doi:10.2533/chimia.2023.159 Chimia 77 (2023) 159–160

How Can Academia Help Industry Reduce the Footprint of Chemicals Manufacture?

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Abstract: Industrial representatives from the Swiss chemistry ecosystem met to formulate unmet needs in the field of sustainability and share the content of the exchange. The aim is to spark inspiration and trigger ambitious and pre-competitive projects collectively at the interface of the academic and industrial worlds, with the hope to profoundly change the current practices and provide an answer to some of the most urgent environmental challenges.

Keywords: Collaboration · Green chemistry · SusChem · Sustainability

SusChem Switzerland[1] (SusChem CH) is one of the platforms of the Swiss Chemical Society (SCS) and a child entity of the European-wide SusChem organization. Its mission is to promote Green and Sustainable Chemistry (GSC). Switzerland has a long history of chemistry and occupies a unique place within the history of chemical activities: through centuries and within a dense ecosystem, it has welcomed and nurtured a wealth of diverse chemical companies performing various types of chemistry, from research to industrial scales (agrochemicals, cements, dyes, explosives, flavors, fragrances, pharmaceuticals, ...).

The SusChem CH group gathers academic and industrial members, and aims at exploiting this unique feature to identify pre-competitive topics to significantly impact the sustainability of our chemical activities. On December 15, 2022, SusChem CH organized a brainstorming session, where invited companies were able to discuss scientific topics which are very relevant to them in order to improve their environmental footprint. We were very happy to host representatives from Arxada, BASF, Dottikon, DSM, Firmenich, Janssen, Lonza, Novartis, Roche, Syngenta, and Christophe Copéret from the Board of SCS GSC, who responded positively to our call for brainstorming. In addition, the Directors of the National Centre of Competence in Research (NCCR) Catalysis Javier Pérez-Ramírez and Jérôme Waser were invited to participate as representatives of the largest research center in Switzerland devoted to sustainable chemistry.

The participants formulated several unmet scientific needs. We share in this article a selection[2] of these, and hope this will serve as a guiding inspiration source for innovators from academia to design solutions with the potential for a high sustainability impact.

We chose to cluster the needs by categories, which are representing a rather holistic view from chemical manufacturing (see Fig. 1).

What Type of Sustainable Chemistries are still Missing Today within the Synthesis Chemist Toolbox?

Catalysis is a highly prominent tool for sustainability. Precious metals, such as Pd, Ru and Ir (list non-exhaustive) are a clear chal-

Fig. 1. Mapping of recognized priorities by participants of SusChem CH workshop (Dec 15, 2022), www.scg.ch/suschem-mindmap.

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lenge for sustainability as well as operability in a great number of cases. The demand for ***efficient alternative catalysts*** – be it ***non-precious abundant metals, small organic molecules*** or ***enzymes*** – is and will continue to grow in coming years. Industry has a continuous need for highly efficient and safe-to-operate catalytic oxidation methods in particular using air or oxygen.

Avoiding waste production is the best way to design efficient and resilient processes. To this end, the development of overall ***redox-neutral reactions*** and sequences which avoid swinging oxidation-states through reaction paths is of high interest. Solvents are by far the largest contributors to the environmental footprint of a given process. The identification and development of ***benign and sustainable alternatives to polar aprotic solvents*** like DMF or NMP are still substantial challenges with emerging solutions – such as water as a solvent – which would benefit from further innovation.

Which Starting Materials Should We Use?

Industry has been and continues using mostly fossil fuel-derived resources as raw materials. Establishing a catalog of ***raw materials readily derived from biomass or more generally renewable or recaptured materials*** is essential to their wide adoption and market share vs their oil-derived competitors. Sound analysis – for example, from a life-cycle analysis (LCA) – will help tremendously in making the right design decisions for what industry's shopping carts will look like tomorrow.

How Do We Measure Sustainability?

The era of digital science began a few years ago. It has a tremendous role to play in helping chemists to design the most sustainable processes possible. In an ideal world, highly valuable data (and metadata) generated by scientists, regardless of where they are located, should be made digitally usable as is by others. However, and despite the formulation of FAIR (Findable, Accessible, Interoperable, Reusable) principles, data scientists and modelers still require adapting their workflows to where the data comes from. A common worldwide ***standardization for data sharing*** would guarantee usage of this data as its maximum potential.

Sustainability is very complex to assess. LCAs aim to provide holistic views of how sustainable a process is, and how sustainable a product's manufacture is. While methodologies on LCAs are available, the field is mostly reserved to experts. There is a clear knowledge gap to be filled for more scientists to substantially increase their awareness towards sustainability. Tools enabling the accurate evaluation of the sustainability of processes are obviously still required. To this end, industry also has a substantial role to play. Such assessments are extremely data hungry and unfortunately, LCA practitioners are in clear need of more data. A collaborative effort across academia and industry will make a difference. Besides, it will increase the overall awareness, the level of creativity, which will hopefully lead to better ways to build trust in sharing such sensitive data and a technical solution to the problem. This is essential to boost both the accuracy and the efficiency of performing sustainability assessments.

How to Do the Chemistry?

New technologies, photo- and electro-chemistry in particular, are promising ways to substantially improve the footprint of chemical processes, by circumventing the requirements of reagents, by its most simple possible form, for example photons, respectively electrons. The development of new photo- and electro-chemical methods is of strong interest. Additionally, there is clear need in the industry for standardized medium to large-scale electrochemical equipment to further lower the barrier to adoption. Finally, chemists, engineers with expertise in such fields and a drive for change are in demand in order to move such technologies in industrial environments from "we do this once in a while" to "we do this often".

What Do We Do with the Waste?

As mentioned above, solvents – as the major component of reactions – are key for improving sustainability. There is a need for ***innovative efficient recycling techniques*** as alternatives to energy-intensive distillations. Every industry faces the challenge of disposing solvent waste. A question is, is it necessarily waste? Could it be useful to anyone else? Today, there is no central body or database where a company would be able to indicate the availability of waste, its compositions and its volume so that an interested partner or academic could use this ***waste and turn it back into a valuable object***, introducing the notion of circularity in our daily life as chemical practitioners.

The discussion showed that in order to improve the sustainability of chemical manufacture, there is a real need for strengthening exchanges and partnerships between academia and industry. We strongly encourage existing joint-ventures between academic and industrial researchers to tackle broad and ambitious problems rather than specific, applied ones as a way forward to bringing answers to such relevant environmental challenges. The group will continue the dialog and prioritization of these topics, and plans to report back on the progress shortly.

Received: January 28, 2023

[1] https://scg.ch/suschem.
[2] The complete list is available from our website: suschem.ch.

The definitive version of this article is the electronic one that can be found at https://doi.org/10.2533/chimia.2023.159