

Innovation Awards 2019

BEST PROCESS INNOVATION

PROCESS FOR SUCCESS

How Linde is revolutionising steam
reforming for a sustainable future



Environmental performance drives chemical innovation

A judging panel of senior industry figures had a tough time choosing winners from such a strong array of entries. A Linde/BASF collaboration takes the top spot. Congratulations from ICIS!

WILL BEACHAM BARCELONA

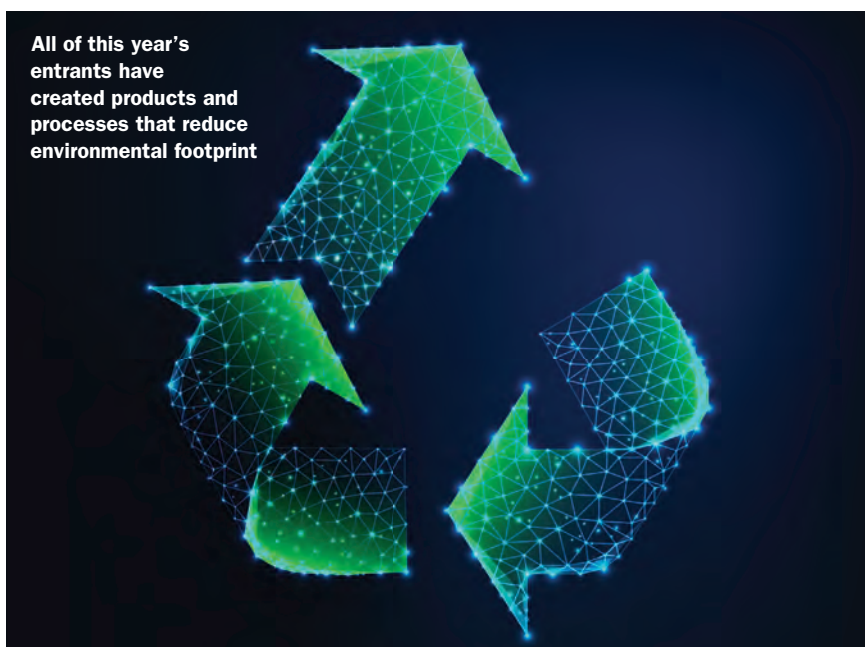
With recycling and sustainability such hot topics for the chemical industry in 2019, it is not surprising that all of this year's ICIS Innovation Awards winners have created products and processes that reduce environmental footprint in some way.

After two hours of intense debate and discussion, the judging panel came to its conclusions, so we can now reveal the results and send our congratulations to the winners, plus commiserations to all entrants who did not make it to the final stage.

The judges paid particular attention to the following areas:

- What stage the technology is at and how

All of this year's entrants have created products and processes that reduce environmental footprint



close to commercialisation

- What applications they serve and the scale of the potential impact they could have
- Sufficient technical and scientific detail plus analytical data in entries
- How far they met category criteria such as cost reduction and environmental performance

THE WINNERS FOR 2019

OVERALL WINNER

Linde
Dryref and Synspire

BEST PROCESS INNOVATION

Linde
Dryref and Synspire

BEST PRODUCT INNOVATION

Croda's
Star Polymer

BEST INNOVATION BY A SMALL OR MEDIUM-SIZED ENTERPRISE

Sironix Renewables
Hundredfold improved hard water performance with Eosix surfactants

INNOVATION WITH BEST BENEFIT TO ENVIRONMENT AND SUSTAINABILITY

INEOS Styrolution
Polystyrene – made for recycling
Carbon Cycle
Phosphogypsum remediation

The overall winner, an entry which also led the Best Process Innovation category, was submitted by Linde in cooperation with BASF. Their entry – “Dryref and Synspire: re-definition of efficiency in steam reforming” – was a clear winner in terms of potential impact on the petrochemical industry and the environment.

The best process category gives entrants a chance to show how innovative they are in the fundamental areas of new process development and process improvement – vital areas of innovation underlying better use of energy and raw materials, improved economics, safer performance and lower environmental impact.

Linde's new Dryref syngas process optimises steam-reforming by reducing surplus process steam and energy consumption while maximising use of recycled and imported carbon dioxide (CO₂). The process uses a new catalyst developed by BASF, Synspire, which claims to

cut costs as well as reducing the carbon footprint of the syngas units.

The new catalyst has high resistance to deactivation by steam, which usually occurs due to carbon accumulation and coke formation. This new catalyst can cope with steam/carbon ratios as low as 0.4.

The technology was developed with academic partners Karlsruhe Institute of Technology, Technical University of Munich, University of Leipzig and DECHEMA Institute.

The judges unanimously agreed that this entry should be both category and overall winner because of its relevance to large segments of conventional chemical production and potential impact on environmental performance plus cost improvement.

To avoid any conflict of interest, judge Detlef Kratz, president of process research and chemical engineering at BASF, did not take part in this discussion. BASF is overall sponsor of the ICIS Innovation Awards.

GREAT TEAMWORK

The judges liked the teamwork between two major players in chemicals as well as the fact the new process allows for the reuse of carbon dioxide on a large scale. They also felt the entry had great strength in terms of impact for society because of the potential improvements to chemical industry production methods and environmental footprint.

It impressed them because syngas production is a key step in many value chains and will be of growing importance in the petrochemical/refinery/fuel interface.

Just Jansz, managing director of business and technology consultancy Expertise Beyond Borders (EBB), said: "Syngas production is a key step in many important value chains as this innovation offers a cost-effective CO2 footprint improvement with global impact. It's a fruitful collaboration between two major companies which capitalises on the complementary capabilities of those companies together with input from academic institutions."

"The alliance between an engineering and chemical firm is really strategic to its success"

The judges identified process innovation as one of the most difficult to develop, so were delighted that there was such a strong entry in this category, which also led the field overall.

Godfrey Motte, founder and managing director of advisory firm Adrialis, said: "The alliance between an engineering and chemical firm is really strategic to its success. I also like the impact of the reduction in surplus steam which maximises the recycling of CO2."

Mike McKenna, president and chief operating officer for North American specialty chemical distributor Maroon Group added: "What is

OVERALL SPONSOR BASF

WE CREATE CHEMISTRY FOR A SUSTAINABLE FUTURE

CHEMISTRY HAS always been an enabler for innovation as it provides solutions to the needs of our society, combining care for the environment and economic success.

Our growing population is set to reach an estimated 10bn people by 2050 and will need access to affordable energy, housing, healthcare and quality food. At the same time, we must strive to consume fewer resources.

"Driving sustainable solutions should be the ultimate goal for companies, start-ups and academia aiming for profitable growth based on innovative chemistry – both ecologically friendly as well as socially accepted," states Detlef Kratz, president for process research and chemical engineering.

"Looking at this year's awards this is clearly a driver of innovation, providing technologies that enable us to consume less with more efficient and better products."

BASF
We create chemistry

With this in mind, sustainability-driven innovation has always been a cornerstone of BASF's strategy leading to a unique track record of novel products and processes.

