S&P Global
Commodity Insights

CHEMICAL INDUSTRIES ASSOCIATION

Project 2035

The chemical industry transition: Pathways for a resilient and sustainable future

Final Report
ABRIDGED

25 November 2024

Contents

The chemical industry transition: Pathways for a resilient and sustainable future

Background

- The Chemical Industries Association (CIA) represents chemical and pharmaceutical businesses in the UK.
- The CIA is in the process of developing a sector plan that sets a long-term outlook for the chemical industry in the UK; with 2035 and 2050 as the reference time horizons.
- The aim is to articulate the key conditions and the rational for action needed vis-à-vis the sector’s present and future challenges.
- The CIA’s current interest covers a broad range of fundamental topics including energy transition and several other sectors adjacent to the chemical industry, with an explicit chemical industry focus on:
  - Potentially informing forthcoming government policies.
  - Providing inputs to a national industrial strategy development if appropriate.

Objectives of this Report

- Understand and, if appropriate, develop a business case and broad social / macro rationale for a strong domestic chemical industry in the UK.
- Provide a robust evidence basis, both quantitative and through quality insights, to characterise the future of the industry and its implications long term.
- Define future scenarios for the UK chemical industry, and under which conditions they could be improved or mitigated: i.e. enablers, restraints, and drivers both internationally and domestically.
- Identify desirable conditions, macroeconomic circumstances, policies (or conversely undesirable conditions) which should be highlighted to stakeholders inside and outside the chemical industry.
- Overall, provide an external, independent view of the key challenges and opportunities for the chemical industry in the UK.

Note: this is an abridged version of the original full report. In this document some pages have not been included and some data, e.g. chart units, have been deliberately left blank

The chemical industry transition: Pathways for a resilient and sustainable future

1. The value of the chemical industry to the UK is predicated on good macroeconomics, a crucial contribution to the energy transition, and ensuring resilience of critical national infrastructures

The *intrinsic* value of the chemical industry cannot be overstated: the vast majority of everything we use in everyday life is made of chemicals. As chemistry has provided one of the pillars on which modern industrialised economies have been built in the last 150 years, virtually all countries have developed chemical industries to various extents.

The chemical industry in the UK has a long and glorious history, which dates back to the late 19th century and transcends national boundaries*.

Today, in the 21st century, the *extrinsic* value of the chemical industry to the UK is predicated on good macroeconomics, a crucial contribution to the energy transition, and ensuring resilience of critical national infrastructures (CNI)**.

The key macroeconomic indicators are positive:

- At £70 bn turnover in 2022, UK chemicals represents 1.2% of UK GDP. In absolute terms it places the UK just below the top 10 countries globally.
- Chemicals account for 15% of UK exports and 12% of imports, the second largest UK export sector.
- The chemical industry is a major UK employer, both directly with over 130,000 people and across its supply chain with 500,000 people: many of the jobs are outside London and still attract above-average salaries.

A successful and accelerated energy transition in the UK relies on the chemical industry to deliver in at least **six areas:**

- Composite materials for wind turbines.
- Substrates for solar panels.
- Advanced chemicals for batteries.
- More efficient Carbon Capture***.
- Sustainable Aviation Fuel (SAF).
- Low-carbon ammonia.

Cross-sector, the chemical industry contribution is essential to at least **three key sectors** in the UK: Aerospace, Automotive, and Biotech.

Four critical infrastructures** are directly affected by secure and dependable access to chemicals in the UK: Defence, Energy, Health, and Water.

(*) See Appendix for a recent history line of the UK chemical industry
(**) CNI are the 13 Critical National Infrastructure sectors identified by the UK Government.
(***) Carbon Capture and Storage (CCS), Carbon Capture, Utilisation and Storage (CCUS)

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2. The chemical industry is cyclical and currently at a trough globally; however, the UK chemical industry has been generally trending downward in the last 20 years, over several cycles

While the chemical industry encompasses hundreds of diverse segments, it can be broadly characterised in terms of commodities and specialties with two distinct dynamics.

- Returns on chemical commodities investments tend to be highly cyclical, primarily driven by cost of raw materials and cost of energy.
- Chemical specialty profitability also shows large variations, but the cycle is less pronounced than for commodities, driven mainly by end-use demand and industry consolidation.

Today the chemical industry is globally at a trough, however, with marked differences by geography and by segment: commodities in the UK and Europe have been hit hard. They are not likely to pick up in earnest before 2026/2027.

- The key cost of energy indicators, oil and gas, are not forecast to decrease on average over the next 18 months. Geopolitical events could move these significantly higher.
- The margins on ethylene, the most important commodity chemical, are still acceptable in the US (ethane) but virtually zero in Europe and Asia (naphtha) and unlikely to change the short term.
- Ethylene capacity overbuild globally is the problem. Further capacity rationalisation and closures in Europe and Asia are almost inevitable to restore profitability in commodity chemicals.
- At the other end of the value chain, specialties continue to show a broad spread of sizes and growth rates across segments and regions, with Western Europe and Japan the slowest mid-term.

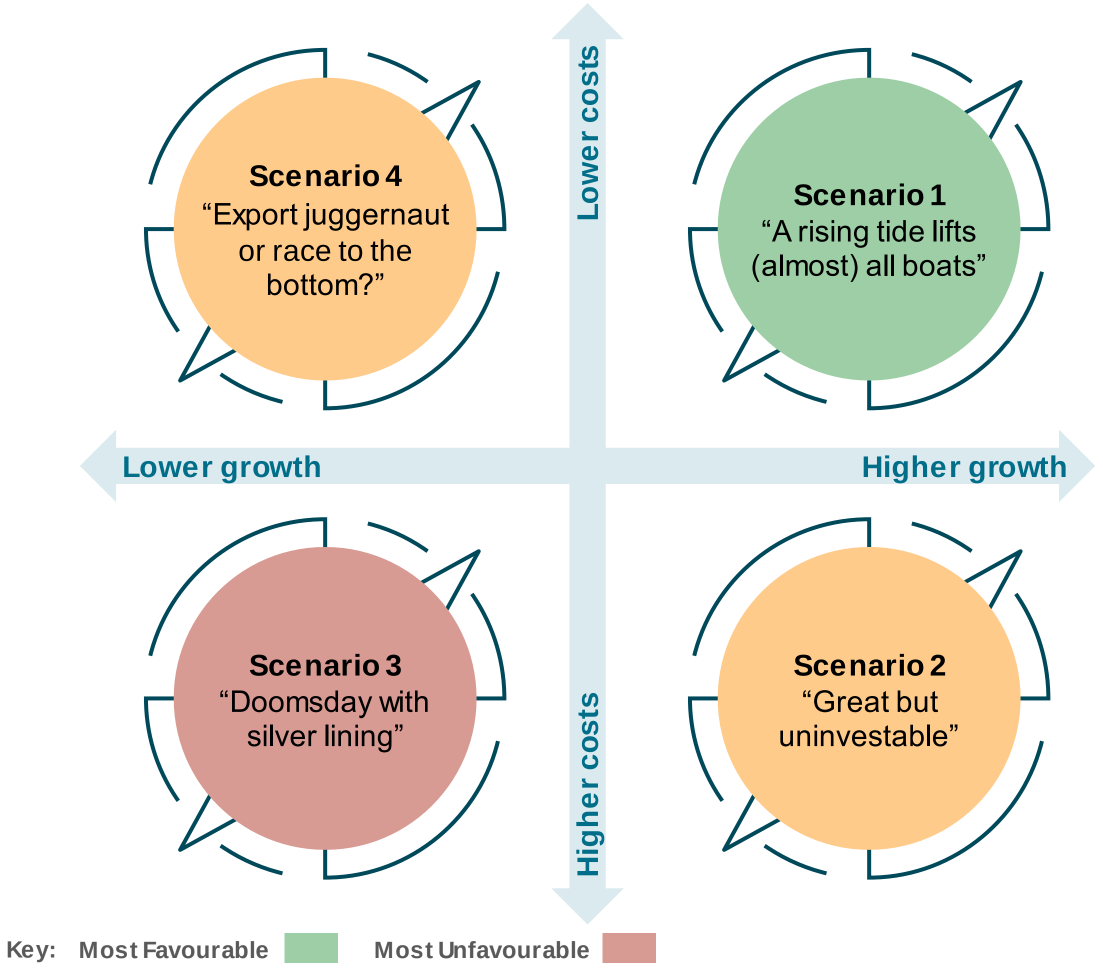
Despite many examples of excellence, particularly at the specialty end, overall, the UK chemical industry has been in steady decline based on key indicators such as assets, consolidation, closures, and R&D spend.

- Analysis of the evolution of chemical capacity in the UK shows a consistent trend towards progressive reduction in number and volume of assets.
- The UK capacity to produce some of the major chemical building blocks and polymers has been declining over the last 20 years.
- From an ownership perspective, since the 1990s the UK chemical industry has undergone extensive consolidation. Over the last 15 years there have been several notable closures in the UK chemical industry, particularly of base chemicals and key intermediates assets.
- Compared to global R&D leaders like China, USA, and Japan, the UK's spend is small; while it has increased over time it has not kept pace, as UK R&D relative share declines.

The reasons for such downward trajectory are clearly visible vis-à-vis the global context: international comparisons show how the UK chemical industry's historical trend is associated with uncompetitive feedstock, changing demand, and with relatively "light" industrial policies.

The chemical industry transition: Pathways for a resilient and sustainable future

3. S&P Global has defined four future scenarios: on its current trajectory, the UK chemical industry is drifting towards the most unfavourable scenario with loss of value, employment, and resilience



S&P Global outlines four future scenarios for the UK chemical industry: from a favourable low cost and high demand growth combination, to very unfavourable high cost and low demand growth situation.

Considering historical trends for the industry and the baseline forecasts for key products and sectors, there is a material risk that, on current trajectory, the UK chemical industry will potentially drift towards the most unfavourable scenario (Scenario 3).

- Growth forecast and prospects for most of the chemical building blocks in the UK are modest or flat – hydrogen and ammonia are special cases.
- Future growth and prospects for end-use chemicals in the UK range from high for premium specialties to low for large-volume commodity plastics.

On balance, unfavourable scenarios imply a significant degradation of macroeconomic value, restraints to the energy transition, and diminished resilience of critical infrastructures vs. today.

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4. Out of many possible options, a few fundamental enablers seem especially attractive as they are likely to have the highest positive impact on the current and future UK chemical industry

S&P Global has considered 17 possible areas of major intervention to enable UK chemical industry growth or mitigate gaps.

Enablers / Mitigation	Category
Access to domestic car production	Industrial / Infrastructure Options
Access to domestic battery production	
Indigenous renewable feedstock	
Circular feedstock from recycling	
Renewable energy, including green hydrogen	
Carbon capture, utilisation and storage	
Clusters (materials, skills)	
Tax relief (R&D, investment); essential this is continued	Regulatory / Policy Options
Accelerated permitting, approval process	
Stable business regulatory framework	
Favourable trade tariffs and certification	
Adjusted UK carbon pricing	
US IRA-type approach	
EU Clean Industrial Deal-type approach	
More chemists / better graduates	Culture / Human Resources Options
More technicians, engineers	
Positive perception of chemicals and industry	

The chemical industry transition: Pathways for a resilient and sustainable future

4. Out of many possible options, a few fundamental enablers seem especially attractive as they are likely to have the highest positive impact on the current and future UK chemical industry *(continued)*

In terms of industry impact and overall effectiveness in multiple scenarios, five priority enablers have the potential to be "game changers", namely:

a) Access to competitive **feedstock and energy**: mitigation and diversification.

- Under S&P base projections for the 2050 global energy landscape, the majority of chemical feedstock will still be fossil-based: the UK is still expected to have a proportion of fossil-based inputs feeding into chemicals long term.
- While the UK dependency on oil, naphtha, and gas as relatively uncompetitive inputs is a geographic reality, such disadvantage can be mitigated by a calibrated carbon pricing approach.
- Sugar operations, and possibly wider biomass processing, integrated with biotechnology and selected petrochemical technologies could reduce the reliance on high cost, fossil-based feedstock.
- Low-carbon feedstock available from chemical and mechanical recycling facilities could become an important element of the UK feedstock mix.
- Clean hydrogen (and ammonia) as a "feedstock" is the start of a supply chain leading to potentially cost advantaged chemicals.
- CCUS (see point c) underpins both the swift expansion of low-carbon hydrogen production and, by definition, the availability of CO2 as a chemical input at scale.

(*) Note: As of 4 October 2024 the UK Government pledged near £22 bn "for projects to capture and store carbon emissions from energy, industry and hydrogen production"
(**) See definition in Appendix, Glossary.

a) Scaled-up domestic **battery production**: demand side and innovation: crucial for achieving net zero, creating thousands of jobs, and fostering innovation, with a significant focus on workforce development and reducing dependence on imported materials.

c) Accelerated **carbon capture, utilisation and storage***: decarbonisation.

d) Increased availability of **skilled technicians**/engineers.

e) Scaled-up **recycling** of both plastics and other materials: not only conventional but also advanced recycling technologies**.

- *Plastics recycling*. Processing of domestic plastics waste via chemical and mechanical means to respectively provide low-carbon feedstocks for chemical building block production, and for end-user solutions (e.g. packaging).
- *Battery materials/electronics*. Cost-effective and environmentally-sensitive technologies to recover lithium, rare earth elements, and electrolyte solvents, are needed to reduce reliance on rare earth sources from abroad.
- *Wind turbine/aircraft*. Recovery of carbon fibres from composites for wider use in automotive and construction industries.
- *Solar panel recycling*. Recovery of silicon for reprocessing and other essential materials for construction (e.g. specialty plastics).

In addition, there are current measures offering tax relief on research and development investment in the UK. Continuation of these schemes is essential for the chemical industry to be successful.

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Throughout this document we have addressed several major themes – current main features of the chemical industry

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Throughout this document we have addressed several major themes – main opportunities for the chemical industry

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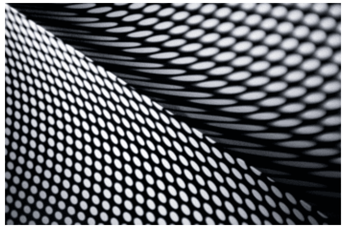

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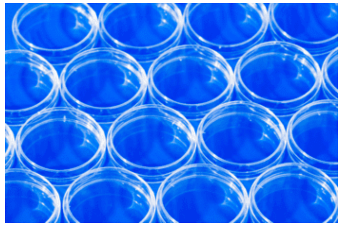

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The key macroeconomic indicators are positive:

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A successful and accelerated energy transition in the UK relies on the chemical industry to deliver in at least six areas:

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Four critical national infrastructures† are directly affected by secure and dependable access to chemicals in the UK: **Defence, Energy, Health,** and **Water.**

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The value of the chemical industry to the UK is predicated on good macroeconomics, a crucial contribution to the energy transition, and ensuring resilience of critical infrastructures *(continued)*

Benefits	I	st	lt	Rationale
Revenues in UK	2	√		At £70 bn turnover in 2022 UK Chemicals represent 1.2% of UK GDP. In absolute terms it places the UK just below the top 10 countries globally
Import/export trade balance	4	√		Chemicals account for 15% of UK exports and 12% of imports, the second largest UK export sector
Employment	3	√	√	The chemical industry is a major UK employer, both directly with over 130,000 people and across its supply chain with 500,000 people
Automotive contribution	3	√	√	The biggest sector drivers, EV penetration and “lightweighting”, rely on advanced chemicals in batteries and new materials in the car
Aerospace contribution	3	√	√	Composites partially replacing traditional aircraft materials; Chemical industry key to developing sustainable aviation fuels (SAF)
Clean Energy† contribution	4		√	Composites for wind turbines; encapsulants for PV panels; advanced chemicals for batteries; better absorbents for carbon capture
Construction contribution	2	√		Beside pipe & conduits, roofing and especially insulation materials play an increasing role in affordable energy efficiency at scale
Biotech contribution	5	√	√	The overlap in terms of know-how, chemical componentry, and skills is such as to make a competitive biotech unlikely without chemical industry support
Defence* resilience	3		√	The value in the defence sector is two-fold: on one hand, availability and deployment of certain advanced military materials and explosives rely on the chemical industry
Energy*† resilience	3		√	As the UK energy mix changes, electric grid stability will depend increasingly on scaling up energy storage and clean energy generation, to which the chemical industry is a key contributor
Health* resilience	2	√		The COVID-19 crisis illustrated well the importance of a broad and efficient chemical supply chain in deploying emergency solutions (e.g., protective materials, high-volume disinfectants)
Water* resilience	4	√	√	Given the general need for water treatment, it is crucial to have availability and in-country production of certain chemicals that are hard to transport (e.g., chlorine value chain)

I: impact or criticality (1 = low….5 = high); st: short-term or immediate; lt: long term

(*) CNI are the 13 Critical National Infrastructure sectors identified by the UK Government

(†) includes Wind, Solar, Energy Storage, CCS/CCSU

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At £70 bn turnover in 2022, UK Chemicals represents 1.2% of UK GDP. In absolute terms it places the UK just below the top 10 countries globally

- In 2022 the chemical industry had a turnover of £70 billion and contributed £21.9 billion of Gross Value Added (GVA). This is comparable to the contributions of the life sciences, automotive and aerospace sectors.
- The sector supports various other industries, including pharmaceuticals, agriculture, and manufacturing, making it a backbone of the UK's industrial landscape.
- Globally, the size of the UK chemical industry is an order of magnitude smaller than the largest economies (China, EU27 and US) but still substantial, and close to the top 10.

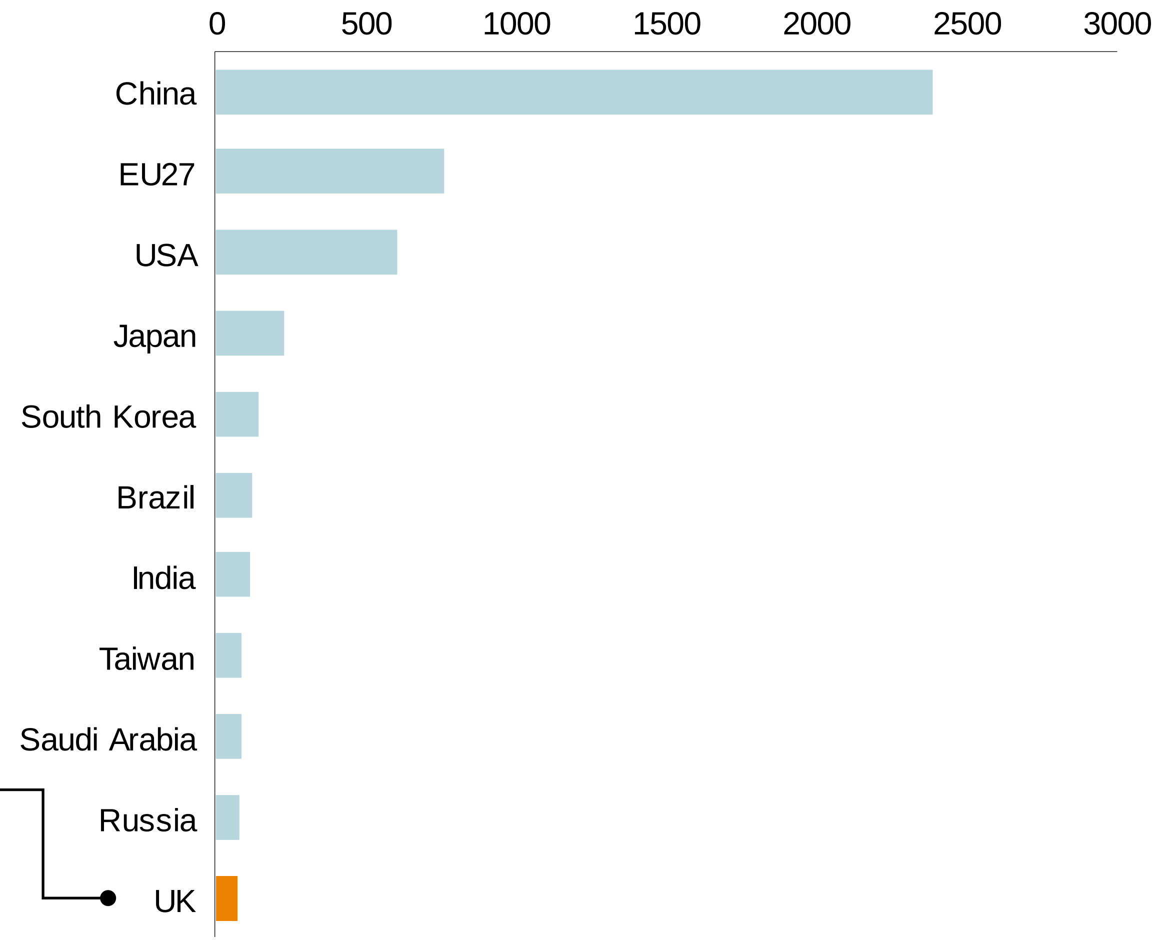
11 %
of £648 bn UK manufacturing output

£22 bn
Value Added

£70 bn
Turnover

World chemical sales: top 10 countries plus the UK

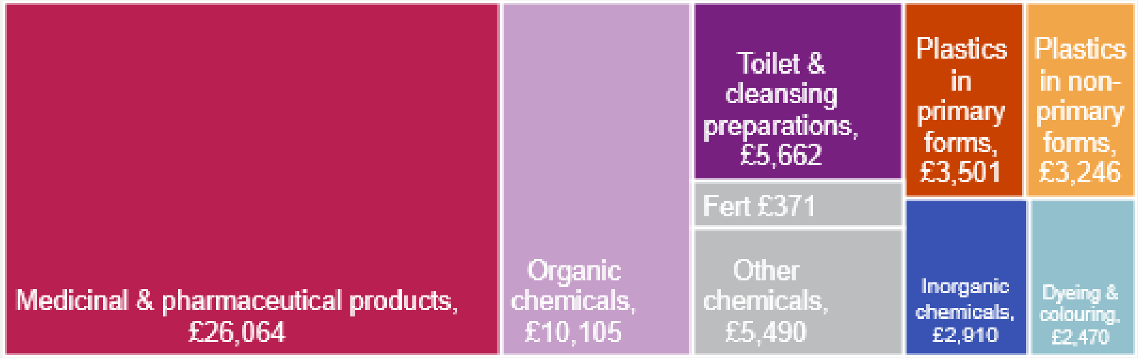
Chemical sales in 2022 (€ billion)



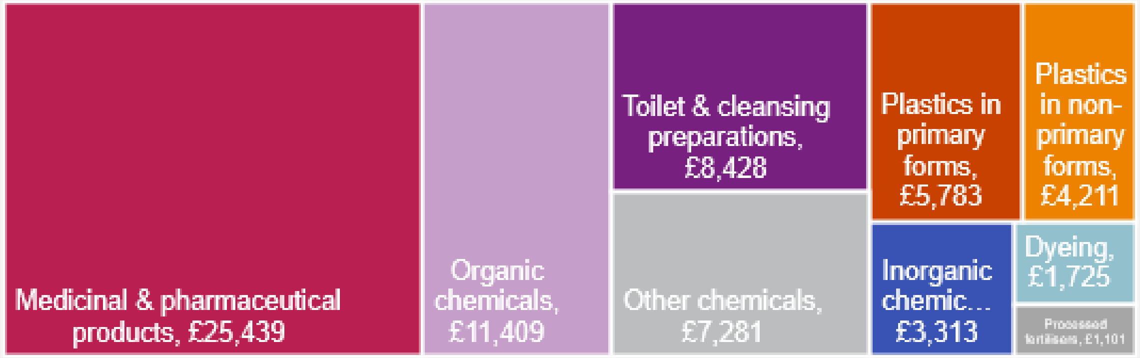
Source: ONS, CEFIC & CIA

Chemicals account for 15% of UK exports and 12% of imports, the second largest UK export sector

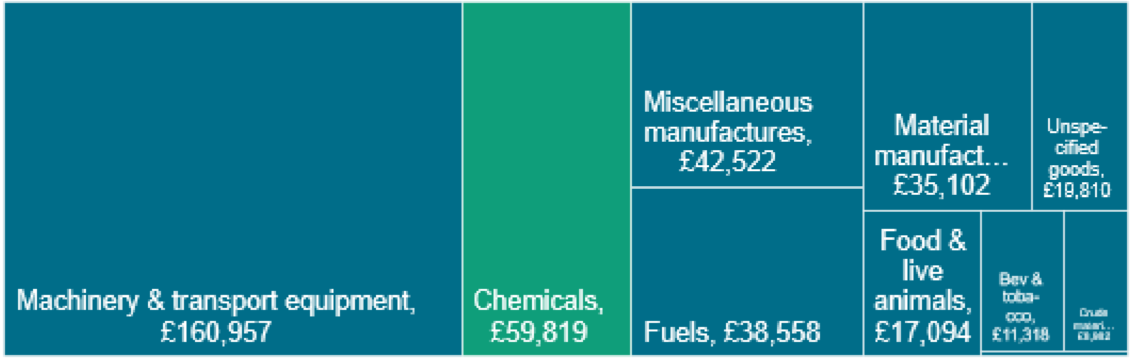
2023 UK Chemical Exports (millions)
Total £59,819 million



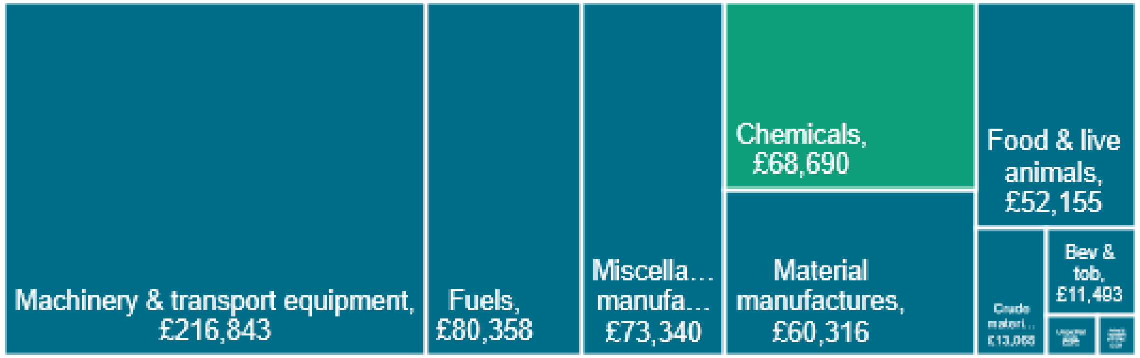
2023 UK Chemical Imports (millions)
Total £68,690 million



2023 UK Total Exports (millions)
Total £394,764 million



2023 UK Total Imports (millions)
Total £581,483 million



Source: ONS

S&P Global Commodity Insights

The chemical industry is a major UK employer, both directly with over 130,000 people and across its supply chain with 500,000 people*

- The chemical industry is a sector of the UK economy consisting of around 4,000 firms employing around 137,000 people directly (this includes R&D), and another 500,000 across its supply chain.
- The UK chemical industry has faced a persistent challenge over the years in maintaining a workforce with the necessary skills. The pandemic has intensified certain challenges, but Brexit, along with an unfavourable immigration policy and an aging workforce, has created a conundrum of workforce-related issues.
- There has been a downward trend in UK workers (excluding R&D) in the chemical industry. This is mainly linked to the closure of chemical capacity in previous decades.

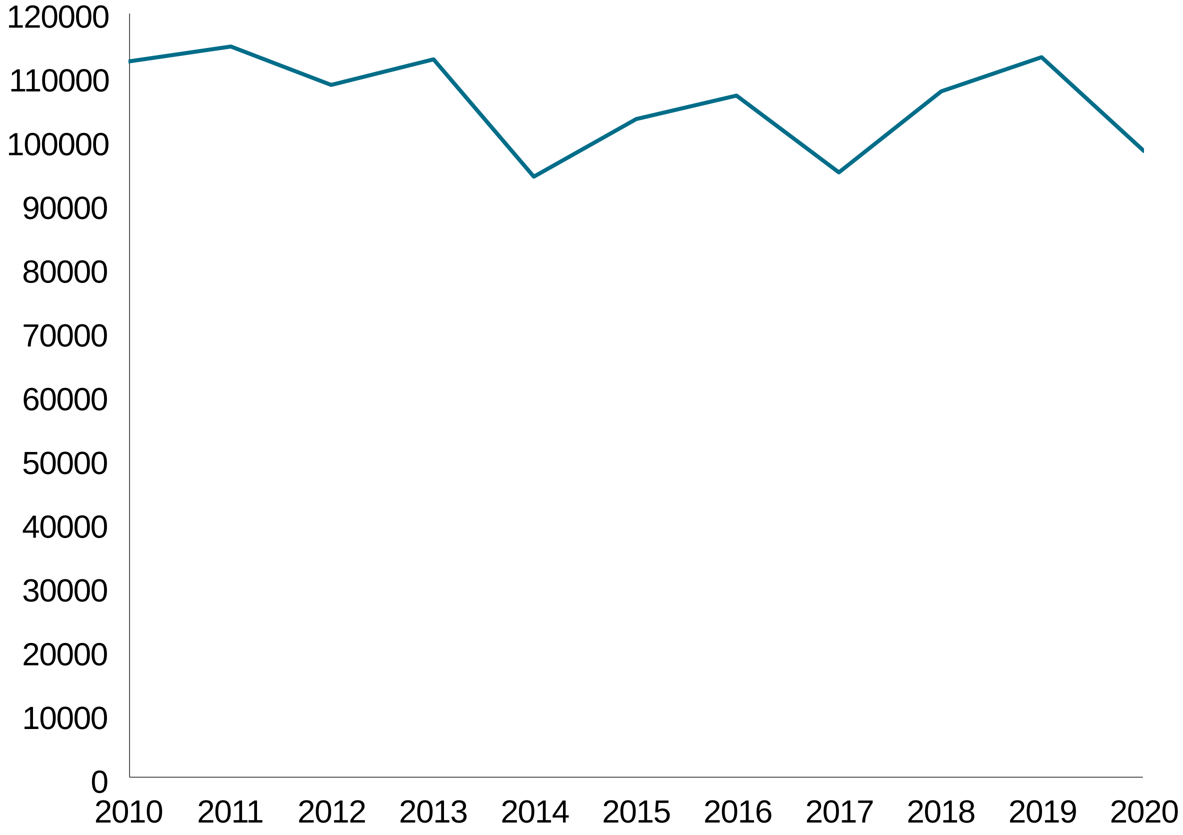
Workforce of over 130,000 people; the equivalent of 46,000 fulltime people work on chemical and pharmaceutical R&D.

Average weekly salary is 21% higher than the rest of the manufacturing sector.

34.8% of the workforce are women, above the 25.2% manufacturing average.

Supports an additional 500,000 jobs in various supply chains, vertically and horizontally.

UK employment in manufacture of chemicals and chemical products (excl. R&D)
Number of people



Source: ONS.

* Direct employment and supply chain employment figures referring to 2023.
Source: CEFIC & CIA

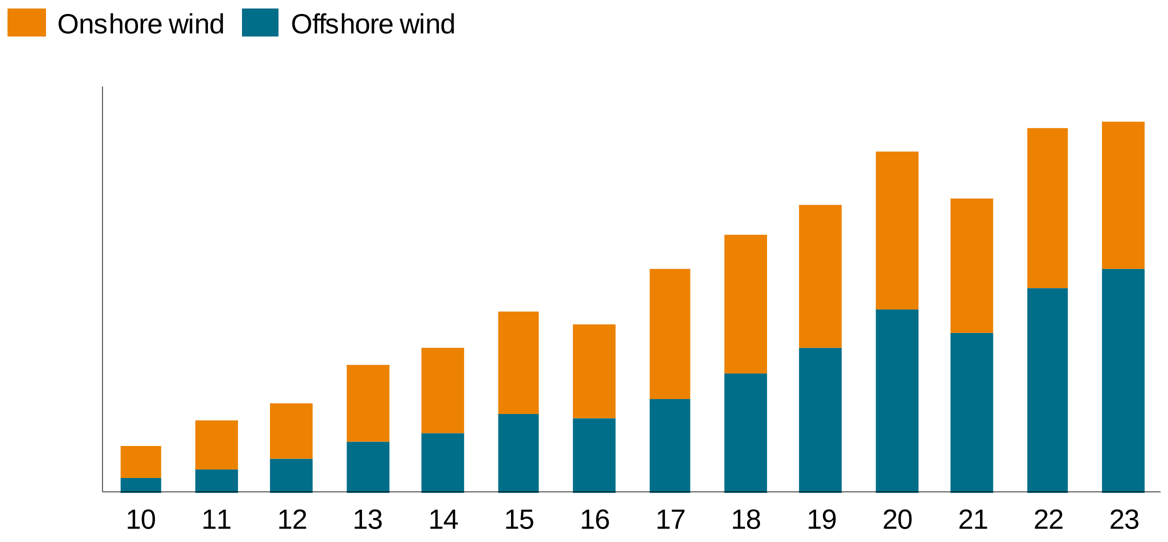
S&P Global Commodity Insights

Composites for wind turbines are crucial to performance; wind turbine capacity in the UK has increased by a CAGR of 10.3% over the last decade

- **The UK has a growing industry for the production of carbon fibre reinforced polymers (CFRPs).** Several companies and research institutions are involved in the development and manufacturing of CFRPs for various sectors, including renewable energy (most notably wind turbines).
- **Blades:** CFRPs are extensively used in turbine blades due to their high strength-to-weight ratio. This allows for longer and lighter blades, which can capture more wind energy and improve overall efficiency.
- **Structural Components:** CFRPs are employed in various structural parts of the turbine, such as the nacelle and tower components, to reduce weight and enhance durability.
- **Enhanced Performance:** The stiffness of CFRPs helps maintain the aerodynamic shape of blades, which is crucial for optimising performance and reducing drag.
- **Corrosion Resistance:** CFRPs offer excellent resistance to environmental factors, making them ideal for offshore wind turbines, which face harsh conditions.
- **Design Flexibility:** CFRPs allow for complex shapes and designs, enabling engineers to create more efficient and innovative turbine configurations.
- Wind energy generation accounted for around 24% of total electricity generation (including renewables and non-renewables) in 2020; with offshore wind accounting for 13% and onshore wind accounting for 11%.
- Wind power makes up just over 50% of the renewable energy capacity in the UK, making it the leading sustainable source of power. Supply of composites will be essential to maintain and install wind turbines in the future

UK Wind Power Generation

Electricity Generated (GWh)



- Vestas, a world-leading wind turbine blade maker, has begun the process of securing planning permission for a site at Leith docks in Edinburgh. This is one of Scotland's green freeports. Freeports are being given tax breaks to encourage investment and companies can apply for these. Vestas' plan is expected to bring hundreds of high-skill jobs to the Edinburgh port.
- There are only two factories in the UK where blades are manufactured for wind turbines. One on the Isle of Wight, operated by Vestas, and the other in Hull, run by the German-Spanish joint venture Siemens Gamesa.

See Appendix for further information.
Source: Department for Energy Security and Net Zero; S&P Global Commodity Insights

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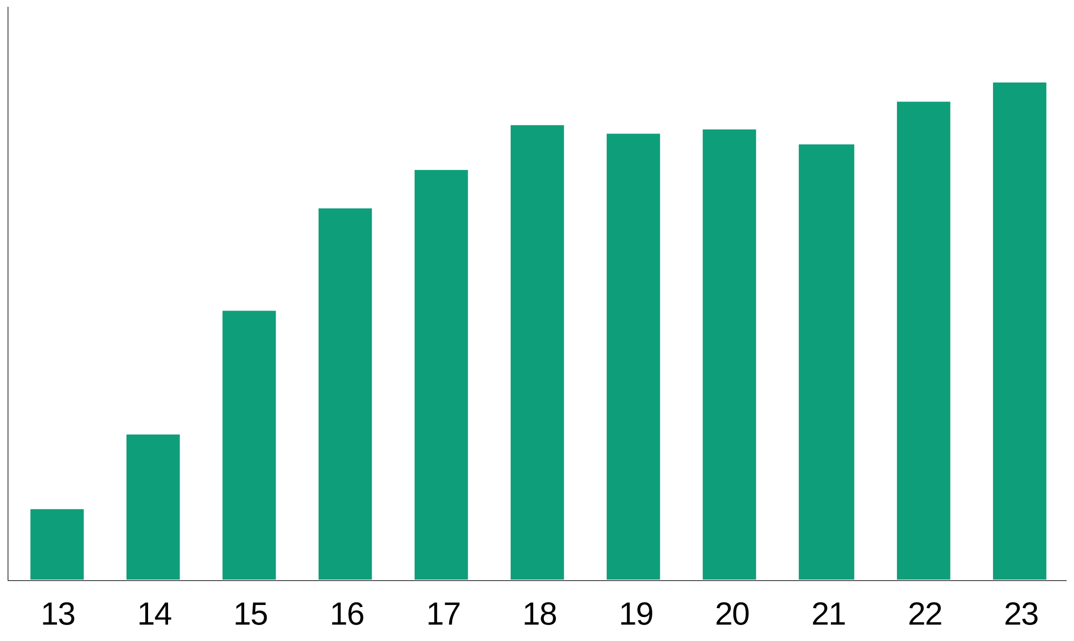
Substrates for PV panels help to improve efficiency and durability; UK PV capacity has increased more than fivefold in the last decade

- The UK is estimated to have over 17GW of solar capacity, and the government's target is 70GW by 2035.
- The substrate for solar panels plays a crucial role in determining their efficiency, durability, and overall performance. Common substrates include glass, plastic, and metal, each impacting the panel's weight, flexibility, and resistance to environmental factors.
- For instance, glass substrates are often favoured for their transparency and durability, enhancing light absorption and protecting the solar cells from weather. In contrast, flexible plastic substrates allow for lightweight and portable designs but may compromise longevity and efficiency.
- Encapsulants for photovoltaic (PV) panels are materials used to protect solar cells from environmental factors while also providing structural support. Typically made from ethylene-vinyl acetate (EVA), these materials ensure durability and enhance the longevity of solar panels.
- Encapsulants serve several key functions: they safeguard against moisture, UV radiation, and mechanical stress, while also maintaining optical clarity to maximise light transmission. The encapsulation process involves sandwiching solar cells between layers of encapsulant and a protective backsheet, often followed by lamination to create a cohesive unit. This ensures that the solar cells remain operational over their lifespan, typically 25 years or more.
- Advanced encapsulant technologies, such as polyolefin elastomers and silicone-based materials, are being developed to improve efficiency and reduce degradation over time. The choice of encapsulant can significantly impact the overall performance and lifespan of solar panels, making it a key consideration in solar module design.

UK Solar Power Generation

Electricity Generated (GWh)



- Recent innovations in solar cells allow for more energy to be absorbed per cell and therefore for the cost of solar electricity to be cheaper. One of the major innovations is the addition of a layer of perovskite, another semiconductor, on top of the silicon layer. This captures blue light from the visible spectrum, while the silicon captures red light, boosting the total light captured overall.

See Appendix for further information.

Source: Department for Energy Security and Net Zero; S&P Global Commodity Insights

Advanced chemicals for batteries are critical to ensure good energy density and a competitive BESS industry

- **Battery energy storage systems (BESS) play a key role in enabling the replacement of fossil fuels with renewable energy sources.**
- Today most industrial rechargeable batteries are manufactured in East Asia; however, the UK and other advanced economies will need to develop domestic expertise and capacity given its importance and the economic benefits of the market.
- The UK ranks third in the world in terms of research quality regarding industrial batteries. Battery chemistry optimisation will be crucial to the advancement of this sector.
- Currently, while novel lithium-ion batteries are the dominant type in electric vehicles, lithium iron phosphate (LFP) batteries are used more extensively in BESS due to their longer lifetime and lower cost while maintaining good energy density. The key driver for future development in BESS is an increase in energy density, i.e., allowing greater storage capacity in the same space and at lower cost.
- Key chemicals include:
  - **Lithium:** Essential for lithium-ion batteries, providing high energy density.
  - **Cobalt:** Used in cathodes to enhance energy capacity and stability (usually the most expensive component of a cell).
  - **Nickel:** Increases energy density and reduces costs in nickel-cobalt-aluminium (NCA) and nickel-cobalt-manganese (NCM) batteries.
  - **Graphite:** Commonly used as an anode material in lithium-ion batteries.
  - **Electrolytes:** Such as lithium salts (e.g., $LiPF_6$) dissolved in specialised organic solvents, crucial for ion transport.
  - **Solid-state materials:** Emerging technologies use solid electrolytes for improved safety and energy density.

- A domestic demand-focused battery industry could create 100,000 jobs by 2040, with most positions expected to be situated outside of London and the South East.
- Increasing skills across the UK battery supply chain will be essential to satisfy increased demand; in particular, there is a crucial need to increase workforce capability and capacity for the expansion of cell manufacturing.
- The resilience of global critical mineral supply chains is important, and the UK has already signed international critical mineral agreements with countries such as Australia, Canada and Kazakhstan.
- Scaling up the UK recycling industry will enable a battery's economic value to be kept within the UK and reusing and repurposing batteries can significantly extend their useful life and support supply chains for other products.

The mining of battery-grade lithium carbonate was announced in Cornwall in mid 2023. This is a joint venture between Imerys and British Lithium; full operations are expected within four years. The development of the site in the St Austell area, could potentially create around 300 direct jobs. It is estimated the mine could produce 20,000 tonnes of lithium carbonate equivalent per year for around 30 years. This could meet around two thirds of the UK's domestic battery demand by 2030.


Cornwall lithium mine

See Appendix for further information

More efficient carbon capture will enable the UK to reach its full potential capacity for CCUS with the potential to store CO_2 for other countries

- Carbon Capture, Utilisation & Storage (CCUS) is a necessity in delivering the UK's target of achieving net zero emissions by 2050 and to supporting a greener economy. Advanced technologies allow for higher efficiency and lower cost CCUS.
- Absorbents for carbon capture are substances that can chemically react with carbon dioxide (CO_2) to remove it from gas streams. Common types include:
  - **Amines:** Organic compounds containing amino groups, such as monoethanolamine (MEA), which chemically bond with CO_2 to form stable carbamate compounds.
  - **Ionic Liquids:** Salts in a liquid state that can capture CO_2 through chemical absorption, often with lower energy requirements for regeneration.
  - **Carbonates:** Solid absorbents like calcium or sodium carbonate can react with CO_2 to form bicarbonates, effectively sequestering the gas.
  - Many technologies have been developed but the use of amines as a solvent for carbon capture is the oldest and most used technology. Amines such as monoethanolamine (MEA) can reversibly react with CO_2 allowing it to be captured and then released for storage or use. Other amines and chemical promotors are also used to create mixed solutions for CCS.
  - **The UK has a global leading geological advantage** having one of the greatest CO_2 storage potentials of any country in the world. The UK Continental Shelf, accounting for approximately 25% of Europe's CO_2 storage potential, can safely store 78 billion tonnes of CO_2.
  - CCUS has yet to be deployed at scale in complex industrial clusters anywhere in the world. This represents an exciting strategic opportunity for the UK and its supply chain. Analysis commissioned by the UK Government suggests that the global market could be worth £260 billion by 2050.

Chemicals for CCS Technologies

Technology	Example Products	Feedstocks/Components
Amine	Ethanolamines, Amino-methyl-propanol	Ammonia, Methanol
Solid	MOFs (for solid state capture)	Oxalic acid, Triazole
Inorganics	Calcium Carbonate, Potassium Hydroxide	Natural, Caustic soda
Methanol/Organic Solvents	Methanol, Glycol Ethers	Methanol, Ethylene oxide, Propylene oxide
Membranes	Polyvinylamine, Polysulfone	Ammonia, Formic acid, Acetaldehyde Benzene/Phenol

- In terms of carbon capture MOFs are highly porous materials that are effective due to their unique properties. With an exceptionally high surface area, MOFs can adsorb large amounts of carbon dioxide (CO_2) molecules. Their pore sizes and structures can be customised to optimise CO_2 capture while minimising the adsorption of other gases. They are also easily regenerable, allowing for the release of captured CO_2 upon heating or reduced pressure, making them reusable for multiple capture cycles.
- An example is the Svante VelexoTherm™ Temperature Swing Adsorption (TSA) process which uses solid sorbents to adsorb CO_2 from a flue gas stream. The Svante adsorbents have been engineered to catch and release CO_2 in less than 60 seconds, compared to hours for other technologies .

See Appendix for further information

In aerospace, composites are partially replacing traditional aircraft materials, and the chemical industry is key to developing sustainable aviation fuels (SAF) [1/2]

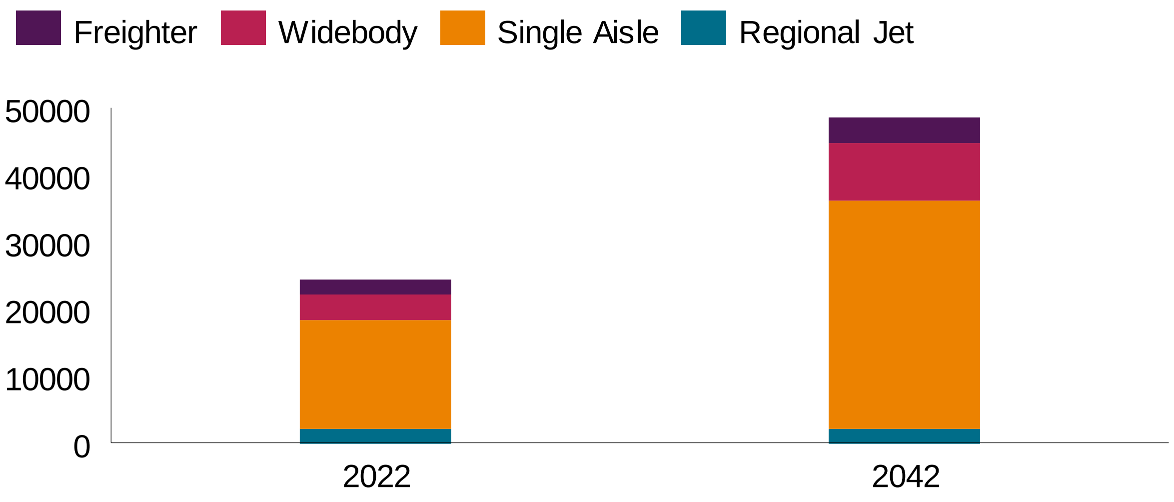
- Aviation is a key pillar of the UK's economic and social prosperity, contributing more than £22 billion to GDP each year and directly employing over 230,000 people. As a hub for the global industry, the UK operates almost 8.4% of global capacity, despite representing just 0.8% of the global population.
- The global aviation industry is one of the sizable components of carbon emissions to the environment and is responsible for about 2–3% of global greenhouse gas (GHG) emissions.
- Advanced materials, such as carbon fibres, are increasingly being used in commercial and military aircraft manufacture. Carbon fibre composites are used in the main body, wings, engines, etc., and can result in reduced aircraft weight, lower fuel consumption, and lower emissions, as well as higher speeds, longer distance ranges, and easier maintenance.
- Notable UK companies, such as Rolls-Royce and GKN Aerospace, incorporate CFRPs in their products. Additionally, the UK Government supports initiatives aimed at advancing composite manufacturing technologies through funding and research programs such as Innovate UK.

- Airbus manufactures aviation structures in Cheshire based on composites supplied from Hexcel operations in Duxford and Leicester using imported carbon fibre from France and epoxies/imide polymers from various sources.

- Other engineering polymer composites based on PEEK (polyether ether ketone), PEI (polyether imide) and PPS (polyphenylene sulphide), are used in aviation.

- In 2023 the Department for Transport (DfT) granted £6 million in funding to Esso (ExxonMobil) to evaluate the feasibility of a project aimed at producing sustainable aviation fuel (SAF) at its Fawley petrochemical complex.

Aircraft Delivery



- The UK aerospace industry is an export-driven industry, with 70% of domestic aerospace production being exported. It is estimated that the UK generates £34 billion from the export of aerospace components. In addition to aerospace, the UK is also seeing growth in the unmanned aircraft systems (drones) sector. The UK has a mature supply chain and is known for its excellence in designing and producing engines, helicopters, wings, structures, and aircraft systems.
- **The need for decarbonisation has been recognised across the UK aviation value chain. Commercial aircraft design is relatively mature and further reduction in emissions via higher aircraft and engine efficiencies is less likely. Hence, any further reductions are expected to be via use of sustainable aviation fuels (SAFs).**

Source: Boeing

S&P Global Commodity Insights

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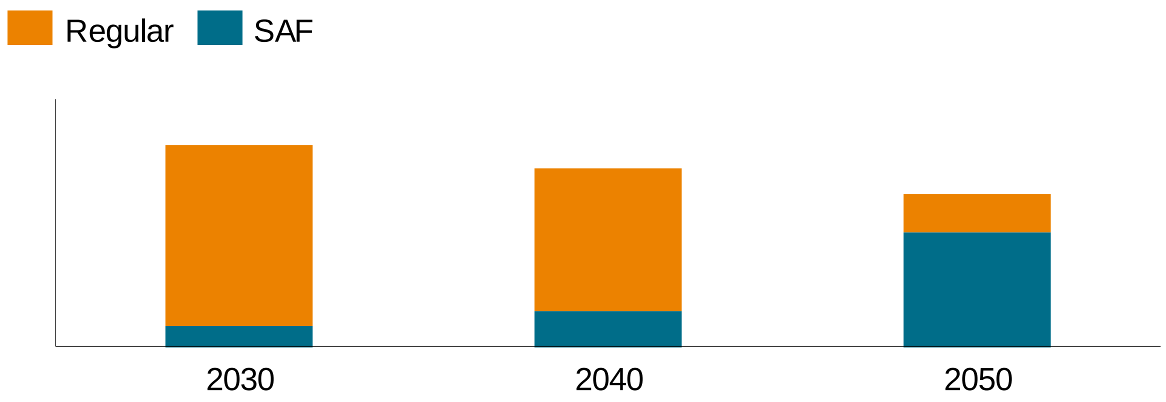
In aerospace, composites are partially replacing traditional aircraft materials, and the chemical industry is key to developing sustainable aviation fuels (SAF) [2/2]

- The UK Government Jet Zero Strategy forecasts aviation emissions of 39 MT (million tonnes) of carbon dioxide equivalent in 2030, decreasing to 29.5 MT in 2050. With major economies looking to decarbonise, aviation presents a huge opportunity to innovate while creating economic value and jobs.
- The UK SAF Mandate sets progressive targets on aviation fuel suppliers to provide increasing amounts of SAF from 2025 to 2040. Starting in 2025, 2% of the jet fuel supplied in the UK must be SAF, increasing on a linear basis to 10% in 2030 and then to 22% in 2040. The obligation will remain at 22% until there is greater certainty regarding SAF supply.
- 1.2 MT of SAF will be required in 2030 to meet the government's ambition, increasing to around 7.0 MT by 2050 to achieve net zero. Achieving 1.2 MT in 2030 will require additional facilities. Announced SAF capacity in the UK is around 0.6 MT, so at least 0.6 MT remains to be met by unannounced capacity or imports.
- There is adequate SAF feedstock in the UK. Conservative estimates indicate that there is feedstock availability for 3.5 MT SAF from waste and advanced feedstocks, and 1.9 MT from renewable electricity. Alongside SAF, almost 3 MT of renewable diesel and naphtha co-products would be produced, accelerating the decarbonisation of the UK road, chemicals, and other sectors.
- Building a SAF industry has significant potential to create jobs and economic growth. Production of 0.6 MT SAF in 2030 could create 10,350 jobs, including operators, construction, and upstream. By 2050, this could increase to 60,000 jobs in the UK. By decarbonising aviation, a SAF industry could sustain a further 210,000 aviation jobs in a carbon-constrained economy.

