Impact Objectives

- Create new possibilities for the use of cheaper, less reactive raw materials
- Reduce environmental impact, energy and raw materials consumption
- Increase process selectivity, create innovative process flow schemes, and reduce the number of process steps and process risks

Breaking down barriers

At the conclusion of the CARENA project, the team members reflected on some of the challenges and highlights of this multifaceted project which fosters cooperation between European researchers and the chemical industry. Here we provide a summary of their experiences on the project

Arend de Groot, Coordinator of CARENA (Senior Researcher Process Intensification, Energy Research Centre, The Netherlands)

You have said flexibility is important in projects like CARENA. Can you explain what you mean?

We have been lucky to work with a wonderful team. First of all, the work package leaders, which have organised their part of the work very well, and all the partners in general, which have shown great willingness to adapt their work to the needs of the project. This is always a challenge in European projects, where you have to plan ahead for four years. Or even five years if you take into account the proposal phase. Often this leads to conflicts of interest when the resources and people committed originally to the project do not match the needs of the project. Therefore it is a good sign if you see that partners agree on new roles and activities during the project to address the most urgent challenges. In the CARENA project I have seen many times this flexibility of the partners to deviate from the original plan if necessary. I think this characterises a good project. The cooperation between the different nationalities is what I enjoyed above all! In the CARENA project about 30 per cent of the people working in the project live abroad. Working outside of your own country broadens your perspectives. I think one of the important benefits of the EU projects lies in the opportunity given to widen your horizons of working in such project, on a personal level and also professionally.

What are some of the main challenges you have faced during the project?

Undoubtedly, you face technical issues which you are sometimes not able to address within the framework of the project. It is research, so you never achieve all your goals. However, overall I am quite impressed with the progress we have made. Of course the world around us has changed since we started on the project. The economic crisis, the shale gas in US, the renewable generation starting to impact the electricity prices, the rapid expansion of the Asian chemical industry, all these factors have impacted the outlook. At the start of the project there was a general expectation of further increasing oil prices and a corresponding increase in prices for feedstocks for the chemical industry. Today's world is very different from what we thought at the beginning of the project. Therefore economic boundary conditions have changed for the processes we develop. That requires reorientation of the business cases.

Celebrating project success is always important. What are some of the project's accomplishments you are particularly proud of?

I think the interactions we had within the project and externally have been very successful. At our first annual meeting, for example, we organised a poster session for our PhD students and postdocs to present their work. I remember this as a very lively event which was helpful to involve the PhDs in the project and generate interest for their work from the partners. The project also organised a series of very successful workshops and seminars. Especially the membrane workshop in Montpellier (2012), the two workshops on palladium membranes in Rome (2012) and Petten (2014), and the catalytic membrane reactor (2015) have been very successful. For me personally, the interaction with our Strategic Advisory Board has been very rewarding, as an opportunity for me to make use of the great experience of the members of the board and their stimulating views.

Hank Vleeming (Chief Technology Officer, Process Design Centre, The Netherlands)

In what ways do you see the efforts to understand more about membrane chemistry supporting recent shifts in the industry?

The idea behind combining membranes with reactors is that it intensifies the chemistry by improving the reaction performance, such as a shift in equilibrium. Often it becomes feasible to work at lower temperatures, which leads to energy savings. Also, it may enable to use different feedstock. This makes the process more sustainable and environmentally friendly.

In CARENA one of the objectives is shifting to cheaper and more abundantly available raw materials. At the Process Design Centre we clearly notice a change in our process design work over the past ten years towards bio-based chemistry.

Emma Palo (Technology Project Coordinator, Kinetics Technology SpA, Italy)

One of the defining features of CARENA is that it brings together research and industry. How important was this to the success of the project?

The presence of an industrial partner within a consortium is of great and strategic importance to better exploit the research product and above all to drive the research in the direction of obtainment of a product appealing from a commercial point of view. In my experience, sometimes the researchers lose the contact with the actual application of novel developed technology, in this sense, the presence of industry could help to find the right way for commercialisation, the best field of application and exploitation.

Many EU research projects foster this kind of participation. What is so valuable about it?

In a lot of novel processes, such as propylene production assisted by membrane, we need the information coming from the people more directly involved in lab research to make our process scheme more and more attractive and close for implementation. In this sense, the participation in an EU project gives the possibility to create cooperation, collaborations and to have visibility for the research of potential partners' projects, as well as external EU projects.

Elizabeth Shotton (Head of Industrial Liaison, Diamond Ltd, UK)

What led you and your team to become involved in this particular EU project?

