was rewarded a Ph.D. degree also in the field of “Polymer Engineering and Science”.

In 1984 Prof. Lang joined BASF AG in Ludwigshafen (FRG), where he first held a research position in the Polymer Laboratory of BASF’s Central Research and Development Division. Subsequently he was assigned a group leader position in the Department for Production and Technology of the Business Unit for Structural Materials and then became Program Manager in the Marketing and Sales Department of the same Business Unit.

As of May 1991, Mr. Lang accepted the call to a Full Professorship at the University of Leoben (Austria), and he is now Head of the Institute of Materials Science and Testing of Plastics at this University. The focus of his research work is in the area of fracture, durability and fatigue behavior of plastics and polymer based composites, which also includes physical and chemical aging phenomena.

A second major field of research addresses the potential of plastics and composites for renewable energy technologies and in sustainable development scenarios. In an industrial survey 1996 Prof. Lang was elected as one of three University Professors in Austria with the most significant industrial cooperation and impact.

Since June 2002 Prof. Lang is also Scientific Director of the Polymer Competence Center Leoben GmbH (PCCL). The major aim of the PCCL is to bridge the gap between the basic research work and know-how in the area of polymer science and engineering available at the University and the needs of industry, suppliers and end-users.