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EDITED BY
Greeshma Gadikota,
Cornell University, United States

REVIEWED BY
Paolo Stufano,
National Research Council (CNR), Italy

*CORRESPONDENCE
Peter Styring,
p.styring@sheffield.ac.uk

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Perspectives for the circular chemical economy post COP26

Katie J. Lamb and Peter Styring*

Department of Chemical and Biological Engineering, The University of Sheffield, Sheffield, United Kingdom

More global action towards climate change in the UK is needed now. Carbon dioxide levels need to be decreased globally and more sustainable practices implemented throughout all sectors in the UK. Whilst many steps have been taken in the UK to reduce its overall carbon footprint, the UK chemical sector must become more sustainable. Whilst carbon dioxide emissions must be reduced, a holistic systematic approach is needed to reduce emissions and improve sustainable manufacture. The circular economy in conjunction with reducing carbon dioxide levels can therefore be used to tackle this issue. Carbon dioxide mitigation technologies, such as carbon capture utilisation and storage amongst others, must help complement a circular economy as well as push towards a more circular carbon-based UK chemical sector. This perspective will discuss policies pledged towards tackling climate change *via* carbon dioxide reduction methods, pre and post COP26, and critically discuss the good and bad aspects of the conference, especially in terms of creating a circular chemical economy in the UK.

KEYWORDS

circular economy, chemicals, policy, carbon, carbon dioxide

Introduction

COP26, carbon and the circular economy

Global carbon dioxide (CO_2) emissions are an important contributor towards climate change. Whilst CO_2 emissions must be tackled, there are numerous other factors that we must consider, such as other greenhouses gas (GHGs), like methane (CH_4), nitrous oxide and halogenated gases, amongst others. There are also other sustainability issues to consider when tackling CO_2 emissions, such as global supply chains, supply chain demands, circularity of materials, reusability and recyclability. In reality we need a holistic whole system (i.e. systems thinking) approach to tackling all aspects of climate change, with a central thread of sustainability running throughout all of our approaches and methodologies. Employing more circular practices, and thus a circular economy throughout all aspects of society and everyday life, is needed urgently in order to reduce the effects of global warming and to employ more sustainable practices throughout society. This way, we can tackle CO_2 emissions without falling into a "carbon tunnel vision" trap (Figure 1) (Konietzko, 2021).

Most carbon in humans comes from CO_2 through the carbon cycle, as CO_2 is absorbed by plants, along with sunlight and water, to create sugars *via* photosynthesis, which helps the plants to grow. These plants are then eaten by humans, or other animals which are consequently eaten by humans, who then break down the sugar, contained within the plant or animal, for energy. This therefore leads to the production of CO_2 again, which is emitted back into the atmosphere when we exhale during breathing (Riebeck, 2022). It is estimated that around 18% of the human body is made up of carbon, in the form of carbohydrates, fats, nucleic acids, and proteins (Sutcliffe et al., 1990; Heymsfield et al., 2005). On the other hand, most of the carbon embedded in organic chemicals and their derived materials (currently) comes from fossil fuel based reserves. From 2010 to 2015, 85% of global carbon demand for organic chemicals came from fossil fuels, the majority of which (68%) came from fossil oil. Only 10% and 5% of global carbon demand came from bio-based and recycled sources, respectively (Kähler et al., 2016). As a result, the UK (and global) chemical sector consists of a highly subsidized and well established fossil fuel, and thus fossil carbon, industry.

Most of the carbon in the atmosphere is now a result of human activity, such as extracting, burning and consuming fossil fuels such as coal, oil and gas etc. (NASA, 2014; Berkeley Earth, 2014). Many experts have expressed that "a third of oil reserves, half of gas reserves and over 80% of coal reserves should remain unused" in order to truly tackle CO_2 emissions. It is thus paramount that the UK (and global) chemical sector decreases their use of fossil fuels and fossil carbon (McGlad and Ekins, 2015; Pidcock and Carbon Brief, 2015). Hence why "defossilisation" and "decarbonisation" are both key to tackling climate change. The term decarbonisation also needs to be more widely understood. Whilst this term is great to emphasize when it comes to removing CO_2 from the atmosphere, and also reducing CO_2 emissions of processes, it must not lead to the confusion that carbon is bad or diminish the importance of carbon in products.