Just to name a few, the range includes highly energy efficient industrial chemical processes, innovative battery materials and projects which make a contribution to the circular economy and chemycling. With its new strategy, the company goes even one step further: "We've set ourselves ambitious targets – as the leading chemical operator, we will grow our production volumes significantly without adding further CO2 emissions until 2030. Our global carbon management programme will help us to live up to our commitment."

Speed and adaptation to change is another challenge in today's multi-faceted innovation landscape. BASF is committed to developing digital technologies and embraces data-driven research methods which have a rapidly expanding influence on research and development (R&D.)

Our supercomputer Curiosity is just one example how this is put into practice.

"We would like to share this spirit with those who work on innovations in the chemical industry and are honoured to support the ICIS Innovation Awards this year. Our recognition goes to all the teams and people behind contributions for a sustainable future," adds Kratz.

"The projects nicely show that brilliant minds come up with outstanding ideas. Congratulations to all teams and especially to the selected winning projects!" ■

Further information at
www.basf.com

really interesting is its flexibility on a wide array of feedstocks, especially when you see the development of natural-gas-based feedstocks in North America. This gives it a lot of potential impact for the future."

ENVIRONMENT WINNER

There was intense competition, and the most entries, for the category Innovation with Best Benefit to Environment or Sustainability, sponsored by Maroon Group.

The category is designed to recognise those companies that have incorporated the ideas of environmental performance and sustainability into their innovation in the areas of product and process developments and approach to business overall.

Entries might include improved manufacturing processes or products that reduce environmental impact, or new products that tackle important issues such as global warming, pollution, recycling, water supply security and nutrition. Judges were looking for entries that showed a distinct benefit to the environment and to the sustainability of the company and its customers.

After intense debate the panel decided to

jointly award two entries: UK-based Carbon Cycle for "Phosphogypsum remediation" and INEOS Styrolution for "Polystyrene [PS] – made for recycling – first demonstration of chemical recycling loop by polymerising styrene from depolymerised polystyrene." PS has proven difficult to recycle, giving this market huge challenges in meeting recycling and circular economy targets.

INEOS made a lab-scale quantity of general-purpose PS from 100% recycled styrene monomer at its Antwerp, Belgium, laboratories. The material is the result of experimental PS production runs with styrene monomer feedstock produced from depolymerisation of styrenic plastic.

These resulted in production of material with the same product properties as PS from new styrene monomers. The secret is PS's low "ceiling temperature" (Tc) of approximately 380°C, at which the polymer chains "unzip" into monomer styrene, which can be extracted in high yields. A distillation step removes impurities and allows styrene to be polymerised back to PS without any compromise in quality, according to the company.

Commenting on the INEOS entry, Paul

THE JUDGES FOR 2019

**PAUL BJACEK**

principal director, global resources
research lead at Accenture

**ADRIAN HIGSON**

director at NNFC

**JUST JANSZ**

managing director at Expertise
Beyond Borders

**DETLEF KRATZ**

president of process research
and chemical engineering at BASF

**MIKE MCKENNA**

president & coo at Maroon Group
LLC

**GODEFROY MOTTE**

founder and managing director at
Adrialis

» Bjaček, a principal director at Accenture, said: “PS packaging recycling could be a game-changer – that sector has been declining because adequate recycling is not yet available. We don’t know if they will go big with this but it has a lot of momentum behind it.”

Maroon Group’s McKenna added: “There is a lot of discussion about the recycling of PS. In some regions they are trying to substitute PS for other products, especially in drinking cups. So this entry really resonates with me.”

According to EBB’s Jansz: “The INEOS entry is good – it’s a first for depolymerising and polymerising PS. But it is going to be a niche because to take PS out of a mixed bag of plastics will be a limitation. Cleverly done, on a small scale, but they showed that it works.”

INORGANIC WIN

The Carbon Cycle entry – which aims to recycle the plasterboard material gypsum – is inorganic and outside the usual chemicals focus of most of the judges. But it caught their eye because of the potential it has to tackle the impor-

“PS packaging recycling could be a game-changer – that sector has been declining because adequate recycling is not yet available... it has a lot of momentum behind it”

tant issue of waste gypsum which could reach 7bn-8bn tonnes worldwide by 2025.

They were also impressed by the simplicity of the process for such a large commodity. If this works, they believe it could have the wow factor they were looking for.

Carbon Cycle said its breakthrough calcium-based mineral purification process provides a commercially viable means of purifying chalk and gypsum. The main focus is on phosphogypsum which can also contain up to 1% by weight rare earths, which the process can isolate.

The process works by reacting gypsum with ammonium sulphate solution to form a double salt, releasing the contaminants that can easily be separated. The double salt is decomposed

by hydration to gypsum, returning ammonium sulphate to be recycled.

SPECIAL MENTION

The judges also wanted to make a special mention for Timeplast’s intriguing entry: “Nanodepolymerisation of polymer chains”, which caught their attention.

TimePlast micro-dissolves the polymer chains in plastic products during the manufacturing process, while maintaining all the mechanical properties found in the standard plastic.

Through the process of nano-depolymerisation, the TimePlast additive creates a plastic that will degrade more quickly after use.

The company says its product is 97.79% wax-based from the moment it leaves the factory. This means that TimePlast does not require soil bacteria, water or oxygen to degrade the plastic. The carbon footprint of TimePlast-treated polyethylene is 65% smaller than that of the untreated polymer, according to the company.

The judges were fascinated by this entry and thought it could have huge potential if it can be commercialised.

They encourage them to apply again once they have more results and can explain the science behind this innovation in more detail. The entry would also benefit from the involvement of one of the big polymer producers or a consumer such as Pepsi.

BEST PRODUCT INNOVATION

The winner of Best Product Innovation – sponsored by Accenture – went to Croda for its entry ‘Star Polymer: changing the shape of surfactant chemistry’.

This new bio-based polyol uses steric stabilisation to enhance surfactant performance. Croda says the star-shaped, polymeric non-ionic surfactant can be used at up to 50% lower

CATEGORY SPONSOR ACCENTURE**HELPING THE CHEMICAL INDUSTRY DRIVE GROWTH IN AN ERA OF EPIC DISRUPTION**

ACCENTURE IS pleased to sponsor the Best Product Innovation category of the 2019 ICIS Innovation Awards. In this period of disruption, the chemical industry is on the brink of profound change. Opportunities abound and chemical companies are looking to reimagine their business and reinvent their future.

We continually look ahead to anticipate what’s next and believe the future of chemicals is now. As a sector that can provide answers to some of the world’s most urgent problems, chemical companies



that understand the forces reshaping the industry and embrace innovation can take the lead. With extensive industry knowledge and innovative thinking, we turn insights into action and collaborate with clients to formulate effective strategies for sustainable growth.