UK Aviation Fuel Forecast

Million Tonnes (MT)



- The United States and EU have recognised the potential of this sector. The US has historically been a large producer of renewable fuels through the federal RFS and BTC policies, augmented by several state-level programs. This has been boosted by the Inflation Reduction Act (IRA), attracting over 70% of announced SAF capacity to the US. The EU is also progressing, with the Fit for 55 policy package.
- The Hydroprocessed Esters and Fatty Acids (HEFA) pathway is currently the dominant method of production, but the waste fats and oils that this approach requires are limited in their availability. To achieve the required growth, SAF producers must commercialise technologies such as Fischer-Tropsch, Alcohol-to-Jet, and others.

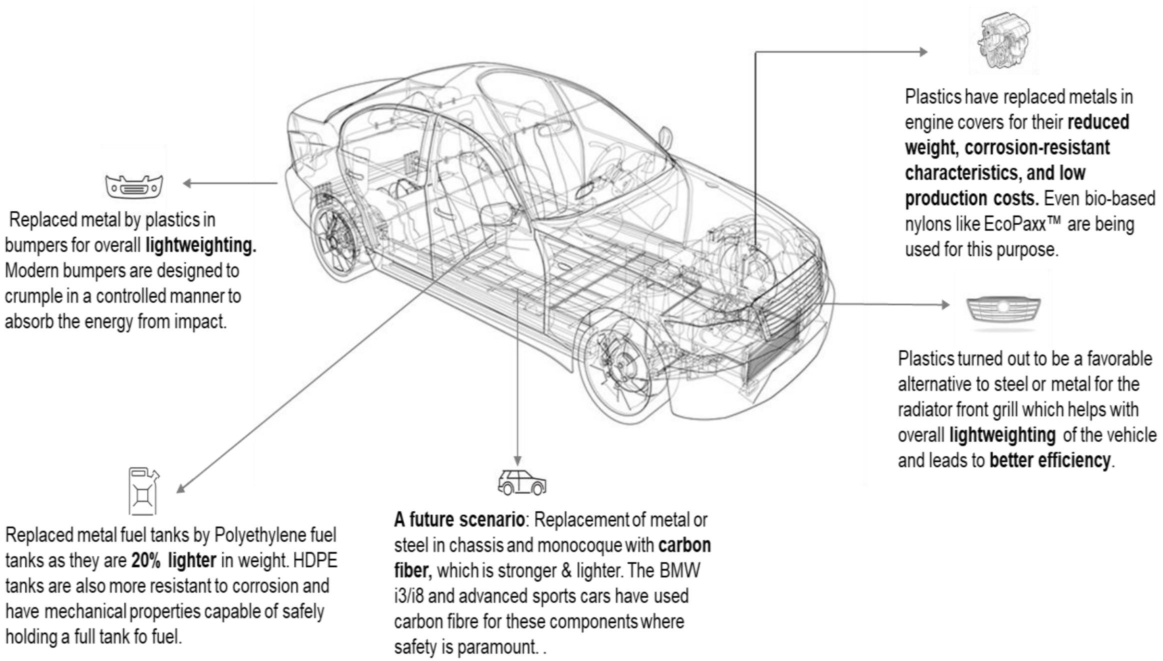
One notable SAF project in the UK is Project Speedbird, a collaboration between British Airways, LanzaJet, and Nova Pangaea Technologies, which aims to develop cost-effective SAF for commercial use by converting agricultural and wood waste into fuel using pyrolysis and ethanol-to-jet technology. The SAF produced is expected to reduce CO_2 emissions by 230Kton annually, equivalent to ca. 26,000 BA domestic flights. The project is currently in the development phase, with plans to build a larger Alcohol-to-Jet (ATJ) facility in the UK by 2027.

Source: S&P Global Commodity Insights.

The biggest automotive sector drivers, EV penetration and “lightweighting”, rely on advanced materials in the car (beside the chemicals needed in batteries)

- Lightweighting in electric vehicles (EVs) refers to the practice of reducing the vehicle's weight to improve efficiency, range, and performance. By decreasing weight, EVs can enhance their battery efficiency, allowing for longer ranges on a single charge.
- Around **79%** of the plastics used in the automotive industry are durable, mainly taking the form of medium performance engineering polymers, often in compounded form. These materials serve various applications ranging from under-hood, vehicle electronic systems, interior fittings, and vehicle exterior trim, bumpers, etc.
- **Under-the-hood applications:** In internal combustion engine (ICE) platforms, compounded durable polymers are used for their strength, heat stability and chemical resistance properties. Some materials like synthetic rubbers and polyurethane elastomers may prove semi-durable due to wear and tear during the vehicle’s life.
- **Vehicle interiors:** Durable polymers are used for various fixtures, screens, etc. Non-durable polymers like ‘soft’ polypropylene (PP) may be used in door trims, etc., for aesthetic reasons.
- **Vehicle exteriors**: Durable polymers like polyamide may be used in air intake manifolds, (polycarbonate/polymethylmethacrylate) PC /PMMA in lighting systems, etc. Non-durable polymers may be used in replaceable components, e.g., EPDM-modified PP for bumpers.
- **Tyres:** Primarily made from a combination of natural and synthetic rubber (such as styrene-butadiene rubber; SBR).

ExxonMobil is the largest producer of halobutyl rubber in the world, producing 115,000 metric tons per annum. Halobutyl rubber is employed in tyres for its excellent air retention, low permeability, and resistance to aging, ozone, and UV light, making it ideal for inner linings and various sealing applications.



See Appendix for further information on EV batteries.

The overlap in terms of know-how, chemical componentry, and skills is such as to make a competitive biotech unlikely without chemical industry support

- Biotechnology and the chemical industry are closely linked through the development of bio-based chemicals and processes. As a matter of fact, conventional chemical production has been using biological processes for decades, e.g. enzyme-based catalysts
- However, biotech specifically utilises biological organisms and systems to produce chemicals, which can lead to more sustainable and environmentally friendly alternatives to traditional chemical manufacturing. This includes:
  - **Bioprocessing:** Using microorganisms or enzymes to produce chemicals, such as biofuels, bioplastics, and pharmaceuticals.
  - **Biocatalysis:** Employing natural catalysts to facilitate chemical reactions, improving efficiency and reducing waste, including the genetic engineering of microorganisms to catalyse various pathways to desired products.
  - **Synthetic Biology:** Engineering organisms to produce complex chemicals that are difficult to synthesise through conventional methods.
- This synergy promotes innovation in green chemistry, aiming to reduce the carbon footprint and enhance resource efficiency in the chemical industry.
- UK research infrastructure is well developed, with significant capabilities in R&D centres such as **CPI** (Redcar), **BDC** (York), **BEACON** (Wales), and **IBioIC** (Scotland) consolidated through the **BioPilots** UK alliance. This alliance aims to develop biorefining technology and bio-based product manufacture. The alliance focuses on supporting the development of new bio-based processes and technologies, particularly in areas such as bioplastics, biofuels, and biochemicals. By fostering partnerships between academia and industry, the alliance aims to accelerate the transition from research to commercial application.
- **UK infrastructure is good, however, there is scope for further improvement by targeted expansion of capacity and capabilities to bridge recognised gaps, which also requires improved funding for access to demonstration and scale-up facilities.**

The biotech sector benefits the following sectors among others:

Food Security	Health and Well-being
Energy Production	Environment

- Increased uptake of industrial biotechnology (IB) and processes will have far-reaching positive impact on the UK economy and society, realised through the creation of jobs in high technology industries delivering better, safer and cleaner products across a range of sectors.

- The UK produces one of the highest densities of household and restaurant waste in Europe. Biotechnology can use the inherent selectivity of biological systems to convert these complex feedstocks to useful chemical products and intermediates.

The value in the defence sector is two-fold: on one hand, availability and deployment of certain advanced military materials and explosives rely on the chemical industry…

- Resilience in the area of military materials and weapons ensures the safety of the country and acts as a deterrent to potentially hostile nations. Collaboration between the chemical sector and defence organisations fosters innovation and enhances national security capabilities.

- An example is the Defence Materials Centre of Excellence (DMEx) which is a new initiative by the UK Government that will bring together leading UK experts in a national effort to accelerate advances in defence material technology for extreme physical environments.
- The DMEx will research, create, and prototype new materials for the armed forces that can survive in the harshest conditions such as:
  - Temperatures of 1,000 °C
  - Polar to tropical operations
  - High impact vibrations
  - Shock
  - Blasts
  - Extreme water depth

- Advanced materials play a crucial role in ensuring the safety of the UK. They are essential for various applications, including body armour for personnel, safeguarding sensitive electronics in satellites against radiation damage, and providing corrosion-resistant components for submarines.
- The Henry Royce Institute for Advanced Materials, based at the University of Manchester, will spearhead the centre of excellence in collaboration with 23 other partners from academia, industry, and research organisations, including the Catapult Network.

- The production of military explosives is primarily handled by specialised defence contractors, such as BAE Systems and QinetiQ, which create a range of military munitions, including explosives for artillery, missiles, and other defence applications. The UK Government also oversees and regulates this production to ensure safety and compliance with international treaties regarding arms manufacturing and trade. The industry is an essential part of the UK's defence capabilities, providing both domestic needs and exports to allied nations.

- The chemical industry plays a vital role in supporting the production of military explosives in the UK. It supplies key raw materials and intermediates used in the formulation of explosives, such as ammonium nitrate, nitrocellulose, and various chemical precursors.
- Moreover, the chemical industry provides expertise in handling hazardous materials, which is crucial for the safe manufacturing and storage of military explosives. This symbiotic relationship ensures that the defence sector has access to the necessary resources and innovations to meet its operational needs.

…on the other, UK defence industry generates £25 billion with clear growth opportunities for chemicals, though incentives are needed to support relevant advanced materials development

- The UK Ministry of Defence (MOD) spent £52.8 billion (38.4% capital, the balance resources) in 2023[1]. This amounts to circa 3.0% of the global total. UK defence spends exceeds 2.0% of GDP, meeting its NATO commitment with 20% spent on equipment. MOD expenditure with wider UK industries includes £6.15 bn on technical, financial and 'other' businesses, £5.5 bn on shipbuilding and repair, £2.09 bn on ammunition/weapon systems, £1.94 bn on aircraft and spacecraft as well as £1.8 bn on construction. The new Labour Government is carrying out a strategic defence review. There is an aspiration to increase defence spend with respect to GDP. However, it is likely given current funding challenging that this aspiration will take some time to realise, possibly during the next parliament.
- In contrast the UK Defence Sector generated £21.4 bn of revenue in 2022[2]. More recent announcements put the 23/24 figure more like £25 billion[3]. Around 64% of revenue is domestic with the UK MOD unsurprisingly the major customer. Of the international revenue component, the Middle East represents 50% of sales.
- In the defence supply chain, around £12 billion covers 'intermediate goods.' These could include materials like composites. The MOD claims circa 540 suppliers. Around 159 'unique enterprises' have been identified as manufacturing materials supporting aviation. Even the defence sector faces increased costs associated with energy, raw materials, etc., especially true of materials like rare earths for electronics.
- Around 36% of revenues fall into the aviation sector, the largest sector, with 72% of revenues from overseas. This is important as the combat aviation sector is a considerable consumer of carbon fibre composites, requiring both high performance carbon fibre grades and specialty thermoset and thermoplastic resins. This does not include rotary wing (helicopters, mainly Leonardo in Yeovil) which is small (£1.2 bn) with 57% for domestic sales. Maritime sales include surface and subsurface and account 29% of revenues, weighted towards subsurface. Land and weapon systems is small at 16.5% of revenues. This is important as this covers ballistic protection. Each sector includes electronics that impacts certain polymers, including advanced plastics. However, electronic revenues are not broken down.
- The defence sector spends around £840 million on R&D with over 60% domestically funded. Over the last three years, cumulative R&D in aviation exceeded £950 million. This is the sector where more advanced materials are needed for future as more is demanded from the performance of military aviation.
- **The UK chemical industry does participate in some value chains at different stages, but many raw materials are lacking locally. There needs to be some mechanism to attract some parties in the composites value chain to invest in the UK. These are strategic materials. Examples include bismaleimide polymers for high-performance composites. Companies in Europe making some of these resins are not back-integrated.**
- Chemicals for composites, etc., in development like advanced polymers need support for commercialisation to avoid 'losing' these technologies to overseas companies.

1 Source: UK Ministry of Defence, Analysis Directorate, Crown Copyright 2024
2. Source: UK Ministry of Defence, Joint Economic Data Hub, UK Defence Solutions Centre, 2024
3. Source: https://military.news/uk-ministry-of-defence-discloses-record-25-billion-defense-expenditure/ [Accessed September 2024].

As the UK energy mix changes, electric grid stability will depend increasingly on scaling up storage and clean energy generation…

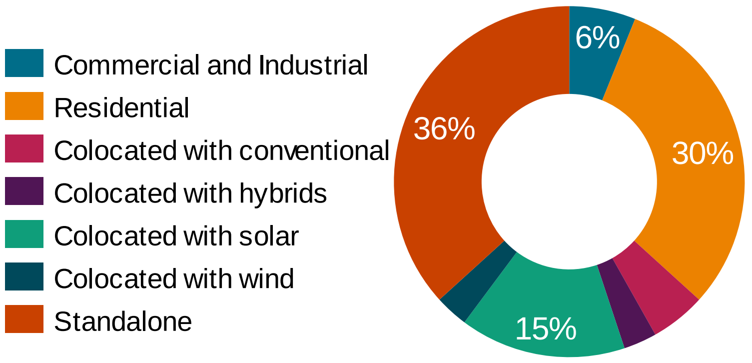
Between 2023 and 2030, **22 GW and 32 GWh** of energy storage is forecast to be installed:

- New frequency regulation services, high spreads in the wholesale market, and high prices in the capacity market (CM) are combining to create an attractive business case.
- Saturation of ancillary services has become a growing risk, leading to a flat forecast for the rest of the period. De-risking of wholesale arbitrage revenues would be a key indicator for increased growth.
- Residential installations register steady growth, driven by escalating energy prices; however, the installations are held back by the lack of incentives to shift self-generation or energy use.

Tata Group's Agratas is establishing the UK's largest electric vehicle (EV) battery manufacturing plant in Somerset. The gigafactory will be located in Bridgwater, Somerset. Expected to be operational by 2026, it will have a production capacity of 40 GWh, aiming to meet nearly half of the UK automotive sector's battery needs by the early 2030s. The project will generate up to 4,000 high-skilled green technology jobs, with additional opportunities across the UK supply chain.

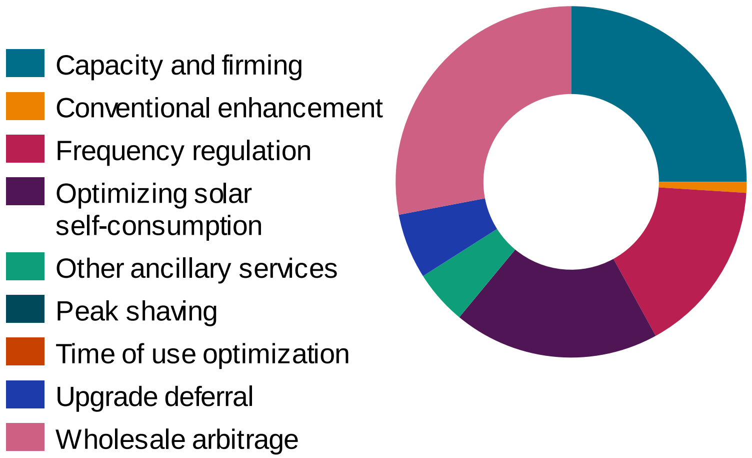
Capacity additions by siting

(2023–30, % of MW)



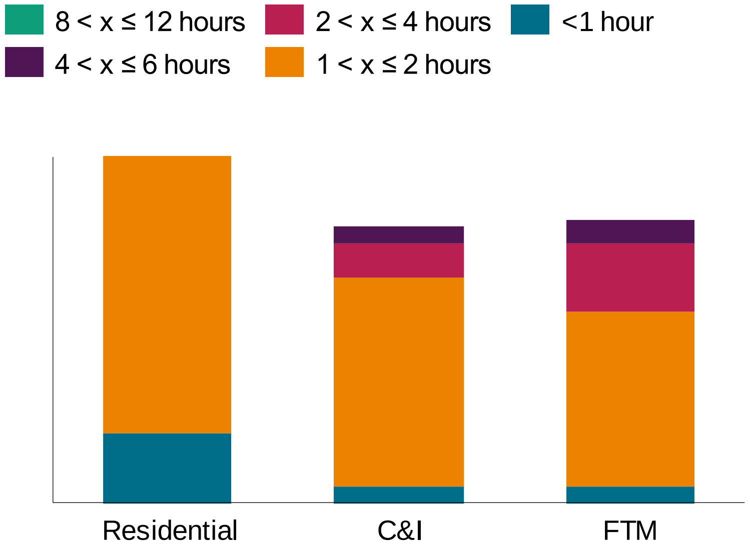
Capacity additions by application

(2023–30, % of MW)



Capacity additions by duration

(2023–30, % of MW)



Data compiled November 2023.
Source: S&P Global Commodity Insights.

…to which the chemical industry is a key contributor

Key Chemicals used in Battery Cell Production

- Anode materials
  - Graphite
  - Silicon
  - Hard carbon (sodium-ion battery)
- Cathode materials
  - Lithium
  - Nickel
  - Cobalt
- Electrolyte materials and its additives
  - Ethylene carbonate (EC)
  - Propylene carbonate (PC)
  - Dimethyl carbonate (DMC)
  - Diethyl carbonate (DEC)
  - Ethyl methyl carbonate (EMC)
  - Vinylene carbonate (VC)
  - Fluoroethylene carbonate (FEC)
  - Lithium Hexafluorophosphate
- Separator materials and its coatings
  - Polyolefins
  - UHMWPE
  - Polyvinylidene Fluoride
  - Alumina
- Binder materials and its solvent
  - Polyvinylidene Fluoride
  - SBR
  - Polyacrylic acid (PAA)
  - N-Methyl-2-Pyrrolidone (NMP)
- Lubricants
  - Polyalkylene Glycols (PAG)
  - Neopolyol Esters/Diesters
- Others
  - Carbon nanotubes

Phillips 66 is a key global supplier of specialty graphite coke, essential in the electric vehicle (EV) manufacturing chain. The company is exploring opportunities to support the development of a UK-based EV supply chain. The Humber Refinery, the only European facility producing battery anode coke, plays a crucial role in this effort. This coke is a vital component for lithium-ion batteries used in EVs and consumer electronics. Currently, the refinery's production capacity supports the manufacture of batteries for 1.3 million EVs annually. Phillips 66 is working on several projects to expand this capacity. By 2027, regulations will require that at least 55% of the vehicle content by value for UK and EU-produced EVs be manufactured domestically.

Source: S&P Global

The COVID-19 crisis illustrated well the importance of a broad and efficient chemical supply chain in deploying emergency solutions in Healthcare

- The COVID-19 pandemic brought challenges to the chemical industry, such as the disruption of supply chains for critical sectors, as well as a sharp change in demand patterns which tested the adaptability and resilience of chemical companies in the UK. However, the pandemic did highlight the benefits and strengths of the chemical industry during unprecedented times.
- **Support for healthcare:** The chemical industry provided essential and critical materials for PPE, with some firms repurposing facilities to manufacture feedstocks for face masks and gowns, significantly contributing to the national stockpile.
- **Vaccine Ingredients:** The UK chemical sector was integral in supplying materials for vaccines. For example, companies (such as Croda) produced critical excipients and adjuvants, with over 165 million doses of vaccines administered in England alone up till July 2024.[1]
  - Over 3 billion doses of the UK-originated AstraZeneca COVID-19 vaccine have been produced, which was innovated at an accelerated pace, and developed to be easily stored and transported, compared to other COVID-19 vaccines at that time.
  - Croda supplied innovative excipients for the manufacture of the PfizerBioNTech vaccine.
- **Sanitiser Production:** In 2020, the production of hand sanitisers increased significantly, with many companies pivoting to produce these products. For instance, the UK Government reported a 250% rise in sanitiser demand.

- **By taking learnings from the COVID-19 pandemic, the chemical industry is well placed to focus on the building of supply chain resilience by moving away from single source supply and considering local manufacturing units to reduce risk of continuous supply.**

- ExxonMobil is the largest producer of halobutyl rubber in the world. During the COVID-19 pandemic, ExxonMobil's halobutyl rubber played a crucial role in the production of vial seals for vaccines and other pharmaceuticals. Halobutyl rubber is known for its excellent barrier properties, making it ideal for sealing vials. This ensures that vaccines remain uncontaminated and maintain their efficacy throughout storage and transportation. It is estimated that Fawley produces around 50% of the world’s demand for specialist rubber that is designed to seal vaccine vials after the needle is pulled out.
- Synthomer’s nitrile latex and other related materials were crucial in producing disposable gloves, which were part of the essential PPE used by frontline healthcare workers.
- Solvay increased the production of hydrogen peroxide, which was critical for disinfectants and sanitation products used in healthcare facilities and public spaces.
- INEOS pivoted its production to manufacture hand sanitisers and donated large quantities to the NHS to help frontline healthcare workers. PE and PP produced at INEOS Grangemouth was essential for PPE manufacture as well as medical equipment (vaccine vials, inhalers, oxygen masks)
- Robinson Brothers ramped up the production of essential chemicals needed for hand sanitisers, disinfectants, and cleaning agents. They also produced various specialty chemicals that were essential in manufacturing these products.

1. https://www.england.nhs.uk; Document: Weekly COVID-19 announced Vaccines 5th July 2024.

Given the general need for water treatment, it is crucial to have availability and in-country production of certain chemicals that are hard to transport (e.g., chlorine value chain)

- Water treatment is critical for the UK as a country because it ensures the safety and quality of water in everyday use and in various industrial processes.
- Chlorine plays a vital role in this by acting as a powerful disinfectant that eliminates harmful microorganisms, making water safe for domestic consumption and industrial use.
- The effectiveness of chlorine in water treatment helps prevent contamination, thereby protecting both public health and the integrity of chemical processes. Additionally, treated water is crucial for cooling systems and other applications within the industry, highlighting the interconnectedness of water treatment and chlorine use in supporting the UK's chemical sector.
- Chlorine is essential for the UK chemical industry for many other reasons as well as water treatment. It serves as a key raw material in the production of various chemicals, including solvents, disinfectants, and plastics, particularly polyvinyl chloride (PVC). Additionally, chlorine compounds are vital in the production of pharmaceuticals and agrochemicals, contributing to public health and food security. The versatility and reactivity of chlorine make it indispensable for synthesising a wide range of chemical products, thus underpinning various sectors of the economy, including construction and healthcare.
- It is important to note that chlorine is a particularly difficult chemical to transport. Chlorine is a highly toxic gas which is also corrosive and requires stringent safety measures during transportation, such as specialised containers to prevent leaks and exposure. Chlorine is typically transported in liquid form, where it must be kept under high pressure or low temperatures, which adds further complexity to logistics.

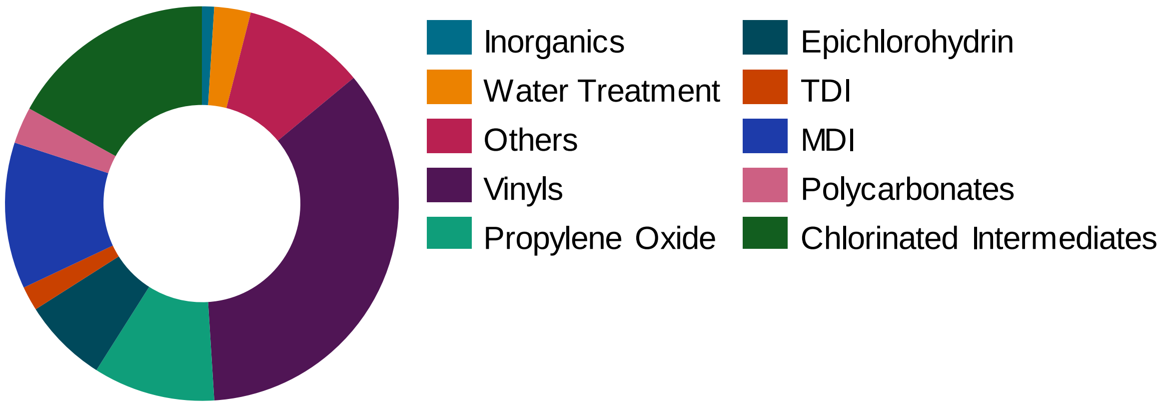
- The largest water treatment plant in the UK is Thames Water's Beckton Treatment Works, located in East London. The facility uses chlorine for disinfection, effectively eliminating harmful pathogens and ensuring the water meets safety standards for drinking. In addition to chlorination, the plant employs various treatment processes to enhance water quality before distribution.

Total Chlorine Capacity, UK, 2018 – 2028 (000 metric tons per year)

Location	Company	2018	2023	2028
Runcorn, Cheshire	INEOS Inovyn Ltd.	430	440	440
Essex, West Thurrock	Industrial Chemicals Ltd.	44	44	44

West Europe: 2023 Chlorine Demand by End Use

Domestic Demand = 6.5 Million Metric Tons



Source: S&P Global Commodity Insights

There are several examples of critical uses of chemicals manufactured by UK chemical companies

Company	Region	Product	Application/Use
ExxonMobil	South East / South	**Halobutyl**	Halobutyl rubber production in the UK to seal vials during the COVID-19 response.
		Halobutyl	Halobutyl rubber for inner lining of tyres and - key with EV vehicles in mind and potential increase in tyre wear.
Croda	North West		Excipients used in the manufacture of a COVID-19 vaccine candidate.
INEOS	Grangemouth, Scotland	**PE and PP**	Medical equip. (COVID-19 vaccine vials, inhalers, oxygen masks, syringes).
			PPE (gowns and masks).
			Bio-reactors to produce COVID-19 vaccines.
			Hospital furniture (storage cabinets for surgery theatres/bedside cabinets).
			Fuel tanks (diesel/oil storage; fuel tanks for tractors/agri).
			Water tanks (agriculture; construction/housing).
			Hydrogen storage tanks – under development.
			Fibre-optic cables for broadband.
			Bank notes.
			Food packaging (bread bags, meat/fish trays) which are very important in terms of allowing large supermarkets to package & supply food to consumers, but likely falls outside of the priorities noted in slide 5.
INEOS Inovyn	North West	**Salt**	Critical to national infrastructure or key building block material for all other industries. Significant barriers to entry for importation, if they were unavailable.
		Chlorine	
		Sodium Hypochlorite	
		Caustic Soda	
		Hydrochloric Acid	
Scott Bader	East Midlands	**MMA structural adhesive**	Structural adhesive used to bond battery cells into the battery box.
			Other applications include wind, marine, transport and building and construction which are well received by the market and, in the case of marine, provide a basis for manufacture in the UK.
Dow	Barry, Wales	**Silicone and polyethylene**	Silicone elastomers help improve energy storage battery capacity and provide high voltage cable insulation.
			Silicone-based adhesives are used to bind the rotor blades of wind turbines, while silicone lubricants improve energy efficiency and minimise wear and tear, by reducing friction in turbine components.
			Silicone elastomers protect defence and space rocket launch equipment from extreme temperatures.
			Silicone elastomers and gels are used in electronic components and devices for encapsulating and protecting sensitive electronic components.

Contents

Note: this is an abridged version of the original full report. In this document some pages have not been included and some data, e.g. chart units, have been deliberately left blank

The chemical industry is cyclical and currently at a trough globally; however, the UK chemical industry has been trending downward in the last 20 years, over several cycles

While the chemical industry encompasses hundreds of diverse segments, it can be broadly characterised in terms of commodities and specialties with two distinct dynamics.

- Returns on chemical commodities investments tend to be highly cyclical, primarily driven by cost of raw materials and cost of energy. Chemical specialty profitability also shows large variations, but the cycle is less pronounced than for commodities, driven mainly by end-use demand and industry consolidation.

Today the chemical industry is globally at a trough, however, with marked differences by geography and by segment: commodities in the UK and Europe have been hit hard. They are not likely to pick up in earnest before 2026/2027.

- The key cost of energy indicators, oil and gas, are not forecast to decrease on average over the next 18 months. Geopolitical events could move these significantly higher.
- Ethylene capacity overbuild globally is the problem. Further capacity rationalisation and closures in Europe and Asia are almost inevitable to restore profitability in commodity chemicals.
- At the other end of the value chain, specialties continue to show a broad spread of sizes and growth rates across segments and regions, with Western Europe and Japan the slowest mid-term.

Despite many examples of excellence, particularly at the specialty end, overall, the UK chemical industry has been in steady decline based on key indicators such as assets, consolidation, closures, and R&D spend.

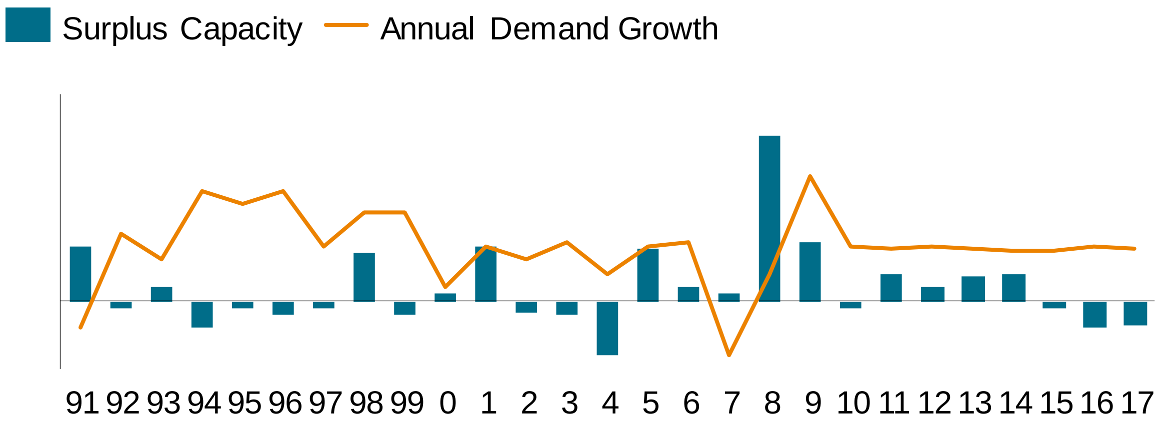
- Analysis of the evolution of chemical capacity in the UK shows a consistent trend towards progressive reduction in number and volume of assets.
- The UK capacity to produce some of the major chemical building blocks and polymers has been declining over the last 20 years.
- From an ownership perspective, since the 1990s the UK chemical industry has undergone extensive consolidation. Over the last 15 years there have been several notable closures in the UK chemical industry, particularly of base chemicals and key intermediates assets.
- Compared to global R&D leaders like China, USA, and Japan, the UK's spend is small; while it has increased over time it has not kept pace, as UK R&D relative share declines.

The reasons for such downward trajectory are clearly visible vis-à-vis the global context: International comparisons show how the UK chemical industry's historical trend is associated with uncompetitive feedstock, changing demand, and with relatively "light" industrial policies.

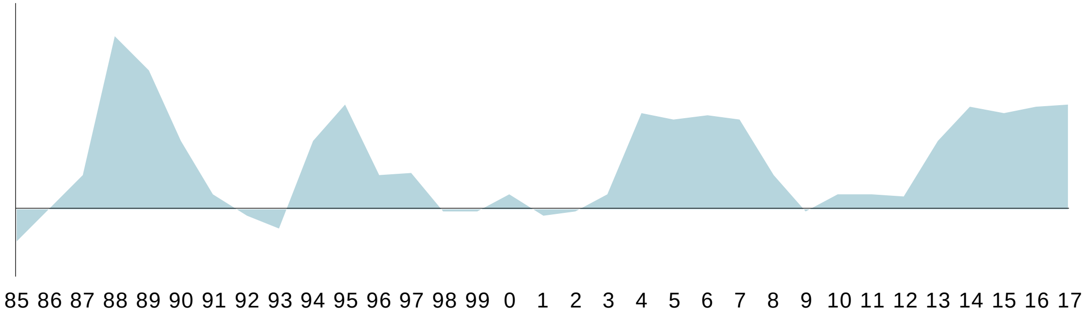
Returns on chemical commodities investments tend to be highly cyclical, primarily driven by cost of raw materials and cost of energy

- The chemical industry is characterised by a cyclical nature influenced by various factors, including economic conditions, demand fluctuations, and raw material prices. During economic expansions, demand for chemicals typically increases, driven by growth in sectors like construction, automotive, and consumer goods. Conversely, during recessions, demand often declines, leading to overcapacity and reduced margins.
- The first graph shows periods of surplus capacity, balanced capacity, and periods where capacity is not sufficient. Naturally when capacity is surplus it causes periods of oversupply which leads to narrow margins. The opposite is true when demand is greater than supply.
- The market tends to fluctuate between these scenarios with some years being fairly balanced. In 2008/9 there was a large increase in Middle Eastern and Chinese chemical capacity, however, this was at the same time the global financial crisis happened which saw demand plummet
- The graph below shows the earnings before interest & tax (EBIT) of global base chemicals and plastics. This shows more clearly the cyclicality of profits in the chemical industry. In periods where demand is high and excess capacity is low, margins are strong and the industry reaches peak profitability.
- The industry experienced an extended upcycle that was largely caused by oil price volatility after the 2014 price crash, as companies were reluctant to invest, and it thereby drove companies to make the most of existing assets. That upcycle was ended by the pandemic. Now the industry is experiencing the opposite – an extended downcycle. The downcycle is caused largely by the Chinese continuing to build new, unneeded production assets even as margins are scraping bottom – and this will extend the trough as we wait for demand to catch up with the new capacity.

Global base chemicals and plastics – surplus capacity and demand growth



Global base chemicals and plastics – weighted average earnings before interest & taxes
Dollars per ton

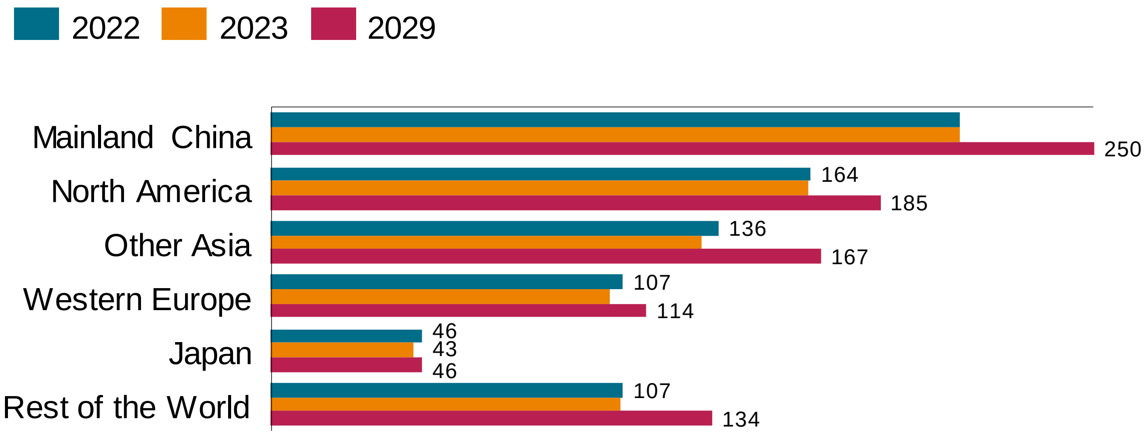


Further information on commodity and specialty chemicals can be found in the appendix
Source: S&P Global Commodity Insights.

Chemical specialty profitability also shows large variations, but the cycle is less pronounced, as specialties are driven mainly by end-use demand and industry consolidation

- Specialty chemicals are produced by a complex, interlinked industry. In the strictest sense, specialty chemicals are products sold on the basis of their performance or function rather than their composition. They can be single-chemical entities or formulations whose composition sharply influences the performance and processing of the customer's product.
- The largest specialty chemical segments in 2023, ranked by market value, were electronic chemicals, specialty polymers, industrial and institutional cleaners, water-soluble polymers, and construction chemicals. These accounted for 38% of the industry's global sales.
- Specialty chemicals are usually used in high-value applications, such as pharmaceuticals and advanced materials, where companies can command premium prices. Conversely, for lower-margin products such as commodity-like chemicals, pricing is more competitive and sensitive to raw material and energy costs.
- The specialty and commodity chemicals sectors display a wide range of EBITDA margins, from less than zero to as high as around 60%. Specialty producers can remain profitable at much lower operating rates. Therefore, prices and profitability have more of a steady and predictable outlook.

World market for specialty chemicals by region
Billion of dollars



Typical segments EBITDA margins	%
Enzymes	--
Nutraceutical ingredients	--
Cosmetic chemicals	--
Electronic chemicals	--
Specialty polymers	--
Food additives	--
Catalysts	--
Flavour and fragrances	--
Surfactants	--
Adhesives and sealants	--

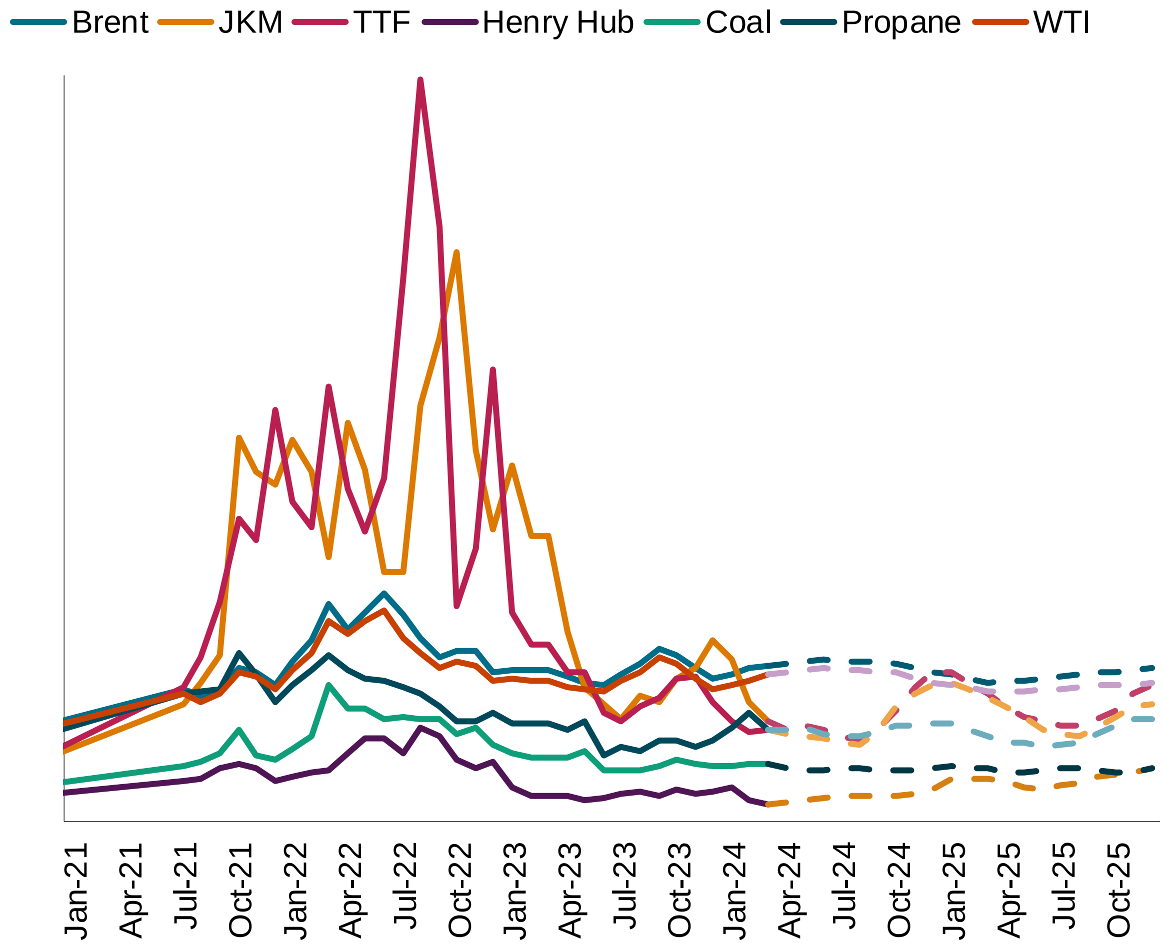
Further information on commodity and specialty chemicals can be found in the appendix
Data compiled July 31, 2024
Source: S&P Global Commodity Insights.

S&P Global Commodity Insights

The key cost of energy indicators, oil and gas, are not forecast to decrease on average over the next 18 months

- The chart on the left illustrates the price trends for various energy commodities from January 2021, including Brent crude oil, TTF (Title Transfer Facility) natural gas, coal, WTI (West Texas Intermediate) crude oil, JKM (Japan Korea Marker) LNG, Henry Hub natural gas, and propane. These commodities are compared because they are key indicators of energy costs, which significantly impact the chemical industry.
  - **Brent and WTI:** These are benchmarks for crude oil prices globally. Brent is used primarily in Europe, while WTI is a major benchmark in the US.
  - **TTF and JKM:** These represent natural gas prices in Europe and Asia, respectively. TTF is a virtual trading point for natural gas in the Netherlands, and JKM is a benchmark for LNG prices in North East Asia.
  - **Henry Hub:** This is a key benchmark for natural gas prices in North America.
  - **Coal and Propane:** These are other important energy sources, with coal being a major fuel for electricity generation and propane used in heating and as a feedstock in the chemical industry.
- The chart shows significant volatility, particularly with TTF and JKM, which experienced large price spikes. These spikes were primarily due to geopolitical tensions, supply chain disruptions, and increased demand post-pandemic. The forecast indicates that energy prices will remain high, suggesting continued pressure on the UK chemical industry due to elevated energy costs.

Key Energy Prices ($/MMBtu)



Data compiled July 31, 2024
Source: S&P Global Commodity Insights.

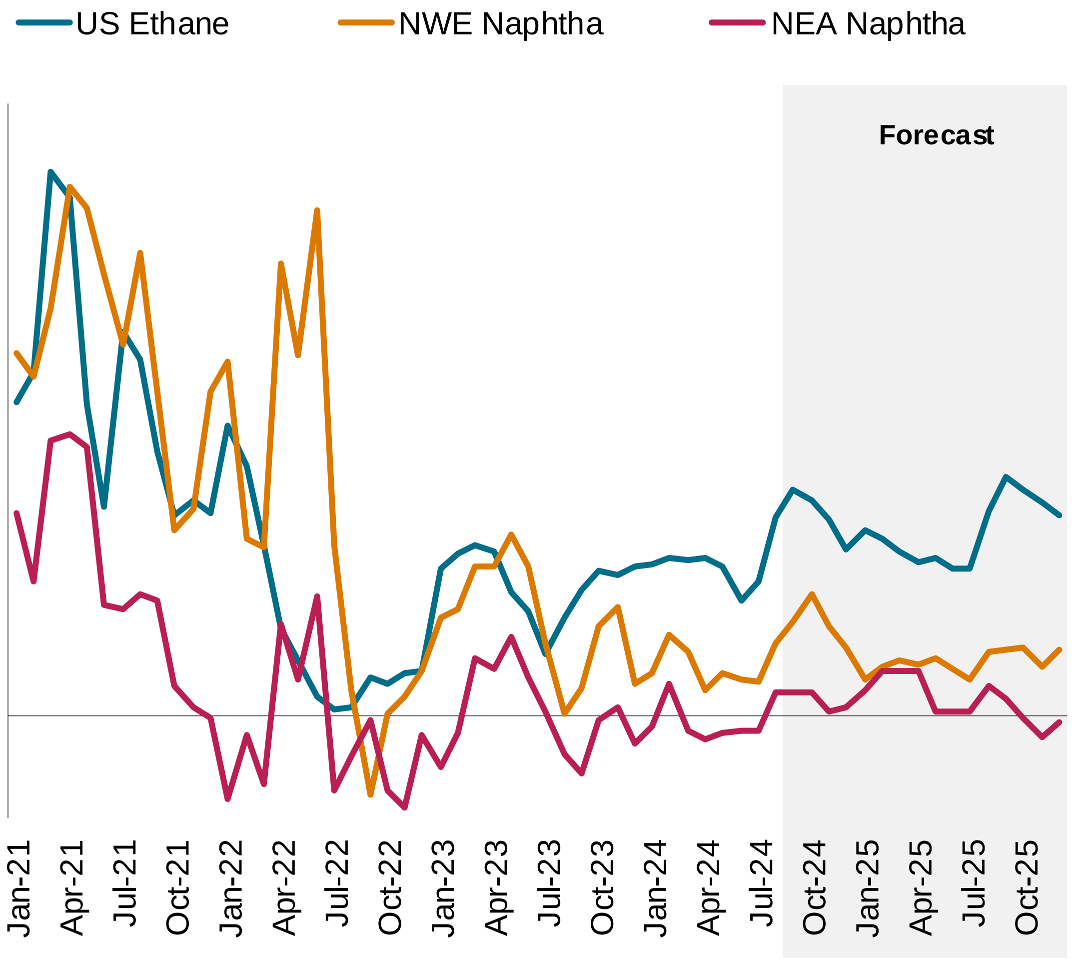
S&P Global Commodity Insights

The margins on ethylene, the most important commodity chemical, are still acceptable in the US (ethane) but virtually zero in Europe and Asia (naphtha) & unlikely to change short term

- The chart displays ethylene margins across different regions, highlighting the disparity in profitability. Ethylene is a fundamental building block in the chemical industry, used to produce a wide range of plastics and other chemicals.
  - **US (Ethane-based):** The US benefits from lower-cost ethane feedstock, resulting in acceptable margins.
  - **Europe and Asia (Naphtha-based):** These regions rely on naphtha, a more expensive feedstock, leading to very low margins.
- The chart underscores the challenges faced by the UK and European chemical industries, where high feedstock costs and energy prices have eroded profitability. The overcapacity in ethylene production exacerbates the issue, leading to low profitability.
- The forecast suggests that without significant changes, such as capacity rationalisation or shifts in feedstock, margins are unlikely to improve in the short term.

Regional Ethylene Margins

US dollars per metric ton



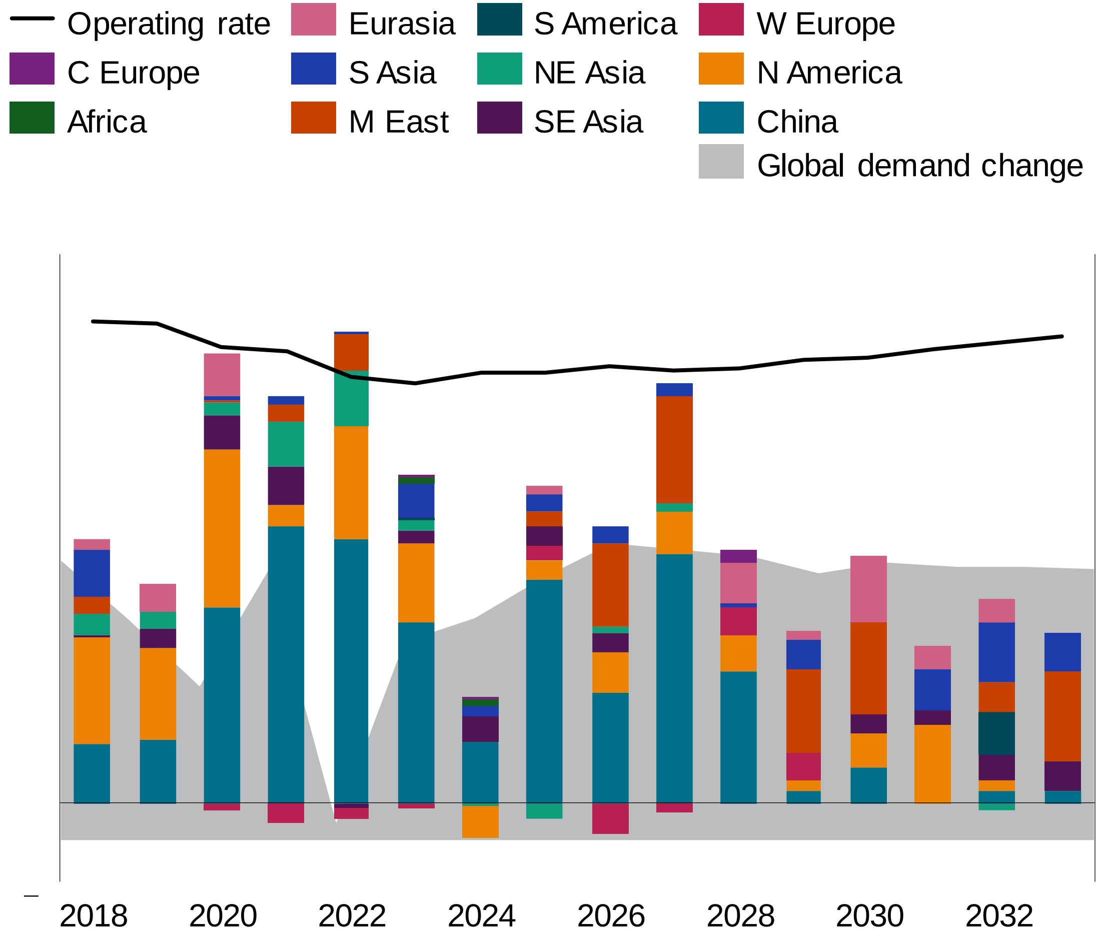
NWE = North West Europe
NEA = North East Asia
Source: S&P Global Commodity Insights.