Carbon dioxide emissions come from all aspects of life, not just from burning coal, oil, gas or transport fuel. All chemicals that are used to make products have a carbon footprint, thus all products used in our daily lives have a carbon footprint. The element carbon is present in many materials found on Earth, and everyday items and commodities used by humans, including diesel, petrol, fossil fuels, trees, pharmaceuticals, mobile phones, construction materials, cars, biomass, plants, sofas, shoes, textiles, paints, food, and many more. Not only does the production of

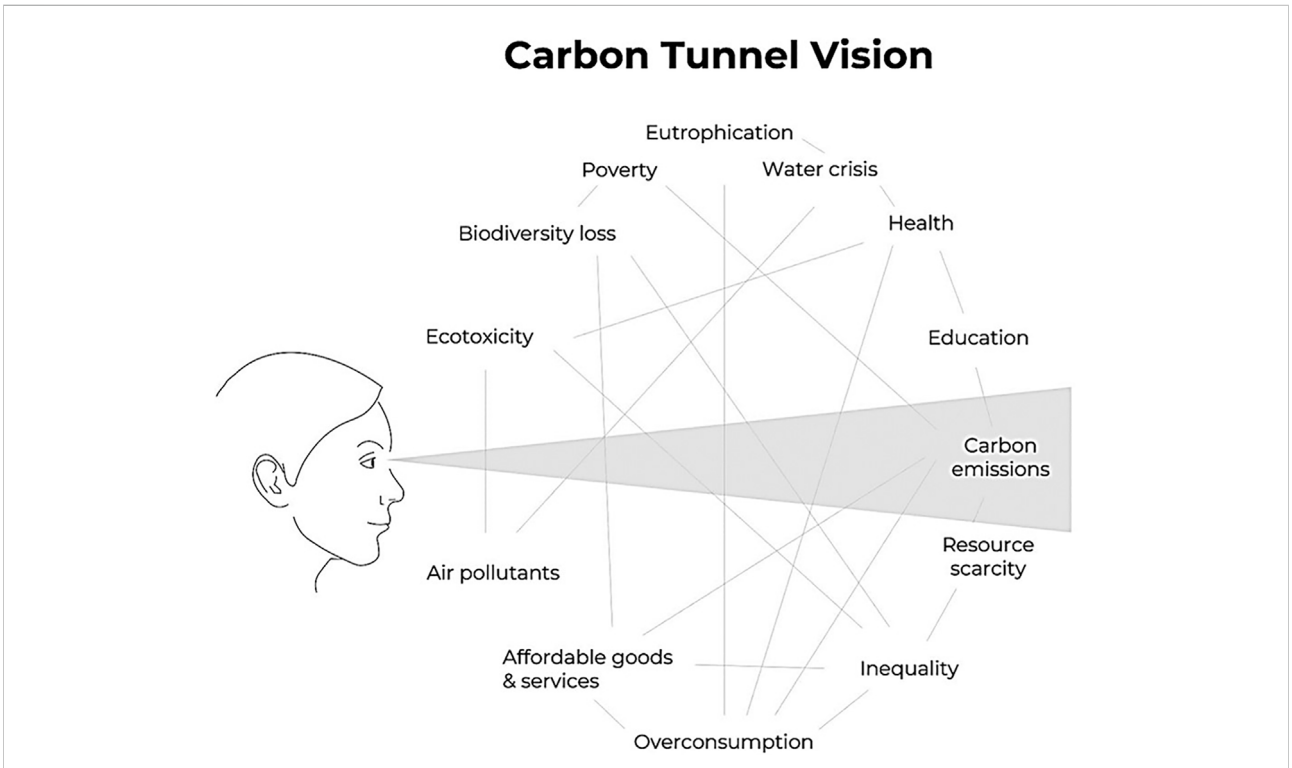

FIGURE 1
The potential fallback of employing a "carbon tunnel vision." We have to tackle CO_2 emissions, but it must not be our only focus. We need to consider social responsibility, social impact factors, and other sustainability metrics. This figure was produced and adapted with permission from Jan Konietzko (Konietzko, 2021).

