Advances in Chemicals Sustainability

Chemical Strategic Report Prospectus

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S&P Global
Commodity Insights

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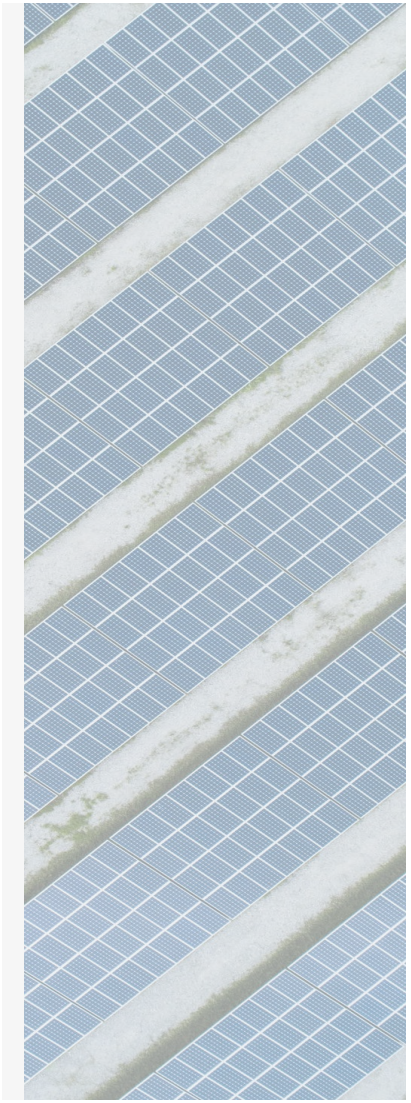
Sustainability is a clear “ hot topic” and concern across the industry and down virtually every value chain from commodities to specialties, from feedstock supply to consumer



- Sustainability was a key initiative within the petrochemicals and allied industries.
- Legislation is moving to more aggressive carbon reduction measures to encourage industry decarbonization in response to climate change targets.
- Petrochemical and derivative consumers through to major brand-owners like Unilever, Proctor&Gamble, Walmart, Lego, Mattel, etc., have stated major ambitions in sustainable procurement and carbon footprint reduction, driven in turn by their customers who are more sustainability conscious.
- The advanced biofuel industry is supplying low carbon feedstocks into the petrochemical industry in Europe and Asia, but at a premium price. New projects are being developed to convert low carbon bioethanol into polymers claiming carbon neutrality.
- The report builds on actual projects in chemicals sustainability undertaken by the S&P Global Chemicals Consulting team as well as wider cost and sustainability modelling developments with S&P Global Commodity Insights.

Many client of chemicals consulting publish annual sustainability reports and comment at length on the many areas of the UN Sustainability Goals where they are involved

- Virtually every client of chemicals consulting and many of its allied business stress their adherence to multiple categories in the above list. From a process perspective decarbonization fits criteria like 11, 12, 13, etc., as well as moving towards legislation-driven like “Fit for 55” in Europe.
- These impact not only the petrochemical majors but also many players in specialties and importantly the major brand-owners downstream who respond to the wants and needs of the consumer.

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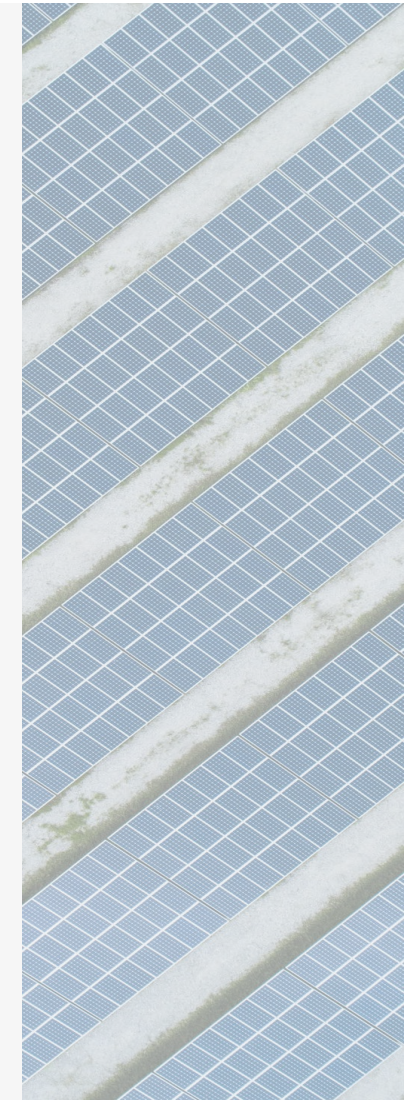
This report covers a wide range of initiatives to reduce the carbon footprint of olefins and aromatics production from feedstocks, emerging technology, and legislation



