Carbon & Cash: Financing a Circular Chemical Economy

Policy White Paper

University of Sheffield

UKRI Interdisciplinary Centre for Circular Chemical Economy

WRAP

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Policy White Paper

Science and politics frequently overlap to address many of the key challenges facing society. None more so than the need to address climate change and the requirement to move towards more sustainable and circular economies. The chemical industry is no exception to the need for change.

This Policy White Paper aims to pull together expertise from stakeholders across the sector – from academia, industry, NGOs and learned societies – to recommend how a circular economy can be realised in this important sector.

Carbon & Cash: Financing a Circular Chemical Economy

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Foreword

Financing a Circular Chemical Economy

The challenge of climate change means that we need to reduce CO_2 emissions significantly if we are to address the warming of the planet. 95% of oil and gas production is used to make fuels and energy. The remaining 5% is used to make millions of everyday products we know today.

Each of the different pathways to creating materials without using virgin fossil fuel feedstocks has challenges and no one solution will be sufficient on its own. Bio based materials compete with food for land usage. Biomass has limited availability and also has competing uses. Biotechnology solutions will yield some significant steps forward but will not provide a panacea for all products. Therefore, a fundamentally different approach to making materials and managing carbon is needed.

This White Paper outlines two approaches which should be urgently progressed. The first is new technology to make a wide range of these everyday materials from $CO_{2,}$ instead of using fossil fuel feedstock. This requires fundamentally different chemistry from the chemistry existing today to be developed and scaled, and significant research funding is required to do this.

The second is to create a valuable market in renewable carbon. Whilst not all carbon can be recycled today several volume products could be targeted, for example certain types of plastics, as well as those made from renewable carbon such as from CO_2 emissions.

This report sets out the range of actions required to drive these two solutions forward, including the key recommendations below:

1. **Changing the regulatory environments to incentivise for the use of renewable carbon.**
    a. CO_2 and plastic waste (where applicable) should be immediately reclassified as materials rather than as waste products.
    b. Renewable carbon should be valued at a premium over virgin carbon in regulatory tools (e.g. carbon border adjustment mechanism and carbon offsetting).
2. **Creating a renewable carbon economy and supporting investment.**
    a. A strategic industry advisory unit with serious funding should be created to support the commercialisation of new technologies that will drive a renewable carbon economy.

   b. Funding should be urgently put in place to develop utilisation technologies (moving from CCS to CCUS) and supporting scale up to full commercialisation of green feedstocks.
   c. The investment case for large chemical companies looking to migrate from virgin carbon to place manufacturing in the UK should be created.

3. **Agree and use a standard measurement process for assessing carbon.**
   a. A BSI standard for Life Cycle Analysis, including a resource depletion indicator, needs to be urgently put in place to measure sustainability as there is currently no credible or common measure of sustainability.
4. **Invest in the new skills we will need for this reinvented core industry.**
   a. The tax relief credits on oil and gas should be repurposed towards reskilling jobs in the circular economy.

It is critical that changes are made to how products are manufactured today in order to address climate change. Advances in new chemistries and the valuing of renewable carbon are critical enablers to developing new, more sustainable products.

Sharon Todd October 2024

Chief Executive Officer, SCI

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Executive Summary

Key findings and recommendations from policy workshops discussing how to finance a transition to a circular economy in the UK chemical manufacturing sector. Senior representatives from academia, industry, special interest groups and learned societies were invited to contribute their views, requirements and perceived challenges.

Moving to a circular economy is imperative not only for environmental reasons. It has potential for wide-ranging economic and societal benefits, giving the capacity to grow and thrive, create green jobs, upskill the workforce, increase self-sufficiency by reducing import reliance, improving infrastructure and providing a brighter outlook for future generations.

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Key Findings

Technologies

CO$_2$ is currently viewed as a waste product, but it is a valuable commodity resource to reduce costs for many industries within the chemical sector and beyond.

Current UK policies place an **over-importance on waste carbon and biomass for fuels**. Valuable chemical feedstocks can be extracted before conversion into fuels, offering much greater GHG reductions as carbon emissions are not immediately re-released.

Accessing resources and facilities for **scaling-up early-stage research and building demonstrator units** is extremely difficult. A portfolio of demonstrator units would help to boost investor confidence and de-risk these new technologies.

Finance & Fiscal

UK-based finance opportunities are severely lacking which poses a significant barrier to developing and scaling innovation. Increasingly, funding of the scale required is being sought and obtained overseas leading to an outward flow of UK innovations.

Investment risk remains a significant challenge, particularly with business-as-usual activities having greater stability and return on investment. Limited investor understanding of this sector further adds to the perceived degree of risk.

Sector funding requirements are far greater than in other areas, in the billions of GBP, with considerably high seed funding costs, CAPEX costs due to operational scale, and a large gap between the early and pre-commercial stages requiring additional support.

Government collaboration, both inter-administration and the devolved nations, with industry and financial institutions, is needed urgently.

General

The utilisation value of carbon must be recognised. A product-focus on waste generation would help to create efficiencies in the supply chain, such as better product design and **incentivising Carbon Capture & Utilisation (CCU) over Carbon Capture & Storage (CCS)** (which is unsustainable, economically unproductive and likened to landfilling).

While intellectual property (IP) generation is generally strong **the transition to commercialisation and retention of IP is weak**. **The UK is not seen as an attractive investment for scaled infrastructure**, which is compounded by high manufacturing and labour costs. In turn this creates an **outward flow of manufacturing** meaning emissions of embodied carbon are overseas.

Prioritising environment over profit needs to be more attractive, facilitated by a longer-term outlook, increased profit potential and decreased risk to invest in these sectors. An over-focus on return on investment under short timeframes is a barrier to change.

Further education is needed to help investors and policymakers understand this technical space. If the risks are not fully understood, investor confidence will be low.

Competing priorities and strategies of government departments are hindering progress. A unified, multi-department approach is needed, with clear, attainable sustainability targets.

The sole focus on Net Zero can hinder broader sustainability achievements. A more holistic view is required to address overall environmental issues, of which emissions reduction is one aspect.

An impediment to change is that **understanding of the chemical industry and circular business models are underdeveloped and different across UK administrations**.

Key Recommendations

Technology

1. **Support industrial symbiosis clusters.** Promote initiatives that see *waste* as containing resources not for discard but as a valuable feedstock, towards overcoming challenges of meeting *end-of-waste* status to accelerate circular businesses.
2. **Create national, collaborative public sector research institutions operating as a commercial business with industry and academia.** To incentivise partnerships and commercialisation and support early-stage research scale-up, plus the added benefits of employment opportunities and revenue generation.
3. **Support novel technologies and early-stage research through all TRL levels to de-risk investment opportunities.** Greater access to financial support and resources to assess and minimise risk in building demonstrator units should enable quicker scale-up and growth.
4. **CCU should be prioritised over CCS.** CCU can be revenue generating and give rise to economic growth and job creation. A longer-term vision for CCU must be realised with investment in infrastructure.
5. **Obtaining sources of sustainable carbon,** including biomass, recycled plastics, and captured carbon, are fundamental to a circular transition.

> ***"There are a lot of 'stick' approaches but not a lot of 'carrot' in the UK… at the moment everything that we're doing is very much a 'stick' approach. There's going to be emissions taxes… but we don't have any incentives."***
>
> *Industrial representative*

Financial & Fiscal

1. **Carbon pricing must be redesigned to provide an incentive for the recirculation of carbon** back into the economy, realising the inherent value of '*waste*' carbon in the creation of new products, thereby displacing virgin

fossil carbon that would otherwise be required. Rooting in the *proximity principle* would help to further prevent offshoring of *waste*. Also consider the carbon emission efficiencies and only subsidise the actual carbon savings.

2. **Greater appreciation of the value of the chemical industry** from an economic, societal, and political perspective, offering security of supply in turbulent times.
3. **Oil and gas tax relief refocussed towards re-skilling and training.** Ensuring minimal job losses and continued sector growth.
4. **Additional support for investment opportunities.** Investment funding guarantees should be offered more frequently and include a requirement of independent investment review to de-risk and boost investor confidence. Public equity, private funds and wider debt and equity instruments are needed to develop and scale CE interventions and technologies.[3]
5. **Redesign of UK ETS to include robust rules for capture projects could act as an incentive for capture-to-chemicals, with current proposals not incentivising this valorisation market.** The carbon offsetting voluntary market is not operating as intended, with the measurement approach vital to its validity.
6. **Embrace longer-term thinking to achieving positive impact.** Sustainable initiatives typically require longer investment and return periods to have measurable impact. Underlying market conditions need government support to ensure future market demand at reasonable production costs.

> ***"The UK is <u>not</u> seen as an attractive place for investment in green tech. It is behind the curve in terms of investment into technology and business growth."***
>
> *Academic Representative*

General

1. **Recognise the value of typical waste products**, such as carbon dioxide, and move towards **valorisation through circular utilisation.** Current '*waste*' streams contain valuable resources and feedstocks for many chemical

industries, helping to reduce environmental damage and boost economic growth.

2. **Adopt a unified industrial strategy for a CE transition in the chemical sector.** Government administrations need to develop a robust, unified, cross-cutting intra-departmental strategy with industry collaboration.

3. **Refocus strategies for waste carbon and biomass on value extraction before fuel generation.** Valuable commodities and chemical compounds should be extracted first before any remainder is turned into biofuel, thus generating new revenue streams and jobs.

4. **Implement a standardised Life Cycle Assessment (LCA) framework** to assist in determining the degree of risk for investment, but current approaches do not fully consider the whole system and related boundaries.

"We do need to have a more collaborative approach in terms of how the financial institutions and the government could work together."

Industry Representative

Chapter 1

Introduction

The CircularChem Centre

The National Interdisciplinary Centre for Circular Chemical Economy (CircularChem)[1] brings together stakeholders from academia, industry, government, NGOs and general public to transform the UK's chemical industry into a fossil-independent, climate-positive and environmentally friendly *circular economy*. As part of a £30 million strategic government investment, it plays a key role in helping the UK to reduce *waste* and the environmental impacts of production and consumption and creating opportunities for new UK industries.