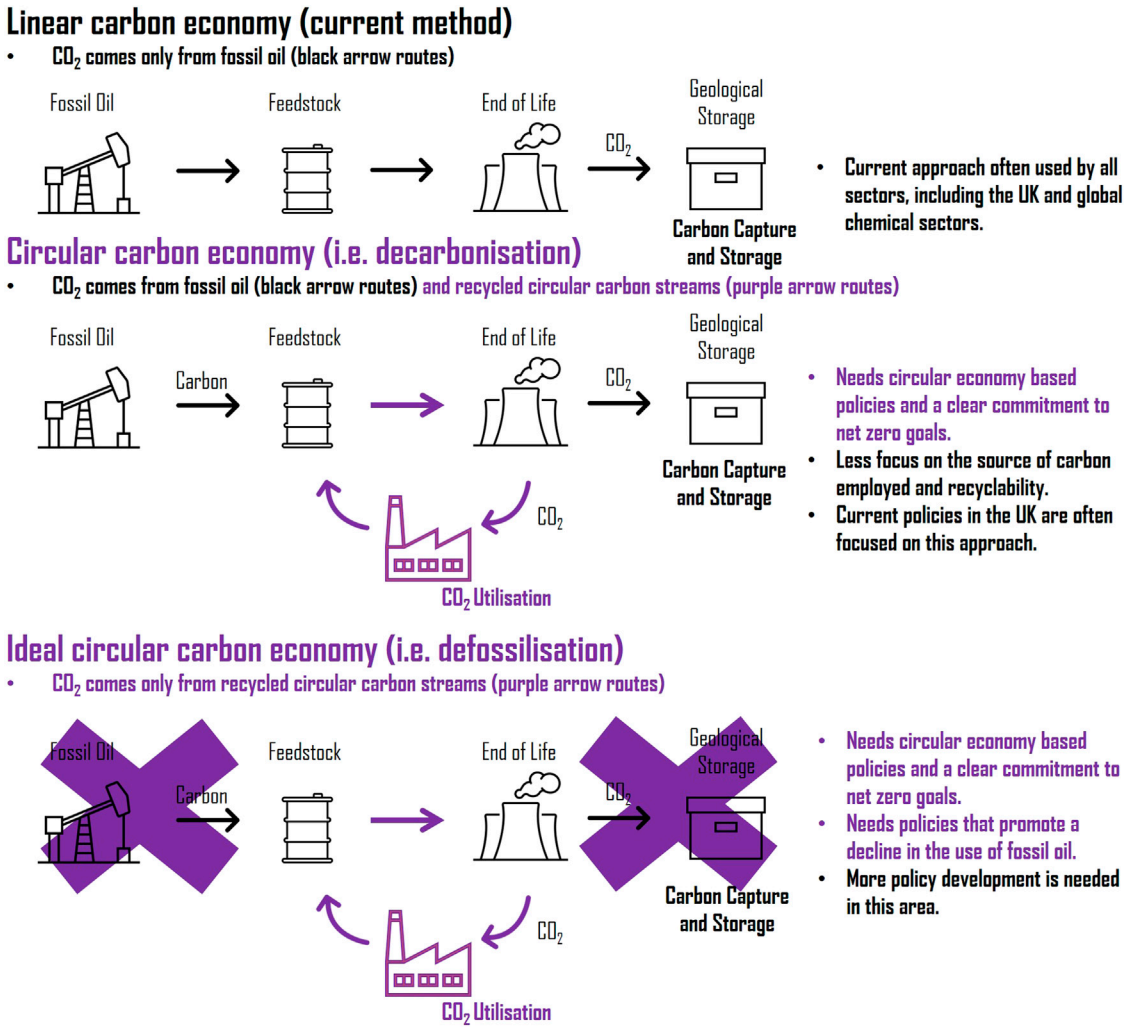

FIGURE 2
General concept of employing a circular carbon economy (and thus a circular chemical economy) vs the linear carbon model currently employed in the UK chemical sector. This figure also comments on policy changes we propose are needed to increase carbon circularity in the UK (and global) chemical sector.

everyday items emit CO_2, but its use and potential disposal also has a carbon footprint. Until the true lifecycle of carbon embedded in everyday products is understood (by Government, scientists and consumers) and considered when tackling carbon emissions, the UK chemical sector (as well as the global chemical sector) will continue to have a large carbon footprint.

