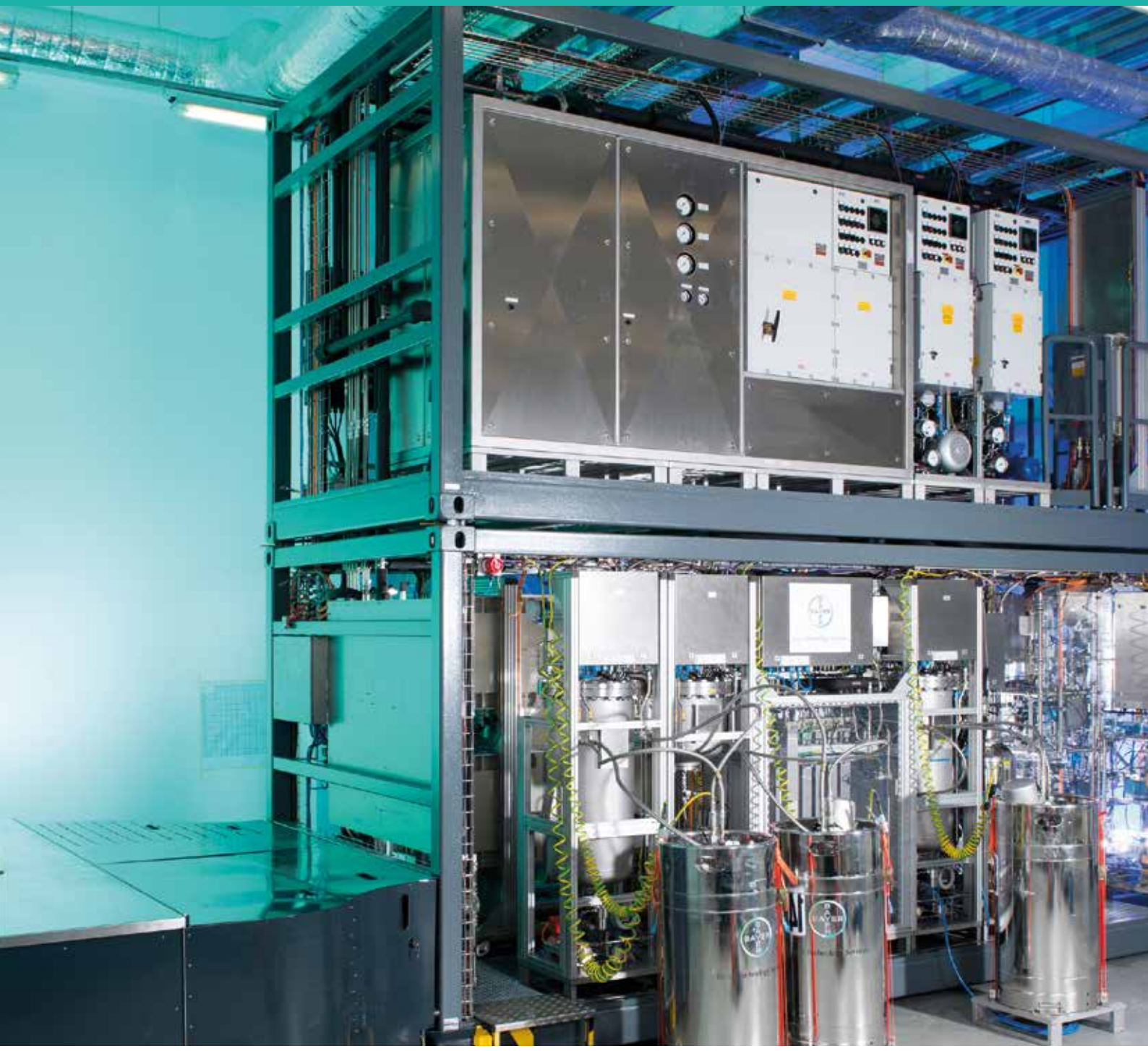
IMPACT

FROM BATCH TO CONTINUOUS FLOW PRODUCTION LINES



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Impact Objectives

- Advance the continuous production of high value and high quality products in flexible intensified continuous plants
- Introduce novel online sensing equipment and closed-loop control of the key product parameters
- Increase resource and energy efficiency of the chemical industry and reduce time to market for new chemical products

