IMPERIAL POLICY FORUM

TRANSITION TO ZERO POLLUTION

The UK’s Chemical Transition

Workshop Report

September 2024

Authors: Ines Wittke, Louise Oldham, Riccardo Standish, Dr Alex Berry

Contents

About this report

This report summarises the views of participants from a workshop on the UK's chemical transition, which was organised by Imperial College London's Transition to Zero Pollution Initiative, in partnership with the Imperial Policy Forum. The workshop took place on 1 May 2024, and was split into two parts. The first part consisted of a series of presentations by Imperial academics and industry experts. The second part of the workshop included a panel discussion with the speakers and wider audience, on the future of the chemicals sector in a Net Zero world. A summary of the main discussion points, along with abstracts from speakers' presentations, are included below. We thank the speakers and workshop participants for their contributions. The panel members were: Dr David Bott (Society of Chemical Industry), Stuart Collings (INEOS), Dr Elena Crina Corbos (Johnson Matthey), Professor Magda Titirici (Imperial College London), Professor Benoit Chachuat (Imperial College London), Professor Nilay Shah (Imperial College London, Co-Chair) and Professor James Durrant (Imperial College London, Co-Chair).

Background

The chemicals sector is a key part of the UK's national economy, ranking as the second biggest manufacturing exporter[1] and directly employing approximately 150,000 people[2], while supporting a further 500,000 jobs[3]. As a vital part of the broader manufacturing landscape, the sector enables the production of an extensive range of goods vital to our daily lives, from pharmaceuticals to agricultural products to consumer items. However, it is also one of the most energy-intensive sectors, responsible for a substantial portion of the UK's industrial greenhouse gas (GHG) emissions. The Climate Change Committee estimated in 2020 that the chemicals sector contributes to around 18% of the UK industrial emissions[4]. Addressing these is critical for the UK to meet its ambitious climate targets and transition to a net-zero economy by 2050.

The sector has already taken active steps to reduce its impact, reducing greenhouse gas emissions by 80% since 1990 in the UK and committing to further reductions of 90% by 2050[5]. Despite these efforts, a clear implementation strategy to make these further reductions remains elusive, primarily due to insufficient government support and direction. The UK Government's Chemicals Strategy, initially slated for release in 2023, was intended to guide this transition toward a sustainable, low-

[1] https://www.cia.org.uk/press-releases/cia-business-survey-top-manufacturing-exporter-has-turned-the-corner/538.article
[2] https://www.allianz-trade.com/content/dam/onemarketing/aztrade/allianz-trade_com/en_gb/documents/hub/economic-news/uk-chemicals-sector-report-2024.pdf
[3] https://www.cia.org.uk/the-chemical-industry#:~:text=We%20directly%20employ%20138%2C000%20people,500%2C000%20jobs%20around%20the%20UK.
[4] https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Manufacturing-and-construction.pdf
[5] https://www.cia.org.uk/energy-and-climate-change/navigating-net-zero/74.article

carbon future. However, as of mid-2024, its absence has created uncertainty and stifled the investment needed for meaningful transformation. Crucial questions surrounding resource efficiency, the logistics of alternative feedstocks, and effective emission reduction strategies linger, underscoring the urgency for decisive action.

Summary of panel and audience discussion

Economic incentives for transitioning aren't there yet, there is an opportunity for policy to create them

The panel highlighted the significant financial barriers that currently impede the chemical sector's transition to net zero, emphasising that without targeted regulatory changes, the sector cannot be expected to bear these costs alone. Such changes will likely lead to increased production costs in the short to medium term, underscoring the need for government intervention in determining how these costs are managed and distributed.