Our Vision

To transform the sector's current linear supply chain model into a fossil-independent, climate positive and environmentally friendly circular economy.

The UK Chemical Industry

The UK chemical sector underpins much of UK industry, such as automotive, aerospace, consumer goods, agriculture and life sciences. It should be at the heart of every political ambition – technological, economic, environmental and social. This diversity and influence facilitates advanced research and innovation both within the sector and important customer sectors.[2]

Economically, the contribution made to the UK economy is significant. With annual exports of £61 billion, corresponding to a gross value added (GVA) of £200,000 per employee and 138,000 direct jobs,[2, 3] it is one of the largest export sectors with UK demand predicted to double in the next 10 years.

However, business as usual is no longer an option. The sector is one of the largest consumers of energy and resources and, consequently, one of the largest emitters of CO_2. Carbon-based chemistries are integral to most sectors within the chemical industry. **Therefore, we need to *decarbonise* our energy supplies and *defossilise* our carbon sources.** Alternative, non-fossil derived sources of carbon are needed urgently to achieve our vision.

Base chemical feedstocks, such as *ethylene* and *propylene* (commonly referred to as *olefins*) are currently derived from fossil sources. These are the building blocks of the petrochemical industry, used to formulate commodity products, such as polyethylene and polypropylene plastics, and more speciality or formulated products, which are used based upon their performance or function for specific consumer products. *Olefins* and their complementary feedstocks account for over 70% of all *organic chemical* production. Current manufacture of *olefins* occurs by a process known as *steam cracking* of *naphtha*, an energy-intensive process that generates large amounts of CO_2 (1.2 – 1.3 tonnes of CO_2 (tCO_2) per tonne of olefin).[4] Their use includes a wide range of intermediate and final products, including plastics, chemical fibres, solvents, fertilisers, synthetic rubber and high-value speciality chemicals. These intermediates are subsequently used by other manufacturing and industrial sectors to produce useable end products (*Figures 1 & 2*).[5] Collectively, inputs from the chemical industry can be found in **96% of all manufactured products in the UK**.[6]

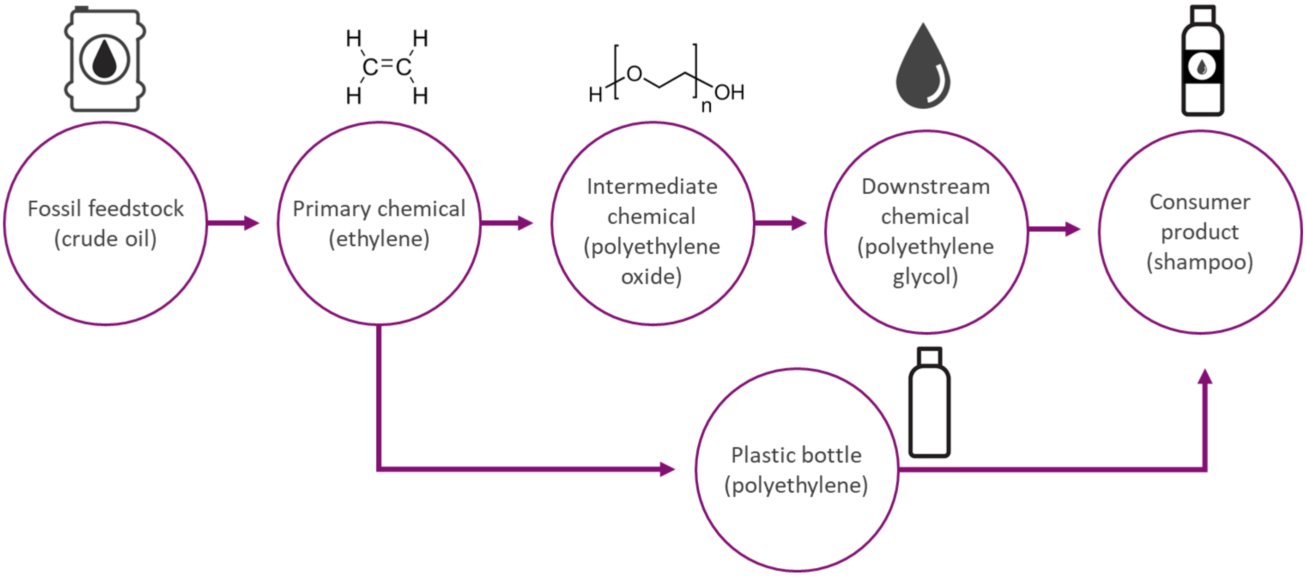


Figure 1: *A simplified example route from a fossil feedstock (crude oil) to a consumer product (shampoo).*

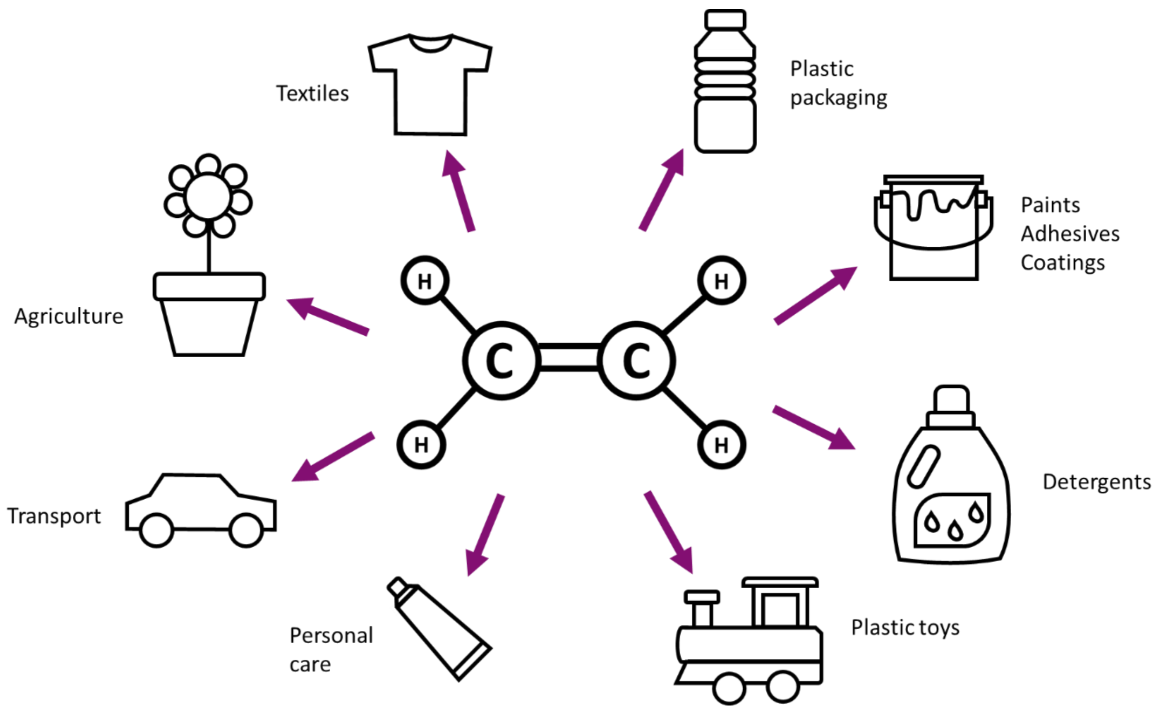


Figure 2: *Chemicals obtained from ethylene can be found in numerous consumer products across many different sectors of the economy.*

Demand for high-value chemicals is predicted to grow by 50% by 2050, with a forecasted global demand of 340 Mt of *ethylene* alone (*Figure 3*).[7]

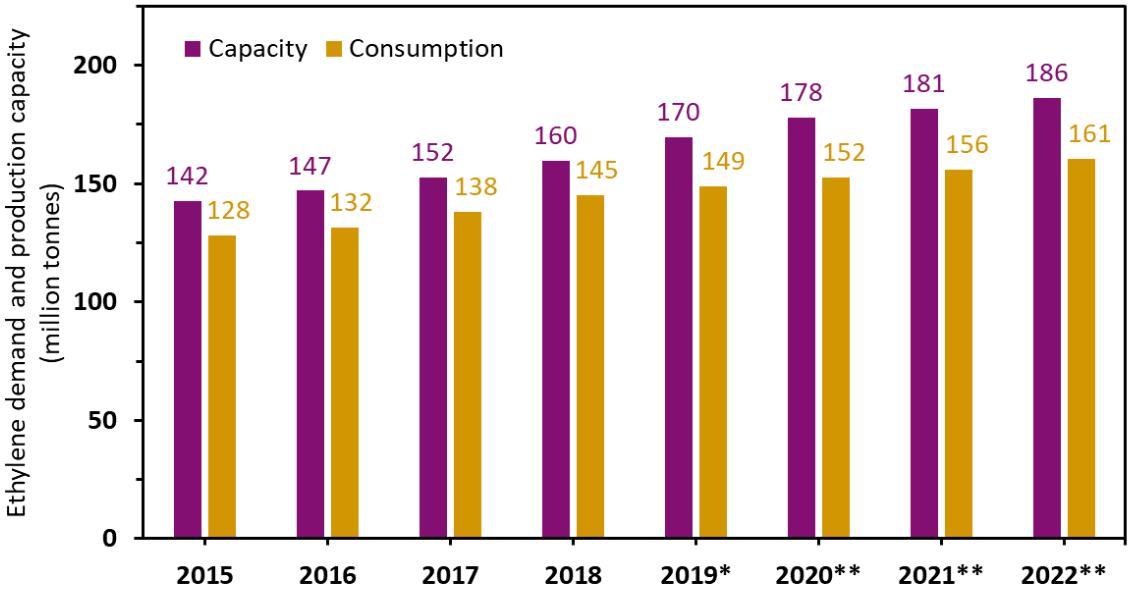


Figure 3: *Global ethylene demand and production capacity (in million tonnes) between 2015 – 2022. The single asterisk (*) refers to estimates and the double asterisks refer to forecasts (**) at the time of data publication.*[8]

Fossil Carbon

The importance of fossil carbon for our modern society cannot be overstated, as evidenced by the vast range of products that can be obtained from fossil carbon sources (*Figure 2*). However, most extracted fossil carbon is used for fuel purposes across sectors including aviation, maritime and personal and commercial transport. Just 5 - 10% is used to make the majority of consumer products available (*Figure 4*). Many of these products are carbon-based and thus would not exist without these fossil carbon sources.