The future of sustainable process technologies

***CONSENS Project Coordinator Manuel Pereira Remelhe** discusses the consortium's work on integrated sensing, process control and online monitoring that will help close the technology gaps in a new flexible plant paradigm in order to replace traditional batch processes in chemical manufacturing*

Firstly, can you share what the goals of CONSENS (Integrated Control and Sensing for Sustainable Operation of Flexible Intensified Processes) are?

We are developing technologies to enable a successful operation of flexible intensified continuous processes. In contrast to traditional batch processes, this new production paradigm gives access to new and difficult-to-produce chemical compounds, leads to better product uniformity and reduces the consumption of raw materials and energy drastically. Moreover, new products can be brought more quickly to the market. If we manage to transfer batch processes to flexible intensified continuous processes in the future, high impacts on the competitiveness of the European process industry can be expected. But we also realised that the complex dynamics of these continuous flow processes calls for more sophisticated automatic control and sensing technology and an integrated approach. Thus, the specific project outcomes will be novel sensors and control methods as well as software for monitoring and engineering of integrated control solutions.

What are the main stages of work in this project?

In a first stage, we derived the functional requirements for our novel sensing and control technology based on the challenges posed by the case studies. Then the technologies were developed in parallel, and now we are entering the validation phase, which means that we embed the novel technologies into the pilot plants and produce the respective products in order to evaluate the benefits and robustness of the new solutions under realistic conditions.

How closely is the CONSENS project aligned with industry needs?

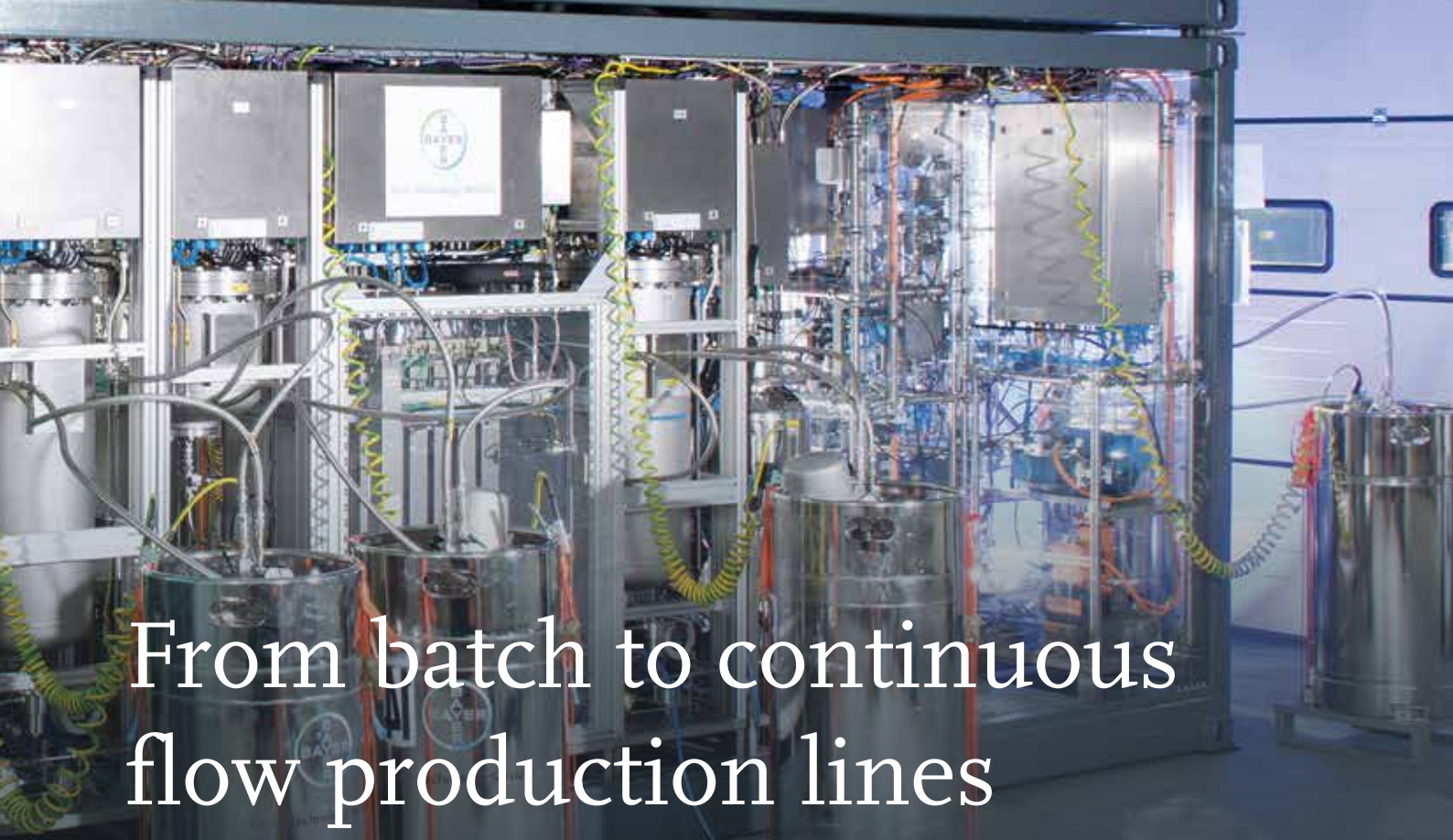
The project is strongly steered by the needs of industry. We have selected three major case studies, which are pilot-scale chemical plants. Two of them were developed in the European Commission's F³ Factory project. The use of such an industrial environment with really complex chemistry and physics helps to develop the novel technologies in a way that they can be commercialised successfully after the CONSENS project.