In particular, the UK chemical sector is the second highest emitters of CO_2 in the UK, with over 18 million tonnes of CO_2 produced annually (GOV.UK, 2015a). In the UK, around 65% of all CO_2 emissions are due to energy use. Therefore, even if the UK managed to switch to renewable energy by 2050, 35% of carbon emissions are still related to products. The UK therefore has a vital materials and products challenge to address.

We have a social responsibility look after carbon. It is a finite element. If we keep emitting carbon into the atmosphere, or keep capturing and storing it away as "waste" that we cannot reuse or access, this will have catastrophic consequences. We need to conserve our carbon, and other elements, by moving to a more sustainable approach. Instead of fossil oil being used as a feedstock for our fuels and chemicals, we need to use more sustainable sources of carbon. As the IPCC recommends that we move away from fossil oil extraction (Westervelt and The Guardian, 2022), this will have an impact on our ability to source, and create, materials and products if we don't act now and change how we obtain and reuse our carbon. The UK subsidizes oil and gas to the tune of £10.5 billion per annum.

If we're going to move towards a circular transition,, that has to change and we need more focus on low carbon technologies.

By employing circular methods when reducing global CO_2 emissions, this can help create a circular carbon system, which in essence combines circular economy thinking with CO_2 reduction technologies (Figure 2). This also needs to be twinned with reducing our reliance on extracting and utilisation carbon from non-recyclable and single-use fossil resources.

One way to implement holistic thinking into the UK chemical sector (as well as all sectors) is to implement more circular economy methodology into policies. The 26th Conference of the Parties (COP26) took park in the UK, in Glasgow, Scotland, during October 2021, and was a great opportunity to create new UK policies and thus make the chemical sector more sustainable. COP26 was hailed as great success in terms of sustainability and tackling climate change, but was that the case? This perspective will briefly overview UK policies raised pre and post COP26, as well as overview how effective COP26 truly was in terms of promoting carbon capture utilisation and storage (CCUS) technologies, encouraging further employment of circular economy thinking, and creating a circular chemical economy.

Overview of UK policy towards carbon dioxide emissions, carbon and the circular economy (so far)

Policies pre COP26

When discussing UK policy, devolution is an important factor of the UK. Since the 1990s, laws, legislation, policies (and thus sectors) of the UK are now either devolved (i.e., England, Scotland, Northern Ireland and Wales set their own policies, regulations or laws) and reserved (i.e., all devolved states of the UK follow the same policy) (GOV.UK, 2020a). Whilst some of the strategies listed below are UK wide or England based, the devolved states of the UK (i.e., Northern Ireland, Scotland and Wales) have set their own rules towards tackling CO_2 emissions and thus climate change, their own strategies to reach net zero emissions, and have different approaches towards improving circularity and reusing (or storing) carbon emissions.

Prior to COP26, many policies and ambitions were set by the UK Government to tackle climate change and to incorporate more sustainable practices across the UK. Carbon dioxide emissions have been an important factor for the UK Government since 2008, when the "Climate Act of 2008" was passed. Since then, many different policies and ambitions have been set by the UK Government. Whilst this act is an overarching law across the UK, the devolved nations have set their own policies and strategies to meet the aims of this Climate Act.

In terms of policies and aims set by the UK Government (and thus set in England) from 2009 onwards, the same year the Low Carbon Transition Plan was set, over 15 plans, roadmaps and ambitions have been launched by the UK Government (excluding the devolved administrations of the UK). The most recent "Net Zero Strategy" for England was set in 2021. Many of the plans set in the early 21st Century have since been updated or superseded, in line with political changes in the UK Government and are thus forever changing (GOV.UK, 2016).