They have proven an invaluable resource in shaping the world as we know it today. The ability of fossil fuels to store TWh worth of energy economically and relatively safely has allowed for supply to be decoupled from demand, alleviating issues such as seasonal demand swing in countries like the UK.[9] However, the environmental damage caused by the extraction and use of fossil carbon now cannot be overlooked. We urgently need alternative sources of carbon, that will allow us to continue producing many of the products we rely on, and energy systems without the consequential environmental damage.[10-12]

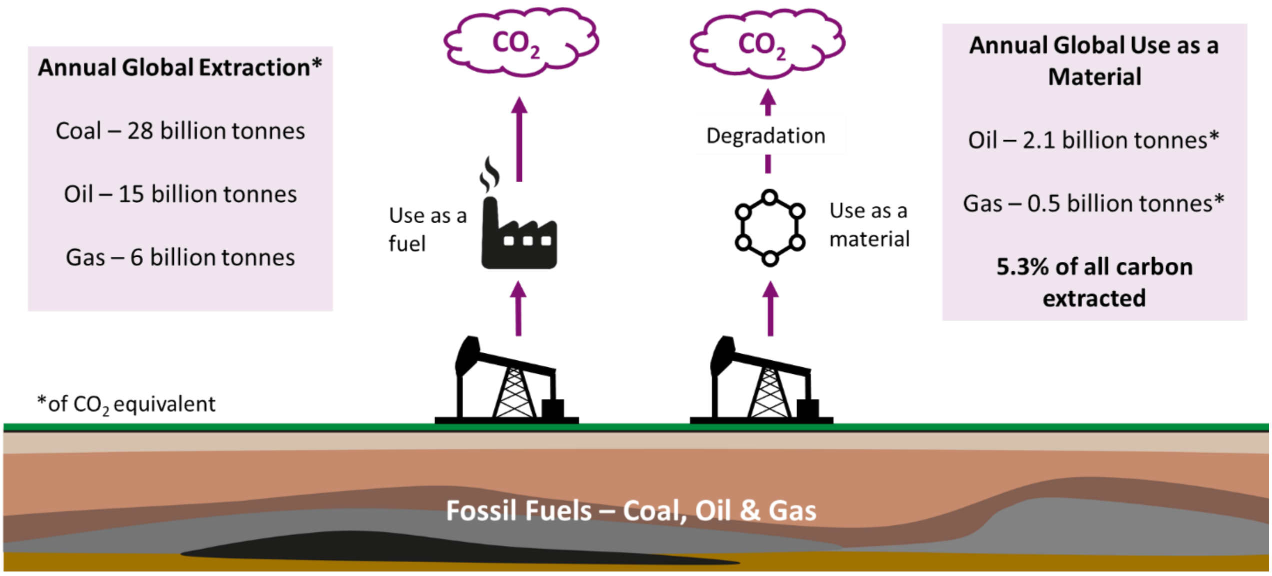


Figure 4: *Annual global extraction and material use of fossil fuels (coal, oil, and gas) considering use cases of fuel or material/product production (in CO_2 equivalents). Carbon emissions arise from both cases, with embedded carbon emissions in the material pathway released as products degrade. Only 5.3% of all carbon extracted globally per year is used to produce products.*[1]

Greater amounts of fossil carbon may be available for the chemical sector in the short- to medium-term, as fossil fuel use in other sectors declines, such as energy and transport.[13] In the long-term, however, an increasing proportion of the costs of oil processing into feedstocks may have to be borne by the chemical sector, consequently increasing prices along the supply chain and for the consumer. Any carbon emission price rises may further compound these rising costs. This uncertainty in costs, supply and demand, and infrastructure requirements necessitates alternative sources of carbon to be utilised in new business models.[13, 14]

The Circular Economy

A *Circular Economy* (CE) offers a vision where products and materials are designed to be reused, repaired or remanufactured, ensuring resource extraction, waste generation and pollution are kept to a minimum. By focussing on society-wide benefits, it seeks to redefine growth by gradually decoupling economic activity from the consumption of finite resources. All of this is underpinned by a transition to a *whole systems approach* and identifying sources of low-carbon energy. Three key principles are the foundation: 1) better product design to remove *waste* and pollution; 2) keeping products and materials in use; 3) regenerating natural systems.[15] Current business models are linear and focus on a ‘take-make-use-dispose’ approach - they are not sustainable (*Figure 5*).

Figure 5: *A linear economy of take-make-use-dispose.*

Crucially, transitioning to a CE also brings many positive benefits, not only addressing the negative aspects of a linear economy. **It represents a fundamental shift that generates business and economic opportunities, provides environmental and societal benefits and builds long-term resilience** (*Figure 6*).

It is estimated that a CE in Britain could create over half a million jobs by 2030.[15] Furthermore, circular models have the potential to identify **reduced production costs and bolster resource security, lessening import dependency and supply chain disruption risks.**

The CE, and Industrial Symbiosis and Resource Efficiency in particular, aims to transform the way we manufacture and consume products. Relying solely on renewable energy solutions to reduce greenhouse gas (GHG) emissions will only address 55% of these emissions. The CE can reduce a significant portion of the remaining 45%.[15] Intense demand for energy and resources can be cut by circulating products and materials, instead of producing new ones.

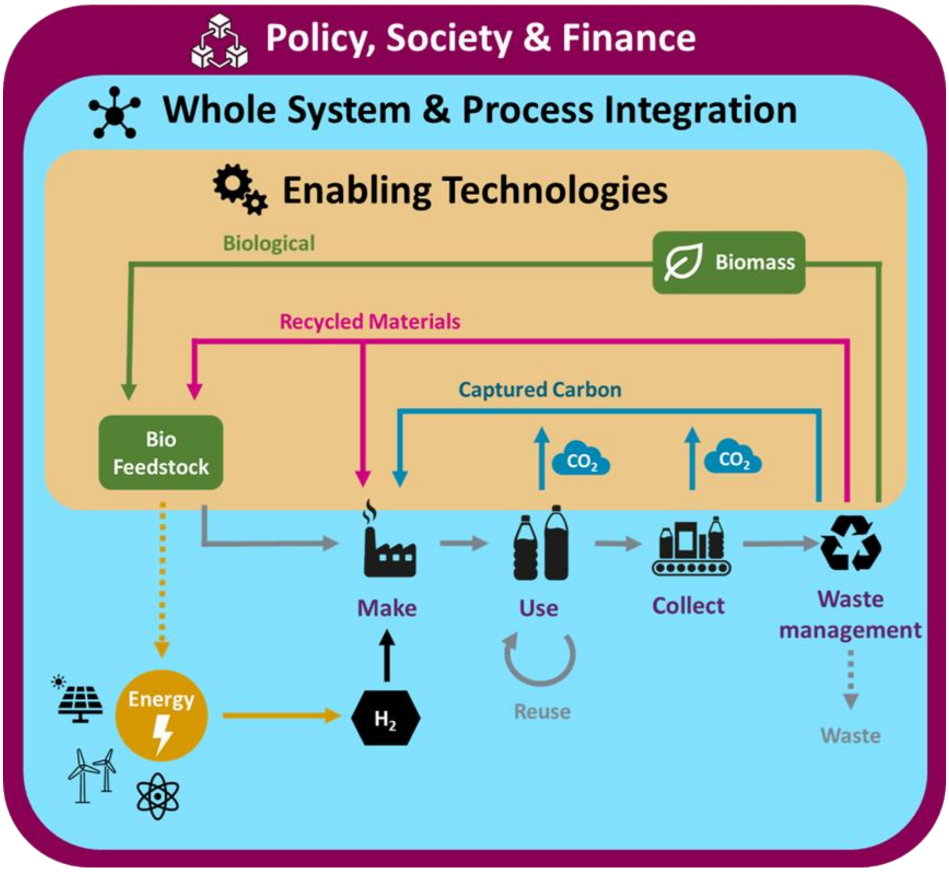


Figure 6: *A circular economy, where extraction of natural resources is minimised, and recycling of materials is promoted.*

Moving to a circular economy is imperative not only for environmental reasons. It has potential for wide-ranging economic and societal benefits, giving the capacity to grow and thrive, create green jobs, upskill the workforce, increase self-sufficiency by reducing import reliance, improving infrastructure and providing a brighter outlook for future generations.

Chapter 2

Key Findings

Key Findings

A series of three, senior stakeholder discussion workshops were conducted under Chatham House Rules (also in accordance with UK Competition Law) with representatives from academia, industry, financial institutions, NGOs, learned societies and the House of Lords. Discussions centred around the policy opportunities and hurdles facing the transition to a circular chemical economy and solutions for delivery. Of particular focus were the financial and fiscal requirements which would enable a smoother transition.

The following chapter presents the key findings from these workshops.

Technologies

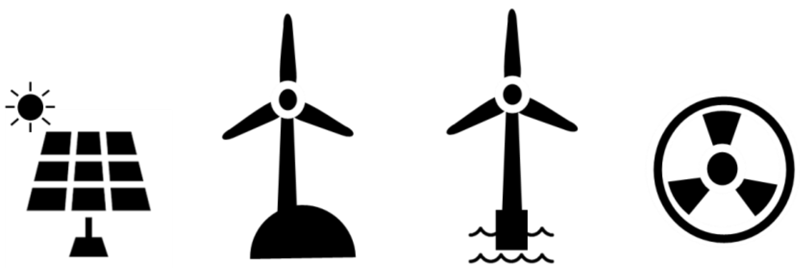
Carbon

As alluded to in the previous section, **CO_2 is currently viewed and classified as a waste product**, but it is a valuable commodity resource for many industries within the chemical sector and beyond, not merely a contributer to climate change. Current uses include cold transport systems and refrigeration, decaffeination and food / feed protection. Instead of 'landfilling' this feedstock, emerging technologies are in development and scale-up phases to enable its use as a chemical feedstock, therefore creating new revenue streams, jobs and growth potential. Policy incentives need to better reflect the utilisation value. The recent announcement of approximately £22bn in funding for CCS projects is a good first step in terms of the scale of funding required, but synergistic funding should also be provided for utilisation projects and technologies.[16]

Hydrogen

The fuel of the future is often regarded to be hydrogen, yet it is an equally important feedstock for the chemical industry such that the energy and chemicals sectors must be equally prioritised for accessing this resource.[17] Of several options to obtain hydrogen, green hydrogen is regarded as the most sustainable – produced from the splitting of water using electricity to obtain H_2 and O_2.[17] An emerging assumption is that plentiful green hydrogen will be obtained by using green electricity. This may not be a guaranteed assumption as, with an increasing drive towards electrification of industry to reduce carbon impact, insufficient amounts may be available at current production levels to support both the energy and chemicals sectors. Currently, the need for hydrogen for the chemical sector is overshadowed by demands for energy. Hydrogen infrastructure must be considered in tandem with carbon infrastructure.