The panel broadly agreed that the government should take an outcome-oriented approach to decarbonising the sector by setting the standards producers should meet with their products. There is precedent for success under such a model in the UK, for example, with regulations that were introduced to limit emissions from cars. This compelled the automotive sector to innovate to meet new standards within a set timeframe. For example, the United States Clean Air Act of 1970 which mandated significant reductions in vehicle emissions led to the widespread adoption of catalytic converters to help convert harmful pollutants in exhaust gases into less harmful substances. The technology became standard in American cars by the mid-1970s and was later adopted globally. Applying this approach to the chemical sector has the potential to drive competition while allowing domestic industry to flourish, leading to the import and export of clean goods.

The UK has an opportunity to act as a leader in standard-setting for decarbonising chemicals production, and to benefit from a first-mover advantage by acting as the benchmark for regulation globally. In recent years, the UK chemicals industry has faced a significant decline, particularly as production has shifted to other countries to drive down costs. Moving early on implementing new policy would help attract investment and shape the competitive landscape to the UK chemical industry's advantage. There are regulatory issues and tools where the UK would be well-suited to act as the leader given its expertise in AI and tech for sustainability, one of them being carbon traceability (allowing tracking of sustainably produced chemicals through the supply chain).

The sector needs a cohesive industrial strategy to navigate its complex transition

The panel emphasised the urgent need for a well-defined industrial strategy to serve as a roadmap toward net-zero emissions. However, the sector's ability to engage effectively with policymakers has been hampered by its fragmented nature. The chemical industry encompasses a wide array of products, processes, and production sites, making it challenging to present a unified voice. This fragmentation has contributed to the sector's difficulties in securing consistent government support, especially amidst the political uncertainties following the UK's departure from the European Union.

A successful transition will not look the same for each site, and an industrial strategy will have to identify common challenges and opportunities while providing targeted guidance and support for sites with more specific needs. In addition to providing coordination, a robust industrial strategy would incentivize innovation and investment in new technologies, such as carbon capture and storage (CCS) or sustainable chemical production methods.

The panel also emphasised that an industrial strategy was key to investor confidence and would help maintain value chains in the UK, which would not only protect jobs, but also simplify the traceability of carbon in chemicals if production remains located within UK borders. This is particularly important for the sector, as carbon traceability will be key to the successful implementation of the Carbon Border Adjustment Mechanism, due to be introduced in 2027.

The UK chemicals sector should maximise flexibility and take advantage of geographical endowments to produce in a net zero landscape

Industry should be thinking about how to best make use of the geographical endowments the UK enjoys, notably wind power whilst avoiding unintended consequences that can be caused if a system is optimised for one outcome (in this case minimising carbon) and fails to consider potential knock-on effects on other economic sectors as well as unintended environmental and societal impacts.

A key challenge with many renewable energy sources is intermittency, and the sector will have to maximise flexibility within its production processes to work with fluctuating supplies of energy and feedstocks. The panel highlighted that there is precedent for this within the industry, with plants scaling production up or down depending on energy costs. Energy storage is also a potential solution to help address intermittent energy supply, and R&D has an important role to play in developing efficient, cheap and scalable storage technologies.

The UK could make greater use blue chemicals to accelerate the sector's emission reduction efforts, and slow the rate of global warming

Blue chemicals, which leverage fossil-based feedstocks while significantly cutting emissions through carbon capture and storage (CCS), present a vital opportunity for the UK to achieve sharp and immediate emissions reductions. Existing clusters, such as those in Scotland (Grangemouth/Mossmoran), Merseyside, Teesside and Humberside, provide established infrastructure and logistical advantages that facilitate the implementation of CCS technologies. CO_2 can be stored in existing oil and gas fields in the north of the UK, making these clusters ideal for integrating blue chemical production, and presenting an opportunity for cost-effective emissions reductions.

There is, however, a risk that as the UK's net-zero strategy evolves and shifts towards green production, using for example biofuels, production will become more fragmented as it relies on more localised feedstock sources which may not be readily available near industrial clusters. Such a shift could reduce the strategic value of existing industrial clusters. To optimise the UK's transition, a balanced approach is needed—one that harnesses the immediate emissions reduction potential of blue chemicals within existing clusters while also planning for the long-term integration of sustainable feedstocks in a diversified production network.