Accenture’s global chemicals practice works across the value chain in all industry segments. Our skilled professionals leverage their

consulting and technology expertise to help companies apply innovation; transformational strategies and digital enablement for growth; differentiation; and superior operations. With more than three decades of experience, we’re helping to redefine the way the chemical industry works.

About Accenture

Accenture is a leading global professional services company, providing a broad range of services and solutions in strategy, consulting, digital, technology and operations.

Combining unmatched experience and specialised skills across more than 40 industries and all business functions—underpinned by the world’s largest delivery network—Accenture works at the intersection of business and technology to help clients improve their performance and create sustainable value for their stakeholders. With 492,000 people serving clients in more than 120 countries, Accenture drives innovation to improve the way the world works and lives. ■

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usage rates than existing technologies. The category gives entrants a chance to show how innovative they are in the traditional but still vital area of product innovation.

EBB's Jansz commented: "Croda has developed a versatile, largely bio-based surfactant giving a molecule with broad functionality. I'm impressed by the broad range of applications which have come out of that."

The judges were impressed by the quality and depth of the Croda's entry, which was the most detailed by far. Maroon Group's McKenna said: "Croda did an amazing job on their submission, scientifically and technically."

They were also pleased with the flexibility Croda showed during the innovation process. BASF's Kratz commented: "Croda started this innovation going in one direction and then expanded its application by trying it in a number of other areas. They multiplied their effort and I really liked that from an innovation point of view – expanding on an idea and building on it."

BEST INNOVATION BY AN SME

The Best Innovation by a Small or Medium-sized Enterprise (SME) is a category which gives SMEs – a great source and reservoir of innovation – a chance to shine. This year the award goes to Sironix Renewables with its entry: "Hundredfold improved hard water performance with Eosix Surfactants."

This technology – synthesised from natural oils and sugar derivatives – uses a bi-functional detergent molecule that serves as both surfactant and chelating agent. This eliminates the need for co-formulated chemicals in laundry detergents. Sironex claims Eosix enables products with higher concentration and re-



Chemical companies are looking to reimagine their business and reinvent their future

duced overall cost – 10-30% cheaper per unit dose. Sironex said it also provides vastly improved performance in hard water; and reduces energy consumption through better cold-water detergency.

Adrialis's Motte said: "I have a preference for Sironex because it has a combination of two products – a surfactant and chelating agent into one bi-functional molecule. It has good documentation showing the comparison with current products so good validation."

McKenna added: "The performance characteristics of this product are very appealing."

According to BASF's Kratz: "We are accus-

tomed to working a lot with the surfactants industry. The idea of putting it all in one molecule doesn't have to be a hit – all in one doesn't mean it works.

"But what they managed to do by combining these intelligently and chemically and getting a hit is impressive."

EBB's Jansz concluded: "There are definitely still some significant challenges to prove the prediction process and anticipated cost reduction, but they are very open about this and have analysed what needs to be done. They offer a potentially promising bio-based surfactant system." ■

CATEGORY SPONSOR MAROON GROUP

CREATING VALUE FOR OUR CUSTOMERS THROUGH INNOVATIVE SOLUTIONS

MAROON GROUP is a leading distributor of specialty chemicals and ingredients across North America and takes a proactive role in addressing corporate social responsibility and sustainability in the global supply chain. Our team continually looks for innovative technology and creative solutions that create value for our customers as well as our principal partners.

Along with being recognised for adopting international sustainable development standards by EcoVadis, Maroon Group is an active member of the National Association of Chemical Distributors (NACS) and holds ISO and Responsible Distribution

M MAROONGROUP

certification. NACD's verification of environmental, health, safety and security programmes demonstrate our commitment to continuous performance improvement and responsible distribution in every phase of chemical storage, handling, transportation and disposal.

In addition, Maroon Group has been recognised by the U.S. Environmental Protection Agency for its commitment to reduce waste, improve efficiency and continuously work to progress as an environmental steward.

We continually strive to improve our corporate social re-

sponsibility, including all aspects related to the environment, social, ethics and the global supply chain.

We take pride in associating with companies that value sustainability and environmental responsibility and that share these values by supplying safe and consistent products, as well as look for environmentally friendly ways to improve processes that impact the global environment.

Through our dedication as a responsible organisation, we are proud to sponsor the Innovation with Best Benefit to the Environment or Sustainability category of the ICIS Innovation Awards.

We recognise the value and benefit innovation and sustainability bring to our customers and the global supply chain and are diligent in reducing our carbon footprint through responsible distribution.

About Maroon Group LLC

Maroon Group is a world class supplier of specialty chemicals and ingredients across North America focused on creating value for customers in a diverse range of end markets. Our business is structured to leverage an infrastructure of industry leading technology, value-added services, global sourcing and logistics network, and a commitment to Creating Customer Success®. ■

Doing more with less

Linde and BASF have collaborated to push the boundaries of chemistry to propose a groundbreaking new catalyst and steam-reforming process with higher efficiency, lower energy demand lower CO₂ footprint

ELAINE BURRIDGE LONDON

Finding the right balance between profitability, energy efficiency and cutting carbon dioxide (CO₂) emissions is a challenging task in process development. Until now, this has been a particularly big dilemma for steam reforming, the conventional route to produce synthesis gas (syngas), an essential raw material for the chemical industry.

Syngas is used to produce key base chemicals such as methanol, acetic acid and ethylene glycol, as well as synthetic fuels such as diesel and gasoline. However, conventional reforming technology typically uses huge volumes of steam, which consequently has a major impact on a plant's energy bill and on its CO₂ footprint.

The industry has long searched for a way of lowering the steam addition, also referred to as the steam-to-carbon ratio, in syngas production. However, it faced a problem, in that when using conventional reforming catalysts, this led to catalyst deactivation, caused by carbon deposits on the catalyst's surfaces, blocking the key reaction.

To resolve this dilemma, German companies Linde and BASF teamed up to find a way of making steam reforming more energy and cost efficient. Specialists at Linde Engineering worked with BASF's catalysts experts, along with academic partners The Karlsruhe Institute of Technology, the Technical University of Munich, the University of Leipzig and the Dechema Forschungsinstitut.

"In the course of developing the novel catalysts and the DRYREF technology, the R&D teams of BASF and Linde raised a whole bunch of very fundamental questions. Teaming



up with the right partners from academia turned out to be extremely helpful to find the right answers and accelerated our research exceptionally,” says Nils Bottke, head of petrochemical catalysts research at BASF.

INITIAL PROJECT STAGES

The first step in the project was to design a new catalyst, SYNSPIRE G1-110T, an area of research where BASF has deep knowledge and expertise. Using a nickel base, just like conventional catalysts, BASF's experts were able to optimise the crystal structure and exact composition of the catalyst to suppress the formation of soot on the surfaces. This allowed the catalyst to remain active even when the steam-to-carbon ratio dropped.

Lab results showed that the SYNSPIRE G1-110T catalyst enabled the reduction of the steam-to-carbon molar ratio to 0.9 with the surface remaining free of carbon deposits. Considering safety margins, this leads to an industrial operation point with a steam-to-carbon ratio of 1.5 in contrast to conventional steam reforming operating at 2.0 to 2.5.