CONSENS is currently aimed at intensified continuous plants. Can the same technology be transferred to other process types?

Indeed, the technologies being developed in CONSENS are not only useful for intensified continuous plants. The sensor technologies can be applied to any kind of fluid processes where the respective properties (rheology, fouling, and composition) are relevant. This includes batch plants and also large-scale continuous plants. The other technologies for control, monitoring and engineering are useful for any kind of continuous plants.

What tools have you used to manage CONSENS's 15 partners in different geographical locations?

As most of the partners knew each other from former EU projects, it was rather easy to build up a trusting and productive working atmosphere inside the consortium. From my point of view, it is crucial to have frequent face-to-face meetings with co-workers from all the partners. This is important especially in the first year of the project in order to establish a common understanding of the goals of the project, the interdependencies among the Work Packages, and the differences in the points of view of the people in the project. It is noteworthy that the most difficult hurdles are not geographical or linguistic in nature, but due to different mindsets and professions. It is quite natural that chemists, physicists, chemical engineers, IT experts, process control engineers, and electrical engineers have different understandings of the content of the project and how specific problems have to be approached. It is one of the most intriguing side effects of the CONSENS project that everybody was able to broaden their horizons. And we are still learning from each other.



From batch to continuous flow production lines

The chemical industry requires flexible production lines with high resource and energy efficiency as well as high quality levels. To address this, the ***CONSENS*** *consortium is seeking to understand, accurately measure and control industrial flexible continuous flow processes*

The European chemical industry faces stiff competition from around the world, and in order to defend market shares and to enable growth, it has to become more and more efficient.