S&P Global Commodity Insights

Ethylene capacity overbuild is the problem. Further capacity rationalisation and closures in Europe and Asia are almost inevitable to restore profitability in commodity chemicals

- This chart depicts the global overbuild of chemical production capacity from 2020 to 2023. The black line represents the global operating rate, while the area plot shows global incremental demand, and the stacked columns indicate capacity additions by region.
- The overbuild has led to operating rates falling below optimal levels, particularly due to excessive capacity additions in Mainland China and the US.
- Although capacity additions appear lower in 2024, this is due to project delays rather than a reduction in planned expansions. From 2025 to 2027, capacity is expected to continue growing beyond market demand, with overbuilding in Mainland China and the Middle East, further suppressing operating rates.
- The forecast suggests that without more aggressive capacity rationalisation or project cancellations, global operating rates will not return to 2021 levels until the early 2030s. A quicker recovery would require significant adjustments in capacity planning and project execution.
- These trends highlight the challenges faced by the chemical industry in balancing supply with demand, impacting pricing, profitability and strategic planning.

Ethylene capacity vs. demand increases
Million metric tons



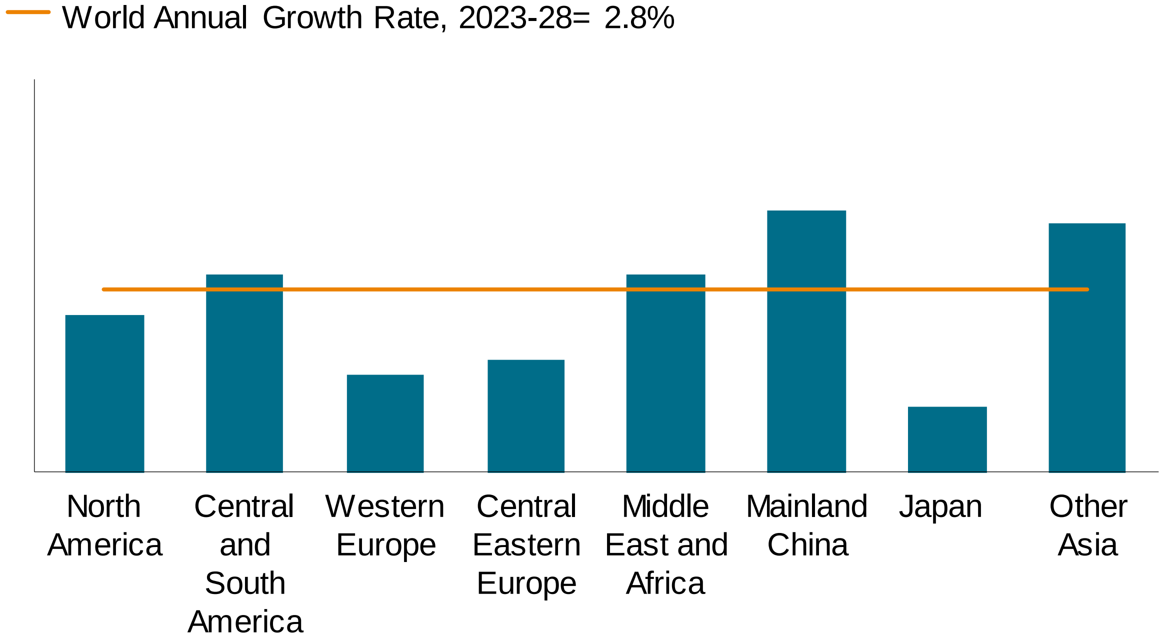
Source: S&P Global Commodity Insights.

At the other end of the value chain, Specialties continue to show a broad spread of sizes and growth rates across segments and regions – Western Europe, Japan slowest mid term

Market Size and Growth Rates for Specialty Chemicals

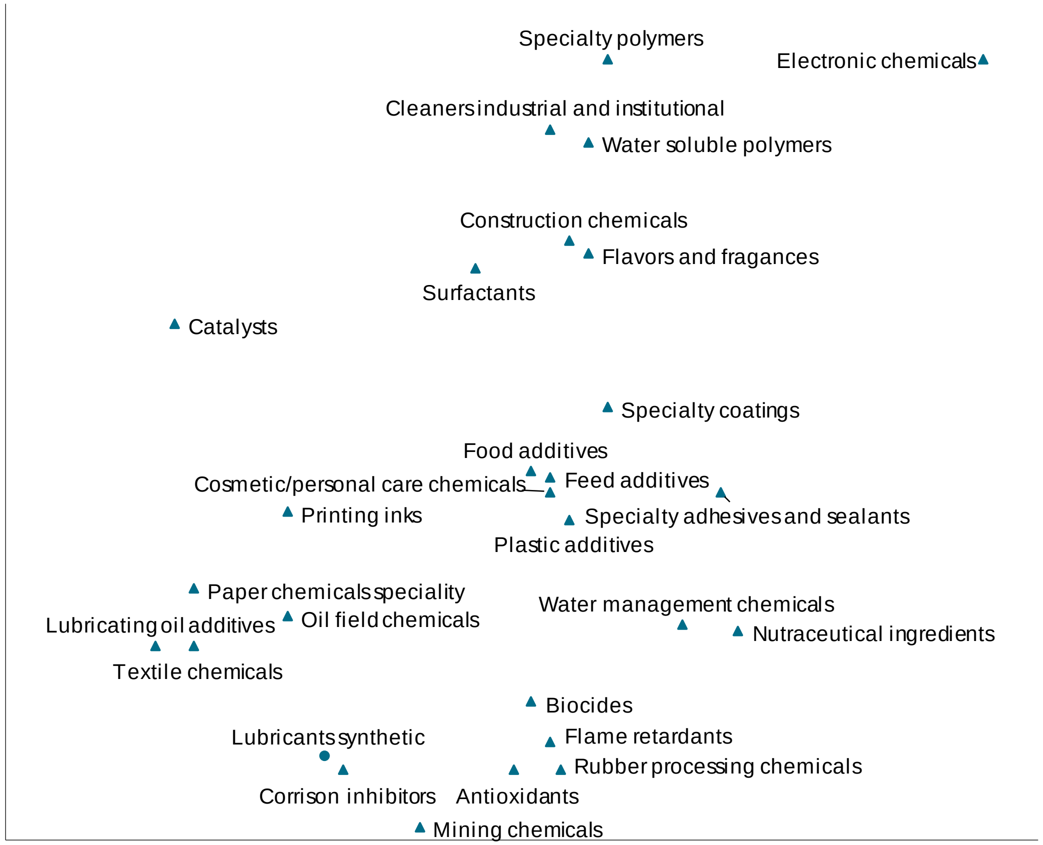
2023 – 2028, Globally and by Region

The global specialty chemicals market is worth circa $750 billion. Growth has returned to trend post-COVID-19 but there are still some areas in recovery. The industry is characterised by flexibility and functionality as customers ultimately buy a performance rather than product. Some facilities making specialty chemicals manufacture multiple grades to serve multiple end-use value chains. Products are typically higher margin than commodities, but players need to commit significant effort in customer technical support.



Average annual growth rate, 2023-28 (percent)

Million Dollars

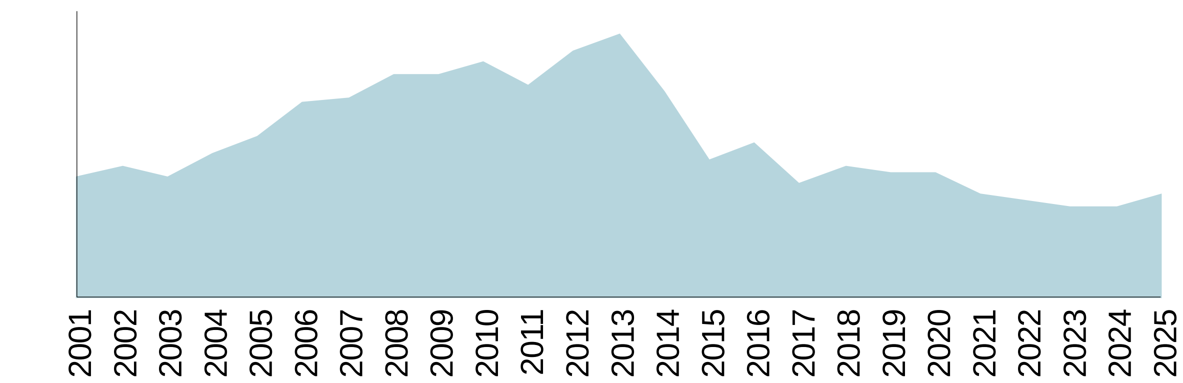


Data compiled Aug. 1, 2023
Source: S&P Global Commodity Insights.

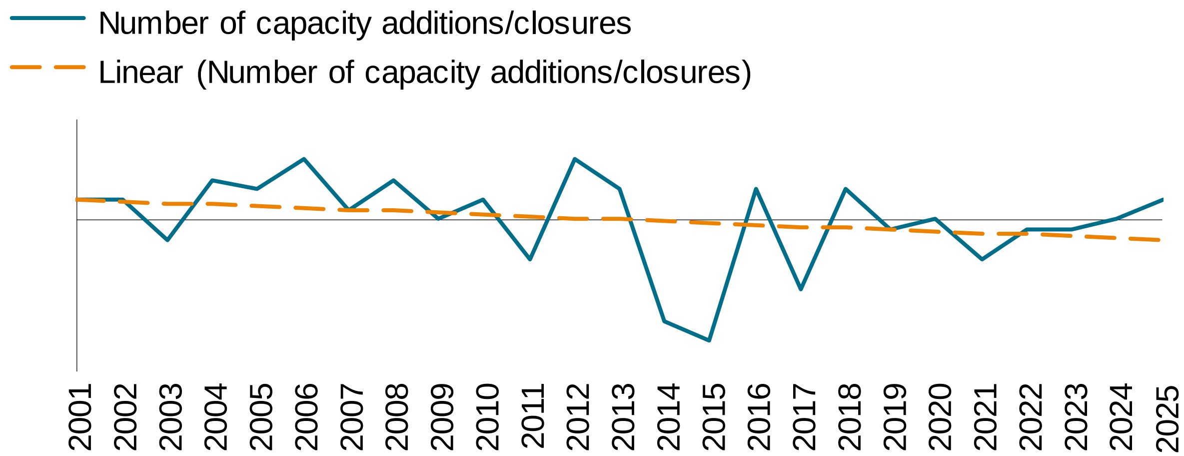
Analysis of the evolution of chemical capacity in the UK shows a consistent trend towards progressive reduction in the number and volume of assets

- Chemical production assets in the UK have steadily dwindled over the last decade. This decline is marked by a significant decrease in facilities producing major chemical building blocks and polymers. The linear trendline opposite shows the overall trend of declining capacity closures. This reflects the broader challenges faced by the UK chemical industry in maintaining domestic production amid global shifts towards regions with lower production costs.
- While there were a number of assets starting up in the prior decade, the year by year capacity additions or closures shows a declining trend since 2001; or indeed that there are fewer assets in 2024 than there were in 2001.
- Several factors have driven this decline. Global competition has intensified, with regions like the Middle East and Asia benefiting from cheaper feedstocks and larger-scale operations. Additionally, high energy costs and stringent environmental regulations have increased operational expenses, leading to the closure of less efficient plants.
- Since the 1990s, the UK chemical industry has undergone extensive consolidation. Many companies have merged or been acquired to streamline operations and focus on core competencies. This consolidation has often resulted in the closure of redundant or less profitable plants.

Number of Chemical assets in the UK



Total number of Capacity Additions/Closures



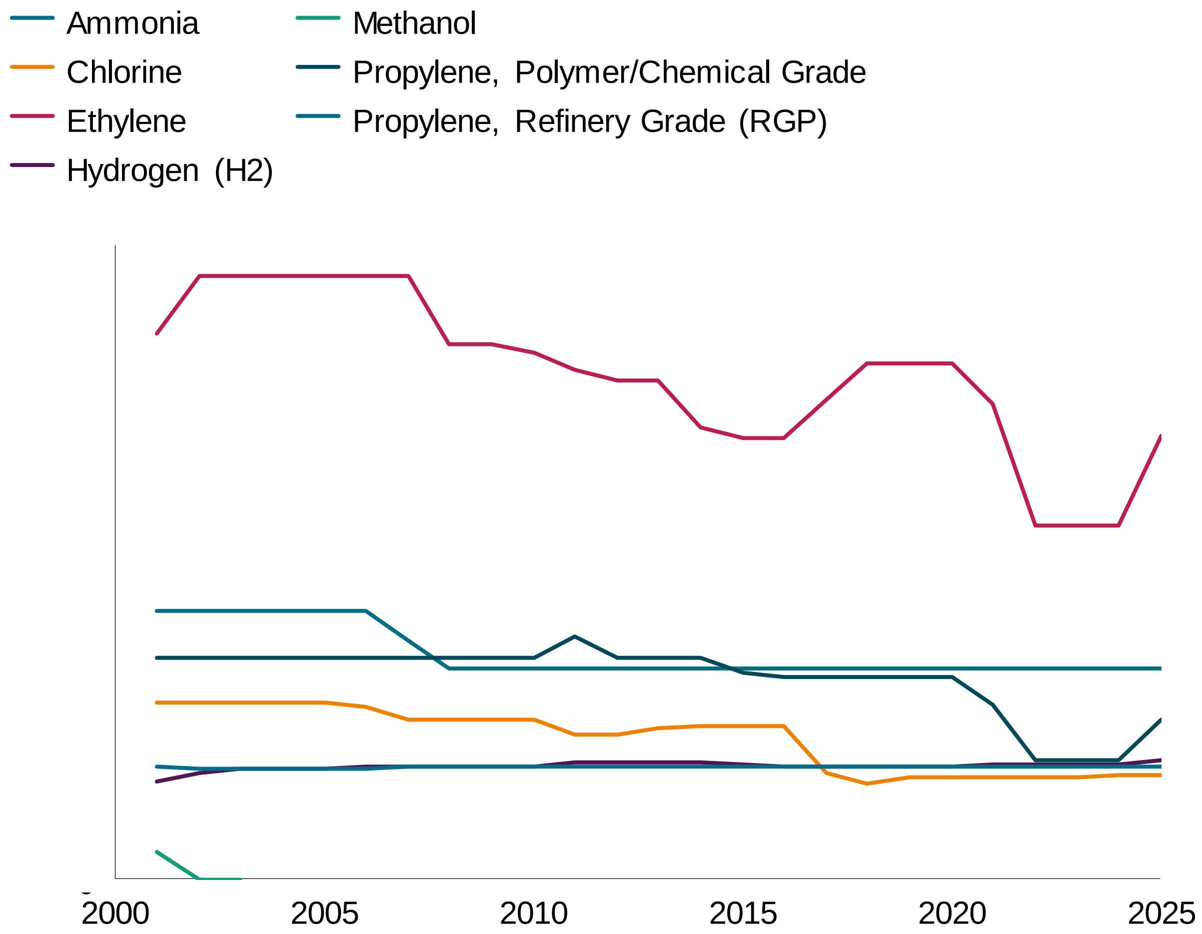
The chemical assets covered here are 158 chemicals that are currently or have been produced in the UK that SPGCI tracks and is not an exhaustive list of all chemicals produced, and therefore assets in the UK. The data is indicative only. This does not include pharmaceutical assets or downstream enterprises like polymer converters
Source: S&P Global Commodity Insights.

S&P Global Commodity Insights

The UK capacity to produce some of the major chemical building blocks and polymers has been declining over the last 20 years [1/2]

- The chart shows a clear decline in the capacities of essential chemical building blocks in the UK over the past two decades.
- Methanol production ceased entirely in the UK, necessitating imports to meet domestic demand. This decline is largely due to the closure of several major facilities, driven by economic pressures and the need for companies to streamline operations. For example, the closure of the methanol plant at Billingham by ICI in 2001 was a strategic decision influenced by rising energy prices and competitive pressures from regions with lower production costs.
- Ethylene capacity reduced particularly after the closures of the Grangemouth plant by INEOS in 2013, and the Wilton cracker by Saudi Arabian company SABIC in 2020 The Wilton cracker's future (which makes ethylene and propylene) was uncertain, however in 2021 SABIC invested £850million to reopen the site.
- A significant recent development is the planned cessation of crude oil refining at the Grangemouth refinery by Petroineos (JV between PetroChina and INEOS). Although the refinery will close, INEOS has confirmed that its petrochemical operations at Grangemouth will continue. The site includes an 850,000 metric tons per year steam cracker producing ethylene and propylene, crucial for the UK's chemical industry. Since 2016, the cracker has utilised imported US ethane.
- Despite these efforts, the overall reduction in chemical production capacity underscores the challenges faced by the UK chemical industry. The closures have reduced self-sufficiency and increased reliance on imports, affecting downstream industries reliant on these basic chemicals.

Capacities of selected major Chemical Building Blocks in the UK
Thousand Metric Tons



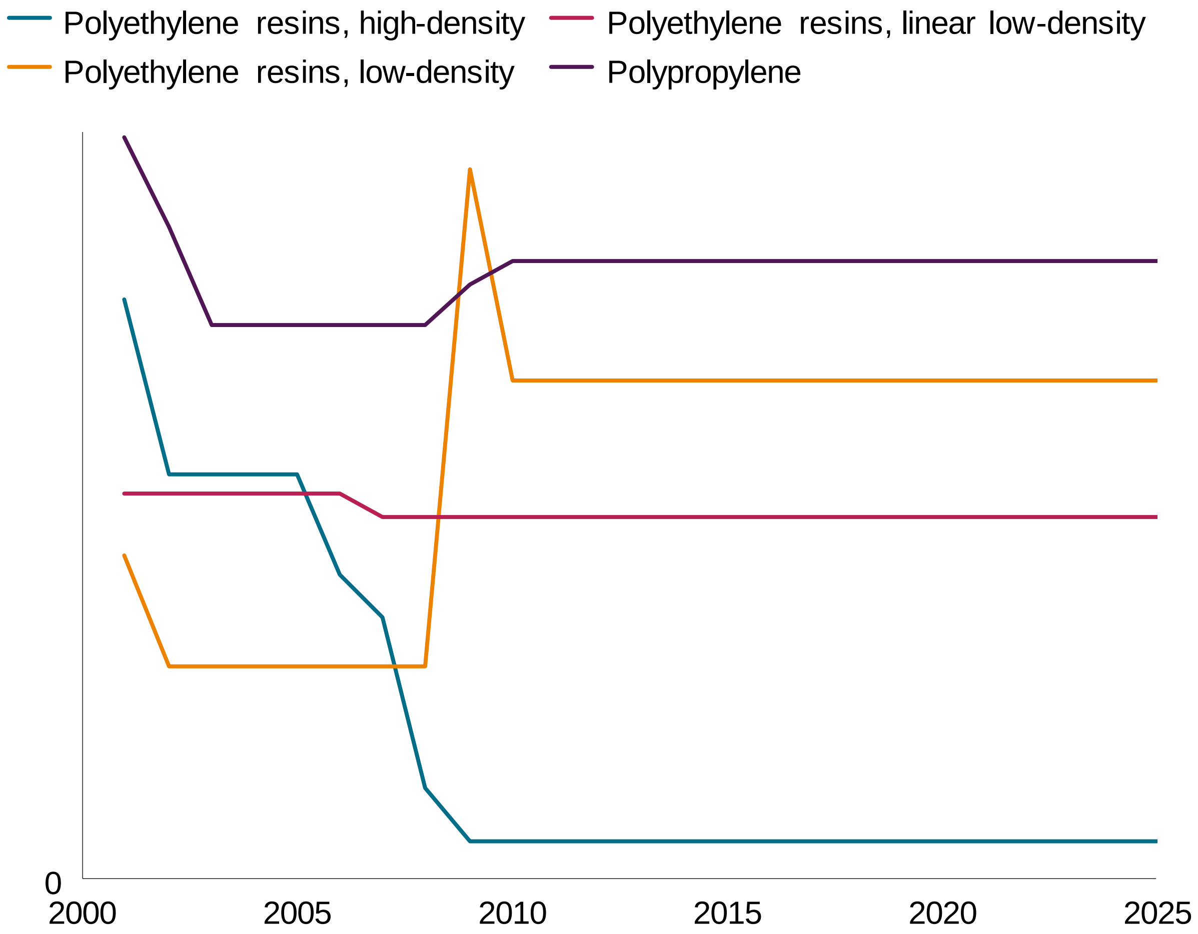
Source: S&P Global Commodity Insights.

S&P Global
Commodity Insights

The UK capacity to produce some of the major chemical building blocks and polymers has been declining over the last 20 years [2/2]

- The chart illustrates the trends in UK production capacities for key polyolefins: Linear Low-Density Polyethylene (LLDPE), Low-Density Polyethylene (LDPE), High-Density Polyethylene (HDPE), and Polypropylene (PP). Over the past two decades, there have been notable shifts in these capacities.
- The decline in HDPE capacity is primarily due to the closure of older, less efficient plants, such as the HDPE facility at Wilton by SABIC in 2009. This reduction is driven by increased competition from regions like the Middle East and Asia, where production costs are lower due to cheaper feedstocks and larger-scale operations
- In contrast, LDPE capacity has seen an increase with SABIC opening a new plant in Wilton in 2009. The growing demand for LDPE is particularly pronounced in the flexible packaging market, which encompasses food packaging, agricultural films, and consumer goods packaging.
- LLDPE and PP capacities have remained relatively stable, with minor fluctuations reflecting market demand and production adjustments. The stability in PP capacity is due to its versatile applications in automotive parts, packaging, and household goods, maintaining steady demand.
- These trends highlight the strategic shifts within the UK chemical industry, focusing on optimising production and aligning with market demands. The changes in polyolefin capacities reflect broader efforts to maintain competitiveness in a challenging global market, where efficiency and adaptability are key.

Capacities of major Polymers in the UK
Thousand Metric Tons



Source: S&P Global Commodity Insights.

From an ownership perspective, since the 1990s the UK chemical industry has undergone extensive consolidation

- **1999** – Albright and Wilson is acquired by Rhodia, a French multinational
- **1999** – Avecia, a specialty chemicals company, is formed as a spin-off from Zeneca, a pharmaceutical company
- **1999** – ICI spins off its pharmaceuticals business to Zeneca in 1993, which later merges with Astra AB to become AstraZeneca in 1999
- **1999** – Huntsman acquires ICI's polyurethanes business
- **2005** – INEOS acquires Innovene, the olefins, and derivatives business of BP
- **2006** – SABIC acquires the petrochemicals business of Huntsman
- **2008** – Akzo Nobel acquires ICI (a deal which included the Dulux brand)
- **2010** – Tata Chemicals acquires British Salt, a leading salt manufacturer in the UK
- **2015** – CF Industries acquired GrowHow, a major nitrogen fertiliser producer in the UK
- **2017** – INEOS acquires the Forties Pipeline System (which connects 80 offshore gas and oil fields to the UK mainland)
- **2020** – INEOS acquires the BP petrochemicals business

Note: this is not an exhaustive list of consolidation

Over the last 15 years there have been several notable closures in the UK chemical industry, particularly of base chemicals and key intermediates assets

- **2010** – Dow Chemical Company closed its ethylene oxide and ethylene glycol production facility at Wilton, Teesside due to unfavourable input costs and declining demand and profit margins for its main outputs, particularly monoethylene glycol (MEG)
- **2013** – Lotte Chemical closed its pure terephthalic acid (PTA) plant in Wilton, Teesside due to increased energy costs and lack of competitiveness
- **2018** – Novartis announced the closure of its production plant in Grimsby. The company encountered unexpected higher demand for two medicines and had to temporarily keep the site operational, finally closing in 2022
- **2019** – INEOS announced the closure of its acrylonitrile (ACN) production plant in Seal Sands, Middlesbrough, citing competitiveness issues
- **2021** – BASF announced the closure of its hexamethylene diamine facility in Seal Sands, Middlesbrough, and transferred production to a site in France
- **2023** – CF Fertilisers stopped ammonia production in the UK at its Billingham complex permanently
- **2023** – Mitsubishi Chemical UK confirmed the closure of its methyl methacrylate (MMA) plant at Billingham, Stockton-on-Tees, due to the high cost of natural gas, which is used as an energy source and feedstock
- **2023** – Versalis announced the closure of its rubber plant at Grangemouth
- **2024** – INEOS O&P proposed the closure of its ethanol plant in Grangemouth, which has been running at a loss for several years

Note: this is not an exhaustive list of closures

Major policy events have resulted in cumulative increases in energy and carbon costs in the UK

2001 – Climate Change Levy (CCL):
The Climate Change Levy was introduced in 2001 as a tax on energy delivered to non-domestic users in the UK. Its primary aim was to encourage energy efficiency and reduce carbon emissions. The levy applied to electricity, gas, and solid fuels, increasing operational costs for energy-intensive industries, including the chemical sector, by adding a financial burden on energy consumption.

2005 – EU Emissions Trading Scheme (EU ETS):
Launched in 2005, the EU ETS was the world's first major international emissions trading system, covering around 45% of the EU's greenhouse gas emissions and remains the largest. It set a cap on the total amount of greenhouse gases that can be emitted by installations covered by the system, requiring companies to hold sufficient allowances to cover their emissions. This introduced a cost for carbon emissions, impacting industries with high emissions, such as chemicals, by increasing compliance costs and influencing investment decisions.

2013 – UK-only Carbon Price Support (CPS):
The UK introduced the Carbon Price Support mechanism in 2013 to top up the EU ETS carbon price, aiming to provide a stronger incentive for low-carbon power generation. However, it led to higher electricity prices for UK industries compared to their European counterparts, affecting competitiveness and increasing operational costs for energy-intensive sectors**.**

2021 – UK Emissions Trading Scheme (UK ETS):
Following Brexit, the UK established its own Emissions Trading Scheme in 2021 to replace its participation in the EU ETS. The UK ETS maintains a similar cap-and-trade system but with a more ambitious cap reduction trajectory. This transition continued to impose costs on carbon emissions, affecting industries reliant on fossil fuels and necessitating further investment in emissions reduction technologies.

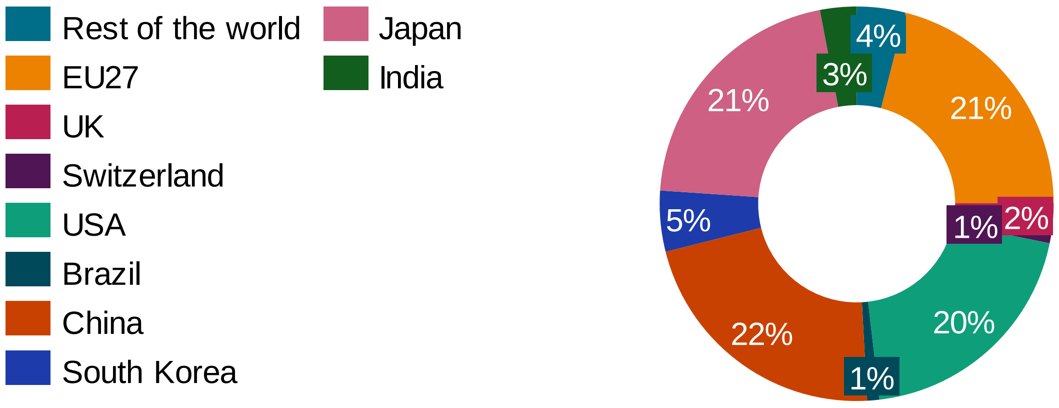
2022 – Energy Crisis:
The energy crisis of 2022, exacerbated by geopolitical tensions such as the Russian-Ukrainian conflict, led to unprecedented spikes in energy prices. This crisis significantly increased energy costs for UK industries, including chemicals, impacting their global competitiveness and operational viability. The crisis highlighted the urgent need for secure and competitive energy supplies as the UK transitions to net zero.

Since the 1990s the UK has targeted the reduction of greenhouse gas emissions around electricity generation. Whilst it has undoubtedly delivered this very successfully, the outcome has resulted in significant increase on the cost of electricity for GB consumers.

Compared to global R&D leaders like China, USA, and Japan, UK's spend is small; while it has increased over time it has not kept pace, as UK R&D-relative share declines

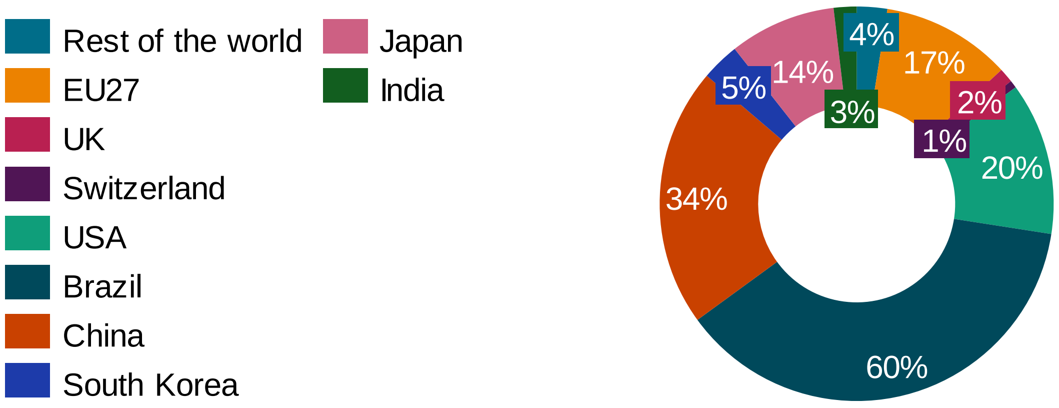
Chemicals R&D Spending by country 2012

€35 billion



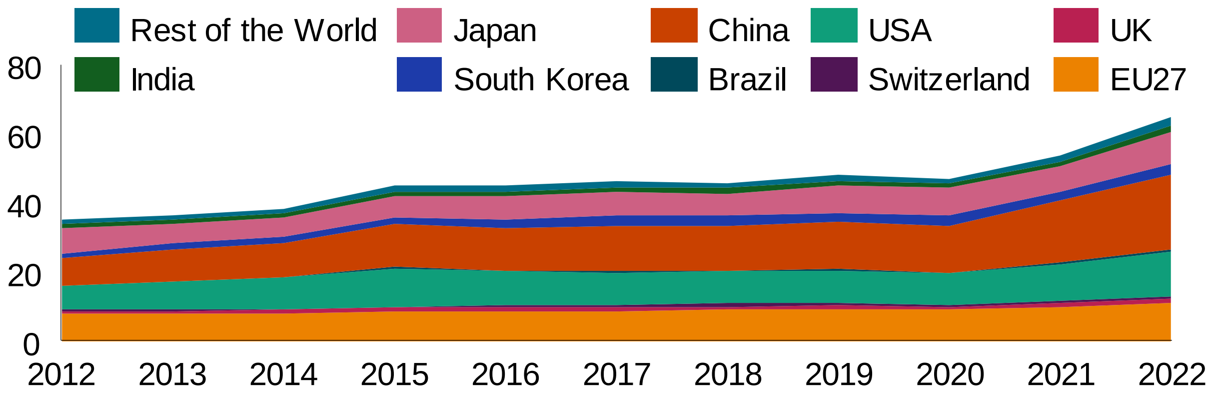
Chemicals R&D Spending by country 2022

€65 billion



R&D expenditure; Chemicals

bn. Euro



- Since 2018 the UK Government no longer publishes the specific amount of money for science, engineering and technology (SET) R&D but instead publishes total non-specific R&D spend.
- Between 2012 and 2022 global R&D spend has increased by around 86% with China and Japan's share significantly increasing. The UK had around 2.3% of the share in 2012 but this dropped to around 1.9% in 2022.
- Although absolute spending has increased in all regions, the rate of increase has been highest in the rest of the world (although from a smaller base) and Asia.

Source: CEFIC, S&P Global Commodity Insights.

International comparisons show how the UK chemical industry historical trend is associated with uncompetitive feedstock, changing demand, and with relatively "light" industrial policies

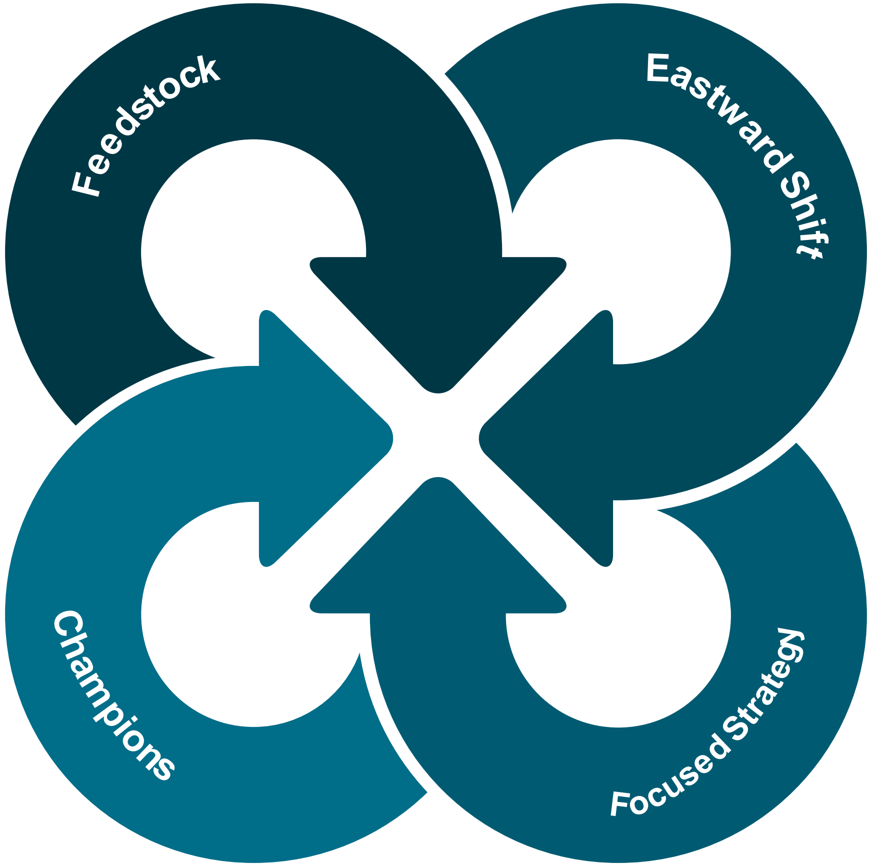
Feedstock Gap

- Traditionally the UK and in general European petrochemicals are typically produced from naphtha / oil, which is a more expensive input than gas and/or in countries where oil is much cheaper – this has put the UK at a cost disadvantage vs. the Middle East.
- Since 2008-09 the US experienced a so-called "shale gas revolution" as availability of natural gas through fracking increased, and it became the input of choice into petrochemicals – this has put the UK at a cost disadvantage vs. the US since fracking is not significantly developed in the UK.
- The UK has since evolved to using gas crackers but now north sea gas is uncompetitive and the high price range of imported ethane in the UK is another example of disadvantaged feedstock*.

National Champions

- Outside the examples of state-owned chemical companies, or even nationalised companies, several countries have adopted successful models of "strong support" of private enterprises with domestic ownership: for instance India, Japan, and to a lesser extent France.
- The German chemical industry is a separate case: originally built around three chemical giants plus smaller specialised companies, Germany is characterised by 21 chemical parks initially anchored to a well-integrated champion. Despite many of the "anchors" having foreign ownership or having being acquired, that solid cluster structure has remained.

International Comparison Elements



Eastward Shift

- Historically China, and to some extent other Asian countries such as India and South Korea, developed chemical industries based on supply of commodity or low-end chemicals and massive import of higher- value chemicals into high growth markets.
- In the last 20 years, not only has China (and others) built an enormous chemical supply side, but it has progressively upgraded its chemical capabilities into advanced polymers and specialty chemicals – this has eroded the "premium" advantage of the UK chemical industry.

Focused Country Strategies

- Several countries in the Middle East, particularly Saudi Arabia, have pursued consistent, long terms industrial strategies typically developing the chemical "downstream" by leveraging the chemical "upstream" within an export-based model.
- China's chemical strategy over the years has exploited the advantages of a planned economy and strong state-enterprise participation, combined with relentless focus on acquisition of IP and know-how.
- Switzerland, on a completely different basis, has stimulated the growth of an oversized domestic fine chemical industry by combining the critical mass and proximity of first-class pharma with aggressive fiscal policies for investment attraction.

Contents

Note: this is an abridged version of the original full report. In this document some pages have not been included and some data, e.g. chart units, have been deliberately left blank

S&P Global has defined four future scenarios: on its current trajectory, the UK chemical industry is drifting towards the most unfavourable scenario with loss of value, employment, and resilience

S&P Global outlines four future scenarios for the UK chemical industry: from a favourable low cost and high demand growth combination, to a very unfavourable high cost and low demand growth situation:

- Favourable – Scenario 1: "A rising tide lifts (almost) all boats".
- Unfavourable – Scenario 2: "Great but uninvestable".
- Very unfavourable – Scenario 3: "Doomsday with silver lining".
- Unfavourable – Scenario 4: "Export juggernaut or race to the bottom?"

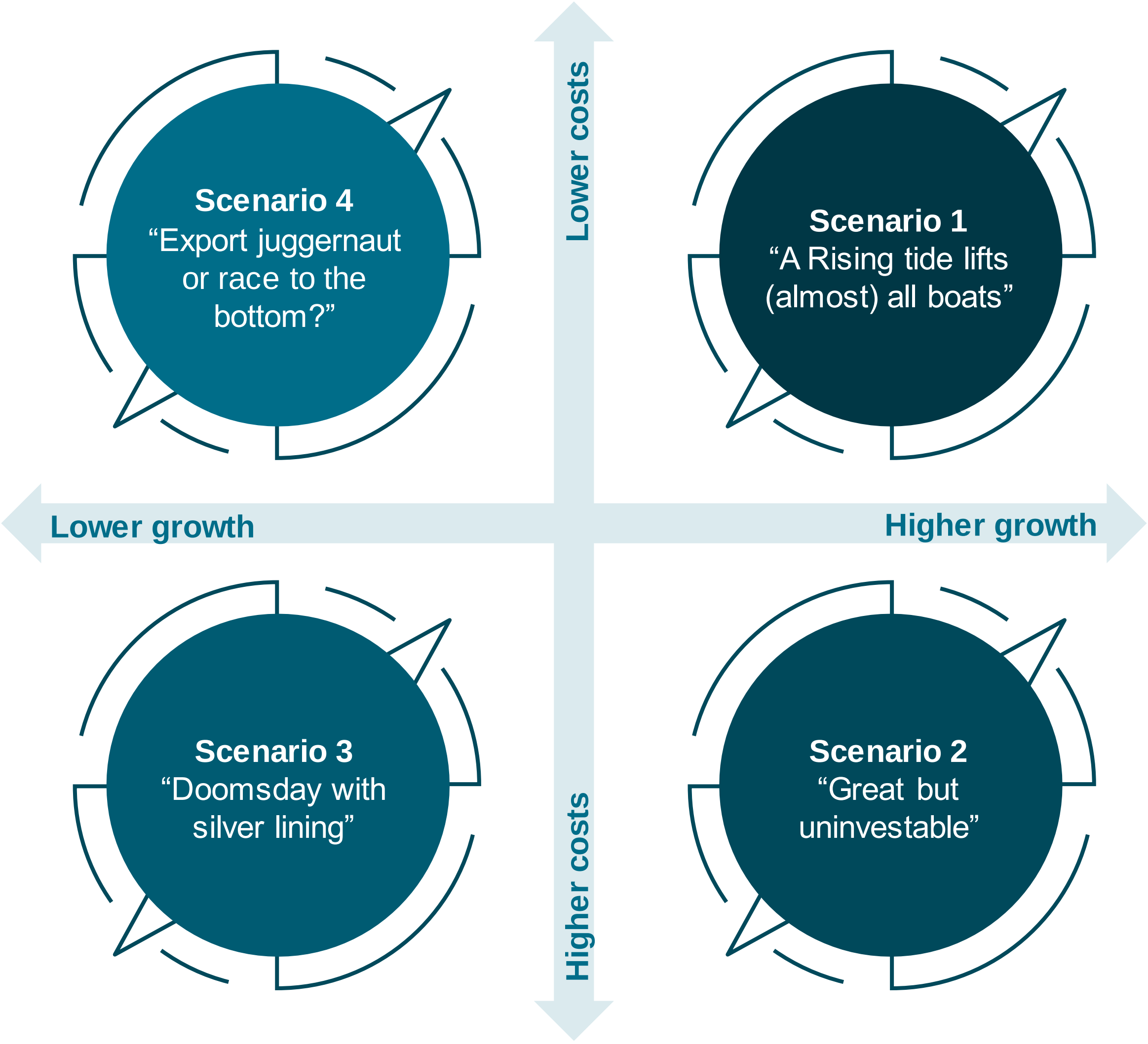
Considering historical trends for the industry and the baseline forecasts for key products and sectors, there is a material risk that, on current trajectory, the UK chemical industry will potentially drift towards the most unfavourable scenario (Scenario 3).

- Growth forecast and prospects for most of the chemical building blocks in the UK are modest or flat – hydrogen and ammonia are special cases.
- Future growth and prospects for end-use chemicals in the UK range from high for premium specialties to low for large-volume commodity plastics.

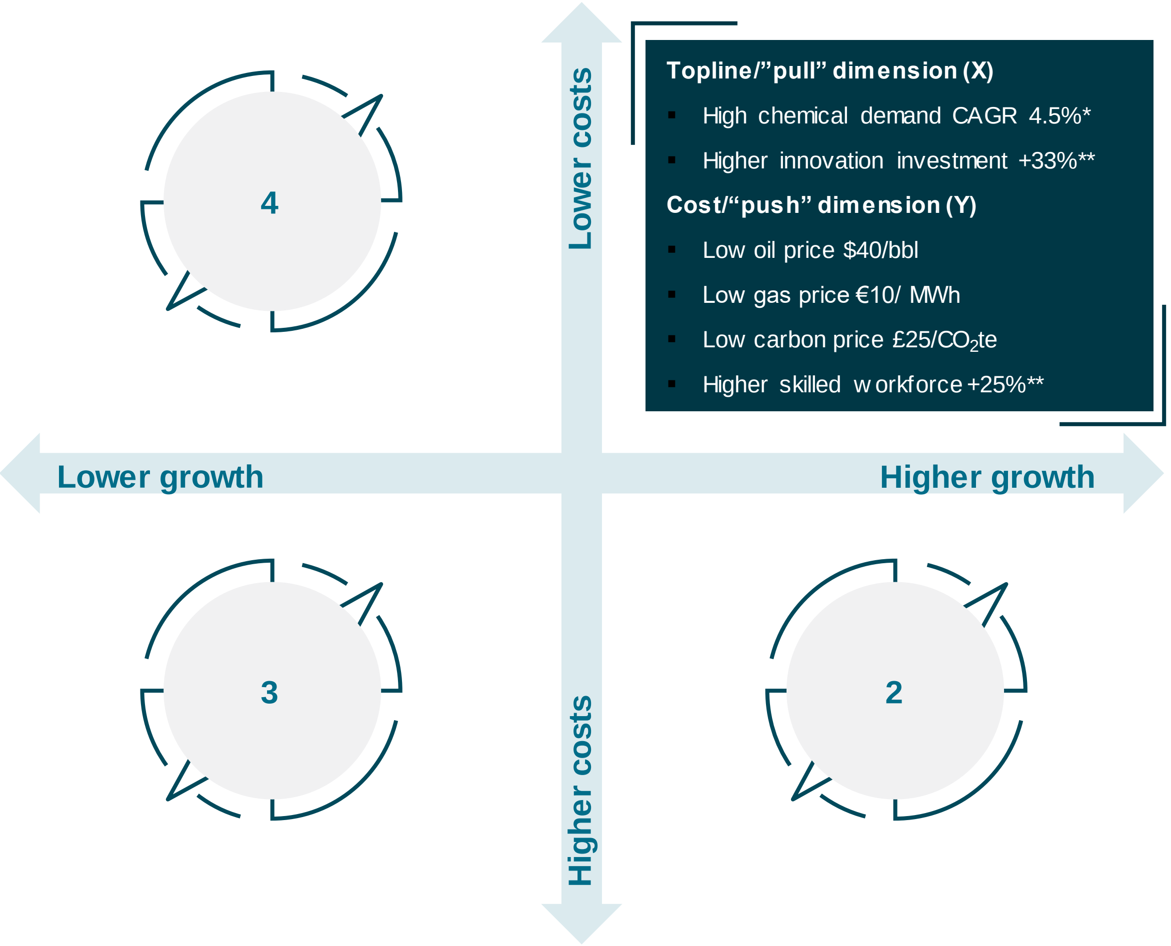
On balance, unfavourable scenarios imply a significant degradation of macroeconomic value, restraints to the energy transition, and diminished resilience of critical infrastructures vs. today.

S&P Global outlines four future scenarios for the UK chemical industry: from favourable low cost and high demand growth, to unfavourable high cost and low demand growth

- In order to understand long term industry dynamics (> 10 years), conventional business projections are typically unhelpful because the "cone of uncertainty", i.e., variance around single, average values, becomes too large.
- An alternative, well established approach is to define a number of future "scenarios", i.e., sets of hypothetical values and conditions, with the assumption that the actual industry "reality" will fall within the boundaries of those scenarios.
- For that reality assumption to be safe, the scenarios typically must satisfy two conditions: (1) they must be driven by highly relevant, differentiating industry factors ("drivers"); and (2) they must be extreme enough to cover major swings in trends, volatility and discontinuities, but still be plausible.
- With the scenario approach in mind, we have gathered data, insights and opinions, from a variety of sources – S&P databases, proprietary information, internal experts, primary research, secondary research, external industry experts, senior executives from the chemical industry (within and outside the membership of the Chemical Industries Association). That extensive material was discussed and reviewed in workshops, and eventually distilled **into four scenarios for the UK chemical industry for the long-term horizon up to 2050.**
- These 2x2 scenarios are driven by a combination of two sets of factors, broadly defined as "costs" and "demand growth". More precisely:
  - (Y-axis) "push side": the cost of chemical feedstock and energy, through crude oil and gas; the cost of emissions/compliance through carbon price; and the cost of human resource input.
  - (X-axis) "pull side": chemical demand and growth, to which UK chemical companies are exposed, through a basket of key chemical products and selected end-use sectors; level of R&D/innovation investment in chemical in the UK.



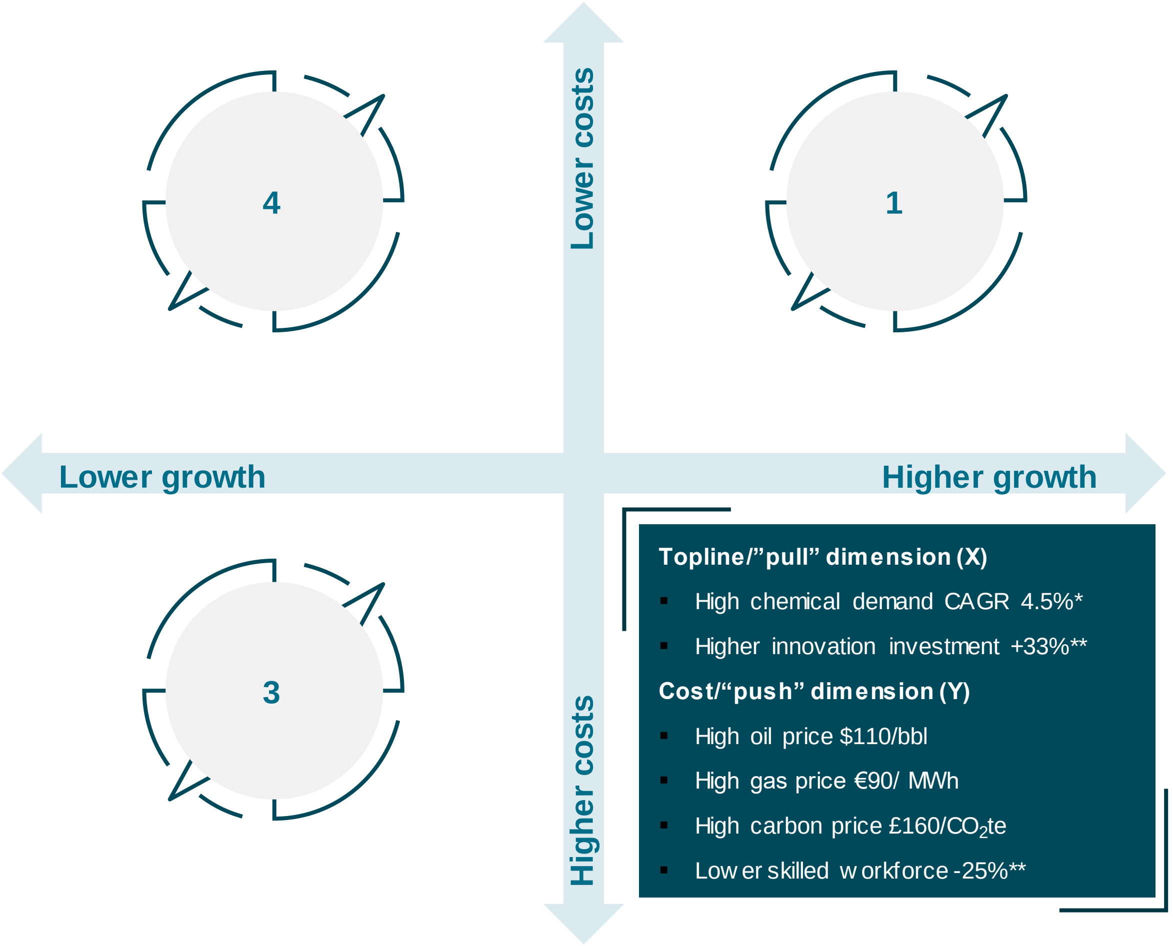
Favourable – Scenario 1: “A Rising Tide Lifts (almost) All Boats”



- Chemical building blocks in the UK are profitable, on average over the cycle.
- Access to cheaper, greener materials for key segments. Chemical industry now aligned with growth-engine industries – e.g., specialty carbonates for battery materials, fluorine chain.
- The industry makes a successful transition to net zero without de-industrialising. The UK becomes a net importer of CO2 for storage.
- Confidence of investment in stable policy environment, with acceleration of planning and permitting process.
- Positive PR/public perception: (vital) “chemistry” rather than (toxic) “chemicals”.