- Legislation is driving the development of the circular economy. Governments are introducing pricing mechanism for emissions as well as providing investment support through legislation, e.g., the Inflation Reduction Act (IRA) in the United States.
- The hydrogenated vegetable oil (HVO) process shown later in this section is designed to make renewable diesel (RD) and sustainable aviation fuel (SAF). It also makes bio-naphtha and bio-propane that can be used as petrochemical feedstocks, e.g., for steam cracking.
- Access to low carbon bioethanol (made with carbon capture and storage) is encouraging investment in low carbon polymers and other ethanol/ethylene derivatives. However, will the push for SAF in North America impact chemical access to low carbon bioethanol if it becomes price-prohibitive?
- Taking into account process design and operation, utility needs, and the carbon footprint of feedstocks up the petrochemical value chain it is possible to derive a carbon footprint and examine the impact of wider sustainability measures beyond just feedstocks, like cracker electrification, hydrogen-fueled cracker furnaces and the implementation of CCS/CCSU.
- Chemicals sustainability is also influenced by the circular economy and new feedstocks sources such as circular naphtha from plastics pyrolysis will become increasingly available. This will be on of many means of plastics recycling that could impact how sustainable chemicals develops.

Special report on advances in chemicals sustainability

Context: Why this report

- Countries have committed to net zero targets. These targets will impact all industries, including the chemical industry. Plastics circularity is back at the forefront
- Regulations are being put in place to facilitate the transition to net zero and plastics circularity
- Brand owners and some Corporates committed to plastics circularity and net zero targets, over and above regulatory requirements
- Investors and consumers are seeking greater commitments and transparency on sustainability from corporates
- Base chemicals have high carbon footprints, though sustainable alternative routes exist