The project started in 2010. Until 2014, Linde and BASF established the catalyst concept and process flow of the DRYREF plant together with its academic partners. BASF's subsidiary the was responsible for extensive catalyst screening.

From 2014 to 2016, the partners worked further on developing the catalyst and performing lab tests. BASF experts upscaled the catalyst's production from a few grams to a few tonnes. Following extensive performance tests, both Linde and BASF were able to confirm that the catalyst offered unique resistance to coking at a low steam-to-carbon ratio.

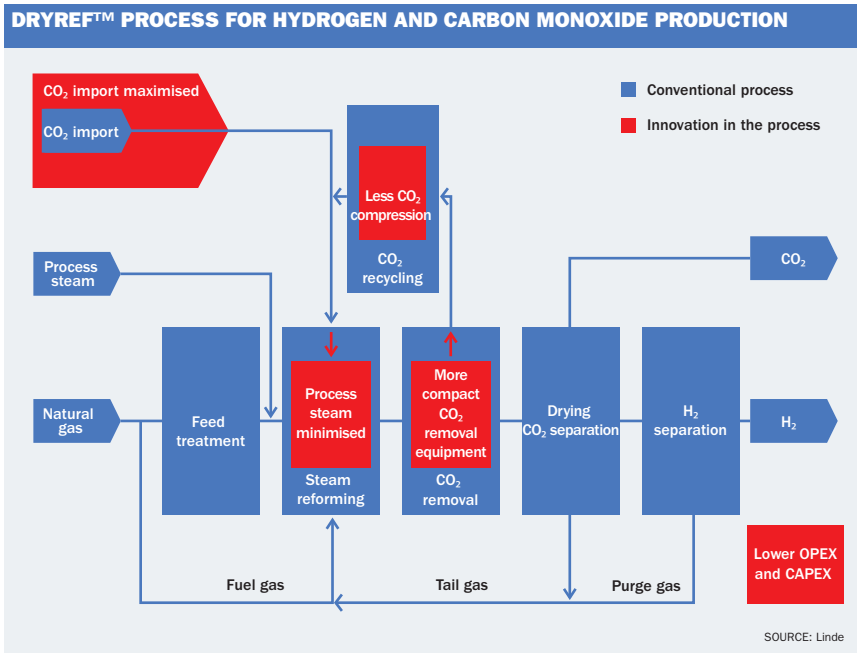
Pilot testing followed from 2016-2017. The Linde Pilot Reformer was installed at Linde's Pullach site in Germany, enabling engineers to test the technology under real-world conditions. As well as analysing the performance of the upscaled SYNSPIRE G1-110T catalyst pellets, the complex measuring equipment also tested the optimised DRYREF process parameters in fine detail, helping to accelerate the catalyst development from lab to commercial scale.

“In this context, the Linde Pilot Reformer played a crucial role to bridge the gap between lab investigation and commercial application,” says Nicole Schodel, head of chemical development & services at Linde.

COMMERCIAL BREAKTHROUGH

Linde finally demonstrated the commercial readiness of DRYREF technology at an industrial-scale syngas plant during 2017-2018.

This breakthrough development allowed Linde to optimise the process design, resulting in the launch of the DRYREF technology based on BASF's SYNSPIRE G1-110T catalyst.



The result, says Linde, is an innovative catalyst and ‘clever’ process technology that is ‘revolutionising’ syngas production by enabling plants to cut their use of steam and reduce their CO₂ footprint by putting the waste CO₂ to good use.

The DRYREF technology, combined with BASF's SYNSPIRE catalyst, provides additional benefits, notably significant advantages to both operating and capital expenditure. Plant components such as the integrated CO₂ removal unit, or the CO₂ recycling compressor, can be downscaled considerably, cutting investment costs for new plants.

NICOLE SCHODEL

Head of chemical development & services at Linde

“The Linde Pilot Reformer played a crucial role to bridge the gap between lab investigation and commercial application”

The DRYREF technology not only cuts CO₂ emissions, but also enables surplus CO₂ to be recycled, giving plant operators another option to improve their carbon balance.

Andreas Seliger, head of conceptual design hydrogen & syngas at Linde, adds: “It is even possible to import CO₂ from other processes using the DRYREF technology as a CO₂ sink.”

“This project is an excellent example of how close collaboration between two top-level companies like BASF and LINDE can drive radical innovation. The common achievement is the result of a long-term engagement of both companies that required trust, openness, excellent technical skills, long-term vi-

sion and readiness to take some risks,” says Detleff Ruff, senior vice president process catalysts at BASF.

CATALYST UNDER DEVELOPMENT

BASF is currently piloting a second type of catalyst – SYNSPIRE G2-120T – for even lower steam-to-carbon ratios.

Piloting is anticipated to finish in 2019 with commercialisation expected in 2020. With this catalyst, the commercial operation window can be enlarged to a range of steam-to-carbon ratios down to 0.8.

The production of syngas worldwide has a significant market penetration. Predicted growth rates are in the range of 10-18% annually. The DRYREF technology based on the SYNSPIRE catalyst family can be used for both new plants and revamps. DRYREF is expected to serve as a platform for the future production of fuels and chemicals, particularly with a shift in the feedstock base, for example coal to natural gas.

One area of significant potential is combining DRYREF with dimethyl ether (DME) technology as a platform for sustainable chemical production – an ideal fit. Linde and BASF are jointly working on a one-step route to DME, eliminating one process step and taking advantage of favourable thermodynamics.

Linde states: “The new technology is expected to have a significant impact on the market with a potential sales volume of around €100m”.

Linde and BASF's innovation has redefined efficiency in steam reforming, also bringing many other benefits and extending the syngas envelope. Challenged solved! ■

Bio-based polymer offers broad uses

Croda's Star Polymer reduces environmental footprint while offering a product that benefits animal health, automotive and agricultural industries and water treatment

JANE GIBSON LONDON

The drive towards a sustainable product portfolio at Croda has led to the discovery of a star innovation, both in terms of performance and appearance.

Croda's Star Polymer is a unique, patented molecule using state-of-the-art steric stabilisation to enhance surfactant performance.

Rick Hanson, managing director at Croda says, "The main drivers for us are innovation and sustainability as well as moving processes and technology forward. The Star Polymer is the next generation of polymer – it has an increased suspensibility at a lower use rate. The product is bio-based; we were looking to bring something new and innovative to market and at the same time reduce our environmental footprint in the long run."

In terms of the technology, a bio-based polyol is ethoxylated and chain-extended with polymerised castor oil derivatives to provide multiple polymer chains offering either hydrophilic or lipophilic attachment, arranged in a star-like shape. This novel polymeric non-ionic surfactant serves as a building block for the development of more stable and effective formulated products across multiple applications.

The broad functionality of the product has led to four application patents either pending or granted.