Meeting the needs of the customer is paramount, and intensified continuous processing is increasingly seen as the most promising way to achieve this. This is a highly specialised field that is shaping how production facilities will respond in the near future. An EU Horizon 2020-funded project known as CONSENS (Integrated Control and Sensing for Sustainable Operation of Flexible Intensified Processes), which started in early 2015 and runs to the end of the year, is at the forefront of research on this complex topic and is developing novel technologies to advance sensing, control and performance monitoring in industrial production plants. The project has been designed to investigate issues that affect the continuous processing of high value products, and is considering how key parameters can be addressed to increase efficiency, quality and throughput.
The CONSENS project was initiated by six multinational companies in the chemical sector and the consortium now includes 15 partners from five European countries, who have worked together for many years. The industrial partners within the team represent over 10 per cent of the European chemicals market. From a teamwork perspective, the group is composed of business partners who have a strong interest in solving some of the major issues with flexible production lines.

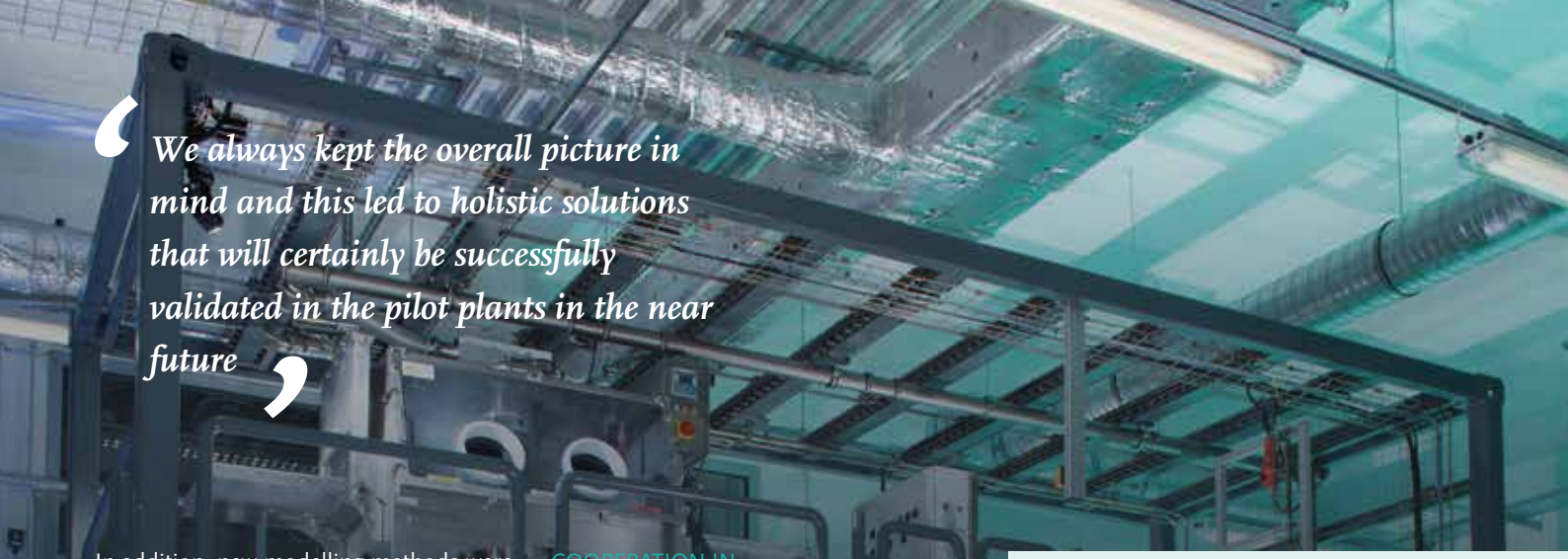
CASE STUDIES OFFER VALUABLE INSIGHTS

Normal continuous plants are designed for specific products and are widely used in large-scale production of low price products, such as petrochemicals, due to the economies of scale and higher efficiency. In contrast, batch plants can produce many different products, and are commonly used for small- and medium-scale production of high value products such as pharmaceuticals and specialty polymers.