Producing the amount of H_2 needed to satisfy both the energy and chemicals sectors will require concerted infrastructure investment. IRENA (International Renewable Energy Agency) is predicting a need for 19 EJ (EJ = exajoule, 19 quintillion joules) of green hydrogen by 2050 for the energy sector alone – between 133 – 158 million tonnes.[18] Producing such a volume would require 6,690 TWh of electricity per year – a breakdown of current and future energy capacity from renewables is given below (*Figure 7*). Thus, it cannot be assumed that H_2 will be readily available without concerted and strategic investment.



	Solar	Onshore Wind	Offshore Wind	Nuclear
2018 (GW)	480	540	23	397
2050 (GW)	4,240	2,243	1,775	957

Figure 7*: Global energy demand predicted for 2050 across four renewable energy technologies – solar, onshore wind, offshore wind and nuclear. Actual values are given from 2018.*[18]

Furthermore, the Biomass Strategy 2023 places an **over-importance on using biomass for fuel and energy production**.[19] The policy incentives in using biomass for fuel generation without consideration for extraction of valuable chemicals first is unsound. Synthetic aviation fuel (SAF) and similar methods derived from biomass reduce CO_2 emissions but also incur higher production costs, making it extremely difficult to produce sufficient quantities for demand without regulatory support.[20, 21] There are valuable chemical feedstocks to be extracted alongside conversion into fuels. The current focus of CCUS and biomass policies needs to be balanced more towards chemical and product production over fuel production.

De-Risking Technologies for Investment

A repeated theme was the importance of de-risking technologies and building *demonstrator units* to attract further investment for scale-up and growth. Accessing these resources and facilities for **scaling-up early-stage research and building demonstrator units** is currently extremely difficult, especially within the biotechnology sector. A 'chicken and egg' scenario arises – researchers seek funds from investors to build *demonstrator units*, yet investors want to see *demonstrator units* before any funds are released. Timely and focussed government intervention to support this demonstration stage is needed. A portfolio of *demonstrator units* would help to boost investor confidence and de-risk these new technologies.

Financial and Fiscal

UK Investment

The UK is not seen as an attractive location for investment in the chemical sector, by industry and financiers. **UK-based finance opportunities are severely lacking which poses a significant barrier to developing and scaling innovation, in part due to a high degree of risk aversion.** Increasingly, funding of the scale required is being sought and obtained overseas leading to an outward flow of UK innovations. Progress on change is slow. UK labour and energy costs are high, compounded by low productivity in a sector with chemical production firmly embedded in the oil and gas industry.

Investment risk remains a significant challenge, particularly with business-as-usual activities having greater stability and return on investment. Policy intervention is urgently needed in this space to assist in de-risking these technologies and more sustainable activities. Dis-incentivising business-as-usual activities with concurrent financial support for new technologies in early-stage commercialisation would be helpful. A hyper-focus on return on investment within short timescales is another challenge. Financiers within the workshops indicated that they follow the policies set by government regarding their business and investment activities. Therefore, policy intervention is urgently needed to drive the necessary changes in behaviour, understanding and investment decisions.

Limited investor understanding of the chemical sector further adds to the perceived degree of risk and reluctance to provide investment funds. **Sector funding requirements are also far greater** than in other sectors, such as the technology sector, in the billions of GBP – as evidenced by the recent €1.25 bn investment in Germany's *Center for the Transformation of Chemistry*.[22] Seed funding costs are considerably higher than other sectors and a large gap exists between the early and pre-commercial stages, requiring additional financial and policy support from government. The scale of funding required depends upon the project in deployment – building new infrastructure is vastly different to retrofitting technologies onto existing infrastructure. This further compounds the lack of understanding of this sector.

As an example, the *Ferrybridge CCPilot 100+* was a demonstration-scale carbon capture plant designed to extract 100 tonnes of carbon per day, equivalent to 5MW of power generation.[23] Construction took two years to complete at an investment cost of £21m in 2011, equivalent to £30.2m today.[24]

Care must be taken by governments to ensure that fiduciary duty is applied, ensuring that public money is put to best possible use for the greatest societal benefit. This will become especially apparent as new technologies emerge, and interventions by government will be needed to financially support and accelerate these technologies onto the market.[11]

Government Support for Investment

Better collaboration between government, industry, academia and financial institutions is sorely needed. Communicating earlier and more frequently will help to remove hurdles to change and make this complex research field more accessible to non-specialists. Furthermore, better collaboration is urgently needed between different government departments as competing priorities and objectives are a barrier to change. The recent appointment of a Circular Economy Minister (Mary Creagh MP) and the creation of a Circular Economy Taskforce are positive and welcome steps. A priority for the Minister must be the creation of a unified industrial strategy for the chemical sector that aligns with government priorities and ambitions and brings this vitally important *circular economy* transition further up the policymaking agenda. A further legislative step should see the creation of a Circular Economy Act, in a similar legally binding manner as the Climate Change Act (2008), with full consideration of the chemical sector's alternative carbon feedstocks, energy and hydrogen inputs and *waste* outputs. With robust regulatory frameworks, a real driver for change can be created and supported by government.

Furthermore, the newly appointed secretary of state for the environment, food and rural affairs (Steve Reed MP) recently announced five core priorities for the new administration, including the creation of a roadmap to move to a zero-*waste* economy – **a circular economy**. Similarly, the Scottish Government launched a *Circular Economy and Waste Route Map to 2030* consultation,[25] and the Northern Ireland Department for the Economy proposed a *Circular Economy Strategy* in 2023.[26] Most recently, the Welsh First Minister (Eluned Morgan MS) included *'Green jobs and growth'* as one of four key priorities for the Welsh Government (in a speech to the Senedd on 17th September 2024).[27]

These are welcome developments and important steps forward, yet environment, *waste*, economy, and many other policies were devolved many years ago. Hence, **multi-nation government collaboration** will be crucial in turning intention into action and roadmaps into deliverable and measurable objectives.

General

Generally, the importance of the UK chemical sector, and particularly the importance of carbon, was believed by workshop participants to be under-appreciated and/or misunderstood by policymakers and consumers. Therefore, the messaging from the chemical sector needs to be simplified and framed in terms of the economic and societal benefits, not just the technical aspects.

Custodians of Carbon – The Value of Sustainable Carbon

Principally, the utilisation value of carbon needs to be recognised, enabling the switch from consumer to custodian of carbon.[11] Vast swathes of the products in our modern society contain carbon of some form, often derived from fossil fuels. Thus, it is a misnomer to claim to **decarbonise** the chemical sector. To do so would eliminate it and the many products it provides – **we need to *decarbonise* our energy supplies and *defossilise* our carbon sources**. Approximately 93% of a barrel of oil is used for fuel. If and when fossil-based fuels are phased out, there will be reduced economic incentive (relative to current operations) to extract the remaining 7% for chemicals manufacture.[5] As such, multiple sources of alternative, non-fossil fuel carbon will be needed. Often market and consumer demands have a strong influence over a particular direction.

Sustainable carbon sources will play a significant role in the transition away from fossil carbon – biomass, recycled plastics and carbon capture. It was agreed that all forms of carbon will be required for a successful transition, but that no one source is currently available at a suitable scale and price point.[6] 88% of carbon currently in use embedded in chemicals and materials is derived from fossil sources (*Figure 8*).[28, 29]

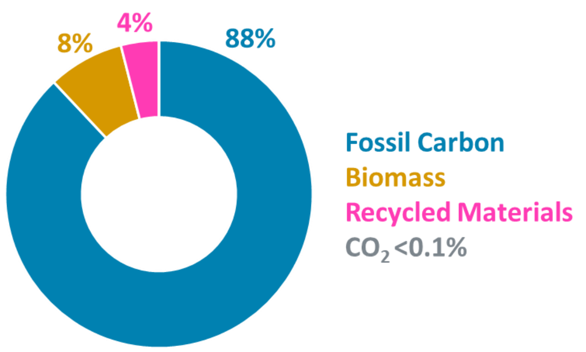


Figure 8: *The distribution of embedded carbon in organic chemicals and materials according to feedstock source. Data obtained from the Renewable Carbon Initiative.*[28, 29]

There remain considerable uncertainties and limitations with each source alone but taken together many of these issues can largely be overcome. To do so, substantial investment and policy intervention is essential, as the amount of carbon that each source can ultimately supply will be tied to the amount of financial investment put towards it. From current levels of sustainable carbon use, increases in utilisation of 709% for biomass, 1,573% for recycled plastics and 236,000% for carbon capture will be required to displace fossil carbon by 2050.[6] In parallel, low-cost and low-carbon renewable energy, low-carbon hydrogen at scale, greatly improved collection, sorting and recycling rates of plastics, significant *point source carbon capture* for utilisation and regenerative sustainable farming practices are essential.[6] **The need for impactful policy intervention and financial investment is clear.** Engineering Biology will also play a role, but it is likely to only address a small percentage of the chemical supply chain unless challenges of scaling-up processes within suitable costs and timeframes can be addressed.