Industry should make a concerted effort to produce demonstrator sustainable chemicals which have the potential to decarbonise large parts of its value chains

There was consensus among attendees on the need for demonstrator sustainable chemicals to stimulate innovation across industry, but some discussion about what the best candidate would be. High value chemicals garner a lot of industry attention, and while initially targeting already expensive chemicals may be a good strategy given that demand is less price-sensitive, these chemicals tend to have limited uses and therefore might not have as great an impact on the sector. On the other hand, cheaper chemicals that are much more widely used have the potential for a greater impact, but the increase in costs may be prohibitively high for consumers. A good compromise would be to focus efforts on a key platform chemical that is produced in large volumes and has comfortable margins. For example, ethylene has intermediate value and is widely used in the downstream manufacture of further chemical products.

Given the complex production chains for chemicals, the panel agreed that focusing on platform chemicals made sense to coalesce decarbonisation efforts on, as they can be produced sustainably at dispersed sites. This was seen as more cost-efficient than relocating entire chemical production chains away from clustered sites that benefit from optimised processes. These platform chemicals can then be transported to clustered sites for further downstream processing, allowing for further innovation in decarbonising the rest of the production chain.

We need to adopt a more global perspective on the way we transition

Panel members highlighted the urgent need to rethink consumption patterns as part of the UK's decarbonisation strategy, noting that many of our emissions reductions have been achieved by offshoring high-polluting manufacturing while continuing to consume these products. This approach not only undermines global climate efforts but also perpetuates environmental and social injustices.

Developed economies like the UK have a moral responsibility to avoid exploiting other countries' natural resources, especially minerals essential for green technologies. These resources are often extracted under damaging and exploitative conditions, driving environmental degradation in poorer nations. To address this, the UK must prioritise sustainable consumption, invest in research and development of alternatives, and promote recycling to reduce dependency on critical minerals.

By leading in sustainable practices and fair resource use, the UK can set a global standard for a just transition, ensuring that our climate actions support rather than harm vulnerable communities. This leadership could be as pivotal as the UK's role in the Kyoto Protocol, reinforcing our commitment to international cooperation and ethical trade practices.

Summary of speaker's presentations

Dr David Bott (Society of Chemical Industry) – Why we need non-virgin fossil fuel feedstocks for the chemicals industry and the challenges that involves

A key challenge for the chemical industry is transitioning away from virgin fossil feedstocks. The Flue2Chem project aims to make a demonstrator product, in this case an important surfactant, entirely from CO_2-derived carbon which the project's industry partners are using to make demonstrator cleaning products. This project has highlighted several important learnings, notably the fact that a lot of hydrogen will be required for clean production process to be implemented at scale, and that significant logistical challenges will arise as production becomes increasingly decentralised with the use of alternative feedstocks. The UK chemicals industry can, in theory, achieve net-zero, but it will require major regulatory and infrastructural changes. significant shifts in regulation and the infrastructure that supports the sector.

Professor Nilay Shah (Imperial College London) - Blue Chemicals

Blue chemicals, which use fossil-based feedstock whilst reducing emissions, have an important role to play in the sector's transition. They can be derived from either virgin or recycled carbon but need to follow key principles to be used responsibly: that production processes minimise scope 3 upstream emissions, feedstocks are sourced from best-practice operations, increase the use of monitoring, measurement & verification and electrification, produce significant reductions in scope 1 and 2 (process) emissions, and make extensive use of CCS and fuel switching where possible. Expansion of blue chemicals production should go hand in hand with better end of life management, maximising recycling, and avoiding combustion.

Blue chemicals allow companies to make significant emissions reductions whilst leveraging existing processing assets. Currently, CO_2 and biomass are not ready at an appropriate scale, and the energy required to reduce CO_2 to other valuable chemicals is greater than can currently be supplied to the sector. Research at the Sargent Centre for Process Systems Engineering shows that industrial clustering can reduce costs through shared infrastructure for electricity, CO_2 transport and storage, and hydrogen production.