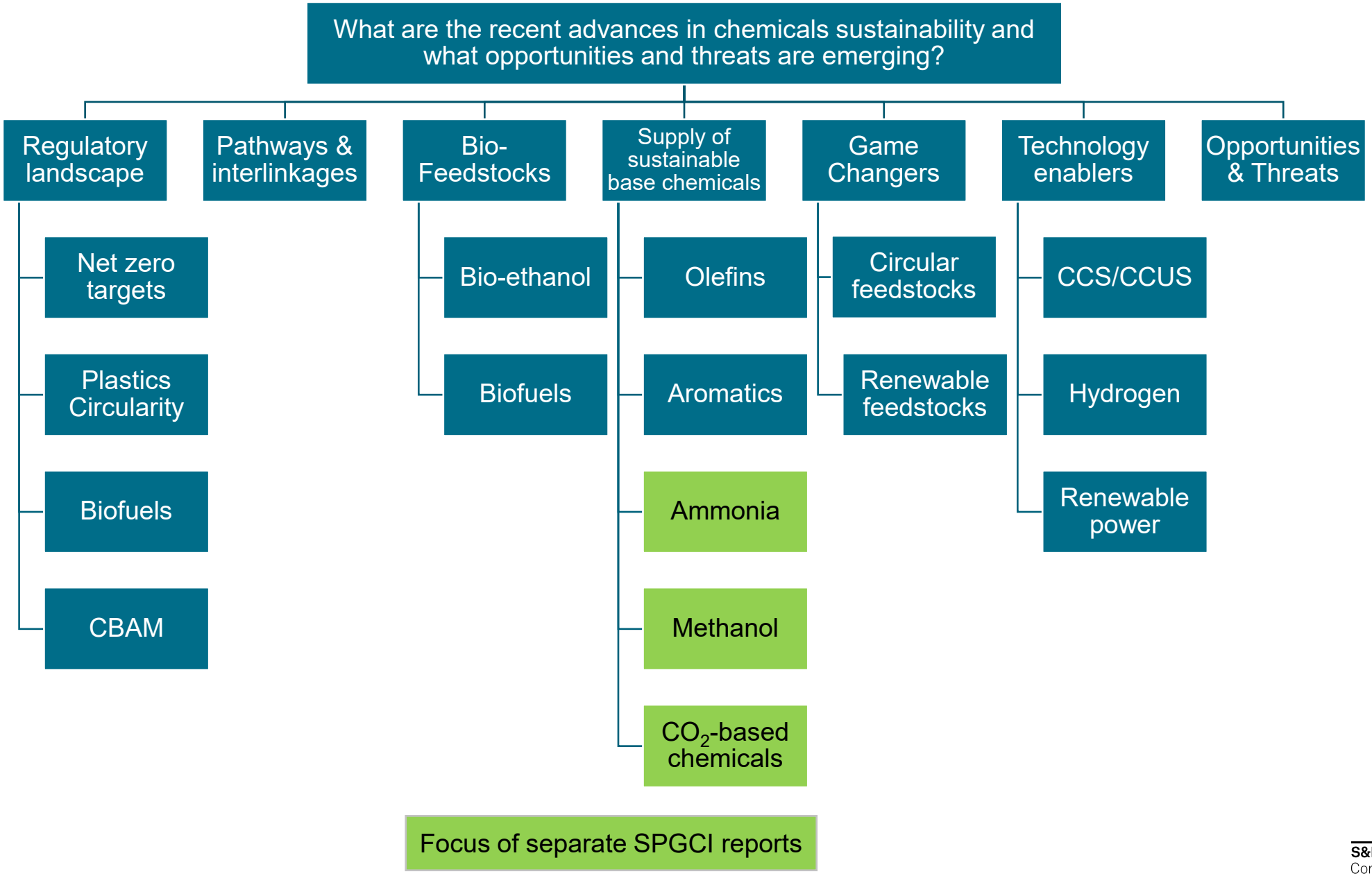
What the report will address

- Generous free emissions allocations are expected to be phased out in the short to medium-term. This will bring additional costs to conventional production. These changes are expected to have a global impact
- There are still some uncertainties on the sustainable regulatory landscape for chemicals
- Bio-feedstocks availability for the chemical industry are dependent on agribusiness and transportation fuels regulatory development. Plastics recycling still requires guidance on taxonomy
- The report focuses on olefins and aromatics and complements other SPGCI chemical strategic reports
- The report will address recent advances in chemicals sustainability and the opportunities and threats emerging

Who will benefit from this report

- **Existing chemical producers** – understand options for sustainable production under tighter environmental regulations, and the impact of development in agribusiness and transportation fuels on the availability of sustainable feedstocks for chemicals
- **Refiners, bio-refiners, agri companies and plastics recycling companies** - understand dynamics and establish partnerships with the chemicals industry
- **New entrants** – develop views as a starting point for strategy decision on where, how, when to participate.
- **Investors** – frame assumptions on potential investments and returns as screening for go / no-go options and early financing viability
- **Technology players** – keep up to date with the implied strategies, possible directions, and “sentiments” of operating companies or financiers considering sustainable chemicals opportunities