There was general agreement that 'chemicals' are still viewed in a negative light and are presented in a manner that is too complex for most audiences. The value of new technologies is not best demonstrated from a technical perspective and so further education is needed, to better promote current successes, the positive impact they are having on economic issues and how more investment would be put to best use for further gains. Simpler forward-facing narratives around 'winning hearts and minds' are required. This should be evidenced using independent LCAs and focused on how new technologies with

circular business models can provide the same or comparable goods with added value.

The Utilisation Value of Carbon

Therefore, greater efforts are needed to **incentivise non-fossil forms of sustainable carbon including biomass, recycled plastics and carbon capture.** For the latter, Carbon Capture & Utilisation (CCU) should be incentivised over Carbon Capture & Storage (CCS). The latter is economically unproductive, possibly even detrimental, and likened to 'landfilling'. Considering the activities of installation and pipe networks will require significant capital expenditure, the final result is an additional cost without ongoing revenue. There must be a long-term vision to continued, sustainable and profitable economic activity, and this will come with **utilisation,** not storage. These utilised carbon emissions are a potentially valuable single carbon (C-1) feedstock for much of the chemical sector, with great potential for further revenue generation.

Nonetheless, urgent action is needed on climate change and CCS remains one of several viable solutions in the short- and mid-term. CCU and CCS currently exist at different technology maturities, with the latter at a more advanced stage of development.[30, 31] Hence, in the mid-term, CCS is likely to reach deployment maturity before CCU – CCS deployment is predicted to occur from 2040, with CCU following from 2050.[6] In the longer-term, however, CCU should be favoured for the reasons listed above. Anecdotally, one suggestion from some workshop participants was to utilise CCS as storage for utilisation – not sequestering CO_2 permanently but holding it for a time when it can be put to best use.

There are currently four established options for reducing carbon emissions – electrification, low-carbon hydrogen (H_2), CCU and CCS. Currently only, H_2 and CCS receive significant government funding and there is no lobby to promote CCU as a solution.[32, 33] While the recommendations from the G20 endorsed Mission Innovation report on *Accelerating Carbon Dioxide Utilisation and Storage (CCUS)*[34] was proposed in 2017, this is now seen as a political mistake as most current policy focusses just on CCS of CO_2, not CCU. The 'U' has been lost, misunderstood, or used to promote *enhanced oil recovery (EOR)* with the captured CO_2 'used' as a working gas. If carbon capture is to be a viable and credible solution, something needs to be done with the CO_2.[35] **Fundamentally, CCS (with permanent**

storage) is not circular and is thus unsustainable. Currently, storage options are limited in the UK and utilisation options are still in infancy and not yet at scale. CCU is a tool to address the issue of using *waste* carbon to replace fossil carbon feedstocks, yet any solutions must be considered from a *whole systems approach* and not taken in isolation.[36] Furthermore, EfW plants performing CCS are utilising a significant amount of their produced energy in the process (40% or more can typically be sacrificed). Therefore, the *carbon efficiencies* of such processes are poor.

Ideally creating localised *circular economies* of carbon utilisation would be beneficial, such as the *Flue2Chem* project, which is capturing carbon from an industrial source and passing it along the chemical supply chain to create an alternative carbon source for consumer products (further information is given in the Case Study example on pg. 36). As a recipient of UKRI funding for this project, Synthetic Aviation Fuel (SAF) from captured CO_2 may appear to be 'utilisation' but is just a delayed emission utilisation, unless *direct air capture (DAC)* can be made commercially and environmentally viable to facilitate *carbon dioxide reduction (CDR)*. The latter has become a new policy of the US DOE with the introduction of incentives through the Inflation Reduction Act (IRA).[37]. Nonetheless, similar arguments can be made for CCUS-based *surfactants* found within detergents, as the carbon embedded within these products is washed down the drain and into water treatment facilities. Full consideration of the carbon 'journey', from source to ultimate destination, through **robust LCA practices must be developed and utilised**. Energy cost of utilisation remains a significant hurdle to wider deployment of CCU technologies. Research has evidenced that green ethylene production routes that are carbon negative from cradle-to-gate are feasible, but 46 - 66 TWh of renewable electricity would be required to replace a single conventional steam cracker (with a production capacity of 800 kt per year).[38] This is equivalent to 14 - 20% of total annual power generation in the UK and requiring an offshore wind farm equivalent in size to Greater London.[38] **Thus, a substantial barrier to future green production routes is the available supply of large-scale, low-cost renewable electricity.**[38] This barrier requires policy intervention to surmount it.

Research, Innovation and Intellectual Property Landscape

Something **must** change if the UK is to remain competitive and a leader in science and innovation technologies. This is compounded by the feeling among participants that current policies rely too heavily on the 'stick' and don't offer much in the way of 'carrot' – policies are quick to punish but slow to reward. The US Inflation Reduction Act was repeatedly highlighted as a good example of prioritising environmental protection coupled with economic growth. This landmark bill was signed into law in August 2022, with the aim of reducing the deficit, fighting inflation, and reducing carbon emissions. The legislation rewards high-emitting companies that store or utilise emitted GHGs with increased tax credits. It is hoped that these credits will give greater incentive and convince investors to make greater effort at CCUS. If the UK was to adopt similar legislation, greater tax credits should be given to utilisation over storage, setting prices that reflect the **value of carbon**, and not incentivising unproductive activity to promote the utilisation of this valuable feedstock and unlock greater economic gain.[37]

While intellectual property (IP) generation is generally strong **the transition to commercialisation and retention of IP is weak**. **The UK is not seen as an attractive investment for scaled infrastructure**, which is compounded by high manufacturing, low productivity, and high labour costs. In turn this creates an **outward flow of manufacturing** meaning emissions of embodied carbon are overseas, with embodied carbon of imports not counted. The new *Carbon Border Adjustment Mechanism (CBAM)*[39] is meant to address this. Reshuffling public investment to support R&D and smaller scale development could increase the attractiveness of the UK. Moreover, **a system that can help to drive efficiencies upstream**, such as a carbon tax or realistic CDR incentives, could trickle benefits throughout the value chain. This should be fairly apportioned by including, as an example, a *CBAM* factor to guarantee that it is not all offshored and we pay for that privilege.

A Different View of Waste

Furthermore, *waste* is generated along the entire supply chain, from extraction to manufacture and ultimately consumer use. The majority is *upstream*, but there is an **overfocus with current policies on the consumer** (*downstream* portion) to deal with *waste* and products at the end of their useable life. Shifting this focus equally along the entire supply chain will enable a greater shared responsibility in reducing *waste* and increasing supply chain efficiencies. Some current incentives and areas of policy focus are disjointed, compounded by regulatory enablers of efficiencies which can be too slow – in turn holding back industrial development or incentivising it to leave the UK. To further the carrot and stick analogy, it is worth reiterating that concomitant 'carrots' need to be put in place towards more environmentally friendly and circular solutions. Otherwise, it can increase costs and thus affect the economic condition and activity of the average consumer (custodian).

> ***"For these multi-million / billion pound [£] investment areas there are few funding mechanisms. Horizon Europe is one, but that is Europe-centric. Most of the partners and mechanisms are in the EU. We generate IP but the connections are not domestic as large-scale funding and partners are elsewhere. We need to get on board with these massive funding bodies and partnerships. It is futile to go alone."***
>
> *NGO representative*

Underlying Market Conditions

A longer-term positive impact and ROI, that considers environmental and sustainability impact as economically attractive, is necessary to allow for novel and emerging technologies to have a real and lasting positive impact. Yet, such technologies must have suitable ROI to be economically viable to succeed.

With respect to the underlying market conditions, these must be considered alongside the push for technology demand. In order to attract investment into a UK-based chemical plant, assurance of suitable future market demand at a price point commensurate with production is necessary. Whilst potential customers currently have lower cost fossil-based options, there is no incentive to consider non-fossil-based alternatives and fix a forward-looking contract

– the uncertainty over the future market price would be too great. Therefore, a mechanism to create and ensure market stability is needed.

There are clear precedents for such government-level incentives being put to best use and encouraging market competitiveness and growth. By way of example, the bioenergy sector faced similar challenges in the past when attempting to promote the uptake of technologies such as combined heat and power (CHP) systems, gasification and anaerobic digestion. In response to market conditions and to encourage uptake, the energy sector utilised Renewables Obligations Certificates (ROCs) and the Renewable Heat Incentive (RHI) to compensate for lag in market competitiveness and to drive commercial investment in bioenergy systems.

For this current focus, support (from UK government and the devolved nations) to ensure a guaranteed price for sustainable base chemical feedstock production would enable the next layer of the market (speciality and formulated products) to operate on standard commercial terms. There are different economic models that could be proposed, but these tend to be commercial plans that are undisclosed. Thus, economic modelling will prove essential in establishing a market incentive and stabilisation model to drive investment and commercialisation.

Required Policy Changes

With respect to policy changes, it was stated that the environment is relatively low on the agenda. The narrative framing from the chemical sector should therefore include more understandable figures based on economics and employment as drivers with opportunities to provide or incentivise finance, plus how the policy changes themselves could be financed, for example the route to shifting subsidies. It must also contend with the scale of the chemical industry with its global reach across sectors. This scale and the time required for transition means long term stability, both political and economic, is required. Yet it is imperative that we do not regulate ourselves out of any (chemical) manufacturing in pursuit of a CE, lest we lose jobs, skills, employment, and a sustainable future. There was further consensus that this transition should be fast as industry needs to act now to avoid chemicals shortages in the UK in the mid-term. In terms of UK economic drivers, there is a real fear that chemicals manufacturing will move further offshore to more accommodating nations where production costs are lower, productivity is higher,[40] access to markets is easier and there are established economies of scale with supportive regulation. We have a real opportunity to onshore chemicals manufacture to create a **new** chemicals industry and supply chains, ensuring ongoing future security of supply in increasingly turbulent times.

The cleanest or most circular processes will have no tangible impact if they are not economically viable and competitive. Furthermore, the **mass roll-out of renewable energy projects to defossilise energy (electricity) supplies and lower energy costs is imperative to driving a CE in the UK** – industrial energy prices in the UK are currently the highest globally.[41] Anecdotal evidence was obtained of quoted timeframes of 10-15 years to connect to the electricity grid, a known issue with regards to the supply side (i.e. new generation) but not the demand side.[42] Investment in clean, circular chemical production is unlikely to progress at the scale and pace required unless a more attractive electricity price and grid connection regime can be provided.