(*) Absolute demand for Construction, Energy storage (Batteries), Food & Drinks; relative UK demand share for Automotive, Aerospace, Wind, Solar, CCS, Biotech
(**) percent higher or lower compared to today’s level
Source: S&P Global Insights, CIA, Chemical Industry Stakeholder Workshops, Chemical Company Interviews

Unfavourable – Scenario 2: “Great but Uninvestable”

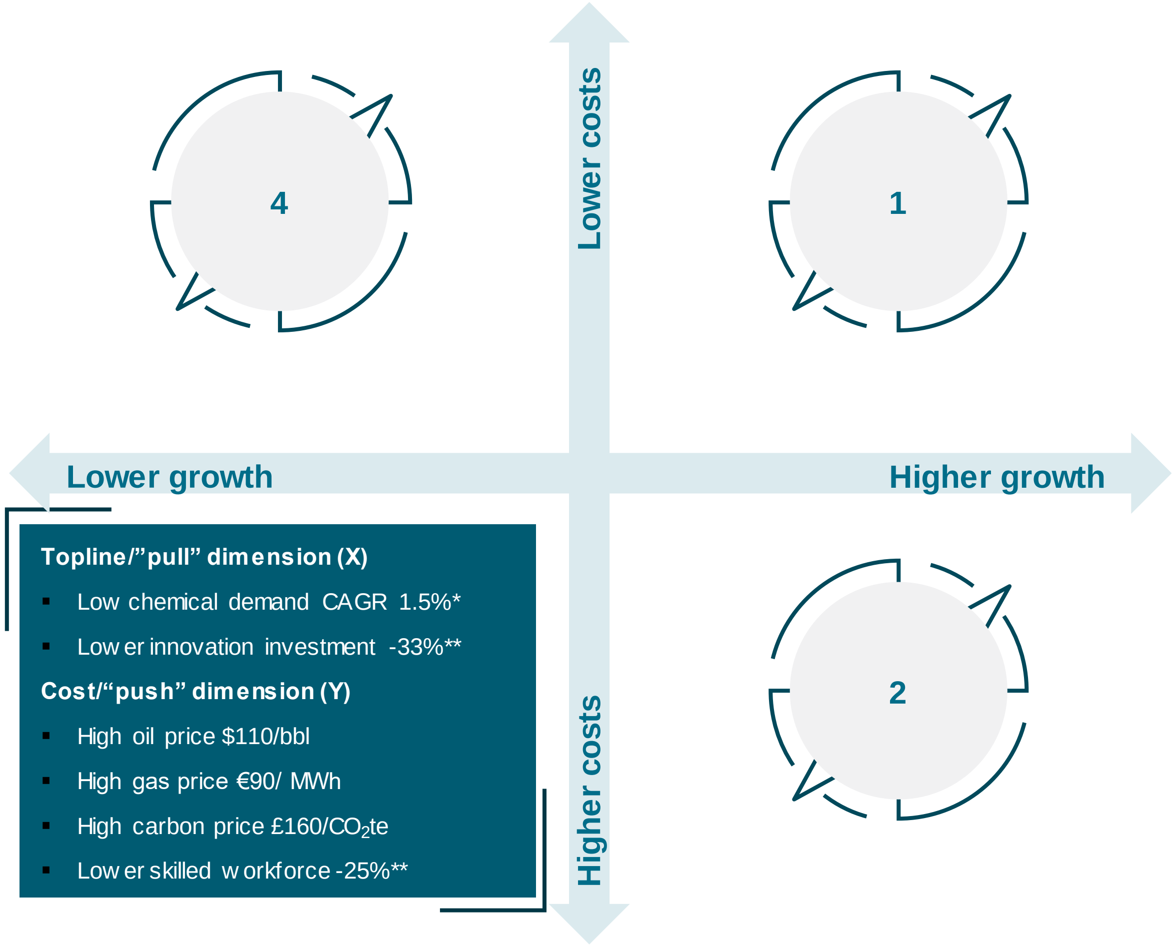


- UK technology competitiveness is strong but supply competitiveness is weak.
- Good aerospace manufacturing capabilities, with upstream supply chains in composites which benefits from a high-level skills base.
- Biotech exploits domestic resource and sugar processing and by-product infrastructure, through to bio-based nutraceuticals and even APIs.
- Use of green materials increases; but e.g., solar panels imported, not cost competitive. No UK supply chain for batteries. Wind energy growing, but no current supply chain.
- Long term foreign investment plans stifled. Tactical investment to convert ‘uninvestable’ into “workable” when UK Government support is forthcoming – grants, subsidies, incentives.
- In “step-out innovation” higher costs can be borne but skills availability is key, therefore, scale-up opportunities have migrated abroad.

(*) Absolute demand for Construction, Energy storage (Batteries), Food & Drinks; relative UK demand share for Automotive, Aerospace, Wind, Solar, CCS, Biotech
(**) percent higher or lower compared to today’s level
Source: S&P Global Insights, CIA, Chemical Industry Stakeholder Workshops, Chemical Company Interviews

Very unfavourable – Scenario 3: “Doomsday with Silver Lining”

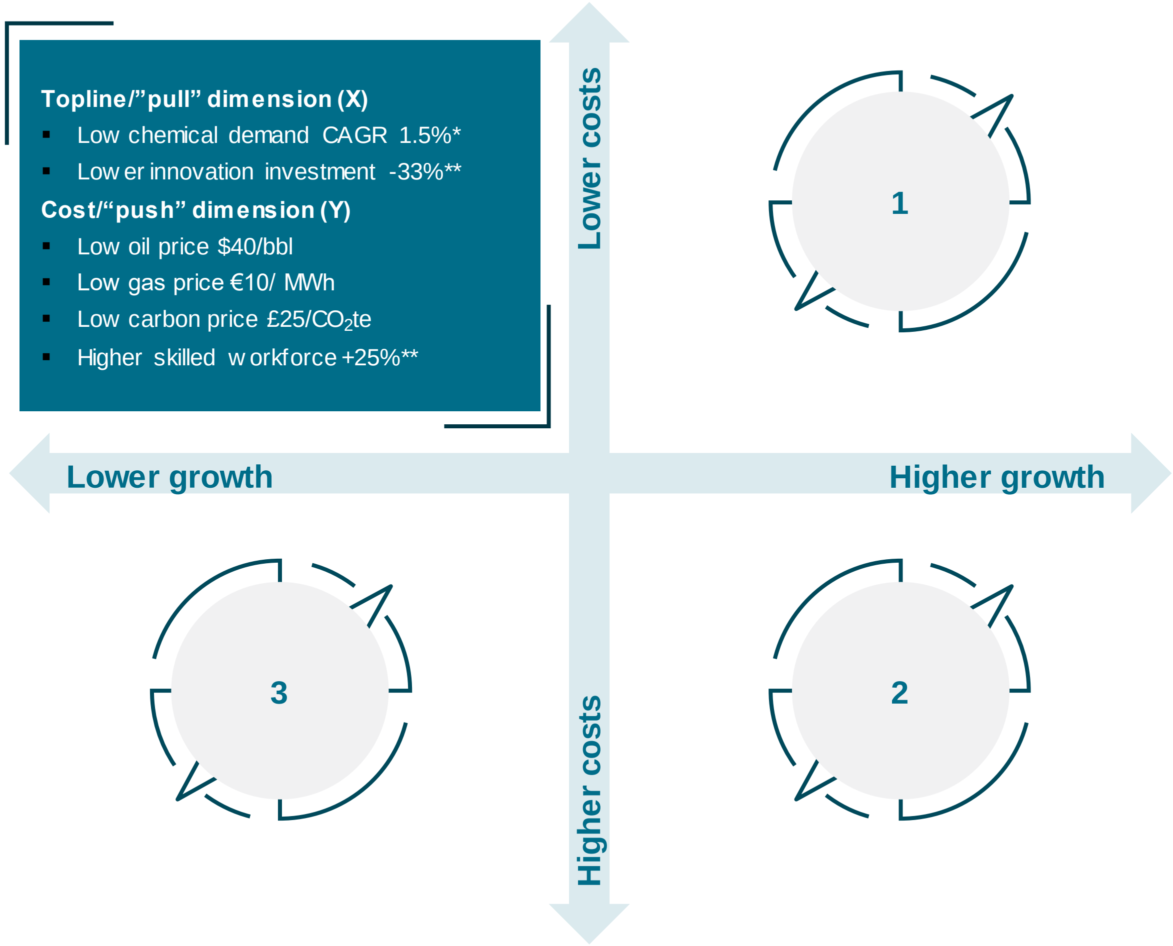
- Minimal base chemical production in the UK, although sugar-derived feedstock likely much larger than today.
- Most derivatives have fallen away: production of big polymers (polyolefins, PVC) has moved off shore. Chlor-alkali may be last man standing. In general, this is a subsidy economy (for chemicals that are absolutely needed).
- Also import-only economy for most chemicals. Some specialties remain, and possibly thrive, especially low volume / high value with criticality on-shore (e.g., water treatment).
- SMEs decimated – because of lack of underlying, direct and indirect job supply feed, though some players may find reliance on import.
- Employment and investments down. Possible exceptions Clean Energy (to the extent it’s non-movable e.g., wind power, CCS) and Food & Drink (at least for parts that can be “legislated in”).



(*) Absolute demand for Construction, Energy storage (Batteries), Food & Drinks; relative UK demand share for Automotive, Aerospace, Wind, Solar, CCS, Biotech
(**) percent higher or lower compared to today’s level
Source: S&P Global Insights, CIA, Chemical Industry Stakeholder Workshops, Chemical Company Interviews

Unfavourable – Scenario 4: “Export Juggernaut or Race to the Bottom?”

- A smaller economy, export based, under the assumption of favourable trade agreements with major economic blocks (not a foregone outcome).
- With low cost structure and low internal demand, potential for bulk/commodity global export; how substantial depends on Middle East and Asia players’ strategies.
- UK specialty players diversify into Europe and participate in high value food additives, and nutraceutical ingredients; but these are generally small volume products sold in formulations.
- Some large specialty markets precluded, at the high-end, especially clean energy where the “virtuous circle” of high growth – feeding innovation – feeding high growth has not materialised.
- On balance, the UK by not exploiting and not competing on traditional core competences (e.g., innovation) is potentially open to more volatile demand/supply conditions.



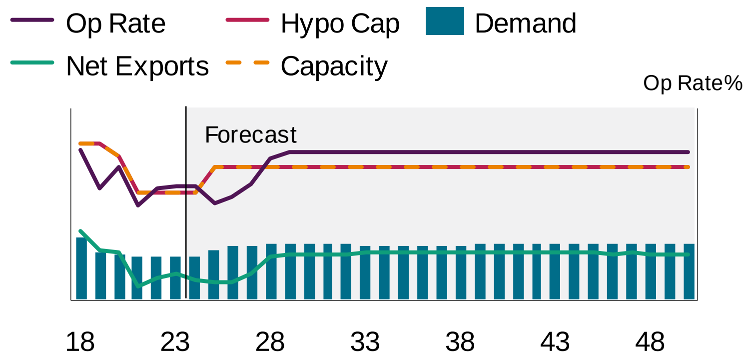
(*) Absolute demand for Construction, Energy storage (Batteries), Food & Drinks; relative UK demand share for Automotive, Aerospace, Wind, Solar, CCS, Biotech
(**) percent higher or lower compared to today’s level
Source: S&P Global Insights, CIA, Chemical Industry Stakeholder Workshops, Chemical Company Interviews

Growth forecast and prospects for most of the chemical building blocks in the UK are modest or flat – hydrogen and ammonia are special cases [1/2]

Ethylene

- Capacity and demand: As of 2023, UK ethylene capacity is around 1.7 million metric tons, expected to increase to 2.1 million metric tons by 2025 with the reopening of the Wilton cracker. Demand is forecast to grow at a modest CAGR of 0.9% to 2050.
- Importance: Ethylene is a crucial building block for polyethylene production, used in various applications like packaging.
- Trade: The UK is a net exporter of ethylene, with negligible imports, indicating self-sufficiency and export potential.

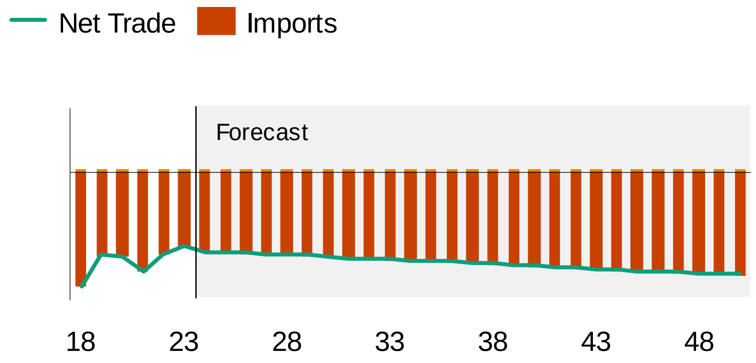
United Kingdom: Ethylene Supply & Demand
Million Metric Tons



Methanol

- The UK ceased methanol production in 2001 with the closure of ICI's Billingham plant. The UK now relies entirely on imports, primarily from the US and South America.
- While there is no production, Johnson Matthey is a global leader in methanol synthesis technology and catalysts, licencing over 100 methanol plants worldwide.
- Different outlook for "green methanol", either from waste gasification or via electrochemistry (e-fuel): high growth potential, for instance in shipping, though competing with low-carbon ammonia.

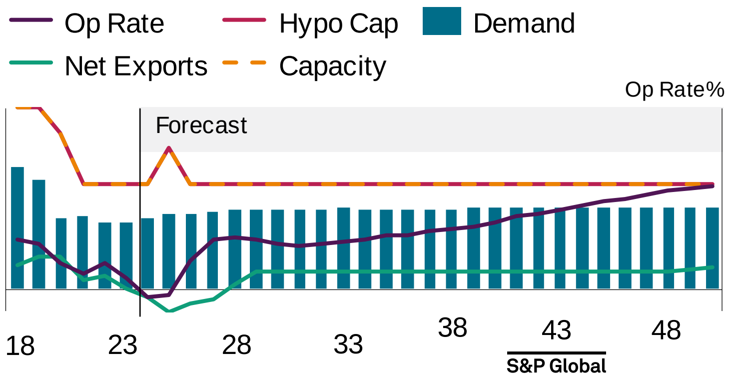
United Kingdom: Methanol Trade
Million Metric Tons



Propylene*

- Capacity and demand: UK chemical grade propylene (CGP) capacity is around 560,000 metric tons, expected to rise to 750,000 metric tons by 2025. Demand is projected to grow at a CAGR of 0.8% to 2050.
- Importance: CGP is primarily used for polypropylene production, essential for automotive and mechanical parts.
- Trade: The UK is expected to be a net importer in the short term, returning to net export by 2028.

United Kingdom: Propylene, CGP Supply & Demand, Million Metric Tons



(*) See also following pages for further propylene considerations
Source: S&P Global Commodity Insights

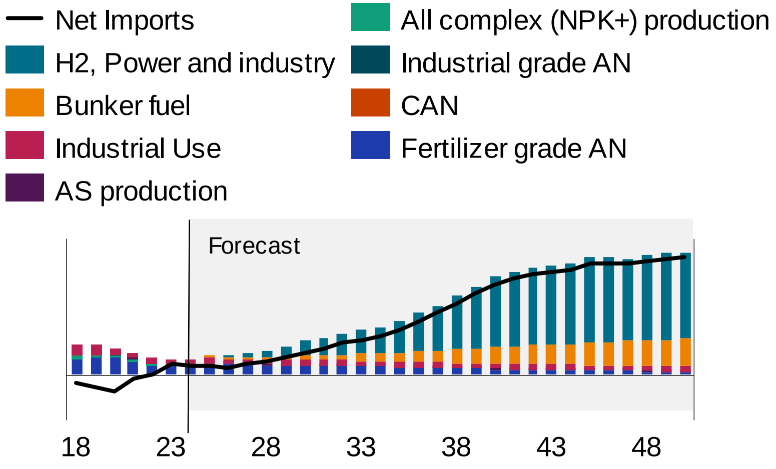
Growth forecast and prospects for most of the chemical building blocks in the UK are modest or flat – hydrogen and ammonia are special cases [2/2]

Ammonia

- Capacity and challenges: UK ammonia capacity is around 270,000 metric tons as of 2023. The industry faces challenges due to high natural gas prices, leading to the closure of CF Fertilisers UK's Ince plant in 2022.
- Future prospects: Potential growth in low-carbon ammonia production using green hydrogen, driven by the UK's renewable energy resources and marine bunker fuel.

United Kingdom: Ammonia Demand and Trade

Million Metric Tons

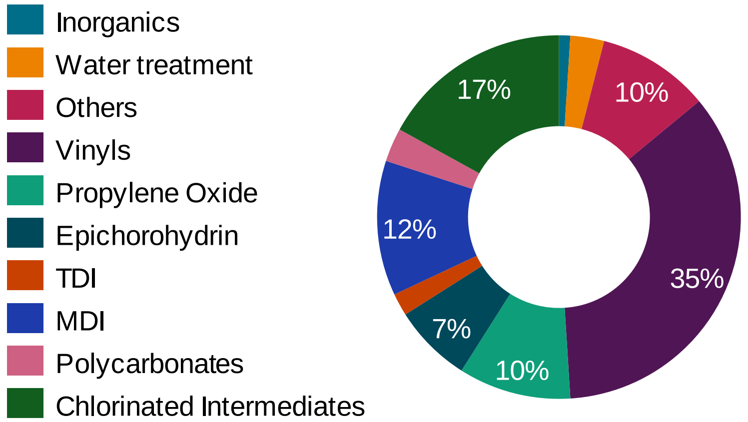


Chlorine

- Capacity and importance: UK chlorine capacity is approximately 480,000 metric tons, with INEOS Inovyn Limited in Runcorn being the largest producer. Chlorine is vital for water treatment and various industrial applications.
- Market dynamics: The UK market is mature with slow demand growth, influenced by environmental policies.

West Europe: 2023 Chlorine Demand by End Use

Domestic Demand = 6.5 Million Metric Tons



Hydrogen

- Capacity and demand: UK propylene capacity is growth potential: Hydrogen demand and supply, especially blue and green hydrogen, are set for significant growth. The UK is well positioned to participate due to its renewable energy capabilities
- Sector impact: Hydrogen is expected to play a larger role as an energy carrier, influencing various sectors.

UK Hydrogen demand by sector

MMtoe

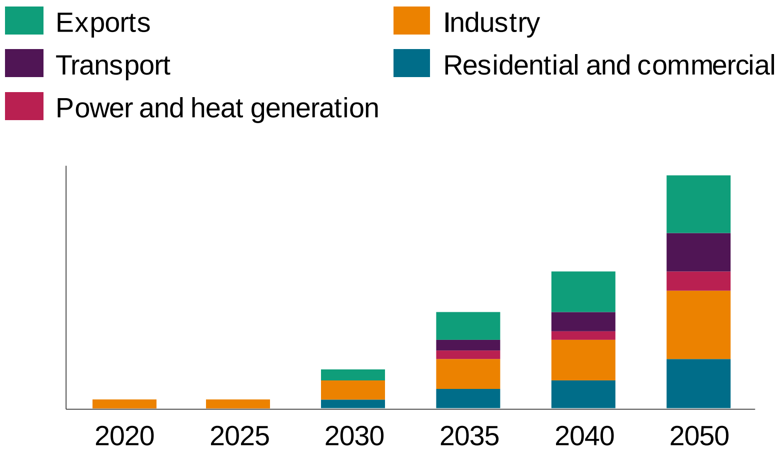


Chart 3: Data compiled July 20 2023.
Source: S&P Global Commodity Insights.

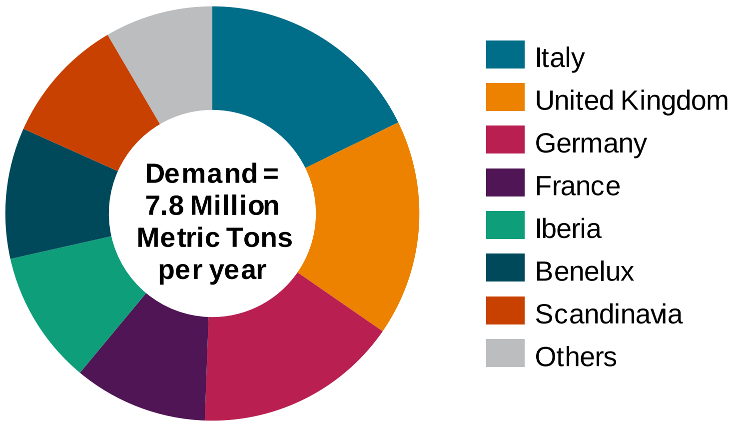
S&P Global Commodity Insights

The UK is using refinery propylene for petrochemical use, some being purified to polymer grade, with some used directly. Significant volumes remain committed to refinery use

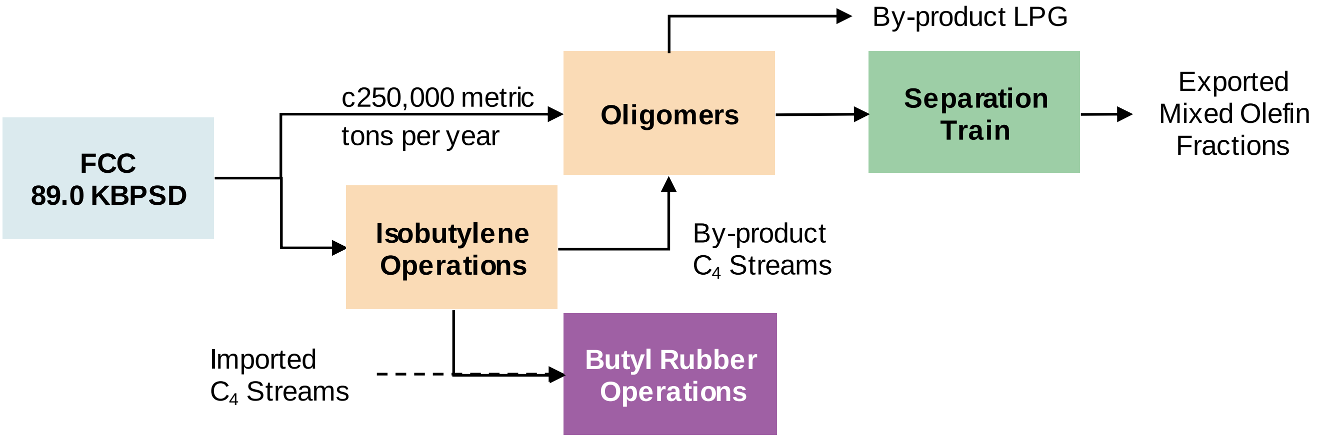
- In the refinery, a propane/propylene stream is generated by the Fluid Catalytic Cracker (FCC), originally designed to upgrade low value streams from the front distillation train in the refinery into mainly transportation fuel blending components. Light fractions including C_3 and C_4 streams are co-produced. With future concerns over markets for transportation fuels in light of the increased electrification of automotive power trains, refiners are looking to maximise chemical feedstocks produced from processes like the FCC. Companies like Honeywell UOP and Lummus offer FCC processes with higher refinery propylene driven by a combination of new catalysts and process redesign or revamping.
- The UK operates around 15% of West Europe's refinery propylene (c75% propylene) capacity. In the UK, refinery propylene is consumed in different ways, for example;
  - Essar Oil in Stanlow, Cheshire recovers refinery propylene from its FCC to supply a propylene splitter to supply the polypropylene operations of Lyondell Basell in Carrington.
  - In contrast, Valero in Pembroke commits its FCC light fractions (C_3, C_4 and C_5) to a 35 KBPSD alkylation unit to boost gasoline octane.
  - ExxonMobil at Fawley uses its refinery propylene and FCC C_4 stream for chemicals production. The latter contains isobutylene, a key feedstock for butyl rubber (IIR) production. The company operates a process to remove the isobutylene it needs which provides a by-product stream containing other C_4 olefins. This is combined with refinery propylene to supply an oligomers unit that makes mixed C_6-C_{12} olefin fractions. These are separated and shipped to ExxonMobil operations in mainland Europe.
- In mainland Europe large volumes of refinery propylene are split to generate polymer grade propylene. However, there are still chemical operations that for example make cumene (a key intermediate in making phenol) from refinery propylene. In future, refinery operations could be generating more refinery propylene given likely FCC revamps. However, such revamps are not simple projects. The closure of the INEOS refinery in Grangemouth in 2025 will significantly impact UK refinery propylene supply.

West Europe Capacity for Refinery Propylene

By Major Country/Region



Example of Refinery Propylene Use for Chemicals Production in the UK- ExxonMobil at Fawley



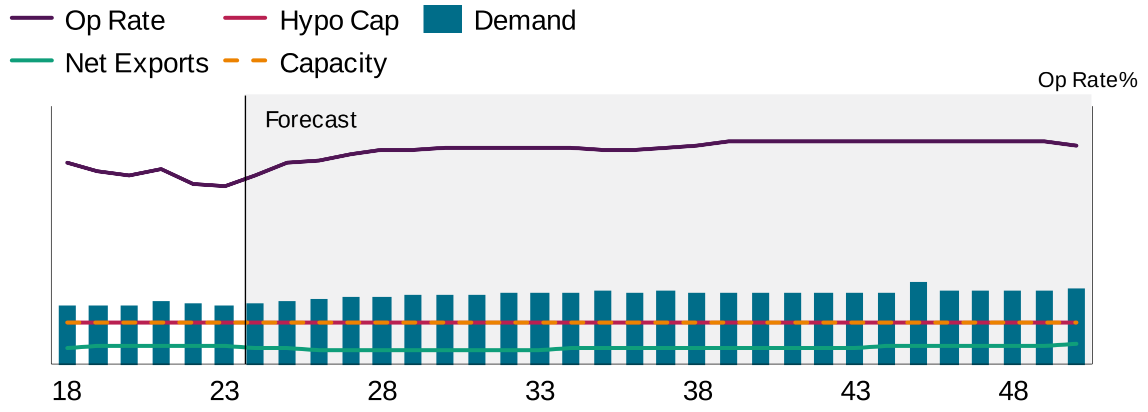
Source: S&P Global Commodity Insights.

Future growth and prospects for end-use chemicals in the UK range from high for premium specialties to low for bigger conventional plastics

- The UK chemical industry is witnessing significant growth potential in specialty chemicals, particularly fluoropolymers. These high-performance materials are increasingly in demand due to their unique properties, such as chemical resistance and high thermal stability. Industries like electronics, automotive, and renewable energy are driving this demand, as they require advanced materials for applications such as semiconductors, fuel cells, and solar panels. The focus on innovation and technological advancement positions fluoropolymers as a key potential growth area in the UK market. Globally, it is set to grow at around 6% per year over the next decade.
- However, conventional plastics such as polyethylene (PE) and polypropylene (PP) are experiencing slower growth. These materials are well-established in industries like packaging and construction, but their markets are mature. Environmental concerns and regulatory pressures are further limiting growth, pushing companies to explore sustainable alternatives.
- The growth forecasts for polyethylene and polypropylene in the UK are constrained by several factors. Firstly, these commodities are entrenched in mature markets, where demand is primarily stable rather than expanding. Additionally, increasing environmental regulations are prompting a shift toward sustainable materials, which detracts from the growth potential of traditional plastics. The rise of alternative materials, such as bioplastics, is also impacting demand, particularly in sectors like packaging. Furthermore, economic fluctuations can influence consumer spending on non-essential goods, affecting the demand for PE and PP. In contrast, specialty chemicals are thriving due to their applications in high-growth sectors, highlighting the divergence in growth trajectories between these two categories.

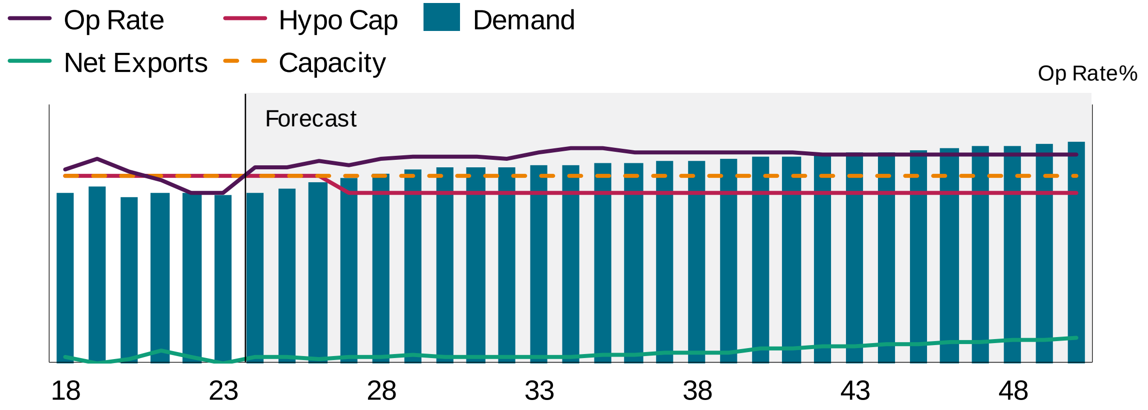
United Kingdom: PP Supply & Demand

Million Metric Tons



United Kingdom: Total PE Supply & Demand

Million Metric Tons



Source: S&P Global Commodity Insights.

S&P Global Commodity Insights

While in construction and food & drink expectations are for "grow with the growth", chemical demand in other (potentially higher growth) sectors is so far at an earlier more tentative stage

Construction Sector

- The construction sector is projected to see long-term growth both globally and in the UK. Chemicals used in construction, such as resins, coatings, adhesives, and sealants, are expected to grow in line with this sector's expansion. Insulation materials, in particular, may experience faster growth due to increased demand for energy efficiency.
- Chemicals are essential in construction for enhancing material performance, including water-proofing, roofing, and concrete specialties. Carbon fibres are also used in structural applications like bridge design for strengthening and remediation .

Food & Drink Sector

- As the largest manufacturing sector in the UK, the food and drink industry is valued at £104.4 billion. Growth is driven by consumer trends towards convenience, health, and sustainability. The sector is also a significant exporter, contributing to the UK's economic output.
- The demand for food additives, preservatives, and processing aids is growing, particularly those derived from natural sources. Innovations in food processing chemicals are driven by the need for healthier, more convenient food options, aligning with consumer preferences for clean labels and natural ingredients.

Clean Energy

- The UK is a leader in onshore wind power, with ambitious targets for expansion. Chemicals like fibre composites are essential for manufacturing larger, more efficient turbine blades, supporting the transition to renewable energy.
- Despite challenges in supply chains and grid integration, the solar sector is poised for growth. Chemicals such as fluoropolymer-based backsheets and EVA-based encapsulants are critical for improving solar panel efficiency and longevity.
- UK demand for chemicals in these sectors currently is small, but poised for growth.

Automotive

- The UK automotive sector is pivotal in reducing CO_2 emissions, with a strong focus on electric vehicle (EV) production. Government initiatives are supporting the growth of battery production, which is crucial for the EV market. This drives demand for chemicals used in battery technology and lightweight materials, enhancing vehicle efficiency and performance.
- Some key projects are expected to contribute to growth in this sector.
- AESC UK, located in Sunderland, has been producing batteries for Nissan's electric vehicles and is expanding its capacity; and Tata Group is investing in a new gigafactory in Somerset, which will produce batteries for Jaguar Land Rover.

Aerospace

- The UK aerospace industry ranks second globally, with a turnover of approximately $34.5 billion in 2022. It is a major exporter, with 70% of production destined for international markets.
- There is significant potential in the development of sustainable aviation fuels (SAFs) and advanced composites.
- These innovations are crucial for reducing the carbon footprint of air travel and enhancing aircraft performance.

Additional information on the construction sector and the Food and Drink sector can be found in the appendix

Contents

Note: this is an abridged version of the original full report. In this document some pages have not been included and some data, e.g. chart units, have been deliberately left blank

Out of many possible options, a few fundamental enablers seem especially attractive as they are likely to have the highest positive impact on the current and future UK chemical industry

S&P Global has considered 17 possible areas of major intervention to enable UK chemical industry growth or to mitigate gaps.

In terms of industry impact and overall effectiveness in multiple scenarios, five priority enablers have the potential to be "game changers", namely:

a) Access to competitive feedstock and energy: mitigation and diversification.
   - Under S&P base projections for the 2050 global energy landscape, the majority of chemical feedstock will still be fossil-based: the UK is still expected to have a proportion of fossil-based inputs feeding into chemicals long term.
   - While the UK dependency on oil, naphtha, and gas as relatively uncompetitive inputs is a geographic reality, such disadvantage can be mitigated by a calibrated carbon pricing approach.
   - Sugar operations, and possibly wider biomass processing, integrated with biotechnology and selected petrochemical technologies could reduce the reliance on high cost, fossil-based feedstock.
   - Low-carbon feedstock available from chemical/advanced recycling and mechanical recycling facilities could become an important element of the UK feedstock mix
   - Clean hydrogen (and ammonia) as a "feedstock" is the start of a supply chain leading to potentially cost advantaged chemicals.
   - CCUS (see point c) underpins both the swift expansion of low-carbon hydrogen production and, by definition, the availability of CO2 as a chemical input at scale.

b) Scaled-up domestic battery production: demand side and innovation.
   - Crucial for achieving net zero, creating thousands of jobs, and fostering innovation, with a significant focus on workforce development and reducing dependence on imported materials.

c) Accelerated carbon capture, utilisation and storage*: decarbonisation.

d) Increased availability of skilled technicians/engineers.

e) Scaled-up recycling of both plastics and other materials: not only conventional but also advanced recycling technologies.
   - Plastics recycling. Processing of domestic plastics waste via chemical and mechanical means to respectively provide low-carbon feedstocks for chemical building block production, and for end-user solutions (e.g. packaging).
   - Battery materials/electronics. Cost-effective and environmentally-sensitive technologies to recover lithium, rare earth elements, and electrolyte solvents, are needed to reduce reliance on rare earth sources from abroad.
   - Wind turbine/aircraft. Recovery of carbon fibres from composites for wider use in automotive and construction industries.
   - Solar panel recycling. Recovery of silicon for reprocessing and other essential materials of construction (e.g. specialty plastics).

*Information on other enablers/mitigants can be found in the Appendix

S&P Global has considered 17 possible areas of major intervention to enable UK chemical industry growth or to mitigate gaps

Category	Enablers/Mitigation	Scenario Impact	Rationale
Industrial / Infrastructure Options	Access to domestic car production	3,4	Virtuous circle: large market for various and advanced automotive chemicals "feeding back" into R&D / competitiveness
	Access to domestic battery production	3,4	Virtuous circle: large market for various and advanced battery chemicals "feeding back" into R&D / competitiveness
	Indigenous renewable feedstock	2,3	Integrate sugar operations with biotechnology and petchem to reduce reliance on high cost, fossil-based feedstock
	Circular feedstock from recycling	2,3	Renewable naphtha available from chemical/advanced recycling and scaled-up mechanical recycling facilities to reduce fossil-based feedstock
	Renewable energy, green hydrogen	2,3,4	Decarbonisation of hard-to-abate parts of the chemical industry needs an efficient wind power to hydrogen chain
	Carbon capture, utilisation and storage	2,3,4	CCS fundamental to reduce carbon footprint of existing supply chain + CCU opportunity to use CO_2 as feedstock
	Clusters (materials, skills)	3	Focus on both conventional and "bio" clusters to ensure scale efficiency of material flows and critical mass of skills
Regulatory / Policy Options	Tax relief (R&D, investment); essential this is continued	4,3	Classic, internationally tested instrument to increase FDI attractiveness, especially in, but not restricted to, specialties
	Accelerated permitting, approval process	3,2,4	Remove/mitigate complexity and lead times for capital project planning, construction, start up
	Stable business regulatory framework	2,3	With assets typically lasting decades, chemical strategies tend to optimise risk/return long term, so reducing uncertainty on a country business environment assumptions is key to investment decisions
	Favourable trade tariffs and certification	4,3	(1) Many chemicals scaled up to serve larger international markets; (2) complex supply chain penalised cross borders
	Adjusted UK carbon pricing	2,3	Cost of carbon / compliance likely to became a bigger and bigger element of total cost
	US IRA-type approach	All	Energy transition & sustainability: the US is focused on credits, grants, rebates for designated US economy sectors
	EU Clean Industrial Deal-type approach	All	Energy transition & sustainability: the EU is focused on admin barrier removal to funds for critical raw materials and cleantech
Culture / Human Resources Options	More chemists / better graduates	2,3	Availability *in the UK* of chemical graduates from top universities
	More technicians, engineers	All	Availability *in the UK* of specialised and skilled technicians, technical personnel especially for EPC and operations
	Positive perception of chemical industry	3,2,4	Change industry image as "stale" and redress confused / incorrect links to pollution and global warming

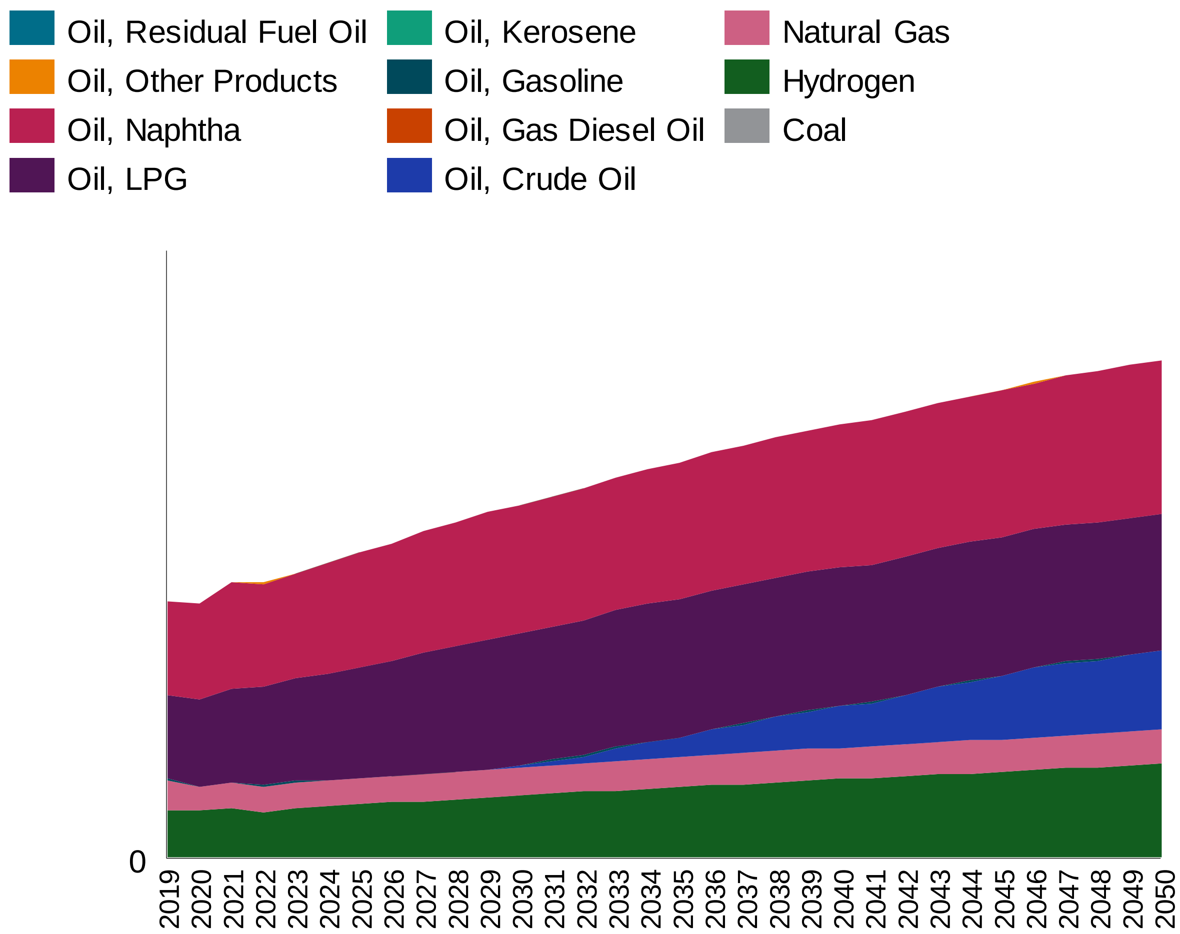
Scenario Impact: which of the 4 scenarios would be most improved by this enabler

Under S&P base projections for the 2050 global energy landscape, the majority of chemical feedstock will still be fossil-based*: the UK is still expected to have a proportion of fossil-based inputs feeding into chemicals long term

- The existing infrastructure for chemical production is heavily reliant on fossil fuels. Transitioning to alternative feedstocks requires significant investment in new technologies and facilities, which can be a slow process.
- Fossil-based feedstocks are currently more economically viable due to established supply chains and economies of scale. This economic advantage makes it challenging for alternative feedstocks to compete without substantial policy support, deployed carbon cost mechanisms, and/or technological breakthroughs.
- While there are advancements in bio-based and recycled feedstocks, these technologies are not yet at a scale or cost that can replace fossil-based feedstocks. Innovations are needed to improve efficiency and reduce costs.
- The UK has set ambitious targets for reducing carbon emissions, which could influence the chemical industry to explore alternative feedstocks.
- The UK has limited domestic fossil fuel resources, which could drive a shift towards more sustainable feedstocks. However, the shift will depend on the availability of local bio-based resources or the import of alternative feedstocks.

World energy demand as a chemical feedstock*

Thousand toe



(*) See also Appendix: 2020 vs 2050 landscapes
Source: S&P Global Commodity Insights

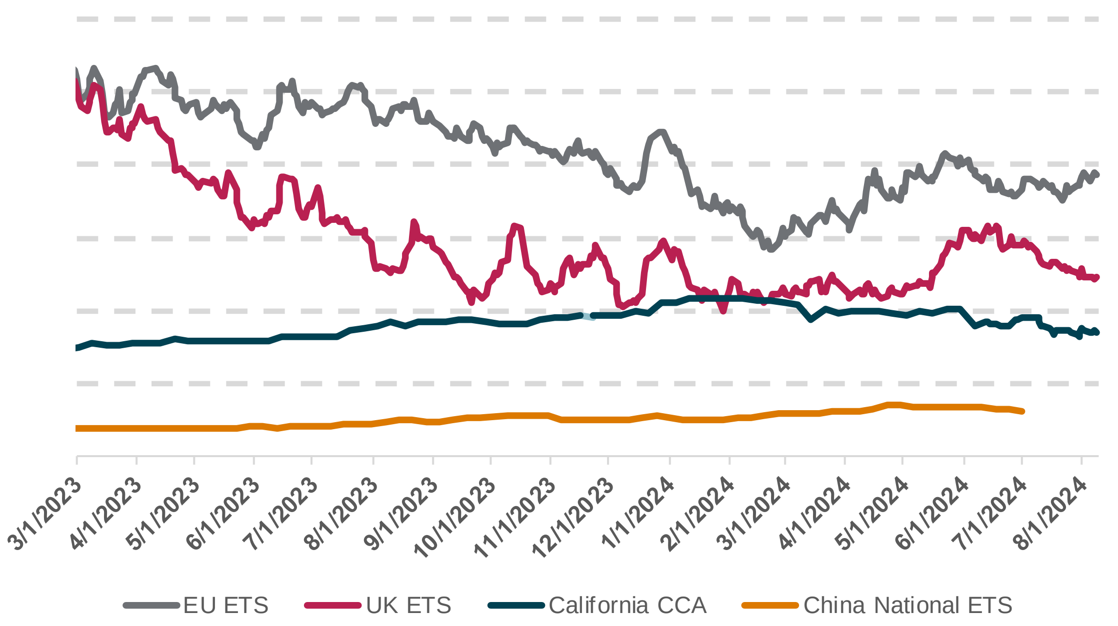
The UK dependency on oil, naphtha and gas as relatively uncompetitive inputs is a geographic reality, but such disadvantage can be mitigated by a calibrated carbon pricing approach

The UK Emissions Trading Scheme (UK ETS), launched in January 2021, replaced the UK's participation in the EU ETS following Brexit. It is a cap-and-trade system designed to reduce greenhouse gas emissions from key sectors, primarily energy intensive industries and aviation.

- **Cap on emissions:** The UK ETS sets a cap on the total amount of greenhouse gases that can be emitted by covered sectors. This cap is gradually reduced over time, aligning with the UK's climate goals.
- **Allowances:** Companies receive or purchase emissions allowances, each permitting the emission of one tonne of CO_2 equivalent. If a company exceeds its allowances, it must buy additional allowances from the market.
- **Trading:** Companies can trade allowances, providing flexibility. Those that reduce emissions below their allocated allowances can sell surplus permits, incentivising lower emissions.
- **Monitoring and Reporting:** Participants must accurately monitor and report their emissions annually, ensuring transparency and accountability.
- **Linking with Other Schemes:** The UK Government has expressed interest in linking the UK ETS with other international carbon markets, potentially expanding its effectiveness.

A sector that could be seriously affected is older crackers. By 2025, carbon prices could be around £70 per ton, potentially rising to £100 or more by 2030 and 2035. Older crackers, which typically have higher emissions, may face significant financial penalties, if they do not invest in upgrades or emissions reduction technologies.

Carbon Price Comparison, USD/tCO_2eq



- Goods imported into the UK from countries with a lower or no carbon price will have to pay a levy from 2027, ensuring products from overseas face a comparable carbon price to those produced in the UK. The analogous EU scheme, in the other direction, is CBAM (Carbon Price Adjustment Mechanism).

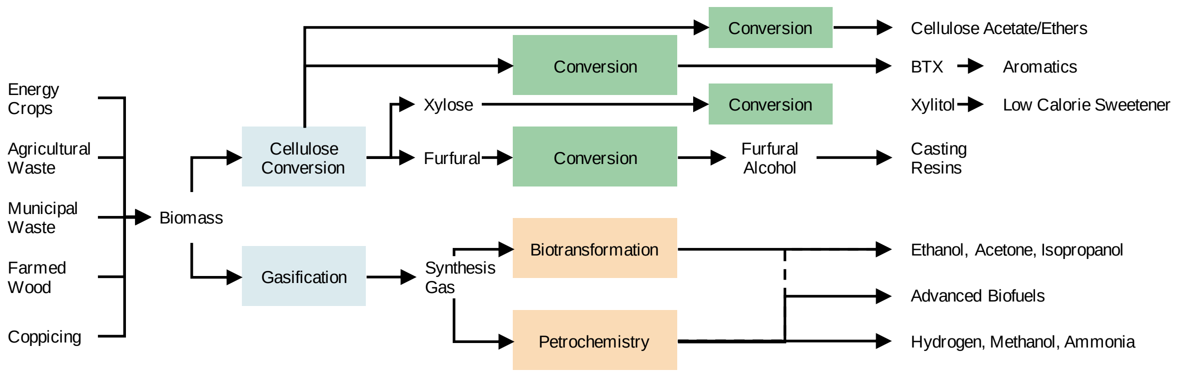
There is therefore an opportunity to optimise the combination of allowances and carbon price, to which UK emitters are subject, so that the total cost to operate is reduced to more internationally competitive levels for high carbon footprint assets.

Updated August 2024.
EU / UK / California CCA from S&P; China prices from CNEEEX.

Sugar operations integrated with biotechnology and petchem would reduce reliance on high cost, fossil-based feedstock

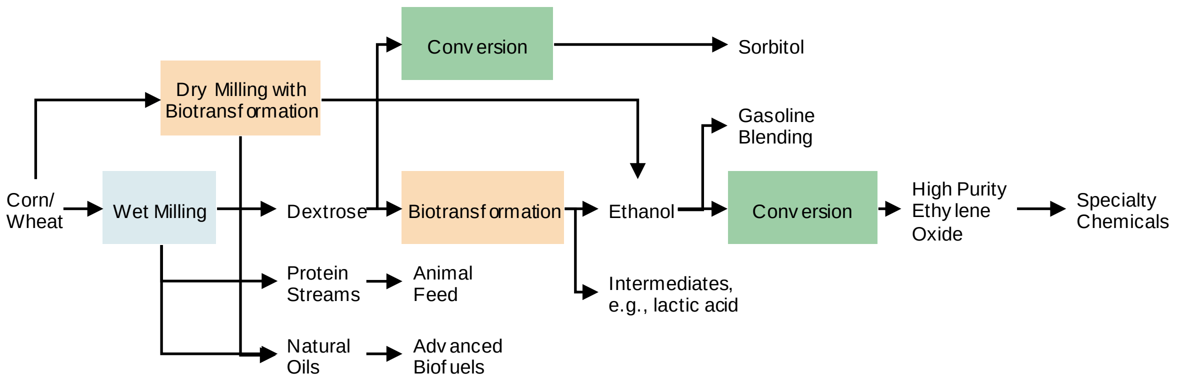
- Indigenous renewable feedstock refers to raw materials sourced locally that are renewable and sustainable, used primarily for producing biofuels, biochemicals, and other bio-based products. These feedstocks are derived from local agricultural, forestry, or waste resources. Using indigenous renewable feedstocks can reduce reliance on fossil fuels, lower transportation emissions, and promote local economic development by utilising regional resources.
- Biomass of various forms is being converted into chemicals through a combination of petrochemical and biochemical means. In theory the simplest approach is to convert biomass from different sources into synthesis gas (a mixture of carbon monoxide, hydrogen, carbon dioxide and water). There are microorganisms that can convert syngas into ethanol and acetone. The petrochemical conversion of syngas is well known and practised at world scale worldwide.
- Processing biomass in certain ways can gain access to cellulose and hemi-cellulose. Enzymes can break down cellulose into sugars that can be biologically or petrochemically converted. High purity cellulose can be derived from certain wood species and used for well-known applications like cellulose ethers and acetate, etc.

Biomass Processing Options



- Virtually all the biotechnology relating to sugars uses dextrose as feedstock. Major industry players like Archer Daniels Midland (ADM), Cargill, etc., operate world-scale corn wet milling operations to produce syrup with high protein animal feed blending components and corn oil as major by-products. In France, Tereos wet-mills wheat to produce dextrose.
- Sugar can be converted using petrochemistry into derivatives. For example, ADM is a leading producer of sorbitol from sugar. This is used not only in confectionery, but also personal care applications and polyurethanes.
- Sugar can be biotransformed into a wide range of chemicals including bioethanol for gasoline and sustainable aviation fuel (via alcohol to jet technology), or products like lactic acid, the building block for the biodegradable plastic – polylactide (PLA). In the UK, grains are not milled. Instead, the sugar produced is sucrose, not dextrose and this is not used generally in biotech applications. In the UK, bioethanol is made from grains via the dry milling process whereby the main by-product is DDGS (distillers dried grains and solubles) used for animal feed. Some by-products like molasses from the sugar beet process to make sucrose can also be used for bioethanol production via fermentation.
- Some microorganisms will need to be genetically engineered to facilitate various chemical pathways within to convert sugars into desired products and intermediates.