Review of key question and study scope



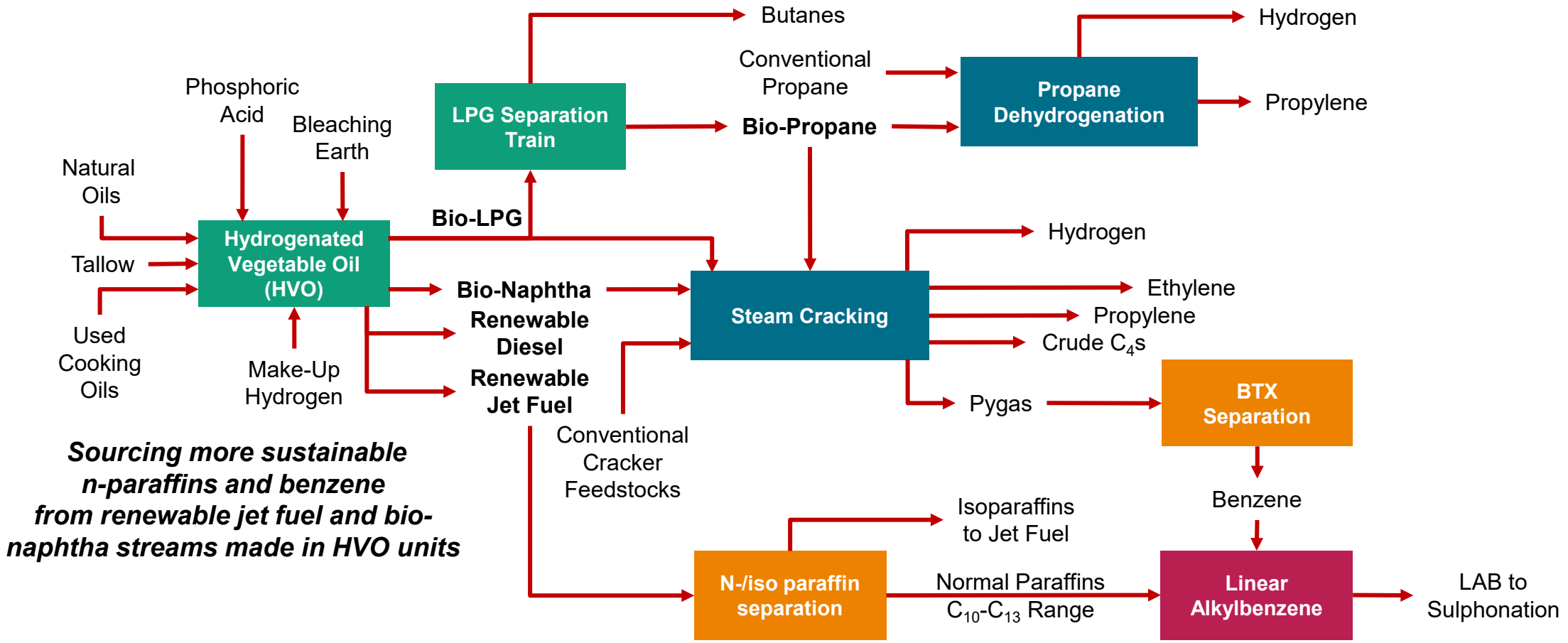
In the major regions there are different directives and pieces of legislation supporting different approaches to chemicals sustainability

Region	Carbon Market	Recycling Mandates	Financial Incentives for Low-Carbon Projects (incl. chemicals)
Europe	Some chemical sectors are under EU ETS, with carbon prices being the highest in the world	Comprehensive plastic recycling targets and taxes for unrecycled plastics	Allocated funding available for low-carbon projects through various programs, but no indirect financial incentives (through tax credits)
The United States	Limited regional ETS (no chemical industry coverage) No federal carbon market	Recycling mandates in some states, targeting different plastic products. No federal plastic recycling law	Strong financial support from the government – Inflation Reduction Act and the US Department of Energy's allocated funding for hydrogen and CCS
Mainland China	ETS limited to the power generation industry, chemicals sector may be included after 2025. Some regional ETS cover chemicals, but has low carbon prices	Recycling mandates covering mainly single use plastic items and evolving mandates to tackle plastic waste	Financial support aimed at R&D projects for clean hydrogen and CCUS