A Carbon Tunnel Vision

Overall, **prioritising environment over profit needs to be more attractive,** facilitated by a longer-term outlook, increased profit potential and decreased risk to invest in these sectors. A repeated theme from financial representatives was the **need to de-risk** technologies to enable investment funds to be released, compounded by a lack of understanding of much of the technical details of these technologies. An impediment to change is that **understanding of the chemical industry and circular business models are underdeveloped and different across UK administrations**. **Further education** is needed to help investors and policymakers understand this technical space. If the risks are not fully understood, investor confidence will be low.

Accessing funds to scale processes up and develop demonstrator units is often difficult. The investment journey is not the same as for the technology industry – timescales are longer and the money needed is much greater. Costs can very quickly grow for investment and there is a misconception that lower funding amounts are needed. There is considerable uncertainty about making changes, with multiple factors at play – economics, market demands, consumer choices, depreciation costs and the decreasing costs of technology over time. A portfolio of *demonstrator units* or national scale-up facilities would help to boost investor confidence in novel technologies as viable investment opportunities and therefore assist in de-risking these new technologies.

More widely, a national 'database' of UK industry capabilities could help to guide innovators and entrepreneurs to these resources and foster greater collaboration. Secure database ownership and maintenance would be required to ensure accuracy and relevance.

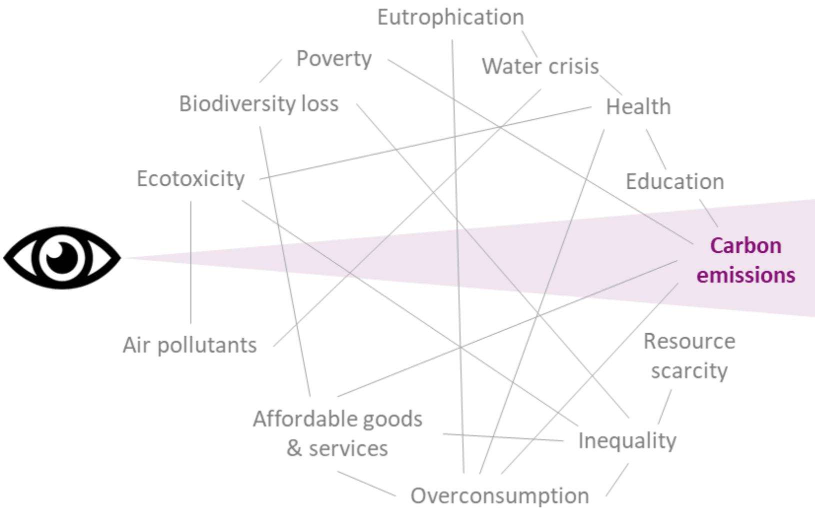


Figure 9: *Adopting a 'carbon tunnel vision' has potentially negative implications for wider sustainability and environmental issues. CO_2 emissions need to be tackled, but not at the expense of social responsibility, social impact factors, and other sustainability metrics. Adapted from Lamb & Styring 2022.*[10]

Finally, competing priorities and strategies of government departments are hindering progress. A unified, multi-department approach is needed, with clear, attainable sustainability targets. **The sole focus on Net Zero can hinder broader sustainability achievements and potentially cause a 'carbon tunnel vision'** (*Figure 9*).[10] Thus a more holistic view is required to address overall environmental issues, of which emissions reduction is just one aspect.

Chapter 3

Key Recommendations

Key Recommendations

From the key findings listed in the previous chapter, a series of key policy recommendations can be proposed to enable an accelerated deployment of a circular chemical economy.

Technologies

1. **Support Industrial Symbiosis clusters as a priority for the CE taskforce.** *Industrial Symbiosis* is defined as an arrangement between two or more industrial facilities or companies by which *waste* or by-products of one become feedstocks for another.[43] These could be intra- or inter-sector depending on the requirements. Such initiatives will help to accelerate circular businesses, promote *waste* reduction and resource efficiency. The issue of *waste* regulations and permitting is a significant hurdle in this instance, and concerted efforts should be undertaken to make Industrial Symbiosis clusters easier to implement and maintain.
2. **Government should spearhead the creation of national, collaborative public sector research institutions operating as a commercial business with industry and academia.** To incentivise partnerships and commercialisation and support early-stage research scale-up, plus the added benefits of employment opportunities and revenue generation. A repeated concern during the workshops was the difficulty in accessing financial and material resources to scale university-level research to commercial readiness, particularly within the biotechnology sector. Shared facilities would help to spread the costs burden and lower the barrier to entry into the market for viable technologies. Funding further projects like the *Faraday Battery Challenge* and *Transforming Foundation Industries*, of which *Flue2Chem* was a successful recipient of funding, should be actively developed.
3. **Support novel technologies and early-stage research through all TRL levels to de-risk investment opportunities.** Greater access to financial support and resources to assess and minimise risk in building *demonstrator units* should enable quicker scale-up and growth. The TRL 'Valley of Death' refers to TRLs 4 – 7 where neither the public or private sector prioritises investment.[44] Consequently, many promising technologies end their commercialisation journey here. Support is available for TRLs 1-3 in the early stage and at TRLs 7-9 approaching commercialisation, but more effort is needed to bridge this gap. By not supporting this middle sector, there is a risk of effectively pushing technologies off a cliff into the 'valley of death'.

Investments and support need to be reorganised into **fewer pots of larger amounts of money** to prioritise investment into the most promising technologies that will have the greatest impact. Attempting to fund everything is not possible and difficult decisions will need to be made by government, with close involvement from industry and academia.

4. **CCU should be prioritised over CCS in the longer-term.** CCS options are akin to landfilling, an option which must be minimised as far as possible according to the *waste* hierarchy.[45] In the nearer term, CCS technologies will likely reach deployment maturity ahead of CCU technologies, therefore both options must be utilised for maximum positive impact. One approach is to treat CCS as a temporary storage until such a time as CCU is best able to utilise this valuable resource.[46-48] Current infrastructure is not only under-developed to enable CCUS, but transport, permitting, and logistical considerations need to be taken into consideration. CCU can be revenue generating and give rise to economic growth and jobs creation (*Figure 10*). A longer-term vision for CCU must be realised with investment in infrastructure. Where carbon obtained from CCU is to be used as a feedstock (for example in *Industrial Symbiosis* clusters), *waste* regulations and transporting permits will need adapting to suit these requirements.

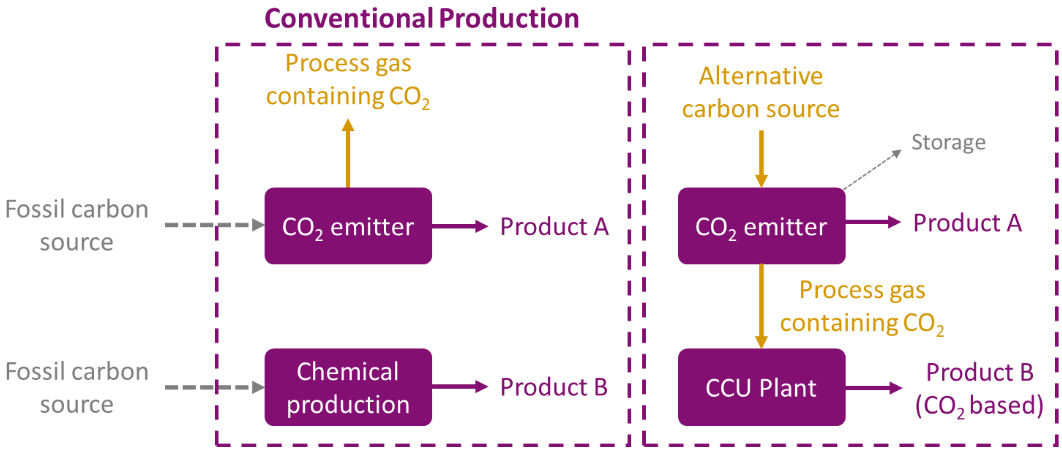


Figure 10: *Conventional production (left) of products from fossil carbon sources results in significant CO_2 emissions released to the atmosphere. Employing carbon capture utilisation and storage (CCUS) (right) captures CO_2-containing process gases to replace fossil carbon sources for further product creation.*[4]

Large-scale CO_2 utilisation offers great potential to fundamentally change the chemical sector. It could change not only the way that fossil resources, feedstocks and renewable energy sources are used, but also lead to the creation of new markets, products and value chains.[49]

Nonetheless, CCU is not a catch-all solution to solving emissions mitigation issues – this is a common misconception. **The reduction of emissions should be pursued in the first instance ahead of mitigation of emissions**, several solutions for which are available, in accordance with the *waste* hierarchy principles (*Figure 11*).[50] Generally, current policies and regulations place an over-emphasis on recycling as a solution to *waste* – a more sustainable approach should follow the *waste* hierarchy with **prevention, reduction and reuse encouraged with greater effort**.