"There was a lot of back and forth in terms of determining the right mix. It took a lot of hard work and dedication. But now we have the benefit of being able to commercialise the molecule in several industries," says Hanson. "We can also expand out into other sectors in the future."

IMPROVE PERFORMANCE

The Star Polymer is able to avoid the potentially negative health and environmental effects of small-molecule surfactants and improve formulated product performance. These attributes enable development of stable complex formulated products, all while providing a positive impact on surrounding communities and the environment. The Star Poly-



Star Polymer can improve fuel economy and extend engine life

mer's main focus industries are currently animal health, automotive, agricultural and water treatment.

Advantages in animal health vaccine formulations have been demonstrated against standard surfactants. This includes vaccine formulation stabilisation at lower surfactant concentrations, increasing shelf-life and producing less waste, with no added injection side effects.

As an automotive friction modifier, the molecule improves fuel economy, extends engine life and increases the time between oil changes. These additive benefits make it a prime candidate for customers to meet ILSAC GF-6 specifications which require significant improvements in engine oil.

The Star Polymer is also an emulsifier and dispersant in agriculture and extends the shelf-life of complex formulations.

In agricultural applications, as in vaccines, it provides increased stability in formulations. This leads to advantages such as better on-target delivery for sprays and decreases the likelihood that products such as weedkillers will move off

target. Better delivery enables less pesticide to be applied, while allowing for potential increased yield and reduced pest resistance.

The molecule also provides excellent stability for high solid loads as the primary emulsifier for inverse polyacrylamide polymerisations. These polyacrylamides are widely used in the wastewater treatment, paper and pulp, oilfield and personal care industries.

The animal health product has yet to be commercialised, says Hanson. "We expect to be in this industry by 2020. But all the other applications are already out there."

COST EFFECTIVE

Hanson points out that the product is competitive on cost. "For the most part, we are out-performing other surface-active technologies. This is because we have a lower use rate and so can typically use half the amount of the product and achieve the same result."

"A lot of participants in the market are sticking with a traditional block polymer structure – but we are ahead of the game with the star-shaped molecule. We want everyone to be able to see our technology so we can expand and grow it."

Hanson says that so far, the Star Polymer-based products have seen a good uptake in most industries.

"It has the bio-feedstock element and customers are acquiring a great performance from it. In terms of the next step, we are always looking for what the new and improved molecule will be. Using 100% bio-ethanol for corn will change the environmental footprint of the polymer and the product will still be competitive in the market when it is made from 100% bio-based ethylene oxide."

"We are looking to accelerate our customers into sustainable ingredients," adds Hanson. "We believe it is an investment in the future of Croda. Sustainability and innovation is at the core of the company and the Star Polymer has only gained from the push towards the company's purpose of using smart science to improve lives." ■



Eosix improves detergent performance and reduces energy consumption

Going green for less cost

Sironix Renewables creates a bio-renewable surfactant that eliminates need for co-formulated chemicals in detergent

JANE GIBSON LONDON

Creating a greener product and bringing it to market often comes at a higher cost to the consumer. Solving this problem is high on the tick list for companies looking to create sustainable products.

With this in mind, Sironix Renewables technology has created an oleo chemical-based bi-functional detergent molecule that serves as both a surfactant and a chelating agent, thereby eliminating the need for co-formulated chemicals in laundry detergents. The Eosix™ Surfactant has improved hard water performance 100-fold.

Christoph Krumm, ceo at Sironix Renewables, says, "There is an inherent cost disadvantage when a product uses green chemistry and so the question is will people want to buy at the higher price? That is what sparked the idea to find a product, which has a functional benefit with a bio-renewable formula."

Krumm started to work on a few green chemistries to make surfactants at graduate school while working on his PHD, looking to find a technology that was both scalable and economical. The fact that the molecule enables improved performance significantly in hard water conditions ignited the idea to further develop the technology and has given the product the edge over other green offerings.

"That was a bit of a eureka moment as we realised this meant the product had a cost benefit. It was an added benefit when we realised how well it worked in cold water too."

Petroleum-based surfactants do not work very well in hard water, which contains calcium and magnesium ions. To overcome this, formulators add ingredients (chelants) to boost function. However chelants add cost, add complexity and are not always eco-friendly.

So while the use of natural oil ingredients increases costs, the company has removed the need for costly chelating agents. This means that Sironix's molecule can actually achieve a

cost benefit, making it economically competitive with large-volume surfactants.

The new surfactant will enable products with higher concentration and reduced overall cost of detergent formulation. As a result, detergent formulations using Eosix will be:

- 10-30% cheaper per unit dose, thereby increasing the market share of bio-renewable products
- Provide 100x improved performance in hard water conditions compared with current conventional and eco-friendly surfactants
- Reduce the energy consumption of wash cycles by providing enhanced cold water detergency compared with existing bio-renewable detergents

"What we have found actually functions better than a petrochemical-based product. We have also tested it in a few different conditions such as on blood and grass stains and the performance was better surfactant on surfactant even when the chelating agent was added to the other products."

In terms of the technology, the Eosix Surfactant, a class of oleo-furan surfactant, is synthesised from natural oils and sugar derivatives, called furans. Core to the technology is a simple and scalable two-step chemical synthesis process, which uses solid acid zeolite catalysts, mild reaction conditions and simple process equipment to produce cost-effective bio-based surfactants. The furan component of the surfactant structure modifies the way in which cations bind to the surfactant, enabling the 100-fold improved hard water function. Current and future work is focused on applications and performance testing, regulatory approvals and process scale up.

Krumm says a challenge was balancing the performance of the surfactants against the economies of scale.

Sironix has demonstrated the scalable production of the surfactant at 1 kg as well as its performance in laundry detergent formulations. Having developed over 20 different iterations of the furan-based surfactant, the company has selected three molecules which are being produced in sample quantities for product co-development with formulation partners.

Sironix secured six non-dilutive government research grants and partnerships totalling \$4.5m for development of the technology for numerous market applications through 2019. Along with this, the company has partnered with Los Alamos National Laboratory to develop improved process technologies and demonstrate continuous production at pilot scale.

The company has grants for a small-scale pilot demonstration plant and the process is currently at the pre-pilot stage.

Other potential markets include traditional end use markets such as paints, inks and coatings, oil field chemicals, agriculture and agrochemicals and personal care and cosmetics. ■

PS is in the loop

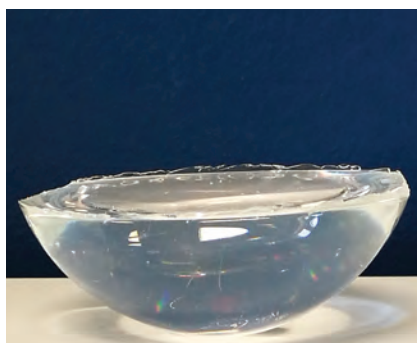
INEOS Styrolution is collaborating with cutting-edge technology providers in both North America and Europe in order to build a circular economy for polystyrene

JANE GIBSON LONDON

A global R&D-led initiative to explore promising chemical recycling technologies for polystyrene (PS) was where INEOS Styrolution's shift towards a circular economy began. This was the major driver behind the company's creation of a process to produce styrene from depolymerised polystyrene. Earlier in 2019, INEOS Styrolution announced its first successful test runs in producing virgin polystyrene from previously depolymerised material.