Primary enabler

Secondary enabler

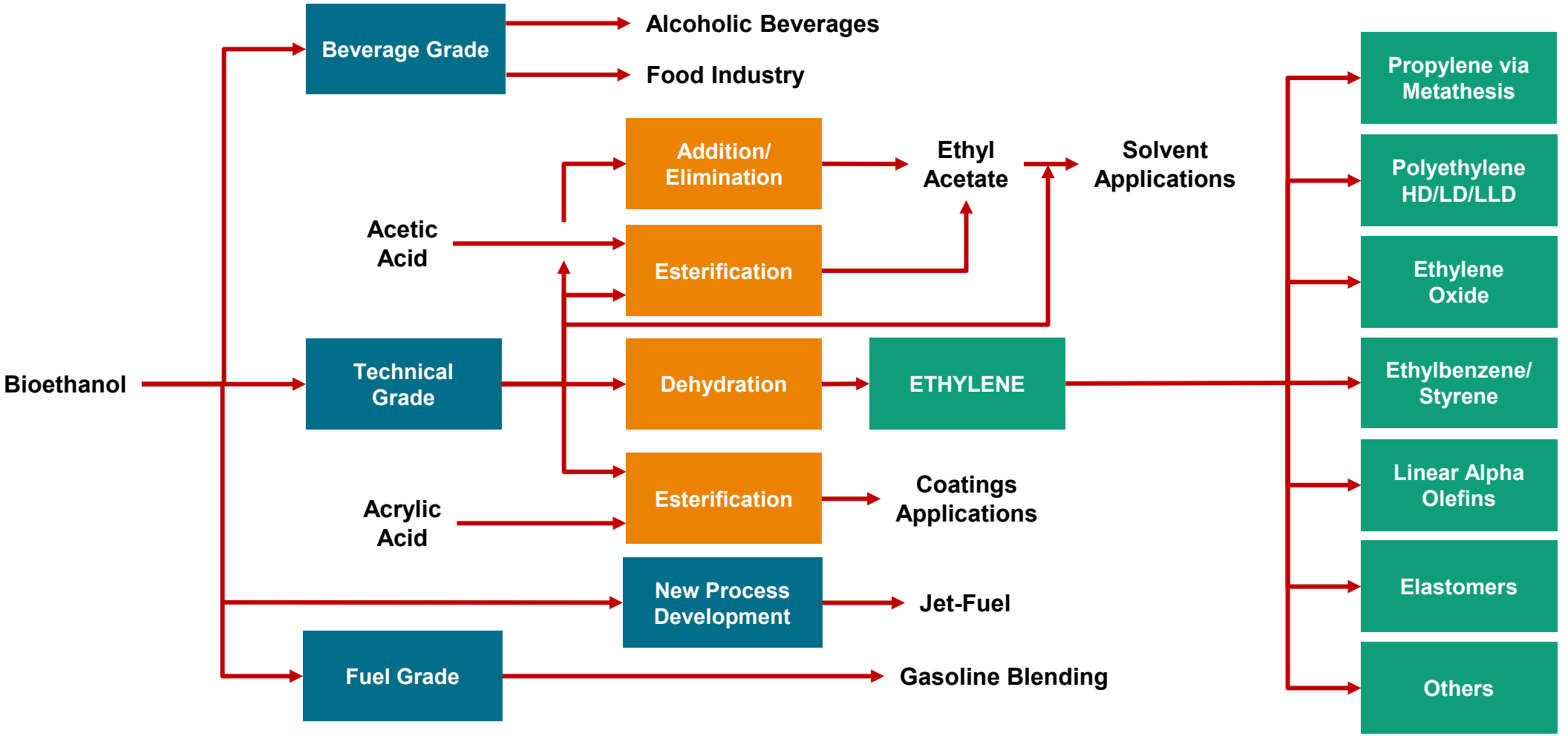
Advanced biofuel developments like HVO co-produce not only bio-naphtha/bio-propane for petrochemical use, but possibly n-paraffins (ex-jet fuel) for surfactants



Sourcing more sustainable n-paraffins and benzene from renewable jet fuel and bio-naphtha streams made in HVO units