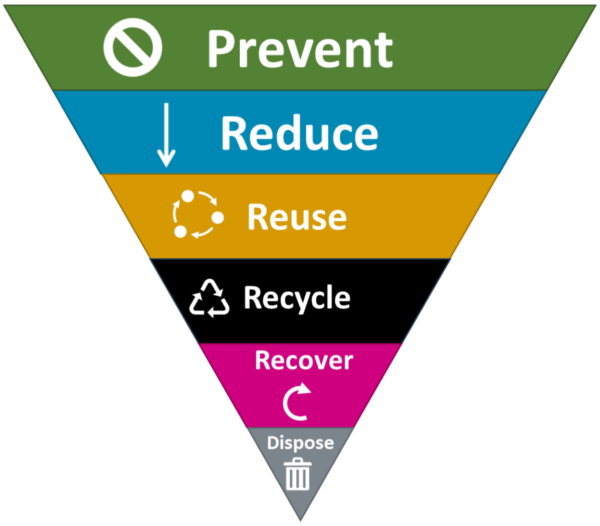
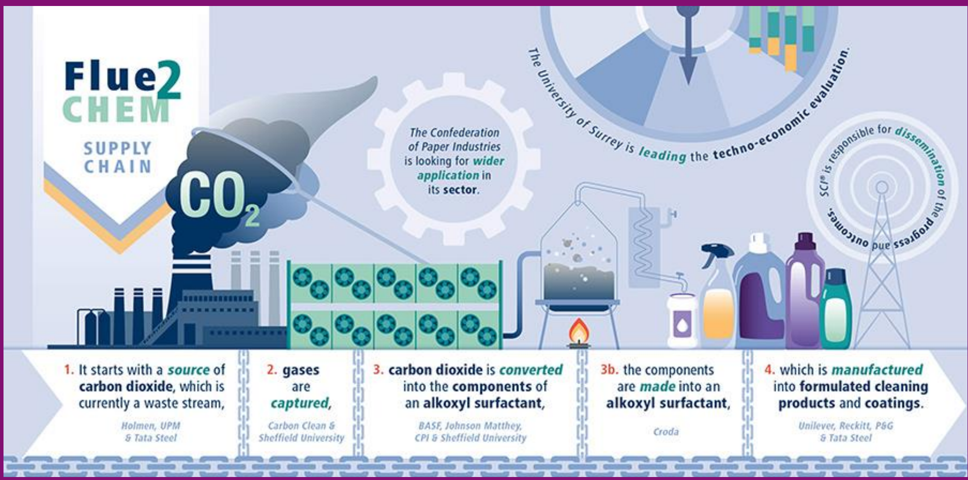


Figure 11: *The Waste Hierarchy Principles for dealing with waste, with the most environmentally favoured option at the top (Prevent), descending in preference to the least favoured option (Dispose) at the bottom.*

5. Sources of sustainable carbon, including biomass, recycled plastics and captured carbon, are fundamental to a circular transition. Disrupting existing linear economies of fossil carbon use requires interventions and scientific innovation at all levels, starting from the development of new disruptive technologies, their integration into existing processes and evaluation of whole system impacts, to the identification of economic, social and policy barriers and opportunities of how they can be overcome.[1] No single alternative carbon source will be enough to satisfy current and future demand.[28, 29] Consequently, timely financial investment, regulatory change and policy intervention in technologies that **valorise the utilisation of waste carbon** will prove fundamental to a successful circular transition for the chemical sector.

Case Study: *Flue2Chem*

The *Flue2Chem* Project is a £5.4m, two-year programme spearheaded by Unilever and SCI, with 13 further organisations involved, representing the full supply chain from resource extraction to consumer product. With funding from Innovate UK, via the UK Research and Innovation (UKRI) Transforming Foundation Industries Challenge, the partners aim to take waste gas from foundation industries such as metal, glass, paper and chemicals, and generate an alternative source of carbon for UK consumer products – one not obtained from fossil fuel extraction.



Carbon dioxide is first captured before conversion into a surfactant, the key ingredient in many cleaning products. This surfactant is passed further along the supply chain for formulation into a detergent, ultimately aiming for sale to consumers.

This novel approach clearly demonstrates the importance of involving the entire supply chain in transforming current and established modes of operation. Change is possible, and necessary.

More funding for similar projects, extending beyond the chemical sector, is urgently needed for a complete and sustainable overhaul of our industrial sectors.

Financial and Fiscal

1. **Carbon taxes should be of a sufficient scale to actively disincentivise poor behaviour and not simply act as a punitive charge.** Anecdotal evidence was heard of companies accepting carbon taxes as a reasonable cost of business, willing to pay those taxes as they were cheaper and easier than altering business practices to reduce emissions. Furthermore, the *carbon emission efficiencies* should be considered with only the actual carbon savings subsidised – see **Box 1**.

Box 1 – Carbon Emission Efficiencies

Carbon emission efficiency refers to the economic benefits of production activities that simultaneously emit carbon, such as carbon capture operations. The fewer carbon emissions generated per unit of production output; the more carbon emission efficient the process is.

In this context, the subsidy incentive for CCUS activities should not be for the total amount of carbon captured, but rather taking the efficiency of the process into account. For example, if a particular process captures 10 tonnes of CO_2, but 9 tonnes of CO_2 are emitted doing so, then the efficiency is just 1 tonne and, therefore, any subsidy should only apply to this 1 tonne (and not the full 10 tonnes).

Adopting this approach would correct incentives towards driving process efficiencies and carbon capture *with value-added purpose*.

Consider the case of biofuels and recycled carbon-derived fuels. When conducting an LCA, CCU from *waste* gases requires power displacement, which could be ‘dirty’ and also has limited indirect emissions accounted for, while indirect emissions from biofuels are not accounted for (under the EU Renewable Energy Directive[51]) but could still be significant. Therefore, producing goods in locations with ‘dirty’ grids is unattractive. As the grid gets ‘cleaner’, the LCA improves (providing argument for a stage-gated threshold, if necessary) but consequently, there is no incentive to move away from burning gas for power, despite the availability of carbon-free power.

There is a further implication regarding the setting of thresholds for GHG emissions savings. For CCU, this would be less stringent with fewer indirect emissions, while for biofuels it would be higher. As a result, there is real risk of continuing with fossil-derived power and CCU recycled carbon fuels as obligations would be lower for emissions savings.

Further Example – The importance of robust taxes

Consider an example from the plastics sector, when comparing the prices of virgin and recycled PET, as used in the manufacture of drinks bottles. Figures were obtained in October 2024 and were current at the time of publication.[52,53]

Virgin PET: £1000 – 1100/tonne **Recycled PET: £1500-1600/tonne**

If a packaging tax (or equivalent) of **£217.85/tonne** is applied for every tonne of virgin plastic used, it still remains cheaper to produce using virgin plastic. This is a volatile pricing market, with the price of recycled PET lower than virgin PET on occasion, but it is difficult to maintain procurement consistency of recycled PET if left solely to market volatility. Any tax must be of sufficient scale and impact to drive the necessary positive change in behaviour and production practices.

Furthermore, there are reports of plastic packaging tax fraud with cheaper virgin material being sold as supposedly recycled material, thus omitting the need to pay the tax and undermining legitimate enterprise.[54] Validation of material origin and quality is a necessary prerequisite to mitigate against system fraud.

2. **Greater appreciation of the value of the chemical industry** from an economic and political perspective. The figures given in the introduction help in some way to convey the value of the chemical industry from an economic perspective. Nonetheless, the value from a societal perspective is enormous, yet often under-appreciated – chemicals are essential to modern life. Chemicals have received a bad reputation, fuelled partly by media coverage of the harmful and sometimes toxic effects of chemicals. To put simply – 96% of all materials contain chemicals.[6]

3. **Oil and gas tax relief refocussed towards re-skilling and training.** Disincentivising current business as usual approaches whilst concurrently promoting more sustainable practices will be required, within both the energy and chemicals sectors. By engaging a phased transition of oil and gas tax relief incentives towards green sector jobs and training, minimal job losses and continued growth are possible - see **Box 2.** Nevertheless, this is contingent on the new, circular chemical industry sector being established and 'taking over' the market - in part this will be fulfilled by longer term ROI and the green skills that are trained.

The UK needs both chemicals and energy. Concerted efforts are already underway in reskilling the oil and gas sector for renewable energy industries and similar effort is needed within the chemicals sector. This is not to pitch energy and chemicals as competing sectors. They can, and must, work together to achieve sustainable and circular business practices.

Box 2 – Reallocation of Incentives Through Tax Relief for Oil and Gas

The UK oil and gas sector employs over 200,000 people[4] and incentives through tax relief have been a part of ensuring continued job retention and economic growth. Opponents of phasing out oil and gas extraction often cite job losses as a reason not to do so. A phased reallocation of such incentives will help to address this concern by ensuring minimal job losses through re-skilling and re-training. Many current oil and gas sector employees possess the necessary skills and expertise to transition to green sector jobs with the correct retraining and education.

By way of an example, assuming an annual tax relief of £11 billion:

- Year 1: £10 billion to oil and gas; £1 billion to green sector/retraining
- Year 2: £9 billion to oil and gas; £2 billion to green sector/retraining
    - Continuing until no oil and gas subsidies are present:
- Year 11: £11 billion to green sector/retraining

4. **Additional support for investment opportunities.** Investment funding guarantees should be offered by government more frequently and include a requirement of independent investment review to de-risk and boost investor confidence. Public equity, private funds and wider debt and equity instruments are needed to develop and scale CE interventions and technologies.[15] As highlighted previously, investor risk-aversion is compounded by a lack of understanding of the technologies and broader sector requirements. An independent body to oversee such investments, capable of bridging the knowledge gap between finance, policy, science, and technology, was suggested as a means of boosting confidence.

5. **A stronger and clearer carbon credit framework** will help to incentivise further emissions reductions and the CE transition. The current framework is weak, unclear and insufficient to incentivise the net zero transition. It was highlighted as an example that solar industry growth is greatest when oil prices surge.[52] Energy decarbonisation and subsidisation of sustainable, renewable sources of carbon should be incentivised more strongly to create revenue generation opportunities in greener sectors. A growing body of evidence highlights that carbon offsetting schemes rarely achieve the claimed climate benefits or long-term carbon removal, but are instead used to justify ongoing business-as-usual emissions practices.[53] Furthermore, voluntary uptake is slow and insufficient, necessitating policies that enable and enforce mandatory implementation.

   Until fossil resources are no longer subsidised, carbon feedstocks obtained from alternative, sustainable sources will not be commercially viable unless significant government support is provided.[6] Fundamentally, this issue depends on whether companies can afford to switch to alternative fuels and carbon feedstocks **and** remain competitive in global markets. This largely hinges on the price of sustainable energy sources from alternative fuels. Companies with speciality chemical products (such as *surfactants*) can charge higher profit margins and so are better able to pass through additional cost to their customers, whereas companies with commodity-type products (such as methanol) and thinner margins are less able. Therefore, for those currently using fossil feedstocks and looking at a transition, driving up the cost of the current feedstock **before** they can switch may make them uncompetitive.