Integration opportunities with sugar operations with biotechnology and/or petrochemistry



S&P Global Commodity Insights

Renewable feedstock available from chemical/advanced recycling and scaled-up mechanical recycling facilities could become an important element of the UK feedstock mix

- Bio-naphtha is a renewable hydrocarbon fuel derived from biomass sources. It is typically produced through processes such as Hydroprocessed Esters and Fatty Acids (HEFA), Biomass-to-Liquids (BTL), and Alcohol-to-Jet (ATJ).
- Bio-naphtha is currently used for two major downstream applications which are fuel blending and bioplastics production.
- Furthermore, the chemical recycling of mixed plastic waste leads to “recycled oil” as a raw material, a pyrolysis oil. Using these feedstocks to produce bio-naphtha and new plastics, results in products that do not differ in chemical composition and performance from those made from fossil-based raw materials.
- Incinerating plastic waste not only contributes to CO_2 emissions but also squanders valuable resources. Transitioning to alternative bio-based feedstocks is crucial for achieving climate neutrality and introducing circular products to the market. Additionally, this approach tackles the plastic waste challenge and decreases reliance on fossil raw materials.
- Phillips66 entered the European renewable diesel market in 2018 with its Humber, UK, refinery and is planning to increase capacity to 5,000 bpd by 2024. Although it is unclear whether renewable naphtha will be produced there the capacity likely exists.
- Chemical, or advanced, recycling of mixed waste plastics, complemented by mechanical recycling, is seen by many of the leading chemical companies as key to achieving the industrial-scale capacity required for recyclate supplies to close the plastics loop. In the UK around five million tonnes of plastic waste is generated every year.
- Dow is targeting up to 600,000 mt/year of advanced recycling capacity by 2030 with partner Mura Technology in London, UK. The companies have committed to build five 120,000-metric tons/year facilities across the US and Europe.

- Mura's first pilot plant, in Teesside, UK, is currently in its final commissioning phase and expected to commence operation before the end of 2024. Using Mura's patented HydroPRS™ conversion process, the Teesside facility will initially produce 20,000 mt/year of recyclate, to be ramped up later to 80,000 mt/year.

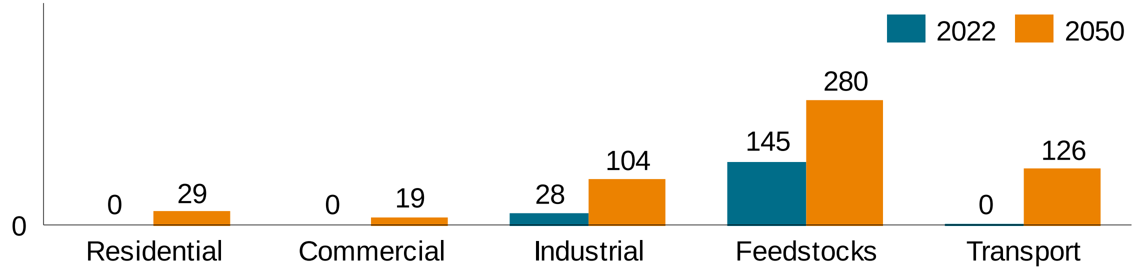
- Aside from chemical recycling, mechanical recycling is still the top option for many plastics as it has the lowest carbon footprint and is the best in terms of minimising overall environmental impact. However, challenges are associated with the sorting and cleanliness of waste plastics. Standardisation of recycling collection and potentially industry-led benchmarking of the purity of sorted waste streams could help to improve the quality and volume of mechanical recycling in the UK.

In addition to direct bottle-to-bottle recycling, there is a diverse array of products (typically non-food-grade) produced from recycled plastic, including:
Refuse sacks and carrier bags
Flowerpots, seed trays, watering cans and water butts
Damp proof membranes, guttering and window profiles
Use in construction
Reusable crates and pallets
Wheelie bins and food caddies
Shampoo or detergent bottles
Polyester fabric for clothing

Green hydrogen (and green ammonia) as a "feedstock" is the start of a supply chain leading to potentially cost advantaged chemicals [1/2]

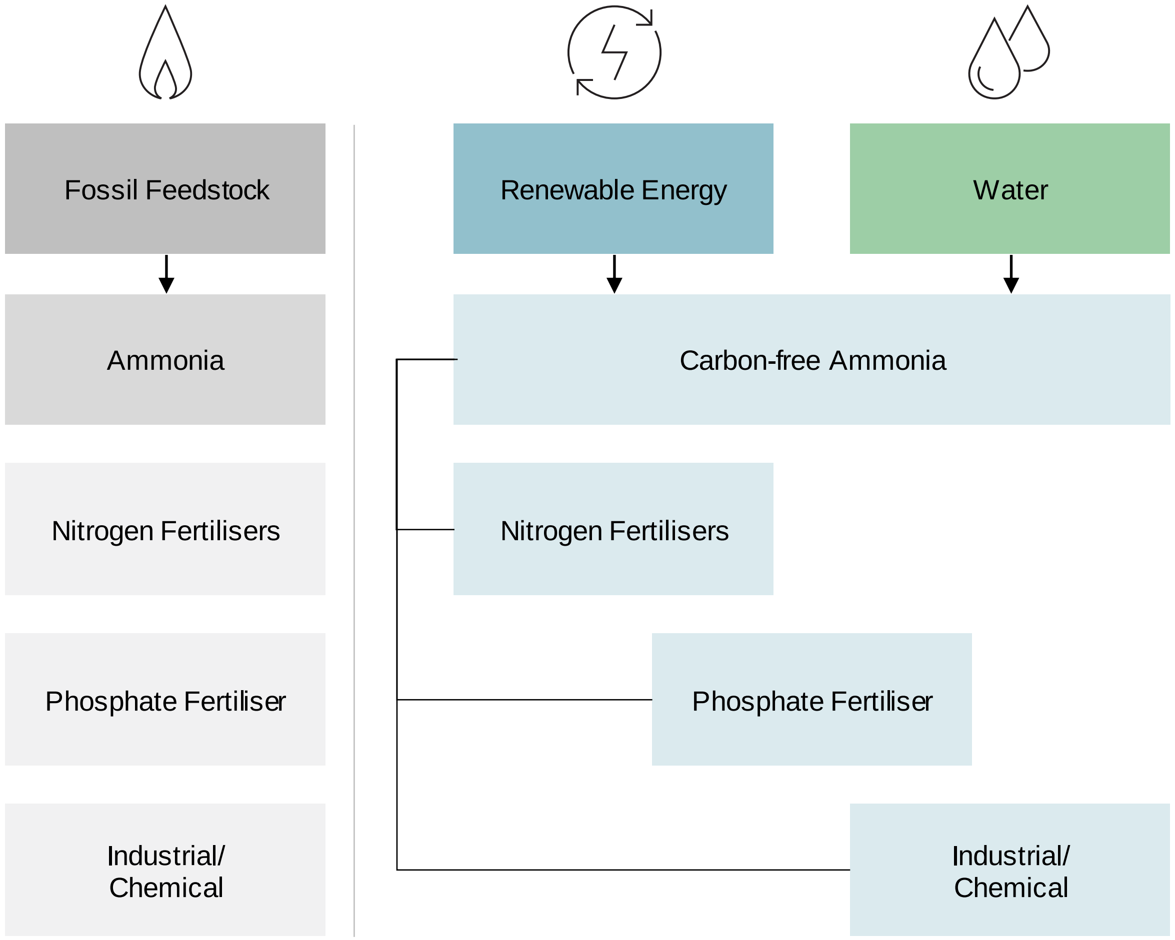
Global Hydrogen demand, 2022 vs 2050

(MMtoe)



- Hydrogen and ammonia will play an important part of the energy mix. Hydrogen end use is dominated by its role as a chemical feedstock, but the transport sector will emerge as the second largest user of hydrogen energy by 2050. Hydrogen can play a strategic role in connecting renewable energy surplus regions with renewable energy deficit regions.
- Green hydrogen plays a crucial role in the decarbonisation of hard-to-abate sectors of the chemical industry. Green hydrogen, powered by renewable energy, offers a sustainable alternative for processes traditionally reliant on fossil fuels. It can be utilised in the production of ammonia and methanol, key feedstocks in the chemical industry. An efficient wind power to hydrogen value chain can play a pivotal role by leveraging renewable energy to produce green hydrogen. Wind power is increasingly cost-effective and scalable. By integrating wind energy with hydrogen production, the chemical industry can meet its large hydrogen demands sustainably.
- Ammonia is one of today's most common chemicals necessary to produce fertilisers. Ammonia is made by introducing nitrogen from the air with hydrogen, derived from fossil fuels. This process is energy intensive and emits significant amounts of CO_2. Global decarbonisation efforts are driving a primary energy shift towards renewable energy. Low carbon ammonia (LC ammonia) primarily includes green ammonia (derived from renewable energy sources) and blue ammonia (derived from fossil fuels but captures and stores the carbon emissions). LC ammonia is viewed as a solution not only to reducing current global CO_2 emissions from agriculture, but also to reduce emissions in industries, power and transport.

The production pathway for low-carbon fertiliser



MMtoe = million metric tons oil equivalent.
Source: S&P Global Commodity Insights.

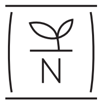
Green hydrogen (and green ammonia) as a "feedstock" is the start of a supply chain leading to potentially cost advantaged chemicals [2/2]

- Ammonia's roles in a low-carbon energy system is transitioning from solely a precursor in agricultural or chemical use to emerging demand sectors where the energy content of ammonia is the determinant.
- Renewable energy may be significantly cheaper if produced in regions with better solar and wind resources. Therefore, there may be a necessity to transport a high percentage of metric tons of oil equivalent renewable energy between the continents. Ammonia can be used as a tool for the transportation of these potentially huge volumes of energy overseas.
- Ammonia represents the most cost-effective method for the transportation of hydrogen, compared to liquid hydrogen and methanol, when large distances are involved. Ammonia demand for marine bunkering is expected to leverage existing storage infrastructure and evolving international trade traffic routes. The non-traditional bunker fuels, such as ammonia and hydrogen, are expected to take more significant shares of the bunker fuel outlook from around 2030 onwards. Ammonia appears to be the favoured fuel, due to its compatibility with LNG – but methanol should not be ruled out.
- Government targets, clean hydrogen standards and the economics of hydrogen in end uses will drive long-term demand for LC ammonia in power generation
- Ammonia can be used as a carrier for hydrogen or directly as power in fuel cells, gas turbines, internal combustion engines and even when co-firing with coal.

The production pathway for low-carbon fertiliser

New demand segments

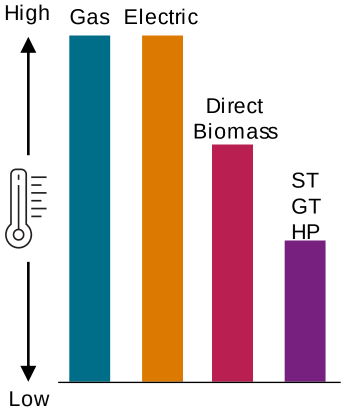
Agriculture - Fertiliser and Chemicals



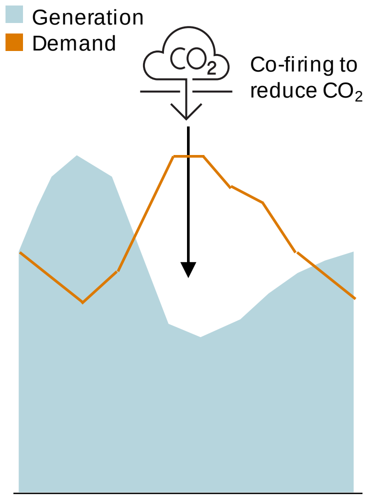
Fertiliser

Grain Miller

Industry – High temperature heat

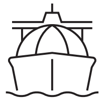


Power generation – Co-firing



Transport – Maritime fuel

Container Ship



LNG

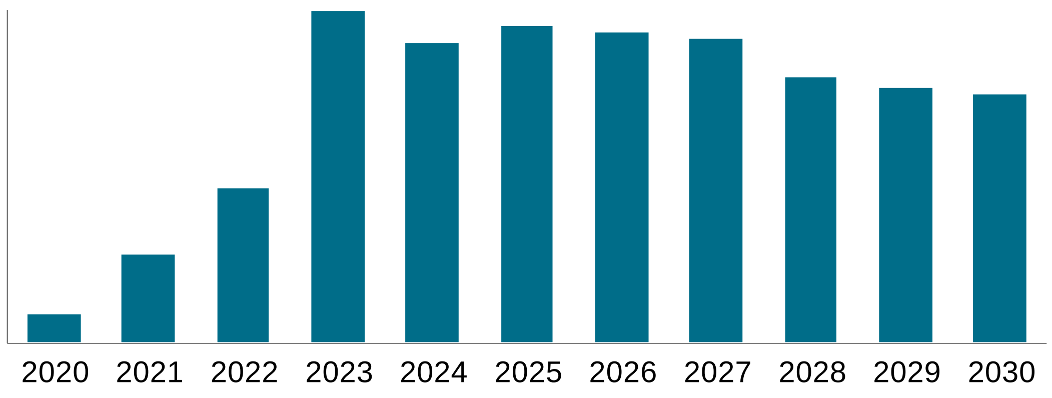
- Another end use for ammonia in power generation is related to storage: renewable energy is intermittent and requires the storage of energy produced when the wind is strong but no immediate demand for electricity. For this purpose, renewable electricity may be converted by electrolysis to hydrogen/ammonia for short-term storage, and then consumed during peak times.
- The growth in renewable energy is driven by improving production economics (solar photovoltaic modules, wind turbines, batteries), government incentives, increasing consumer awareness and the fundamental necessity to decarbonise energy markets.
- The appetite for LC ammonia is growing. SPGCI recognises that some projects may be delayed or cancelled, however this is expected with this evolving market. The overall direction of the market dictates that the supply must increase to meet the demand.

MMtoe = million metric tons oil equivalent. As of June 15, 2023. ST = solar thermal; GT = geothermal; HP = heat pump. Role of Ammonia in a low-carbon energy system is transitioning from solely as precursor in agricultural or chemical uses to emerging demand sectors where the energy content of ammonia is the determinant.
Source: S&P Global Low- Carbon Ammonia Report, September 2023

Scaled up domestic battery production is possible…

- Batteries are essential products in modern, industrialised economies. In recent years, they have grown in importance as they power many of the technologies that will enable the transition towards net zero. Primary uses include personal and commercial transportation and grid-scale battery energy storage systems (BESS), which allow us to use electricity more flexibly and decarbonise the energy system in a cost-effective way.
- A successful battery industry in the UK depends on a skilled workforce proficient across the entire battery value chain and at all levels. Access to these skills has become a crucial factor for companies considering global investments in battery development and manufacturing. A domestic demand focused battery industry could create thousands of jobs by 2040, with most positions expected to be situated outside of London and the South East.
- The positive employment impact of battery production would not just be felt across advanced manufacturing, but also in innovation and R&D.
- The clearest and most urgent requirement for increasing the battery workforce capability and capacity is currently in supporting the expansion of cell manufacturing.
- Recent announcements from AESC UK (in Sunderland) and Agratas (in Somerset) will increase production by at least 52GWh of capacity by 2026. This growth will necessitate the upskilling, reskilling, or new training of over 7,000 manufacturing workers within the next two years.
- Each gigafactory requires a highly skilled workforce to produce high-performance, cost-effective batteries while adhering to strict safety standards.
- The UK is starting to take a global role in the development and optimisation of battery chemistry, supported by the strength of its exceptional research foundation. This needs to be further encouraged with an emphasis on recycling.
- The development of a circular economy would allow for significantly more of a battery's economic value to be kept within the UK economy while reducing dependence on other countries for critical minerals and lowering the environmental impact of battery manufacturing. Developing full commercial recycling capabilities is a significant opportunity for the UK given the growing demand for EVs.
- Recyclus Group (Wolverhampton), is the country's only industrial-scale recycling facility. It is licenced to turn 22,000 tonnes of spent lithium-ion batteries, taken from a range of sources including electric cars, each year.

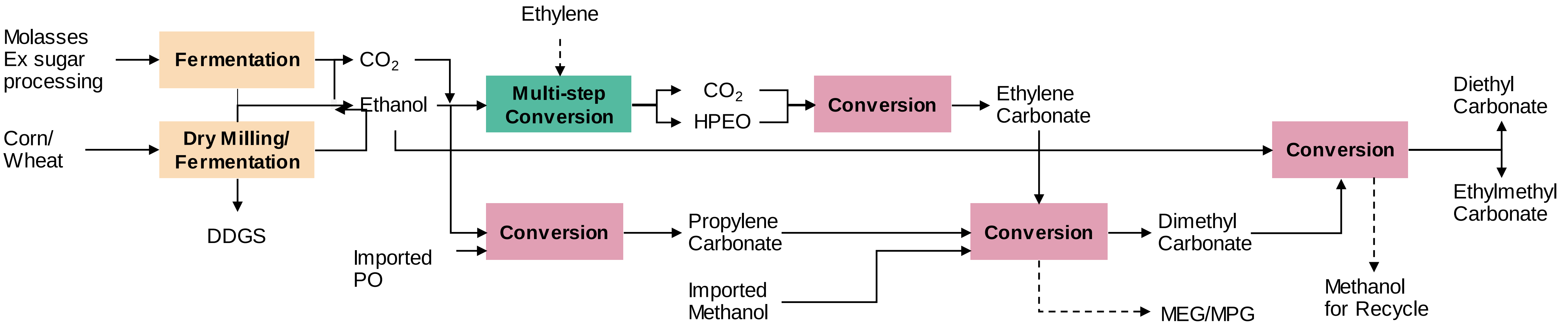
Forecast Energy storage capacity additions in the United Kingdom (MW)



Source: S&P Global Commodity Insights

S&P Global Commodity Insights

…in particular, there is an opportunity for the UK to develop its own battery electrolytes industry based mainly on locally available feedstocks – this will also consume carbon dioxide

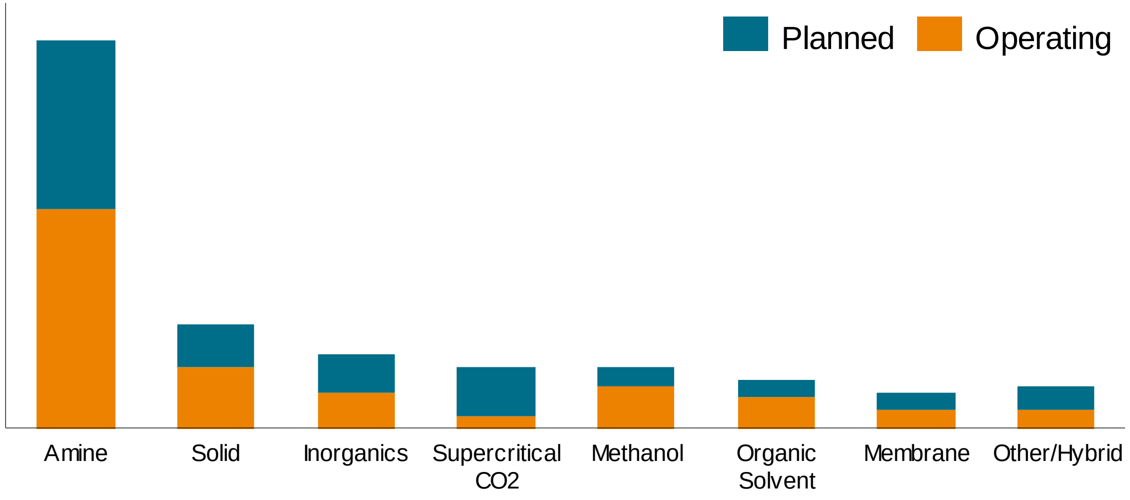


- An example of a battery chemicals value chain that could work in the UK, is the production of electrolytes. The above figure shows the chain of processes starting from technical grade bioethanol. The ethanol can be derived from grains, e.g., Ensus on Teesside or from molasses, e.g., British Sugar at Wissington. Ethanol production via fermentation also generates carbon dioxide.
- There are commercial processes to convert ethanol into high purity ethylene oxide (HPEO) via ethylene as an intermediate. This is designed to operate at intermediate scale rather than large scale plants in the Middle East focused on ethylene glycol (MEG) production. Any 'spare' petrochemical ethylene could also supply this HPEO unit theoretically. Combining HPEO and CO_2 yields ethylene carbonate (EC). In parallel some propylene carbonate (PC) could be made based on imported propylene oxide (PO). Importing HPEO is not an option given its hazardous nature.
- Either of these carbonates could be used to make dimethyl carbonate (DMC) whereby respective glycols would be made as by-products. DMC in the presence of ethanol can be converted into ethylmethyl carbonate (EMC) and diethyl carbonate (DEC).
- The salt lithium hexafluorophosphate is made from lithium carbonate/hydroxide, hydrogen fluoride and phosphorus pentachloride. This salt is dissolved into different carbon solutions to make electrolytes for different battery OEMs for different applications, hybrid vehicles, wholly electric vehicles, energy storage, etc. Hence it is advisable to build a facility with multiple carbonates for blending to meet battery OEM needs.
- The complex is also a considerable consumer of carbon dioxide, so such a complex can also help the UK meet its some of its sustainability goals. As a rough guide, a 250,000 metric tons per year of mixed specialty carbonate could consume around 140,000 metric tons per year of carbon dioxide.

Accelerate carbon capture, utilisation and storage: de-carbonisation without de-industrialisation is possible

- The UK features unique geological characteristics that enable it to potentially store between 20 to 30 million tonnes of CO_2 each year by 2030. This capacity is comparable to taking four to six million cars off the roads annually and could create around 50,000 jobs.
- Realising this potential by establishing CO_2 transport and storage networks could create valuable national assets capable of storing both domestically produced and internationally imported CO_2. Government-commissioned analysis suggests that this market could reach a value of up to £54 billion by 2050.[1]
- The government has announced a substantial investment of up to £20 billion, potentially one of the largest in Europe.
- CCUS can facilitate the swift expansion of low-carbon hydrogen production to satisfy growing demand from various sectors, including transport, industry, and buildings. Cleaner blue hydrogen is a crucial factor in driving the UK market. In collaboration with industry partners, it is estimated that the UK could establish 10GW of low-carbon hydrogen production capacity by 2030.
- The UK Government has allocated £21.7 billion for carbon capture and low-carbon hydrogen projects under its Track 1 industrial cluster decarbonisation program. This funding supports initiatives like HyNet in the North West and the East Coast Cluster around Teesside in the North East. The projects, set to begin in 2028, aim to remove over 8.5 million metric tons of CO_2 annually.
- HyNet's blue hydrogen project, led by EET Hydrogen, is nearing a final investment decision and is poised to become the UK's first large-scale blue hydrogen plant. The East Coast Cluster includes BP’s H2Teesside blue hydrogen plant and other decarbonisation projects. The UK targets 4 GW of blue hydrogen production by 2030 and aims for significant CO_2 capture and storage capacity.
- The government plans to open the HyNet CCS cluster to more companies by 2030 and has awarded Track 2 status to other CCS projects. Despite some environmental concerns, the initiative is seen as crucial for meeting the UK's climate targets.

Global CCS Projects by Technology



- A range of technologies have been developed for use in carbon capture, many of which have so far been used only in a limited capacity at industrial scale.
- Of emerging technologies, metal organic frameworks (MOFs) and high surface area solids show promise for absorbing large volumes of CO_2 at competitive costs.
- Cost is a key consideration in the development of a CCS technology.
- While some projects are developed to meet obligations, the widespread uptake of a technology is only incentivised when either it becomes lower cost than paying emission penalties (carbon taxes etc.) or it is otherwise encouraged by legislation (tax incentives, subsidies etc.).

Source: (1) Energy Innovation Needs Assessment: Carbon capture, utilisation, and storage. (October 2019). As of February 2024
Source: S&P Global Commodity Insights

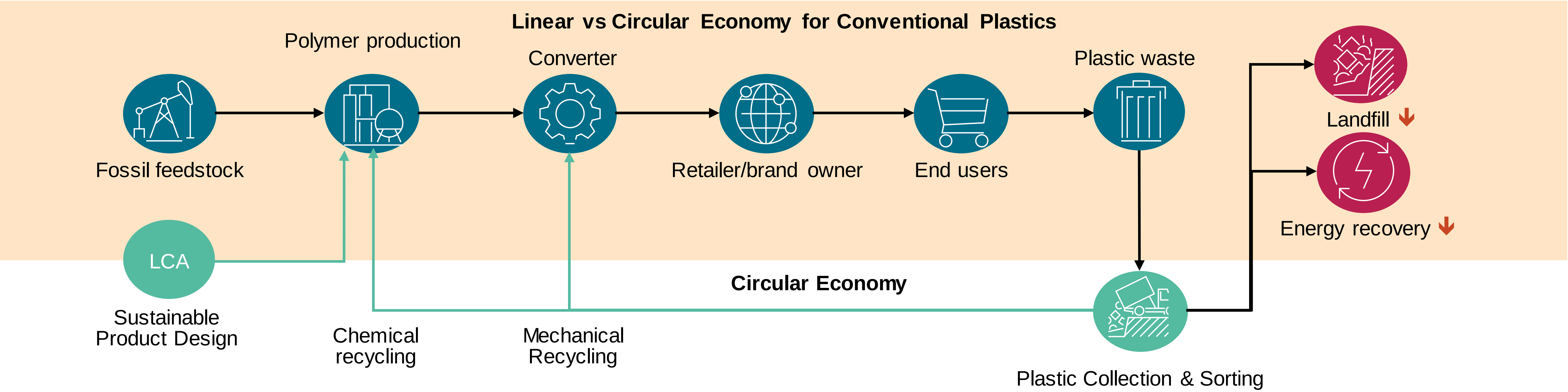
Increased availability of skilled technicians/engineers is an issue

- The availability of specialised and skilled operators and technical personnel in the UK, particularly for Engineering, Procurement, and Construction (EPC) and operations, is influenced by various factors, including industry demand and training programs. The UK has a strong educational framework with universities offering relevant degrees. However, sectors like energy and construction are facing shortages due to an aging workforce and the need for new skills in emerging technologies.
- The number of science apprenticeships has decreased from 2016 to 2020. Data indicates that there were 3,150 new science apprentice starts in the 2019-2020 academic year, compared to 5,200 new starts in 2016-2017.[1]
- Concurrently, there is a significant challenge in attracting and retaining individuals in technical roles within the UK. The availability of career information seems to impact apprenticeship uptake. According to data from the Careers and Enterprise Company, schools that offered comprehensive information about various apprenticeships to most or all students saw an uptake that was approximately 16% higher than those that provided information to only a small minority.
- Additionally, ASPIRES2 found that students intending to pursue apprenticeships were 1.68 times more likely to have received careers education than their peers planning to enter full-time employment.
- Additionally, the UK Government and industry bodies need to work on initiatives to attract talent through apprenticeships and partnerships with educational institutions.
- To address this shortage we see several strategies, partly implemented.

Education and Training Programs	Collaborate with educational institutions to develop specialised courses and degree programs tailored to the chemical industry including apprenticeships
	Continuous Professional Development (CPD): Encourage ongoing training and certification programs for existing employees
Industry Collaboration	Foster collaborations between industry players and academic institutions to ensure that the curriculum aligns with industry needs and that students gain practical experience through internships.
	Engage with professional bodies and associations to develop industry-wide standards and certifications that ensure a consistent level of expertise among professionals.
Government Initiatives	Provide financial incentives, such as grants or tax breaks, to companies that invest in training and development programs for their employees.
	Implement policies that make it easier for skilled workers from other countries to work in the UK, addressing immediate shortages while local talent is being developed.
Technology and Innovation	Invest in automation and digital technologies that can enhance productivity and reduce the reliance on manual labour. This includes the use of AI and robotics in chemical processes.
	Support R&D initiatives that focus on developing new technologies and processes that can streamline operations and reduce the need for highly specialised skills.
Workforce Planning and Development	Conduct regular assessments to identify current and future skills gaps within the industry. This can help in planning targeted training programs and recruitment strategies.
	Develop talent pipelines by engaging with schools and universities early on, promoting careers in the chemical industry, and offering scholarships and internships to attract young talent.

Source: (1) Royal Society of Chemistry

Opportunities to recycle not only plastics but also other valuable materials in the UK are substantial; but scaling up volumes will require an overhaul of the "collection ecosystem"



- Recycling covers multiple development areas with a focus on the following:
  - **Plastics recycling:** This involves the processing of collected and separated domestic as well as industrial plastics waste via chemical and mechanical means to respectively provide recompoundable and/or blendable plastics for fabrication, moulding, etc., and potentially low-carbon feedstocks for chemical building block production, e.g., ethylene and propylene for virgin polymer production. Initial major focus on various packaging solutions, to support major brand-owner sustainability targets and those increasingly driven by legislation from governments, the European Commission, etc.
  - **Battery materials/electronics:** Cost-effective and environmentally-sensitive technologies to recover lithium, rare earth elements and electrolyte solvents, are needed to reduce reliance on rare earth sources especially from countries with much less environmentally favourable conditions.
  - **Wind turbine/aircraft:** Recovering carbon fibre from composites for wider use in automotive and construction industries. Future recovery of polymer components, e.g., epoxy resin building blocks, from composites for re-use.
  - **Solar panel recycling:** Recovery of silicon to reprocessing and other essential materials of construction, e.g., specialty plastics.

Contents

Note: this is an abridged version of the original full report. In this document some pages have not been included and some data, e.g. chart units, have been deliberately left blank

Appendix 1:
Value of the Chemical Industry

Supporting information for Section 1

(1990-1999) the chemical industry saw the last steam cracker built in the UK, namely the KG NGL cracker in Grangemouth, onstream in 1993 – a unique event in challenging times

Mergers and acquisitions

- The 1990s witnessed significant consolidation in the UK chemical industry, characterised by numerous mergers and acquisitions. Prominent UK chemical companies like ICI saw their assets and operations being acquired by international firms. For example, ICI's chloro- and fluorochemicals businesses were acquired by INEOS, a major player in the global chemicals market.
- Other notable acquisitions included the merging of Shell's polyolefins unit with BASF's to form Basell, which was later acquired by Access Industries and merged with Lyondell in 2007.

Company closures and name changes

Several household names and spin-off companies from industry majors ceased to exist independently due to acquisitions. Companies such as: Laporte, Inspec, Avecia, Acordis, BTP, Ascot, Allied Colloids, Albright and Wilson, and BOC, were either absorbed or rebranded under new ownerships.

Foreign ownership

By the end of the decade, many UK chemical production plants were owned by non-UK companies. This shift in ownership was a significant trend, with names like SABIC, Huntsman, Valero, Polimeri, Degussa, Linde, Lonza, Essar, Lucite, BASF, Rhodia, Rockwood, Tata, Fujifilm, and Aurelius appearing on former UK-owned sites.

Industry growth and decline

Despite the changes in ownership and the consolidation, the UK chemical industry remained significant. In 2010, it was reported that chemical production in the UK totalled $93.5 billion[1], making it the tenth-largest in the world at that time. However, it had ranked eighth just two years earlier, indicating a relative decline in its global standing.

Specialty chemicals and pharmaceuticals

The UK established a strong position in specialty chemicals with companies like Croda, Johnson Matthey, Elementis, and Yule Catto leading the market. The pharmaceuticals sector also saw significant success, with GlaxoSmithKline and AstraZeneca becoming two of the world's top-ten drug companies headquartered in the UK.

(1) American Institute of Chemical Engineers

(2000-2009) This decade witnessed new players coming to the fore and regulatory challenges for the UK chemical industry, combined with the financial crisis

Further consolidation and acquisitions

- The trend of mergers and acquisitions continued into the 2000s, with significant transactions reshaping the industry landscape. For instance, Akzo Nobel acquired ICI in 2008.
- The acquisition of BP's olefins and derivatives business by INEOS in 2005 was another pivotal event, further consolidating INEOS' position as a major player in the global chemical industry.

Emergence of new players

- New companies emerged from the restructuring of existing businesses. For example, INEOS, originally a small player, grew rapidly through strategic acquisitions to become one of the largest chemical companies globally by the end of the decade.
- Other notable new entrants included Lucite International, formed from the acrylics (MMA/PMMA) businesses of ICI and DuPont, which was later acquired by Mitsubishi Rayon.

Global financial crisis impact

- The global financial crisis of 2008 had a significant impact on the UK chemical industry, leading to reduced demand and production cuts. Many companies had to restructure and streamline their operations to survive the economic downturn.
- Despite the challenges, the industry showed resilience, with some sectors, such as pharmaceuticals, continuing to perform well during the crisis.

Regulatory changes

The introduction of the EU's REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) regulation in 2007 imposed new compliance requirements on the industry. Companies had to adapt to these stringent regulations, which aimed to protect human health and the environment from the risks posed by chemicals.

Focus on sustainability

- The 2000s saw a growing emphasis on sustainability and environmental responsibility within the UK chemical industry. Companies increasingly adopted green chemistry practices and invested in sustainable technologies to reduce their environmental footprint.
- The EU's Circular Economy Package, which began negotiations in the late 2000s, aimed to transition to an economy where the value of products, materials, and resources is maintained for as long as possible, and waste generation is minimised.

The decade from 2000 to 2009 was marked by continued consolidation, the emergence of new players, and significant regulatory and economic challenges. Despite these hurdles, the UK chemical industry demonstrated resilience and adaptability, maintaining its position as a key player in the global market through technological advancements and a focus on sustainability.

S&P Global Commodity Insights

(2010-2019): Steam cracker capacity falls as Grangemouth G4 closes in 2013-2014, while KG then moves to imported ethane (ex shale gas)

Post-Financial Crisis Recovery	The UK chemical industry began to recover from the global financial crisis of 2008, with gradual improvements in production and investment levels. The sector showed resilience, rebounding with a focus on innovation and efficiency to regain its competitive edge.
Brexit Uncertainty	The announcement of the Brexit referendum in 2016 and the subsequent vote to leave the European Union introduced significant uncertainty for the UK chemical industry. Concerns over regulatory changes, market access, and potential tariffs impacted investment decisions and strategic planning.
Investment in Innovation and R&D	There was a strong emphasis on innovation and R&D to drive growth and competitiveness. The UK chemical industry invested heavily in new technologies, with a focus on developing advanced materials, green chemistry, and sustainable processes.
Growth in Specialty Chemicals and Pharmaceuticals	The UK continued to excel in specialty chemicals and pharmaceuticals. Companies like Croda, Johnson Matthey, and GlaxoSmithKline remained leaders in their respective fields, contributing significantly to the industry's overall performance. The pharmaceutical sector, in particular, saw robust growth, driven by advancements in biotechnology and the development of new therapeutic products.
Sustainability Initiatives	Sustainability became a central theme, with the industry adopting various initiatives to reduce its environmental impact. Efforts included improving energy efficiency, reducing emissions, and increasing the use of renewable resources. The UK chemical industry aligned itself with the United Nations Sustainable Development Goals (SDGs) to contribute towards environmental and social objectives.
Regulatory Adjustments	The industry had to navigate regulatory changes, including adjustments to comply with both existing EU regulations and the uncertainty around new UK-specific requirements post-Brexit. Ensuring compliance while maintaining competitiveness was a critical challenge during this period.

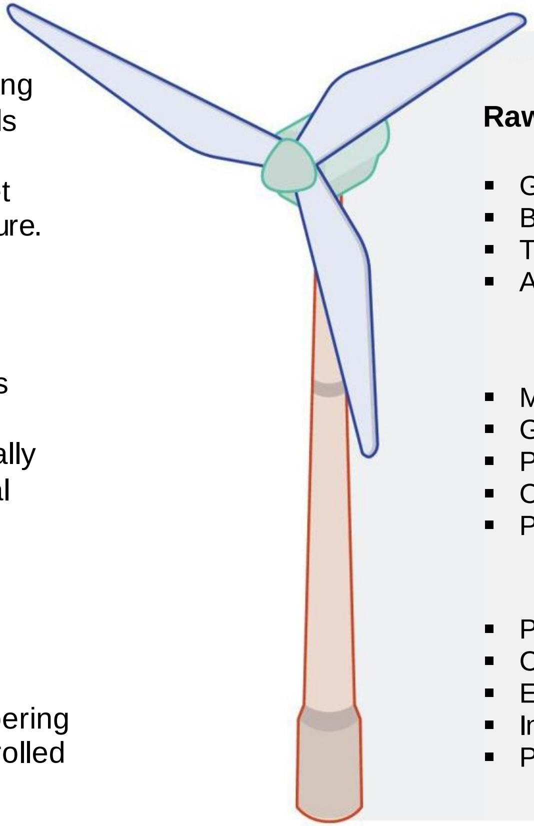
The decade from 2010 to 2019 was marked by recovery from the financial crisis, Brexit-related uncertainties, and a strong focus on innovation and sustainability. The UK chemical industry continued to adapt and evolve, maintaining its position as a vital contributor to the national and global economy through strategic investments and regulatory compliance.

S&P Global Commodity Insights

Production of each primary component of a wind turbine requires dedicated and specialised facilities due to differences in materials, sub-components and equipment needed

Raw materials and infrastructure of a wind turbine

Low | Medium | High | Labour intensiveness | Scalability | Degree of standardisation | Proprietary



Blades

A blade is manufactured using layers of composite materials bonded with resin, and then finished into a lightweight yet durable aerodynamic structure.

Raw materials and/or components used

- Glass fibre and carbon fibre.
- Balsa wood and PET (Polyethylene terephthalate).
- Thermoset and thermoplastic resins
- Adhesives and coatings.

Factory requirements

- Blade moulds.
- Cutting, trimming and laminating equipment.
- Infusion, curing and surface finishing systems.
- Cranes and hoists.

Nacelle Assembly

A nacelle consists of various sub-components, each with distinct supply chains, typically not manufactured at the final assembly facility.

Raw materials and/or components used

- Main frame.
- Generator and gearbox assembly.
- Pitch, yaw, and breaking systems.
- Control systems.
- Power electronics and transformers.

Factory requirements

- Assembly lines and automation systems.
- Equipment and software testing stations.
- Cranes, hoists and assembly fixtures.

Towers

A complete turbine tower is assembled from multiple tapering sections constructed using rolled steel plates or reinforced concrete.

Raw materials and/or components used

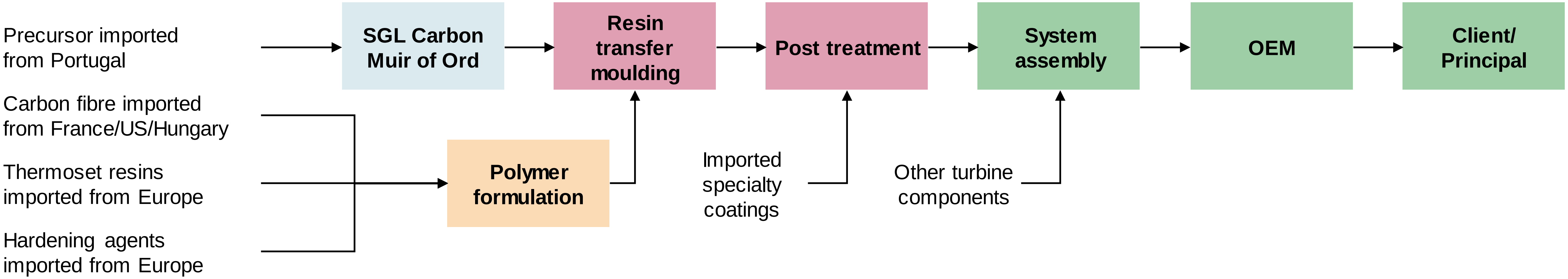
- Plated steel and iron castings.
- Concrete and steel rebar.
- Electrical cabling and internal lift systems.
- Insulation materials.
- Paints and coatings.

Factory requirements

- Plate rolling machines.
- Welding and cutting stations.
- Sandblasting and painting stations.
- Cranes and hoists.
- Concrete preparation and pouring systems.

As of March 18, 2024
Source: S&P Global

The UK plays a role in wind turbine blade manufacture given its local carbon fibre supply and blade manufacturing operations on Humberside and on the Isle of Wight



- The UK does provide raw materials for wind turbine blades. The SGL Carbon Muir of Ord (near Inverness) plant makes some SIGRAFRIL® grades suitable for wind turbine blade production. Some OEMs in the industry may have preferred carbon fibre suppliers. For example, Toray, a leading carbon fibre player acquired Zoltek around ten years ago and revamped its asset base to improve quality. Zoltek offers its PX® 35 for turbine blade production.
- Turbine blades require formulated epoxy thermoset resins. The resin will be combined with a selected curing agent, typically a specialty amine system.
- In Europe, the leading epoxy resin producers serving wind turbine blade production include Hexion (formerly the Shell epoxies business) with bases in Germany and Spain, as well as Olin (acquired Dow Inc., assets) in Germany and Italy. At Baltringen in Germany, Olin manufactures specialty additives that act as curing agents for epoxy resins. The amine-based hardening agents are chosen specifically for wind turbine resin formulations.
- Companies such as Gurit use large scale resin transfer moulding techniques to ‘cast’ a turbine blade. The process is slow as the epoxy resin is viscous and difficult to pump. The cycle time for a turbine blade is a minimum of 24 hours. Companies are looking for faster solutions that can reduce costs, improve cycle whilst not compromising blade performance. Ideas under serious development include a polydicylopentadiene (poly-DCPD) system where the resin has the viscosity of water and cures much faster than an epoxy.
- Some specialty coatings are used to treat the turbine blade for protection and improved aerodynamics.
- Blades are then shipped to wind farm locations for final assembly by specialised teams in the OEM’s operations to serve the client which can include private companies, energy companies, governments and even chemical companies such as BASF SE.

Chemicals have been, and are, fundamental to the constant efficiency gain of solar power, in particular fluoropolymer-based backsheets and EVA-based encapsulants

Sector definition

The photovoltaic (PV) materials generally consist of the following:

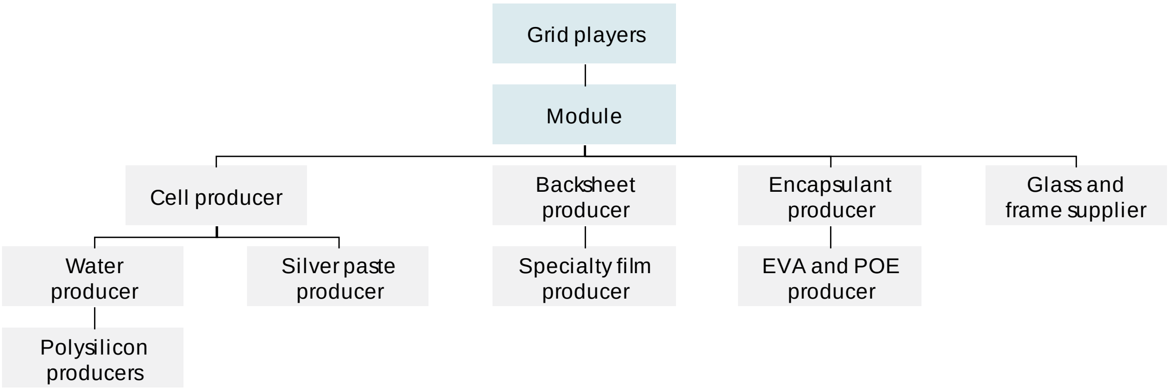
- Cell materials, including polysilicon, single silicon and silver paste.
- Backsheet materials, including fluoropolymers, PET and polyolefins.
- Encapsulant materials including EVA and POE.

The manufacturing of PV modules starts with the production of wafers, which are then assembled into cells and then to modules. Worldwide, nearly 97% of the wafers are produced in mainland China and shipped worldwide for assembly into PV cells and modules.

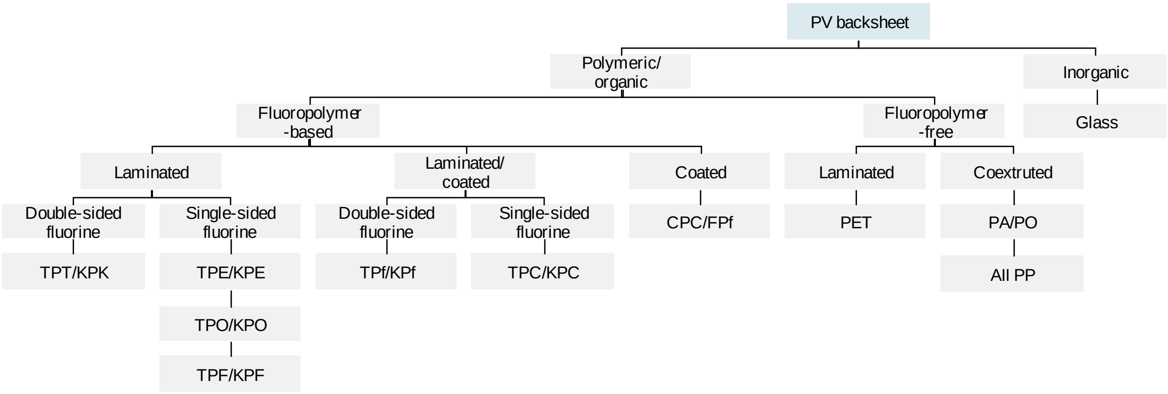
The polymer-based backsheet market is still dominated by fluoropolymers (PVDF and PVF). PVF films are mainly produced in Europe and North America and imported by mainland China to produce backsheets and PV cells, while nearly all the PVDF film is produced in mainland China. FFC (fluororesin coating) has been developed as a thinner specialty polymer film to reduce the thickness of fluoropolymer.

EVA and POE dominate the encapsulant market, with EVA accounting for 84% of the global consumption in 2022. Like PVF films, POE films are mainly imported by mainland Chinese encapsulant producers from Europe and North America.

Industry structure



Classification of backsheet materials



As of February 27, 2023
Source: S&P Global

Despite substantial growth potential, photovoltaic (PV) installation in the UK has been restrained by supply chain issues and electric grid weaknesses

UK PV market summary

PV market drivers

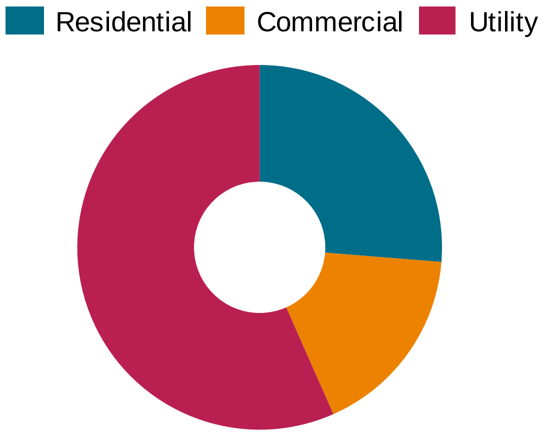
- Smart Export Guarantee (SEG) scheme.
- Contracts for difference (CFD) scheme.
- Power purchase agreements (PPAs).
- Merchant solar.

Forecast

- SPGCI forecasts 25.5 GW of solar photovoltaic (PV) to be installed in the United Kingdom between 2022 and 2030. This number will likely increase if government support continues in the latter half of the decade.
- 14.6 GW of utility scale installations are expected between 2022 and 2030.

- While the utility segment has been impacted by the supply chain, residential and commercial rooftop installations continue to grow in the UK and appear unimpacted.
- Commercial scale additions between 2022 and 2026 are expected to be 2.2 GW, while residential additions will be just over 3.4 GW.

SPGCI forecasts 13 GW of PV capacity to be added in 2022–26



PV policy

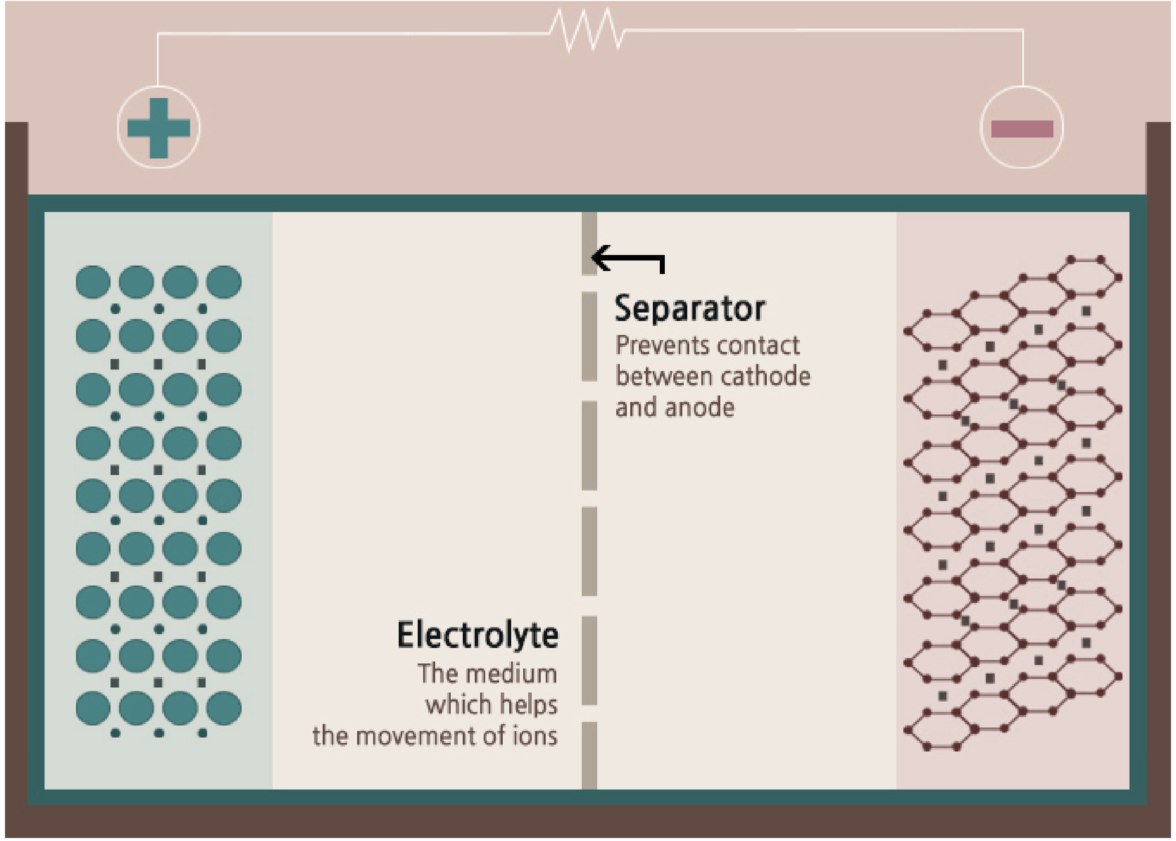
- On 1 January 2020, the SEG became effective, involving an export tariff being offered to households or small businesses.
- The Future Homes Standard requires new builds to produce 31% less carbon dioxide (CO_2) emissions from June 2022 and will require 75% lower emissions by 2025.
- Rooftop solar PV will be exempt from business rate rises from April 2023
- Solar PV was reintroduced to Round 4 of the CFD, with 2.2 GW of projects successful.
- The government's latest target is for electricity to be powered by 100% clean sources by 2035.
- On 18 July 2022, the English High Court ruled that the UK Government was required to produce a new Net Zero Strategy (NZS) by March 2023 detailing how a shortfall of 5% in required emissions reductions will be met.