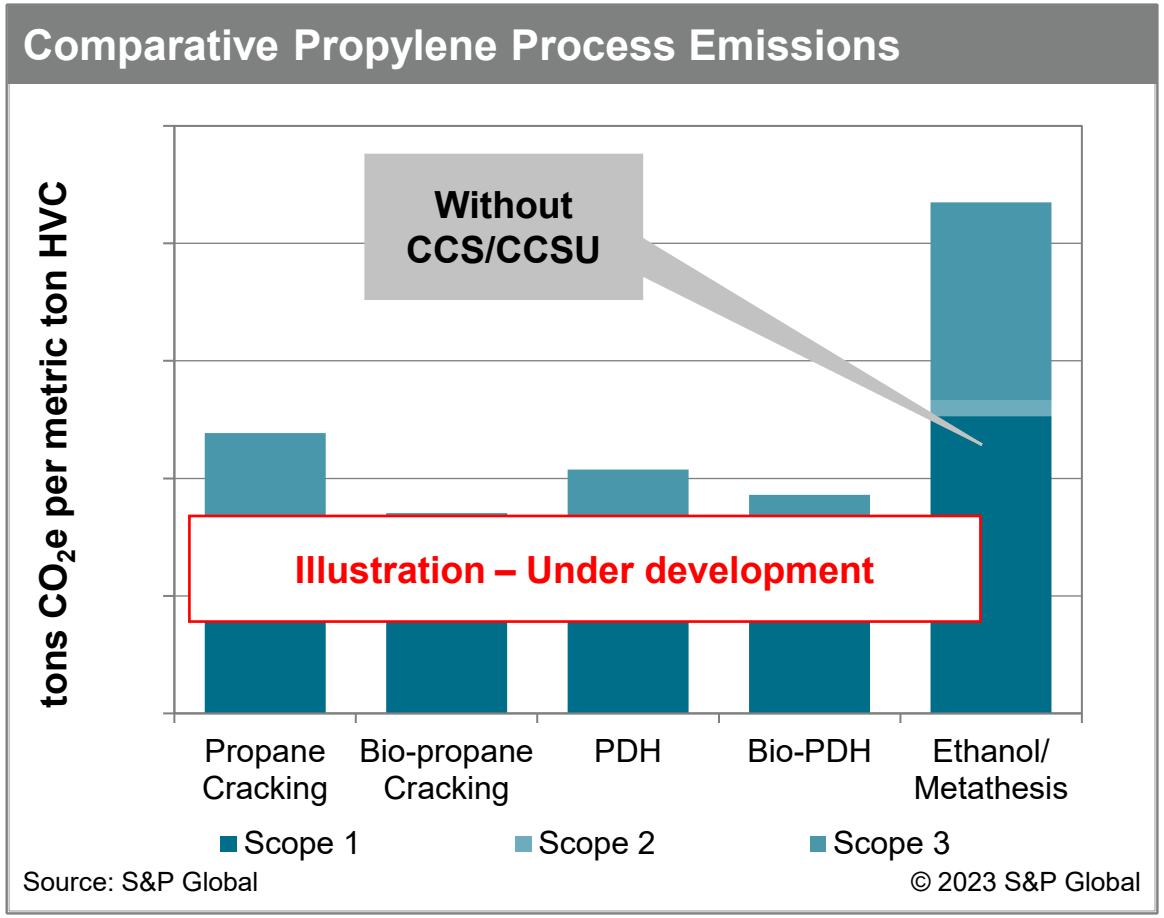
- SABIC, Lyondell-Basell and others are already consuming bio-naphtha for the production of olefins and aromatics. Fibrant off-takes bio-benzene from SABIC in Geleen for low carbon caprolactam production. Borealis consumes bio-propane from Neste for its PDH unit in Antwerp.
- Major LAB players like Sasol and CEPSA are looking to acquire not only bio-benzene but also bio-based n-paraffins, ex renewable jet fuel, for low carbon surfactant production.

Low carbon initiatives and biofuel legislation encourage companies to explore and exploit ethanol as an ethylene source for bio-based chemicals production



- Croda has invested in ethanol to HPEO for specialties in the US. In Germany CropEnergies has invested in ethanol to ethyl acetate. Citroniq and Lummus have recently signed a MOU to develop corn to polypropylene in Kansas, citing the use of CCS to capture the CO_2 from bioethanol production to reduce the carbon footprint of the project.