Interestingly (and worryingly), on performing a word search for "chemicals" and "circular economy" on over 15 roadmaps, plans, ambitions and reports produced by The Department for Environment, Food and Rural Affairs (DEFRA), The Department for Business, Energy and Industrial Strategy (BEIS) and English-based Government departments, only the Net Zero Strategy mentions circular economy, with chemicals mentioned even less. The circular economy was mentioned in reference to increasing the deployment of reuse and repair methodology, the waste sector, reducing waste sent to landfill, and raw material efficiency (to name just a few examples). This perhaps highlights that for over 10 years, policies have not been developed with circular economy thinking, especially when it comes to CO_2 reducing technologies in the chemical sector (at least by DEFRA, BEIS and England anyway).

Since 2008, the Government has been setting UK Carbon Budgets, in which the CO_2 emissions of the UK are monitored and targets are set to continually reduce the total emissions of the UK by 2050. A total of six Carbon Budgets have been set since 2008, with consultation and advice from the Committee on Climate Change. This includes counting carbon emissions from the trading sector, based on our share of the EU Emissions Trading System (when we were part of the EU), and the non-traded sector, which covers everything else like road transport, agriculture and buildings (GOV.UK, 2016; GOV.UK, 2021a). Whilst the Carbon Budgets act as an overarching UK scheme, each devolved nation can meet these Budgets however they see fit.

Since the start of the UK carbon budgets, important update reports and on these targets have been produced every year. These reports explain and explore the data and methodology used to produce the budgets, detail responses received from external sources and consultations, such as the Climate Change Committee, and provide honest feedback as to how effectively these targets are being met. These reports from the UK Government and the Climate Change Committee also analyze the progress of the devolved nations in the UK (GOV.UK, 2015b; GOV.UK, 2021b). These reports and evaluation based approaches are vital in terms of addressing our decarbonisation and sustainability goals, and therefore are a step in the right direction, as without evaluating and assessing our progress it would be difficult to achieve our goals.

During the time of the recent UK Coalition Government, investments and incentives towards investigating and developing

CCS technologies in the UK were provided, to help tackle climate change, reduce UK greenhouse gas emissions, and set out a CCS roadmap (GOV.UK, 2010a; GOV.UK, 2010b; GOV.UK, 2012; GOV.UK, 2015c). Towards the end of the scheme however, the final stage of funding was unexpectedly pulled from the CCS programme, stating that due to CCS not working the final stage of funding will not go ahead (Mason and The Guardian, 2016; UK Parliament, 2016). The UK Government has recently launched a new set of calls to investigated CCUS in the UK (GOV.UK, 2021c; GOV.UK, 2021d), but perhaps trust is low as to whether the full amount of funding will be provided. Whilst working towards CCUS technologies is more effective for circular economy principles, and utilisation alongside capture and storage is a step in the right direction, only time will tell if the Government commits wholeheartedly towards future CCUS technologies in the UK.

More recently in terms of Carbon Budgets, the UK Government announced the sixth Carbon Budget in April 2021, which declared by law the ambitious decarbonisation target to reduce UK GHG emissions by 78% by 2035 compared to 1990 levels (965 $MtCO_2e$). Interestingly, the announcement of this budget stated that "setting this budget is about the government's ambition to cut emissions, rather than announcing specific policies that will deliver that reduction in emissions. We will bring forward policies to meet Carbon Budgets." Ambition is not the same as action. In the budget, CO_2 emissions were accounted for from buildings, power, transport, industry, agriculture and land use, waste and F-gas emissions. There was no specific mention of chemicals or the chemical sector, which needs to be addressed (GOV.UK, 2021a).

In terms of devolved nations aim and policies, there are similarities but also differences in terms of policies and strategies. In Northern Ireland, the Department of Agriculture, Environment and Rural Affairs (DAERA) set and propose policies towards Northern Ireland's net zero targets, on behalf of the Northern Ireland Executive. Within DAERA, there is "Climate Northern Ireland", which is an inter-sectoral network aiming to tackle climate change and its effects within Northern Ireland (DAERA, 2022a). Northern Ireland are also striving to achieve net zero goals by 2050, and have set Climate Change Adaptation Programmes in response to the UK Carbon Budgets and Climate Act of 2008 (DAERA, 2022a). The Northern Ireland Environment Agency (NIEA) also contribute towards tackling carbon emissions, with the launch of the Prosperity Agreements in 2014. These agreements are "voluntary agreements through which NIEA and an organisation can explore opportunities for reducing environmental impacts (such as carbon emissions) in ways that create prosperity and wellbeing" (DAERA, 2022b).