Market hurdles

- Global supply chain constraints have resulted in lower-than- expected solar PV installations globally, and the United Kingdom is no exception
- PV module production capacity continues to increase along all nodes of the module supply chain.
- There is increased competition in the supply chain as the UK market doubled in 2022 and the global market bounced back post–COVID-19.
- Grid weakness in some areas has severely curbed connections, with ongoing grid infrastructure to be rolled out throughout the decade to support utility scale projects.

Source: S&P Global Commodity Insights

What is inside the Li-ion battery cell?



Cathode

The source of lithium ions, determines the capacity and the average voltage of a battery.

Anode

Stores and releases lithium ions from the cathode, allowing the pass of currents through an external circuit.

Source: Samsung SDI

Inside the Li-ion battery contains four main components: Anode, cathode, electrolyte and separator

- **Anode**: Keeping Li-ions stored when battery is charged and releasing Li-ions and electrons back to cathode when discharged. The most popular material used for the anode is graphite.
- **Cathode**: Contributing Li-ions through the channel of electrolyte and electrons to be stored at anode side. The higher amount of lithium, the bigger the capacity; and the bigger potential difference between cathode and anode, the higher the voltage. Common cathodes in the market include NMC, LFP, NCA, LMO and LCO.
- **Electrolyte**: Chemical medium that helps transport the positive Li-ions between the anode and cathode. Providing Li-ions with a good conductivity while maintaining a good thermal stability and a wide operable voltage window. The electrolyte is composed of salts, solvents and additives. The most common solvents are a mixture of carbonates while salts in the electrolyte are lithium salts
- **Separator**: Located between the anode and cathode is the separator, which is a thin sheet of material that allows the lithium ions to pass through but does not conduct electricity. It prevents the anode and cathode from shorting together electrically and forces the electrons to flow through your electronic device, giving it power.
- **Binder**: An additive that helps the active materials and conductive agents adhere to the current collector like an adhesive. Binders can have a significant impact on battery performance. In particular, a repeated charge-discharge cycle of a battery can result in a change in anode volume, undermining battery life and charging time.

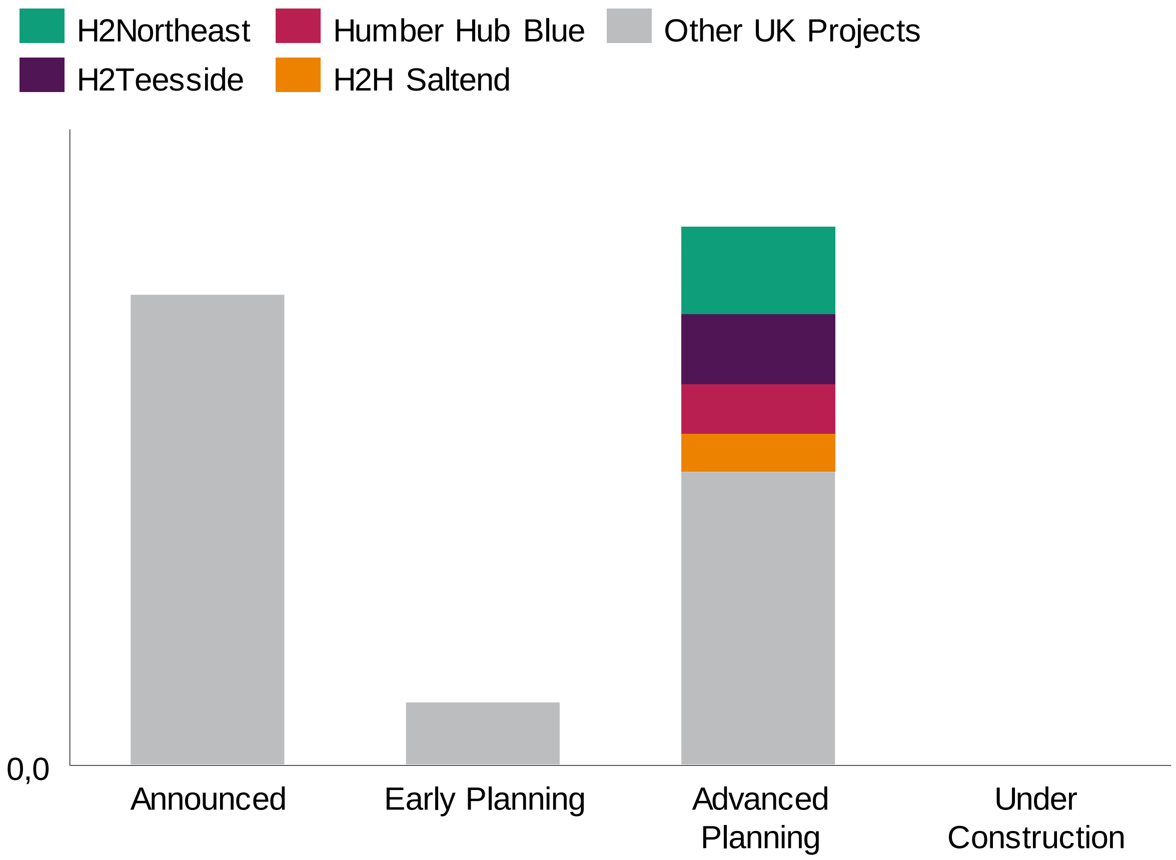
Spotlight: UK East Coast Hydrogen Cluster

Over half of advanced-stage capacity in the UK is in the East Coast Cluster

- The East Coast Cluster is a group of hydrogen and other CCS projects that plan to build CO_2 pipelines from Teesside and the Humber to a storage site in the North Sea.
- This site was chosen to be one of the first CCUS clusters by the UK Government.
- The four hydrogen projects that are a part of the cluster make up a third of the UK's hydrogen pipeline and include
  - H2Teesside — 160,000 metric tons per year; partners: BP PLC, Abu Dhabi National Oil Co. (ADNOC).
  - Humber Hub Blue — 189,000 metric tons/year; partners: Shell PLC, Uniper SE.
  - H2NorthEast — 357,000 metric tons per year; partners: Kellas Midstream Ltd., SSE Thermal Energy Operations Ltd., RWE AG
  - H2H Saltend — 160,000 metric tons/year; partners: Equinor ASA, Px Group Ltd., Triton Power Partners LP, Associated British Ports, BP, Centrica PLC.

Capacity by phase including projects in the UK East Coast Cluster

(MMt H2 per year)



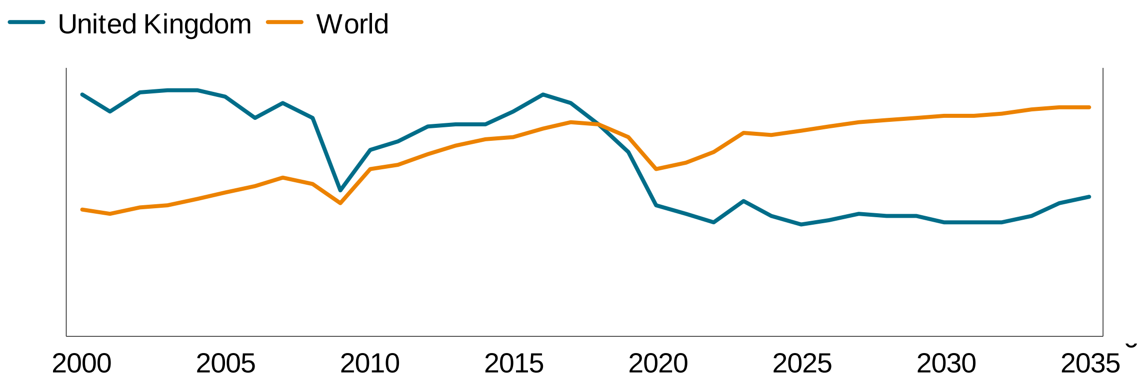
As of March 12, 2024.
Sources: S&P Global Commodity Insights; East Coast Cluster.

The fundamental trend in Automotive is unquestionably the penetration of EVs which has the potential to offset the projected decline in UK total vehicle production

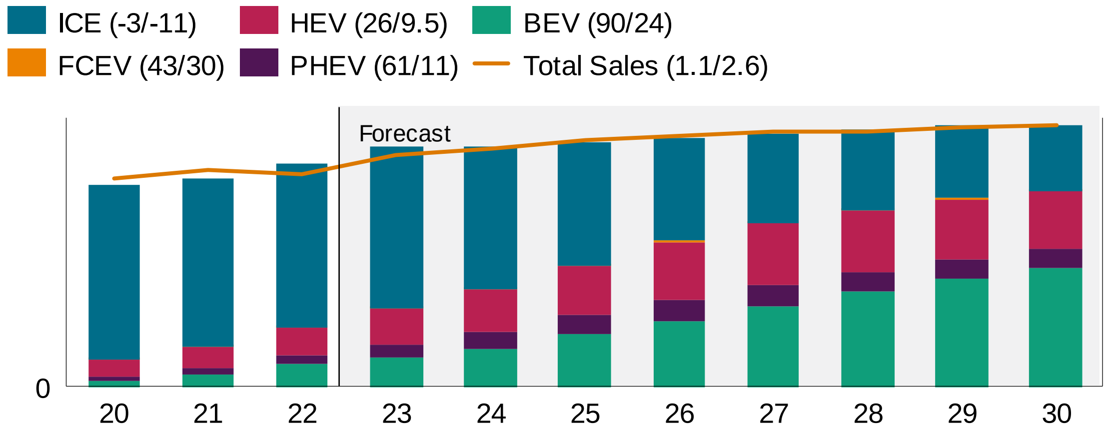
Sector Definition

- The UK automotive industry plays a crucial role in the country's economy, generating significant funding through tax revenues. The sector has been a pioneer in vehicle taxation based on carbon dioxide (CO_2) emissions, with taxation regimes for company cars and Vehicle Excise Duty now based on CO_2 emission bands.
- The UK has a mature light-vehicle market with a large manufacturing and component supply network. Light-vehicle production has fallen in recent years, but efforts are being made to attract business back to the UK, especially in battery production.
- The UK Government has been actively supporting the growth of the electric vehicle market through initiatives such as grants for electric vehicle purchases, funding for EV charging infrastructure expansion, and measures to improve air quality and reduce emissions.
- S&P Global Mobility expects 65% of the global light vehicle production outlook to be Battery Electric Vehicles (BEVs) by 2035.
- EV player volumes are forecasted to reach 10 million p.a. units by 2035.

Light Vehicle Production Forecast (Million Units)



World: Light Vehicle Production and Sales (Million units)



(% CAGR = 20-22 / 22-30)

Source: S&P Global Commodity Insights.

S&P Global Commodity Insights

EV penetration relies on advanced chemicals in batteries and new materials in the car

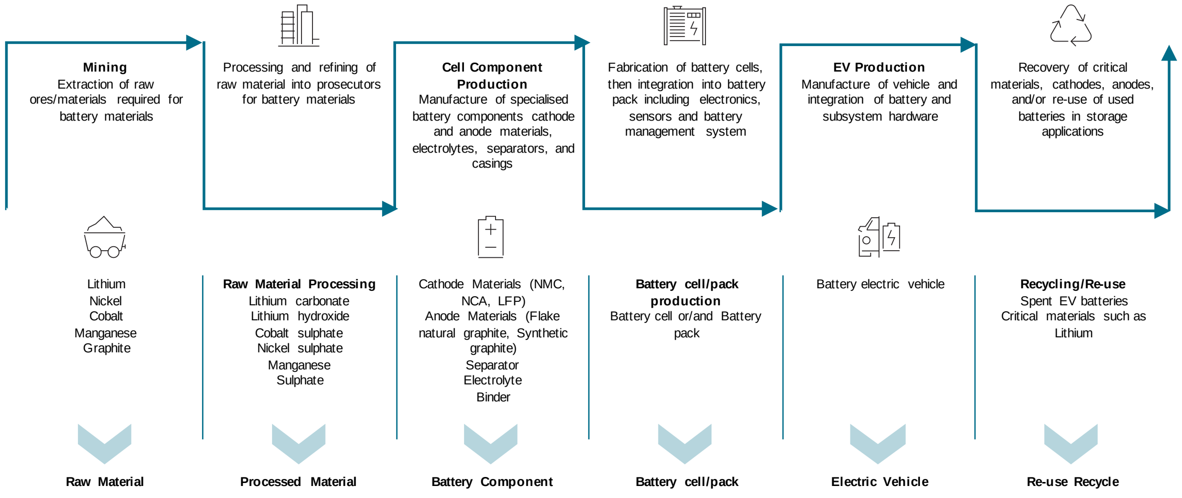
Advanced chemicals in batteries refer to the development of new battery technologies and materials that improve energy density, charging speed, and lifespan. Innovations such as solid-state batteries and the use of lithium-sulphur or silicon anodes promise to increase the efficiency and performance of EV batteries, making them lighter and more effective.

In order to achieve mainstream adoption of electric vehicles, there are several critical elements that future batteries must possess. These include increased energy density, increased power density, increased life span & recyclability, larger temperature range, reduced cost and eliminating thermal runaway at pack level to reduce pack complexity. These advancements are necessary to encourage a decisive shift away from traditional internal combustion engines to fully electric vehicles.

Lithium-ion (Li-ion) dominates battery technology, but new technologies build market share starting in the late 2020s. Investments in battery technology grow, strongly propelled by investments from EV manufacturers, with conventional Li-ion batteries dominating the space based on continuous improvements in energy density and cost. However, a range of different battery technologies also emerge that are developed to increase performance, reduce reliance on volatile metals and/or reduce cost. Solid-state batteries are adopted in some EVs in the late 2020s and by 2030 account for 30% of batteries consumed by that sector.

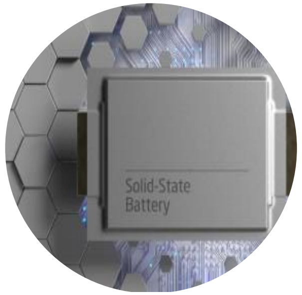
In the early 2020s, the electrification of transport accelerates, with automotive manufacturers meeting their commitments to various emissions standards and targets that are imposed around the world. This uptake of EVs is the predominant driver of global battery demand. Uptake of EVs continues throughout the 2030s, and electric models are starting to dominate the offerings of all major automotive OEMs (varies by market). Policy support continues to be strong, and gradually reducing battery costs help make EVs increasingly competitive with ICEs. This drives continued growth in battery demand. Beyond the 2040s, light vehicle (LV) sales begin to be dominated by EVs, driving continued strong demand for batteries out to 2050.

The value chain of batteries as part of EV production



Sodium-Ion Battery

Solid-State Battery



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It is customary to refer to the global biotechnology industry by means of colours that designate particular sectors and technologies, generally aligned with end-use industries

Red biotechnology

'Red biotechnology' focuses on pharmaceutical applications and can take various forms from therapy development, e.g., developing a COVID-19 vaccine, through to using natural feedstocks and fermentation to develop various building blocks and even using microorganisms to separate chiral (left-handed and right-handed) molecules.

Blue biotechnology

'Blue biotechnology' focuses on aquaculture, and this can include deriving nutraceuticals from aquatic sources, enhancements to aquatic farming through to exploiting oceanic feedstocks like algae and seaweed, etc.

Green biotechnology

'Green biotechnology' focuses on land-based agriculture and can cover areas like animal husbandry, e.g., feed ingredients for methane emissions reduction from cattle. Plant biotechnology is also included to improve crops yields, disease resistance, e.g., modifying jatropha plants to increase oil content closer to palm oil.

White biotechnology

- 'White biotechnology' covers a wide range of activities with a major emphasis on the use of microorganisms to perform chemical reactions. These microorganisms can perform chemistry with naturally sourced oxygenates, typically sugars but even work on hydrocarbons.
- The term has also expanded to include a wider range of processing naturally occurring raw materials, some converted with or without microorganisms.
- It also includes cases where petrochemistry can be performed with natural raw materials. This is especially the case when biomass processing is considered.
- The core of the technology remains that of microorganisms effecting chemical conversions, even converting CO_2 into desirable chemicals.
- Over the last 20-25 years there has been a converted effort worldwide to develop and commercialise bio-based chemistries for commodity and specialty chemicals. This has met with mixed success as many development companies including some in the UK have failed to commercialise their processes as full scale and in effect run out of money. The drivers were often around low carbon, sustainability, theoretical cost-competitiveness, etc
- Key to developing new processes in this field is the collaboration of developers with organisations that can facilitate cost-effective scale-up, partners with finance and know-how, especially when petrochemistry was combined with biochemistry, etc. This can include microorganism genetic engineering.
- In the specialty chemicals sector, there have been successes, given generally lower scale, lower capex and a focus on performance.

S&P Global considers “white biotechnology” to cover several disciplines beyond simply the use of biotransformation (fermentation) processes. Some examples are given here for clarity

Integration opportunities with sugar operations with biotechnology and/or petrochemistry

- Virtually all the biotechnology relating to sugars uses dextrose as feedstock. Major industry players like Archer Daniels Midland (ADM), Cargill, etc., operate world-scale corn wet milling operations to produce syrup with high protein animal feed blending components and corn oil as major by-products. In France, Tereos wet mills wheat to produce dextrose.
- Sugar can be converted using petrochemistry into derivatives. For example, ADM is a leading producer of sorbitol from sugar. This is used not only in confectionary, but also personal care applications and polyurethanes.
- Sugar can be biotransformed into a wide range of chemicals including bioethanol for gasoline and sustainable aviation fuel (via alcohol to jet technology), or products like lactic acid, the building block for the biodegradable plastic – polylactide (PLA). In the UK, grains are not milled. Instead, the sugar produced is sucrose which is not used generally in biotech applications. In the UK, bioethanol is made from grains from the dry milling process whereby the main by-product is DDGS (distillers dried grains and solubles) used for animal feed. Some by-products like molasses from the sugarbeet process to make sucrose can also be used for bioethanol production via fermentation.

Natural oil operations with biotechnology and/or petrochemistry

- South East Asia provides the majority of natural oils used in chemical processes. Palm kernel oil (PKO) for example contains fatty acids with carbon numbers suitable for making surfactant building blocks. Tallow fats and oils as well as castor oil are also used in certain applications as raw materials. There are many ways to process natural oils and fats. A simple fats-splitting approach is assumed on the following page. This generates fatty acids.
- A conventional petrochemical approach can convert fatty acids into alcohols. These alcohols can be converted further into non-ionic surfactants through ethoxylation with high purity ethylene oxide, which itself may be derived from petrochemical or ethanol-derived ethylene.
- Fatty acids can also be treated using microorganisms that can convert these into di-acids. These are used to make high performance nylon products which, when compounded, find use in truck hydraulic systems, aerospace hydraulics, renewable energy platforms, etc.
- The same microorganisms can also convert normal paraffins derived from kerosene into these diacids demonstrating that microorganisms can convert certain hydrocarbons from conventional petrochemical processes into new products.

The figures on the follow page illustrate the wide range of products and manufacturing approaches that could be considered part of the world of industrial biotechnology

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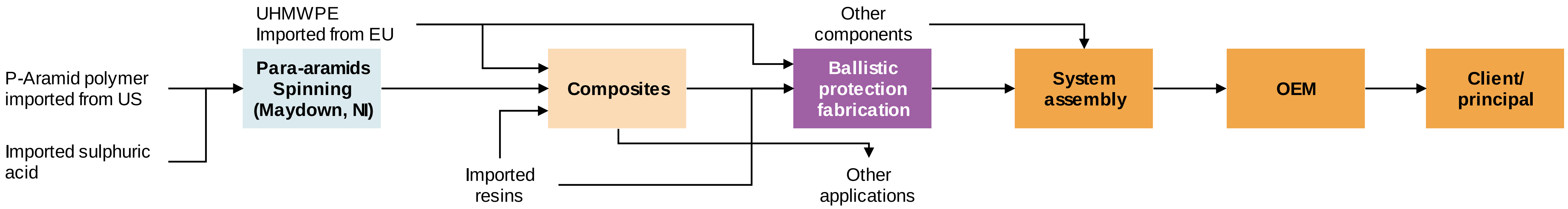
White biotechnology can include the conversion of CO_2 through a combination of petrochemical and bio-based chemistries

Carbon dioxide processing options

- There is already a worldwide industry in producing chemicals from carbon dioxide employing sunlight in so-called photobioreactors. This family of processes falls under the white biotechnology umbrella.
- The most significant application of this technology to date is the production of certain nutraceuticals, notably astaxanthin. In the right location, photobioreactors can make astaxanthin in volumes of around 200-500 metric tons per year. Natural astaxanthin can command market prices of $80-$150 per kilogram. Astaxanthin can be synthesised in a multi-step pathway from citral (derived from isobutylene and methanol) but commands a significantly lower market price.
- There are major efforts in converting carbon dioxide in chemicals using biochemistry, electrochemistry (e.g., for formic acid) and reduction, e.g., with green/blue hydrogen for low carbon methanol.
- The concept of photobioreactor conversion is gaining traction. In the UK, the company Cyanocapture is looking to capture carbon dioxide for sequestration. However, Photanol in the Netherlands has a different approach.
  - The company was established in 2008 as a spin off from the University of Amsterdam with support from Private Equity firms.
  - Technology applied to lactic acid, glycolic acid, erythritol and 1,3-propanediol.
  - Photanol has multiple patents granted. The company's patent for lactic acid (US20130071895A1) was granted in 2010.
  - The company has developed some strategic partnerships with Corbion (formerly Purac) and also Nouryon (formerly part of Akzo Nobel).
  - In 2019, Photanol established a small demonstration facility on the Nouryon site in Delfzijl in the Netherlands. The company is looking to transit to full scale by the end of the decade.
- Ideas like using microorganisms to convert carbon dioxide into specialty chemicals has significant scope for innovation in the UK.
- Cyanobacteria can be modified through genetic engineering to introduce various reaction steps powered by enzymes to convert carbon dioxide into desirable chemicals.

Source: With kind permission from Photanol

Defence sector value chains: Ballistic protection derived from advanced fibres and specialty resins as well as some selected commodity resins



- Ballistic protection is a significant industry in the UK. There are some players in this business including Aegis Engineering Ltd. and NP Aerospace, although in recent years, some companies like Solo International Ltd. have exited the business. These players operate in the fabrication and assembly part of the value chain.
- The British Army now uses the Mark 7 helmet which uses a KEVLAR® fibre supplied by DuPont. DuPont operates a KEVLAR® fibre spinning facility in Maydown, near Londonderry in Northern Ireland, i.e., within the UK. The fibre is spun in 100% sulphuric acid. Make-up volumes are imported as INEOS closed its UK facility. The polyaramids polymer is made in the US and imported.
- Different types of ballistic protection require not only aramid fibres but also ultra-high molecular weight polyethylene (UHMWPE), e.g., DYNEEMA®. Avient acquired the DSM business in 2022. Other materials can be used in tandem such as high tenacity nylon 6,6 (CORDURA®).
- Different resins are used in armour fabrication. These can include epoxies, polyimides, etc., some of which are not made in the UK. Some applications may use more commodity-like resins including high density polyethylene (HDPE) and polypropylene (impact grade PP).
- Body armour fabrication is very different to helmets, knee pads, etc. However, most value chains include assembly where various attachments are added to the unit, e.g., attachment for bodycam.
- While the Maydown operation is small at 4000 metric tons per year, it is still a high margin product.
- Companies like Huntsman make specialty resins in Switzerland for advanced composites, based on imported raw materials. Is there an opportunity to attract such companies to invest the UK?

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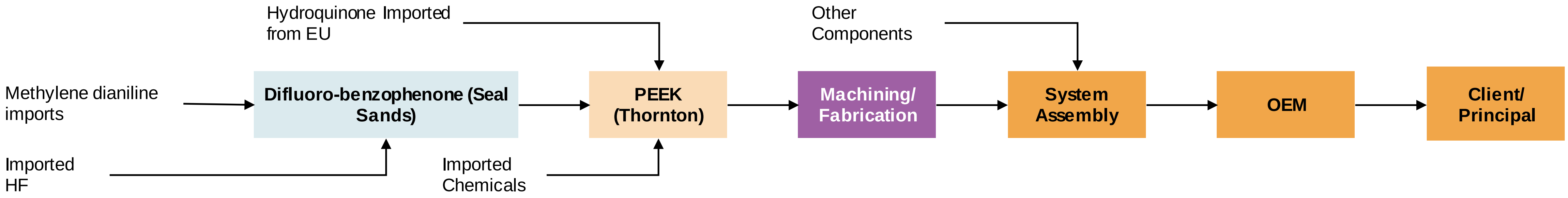
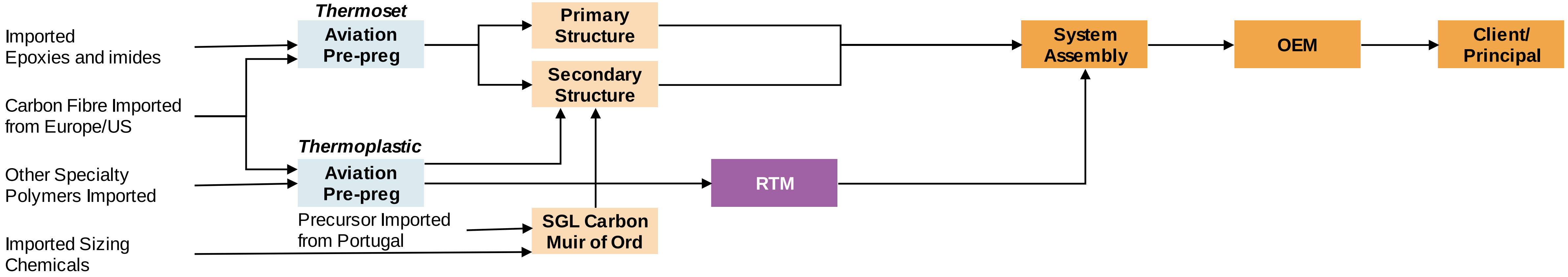
Defence Sector Value Chains: The UK has a world-leader in Victrex in the polyether – etherketone (PEEK) sector of high-performance thermoplastics use in battlefield electronics



- The Victrex plc business dates back to the time of ICI Chemicals, being established in around 1989. The company expanded its facility in Thornton in Lancashire around 10 years ago and now operates around 7000 metric tons per year of capacity to make PEEK and some PEK (polyetherketone).
- The company is basic in one monomer 2,2-diflurobenzophenone as it acquired the Degussa business in Seals Sands. The company needs to import the feedstocks for this fluorinated aromatic compound namely hydrogen fluoride (HF) since Koura closed its facility in Cheshire. Methylene dianiline (MDA) may be sourced from Huntsman facilities in Rozeburg as MDA is an intermediate in the isocyanates chain.
- Hydroquinone (from the phenol chain) is also imported. Some other chemicals like caustic soda can be sourced locally while others like acetone are imported. Once PEEK is made it is a difficult material to manipulate because of its properties. PEEK can be machined like metal as well as moulded.
- PEEK is used to make various component holders for battlefield electronics as well as multiple applications in selected high wear components in armoured vehicles, military aerospace, and so on.
- Fabricated components are used in system assembly – radios, electronic counter-measures, radar systems. There are a number of companies in this value chain from specialised contractors like Roke through to larger brands like BAE Systems.
- Victrex operates in a high growth business where it has a technical edge today. However, China is developing its own PEEK capacity, although quality and certification remain a challenge.
- These are small volume, high margin products that are profitable. Is there an opportunity to support new initiatives in high-performance thermoplastics, e.g., supporting he commercialisation of PEKK (polyetherketoneketone)? Arkema makes PEKK under the KEPSTAN® brand in Couterne, France. The company acquired the technology from Oxford Performance Materials in 2009. Perhaps this was an opportunity lost and there is need to support commercialisation efforts in novel advanced polymers.

S&P Global Commodity Insights

Defence Sector Value Chains: Military Aviation and the Role of High-Performance carbon fibres and composites – Can UK plc attract specialty resin producers to invest upstream



- The aviation industry as a whole relies on access to high performance carbon fibres for commercial use where the OEMs are mainly airlines, military (fixed wing, swing wing, and rotary), and civilian (police and rescue services). Airbus, for example makes the wings for the A380 and A350 in Cheshire. A special aircraft nicknamed the 'Beluga' flies the wing to Toulouse for aircraft assembly.
- Carbon fibre is used to make the primary structure – the plane's airframe superstructure as well as secondary structure. In the UK, for example Hexcel Industries imports high modulus grades from France to its Duxford site for primary structure. Toray can provide similar grades, but SGL cannot. Hexcel imports bismaleimide resins from Huntsman in Switzerland and a range of specialty epoxies from Germany, etc., to make thermosetting pre-pregs for fabricating primary structure. Secondary structure can be made using thermoset pre-pregs and techniques like resin transfer moulding (RTM). Lower performance carbon fibre grades are used. With suitable sizing agents, carbon fibres can adhere to selected high performance thermoplastics like polyphenylene sulphide used by Airbus in the wing leading edge for the A350/A380.
- Military aviation puts greater demand on the carbon fibre used in its structure. The F-35B 'Lightning' uses higher modulus (hence higher cost) carbon fibre grades, e.g., TORACA® T1100MM from Toray given the performance needs of the airframe. Lockheed Martin has subcontracted F-35 manufacturing to multiple organisations including BAE Systems in the UK. Pre-preg panels are baked under controlled conditions under vacuum to form key components for the fighter jet production.
- Some processes like Airbus and Boeing aircraft production are semi-automotive with robots "painting" moulds with pre-pregs. Military tends to be small scale and may involve hand assembly. More thermosets are being used, but cautiously as specifications are very tight as is the administration and approvals around audit, quality, etc.
- As in the case of ballistic protection, some of the specialised resins are made in countries like Switzerland with limited upstream. Could some players be persuaded to come and invest in the UK to support the growing defence sector?

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Appendix 2: Chemical Industry Evolution

Supporting Information for Section 2

Compared to commodity petrochemicals and fine chemicals for active pharmaceutical ingredients, specialty chemicals have some unique characteristics

Characteristics	Base Chemicals	Specialty Chemicals	Fine Chemicals
Market drivers	Price/availability	Performance/Service	Quality/documentation/availability
Production	Continuous	Generally batch	Generally batch
Volume	High	Medium	Low
Variety	Low	Very high	High
Products	Standard	Customised	Standard
Product form	Pure	Pure / formulated	Molecules
Innovation	Process	Product/End-use	Product
Price per metric ton	< $3000	> $3000	> $20000
Sensitivity to raw material cost	High	Medium	Low
Service offered	Minimal	High	Some
Purity	80–99.5%	90 - 98 %	> 99.995%
Government authorisation	Registration	Registration; Approval	Approval and control
Markets	Multiple	Multiple	Single
Sustainability	High	High	Medium

S&P has focused on a basket of chemicals and selected segments to define the dynamics of the chemical industry and some key projections long term

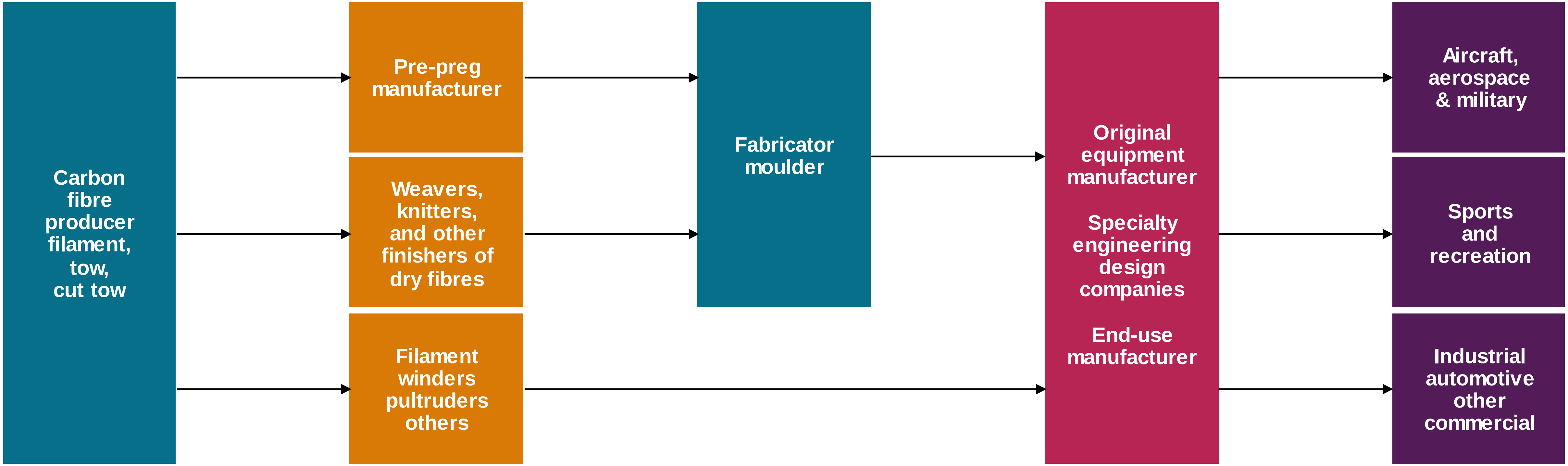
Building blocks
Chlor-alkali
Ethylene
Hydrogen/Ammonia
Methanol
Propylene
Sugar

End use chemicals
Carbon fibres
Fluoro-materials (e.g., PVDF)
Polyolefins
PVC
Resins (formaldehyde-based)
Vitamins

Industry segments
Aerospace
Automotive
Clean energy:
▪ Wind power
▪ Solar power (PV)
▪ Energy storage
▪ CCS/CCUS
Construction
Food and drink
Industrial biotech

Carbon fibre industry structure and dynamics

- Most of the world's large carbon fibre producers are forward-integrated into tape, fabric, and prepreg manufacturing, and occasionally into filament winding and other composite fabrication processing. A prepreg is composed of fibre reinforcement (tape or fabric) embedded in a thermoset polymer matrix or a thermoplastic matrix. Prepregs can be manufactured using resin-coated film, molten resin, or wet resin. Carbon fibre prepregs are mainly based on epoxy resin, but high-temperature-resistant thermoplastics are also available.
- Carbon fibre tapes and fabric used in sports, recreational products, and industrial parts are generally sourced from an independent prepregger or fabricator, and in some cases directly from a fibre producer (as depicted in the following figure displaying the structure of the carbon fibre composites industry).



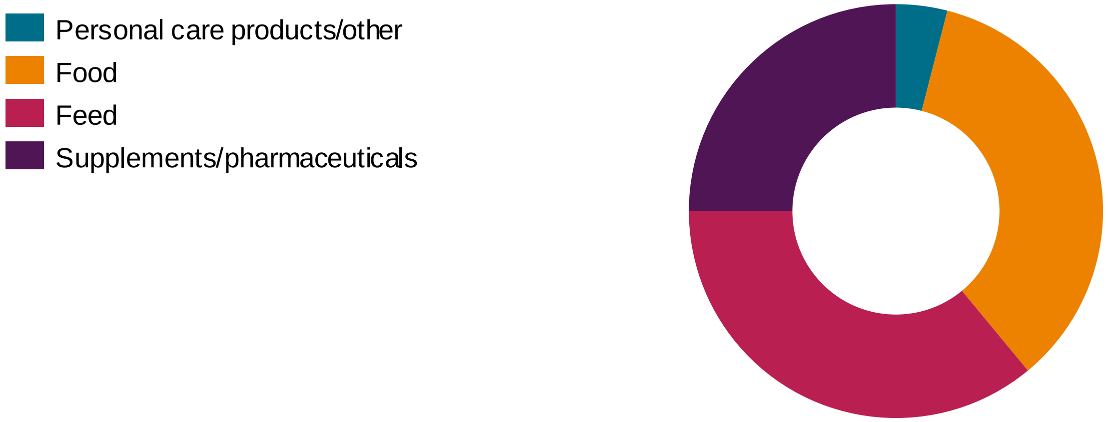
S&P Global Commodity Insights

UK vitamins supply, demand and trade

- There is only one producer of vitamins in the UK and this is DSM located in Dalry, North Ayrshire, Scotland. They produce 15,000 metric tons of Vitamin C and Vitamin B5 is also produced on site.
- Vitamin C is by far the most highly consumed vitamin in the world and accounts for around 50% of global vitamin demand.
- Western Europe as a whole is a major producer of vitamins, second only to mainland China as a source of micronutrients. The largest producers in the region include DSM Nutritional Products, BASF, Adisseo France, and Lonza. (All of these companies have significant vitamin manufacturing operations outside of Western Europe as well).
- In 2023, mainland China accounted for around 76% of vitamin production, versus 18% for Western Europe and 3% for India. Mainland China was also responsible for the majority of global exports. In contrast, the United States was the largest importer of vitamins.

West Europe consumption of vitamins

By end use 2023



World vitamin consumption

By type 2023

Source: S&P Global Commodity Insights.

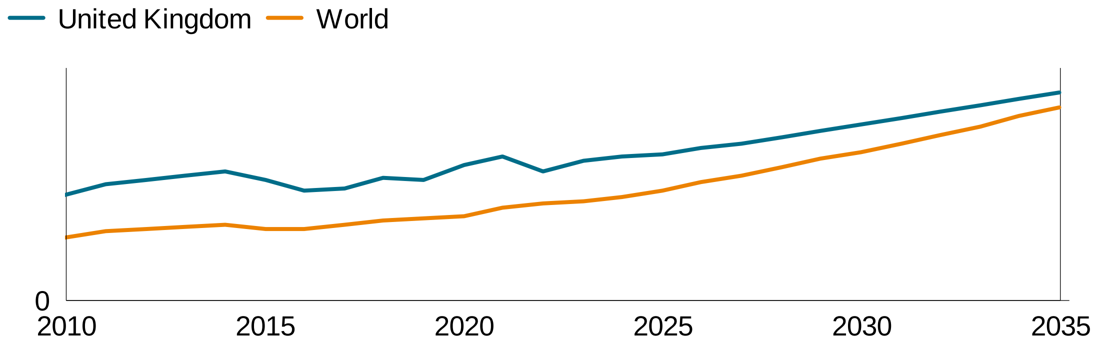
The food and drink (F&D) sector in the UK is not just very large in terms of turnover but is also growing, driven by secular trends. F&D additives will continue to “grow with the growth”…

Sector definition, drivers and trends

- The UK food and drink industry is the largest manufacturing segment by turnover, valued at £104.4 billion and with exports of over £23 billion in 2019.[1] Total consumer expenditure on food, drink and catering was £254 billion in 2022. The food and drink sector employed 3.7 million people in the UK in 2022 accounting for 12.1% of total employment.
- Major trends that are impacting the global food and drink industry include an increased demand for convenience and rising living standards in developing countries that are increasing demand for processed food. In more established markets such as the UK, the drive is more towards healthier lifestyles with considerations such as:
  - Increased interest in healthy food.
  - Growing preference for natural ingredients.
  - Changing demography — aging populations, rising healthcare costs and interest in self-care and alternative medicine.
  - Rising awareness about health and wellness, understanding the links between nutrition, mood and mental well-being.
  - Changing lifestyle, driving the growth of on-the-go breakfast and plant-based foods.
  - Increasing scientific understanding of the link between diet and health and validation of nutrient efficacy.
  - Innovations leading to the availability of bioactive natural compounds and to production of better tasting and less expensive natural ingredients.
  - The obesity epidemic and reduction of sugar intake.
  - The need to increase shelf life and reduce waste.
  - The drive towards convenience and the need to facilitate food processing.

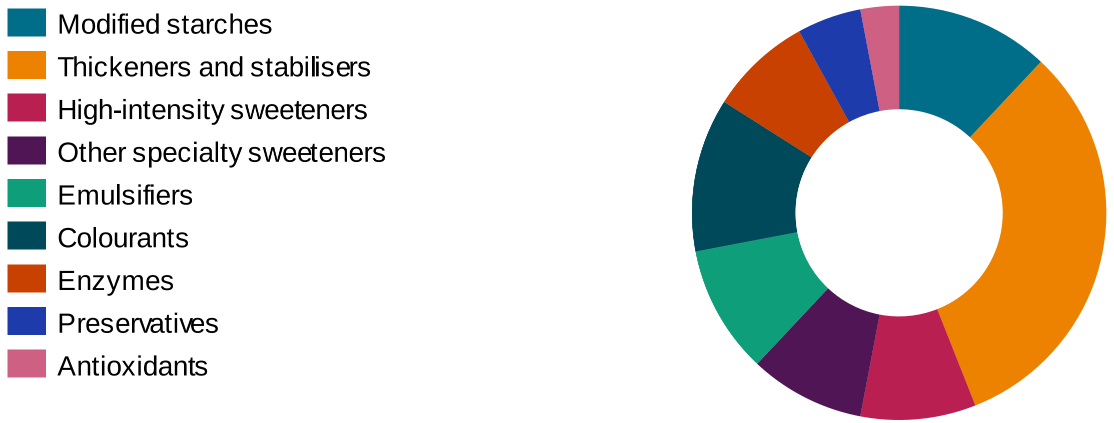
Total consumer food and drink spending

Billion US$



Global consumption of food additives

By type



1 This information is provided by the Department for Business and Trade and used as permitted by the Open Government Licence v3.0
Source: S&P Global Commodity Insights.

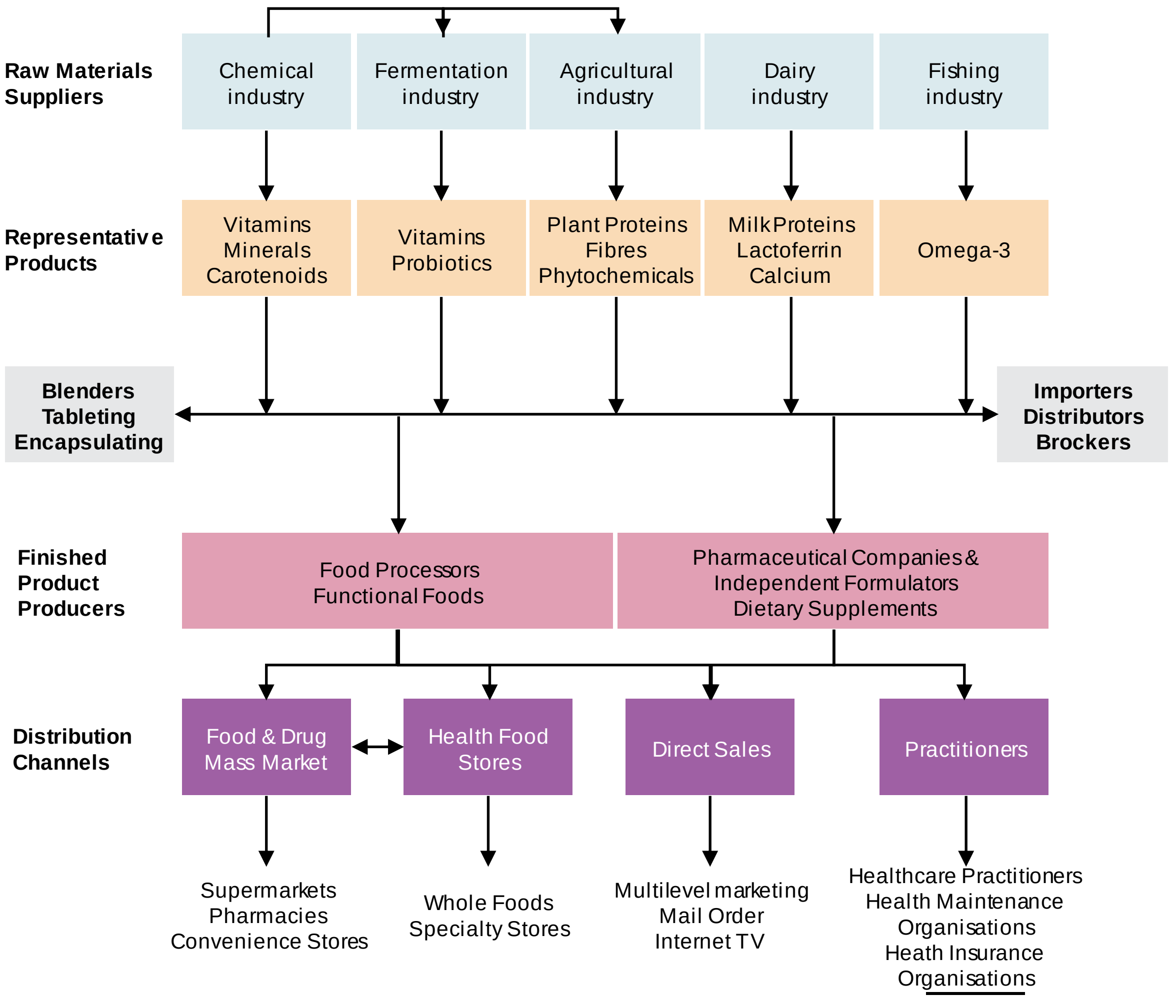
S&P Global Commodity Insights

Food and drink – Nutraceuticals

Sector definition, drivers and trends (Global and UK)

- Nutraceuticals, according to the widely accepted definition, are types of foods or drinks that, through addition of certain ingredients, can offer extra health benefits besides the basic nutritional value other foods offer.
- The structure of the nutraceutical industry is somewhat complicated (see flow chart opposite), and it should not be viewed as a single homogeneous industry, but as a composite of closely interrelated and somewhat overlapping business sectors (e.g., chemical companies, fermentation, plant extraction specialists, agri industry, dairy companies and fisheries). An unusual feature of the global nutraceutical ingredient supply industry is that many of the important participants are giant agribusiness companies, such as ADM, Cargill, Ingredion, and ConAgra Grain Processing, that produce natural vitamins, tocotrienol, carotenoids, amino acids, proteins, bran, and fatty acids.
- The nutraceuticals market has become more competitive with the entry of pharmaceutical and major food companies into the nutraceuticals arena. Many food companies have established their nutraceuticals divisions with a view toward a diversified product line. Pharmaceutical companies have joined the race by acquiring dietary supplement producers.
- Significant market drivers for nutraceuticals include the following:
- Changing demography — aging populations, rising healthcare costs and interest in self-care and alternative medicine.
- Rising awareness about health and wellness, understanding the links between nutrition, mood and mental well-being.
  - Changing lifestyle, driving the growth of on-the-go breakfast and plant-based foods.
  - Increasing scientific understanding of the link between diet and health and validation of nutrient efficacy.
  - Innovations leading to the availability of bioactive natural compounds and to production of better tasting and less expensive natural ingredients.
  - Changing food regulations, allowing more health claims.
  - Personalised approach for dietary supplements as opposed to mass marketing.
  - Focus of infants' and children's nutrition on healthier food choices.
  - Media coverage of diet issues.

Nutraceuticals Industry Structure Overview



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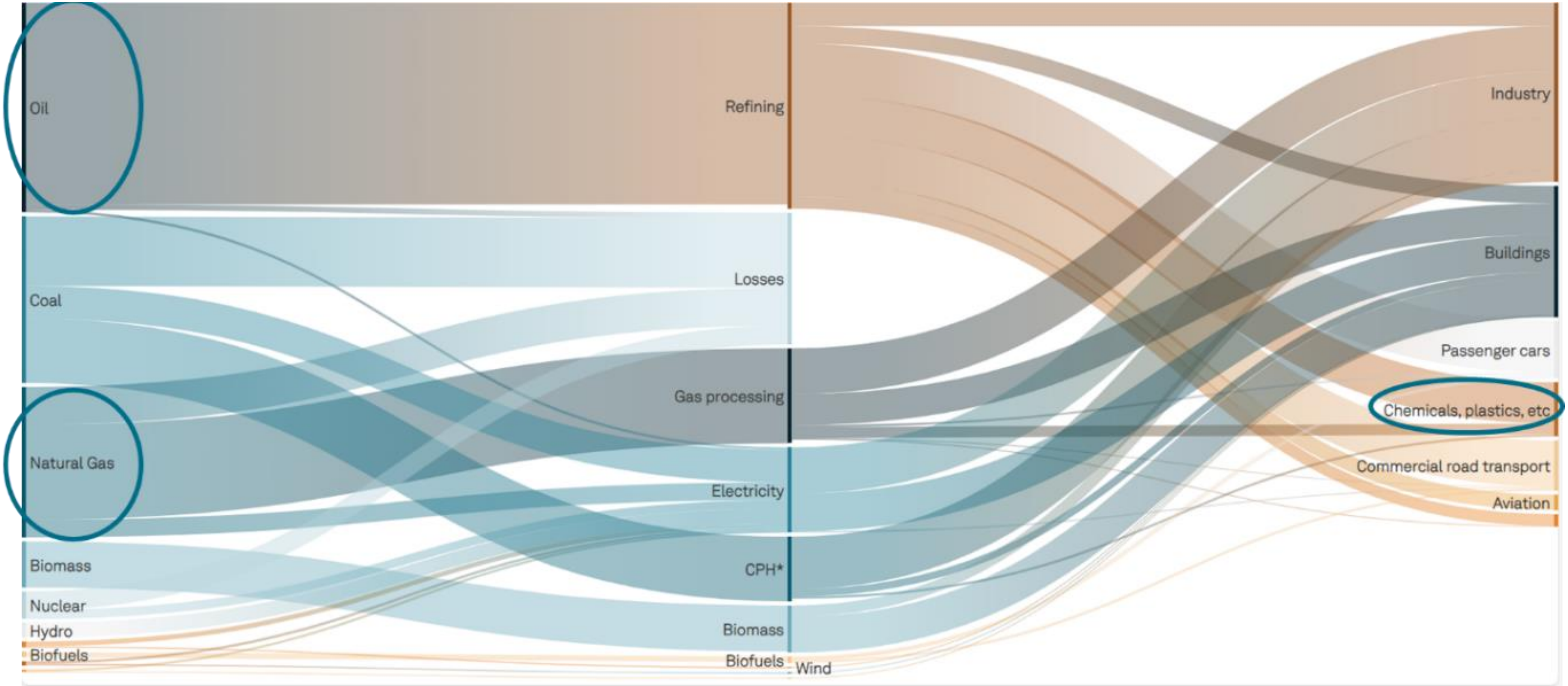
Appendix 3: Future Chemical Scenarios

Note: this is an abridged version of the original full report. In this document some pages have not been included and some data, e.g. chart units, have been deliberately left blank. Appendix 3 has not been included.