This process, known as depolymerisation, can be seen as the practical proof of the recyclability of polystyrene and is achievable at commercial scale.

Dr Norbert Niessner, director Global R&D/Intellectual Property at INEOS Styrolution Group says, "As a result of our demonstration of the chemical recycling loop through depolymerisation, we can clearly say that polystyrene is indeed made for recycling at the highest quality. Together with today's progress in



INEOS successfully produced virgin polystyrene from previously depolymerised material

sorting technologies of post-consumer waste, I am confident that there is no longer a reason for polystyrene not to be recycled."

Currently INEOS Styrolution is assessing different technologies at lab scale and some at pilot scale. Upscaling to pilot plants as well as on an industrial scale is expected by around 2021-2023 in order to bring material to market

by 2025. INEOS Styrolution is collaborating with cutting-edge technology providers in North America and Europe, such as Agilyx, Pyrowave, GreenMantra and Indaver to build a circular economy for polystyrene.

In terms of the technology, the secret of polystyrene's benign behavior is its low "ceiling temperature".

At a temperature of approximately 380°C, the polymer chains "unzip" into their monomer styrene, which can be extracted from the process in high yields.

A subsequent distillation step removes the impurities and allows styrene to be polymerised back to polystyrene without any compromise in quality.

"With the new process, even if the material is mixed with polyolefins you can still recycle it – which means you can get a high yield," says Niessner.

"Going forward, we aim to shift commercial scale by setting up demo plants. We expect our first plants in Europe and the US to be operational from 2021-2022 onwards." ■

Carbon Cycle finds clean solution

Carbon Cycle did not initially set out to develop a process to clean up gypsum. The company was working to develop a carbon capture and utilisation process to convert gypsum into chalk for use as a white filler to make paper.

The process requires clean white gypsum but, as this is in short supply, they turned their attention to cleaning "dirty" gypsums in order to create fillers with a high level of purity.

"Experts told us it was impossible," said David Sevier, director of Carbon Cycle Limited. "The industry had been trying to solve this problem for a hundred years."

After two years of work, the team tried something completely new. "It was like turning a switch," said Sevier. "Suddenly we could take a very dirty product and produce bright white material."

The PureGyp mineral purification process created a commercially viable means of purifying minerals such as chalk and gypsum for the first time. The process works by reacting gypsum with a complexing agent. It is quick and the reagents are recyclable, which keeps



PureGyp purifies gypsum for use as a high-level purity filler to make paper products

costs and damage to the environment down. The company began to get so much commercial interest that they ceased working on carbon capture and the focus is now on their PureGyp process, cleaning phosphogypsum.

The phosphoric acid production industry has a multibillion tonne waste and pollution problem, producing 300m tonnes/year of waste, most of which cannot be used due to high levels of impurities. It is stored in large waste stacks or discharged into the ocean presenting a risk for the local population and the environment.

The demand for clean gypsum for cement and plasterboard production runs at 280m tonnes/year and rising.

The process could also meet another global need for rare earths, essential for making wind turbines, electric motors, batteries and electronics. Phosphogypsum can contain up to 1% by weight of rare earths, and the company is now looking to unlock significant new supplies.

"The first step towards commercialisation is to build a pilot plant which is in progress," says Sevier. "But the main challenge now is that we simply need more investment." ■

Circularity for Polymers: The ICIS Recycling Conference

Redefining the discussion on circularity to find sustainable solutions

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Director of R&D
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Gary Calicdan
Packaging and Print Buyer
**Lush Fresh Handmade
Cosmetics**



Richard Daley
Managing Director
ReNew ELP



Tristanne Davis
Senior Manager
**The Sustainable
Packaging Coalition**

SESSION HIGHLIGHT

As brand-owners continue to support and introduce circularity initiatives, the plastics industry looks for ways to support those targets to advance global commitments to the circular economy, and one session on the agenda addresses this exact topic. **Lush Fresh Handmade Cosmetics** is already confirmed to share their perspective.

The FMCG Panel: Maintaining brand values while supporting circularity

- ✓ Discuss the global differences in circular economy and recycled packaging plans
- ✓ Analyse the impact of customer perception of plastic on brand's strategy
- ✓ How can the rest of the value chain work together with brands to meet recycling goals?

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How chemistry enables the circular economy

Chemical recycling offers an opportunity to recover plastic waste that has not previously been recycled, helping to improve sustainability while maintaining quality

At BASF, our purpose is to create chemistry for a sustainable future. Chemistry plays a key role in many value chains of the mobility, packaging, construction or agricultural industries. Circular economy (CE) approaches enable us to decouple growth from resource consumption. Together with our customers, we find innovative and sustainable solutions to reduce waste, save emissions, or enable a sharing economy.

By developing circular approaches with customers in the different industries, the chemical sector can contribute to making best use of the available resources in these value chains. The circular economy demands massive transformations that can only take place if corporations in the value chain collaborate to jointly implement solutions. The processes along the value chain are highly interconnected, and the circular economy concept encourages businesses to think not only about their individual production steps, but also to consider the supply and value chains involved in their product development.

TECHNOLOGY

BASF is investing in cutting-edge technologies and already applying the circular economy concept in a number of ways to speed up the transition. We are pursuing two complementary approaches: With 'Keep it smart', the company constantly looks for techniques to decrease material use but keep function and durability at their optimum. With 'Close the loops' we look at solutions for customers along the value chain to re-enter waste back into product lifecycles. The participation in multi-stakeholder partnerships like the CE100 program of the Ellen MacArthur Foundation is an important element to further advance and realise circular economy solutions.

Even after use, plastics are a valuable resource and should not end in landfill, and certainly not in the environment

Reuse, recovery and recycling of plastics is one of the hottest topics on the agenda.