The DAERA recently ran a consultation towards "A Green Growth Strategy for Northern Ireland" in 2021. Within this strategy, Northern Ireland hope to support behavioral changes towards achieving a low emissions economy, and to support local citizens and businesses to reduce their carbon footprint (DAERA, 2022c; DAERA, 2022d). This strategy was still under development as of 2022, with the consultation only recently ending in late 2021. The circular economy is mentioned as an approach to employ within this strategy, but more in terms of dealing with waste and less so in terms of the chemical sector. Carbon Capture and Storage methods such as combustion of bioenergy with carbon capture and storage (BECCS), and Direct Air Capture of CO_2 with storage (DACCS) are referenced in the document, but less emphasis is given to CCUS techniques (DAERA, 2022c).

In Scotland, the Scottish Government (Riaghaltas na h-Alba) has the Energy and Climate Change Directorate, which aims to deliver "a low carbon society, with sustainable economic growth and reduced greenhouse gas emissions," with their own Directors of General Net Zero and Energy & Climate Change (Scottish Government, 2022a). Scotland also set up a "Scotland's Climate Assembly," which operates independently to the Scottish Government and offers over 100 people in Scotland to present their views and opinions on climate change actions (Scottish Government, 2022b).

Following the UK Climate Change Act of 2008, Scotland set their own legislation titled the "Climate Change (Scotland) Act of 2009" (Legislation.gov.uk, 2009), which was superseded and updated by the "Climate Change (Emissions Reduction Targets) (Scotland) Act of 2019" (Legislation.gov.uk, 2019). Scotland have a more ambitious plan than the rest of the UK, as the Climate Change Act of 2019 commits Scotland to achieve net zero emissions by 2045 (5 years earlier than the target of 2050) and to also achieve net zero emissions of all greenhouse gases (not just CO_2 emissions) (Scottish Government, 2022b).

Scotland's Climate Change Plan encompasses many net zero goals and was updated in 2020 (Scottish Government, 2020a; Scottish Government, 2022c).

This updated plan mentions the concept of a circular economy, with the aim to incorporate circular economy thinking and approaches in terms of tackling waste, energy, transport, buildings and society. In conjunction with Zero Waste Scotland and the Scottish Environment Protection Agency (SEPA), this plan will also aim address emissions associated with production, consumption and waste of products and resources. Whilst the chemical sector is not mentioned specifically, and this report seems more focused on the circular economy of waste, this plan in conjunction with Zero Waste Scotland and SEPA seems to be a step in the right direction. The plan is also heavily dedicated towards increasing the employment of both CCS and CCUS across Scotland, with promises of grant funding towards CCUS and industrial decarbonisation (Scottish Government, 2020b). This will also work alongside the Scottish Net Zero roadmap, which consists of academia and industrial funding to help Scottish industries reach

net zero carbon emissions by 2045 (Scottish Net Zero Roadmap, 2022).

The Welsh Government (Llywodraeth Cymru) and Welsh Parliament (Senedd Cymru) have set the goal to achieve net-zero by 2050 under the "Net Zero Wales" policy, under the guidance of the Climate Change, Environment and Rural Affairs Committee (Y Pwyllgor Newid Hinsawdd, Amgylchedd a Materion Gwledig) and the Ministers for Climate Change (Llywodraeth Cymru, 2022a). Since 2010, Wales has set devolved strategies and goals to achieve net zero, under the guidance of the Welsh Government and the Climate Action Wales (Gweithredu Hinsaedd Cymru) initiative (Llywodraeth Cymru, 2020). In 2010, Wales adopted a "Climate Change Strategy for decarbonisation and adaptation." In 2013, the "Active Travel (Wales) Act" was set, with the intention to encourage more emission free modes of travel in order to reduce their carbon emissions. (Llywodraeth Cymru, 2021a), In 2015, the "Wellbeing of Future Generations Act" was passed, which is a legislative approach towards sustainable development in Wales in line with the UN Sustainable Development Goals (Llywodraeth Cymru, 2021b). Following this, an independent Future Generations Commissioner for Wales position was established, to act as "a Guardian of future generations," encourage public bodies to take greater account of their long-term impacts and to advise on any future laws that are set by the Welsh Government (Llywodraeth Cymru, 2021b). In 2019, two "Prosperity for all" strategies were also created, with the aim to set out how Wales will adapt to the impacts of Climate Change, and 100 policies and proposals were written with the intention of reducing Welsh emissions and making Wales "Low Carbon" (Llywodraeth Cymru, 2020; Llywodraeth Cymru, 2022b). Carbon Capture and Storage and CCUS are both seen as an integral part to the low carbon and low carbon energy goals of Wales (Llywodraeth Cymru, 2019a; Llywodraeth Cymru, 2021c). Pleasingly, the "Prosperity for All: A Low Carbon Wales act" does include (and mention) circular economy approaches, highlights the importance of reducing emissions in industrial sectors such as the chemical sector, and discusses the importance of CCS and CCUS (Llywodraeth Cymru, 2019b).