Appendix 4: Enablers and Mitigation

Supporting Information for Section 4

Energy landscape in 2020: from generation to end use



Source: S&P Global Commodity Insights

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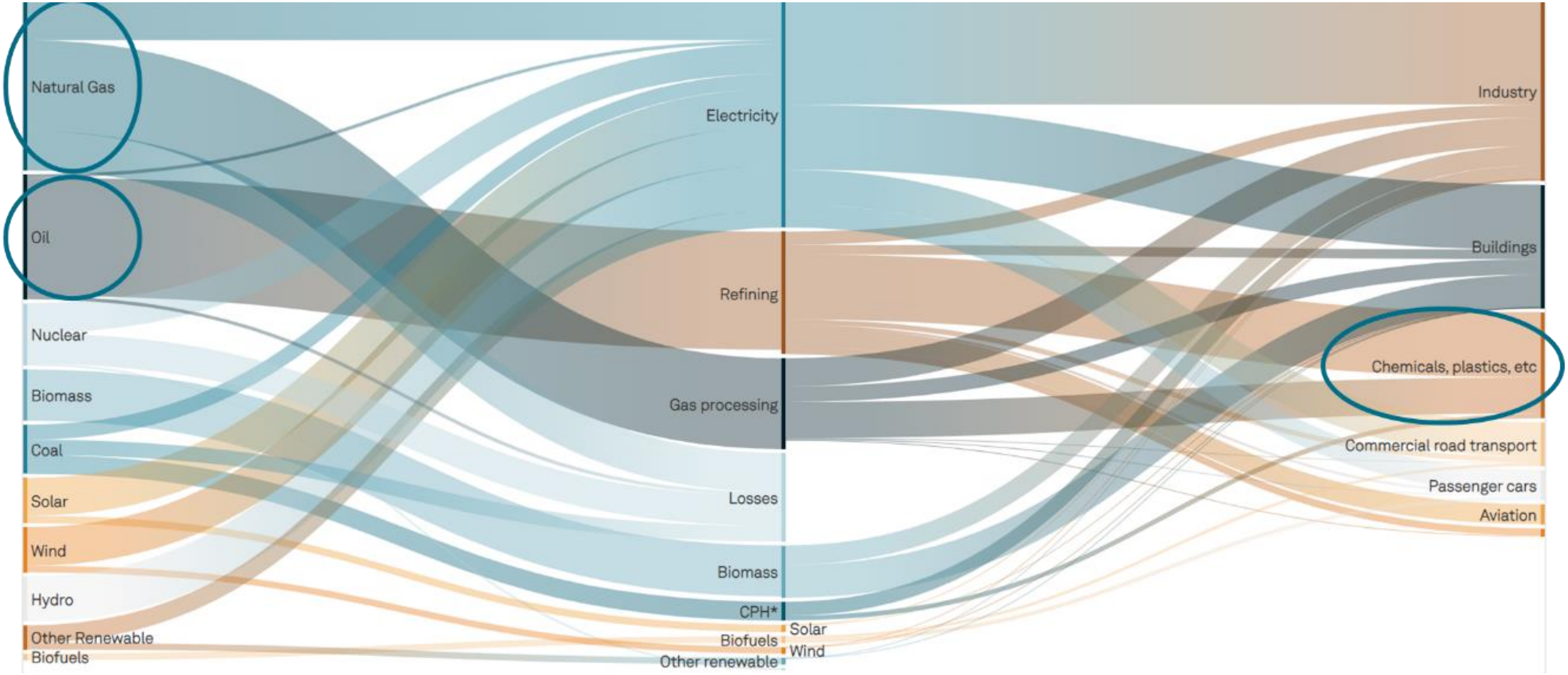
Energy landscape in 2050: from generation to end use



Source: S&P Global Commodity Insights

S&P Global
Commodity Insights

Virtuous circle: large market for various and advanced *automotive chemicals* “feeding back” into R&D/competitiveness

The automotive chemicals sector serves as a catalyst for transformation within the chemical industry, fostering innovation and growth across multiple dimensions. These include:

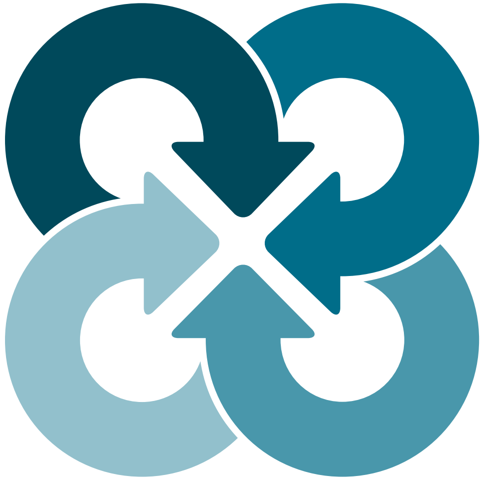
- Demand for Advanced Materials: The production of EVs requires innovative materials, such as lightweight composites, advanced polymers, and specialised coatings, driving demand for chemical manufacturers to develop new products.
- Battery Production: The rise of EVs significantly boosts the demand for batteries, particularly lithium-ion batteries. This creates opportunities for chemical companies to supply essential materials, such as lithium, cobalt, and nickel.
- Investment in R&D: Companies are motivated to invest in R&D to develop innovative materials that enhance EV performance, safety, and efficiency. This includes research into new battery chemistries, recycling processes, and sustainable sourcing of raw materials.
  - Battery electrolytes derived from specialty carbonates are gaining traction in the automotive industry, particularly for EVs. These carbonates offer enhanced electrochemical stability, improved ionic conductivity, and a wider electrochemical window, which are critical for optimising battery performance. As the demand for high-performance batteries increases, the market for advanced automotive chemicals, including these electrolytes, is expanding significantly.
- Sustainable Practices: The push for EVs aligns with sustainability goals, prompting chemical companies to innovate in green chemistry and develop environmentally friendly processes and materials.
- Collaboration Opportunities: The integration of chemical companies in the EV supply chain fosters partnerships and collaborations, leading to technological advancements and shared research initiatives.
- Economic Growth: As the EV market expands, it stimulates economic growth, benefiting the chemical sector through increased investment and job creation, therefore creating larger sector demand.
- These factors position the chemical industry as a crucial player in the transition to sustainable transportation.

Large Market Demand

A robust demand for diverse and advanced battery chemicals (e.g., for electric vehicles, energy storage) drives companies to innovate.

Investment in R&D

Increased market demand encourages companies to invest more in research and development to create superior battery technologies and chemicals.



Feedback Loop

The success of these innovations generates profits, which can be reinvested into further R&D, thus perpetuating the cycle.

Enhanced Competitiveness

As companies develop better products, they become more competitive, attracting more customers and potentially gaining market share.

Virtuous circle: large market for various and advanced *battery chemicals* "feeding back" into R&D/competitiveness

Domestic battery production is crucial for integrating renewable energy sources, such as solar and wind, into the energy grid. Batteries store excess energy generated during peak production times and release it when demand is high, ensuring a stable and reliable energy supply. As the automotive industry shifts towards electric vehicles, domestic battery production plays a vital role in supporting this transition. Local battery manufacturing ensures a steady supply of high-performance batteries needed for EVs, reducing reliance on foreign suppliers and enhancing the local automotive industry's competitiveness.

By producing batteries domestically, the UK can reduce its dependence on imported battery technologies and critical raw materials (like lithium, cobalt, and nickel). This independence enhances national security and resilience against global supply chain disruptions.

Establishing domestic battery production facilities stimulates local economies by creating jobs in manufacturing, research and development, and supply chain management. It fosters a skilled workforce and can lead to additional economic activity in related sectors.

Domestic battery production aligns with the UK's sustainability targets. By manufacturing batteries locally, transportation emissions are minimised, lowering the overall carbon footprint associated with battery supply chains.

The graphics show the historical, current and potential future manufacturing capacity of battery cathodes in the UK. Three types of battery cathodes are outlined: Lithium Iron Phosphate (LFP), Nickel Cobalt Aluminium Oxide (NCA) and Nickel Manganese Cobalt Oxide (NMC).

LFP offers high thermal stability, safety, and a long cycle life. It has a lower energy density compared to other cathodes but is less prone to overheating and thermal runaway. LFP is commonly used in EVs, stationary energy storage, and applications where safety is a priority.

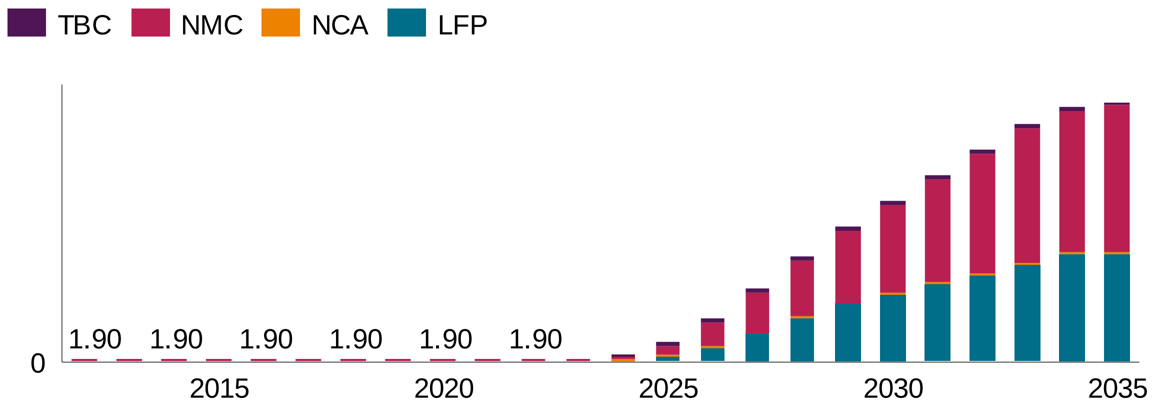
NCA provides high energy density and good thermal stability. It has a longer lifespan and better performance at high temperatures compared to some other chemistries. NCA is often used in high-performance applications like electric vehicles (notably by Tesla) and aerospace.

NMC balances energy density, thermal stability, and cost. It can be tailored for specific applications by adjusting the ratios of nickel, manganese, and cobalt. NMC is widely used in electric vehicles, consumer electronics, and energy storage systems.

The UK has historically focused on the production of NMC, however SPGCI predicts a major increase in domestic NMC production over the next 10 years, as well as the domestic production of LFP.

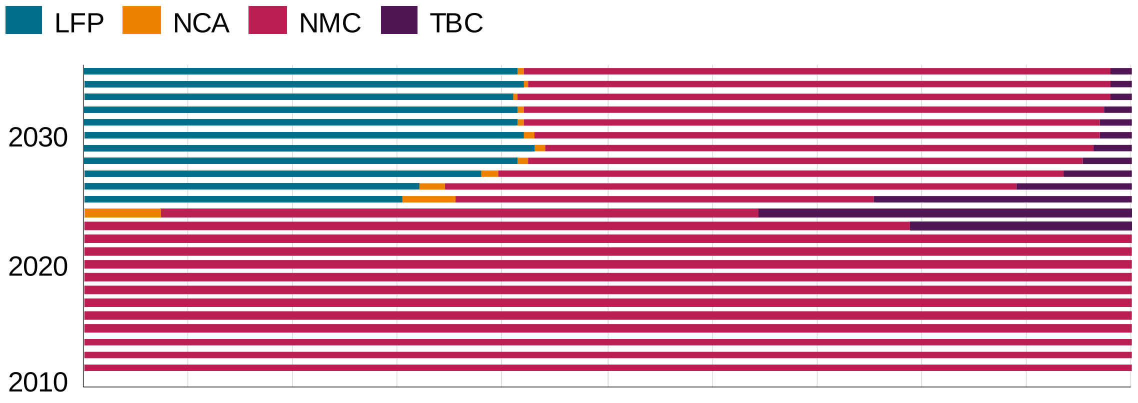
Manufacturing capacity by cathode type

GWh



Manufacturing capacity by cathode type

% share



Capacity (GWh, %)

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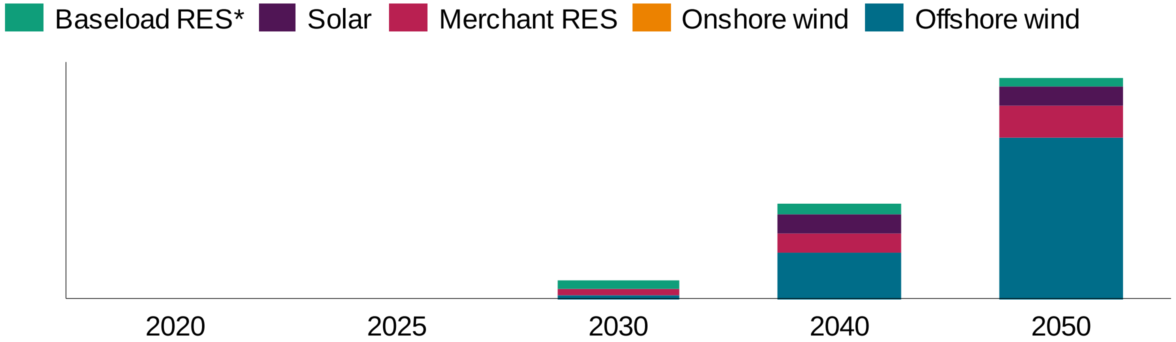
Decarbonisation of hard-to-abate parts of the chemical industry needs an efficient wind power to hydrogen chain

- An efficient wind power to hydrogen value chain can play a pivotal role by leveraging renewable energy to produce green hydrogen through electrolysis. Wind power is increasingly cost-effective and scalable. By integrating wind energy with hydrogen production, the chemical industry can meet its large hydrogen demands sustainably. This shift is crucial for meeting global climate targets and fostering a circular economy within the sector and the UK chemical industry.
- Green hydrogen plays a crucial role in the decarbonisation of hard-to-abate sectors of the chemical industry. Green hydrogen, produced through electrolysis powered by renewable energy, offers a sustainable alternative for processes traditionally reliant on fossil fuels. It can be utilised in the production of ammonia and methanol, key feedstocks in the chemical industry.
- The UK is the fifth largest market of wind turbine orders, behind Mainland China, India, Germany and Poland. The UK is aiming for 50GW of offshore wind by 2030, 5GW of which should be floating. The Scottish Government has set a target to deliver up to 11GW of offshore wind capacity by 2030 to support Scotland's commitment to net zero emissions by 2045.

Installed capacity of electrolysis – United Kingdom

GW(e)



*Total baseload RES electrolysis capacity is lower than the sum of onshore wind, solar and offshore wind capacity as renewable capacity is oversized for hydrogen baseload generation

As of December 2023

Source: S&P Global Commodity Insights.

Wind power to hydrogen value chain

Wind Energy Generation	▪ Wind turbines harness kinetic energy from the wind and convert it into electrical energy ▪ The efficiency of this process depends on turbine design, location, and wind conditions
Electrolysis	▪ The generated electricity is used to power an electrolyser, which splits water (H_2O) into hydrogen (H_2) and oxygen (O_2) through electrolysis ▪ The efficiency of this step is crucial, as it determines how much hydrogen can be produced from a given amount of electricity
Hydrogen Storage	▪ The produced hydrogen can be stored for later use ▪ Efficient storage solutions, such as high-pressure tanks or chemical storage, are essential to maintain the energy density and usability of hydrogen
Distribution and Utilisation	▪ The stored hydrogen can be transported to various end-users, including chemical plants, fuel cells, or other industries that require hydrogen as a feedstock or energy source
Integration with Existing Infrastructure	▪ To maximise efficiency, the wind power-to-hydrogen chain can be integrated with existing energy systems, allowing for grid stability and optimising energy use

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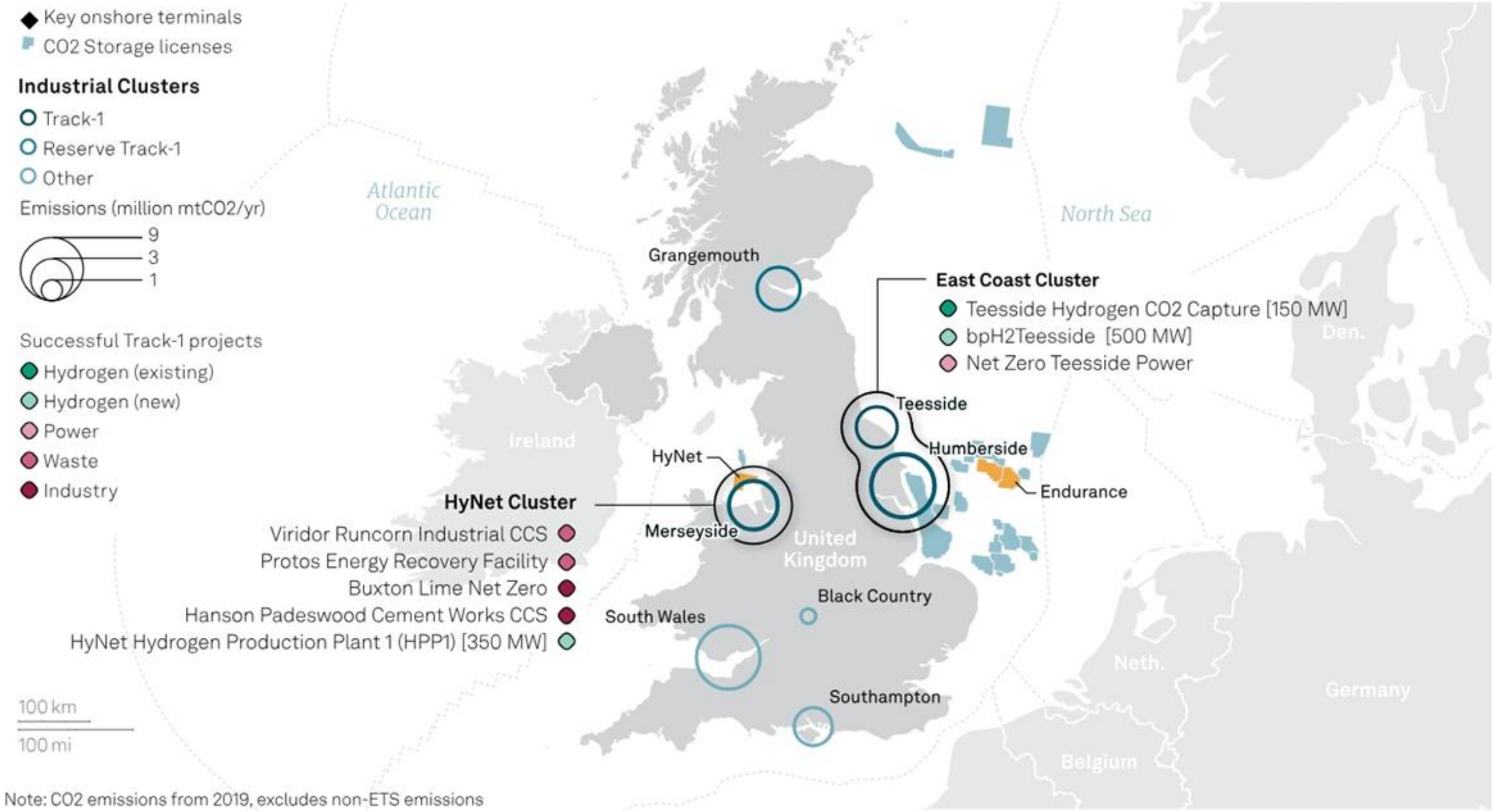
CCS is fundamental to reduce the carbon footprint of existing supply chains

UK hydrogen and CCS projects

- Blue hydrogen is derived from natural gas with carbon capture and storage (CCS) technologies to mitigate emissions. This method serves as a transitional solution, enabling industries to reduce their carbon footprint while renewable hydrogen production scales up.
- In the UK specifically, much of the planned CCS capacity is associated with the production of hydrogen (although only 8% is globally).
- The UK has an advanced policy framework for hydrogen. The main subsidy mechanism, the Hydrogen Production Business Model (HPBM) is in place. The first Hydrogen Allocation Round (HAR 1) awarded contracts for 125 MW of electrolytic hydrogen in December 2023. HAR 2, for a further 875 MW of capacity, is underway.
- Progress has also been made in the development of the UK CCS clusters, which include projects for low-carbon hydrogen production via methane reforming with CCS. Overall, around 3 million metric tons per year of hydrogen capacity utilising CCS is under development in the UK.

UK CCUS and blue hydrogen clusters

The UK is poised to kickstart its blue hydrogen economy, awarding funding support for the first industrial CCUS clusters. First offtakers will be local, but the ambition stretches to a number of offtakers in expanded clusters around the country.



Note: CO2 emissions from 2019, excludes non-ETS emissions

Credit: CI Content Design
Source: S&P Global Commodity Insights, NSTA, East Coast Cluster, HyNet, NAEI

Data complied October 3rd, 2024
Source: S&P Global Commodity Insights

S&P Global Commodity Insights

Carbon capture is also at the heart of a future "hydrogen economy" as *blue* hydrogen is broadly seen as both a precursor and a complement to *green* hydrogen

Track 1 industrial cluster decarbonisation program

- The UK Government has committed £21.7 billion to carbon capture and low-carbon hydrogen projects under the Track 1 industrial cluster decarbonisation program.
- This funding supports initiatives like HyNet in the North West and the East Coast Cluster around Teesside, with projects set to begin in 2028.

Key projects and impact

- **HyNet Blue Hydrogen**: EET Hydrogen is poised to become the first large-scale blue hydrogen plant to reach a final investment decision (FID) by the end of 2024. The project will significantly reduce hydrogen production costs compared to green hydrogen.
- **East Coast Cluster**: Includes BP's 1.2-GW H2Teesside plant and Net Zero Teesside Power. These projects aim to decarbonise industrial sectors and are expected to remove over 8.5 million metric tons of CO_2 annually.

Funding and development

- The funding spans 25 years, marking a commercial agreement with developers. It paves the way for the UK's first large-scale hydrogen production plant.
- The UK targets at least 4 GW of blue hydrogen production capacity by 2030, with a total of 10 GW of low-carbon production, including renewables-powered electrolysis.

Future plans

- From 2027, a competitive allocation process for CCS projects will be introduced, with the HyNet CCS cluster opening to more companies by 2030.
- Track 2 status has been awarded to the Acorn and Viking CCS cluster projects.

Environmental considerations

- While some environmental groups express concerns about fossil fuel dependency, the Climate Change Committee supports the commitment to CCUS as essential for meeting climate targets.

Importance

- This investment marks a significant step in the UK's clean energy transition, supporting industrial decarbonisation and advancing the nation's climate goals.

Focus on both conventional and "bio" clusters to ensure scale efficiency of material flows and critical mass of skills

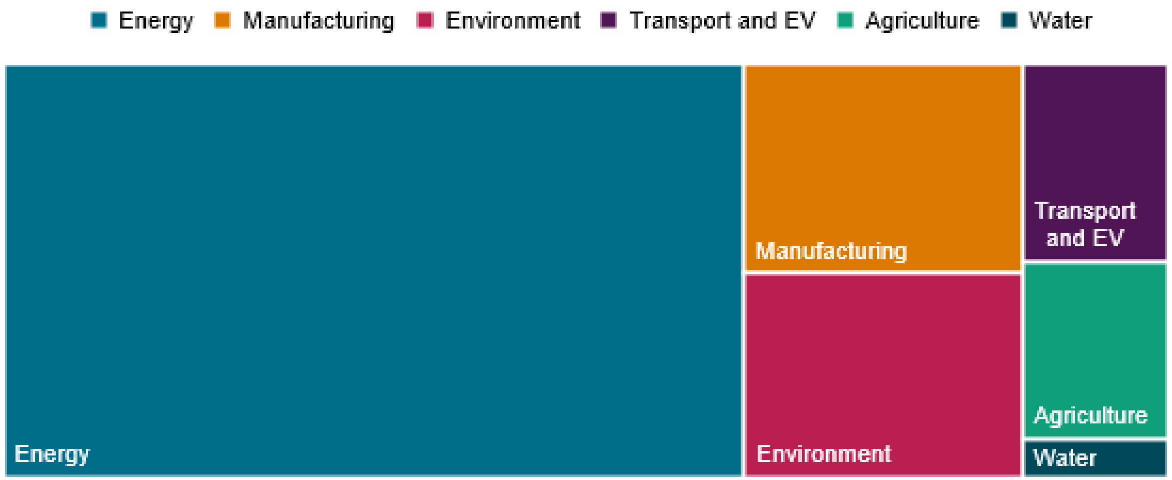
- Clustering serves as a significant enabler for the chemical industry by fostering collaboration, innovation, and efficiency. Key benefits include:
  - **Resource sharing:** Companies within a cluster can share resources, such as infrastructure and logistics, reducing operational costs and improving efficiency.
  - **Knowledge exchange:** Proximity encourages collaboration among firms, research institutions, and universities, facilitating knowledge transfer and innovation in processes and products.
  - **Supply chain optimisation:** Clusters streamline supply chains by consolidating suppliers and customers, enhancing responsiveness and reducing lead times.
  - **Talent pool:** Clusters attract skilled labour and expertise, creating a competitive workforce that can drive innovation and productivity.
  - **Sustainability initiatives:** Collaborative efforts within clusters can lead to shared sustainability practices, such as waste reduction and energy efficiency, benefiting the environment and the bottom line.
- Overall, clustering enhances competitiveness and drives growth in the chemical industry.
- Potential new cluster areas in the UK could focus on emerging industries and technologies.
- Areas like the North East and South West could leverage existing industrial bases to focus on renewable energy, sustainable materials, and carbon capture technologies. To combine agriculture and technology, areas in East Anglia and the Midlands could develop clusters around precision farming, biotechnology, and sustainable practices. Cities in the Midlands and North West could focus on smart manufacturing technologies, robotics, and automation, enhancing the UK's manufacturing capabilities.

Existing UK clusters	Focus
Teesside	Known as a major hub for chemical production, Teesside hosts companies like SABIC and INEOS, focusing on petrochemicals, specialty chemicals and turning sustainable feedstocks into biopharmaceuticals.
Grangemouth	Located in Scotland, this cluster is home to the Grangemouth Refinery and various chemical companies, producing a range of chemicals and plastics. Petroineos however will close operations at the Grangemouth refinery from spring 2025 and transition it to a fuel import terminal and is evaluating a range of low-carbon opportunities for the site.
Runcorn	A significant centre for chemical manufacturing, Runcorn hosts companies like INEOS and several other firms involved in producing chemicals and materials.
Cambridge	This cluster combines biotech and chemical industries, focusing on bio-based chemicals and materials. Companies like AstraZeneca and others leverage local research institutions.
Manchester	The Manchester Science Park supports bio-chemical companies, fostering innovation in biomanufacturing and sustainable chemistry.
Bristol	Known for its focus on bio-based chemicals and sustainable materials, Bristol hosts companies like CytoSeek, Zentraxa and Halo Theraputics in the biotech sector.
Hull	Known for its strong chemical sector, Hull hosts several companies involved in producing basic chemicals, fertilisers, and specialty chemicals, benefiting from its port facilities at Humber for raw material imports. Humber Zero and Gigastack are new decarbonisation projects in the region.
Solent	The "Solent Cluster", founded originally by Solent Local Enterprise Partnership, The University of Southampton and ExxonMobil, is an industry-led body for the promotion of a lower carbon economy across the South of England and wider UK. The cluster, with more than 140 organisations now involved, leverages synergies between existing infrastructure and emerging biogenic feedstocks. The cluster aims to generate circa 19,000 new skilled jobs by 2035 and generate £12 billion of new investment. "Anchor" projects include Solent SAF, which is developing a non-recyclable waste to jet fuel project (via gasification and methanol). This attracted UK DoT investment of circa £6.0 million. A blue hydrogen project is also planned with an initial capacity of 1.4 GW, potentially onstream by 2030. The "English Channel Offshore Storage" project for carbon capture and storage encountered a setback as sponsors withdrew following local protests. The parties will now seek alternative technology solutions for CO_2 sequestration and/or re-use.

IRA – Energy transition and sustainability: the US is focused on credits, grants and rebates for designated US economy sectors

- In the coming years, the US Inflation Reduction Act (IRA) will allocate nearly $400 billion in federal funds to clean energy initiatives, aiming to significantly reduce the nation's carbon emissions by 2030. The act (passed in 2022) aims to enhance America's global economic competitiveness, drive innovation, and boost industrial productivity.
- Interesting aspects of the policy include:
  - **Climate Investments**: It allocates around $390 billion for energy security and climate change initiatives, aiming to reduce greenhouse gas emissions by about 40% by 2030. Around $250 bn has been allocated to energy which is the largest investment sector.
  - **Tax Credits**: The IRA offers tax incentives for renewable energy projects, electric vehicles, and energy-efficient home improvements, encouraging both consumers and businesses to invest in sustainable options.
- The funds will be provided through a combination of tax incentives, grants, and loan guarantees. The largest portion will be allocated to clean electricity and transmission, followed by investments in clean transportation, which includes incentives for EVs.
- Tax incentives are designed to stimulate private investment into clean energy, transport and manufacturing. To ensure that talent in STEM is encouraged, manufacturing facilities are only eligible for full IRA tax credits if they meet current wage and apprenticeship guidelines.
- Many tax incentives under the IRA include requirements for scaling domestic production or domestic procurement. This prevents recipients from setting up facilities in foreign nations.

IRA investments by sector



Sector	$ bn
Energy	250
Manufacturing	46
Environment	45
Transport and EV	23
Agriculture	21
Water	5

Clean Industrial Deal - Energy transition and sustainability: the EU is focused on admin barrier removal to access funds for critical raw materials and cleantech

As the European Commission sets new priorities, the upcoming **Clean Industrial Deal** has been announced as a pivotal initiative. This is designed to align with the broader objectives of the EU Green Deal, which aims for climate neutrality by 2050.

The Clean Industrial Deal, part of the broader EU Green Deal, includes several key policies aimed at fostering a sustainable and competitive industrial sector in Europe:

- **Net-Zero Industry Act:** This act sets goals for net-zero industrial capacity and provides a regulatory framework to support the rapid deployment of clean technologies. It includes simplified and fast-track permitting processes.
- **Critical Raw Materials Act:** This policy ensures a secure and sustainable supply of critical raw materials essential for manufacturing key technologies. It aims to streamline permitting processes and reduce bureaucratic hurdles for mining and recycling operations.
- **Reform of Electricity Market Design:** This reform helps consumers benefit from the lower costs of renewable energy by creating a more predictable and simplified regulatory environment.
- **European Sovereignty Fund:** This proposed fund aims to address the investment needs for clean tech innovation, manufacturing, and deployment, ensuring that Europe remains competitive in the global market.
- **Skills Development Initiatives:** The plan includes establishing Net-Zero Industry Academies to support up-skilling and re-skilling programs in strategic industries, ensuring the workforce is prepared for the green transition.
- **Open Trade Policies:** The deal promotes global cooperation and fair trade practices to support the green transition, building on engagements with the EU's partners and the work of the World Trade organisation (WTO).

The EU Green Deal aims to achieve climate neutrality by 2050 through a transformative approach to sustainability, focusing on reducing emissions, promoting renewable energy, and enhancing biodiversity. A crucial aspect of the deal is the removal of administrative barriers to facilitate access to funding for critical raw materials and cleantech innovations. This focus is essential because streamlined funding processes can accelerate the development and deployment of technologies necessary for the green transition. By reducing bureaucratic hurdles, the EU aims to attract investments in critical raw materials, which are vital for technologies like batteries and renewable energy systems.

The UK has its own set of initiatives aimed at fostering a green economy, which can be seen as a counterpart to the EU Green Deal. The UK Government has emphasised removing administrative barriers to facilitate funding for critical raw materials and cleantech through various strategies.

Key area	UK Green Deal	EU Green Deal
Regulatory Framework	Shaped by the UK's independent policies post-Brexit, allowing for more tailored approaches.	Operates within the EU's regulatory framework, emphasising collective action among member states.
Targets & Timelines	Aiming for net-zero emissions by 2050. UK aims for a 68% reduction by 2030 compared to 1990 levels.	Aiming for net-zero emissions by 2050. EU aims for a 55% reduction by 2030.
Funding Mechanisms	Relies on domestic funding mechanisms, such as the Green Homes Grant and investment in green technologies.	Includes the NextGenerationEU recovery fund to finance green initiatives across member states.
Sector Focus	Places a stronger emphasis on clean growth and the transition to electric vehicles.	Encompasses a broader range of sectors, including agriculture and biodiversity.

Source: European Commission

Availability *in the UK* of chemical graduates & chemical engineers from top universities

- The general public holds a somewhat negative perception of the chemical industry. To attract a more diverse talent pool, it is essential to change these unfavourable views of careers in the industry. This can be accomplished if companies actively combat stereotypes by promoting their organisations, highlighting the industry's overall value, and showcasing the variety of inclusive opportunities available in the broader chemical sector.
- Research indicates that students' aspirations to be scientists are formed early on and remain stable over time so careers advice and education should start early in secondary school.
- UCAS figures available for chemistry show a 18% drop in applications between the years 2015-2018. Since then, the most recent figures available for chemistry appear to show application numbers may have stabilised at this lower point, with a slight downturn in the most recent number for 2021. This decline is despite the number of students sitting A-level chemistry increasing. In England, numbers have increased from 48,765 to 55,485 students from 2017 to 2021.
- Statistics of A-level chemistry takers indicate that there is genuine interest in chemistry as a subject. The challenge is to convert more of these students into chemistry and chemical engineering graduates with a clear route into industry upon graduation.
- The Chemical Industries Association (CIA) works to improve public understanding of the chemical industry's contributions to society, the economy, and everyday life. CIA's ChemTalent is a network of people working in chemical and pharmaceutical businesses in the UK who are either at the start of their careers or keen to broaden their skills and voice their opinions on behalf of the UK chemical industry. The aim of this network is to provide a voice for all future talent working within the industry, from apprentices, to graduates, across every function that enables companies to operate efficiently. This initiative was formerly known as Future Forum and was the first of its kind in the UK.
- The CIA Young Ambassador Award is an annual program that recognises outstanding young professionals under 35 in the UK chemical industry. It celebrates individuals who demonstrate excellence, leadership, and a commitment to innovation, sustainability, and community engagement. Candidates are evaluated on their technical achievements, leadership potential, and efforts to inspire others while promoting workplace safety and diversity. Winners serve as ambassadors for the industry, promoting its positive impact and attracting new talent. The award provides recognition, networking opportunities, and a platform to influence the future direction of the chemical sector.

The UK is home to some of the best universities in the world

Top UK Universities for chemical engineering and chemistry: (no particular order)	
University of Cambridge	University of St Andrews
University of Oxford	University of Bristol
University of Birmingham	Durham University
University of Manchester	University of Glasgow
University of Leeds	University of York
UCL (University College London)	University of Bath
The University of Edinburgh	University of Nottingham
Imperial College London	University of Liverpool

Source: Britannia, Complete University Guide, The Guardian

Gaps to optimise workforce composition and skills are not limited to vocational vs. graduate issues: surveys also show disconnects in STEM take-up, culture, and gender balance [1/2]

- Children often dream of becoming professional athletes, movie stars, doctors, veterinarians, and more, reflecting their boundless imagination and societal influences. Early exposure to STEM education is crucial for maintaining interest and can lead to rewarding careers characterised by creativity and innovation. However, as girls grow older, their interest in STEM diminishes, resulting in women comprising only 25% of the STEM workforce. This decline is partly due to the scarcity of female role models.
- Socioeconomic factors significantly impact career paths. Children from affluent families are more likely to become inventors, and white children are more likely to innovate compared to their African-American peers. This disparity highlights the need for early exposure to innovation, often lacking in low-income and minority families, affecting their interest in STEM careers.
- Encouragement and support through programs and mentorship are vital for sustaining interest in STEM, especially among underrepresented groups. Imagination drives diverse career aspirations, with early exposure to arts and crafts linked to innovation and entrepreneurship in adulthood.
- Hands-on learning and teamwork are essential for fostering creativity and problem-solving skills, crucial for success in STEM fields. Family influence also plays a role, as children whose parents hold patents are more likely to innovate in the same field.
- To address gender disparities, encouraging girls to participate in science activities, particularly those led by female educators, can help bridge the gap. This approach challenges stereotypes and helps girls see themselves as potential scientists and innovators.
- Incorporating career education into primary schools, can further support these efforts. Research shows that early career education increases children's awareness of various life opportunities and reduces stereotypical thinking about careers. Starting career education early, ideally by age seven, aligns with the development of children's aspirations and can positively influence their engagement and attainment in school.
- Overall, there is a need for a concerted effort to support children's interests in STEM and career exploration from a young age, emphasising exposure, encouragement, and role models to nurture the next generation of innovators.

Sources: https://www.invent.org/sites/default/files/report/2020-09/What%20Do%20Children%20Want%20to%20Be%20When%20They%20Grow%20Up%20White%20Paper%20FINAL.pdf; Explainer: when should children start to think about their careers? (theconversation.com)

Gaps to optimise workforce composition and skills are not limited to vocational vs. graduate issues: surveys also show disconnects in STEM take-up, culture, and gender balance [2/2]

Skills/Age Gap in the Workforce

The chemical industry is facing a significant skills and age gap. Many experienced professionals are retiring, and there is a shortage of mid-career professionals to take their place. This gap is exacerbated by a lack of younger workers entering the field. The median age of the chemical workforce is higher than in many other industries, and a large percentage of the workforce is nearing retirement.

Government Policy/Public Understanding

While specific policies from 20-30 years ago directly affecting the chemical industry workforce are not well-documented, broader trends in education and career preferences have influenced the current situation. During the 1990s and early 2000s, there was a significant push towards careers in IT and finance, which may have diverted potential talent away from traditional industries like chemicals.

Importance of Apprenticeships and Graduate Programs

To address the skills gap, there is a strong emphasis on promoting apprenticeships and graduate programs. These initiatives are crucial for attracting and retaining young talent in the industry. Encouraging students to pursue careers in chemistry through these programs can help bridge the gap left by retiring professionals.

Public Perception of the Chemical Industry

Public perception is indeed a significant issue for the chemical industry. According to surveys, the industry is often viewed negatively, which affects its ability to attract new talent. This perception is influenced by concerns about environmental impact and safety, which can deter students from pursuing careers in chemistry.

A-Level Chemistry Statistics

Statistics show that a significant number of students take A-level chemistry, but many do so as a prerequisite for careers in medicine or veterinary science rather than out of a genuine interest in chemistry. This trend suggests that, while there is interest in the subject, it is often driven by external career goals rather than a passion for the field itself.

Sources: ChemTalent | Our focus | Chemical Industries Association; Chemistry's image is harming talent acquisition (acs.org); A level and GCSE results analysis 2022 - CaSE (sciencecampaign.org.uk)

Appendix 5: Glossary

Glossary – Geographical Definitions

Region	Definition
Europe	Europe excluding Eurasia.
Eurasia	Eurasia is Armenia, Azerbaijan, Belarus, Georgia, Moldova, Russia and Ukraine.
Africa	Africa is all of the African continent, including North Africa.
Middle East	Middle East includes Cyprus and Turkey.
Central Asia	Central Asia is Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.
Southern Asia	Southern Asia is Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka.
Eastern Asia	Eastern Asia is mainland China, Hong Kong, Japan, Mongolia, Korea and Taiwan.
South East Asia	South East Asia is Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.
Oceania	Oceania is Australia, Christmas Island, Nauru, New Caledonia, New Zealand and Papua New Guinea.
North America	North America is Canada, Mexico, and the United States, including the US Virgin Islands.
Latin America	Latin America is Central and South America, including the Caribbean.

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Commodity Insights

Glossary – Acronyms

Acronym	Definition
2EH	2-Ethylhexanol
ABS	Acrylonitrile-butadiene-styrene
ACE	Acetone
CAN	Acrylonitrile
AcOH	Acetic acid
AN	Ammonium Nitrate
API	Active Pharmaceutical Ingredient
AS	Ammonium Sulphate
ASPIRES2	Advancing the Sustainable Production of Innovative Renewable Energy Solutions
ATJ	Alcohol-to-Jet
BBL	Barrel (as in crude oil barrel)
BDO	1,4-Butanediol
BESS	Battery Energy Storage Systems
BEV	Battery Electric Vehicles
BHA	Butylated Hydroxyanisole
BHT	Butylated Hydroxytoluene
bn	Billion
BTC	Bureau of Tranportation Statistics
BTL	Biomass-to-Liquids
BTX	Benzene Toluene Xylene
BUTAc	Butyl Acetate
C Europe	Central Europe
Ca	Calcium
CAA	Crude Acrylic Acid
CAGR	Compound Annual Growth Rate
CAN	Calcium Ammonium Nitrate

Acronym	Definition
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CELA	Cellulose Acetate
CELE	Cellulose Ethers
CFD	Contracts for difference
CFRP	Carbon Fibre reinforced polymers
CGP	Chemical Grade Propylene
CIA	Chemical Industries Association
CIS	Commonwealth of Independent States
CIT	Citric Acid
CM	capacity market
CMC	Carboxymethyl cellulose
CNI	Critical National Infrastructure
CO_2	Carbon Dioxide
CO_2te	Carbon Dioxide Tons Equivalent
COP	Cost of Production
CPC	Copolymer Polypropylene Composite
CPD	Continuous Professional Development
CPH	Cogeneration of power and hydrogen (from coal)
Cr	Chromium
CSPE	Chlorosulfonated polyethylene
CTFE-VDF	Poly(chlorotrifluoroethylene-vinylidene fluoride)
DAP	Diammonium Phosphate
DCPD	dicylopentadiene
DDGS	Distillers dried grains and solubles
DEC	Diethyl carbonate
DEIPA	Diethanol monoisopropanolamine

Acronym	Definition
DMC	Dimethyl carbonate
DMEx	Defence Materials Centre of Exellence
EB	Ethylbenzene
EBIT	Earnings before Interest and Taxes
EBITDA	Earnings before Interest, Taxes, Depreciation, and Amortization
EC	Ethylene Carbonate
ECH	Epichlorohydrin
ECTFE	Poly(ethylene-chlorotrifluoroethylene)
EDIPA	ethoxylated diisopropanolamine
EMC	Ethyl methyl carbonate
EPC	Engineering, Procurement and Construction
EPDM	Ethylene Propylene Diene Monomer
EPS	Expanded Polystyrene
ETFE	Poly(ethylene-tetrafluoroethylene)
ETOH	Ethanol for Chemicals
ETS	Emissions Trading Scheme
EU	European Union
EU27	27 member states of the European Union
EV	Electric Vehicle
EVA	Ethylene Vinyl Acetate
FCC	Fluid Catalytic Cracker
FCEV	Fuel Cell Electric Vehicle
FDI	Foreign Direct Investment
Fe	Iron
FEC	Fluoroethylene carbonate
FEP	Fluorinated ethylene-propylene polymers
FFAs	Free Fatty Acids

S&P Global
Commodity Insights

Glossary – Acronyms

Acronym	Definition
FFC	Fluorinated Film Composite
FPF	Fluoropolymer Film
F-Poly	Fluoropolymer
FUM	Fumaric Acid
FUR	Furfural
GHG	Greenhouse Gas
GLY	Glycerin
GT	Geothermal
GVA	Gross Value Added
GW	Gigawatt
GWh	Gigawatt-Hour
H2	Hydrogen
HAR	Hydrogen Allocation Round
HDPE	High Density Polyethylene
HEFA	Hydroprocessed Esters and Fatty Acids
HEV	Hybrid Electric Vehicle
HP	heat pump
HPBM	Hydrogen Production Business Model
HPEO	High Purity Ethylene Oxide
HR	Human Resources
I	Iodine
IB	Industrial biotechnology
ICE	Internal Combustion Engine
IP	Intellectual Property
IPA	Isopropylalcohol
IPA	Isopropanol
IRA	Inflation Reduction Act

Acronym	Definition
ISOS	Isosorbide
JKM	Japan Korea Marker
JV	Joint Venture
K	Potassium
KBPSD	Thousand barrels per stream day
kg	kilogram
KG NGL	Kilograms of Natural Gas Liquids
KPC	A type of polyolefin or polymer-based backsheet material with specific chemical and physical properties for durability and protection.
KPE	A type of polyolefin or polymer-based backsheet material known for its enhanced environmental resistance and mechanical strength.
KPF	A type of polyolefin or polymer-based backsheet material offering high resistance to UV radiation and weathering.
KPK	A type of polyolefin or polymer-based backsheet material designed for superior thermal stability and chemical resistance.
KPO	A type of polyolefin or polymer-based backsheet material optimised for optimal performance in various environmental conditions.
kWh	kilowatt hour
LAC	Lactic Acid
LC Ammonia	Low carbon Ammonia
LCO	Lithium Cobalt Oxide
LDPE	Low-density Polyethylene

Acronym	Definition
LFP	Lithium Iron Phosphate
LiPF6	Lithium Hexafluorophosphate
LLDPE	Linear Low-density Polyethylene
LMO	Lithium Manganese Oxide
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LV	Light Vehicle
LYS	Lysine
M East	Middle East
MAL	Malic Acid
MAP	Monoammonium Phosphate
MDA	Methylene Dianiline
MDEA	N-methyldiethanolamine
MDF	Medium-density fibreboard
MDI	Methylene Diphenyl Diisocyanate
MEA	Monoethanolamine
MEG	Monoethylene glycol
MF	Melamine formaldehyde (resin)
Mg	Magnesium
MIN	Methionine
MMA	Methyl Methacrylate
MMBtu	Million metric British Thermal Units
MMtoe	Million metric tons of oil equivalent
Mmtpa	Million Metric Tons per Annum
Mn	Manganese
MOD	Ministry of Defence
MOF	Metal Organic Framework

S&P Global Commodity Insights

Glossary – Acronyms

Acronym	Definition
MPG	Monopropylene Glycol
MSG	Monosodium Glutamate
MT	Million tons
MTBE	Methyl Tertiary-Butyl Ether
MTO	Methanol to Olefin
MW	Megawatt
N America	North America
NATALCS	Natural Alcohols
NATO	North Atlantic Treaty organisation
nBUTOH	n-Butanol
NCA	Nickel-Cobalt-Aluminium
NCM	Nickel-Cobalt-Manganese
NE Asia	North East Asia
NEA	North East Asia
NMC	Nickel Manganese Cobalt
NMP	N-Methyl-2-Pyrrolidone
NPK	Nitrogen, Phosphorus, Potassium
NWE	North West Europe
NZS	Net Zero Strategy
OEM	Original Equipment Manufacturer
PA	Polyamide
PAA	Polyacrylic Acid
PAG	Polyalkylene Glycol
P-aramid	Para-aramid (para-aromatic polyamide)
PC	Propylene Carbonate
PC/PMMA	polycarbonate/polymethylmethacrylate
PCTFE	Polychlorotrifluoroethylene

Acronym	Definition
PDMDA	N-propyl-dimethyldopamine
PDO	1,3-Propanediol
PE	Polyethylene (all forms)
PEEK	Polyether ether ketone
PEI	Polyether imide
PEK	Polyetherketone
PEKK	Polyetherketoneketone
PEM	Proton Exchange membrane
PENTAc	Pentanoic Acid
PET	Polyethylene terephthalate
Petchem	Petrochemical
PF	Phenol formaldehyde
PFA	Perfluoroalkoxy
PHEV	Plug-in Hybrid Electric Vehicle
PKO	Palm Kernel Oil
PLA	Polylactide
PMDA	1,5-pentamethylene diamine
PO	Propylene Oxide
POE	Polyolefin Elastomer
Polyiso	Polyisocyanate
POM	polyoxymethylene
PP	Polypropylene
PPA	Power purchase agreement
PPE	Personal Protective Equipment
PPS	polyphenylene sulphide
PROPA	Propionic Acid
PTA	Pure Terephthalic Acid

Acronym	Definition
PTFE	Polytetrafluoroethylene
PV	Photovoltaic
PVC	Polyvinyl Chloride
PVDF	Polyvinylidene Fluoride
PVF	Polyvinyl fluoride
R&D	Research and Development
REACH	Registration, Evaluation, Authorisation, Restriction of Chemicals
RFS	Renewable Fuel Standard
RGP	Refinery Grade Propylene
RoW	Rest of the World
RTM	resin transfer moulding
S America	South America
S Asia	South Asia
SAF	Sustainable Aviation Fuel
SBR	Styrene-butadiene rubber
SBS	Styrene-Butadiene-Styrene
Se	Selenium
SE Asia	South East Asia
SEBA	Sebacic Acid
SEG	Smart Export Guarantee
SET	Science, Engineering and Technology
SG&A	Selling, General, and Administrative Expenses
SME	Small and Medium-sized Enterprises
SORB	Sorbitol
SPF	Spun polyurethane foam
ST	Solar Thermal
SUC	Succinic Acid

Glossary – Acronyms

Acronym	Definition
TAME	Tert-Amyl Methyl Ether
TART	Tartaric Acid
TBHQ	Tert-Butylhydroquinone
TDI	Toluene Diisocyanate
TEA	Triethanolamine
THRE	Threonine
THV	Tetrafluoroethylene/hexafluoropropylene/vinylidene fluoride
TIPA	triisopropanolamine
TPC	Thermoplastic Copolyester
TPE	Thermoplastic Elastomer
TPF	Thermoplastic Polyfluoroethylene
TPO	Thermoplastic Polyolefin
TPT	Thermoplastic Polyvinyl Fluoride
TRYP	Tryptophan
TSA	Temperature Swing Adsorption
TTF	Title Transfer Facility
UF	Urea-Formaldehyde
UHMWPE	Ultra High Molecular Weight Polyethylene
US	United States
UV	Ultraviolet
VAM	Vinyl Acetate Monomer
VC	Vinylene carbonate
W Europe	West Europe
Wh/L	Watt-hours per Litre
WTI	West Texas Intermediate
Zn	Zinc

Glossary – Definitions

Term	Definition
0	
1,3-propanediol	A biologically-derived chemical building block used in making high performance polyesters and rubber-like materials. It also has a growing use in the flavour and fragrance industry
1,4-butanediol (BDO)	A versatile chemical used in the production of engineering plastics, spandex fibres, and high-performance polyurethanes.
1,5-pentamethylene diamine	Used for making polyamides for fibres and other polyurethanes for automotive coatings.
1,6-hexamethylene diamine	Used primarily in making nylon 6,6 and specialised polyurethane components
1-ethylpyrrolidin-2-one	A ‘green’ solvent used in the pharmaceutical and chemical industries.
2-ethylhexanol (2-EH)	A chemical used in the production of plasticizers, which make plastics like PVC more flexible.
A	
Absorption	The process by which one substance takes in or absorbs another substance.
Accelerator	A substance that increases the rate of a chemical reaction.
Acesulfame K	A calorie-free sweetener used in food and beverages.
Acetaldehyde	A volatile compound used in the production of acetic acid, perfumes, and flavours.
Acetic acid	A colourless liquid organic compound with a pungent smell, used in vinegar and as a chemical reagent for polyesters and adhesive building blocks
Acetone	A solvent used in cleaning, nail polish remover, and as a precursor in chemical synthesis,e.g., For making perspex® and plexiglass®
Acrylonitrile (ACN)	A chemical used in the production of engineering plastics and rubber as well as building blocks for water treatment chemicals.
Acrylonitrile-butadiene-styrene (ABS)	A common thermoplastic polymer used in a wide range of applications, including LEGO bricks.