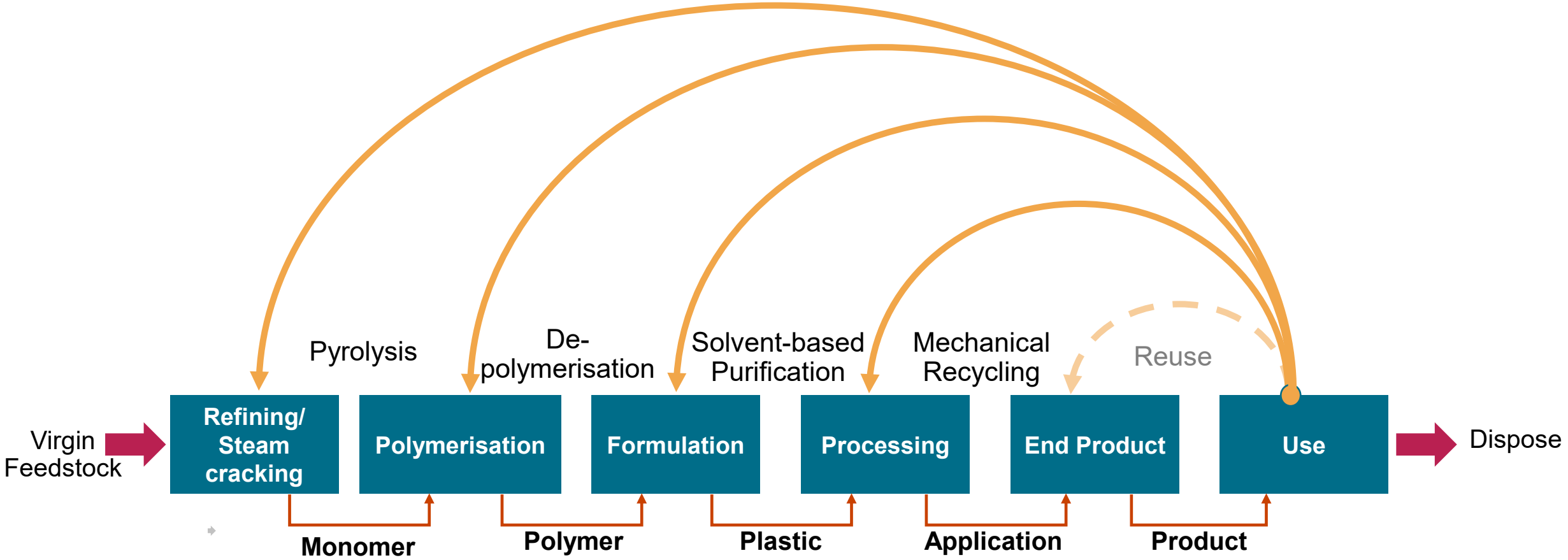
S&P Global has developed carbon footprint analysis for several processes that produce major petrochemical building blocks



Includes upstream value chain carbon footprint analysis and relevant process steps

- Emissions are computed per metric ton of high value products (HVC – ethylene, propylene, butadiene, benzene, etc.)
- Emissions described in terms of 'scope':
  - Scope 1 – process emissions
  - Scope 2 – imported utilities, e.g., power
  - Scope 3 – feedstock
- Using feedstocks from HVO processes can significantly reduce CO_2 emissions from steam cracking.
- HVO-based feedstocks form part of the wider strategies S&P Global can include that could reduce cracker emissions, including electric furnace development, renewable energy/hydrogen use and so on.
- Some processes may at first suggest a lower carbon route, e.g., propylene from ethanol, but process complexity and energy needs can lead to higher emissions.
- In this case the level of emissions could be reduced very substantially if CO_2 from bioethanol and utilities were captured and sequestered as planned by Citroniq/Lummus in its proposed Kansas polypropylene project.