In terms of similarities across the UK, all devolved nations regularly take part in UK Carbon Budget assessments, are advised by the Climate Change Committee about whether their net zero targets are feasible and receive suggestions as to what policies (or changes to policies) are needed in order to make their targets a reality, and publish strategies and plans on how they will work towards the UK Climate Change Act of 2008. Devolved approaches may differ in terms of deadlines and tactics, especially in terms of alternative green energy sources utilised, due to geographical (e.g., weather, location and terrain differences), supply chain and economical differences, but overall have the same overarching aims and goal.

Wales perhaps are a beacon example of policies and legislative approaches in the UK, as whilst the aims across the devolved nations to tackling CO_2 emissions and global warming have similar deadlines and final goals, Wales has the unique example of addressing future laws with a sustainability mind-set. Due to the launch of the Future Generations Act in 2015, Wales now ensure that "any decision the government makes today must be the right thing for our children and grandchildren, and their children too." This perhaps is something that needs to be explored by England, Northern Ireland and Scotland as well. Wales and Scotland also have dedicated positions to deal with climate change in their Parliament, with a Minister and Deputy Minister for Climate Change built into the Welsh Government under the authority of their First Minister, and the Directors of General Net Zero and Energy & Climate Change in Scotland. A similar approach should be employed across the UK as a whole. Scotland's ambition to also tackle other greenhouse gases (within a quicker timeframe) also highlights Scotland's holistic approach towards climate change and should also be considered by other parts of the UK.

Policies and ambitions raised at COP26

The mantra of COP26 was "Cash, Coal, Cars, and Trees." The Clean Green Initiative was launched, with the UK promising to spend more money on climate change adaption and mitigation. The Global Coal to Clean Power Transition Statement was launched, with the UK promising to phase down the use of coal for energy. A declaration pledging that only 100% zero emission vehicles will be on sale in the UK by 2035 was also signed. The Glasgow Leaders' Declaration on Forest and Land Use was also launched, with the UK promising to decrease deforestation and plant more tress to sequester CO_2 emissions (United Nations and Climate Change Conference, 2021).

Increasing the amount of money dedicated towards tackling climate change is a step in the right direction, but will be difficult to achieve due to the current financial situations in the UK and globally. Resilient, adaptable and flexible policies must therefore be created to ensure climate change is tackled, and that these promises are made, without there being a cost or downside to the poorest in society.

The declaration to phase down coal is a step in the right direction, but changing the declaration to "phase out" rather than "phase down" coal may cause issues. We believe that a stronger emphasis towards "defossilisation" as well as "decarbonisation" needs to be in place across the UK. Coal should not be the only fossil fuel source tackled in the hope to achieve greater sustainability and a lower carbon footprint.

Whilst a push towards less petrol and diesel cars being sold is welcomed, a more detailed and thoughtful approach, with an appreciation of other sustainability metrics, must be considered when increasing the use and sale of electric vehicles (EVs). The

materials required to make EVs rely on vital metal supply chains. Lithium, nickel, manganese, and cobalt are key battery materials, but are also critical metals, used for EV batteries (Ellingsen et al., 2013). Nickel itself has more than doubled in cost price from March 2020 to March 2022, whilst global London Metal Exchange (LME) stocks have decreased from approx. 650 to approx. 250 metric tonnes in the same time period (Cobalt Statistics and Information, 2022). Careful consideration of potential supply chain shortages and geopolitical issues must be considered, as well as knock-on effects such as increased material costs.