While green chemicals are critical for the long term, there are significant challenges including cost and infrastructure that prevent the sector from deploying them at scale. Whilst address these barriers, it is important that the chemical industry explores the near-term opportunities of blue chemicals, as well as blue-green hybrids, which are products that are synthesised by combining blue and green precursors.

Stuart Collings (INEOS) - Blue Chemical Opportunities for INEOS

Grangemouth, one of the UK's largest petrochemical sites, produces ethylene, polyethylene, polypropylene, and ethanol. The site emits 3 million tonnes of CO_2 annually, down from 5 million in 2000, with a net-zero goal by 2045. The majority of these CO_2 emissions come from fuel that is used for heat rather than chemical production itself. If the refinery was to close, then emissions would drop by another circa one million tonnes. INEOS's net-zero strategy includes fuel switching to hydrogen and further site optimisation.

INEOS plans to transition to green hydrogen (rather than blue hydrogen) as economics improve and continues to explore green hydrogen technology. They aim to grow the hydrogen business further and offer hydrogen to other on-site or off-site users, leveraging Grangemouth's existing infrastructure and expertise in large-scale industrial processes.

Dr Elena Cristina Corbos (Johnson Matthey) – Green Chemicals at Johnson Matthey

Johnson Matthey (JM) work on the chemical industry's transition to net-zero across four key areas: transforming global energy systems, decarbonising chemicals production, driving down automotive emissions and creating a circular economy. JM has leading technology to enable blue hydrogen and is working with customers on commercial-scale CCS-enabled hydrogen production projects. To enable the energy transition, JM is developing catalysts and components for electrolysers and fuel cells. JM's technologies are enabling sustainable aviation fuels production using a range of feedstocks including waste, biomass, captured CO_2 and renewable hydrogen. Significant work looks at syngas production, as it is a platform chemical used in the production of 40% of chemicals. JM also a leader in secondary recycling of platinum group metals enabling a circular chain/economy and thus large-scale deployment of PEM electrolysers. Looking ahead, JM is researching electrochemical transformations to make products directly from CO_2 and skip the hydrogen step; exploring opportunities for new platform molecules; and investigating green routes to ammonia.

Professor Magda Titirici (Imperial College London) – Green chemicals

Research in the Titirici Group focuses on sustainable energy materials, including catalysts for electrolysis with biomass-derived proton sources. Biomass oxidation at the anode can be used to produce high value chemicals, while still deriving green hydrogen at the cathode. The catalysts for biomass oxidation must have high selectivity for a particular product. Glycerol is a strong candidate for biomass, as it is a byproduct of biodiesel production that is low cost and with a surplus to demand. Platinum can oxidise glycerol at low potentials, and some recent work in the Titirici group has investigated the impact of replacing some of the platinum atoms with non-critical nickel.

Professor Benoit Chachuat (Imperial College London) - Taking a Systems View of Blue and Green Chemicals Production

A major focus of Professor Chachuat's research is on ethylene production. The largest volume chemical produced in the UK, ethylene is a building block for products such as plastics and has significant CO_2 emissions. The challenge lies in finding alternatives to traditional steam cracking used to produce ethylene from fossil fuels. Whilst alternative ethylene production pathways that lower CO_2 emissions are possible by varying feedstocks, intermediates and technologies, technoeconomic analysis of green ethylene show that utilising only renewable electricity and hydrogen while capturing all CO_2 during production would triple the production costs over using a single steam cracker. The most economical pathway identified was converting CO_2 to methanol then ethylene, with electrochemical routes also showing potential. High energy demands are also an issue. Producing green ethylene would require 52 TWh of electricity and 14 TWh for direct air capture for a single cracker, an amount of energy that would demand a dedicated offshore wind farm larger than Greater London.

Professor Chachuat's research demonstrates that when decarbonising chemical manufacturing, it is essential to take a systems approach to compare different production paths and determine the economically and environmentally optimal route.