CONSENS Project Coordinator Manuel Pereira Remelhe from Bayer AG explains that flexible intensified continuous plants combine 'efficiency and flexibility for producing continuously high value products in small to medium scale'. The consortium selected industrial pilot plants to act as case studies to validate the new control technologies, which are respectively focused on intensified continuous organic synthesis, intensified continuous polymer production, and the continuous formation of complex liquids.

The first case study involves studying the intensified synthesis of an organic pharmaceutical precursor. The researchers are exploring a number of factors here, including a novel inline fouling sensor to accurately measure the fouling layer thickness in the reactor. This helps to reduce the frequency of cleaning procedures which leads to fewer interruptions of the continuous process. In addition, they developed an explosion-proof online sensor to measure accurately ratios of product, reactant residues and side products using nuclear magnetic resonance (NMR) spectroscopy. 'Besides the two sensors, the consortium developed a self-adapting control method, a tool for sensor failure detection, and a new Big Data mining approach for performance evaluation, and all these technologies will be validated in an integrated way,' highlights Remelhe.

The second case study is attempting to validate process analytical technology (PAT)-based control for intensified continuous polymer production. This encompasses the use of Raman and near infrared (NIR) online sensors and a control solution to ensure that the system can cope with changing conditions and feedstock quality.



> *We always kept the overall picture in mind and this led to holistic solutions that will certainly be successfully validated in the pilot plants in the near future*

In addition, new modelling methods were developed to accelerate the design of the control approach.

The third and final case study is investigating the continuous formulation of complex liquids. To ensure a smooth filling of the formulated product within milliseconds, the non-Newtonian flow characteristics of the liquid must be controlled tightly; otherwise large amounts of waste can be produced. This quality feature is known as the 'rheology profile'. The consortium invented an ultrasound-based inline sensor and a data-driven control approach to ensure the quality is consistent.

PAN-EUROPEAN TEAMS SOLVING COMPLEX PROBLEMS

The different teams working on CONSENS come from a range of disciplines and industries, meaning they offer highly complementary skills and expertise. These are all needed to achieve the ultimate goal of the project, which is to advance the continuous production of high value products in flexible intensified continuous plants by introducing novel online sensing equipment and closed-loop control of the key product parameters. The CONSENS consortium supplies the necessary collection of resources that cover a broad scientific and technological spectrum.

Remelhe points out that while flexible intensified continuous production is often more sustainable and efficient, it is also more delicate, because of being more prone to fouling and clogging. It also involves more complex and fast process dynamics. 'To operate such processes successfully, automated real-time measurements and tight closed-loop control of the product quality are required,' he says. 'If these are not available, there is a huge risk of producing large amounts of off-spec product.'

COOPERATION IN THE SPIRE COMMUNITY

Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) is a contractual public private partnership between the process industry and the European Commission. The CONSENS project is one of five projects focusing on the topic 'Integrated Process Control' within the SPIRE programme. Remelhe says that it is great to have the opportunity to cooperate with the other projects within SPIRE: 'We hosted a joint industry workshop together with the ProPAT project and invited the other three projects and many industry representatives. This was very successful, because we had more than 100 participants. The joint approach increases the interest in industry and the impact of our projects.'

AN INTEGRATED VIEW

The CONSENS consortium is already making significant advances in the sensing, control and monitoring of flexible continuous flow processes and has a structured plan for fulfilling all three work streams. Remelhe says that he is particularly proud that the CONSENS teams have developed very different technologies simultaneously within one project: 'These include the three sensors (rheology, fouling, and online NMR), several approaches for PAT-based closed-loop control, software that detect sensor failures by comparing the data patterns of many sensors, software for the performance monitoring of PAT-based control systems, and an approach to evaluate the economic potential of PAT-based control solutions in the design phase.' The different teams managing to keep an integrated point of view throughout the project has been particularly pleasing for Remelhe, and meant that they did not simply develop the technologies independently: 'We always kept the overall picture in mind and this led to holistic solutions that will certainly be successfully validated in the pilot plants in the near future.'

Project Insights

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PARTNERS

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