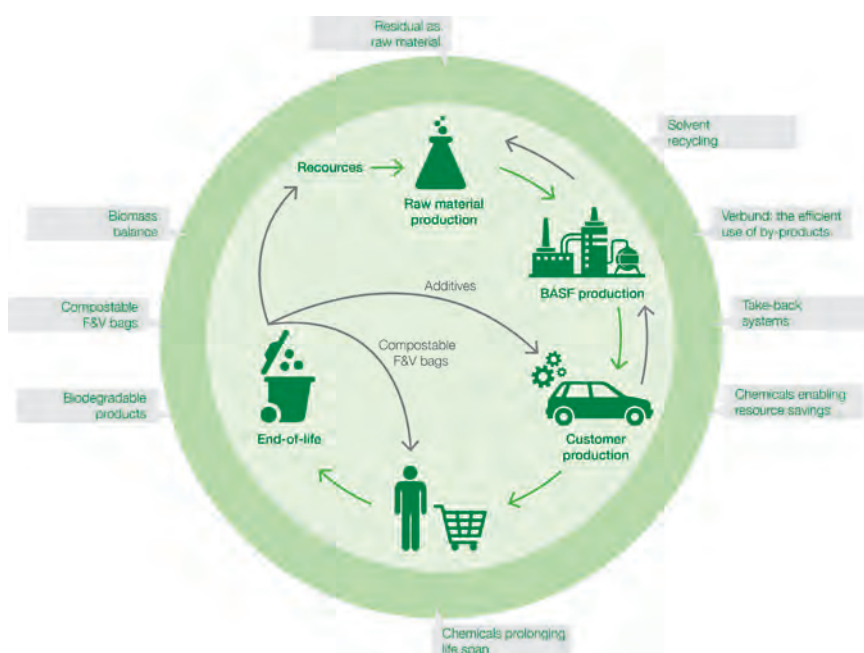
Over the last few decades, plastics have become the material of choice in various applications – e.g. from medicine, to electronic devices, transportation, and packaging – because they provide a better ecological and economic profile than concurring materials, both in production and during the use phase. Even after use, plastics are a valuable resource and should not end in landfill, and

certainly not in the environment. However, plastic waste in the environment is a global challenge.

To counter this in a joint effort, BASF has co-founded the Alliance to End Plastic Waste in 2019. The Alliance's aim is to develop, deploy and bring to scale solutions that will minimise and manage plastic waste and promote post-use solutions. These can be recycling, reuse and repurposing of plastics.

CHEMICAL RECYCLING

Chemical recycling can contribute to recovering different kinds of plastic waste which have not been recycled so far. It is complementary to mechanical recycling which



Circular approaches require innovation and collaboration throughout the value chain

works well for sorted plastic waste streams. The recycling option that provides better results in an eco-efficiency assessment should be chosen. With chemical recycling, we can offer virgin-grade materials based on plastic waste to customers who attribute great importance to recycling but do not want or cannot compromise on quality.

One example for chemical recycling of plastic waste is our ChemCycling pilot project. We have purchased pyrolysis oil which has been derived from plastic waste from partners and fed small amounts into our integrated production network. The aim is to replace some fossil resources with recycled feedstock obtained from plastic waste.

The amount of recycled feedstock is allocated to the chem cycled products via a certified mass balance approach. Independent auditors evaluate and validate the method.

QUALITY AND PERFORMANCE

The pilot projects with customers from various industries have shown that the products made with chemically recycled raw materials exhibit the same high quality and performance as products made from fossil resources. Our customers developed prototypes e.g. for high-performance automotive parts, food-grade refrigerator drawers or multilayer cheese packaging. With ChemCycling, we can help customers achieve their own sustainability targets.

We want to develop ChemCycling as a business. To move from the pilot phase to market roll-out, however, various issues will need to be resolved.

With chemical recycling, we can offer virgin-grade materials based on plastic waste to customers who attribute great importance to recycling but do not want or cannot compromise on quality

The existing technologies for transforming waste plastics into recycled raw materials must be advanced and adapted for the use at industrial scale, in order to ensure the consistently high quality of the pyrolysis oil. BASF is currently investigating various options for supplying the company's production Verbund with commercial volumes of pyrolysis oil in the long term.

Besides the technical issues, economic aspects also play a role. For chemical recycling to find acceptance in the market, regulators must also recognize the process officially as recycling.

We closely engage with the relevant stakeholders to tackle these challenges because we want to contribute to the circular economy and create value for economy, society and the environment. ■

INNOVATION KEY FOR SURVIVAL

Elaine Burrigge talks to Detlef Kratz, BASF's president of process research and chemical engineering, about why innovation is so important and the key dos and don'ts for a successful outcome

WHAT ARE THE CURRENT TRENDS AND TOPICS IN INDUSTRY DRIVING INNOVATION?

■ Sustainability, climate change and greenhouse gas emissions, along with chemical recycling, are the big topics at the forefront of everyone's agenda. Many companies are working on technologies to reduce or even better avoid carbon dioxide (CO₂) emissions, be it through incremental changes or breakthrough technologies.

This is also reflected in the ICIS Innovation Awards where, from the more than 60 applications, all had a sustainability aspect. Similarly, BASF has established a Carbon Management Programme, under which we develop new CO₂ reduction technologies. We aim to make the same products and grow as a company, but we are doing these in a carbon-neutral way.

WHAT MUST COMPANIES DO TO DRIVE FORWARD INNOVATION AND BRING PRODUCTS SUCCESSFULLY TO THE MARKET?

■ First of all, industrial research is different from academic research. Companies must understand the needs of their customers and their value chains. A key factor behind successful innovation is also the spirit and culture of an organisation to drive a project through to completion. The teams behind the project must be passionate about what they are doing, be open to new ideas and apply diligence and endurance in their research. Research doesn't happen by just doing an experiment in a flask. New technologies such as digitalisation help companies to do things faster and more effectively. Collaborations with industry and academia open the perspective to explore new options.

WHAT ARE THE MAIN STUMBLING BLOCKS TO INNOVATION?

■ The big killer to any project is a 'stop-and-go' mentality. If you do not continuously drive innovation, it will be the death of your company. Research is the lifeblood of a company and, especially in the chemical industry, requires endurance to remain on track. Companies must stay young over time by continuously investing in research and maintaining an innovation pipeline, otherwise it will not be sustainable. A successful innovation takes time, leadership commitment, continuity and consistency, also with regard to funding. It is very clear that small start-up companies, often centred on just one or two technologies, have a consistent focus. At BASF,



as a large company, we have an additional challenge not to lose focus on our key drivers. The worst thing is to do a little bit of everything which would ultimately lead to nothing.

HOW CAN COMPANIES ENCOURAGE INNOVATION AND PUBLICISE THEIR EFFORTS OUTSIDE THE INDUSTRY?

■ Encouraging creativity and an entrepreneurial spirit is a major step towards stimulating ideas. Corporate branding can be important too, where creativity can be part and parcel of a company's sales proposition, for example promoting itself as being at the forefront of developing technology to drive sustainability and climate change. This can also generate passion from outside the industry, such as from friends and family.

The chemical industry still needs to do a better job in explaining the good things it is doing, spanning the range from combating climate change all the way to providing pharmaceuticals to fight diseases. As an industry, we provide a service to society with regards to agrochemicals, food and nutrition, engineering, construction and housing but we must be better at telling the story. If I look at the winners of this year's ICIS Innovation Awards, they are not only excelling technologically but they are also good at promoting what they do and they have all done a very good job of bringing their products to market.

WHY IS IT IMPORTANT TO RECOGNISE AND REWARD R&D AND INNOVATION?