Term	Definition
Adjuvants	Substances added to vaccines to enhance the body's immune response to the antigen. They help to create a stronger and longer-lasting immunity.
Adsorption	The process by which atoms, ions, or molecules adhere to a surface.
Advanced recycling	Technologies beyond conventional mechanical recycling based on biochemical processes and thermal processes, e.g. pyrolysis, gasification and incineration coupled with CCS/CCU
ASPIRES	Advancing the sustainable production of innovative renewable energy solutions: an initiative focused on promoting sustainable energy technologies.
Air entrainers	Additives used in concrete to introduce tiny air bubbles, improving its workability and durability.
Alcohol-to-Jet (ATJ)	A process that converts alcohols like ethanol into jet fuel.
Alginate	A natural polysaccharide extracted from seaweed, used in food and pharmaceuticals as a thickener and stabiliser.
Aliphatic	Organic compounds composed of carbon and hydrogen arranged in straight or branched chains.
Alkanolamine	Compounds used in gas treatment processes to remove acidic gases.
Alumina	A compound of aluminum and oxygen, used in the production of aluminum metal and as an abrasive.
Aluminium	A lightweight, silvery-white metal used in a wide range of applications, from packaging to aerospace.
Amines	Organic compounds derived from ammonia, used in dyes, drugs, and as intermediates in chemical synthesis.
Amino acid	Organic compounds that combine to form proteins, essential for life.
Amino-methyl-propanol (AMP)	A chemical used in personal care products and as a pH adjuster.
Ammonia	A colourless gas with a pungent smell, used in fertilisers and as a refrigerant.
Ammonium nitrate	A chemical compound used in fertilisers and explosives.

S&P Global Commodity Insights

Glossary – Definitions

Term	Definition
Ammonium sulphate (AS)	A fertiliser providing nitrogen and sulfur to plants.
Amylase	An enzyme that helps break down carbohydrates into sugars.
Anode	The positively charged electrode in a battery or electrochemical cell.
Anthocyanins	Pigments found in plants that give red, purple, and blue colours to fruits and flowers.
Antioxidants	Compounds that inhibit oxidation, protecting cells from damage.
Aromatics	Organic compounds characterised by one or more benzene rings, used in the production of chemicals and plastics.
Ascorbic acid	Also known as vitamin C, an essential nutrient and antioxidant.
Aspartame	A low-calorie sweetener used in food and beverages.
Asphalt	A sticky, black, and highly viscous liquid used in road construction and roofing.
Astaxanthin	A red pigment found in algae and seafood, used as a dietary supplement. Made from CO_2 using photo-biotechnology
Atactic polypropylene	A form of polypropylene with a certain arrangement of methyl groups, that gives properties useful for adhesives and sealants.
B	
Barrel (BBL)	A unit of measurement for oil and petroleum products, equivalent to 42 US gallons.
Base chemicals	Fundamental chemicals used as building blocks for more complex compounds.
Battery electric vehicles (BEV)	Vehicles powered entirely by electricity stored in batteries.
Battery energy storage systems	Systems that store energy for later use, often used in renewable energy applications.
Benzene	A colourless, flammable liquid used as a precursor in the production of various chemicals.

Term	Definition
Benzoate	A salt or ester of benzoic acid, used as a preservative in food and beverages.
β-glucanase	An enzyme that breaks down beta-glucans (natural polysaccharides found in the cell walls of cereals, bacteria, and fungi), used in brewing and animal feed.
β-sitosterol	A plant sterol with a structure similar to cholesterol, used in dietary supplements.
Bifidobacterium	A genus of bacteria found in the intestines, used as probiotics to promote gut health.
Binder	A substance that holds materials together, used in paints, coatings, and construction.
Biocides	Chemicals that kill or inhibit the growth of harmful organisms, used in agriculture and water treatment.
Bio-feedstock	Renewable biological materials used as raw materials in industrial processes.
Biofuel	Fuel derived from organic materials, used as an alternative to fossil fuels.
Biomass	Organic material from plants and animals, used as a renewable energy source.
Biomass-to-liquids	A process that converts biomass into liquid fuels (diesel, jet fuel, naphtha)
Bio-naphtha	A renewable feedstock derived from biomass, used in the production of chemicals and fuels.
Bioplastic	Plastics derived from renewable biomass sources, such as vegetable fats and oils.
Bio-scissors	Enzymes used to cut DNA at specific sites, used in genetic engineering.
Biotech	Short for biotechnology, which is the use of living organisms or biological systems to develop products and technologies that improve health, agriculture, and industry, driving innovation and economic growth in various sectors.
Biotin	Vitamin B7, essential for the metabolism of fats, carbohydrates, and proteins.

S&P Global Commodity Insights

Glossary – Definitions

Term	Definition
Bis-amidoamines	Compounds used as curing agents in epoxy resins and coatings.
Bismaleimide polymers	High-performance composites used in aerospace and electronics for their thermal stability.
Blue ammonia	Ammonia produced with low carbon emissions, often using carbon capture technology.
Blue biotechnology	The application of biotechnology in marine and aquatic environments.
Blue hydrogen	Hydrogen produced from natural gas with carbon capture and storage to reduce emissions.
Building blocks	Basic chemicals used as starting materials for more complex chemical products.
Bureau of Transportation Statistics (BTS)	A US Government agency providing data on transportation.
Butylated hydroxyanisole (BHA)	An antioxidant used to preserve food and cosmetics.
C	
Calcium (Ca)	A chemical element essential for living organisms, used in construction and manufacturing.
Calcium ammonium nitrate (CAN)	A fertiliser providing nitrogen and calcium to plants.
Calcium carbonate	A common substance found in rocks, used in construction, as a dietary supplement, and in antacids.
Calcium stearate	A calcium salt used as a stabiliser and lubricant in plastics and rubber moulding
Calcium sulfoaluminate	A compound used in the production of fast-setting cements.
Campesterol	A plant sterol similar to cholesterol, used in dietary supplements.
Caprolactam	A chemical used in the production of nylon-6 fibres and plastics.

Term	Definition
Carbamate	A class of organic compounds used in pesticides and as intermediates in chemical synthesis.
Carbon capture	The process of capturing carbon dioxide emissions from sources like power plants to prevent them from entering the atmosphere.
Carbon capture absorbents	Materials used to capture and store carbon dioxide from emissions.
Carbon capture and storage (CCS)	A technology designed to capture carbon dioxide emissions from industrial sources and store them underground to prevent them from entering the atmosphere and contributing to climate change.
Carbon capture, utilisation and storage (CCUS)	A technology that captures carbon dioxide emissions for storage or use in other processes.
Carbon dioxide (CO_2)	A colourless gas produced by burning carbon and organic compounds, and by respiration.
Carbon dioxide tons equivalent (CO_2te)	A measure used to compare the emissions of various greenhouse gases based on their global warming potential.
Carbon fibre	A strong, lightweight material made of thin, strong crystalline filaments of carbon, used in aerospace and automotive industries.
Carbon fibre reinforced polymers (CFRP)	Composite materials made of carbon fibres and a polymer matrix, known for their strength and lightweight properties.
Carbon footprint	The total amount of greenhouse gases emitted by an individual, organisation, event, or product.
Carbon monoxide	A colourless, odourless gas produced by burning carbon-based fuels, toxic to humans and animals.
Carbon nanotubes	Cylindrical molecules with extraordinary strength and electrical conductivity, used in nanotechnology and materials science.
Carbonates	Salts or esters of carbonic acid, used in various industrial applications.
Carboxymethyl-cellulose (CMC)	A cellulose derivative used as a thickener and stabiliser in food, oilfield chemicals and pharmaceuticals.

Glossary – Definitions

Term	Definition
Carotenoids	Pigments found in plants and algae, important for photosynthesis and as antioxidants.
Carrageenan	A natural thickener and stabiliser derived from red seaweed, used in food products.
Casein	A protein found in milk, used in cheese production and as a food additive.
Catalase	An enzyme that catalyses the decomposition of hydrogen peroxide to water and oxygen.
Catalysts	Substances that increase the rate of a chemical reaction without being consumed in the process.
Cathode	The electrode where reduction occurs in a battery or electrochemical cell.
Caustic soda	Also known as sodium hydroxide, a strong alkaline compound used in cleaning and manufacturing.
Cellulase	An enzyme that breaks down cellulose into glucose, used in biofuel production and food processing.
Cellulose	A complex carbohydrate that forms the main constituent of plant cell walls, used in paper and textiles.
Cementitious	Materials that have cement-like properties, used in construction.
Chemical grade propylene (CGP)	A propane/propylene product with (>97 wt% propylene) used in chemical manufacturing.
Chemical Industries Association	An organisation representing UK chemical and pharmaceutical businesses.
Chemical recycling	A process that breaks down plastic waste into its chemical components, allowing it to be reused to produce new plastics or other products, thereby reducing waste and conserving resources.
Chiral intermediate product	A compound with a specific three-dimensional arrangement of atoms, used in pharmaceuticals.
Chlor-alkali	An industrial process for producing chlorine and sodium hydroxide from salt.
Chlorinated intermediates	Compounds containing chlorine used as intermediates in chemical synthesis.

Term	Definition
Chlorine	A greenish-yellow gas used in water purification and the production of various chemicals.
Chloroprene	A synthetic rubber used in the production of neoprene.
Chlorosulfonated polyethylene (CSPE)	A synthetic rubber known for its resistance to chemicals and weathering.
Cholecalciferol	Also known as vitamin D3, essential for calcium absorption and bone health.
Chromium (Cr)	A metal used in stainless steel and as a protective coating for other metals.
Chromium oxide	A green pigment used in paints and coatings.
Citric acid	A weak organic acid found in citrus fruits, used as a preservative and flavouring agent.
Clean energy	Energy derived from renewable, zero-emissions sources, as well as energy saved through efficiency measures.
Cobalt	A metal used in batteries, alloys, and as a pigment.
Cobalt oxide	A compound used in ceramics, batteries, and as a catalyst.
Cogeneration of power and hydrogen (from coal) (CPH)	A process that simultaneously produces electricity and hydrogen from a single energy source.
Cohesive unit	A term used to describe a group of particles or molecules that stick together.
Commodity	A basic good or raw material, such as oil, gold, or agricultural products, that is interchangeable with other goods of the same type and is often traded on markets for investment and economic purposes.
Composite materials	Engineered materials made from two or more different substances that, when combined, create a stronger and lighter product, commonly used in industries like wind turbines, aerospace, automotive, and construction for enhanced performance and durability.
Compound annual growth rate (CAGR)	A measure of the mean annual growth rate of an investment over a specified time period longer than one year.

S&P Global Commodity Insights

Glossary – Definitions

Term	Definition
Conjugated linoleic acid	A type of fatty acid found in meat and dairy products, believed to have health benefits.
Contracts for difference (CFD)	A financial contract that pays the differences in the settlement price between open and closing trades.
Conventional plastic	Plastics made from petrochemicals, as opposed to bioplastics.
Copolymer polyproplyene composite (CPC)	A material made by combining polypropylene with other polymers to enhance its properties, used to improve strength, flexibility, and resistance to impact, making it suitable for various industrial applications, including automotive and packaging.
Coppicing	A traditional method of woodland management that involves cutting trees to ground level to promote new growth.
Cost of production (COP)	The total cost incurred by a company to produce a specific quantity of a product.
Critical National Infrastructure	The UK Government's policy on critical national infrastructure focuses on identifying, protecting, and ensuring the resilience of essential services and assets to safeguard national security, economic stability, and public safety against various risks and threats.
Crude acrylic acid (CAA)	A raw material used in the production of superabsorbent polymers (after purification) and coating resins (after esterification)
Crude oil	Unrefined petroleum, a fossil fuel used to produce gasoline, diesel, and other petrochemicals.
Cumene	An organic compound used as a precursor to phenol and acetone.
Cyanocobalamin	A synthetic form of vitamin B12, used to treat and prevent vitamin B12 deficiency.
Cycloaliphatic ether alcohol	A type of chemical compound used in coatings and adhesives.
D	
Decarbonisation	The process of reducing carbon dioxide emissions from energy sources.

Term	Definition
Defence materials centre of exellence (dmex)	An organisation focused on developing advanced materials for defense applications.
Dextrose	A form of glucose used as a sweetener and in medical treatments.
Diammonium phosphate (DAP)	A fertiliser providing nitrogen and phosphorus to plants.
Dianiline	An organic compound used in the production of dyes and polymers.
Dicylopentadiene (DCPD)	A C10 di-olefin compound used in the production of resins and as a specialty monomer in polymerisation.
Diethanol monoisopropanolamine (DEIPA)	A chemical used as a grinding aid in cement production.
Diethyl carbonate (DEC)	A solvent used in the production of lithium-ion batteries and as a reagent in organic synthesis.
Difluorobenzophenone	A chemical used in the production of advanced high-performance polymers like PEEK and as a UV absorber.
Diglycerides	A type of fat used as an emulsifier in food products.
Dimethyl carbonate (DMC)	A solvent for battery electrolytes and reagent used in the production of polycarbonate plastics and as a fuel additive.
Distillers dried grains and solubles (DDGS)	A by-product of ethanol production when grains like corn and wheat are processed, used as animal feed.
Drag	The resistance experienced by an object moving through a fluid, such as air or water.
E	
Earnings before interest and taxes (EBIT)	A measure of a company's profitability that excludes interest and income tax expenses.

S&P Global Commodity Insights

Glossary – Definitions

Term	Definition
Earnings before interest, taxes, depreciation, and amortisation (EBITDA)	A measure of a company's overall financial performance.
Effluorescent	A term used to describe a substance that loses water of crystallisation and becomes powdery upon exposure to air.
Elastomer	A polymer with elastic properties, used in rubber products.
Electric vehicle (EV)	A vehicle powered by an electric motor instead of an internal combustion engine.
Electrolyte	A substance that conducts electricity when dissolved in water, used in batteries and electrochemical cells.
Emissions trading scheme (ETS)	A market-based approach to controlling pollution by providing economic incentives for reducing emissions.
Encapsulants	Materials used to enclose or protect electronic components and solar cells.
Energy density	The amount of energy stored in a given system or region of space per unit volume.
Energy transition	The global shift from traditional energy sources (such as oil or coal) to renewable and sustainable alternatives, driven by the need for environmental sustainability, energy security, and economic growth.
Engineering, procurement and construction (EPC)	A form of contracting arrangement used in the construction industry.
Enzymes	Proteins that act as biological catalysts, speeding up chemical reactions in living organisms.
Epichlorohydrin	A chemical used in the production of epoxy resins and as a solvent.
Epoxies	A class of reactive prepolymers and polymers used in adhesives, coatings, and composite materials.

Term	Definition
Erythorbates	Salts of erythorbic acid, used as antioxidants in food preservation.
Erythritol	A sugar alcohol used as a low-calorie sweetener in food and beverages.
Ethane	A colourless, odorless gas used as a feedstock in the production of ethylene.
Ethanol	A volatile, flammable liquid used as a fuel, solvent, and in alcoholic beverages.
Ethanolamine	A chemical used in the production of detergents, emulsifiers, and pharmaceuticals.
Ethoxylated diisopropanolamine (EDIPA)	A chemical used as a surfactant and in the production of personal care products.
Ethyl methyl carbonate (EMC)	A solvent used in lithium-ion batteries and as a reagent in organic synthesis.
Ethylbenzene (EB)	A chemical used in the production of styrene, which is used to make polystyrene plastics.
Ethylene	A colourless gas and a key building block in the production of various chemicals and plastics, primarily used in the manufacturing of polyethylene and other synthetic materials.
Ethylene carbonate (EC)	A solvent used in lithium-ion batteries and as a plasticiser.
Ethylene glycol (EG)	A chemical used as an antifreeze and in the production of polyester fibres.
Ethylene oxide	A chemical used in the production of ethylene glycol and as a sterilising agent.
Ethylene propylene diene monomer (EPDM)	A type of synthetic rubber used in automotive and construction applications.
Ethylene vinyl acetate (EVA)	A copolymer used in the production of flexible films, foams, and adhesives.
Ethyleneamine	A class of chemicals used in the production of resins, adhesives, and as intermediates in chemical synthesis, e.g. specialised surfactants.

Glossary – Definitions

Term	Definition
Ethylene-methyl acrylate	A specialty copolymer used in packaging films and as a modifier for other polymers.
EU green deal	A set of policy initiatives by the European Union aimed at making Europe climate-neutral by 2050.
Excipients	Inactive substances that serve as carriers for the active ingredients. They help stabilise the vaccine, enhance its shelf life, and improve the delivery of the active components.
Expanded polystyrene (EPS)	A lightweight, rigid foam used in packaging, insulation, and construction.
F	
Fatty acids	Carboxylic acids with long hydrocarbon chains, used in the production of soaps, detergents, and cosmetics.
Feedstock	Raw material used to supply or fuel a machine or industrial process.
Fibreglass batts	Insulation material made from fine glass fibres, used in building construction.
Fine chemicals	Pure, single chemical substances produced in limited quantities, used in pharmaceuticals and agrochemicals.
Fischer-tropsch	A process that converts carbon monoxide and hydrogen into liquid hydrocarbons, used in synthetic fuel production.
Flake natural graphite	A form of graphite used in batteries, lubricants, and as a refractory material.
Flame retardants	Chemicals used to prevent or slow the spread of fire in materials.
Flavonoids	A group of plant metabolites with antioxidant properties, found in fruits and vegetables.
Flue gas	The gas emitted from the combustion of fuels, often containing pollutants that need to be treated.
Fluid catalytic cracker (FCC)	A process used in oil refineries to convert heavy hydrocarbons into lighter products like gasoline with light chemical feedstocks as co-products
Fluorinated ethylene-propylene (FEP)	A copolymer used in the production of non-stick coatings and as an electrical insulator.

Term	Definition
Fluorinated film composite (FFC)	A material made from fluorinated polymers, used in high-performance applications.
Fluoroethylene carbonate (FEC)	A solvent used in lithium-ion batteries to improve performance and safety.
Fluoropolymer film (FPF)	A film made from fluoropolymers, known for its chemical resistance and durability.
Fluoropolymers	A class of high-performance plastics known for their resistance to heat, chemicals, and electrical insulation properties.
Fly ash	A byproduct of coal combustion, used as a supplementary cementitious material in concrete.
Folic acid	Vitamin B9, essential for DNA synthesis and repair, used in dietary supplements and fortified foods.
Foreign direct investment (FDI)	Investment made by a company or individual in one country with business interests in another country.
Formaldehyde	A colourless, pungent gas used in the production of resins, textiles, and as a disinfectant.
Formic acid	A colourless liquid used as a preservative, antibacterial agent, and in leather production.
Fossil fuel	Natural fuels formed from the remains of living organisms, such as coal, oil, and natural gas.
Fossil-based	Products or processes derived from fossil fuels.
Fracking	A method of extracting natural gas and oil from deep underground by fracturing rock formations.
Fuel cell electric vehicle (FCEV)	A vehicle powered by a fuel cell that generates electricity from hydrogen.
Fumaric acid	An organic acid used as a food additive and in the production of resins and plastics.
Furfural	An organic compound derived from agricultural byproducts, used in the production of resins and as a solvent.
G	
Gas	A state of matter characterised by low density and viscosity, used as a fuel and in industrial processes.

Glossary – Definitions

Term	Definition
Geothermal (GT)	Energy derived from the heat of the earth's interior, used for electricity generation and heating.
Gigafactory	A large-scale manufacturing facility for the production of batteries and electric vehicles.
Gigawatt (Gw)	A unit of power equal to one billion watts, used to measure the output of large power plants.
Gigawatt-hour (Gwh)	A unit of energy representing one billion watt-hours, used to measure electricity consumption.
Glycerin	A colourless, odourless liquid used as a moisturiser in cosmetics and as a sweetener in food.
Glycol ethers	A class of solvents used in paints, coatings, and cleaning products.
Glycolic acid	An alpha hydroxy acid used in skincare products for its exfoliating properties and polymers for medical sutures
Graphite	A form of carbon used in pencils, lubricants, and as a conductor of electricity.
Green ammonia	Ammonia produced using renewable energy sources, with low carbon emissions.
Green biotechnology	The application of biotechnology to agriculture and environmental management.
Green hydrogen	Hydrogen produced using renewable energy sources, with no carbon emissions.
Greenhouse gas	Gases that trap heat in the atmosphere, contributing to global warming.
Grey ammonia	Ammonia produced using fossil fuels, with higher carbon emissions.
Grinding aids	Chemicals added to cement to improve its grinding efficiency and performance.
Gross value added (GVA)	A measure of the value of goods and services produced in an area, industry, or sector.
Guar gum	A natural thickener and stabiliser derived from guar beans, used in food and industrial applications.

Term	Definition
Gum Arabic	A natural gum made from the sap of acacia trees, used as a stabiliser in food and beverages.
H	
Halobutyl rubber	A type of synthetic rubber with air/water impermeability properties used in tire inner linings and pharmaceutical closures.
Hemi-cellulose	A group of complex carbohydrates found in plant cell walls, used in biofuel production.
Hexamethylene diamine	A chemical used in the production of nylon and urethane building blocks for coatings
High-density polyethylene (HDPE)	A strong, durable plastic used in containers, pipes, and geomembranes.
High purity ethylene oxide (HPEO)	A chemical used in the production of non-ionic surfactants, and a wide range of specialty chemicals
Hybrid electric vehicle (HEV)	A vehicle powered by both an internal combustion engine and an electric motor.
Hydrocarbon	Organic compounds consisting entirely of hydrogen and carbon, used as fuels and in chemical synthesis.
Hydrochloric acid	A strong acid used in industrial processes, cleaning, and as a laboratory reagent.
Hydrogen	The lightest and most abundant element, used as a fuel and in chemical synthesis.
Hydrogen allocation round (HAR)	A process for allocating funding or resources for hydrogen projects.
Hydrogen cyanide	A highly toxic gas used in chemical synthesis and as a fumigant.
Hydrogen fluoride	A chemical used in the production of fluorocarbons and as an alkylation catalyst in petroleum refining, as well as in uranium refining

Glossary – Definitions

Term	Definition
Hydrogen production business model (HPBM)	A framework for producing and commercialising hydrogen.
Hydrolyzates	Products of hydrolysis, used in food and feed applications.
Hydroprocessed esters and fatty acids (HEFA)	A process for producing renewable diesel and jet fuel from fats and oils.
Hydroquinone	A chemical used in skin lightening products and as a photographic developer as well as building blocks for advanced plastics
Hypo cap	Hypothetical capacity
I	
Imidazolines	A class of compounds used as corrosion inhibitors, surfactants and in pharmaceuticals.
Imide	A type of chemical compound used in the production of polymers and as a reagent in organic synthesis.
Industrial biotechnology (IB)	The application of biotechnology for industrial purposes, including the production of chemicals, materials, and energy.
Inflation Reduction Act (IRA)	United States legislation aimed at reducing inflation through various economic measures.
Inorganic chemicals	Compounds that do not contain carbon-hydrogen bonds, used in a wide range of industrial applications.
Internal combustion engine (ICE)	An engine that generates power by burning fuel inside a cylinder.
Inulin	A type of dietary fibre found in plants, used as a prebiotic and in food products.
Invertase	An enzyme that catalyses the hydrolysis of sucrose into glucose and fructose.

Term	Definition
Iodine (I)	A chemical element used in medicine, photography, and as a nutritional supplement.
Ionic liquids	Room temperature molten salts, used as solvents and in various industrial applications.
Iron (Fe)	A metal used in construction, manufacturing, and as a component of hemoglobin in blood.
Iron oxide	A compound used as a pigment, in magnetic materials, and as a catalyst.
Isobutylene	A chemical used in the production of synthetic rubber and as a fuel additive.
Isoflavones	A class of phytoestrogens found in soy and other plants, used in dietary supplements.
Isopropanol	A solvent used in cleaning, disinfectants, and as a precursor in chemical synthesis.
Isopropyl alcohol (IPA)	A colourless, flammable liquid used as a solvent and in personal care products.
J	
Japan Korea marker (JKM)	A pricing index for liquefied natural gas (LNG) in the Asian market.
Joint venture (JV)	A business arrangement in which two or more parties agree to pool their resources for a specific project.
K	
Kerosene	A flammable hydrocarbon liquid used as a fuel in jet engines and heating.
Kilograms of natural gas liquids (kg NGL)	A unit of measurement for natural gas liquids, used in the energy industry.
Kilowatt hour (kWh)	A unit of energy equal to one kilowatt of power used for one hour, used to measure electricity consumption.

S&P Global Commodity Insights

Glossary – Definitions

Term	Definition
L	
Lactase	An enzyme that breaks down lactose into glucose and galactose, used in lactose-free products.
Lactic acid	An organic acid used in food, pharmaceuticals, and as a preservative.
Lactobacillus	A genus of bacteria used in the production of yogurt and other fermented foods.
Lamination	The process of bonding layers of material together to form a composite.
L-carnitine	A compound involved in the metabolism of fatty acids, used as a dietary supplement.
Lecithin	A fatty substance found in animal and plant tissues, used as an emulsifier in food products.
Light vehicle (LV)	A category of vehicles that includes cars and light trucks.
Lightweighting	The process of reducing the weight of a product, often to improve fuel efficiency.
Lignosulfonate	A byproduct of the paper industry used as a dispersant and binder.
Linear low-density polyethylene (LLDPE)	A type of polyethylene used in packaging films and containers.
Liquified natural gas (LNG)	Natural gas that has been cooled to a liquid state for storage and transport.
Liquified petroleum gas (LPG)	A mixture of propane and butane used as a fuel for heating and cooking.
Lithium	A metal used in batteries, ceramics, and as a mood stabiliser in medicine.
Lithium carbonate	A compound used in the production of lithium-ion batteries and as a treatment for bipolar disorder.
Lithium cobalt oxide (LCO)	A compound used as a cathode material in lithium-ion batteries.

Term	Definition
Lithium hexafluorophosphate ($LiPF_6$)	A salt used together with specialty carbonate solvents in formulating electrolyte solutions for lithium-ion batteries.
Lithium hydroxide	A compound used in the production of lithium-ion batteries and as a carbon dioxide scrubber.
Lithium iron phosphate (LFP)	A compound used as a cathode material in lithium-ion batteries.
Lithium manganese oxide (LMO)	A compound used as a cathode material in lithium-ion batteries.
Lithium nitrate	A compound used in heat transfer applications and as a reagent in chemical synthesis.
Lithium silicate	A compound used in ceramics and as a binder in construction materials.
Low carbon ammonia	Ammonia produced with reduced carbon emissions, often using renewable energy sources.
Low-density polyethylene (LDPE)	A type of polyethylene used in packaging films, containers, and insulation.
Low-carbon hydrogen	Hydrogen produced with reduced carbon emissions, often using renewable energy sources.
Lutein	A carotenoid found in green leafy vegetables, used as a dietary supplement for eye health.
Lycopene	A red pigment found in tomatoes and other red fruits, used as a dietary supplement and food colouring.
Lysine	An essential amino acid used in animal feed and as a dietary supplement.

Glossary – Definitions

Term	Definition
M	
Magnesium (Mg)	A metal used in alloys, as a dietary supplement, and in various industrial applications.
Maleic anhydride	A chemical used in the production of resins, coatings, and as a precursor in chemical synthesis.
Malic acid	An organic acid found in fruits, used as a food additive and in skincare products.
Manganese (Mn)	A metal used in steel production, batteries, and as a dietary supplement.
Mechanical recycling	The process of recovering plastic waste through mechanical processes such as grinding and melting.
Medicinal and pharmaceutical products	Products used for medical treatment and health maintenance.
Megawatt (MW)	A unit of power equal to one million watts, used to measure the output of power plants.
Melamine foam	A type of foam used in soundproofing and cleaning products.
Melamine formaldehyde (MF)	A resin used in laminates, adhesives, and coatings.
Menadione	A synthetic form of vitamin K, used in animal feed and dietary supplements.
Metal organic framework (MOF)	A class of compounds consisting of metal ions coordinated to organic ligands, used in gas storage and separation.
Methanol	A colourless, volatile liquid used as a fuel, solvent, and in the production of formaldehyde.
Methanol to olefin (MTO)	A process that converts methanol into olefins, mainly ethylene and propylene used in the production of plastics.
Methyl methacrylate (MMA)	A chemical used in the production of acrylic plastics and resins.

Term	Definition
Methyl tertiary-butyl ether (MTBE)	A chemical used as a fuel additive to increase octane and reduce emissions.
Methylene	A chemical group consisting of one carbon atom bonded to two hydrogen atoms, used in organic synthesis.
Methylene dianiline (MDA)	A chemical used in the production of polyurethane and epoxy resins.
Methylene diphenyl diisocyanate (MDI)	A chemical used in the production of polyurethane foams and elastomers.
Microorganisms	Microscopic organisms, including bacteria, viruses, and fungi, used in biotechnology and medicine.
Million metric British thermal units (MMBTU)	A unit of energy used to measure the heat content of fuels.
Million metric tons of oil equivalent (mmtoe)	A unit of energy used to compare different types of energy sources.
Million metric tons per annum (mmtpa)	A unit of measurement for the production capacity of a facility.
Ministry of Defence (MOD)	A government department responsible for implementing defence policy.
Molecular weight	The mass of a molecule, calculated as the sum of the atomic weights of its constituent atoms.
Mono-amidoamines	Compounds used as intermediates in chemical synthesis and as surfactants.
Monoammonium phosphate (MAP)	A fertiliser providing nitrogen and phosphorus to plants.

Glossary – Definitions

Term	Definition
Monoethanolamine (MEA)	A chemical used in gas treatment processes and as a surfactant.
Monoethylene glycol (MEG)	A chemical used as an antifreeze and in the production of polyester fibres.
Monoglycerides	A type of fat used as an emulsifier in food products.
N	
Nacelle	The housing that holds the engine, generator, and other components of a wind turbine.
Naphtha	A flammable liquid hydrocarbon mixture used as a feedstock in petrochemical production.
Naphthalene	A white, volatile solid used in mothballs and as a precursor in chemical synthesis.
Neopolyol esters/diesters	Synthetic esters used as lubricants and in the production of plastics.
Net zero strategy (NZS)	A plan to achieve net zero carbon emissions by balancing emissions with removal or offsetting.
Niacin	Vitamin B3, essential for energy metabolism, used in dietary supplements and fortified foods.
Nickel	A metal used in stainless steel, batteries, and as a catalyst.
Nickel-cobalt-aluminium (NCA)	A type of lithium-ion battery cathode material.
Nickel-cobalt-manganese (NCM)	A type of lithium-ion battery cathode material.
Nitrite	A compound used as a preservative in food and in the production of fertilisers.
Nitrocellulose	Known as 'gun-cotton', a highly flammable compound used in the production of explosives and lacquers.

Term	Definition
Nitrogen, phosphorus, potassium (NPK)	The three primary nutrients in fertilisers, essential for plant growth.
N-methyl-2-pyrrolidone (NMP)	A solvent used in extractive distillation processes as well as in the production of para-aramid polymers and as a paint stripper.
N-methyldiethanolamine (MDEA)	A chemical used in gas treatment processes and as a surfactant.
Nonionic synthetic associative	A type of thickener used in paints and coatings.
Non-starch thickeners	Substances used to thicken food products without using starch.
North Atlantic Treaty organisation (NATO)	A military alliance of North American and European countries.
Nutraceutical	A food or food product that provides health and medical benefits, including the prevention and treatment of disease.
O	
Offshore wind	Wind farms located in bodies of water, used to generate electricity.
Oil	A viscous liquid derived from petroleum, used as a fuel and in the production of chemicals.
Oligosaccharides	Carbohydrates composed of a small number of sugar molecules, used in food and as prebiotics.
Omega-3	A type of polyunsaturated fatty acid found in fish and flaxseed, used as a dietary supplement.
Omega-6	A type of polyunsaturated fatty acid found in vegetable oils, used as a dietary supplement.

Glossary – Definitions

Term	Definition
Onshore wind	Wind farms located on land, used to generate electricity.
Optical clarity	The transparency and clearness of a material, important in applications like lenses and screens.
Organic chemicals	Compounds containing carbon, used in a wide range of industrial and consumer products.
Organic solvent	A solvent containing carbon, used to dissolve organic compounds.
Original equipment manufacturer (OEM)	A company that produces parts and equipment that may be marketed by another manufacturer.
Oxalic acid	A colourless, crystalline organic acid used as a cleaning agent and in chemical synthesis.
Oxygenates	Compounds containing oxygen, used to increase the oxygen content of fuels.
Ozone	A molecule composed of three oxygen atoms, used in water purification and as a disinfectant.
P	
Palm kernel oil (PKO)	An edible oil derived from the kernel of the oil palm fruit, used in food and as a sources of fatty acids for conversion into natural alcohols.
Pantothenic acid	Vitamin B5, essential for energy metabolism, used in dietary supplements and fortified foods.
Para-aramid (p-aramid)	A type of synthetic fibre known for its strength and heat resistance, used in protective clothing and composites.
Paraben	A class of preservatives used in cosmetics and pharmaceuticals.
Pectinases	Enzymes that break down pectin, used in fruit juice production and as a clarifying agent.
Peptide	Short chains of amino acids, used in pharmaceuticals and as dietary supplements.
Perfluoroalkoxy (PFA)	A type of fluoropolymer known for its chemical resistance and non-stick properties.

Term	Definition
Performance enhancers	Substances used to improve the performance of materials or products.
Perovskite	A type of crystal structure used in solar cells and other electronic applications.
Petrochemical	Chemicals derived from petroleum or natural gas, used in the production of plastics, fertilisers, and other products.
Phenol	A chemical used in the production of resins, plastics, and as a disinfectant.
Phenol foam	A type of foam used in insulation and as a fire-resistant material.
Phenol formaldehyde (PF)	A resin used in the production of adhesives for fibreboard, coatings, and molded products.
Phosphoric acid	A chemical used in fertilisers, food additives, and as a rust remover.
Phosphorus pentachloride	A chemical used in the production of phosphorus compounds and as a chlorinating agent.
Photobioreactors	Systems used to cultivate microorganisms or cells using light, used in biotechnology and biofuel production.
Photovoltaic (PV)	Technology that converts sunlight into electricity, used in solar panels.
Phytosterols	Plant-derived compounds similar to cholesterol, used in dietary supplements and as a food additive.
Pigments	Substances used to impart colour to materials, used in paints, inks, and cosmetics.
Plasticisers	Chemicals added to plastics to increase their flexibility and durability.
Plug-in hybrid electric vehicle (PHEV)	A vehicle powered by both an internal combustion engine and an electric motor, with the ability to recharge from an external source.
Poly(chlorotrifluoro ethylene-vinylidene	A copolymer used in high-performance applications for its chemical resistance.
Poly(chlorotrifluoro ethylene-vinylidene fluoride) (CTFE-VDF)	A copolymer used in high-performance applications for its chemical resistance.

Glossary – Definitions

Term	Definition
Poly(ethylene-chlorotrifluoroethylene) (ECTFE)	A copolymer used in high-performance applications for its chemical resistance.
Poly(ethylenetetrafluoroethylene) (ETFE)	A high-performance fluoropolymer known for its exceptional resistance to chemicals, heat, and UV radiation, making it ideal for applications in construction and solar panels.
Poly(ethylene-tetrafluoroethylene) (PTFE)	A fluoropolymer known for its non-stick properties and chemical resistance, used in cookware and industrial applications.
Polyacrylic acid (PAA)	A polymer used as a thickener, dispersant, and in superabsorbent materials.
Polyalkylene glycols (PAG)	A class of polymers used as lubricants and in hydraulic fluids.
Polyamide (PA)	A class of polymers known for their strength and resistance to wear, used in textiles and engineering plastics.
Polyamide 5,10	A type of nylon used in high performance fibres for its strength and durability.
Polyamide 5,6	A type of nylon used in apparel fibres and new applications as an engineering polymer for its strength and durability.
Polycarbonate/polymethylmethacrylate (PC/PMMA)	A blend of polymers used in optical applications for their clarity and impact resistance.
Polychlorotrifluoroethylene (PCTFE)	A fluoropolymer known for its chemical resistance and low permeability, used in aerospace and electronics.
Polydextrose	A synthetic polymer used as a low-calorie bulking agent in food products.
Polyether ether ketone (PEEK)	A high-performance polymer used in aerospace, automotive, and medical applications for its strength and heat resistance.

Term	Definition
Polyether imide (PEI)	A high-performance polymer used in aerospace and electronics for its strength and heat resistance.
Polyetherketone (PEK)	A high-performance polymer used in aerospace and electronics for its strength and heat resistance.
Polyetherketoneketone (PEKK)	A high-performance polymer used in aerospace and electronics for its strength and heat resistance.
Polyethylene (PE)	A common plastic used in packaging, containers, and pipes.
Polyethylene terephthalate (PET)	A plastic used in beverage bottles, food packaging, and textiles.
Polyisocyanate (polyiso)	A type of polymer used in the production of rigid foam insulation.
Polylactide	A biodegradable polymer used in packaging and disposable products.
Polymer emulsion	A dispersion of polymer particles in water, used in paints, adhesives, and coatings.
Polymer/chemical grade propylene (CGP)	A high-purity form of propylene used in chemical manufacturing.
Polymers	Large molecules composed of repeating structural units, used in a wide range of applications.
Polyol	A type of alcohol used in the production of polyurethanes and as a sweetener.
Polyolefin	A class of polymers derived from olefins, used in packaging, textiles, and automotive applications.
Polyolefin elastomer (POE)	A type of elastomer used in automotive and packaging applications for its flexibility and durability.
Polyolefin foam	A type of foam used in packaging, insulation, and automotive applications for its lightweight and cushioning properties.
Polyoxymethylene (POM)	A medium-performance engineering plastic used in precision parts for its strength and stiffness. Also known as polyacetal.

Glossary – Definitions

Term	Definition
Polyphenol	A class of compounds found in plants, known for their antioxidant properties.
Polyphenylene sulphide (PPS)	A high-performance polymer used in automotive, aerospace and electronics applications for its chemical resistance and heat stability.
Polypropylene (PP)	A versatile plastic used in packaging, textiles, and automotive applications.
Polysorbate	A class of emulsifiers used in food, pharmaceuticals, and cosmetics.
Polysulfone	A high-performance polymer used in medical and filtration applications for its strength and heat resistance.
Polyurethane	A versatile polymer used in foams, coatings, adhesives, and elastomers.
Polyvinyl chloride (PVC)	A plastic used in construction, pipes, and medical devices.
Polyvinyl fluoride (PVF)	A fluoropolymer used in films and coatings for its chemical resistance and weatherability.
Polyvinylamine	A polymer used in water treatment and as a flocculant.
Polyvinylidene fluoride (PVDF)	A fluoropolymer used in piping, films, and coatings for its chemical resistance and durability.
Potassium (K)	A chemical element essential for plant growth, used in fertilisers.
Potassium hydroxide	A strong alkaline compound used in soap making and as a chemical reagent.
Power purchase agreement (PPA)	A contract between a power producer and a buyer, outlining the terms of electricity sales.
Probiotics	Live microorganisms that provide health benefits when consumed, used in dietary supplements and food products.
Propionate	A salt or ester of propionic acid, used as a preservative in food products.
Propylene carbonate (PC)	A solvent used in lithium-ion batteries and as a plasticiser.
Propylene oxide (PO)	A chemical used in the production of polyurethanes and as a solvent.

Term	Definition
Proteases	Enzymes that break down proteins into peptides and amino acids, used in food processing and detergents.
Proton exchange membrane (PEM)	A type of membrane used in fuel cells to conduct protons while acting as an electronic insulator.
Pyridoxine	A form of vitamin B6, used in dietary supplements and fortified foods.
Pyrolysis	A process of decomposing organic material at high temperatures in the absence of oxygen, used in biofuel production.
R	
Red biotechnology	The application of biotechnology in medicine and healthcare.
Refinery grade propylene (RGP)	A form of propylene used in the production of chemicals and plastics.
Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	A European Union regulation aimed at ensuring the safe use of chemicals.
Reichstein synthesis	A method for synthesising vitamin C from sugar, used in the nutraceutical industry.
Renewable energy	Energy derived from natural sources that are replenished constantly, such as solar, wind, and hydroelectric power.
Renewable feedstock	Raw materials derived from renewable sources, used in the production of chemicals and fuels.
Renewable fuel standard (RFS)	A US policy that requires a certain volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel.

Glossary – Definitions

Term	Definition
Rennet	An enzyme used in cheese production to coagulate milk.
Resin transfer moulding (RTM)	A manufacturing process for producing composite materials, used in aerospace and automotive applications.
Retarders	Chemicals used to slow down the setting time of cement and concrete.
Retinol	A form of vitamin A, used in skincare products for its anti-aging properties.
Rheology	The study of the flow and deformation of matter, used in the formulation of paints, coatings, and food products.
Riboflavin	Vitamin B2, essential for energy metabolism, used in dietary supplements and fortified foods.
S	
Saccharomyces	A genus of yeast used in baking, brewing, and winemaking.
Selenium (Se)	A chemical element used in electronics, glassmaking, and as a dietary supplement.
Selling, general, and administrative expenses (SG&A)	The costs associated with running a business, excluding production costs.
Sequestration	The process of capturing and storing carbon dioxide to prevent it from entering the atmosphere.
Set accelerating water reducer	A chemical additive used in concrete to speed up the setting time and reduce water content.
Shale gas	Natural gas extracted from shale rock formations, using techniques like hydraulic fracturing.
Sheet membrane	A waterproofing material used in construction to prevent water penetration.
Shotcrete	A method of applying concrete by spraying it onto a surface, used in construction and repair.
Silanes	Compounds containing silicon and hydrogen, used as coupling agents and in the production of silicones.

Term	Definition
Silicone	A polymer made from silicon, used in sealants, adhesives, and medical devices.
Siloxanes	Compounds containing silicon-oxygen bonds, used in the production of silicones.
Silver paste	A conductive material used in electronics and solar cells.
Slag powder	A byproduct of steel production, used as a supplementary cementitious material in concrete.
Smart export guarantee (SEG)	A UK policy that requires energy suppliers to pay small-scale generators for the electricity they export to the grid.
Sodium	A chemical element used in the production of chemicals, glass, and as a dietary supplement.
Sodium gluconate	A compound used as a chelating agent and in the production of concrete admixtures.
Sodium hypochlorite	A chemical used as a disinfectant and bleaching agent.
Sodium-ion	A type of battery technology that uses sodium ions for energy storage.
Solar module	A device that converts sunlight into electricity, used in solar power systems.
Solar thermal (ST)	Technology that uses sunlight to generate heat, used in water heating and power generation.
Solid-state	A term used to describe electronic devices that use solid materials to control the flow of electricity.
Solid-state battery	A type of battery that uses solid electrodes and a solid electrolyte, offering improved safety and energy density.
Sorbate	A salt or ester of sorbic acid, used as a preservative in food products.
Sorbents	Materials used to absorb or adsorb liquids or gases, used in environmental cleanup and industrial processes.
Sorbitol	A sugar alcohol used as a sweetener and humectant in food and personal care products.

Glossary – Definitions

Term	Definition
Specialty	In the context of specialty chemicals, "specialty" refers to high-performance chemical products designed for specific applications, often tailored to meet unique customer requirements in industries like pharmaceuticals, agriculture, and electronics.
Spun polyurethane foam (SPF)	A type of foam used in insulation and cushioning applications.
Stanol	A type of plant sterol used in dietary supplements and as a cholesterol-lowering agent.
Starch	A carbohydrate found in plants, used as a food ingredient and in industrial applications.
Sterol	A type of organic molecule found in plants and animals, used in dietary supplements for lowering cholesterol
Stigmasterol	A plant sterol used in the production of steroid hormones and as a dietary supplement.
Styrene-butadiene rubber (SBR)	A synthetic rubber used in tires, footwear, and adhesives.
Styrene-butadiene-styrene (SBS)	A thermoplastic elastomer used in adhesives, sealants, and asphalt modification.
Substrate	A material or surface on which a process occurs, used in electronics, printing, and biotechnology.
Sucralose	A calorie-free artificial sweetener used in food and beverages.
Sulphites	Compounds used as preservatives in food and beverages, known to cause allergic reactions in some individuals.
Supercritical CO_2	A state of carbon dioxide used as a solvent in extraction processes and as a working fluid in power generation.
Surfactants	Compounds that lower the surface tension between two substances, used in detergents, emulsifiers, and foaming agents.
Sustainable aviation fuel (SAF)	A type of fuel derived from renewable sources, used to reduce the carbon footprint of aviation.
Syngas	A mixture of hydrogen and carbon monoxide used as a fuel and as a feedstock in chemical synthesis.

Term	Definition
T	
Tartaric acid	An organic acid found in grapes, used as a food additive and in winemaking.
Taurine	An amino acid used in energy drinks and as a dietary supplement.
Temperature swing adsorption	A process used to separate gases by cycling between adsorption and desorption at different temperatures.
Terephthalic acid (PTA)	A chemical used in the production of polyester fibres and resins.
Tert-amyl methyl ether (TAME)	A chemical used as a fuel additive to increase octane and reduce emissions.
Tert-butylhydroquinone (TBHQ)	A synthetic antioxidant used to preserve food and cosmetics.
Tetrafluoroethylene/hexafluoropropylene/vinylidene fluoride (THV)	A copolymer used in high-performance applications for its chemical resistance.
Thermoplastic	A type of plastic that becomes pliable or moldable at a certain temperature and solidifies upon cooling.
Thermoplastic copolyester (TPC)	A type of thermoplastic used in automotive and consumer goods for its flexibility and durability.
Thermoplastic elastomer (TPE)	A type of elastomer that combines the properties of rubber and plastic, used in automotive and consumer goods.
Thermoplastic olefin (TPO)	A type of thermoplastic used in automotive and construction applications for its durability and weather resistance.
Thermoplastic polyfluoroethylene (TPF)	A type of fluoropolymer used in high-performance applications for its chemical resistance.

Glossary – Definitions

Term	Definition
Thermoplastic polyvinyl fluoride (TPT)	A type of fluoropolymer used in films and coatings for its chemical resistance and weatherability.
Thermoset	A type of plastic that becomes irreversibly hard upon curing, used in adhesives, coatings, and composites.
Thiamine	Vitamin B1, essential for energy metabolism, used in dietary supplements and fortified foods.
Thiocyanate	A compound used in the production of pharmaceuticals and as a reagent in chemical synthesis.
Threonine	An essential amino acid used in animal feed and as a dietary supplement.
Titanium dioxide	A white pigment used in paints, coatings, and as a UV filter in sunscreens.
Title transfer facility (TTF)	A virtual trading point for natural gas in the Netherlands, used as a pricing benchmark in Europe.
Tocopherol	A form of vitamin E, used as an antioxidant in food and cosmetics.
Tocotrienols	A form of vitamin E, used as an antioxidant in dietary supplements and cosmetics.
Toluene diisocyanate (TDI)	A chemical used in the production of polyurethane foams and elastomers.
Tower	A structure used in various applications, such as wind turbines, telecommunications, and construction.
Triazole	A class of compounds used in the production of pharmaceuticals and as fungicides.
Triethanolamine (TEA)	A chemical used as a surfactant, emulsifier, and pH adjuster in personal care products.
Triisopropanolamine (TIPA)	A chemical used as a grinding aid in cement production and as a surfactant.

Term	Definition
U	
Ultra-high molecular weight polyethylene (UHMWPE)	Known for its strength and impact resistance, used in medical and industrial applications and defence equipment.
Ultraviolet (UV)	A type of electromagnetic radiation used in sterilisation, curing, and as a light source.
Urea-formaldehyde (UF)	A resin used in adhesives, coatings, and as a binder in particleboard.
V	
Vinsole	A term that could refer to various products or concepts, depending on the context.
Vinyl acetate monomer (VAM)	A chemical used in the production of polyvinyl acetate and other polymers.
Vinylene carbonate (VC)	A chemical used as an electrolyte additive in lithium-ion batteries.
Vinyls	A class of polymers derived from vinyl compounds, used in a wide range of applications.
W	
Water-soluble polymers	Polymers that dissolve in water, used in detergents, personal care products, and as thickeners.
Watt-hours per litre (Wh/L)	A unit of energy density used to measure the energy content of a fuel or battery.
Welan gum	A polysaccharide used as a thickener and stabiliser in food and industrial applications.

Glossary – Definitions

Term	Definition
West Texas intermediate (WTI)	A grade of crude oil used as a benchmark in oil pricing.
Wet milling	A process used to separate components of grains, used in the production of corn syrup and ethanol.
White biotechnology	The application of biotechnology in industrial processes, including the production of chemicals, materials, and energy.
Wind energy	Energy generated from wind using turbines, used as a renewable energy source.
Workability enhancers	Additives used in concrete to improve its workability and performance.
Xanthan gum	A polysaccharide used as a thickener and stabiliser in food and industrial applications.
Xylitol	A sugar alcohol used as a sweetener in food and dental products.
Xylose	A sugar found in wood and plant fibres, used in food and as a precursor in chemical synthesis.
Zeaxanthin	A carotenoid found in green leafy vegetables, used as a dietary supplement for eye health.
Zinc (Zn)	A metal used in galvanising, alloys, and as a dietary supplement.

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