General

1. **Recognise the value of typical waste products, such as carbon dioxide.** Current '*waste'* streams contain valuable resources and feedstocks for many chemical industries, helping to reduce environmental damage and boost economic growth. Collaboration between government departments would help to address this.

2. **Adopt a unified industrial strategy for a CE transition in the chemical sector, with mechanisms to ensure future market demand and stability.** Government departments need to develop a robust, unified, cross-cutting intra-departmental strategy, with industry collaboration, that looks to the longer-term future. The objectives and boundary conditions should be determined within this strategy with enough flexibility to allow industry and academia to innovate towards the goals themselves.

3. **Refocus strategies for using alternative carbon sources (e.g. Biomass Strategy 2023) on value extraction before fuel generation.**[19] Valuable commodities and chemical compounds should be extracted first before any remainder is turned into fuel, thus generating new revenue streams and jobs. We need alternative sources of carbon that are not derived from fossil fuels.

4. **Implement a standardised Life Cycle Assessment (LCA) framework** to assist in determining the degree of risk for investment, but current approaches do not fully consider the whole system and related boundaries. Too often, LCAs are manipulated to give a desired outcome or full boundary conditions or environmental impacts are not considered. It is important not to adopt a carbon tunnel vision and neglect other metrics of sustainability.[10] Standardised frameworks and guidelines would enable better comparisons between technologies and selection of the most environmentally beneficial option.

5. **Embrace longer-term thinking to achieve positive impact.** Sustainable initiatives typically require longer investment and return periods to have measurable impact. A hyper-focus on short-term, high return technologies is unsustainable and hindering progress.

Chapter 4

Conclusions

Policy Recommendations

Moving to a *circular economy* is imperative not only for environmental reasons. It has potential for wide-ranging economic and societal benefits, giving the UK the capacity to grow and thrive, create green jobs, upskill the workforce, increase self-sufficiency by reducing import reliance, improve infrastructure and provide a brighter outlook for future generations.

By engaging with senior stakeholders from academia, industry, NGOs and government, we have identified the key challenges and opportunities in transitioning the UK chemical sector towards a *circular economy*. These challenges and opportunities are wide-ranging but can be classified into general, technology and financial. Additionally, these recommendations have shaped a number of key recommendations across the same themes and culminated in three policy priorities for this new chapter of government:

1 A unified, long-term, forward-looking industrial strategy for the chemical sector.

2 Leverage more public and private finance to rapidly scale-up research activities to commercial readiness.

3 Short-term fiscal support for an accelerated deployment followed by transitional oil and gas tax relief incentives towards green sector jobs and training.

The scale of this challenge is vast, but surmountable. With dedicated perseverance and collaborative efforts towards a common goal, a new, sustainable way of living is achievable.

Regulatory Quick Wins

Recommendation 1: The value of typical waste products, such as CO_2 and plastic *waste*, should be recognised.

Recommendation 2: Renewable carbon should be valued at a premium over virgin carbon in regulatory tools (e.g. carbon border mechanism and carbon offsetting).

Creating a Renewable Carbon Economy and Supporting Investment

Recommendation 3: Create a strategic industry advisory unit with substantial funding to support the commercialisation of new technologies that will drive a renewable carbon economy – such as developing utilisation technologies (moving from CCS to CCUS) and supporting scale up to full scale commercialisation of green feedstocks. This would be an industry-government partnership, akin to similar initiatives from the transport sector, namely the Automotive Transformation Fund (ATF) delivered by a partnership between the Department of Business and Trade and Advanced Propulsion Centre (APC).[54]

This unit would also help to strengthen the underlying market conditions and create the investment case for large chemical companies looking to migrate from virgin carbon and place manufacturing in the UK. It could furthermore help to drive foreign direct investment (FDI) and also consider the most appropriate uses of green feedstocks, such as biomass. Together, these factors can help to create stable and lasting links between economies.

Key Underpins

Recommendation 4: A BSI standard incorporating a resource depletion indicator, highlighting whether fossil or bio-resources are being utilised or not, in conjunction with LCA standards.

Skills

Recommendation 5: Develop a strategy to migrate the tax relief on oil and gas towards reskilling jobs in the *circular economy*.

Closing Remarks

We stand at an exciting and important point in time, nationally and globally. Important not only with respect to the climate emergency, but also in terms of maintaining national security in chemicals manufacture. As we transition away from fossil fuel extraction and use, we run the risk of creating a supply chain issue in the use of carbon in chemicals. We have an obligation to the environment and to civil society to become custodians of carbon rather than consumers.

While there are several issues that have been identified for the use of biomass and biotechnological approaches, there are two clear routes to chemicals from recycled feedstocks: (a) carbon dioxide utilisation and (b) recycled plastics.

In the recently published policies from Secretaries of State The Rt Hon Ed Miliband MP (Net Zero) and The Rt Hon Jonathan Reynolds MP (Industrial Strategy), there have been major omissions in each. At Mission Innovation the term CCUS was established: carbon capture, utilisation and storage. In the Net Zero policy this has now been replaced by CCS. Where has the U gone? In the Industrial Strategy policy, 10 areas of focus are identified, but the chemicals industry is not one of them. CCS will always be a cost to the emitter as it is waste disposal. However, utilisation treats carbon dioxide as a commodity that can add value to the adopters and to the national economy.

CCS is a linear process. We cannot continue to consume carbon without setting up an alternative to fossil carbon. CCU is not a perfect solution as it needs a robust energy infrastructure. We cannot perpetuate the financial mistakes of the past by spending public money on technologies and policies that have been shown to fail. However, we need to act quickly if we are to avoid catastrophic damage to the economy and subsequent decrease in the quality of life. We need technologies and processes that can be put into action now. The time for hesitation has long passed. However, these new technologies must show environmental, economic, and social advantages to be realistically adopted. In the early stages this will need fiscal as well as financial support. The recent UK Investment Summit has shown how co-investment can be made to work. However, once again this has been focused on other sectors rather than chemical manufacture.

This White Paper has been commissioned to provide a platform for discussion with government, industry, and financial institutions to highlight the benefits of a circular chemical economy to create a stable manufacturing future for the UK. We had considered it essential that a move to a circular economy should be a transition. However, it was clear from industry that this move should be immediate. Such a step-change in manufacturing needs to be embedded in a company's strategic business planning for them to act now. A slow transition is likely to add risk and uncertainty.

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Glossary

CCS	Carbon Capture & Storage
CCU	Carbon Capture & Utilisation
CCUS	Carbon Capture, Utilisation & Storage
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
EfW	Energy from waste
ETS	Emissions Trading Scheme
GHG	Greenhouse gas
H_2	Hydrogen
IP	Intellectual Property
LCA	Life Cycle Assessment
O_2	Oxygen
PET	Polyethylene terephthalate
RHI	Renewable Heat Initiative
ROC	Renewables Obligation Certificate
ROI	Return on Investment
SAF	Synthetic Aviation Fuel
tCO_2	Tonnes of CO_2

Carbon Border Adjustment Mechanism (CBAM): A policy that aims to ensure that carbon-intensive imported goods are subject to a carbon price that is similar to that of equivalent domestic production.

Carbon Dioxide Reduction (CDR): Technologies and processes that reduce atmospheric levels of carbon dioxide. Also refers to chemical processes that transform carbon dioxide into other chemicals, such as carbon monoxide and methane.

Carbon efficiency: A metric used to measure how much carbon is emitted to produce a given output amount.

Circular Economy (CE): A system in which resources are kept circulating for as long as possible, through efficient material use, reuse and recycling loops. It is an alternative to the linear economy in which materials are made, used and disposed.

CO_2 equivalent: A metric used to compare the global warming potential (GWP) of different greenhouse gases.

Demonstrator units: Small pre-commercial units that show proof of concept at suitable scale.

Direct Air Capture (DAC): Technologies that extract carbon dioxide directly from the atmosphere, as opposed to point source capture.

Downstream: For petroleum refining, refers to processes that produce finished products for consumers.

End-of-waste: Processes to facilitate the recovery or recycling of waste for use as a resource, as a direct replacement for raw materials.

Enhanced Oil Recovery (EOR): The practice of extracting oil from a well that has already undergone primary and secondary extraction processes. Carbon dioxide can be injected into oil wells, increasing the pressure and increasing extracted oil.

Ethylene: A hydrocarbon consisting of 2 carbon atoms and 4 hydrogen atoms with global production exceeding that of any other hydrocarbon. A common use is in the formation of the plastic polyethylene (PE).

Hydrocarbon: A chemical compound consisting solely of carbon and hydrogen atoms.

Industrial Symbiosis: A practice where companies and industrial facilities, both within or across sectors, exchange waste and by-products to create mutual benefit.

Indirect Emissions: Emissions resulting from organisational activities but actually emitted from sources owned by other entities.

Investment Funding Guarantees: Provides assurance to stakeholders (investors, lenders, and project owners) that all obligations related to an investment will be fulfilled. They serve as instruments to secure funding, protecting projects against potential losses in the event of non-performance.

Life Cycle Assessment (LCA): A process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities.

Naphtha: A general term applied to petroleum products distilled from crude oil at temperatures less than 240 °C.

Olefins: Unsaturated hydrocarbons consisting of at least one carbon-carbon double bond.

Organic chemical: A class of carbon-based chemical compounds also containing elements of hydrogen, oxygen and/or nitrogen.

Point Source Capture: Technologies that extract carbon dioxide from single, highly carbon-emitting sources such as flue stacks.

Propylene: A hydrocarbon consisting of 3 carbon atoms and 6 hydrogen atoms. Also known as propene, a common use is in the formation of the plastic polypropylene (PP).

Proximity Principle: Waste should be handled and processed as close to the origin of production as possible.

Steam Cracking: The primary method of producing ethylene and propylene from petroleum sources. A hydrocarbon feed is heated to around 850 °C in the presence of steam.

Surfactant: A chemical frequently used in detergents and other cleaning products as the key active ingredient.

Upstream: For petroleum refining, refers to exploration, drilling, and extraction activities.

Waste: any substance or object which the holder discards, intends to or is required to discard.

Whole Systems Approach: A method of addressing problems within complex systems by considering all interconnected parts to create solutions.

Scan to learn more

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