■ The best recognition you can receive is from your customers buying what you have made. However, customers are only interested in your product and not in the technology that makes it. In the early stages of an innovation, to receive recognition from your industry peers and experts is very worthwhile. This is why the ICIS Innovation Awards are good because they are part of our industry recognition. We are only human after all and we like to get positive feedback. ■



Changes on the ground level of the organisation could have far-reaching impact for the top-level goals of becoming more sustainable

Sustain the course

Maroon Group president and COO Mike McKenna highlights talk versus action, and how the chemical industry has a chance to spearhead the way into a green future

CAMERON ROBERTS LONDON

Environmental consciousness and sustainability are two of the key buzzwords for the chemicals industry in today's climate. But how can sustainability be put into practice in the real world? We speak to president & COO at Maroon Group LLC to find out.

Businesses the world over are driving the importance of being sustainable and eco-friendly. With political powers always looking over the shoulder of the chemicals industry, businesses in this space have a chance to spearhead the way into a green future.

We spoke to Maroon Group, sponsors of the Best Benefit for Environment and Sustainability category in the ICIS Innovation Awards, to find out how the industry can realistically input sustainable practices into their businesses. Mike commented on the company's commitment to maintaining this goal.

"Maroon Group strives to improve the quality and length of life. We have a responsibility to support innovation and take a leading role in sustainability. Our employees want to be a part of an organisation that focuses on sustainability, corporate social responsibility and protecting our environment. On top of this, our customers are relying on us to keep to these standards we set ourselves.

"If our organisation is going to be success-

ful long term, we need to be on the leading edge of sustainability and innovation. We need to find environmentally friendly creative solutions for our customers. We've been investing heavily in innovation for many years, with teams of scientists helping our customers formulate to improve the performance of their products and develop amazing new technologies."

Culture and employee engagement are vital cogs in encouraging an environmentally conscious firm. Mike went on to talk about the softer side of their sustainability initiatives, including programmes that attempt to create the next generation of chemists.

"We have supported this award for many years because sustainability is important to us. We are a certified EcoVadis organisation and invest in programmes that address environmentalism, recycling, sustainability and innovation in our supply chains and operations. We are ardent supporters of youth education programmes such as the "You Be The Chemist Challenge" sponsored by The Chemical Education Foundation and encourage children to actively participate in finding sustainable solutions."

LOOKING FORWARD

Innovation, by its very nature, is always looking to the future – meaning those aligned with this vision must also do so. Therefore, we

asked Mike what the next big step Maroon Group was looking towards and how this might impact beyond the chemical industry.

"We're looking for process and performance innovations for our customers and our principal partners to identify and drive efficiencies in their operations. We are looking for innovation in our global supply chains and we support this with new technology and sustainable global sourcing practices.

"We are also interested in innovation in the packaging, food and beverage industries supported by researching organic and healthier ingredients, alternative proteins and sweeteners as well as active products that help slow the aging process. These are all innovations that we support spanning our portfolio of industries."

While the innovations mentioned may be on a large scale at first thought, Mike was also keen to add that changes on the ground level could have far-reaching impact for the top-level goals of becoming more sustainable.

"Some of the greatest technology advancements are coming from chemical producers driving innovation in their processes and products. Through innovation, we can drive improvements in operations, light-weighting vehicles, reducing VOC's, etc. Each of us can make a positive impact. It's our collective responsibility to innovate and improve the environment for generations to come." ■

Capitalising on circular economy

The circular economy and plastics recycling are major areas for innovation. Large refining and petrochemical companies are ideally placed to leverage their capabilities and expertise to resolve the plastic waste problem

ELAINE BURRIDGE LONDON

A circular economy and plastics recycling are major areas for innovation right now, driven both by upcoming regulation and consumer demands.

Indeed, of the 64 entries for the ICIS Innovation Awards this year, many were focused on the circular economy and the growing problems around plastics recycling, notes Paul Bjacek, principal director and lead of Resources strategic research at Accenture.

Bjacek sees the circular economy as a disruptive trend and believes companies need to take bold actions if they are to be successful.

Companies must become more circular by generating value through controlling the molecule lifecycle and enabling circularity downstream by adopting new business models, he says. This includes product stewardship, for example being more selective about the applications in which products are used. Are they easily collected and recycled? If in durable uses, like appliances, will they fail sooner versus a part made from competing materials?

As plastics producers make inroads in new applications, they will be held accountable for the resulting product's end-of-life waste. For instance, in the average car, plastics and rubber account for roughly 42% of the cubic volume. This will rise to 56% by 2040, according to Bjacek, as automakers incorporate new lightweight polymer-based materials to replace metals.

WASTE STREAMS

Many of the plastic materials used in cars, such as nylon, acrylonitrile-butadiene-styrene (ABS) and composites, are not readily broken down by mechanical recycling technology. Consequently, there will be a need for a greater understanding of – and possibly more involvement in – how multiple polymer waste streams will be handled.

The past focus has been on the polymers themselves and making them more recyclable or from renewable resources. Going forwards,



Chemical recycling will be the future focus

along with enhancing mechanical recycling technologies, research and development efforts will include more on chemical recycling. This is an area where some of the solutions lie, says Bjacek, it will also be where the largest chemical and refining producers have an advantage given the scale of their manufacturing facilities.

Accenture's term for its conceptual approach for an integrated circular business model is "Scale Circular Integration". This envisages volumes of processed and unprocessed polymer waste returned to an integrated refining and petrochemical site to be broken down into various hydrocarbon streams, including feedstock for virgin polymer manufacture.

The scale of circular integration is where chemical and refinery companies are experts at optimising product flows and adjusting for variations in materials, Bjacek says.

Energy and petrochemical companies already operate on large production sites, often integrated with storage facilities along with access to transport networks such as ports and railways. Consequently, he says these organisations are in a position to capitalise on their

existing infrastructure and logistics to focus their skills and expertise in research, manufacturing, marketing as well as sales on resolving the plastic waste problem.

He adds that their large production sites are ideal for incorporating recycling technology, especially chemical recycling, pyrolysis and gasification, where various durables, such as composites, and non-durable plastics, for example packaging, can be handled. There will also be byproduct streams that can be used on-site as polymer feedstock, other chemicals or as a fuel /fuel blend.

Bjacek believes these large companies can also be the ones that have great influence on and benefit the most within a circular economy.

In the future, Accenture sees new technologies and software being used to sort waste, with machine learning and artificial intelligence also being applied to scale-up processes.

INNOVATION

While most of the technology for chemical recycling already exists, Bjacek says there must be more innovation along the supply chain.

Again, this is where the large complexes such as Antwerp, Rotterdam and Amsterdam in Europe, Shanghai in China, and Houston in the US, will be the optimal places to start, given their infrastructure capacities.

However, there still needs to be innovation around handling and moving the huge volumes that are envisioned. The chemical industry could look at other markets, such as grain and coal, where huge volumes are moved over long distances. Bjacek says the same could be done for waste. Barge transport of plastics waste to petrochemical complexes is another possibility.

"The industry needs to be inclusive as it looks to the future. In the next 10 to 20 years, companies are going to start thinking big and broad," Bjacek says. "This will mean strong and closer collaboration along the supply chain with other sectors of the industry, including waste handling companies as well as governments." ■

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