The development of the circular economy is providing various streams that can be placed in the chemicals value chain from use in refinery, steam cracking and intermediates operations



- Certain technologies for plastics recycling like pyrolysis can yield hydrocarbon streams that depending on their composition can be placed in the refinery as a syncrude or fed to the FCC to make transportation fuels and propylene/C_4s. Some streams are also suitable for steam cracker use for olefins and aromatics. Reformers could also consume some streams.
- From a chemicals sustainability this only makes real sense if carbon can be sequestered from recycling processes and that legislation is supportive.

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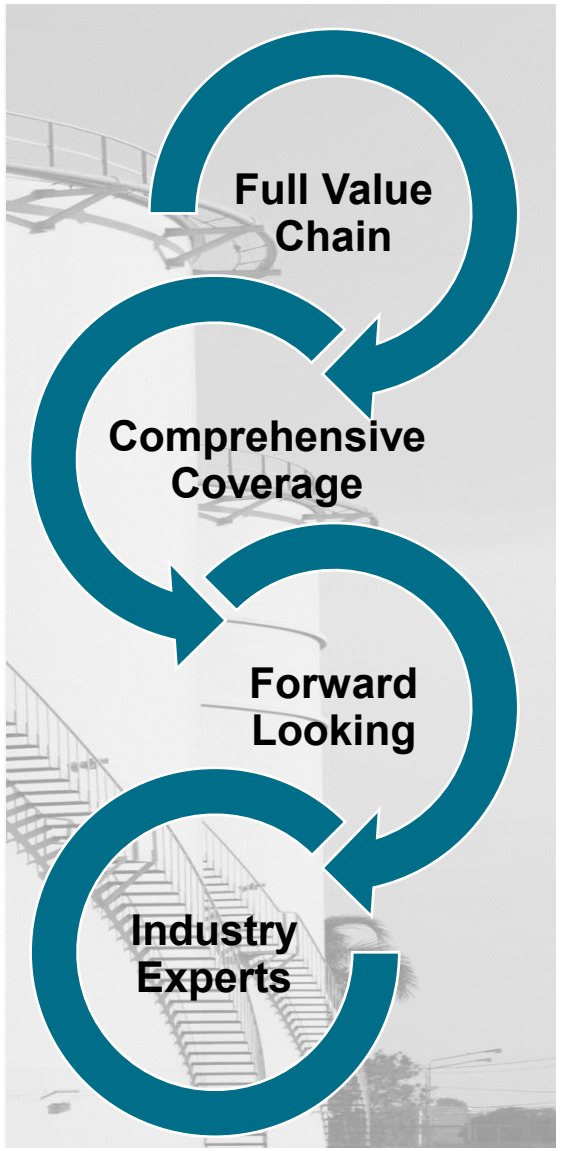
Chemicals consulting brings a comprehensive report on sustainable chemicals development based on its experience from actual projects and wider S&P Global expertise



- The value chain from agriculture through biofuels to petrochemical building blocks is covered from sustainable market development, technology, low carbon initiatives, cost impact together with carbon footprint and competitiveness implications

- The report covers the major petrochemical building blocks and supporting areas, agriculture, biofuels, hydrogen, renewable energy, CCS/CCSU, technology, etc.

- The future of sustainable chemicals, focused on the major petrochemical building blocks, is considered, together with how technologies will influence developments worldwide and what the cost implications are, especially when legislation intervenes.

- The report makes use of very recent experience in the sector, working with clients on real world projects. S&P Global team members cover multiple disciplines in petrochemicals, green technologies, biofuels, CCS, hydrogen, and renewable energy

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Contacts

Tanya Duggal (North America)

Tanya.Duggal@spglobal.com

Marisabel Dolan (Latin America)

Marisabel.Dolan@spglobal.com

Ryan Monis (Europe)

Ryan.Monis@spglobal.com

Mohit Sood (Middle East)

Mohit.Sood@spglobal.com

Aman Arora (India)

Aman.Arora@spglobal.com

Juan Song (China)

Juan.Song@spglobal.com

Kitiya Atthayuwat (Asia excl. China)

Kitiya.Atthayuwat@spglobal.com

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