I am Head of Industrial Liaison at Diamond and my job is very much about facilitating research and ensuring that our industrial users do the best experiments that they can during their short time at Diamond. Johnson Matthey is one of our key clients at Diamond and they brought us into the CARENA project – this was the first time that the Industrial Liaison team had participated directly in an EU project.

How do you see CARENA's emphasis on multidisciplinary research being beneficial to industry?

The synchrotron environment is a multidisciplinary one and we see daily advantages by working with colleagues from other backgrounds. Here chemists, physicists, metallurgists, biologists, earth scientists, archaeologists to name but a few work together regularly. By bringing a range of experiences to bear on a scientific problem, creative solutions can often be found and new advances made.

Jürgen Caro (Professor, Leibniz University of Hanover, Germany)

How do you see the collaboration between different countries on a project like CARENA adding value to European research generally?

European projects are per se interdisciplinary and multi-cultural, people with different backgrounds come together. I have profited from the co-operation in the different European projects not only scientifically, the work together has opened my mind and in a general way. Usually the national media of a country (TV, radio, press), report about other European countries through a 'National glass'. After direct discussion with colleagues from these European countries, I have developed in many cases a deeper and different understanding for the problems and wishes of my European colleagues – which is slightly different.

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Chain reaction

By focusing on developing new membrane materials and intensifying technological reaction processes, the CARENA project has supported a shift towards a more sustainable European chemical industry

A high level report on the competitiveness of Europe's chemical industry by the European Commission's Enterprise and Industry Directorate-General in 2009 recognised the importance of a sustainable chemical industry. It highlighted the need for innovation to reduce energy demand and move towards more sustainable use of natural resources. At the heart of this is the significant dependence the European chemical industry has on imported oil, which is around 70 per cent of all energy used by the sector. The European Chemical Industry Council supports this view, observing that energy costs are the industry's 'Achilles' heel'.

In 2011 an EU project called CARENA (CAtalytic membrane REactors based on New mAterials for C1-C4 valorization) began with an aim to enhance the effectiveness of catalytic membrane reactors (CMRs) by developing new materials and improving existing processes within the chemical industry. This is being realised by focusing on technologies which efficiently convert less popular feedstocks, such as short-chain alkanes and CO_2, and converting these into chemicals with a higher value. The challenge is that, unlike oil, light alkanes and CO_2 are stable molecules and hard to activate and so require novel technologies to help transform them into added-value products.

FROM RESEARCH TO APPLICATION

The aim of CARENA is to identify new ways to use cheaper, more sustainable raw materials. Understanding how these can be incorporated into existing production is critical. There are 19 partners in the consortium representing six universities, four institutes, two innovative SMEs, six industry companies and one European network. Their goal is to advance novel process intensification methods using CMRs, and to support the uptake of these within the European chemical industry. To this end the project is split into eight work packages. The integration of industry representatives throughout a project can be a major obstacle in terms of balancing other requirements observes CARENA's Coordinator, Arend de Groot: 'This is always a challenge in European projects, where you have to plan ahead for four years ahead. In the CARENA project I have seen many times the flexibility of partners to deviate from the original plan if necessary. I think this characterises a good project.'

INDUSTRY TOOLBOX

A number of applications have been investigated, including reforming of natural gas; a new way to move from propane to acrylic acid; producing methanol from hydrogen and CO_2; and producing dimethyl carbonate from methanol and CO_2. Process schemes and techno-economic assessments of these applications have been completed. The team focused on advancing reactor concepts that are highly applicable to industry, as well as the development of new nano-architectured materials and how these are integrated into processes. The project delivered three bespoke toolboxes, including one which involves studying how state-of-the-art membranes react and degrade under a range of industrial process conditions.

Developing CMRs to the point of industrial application demands the kind of multifaceted approach supported by CARENA. Now that CARENA has reached its conclusion, the true value of the research efforts and results is being realised. The team have identified where results can be exploited further through industry routes and highlighted opportunities for partnerships to further develop CMR technology. Along with patent analysis and mapping, this means industry partners are able to have reassurance about the potential applicability of process intensification. All of these results play a key part in the significant steps CARENA has taken to support the European chemical industry's move away from reliance on oil and towards a more sustainable future.

Project Insights

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Arend de Groot is Coordinator of CARENA and Senior Researcher Process Intensification at the Energy Research Centre, The Netherlands. After completing his PhD in Mechanical Engineering at the Technical University of Delft, de Groot has concentrated on process intensification within the chemical industry, with a focus on energy efficiency and the barriers to the wide-scale use of hydrogen as an energy carrier.

SEVENTH FRAMEWORK PROGRAMME

CARENA

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