Electric vehicles may produce zero-emissions at the tailpipe, but the carbon footprint of sourcing the materials for these vehicles and the whole lifecycle of the car must also be considered (Styring et al., 2021), as well as the energy used to power the vehicle. If fossil fuel derived electricity is used to power EVs during their use phase, the lifecycle and carbon emissions of these vehicles increases dramatically (Ellingsen et al., 2016). Decarbonisation of the UK National Grid, and increases in the production of electricity from renewable and low carbon energy resources, must occur before the ban of petrol/diesel vehicles and EVs sales increase, to satisfy the potential growth in demand of electricity for EVs.

Public transport of course is another way to decrease emissions from petrol and diesel cars, by encouraging a reduction in car use. Availability and reliability of public transport must be improved to make this a reality. In the UK, public transport is often more available and reliable in major cities, but is often poor and infrequent in rural areas. Electric vehicles are also currently more expensive than petrol and diesel cars. Until the cost of these vehicles come down, public transport routes must be improved or incentives provided, to avoid creating a social underclass and reducing the number of people who have access to, or can buy, their own car.

In terms of an international example, the EU have set a "Green Transport" topic within their European Climate Pact. As a result, the EU is aiming to make "cities cleaner, and our jobs greener, by implementing innovative and digital solutions for public transport, cycling, walking and other forms of clean mobility." Within this pact, the EU is not only improving public transport (in rural areas as well as cities and towns) but also increasing the ability to share EVs and bikes (The European Union, 2021a). Both issues of public transport and EV are therefore being addressed in the EU. In terms of a UK example, Wales have the Active Travel (Wales) Act, which has the ultimate aim to make "45% of all journeys in Wales to be made by walking, cycling and public transport by 2040" (Llywodraeth Cymru, 2021a). This act also states that "pilot schemes to make use of electrically assisted bikes (e-bikes) and e-cargo bikes an affordable option for more individuals and businesses" will be launched.

Ultimately, both EVs use and public transport availability and reliability need to be addressed holistically, in order to avoid creating a social underclass in the UK (and globally) whilst reducing carbon emissions from vehicles and the transport sector (Styring et al., 2021).

Whilst planting trees will overall have some benefits, it will not provide a long-term and large scale solution towards tackling climate change, as trees take a long time to sequester large amounts of CO_2 and large quantities of land are needed to mitigate a meaningful amount of CO_2. A stronger focus should be given to prevention and mitigation of CO_2 emissions, and techniques such as CCUS, to lower global CO_2 emissions.

Whilst key ambitions were set in terms of tackling CO_2 emissions, chemicals were not highlighted as a key theme or mantra of COP26. Although chemicals are embedded in every aspect of life, and therefore it is arguable that chemicals were considered during COP26, tackling the complexity of transforming the UK (and global) chemical sector into a more circular and sustainable system must be performed.

Circular economy was also discussed at COP26, but was not really highlighted as a key aspect of the goals and ambitions of the conference. As circular economy itself is a large concept which encompasses many aspects of sustainability, this approach was underpinned in some of the goals of the conference. The same can be said for the UN Sustainable Development Goals.

It is not uncommon for national policies to employ circular economy thinking without explicitly stating the term. Considering the EU as an example, the circular economy is built into the European Green Deal, which was officially launched in 2019, and include a "set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels" (The European Union, 2022). The European Green Deal was made with the aim to "improve the wellbeing and health of citizens and future generations," by focusing on delivering energy efficient buildings, clean water, healthy soil and biodiversity, and "longer lasting products that can be repaired, recycled and re-used," amongst other things. This is a circular economy principle. The European Green deal also covers many aspects which follow circular principles, such as the Land Use Forestry Regulations promises, which pledges to create and increase natural carbon sinks in the EU by promoting a "circular and sustainable management of these resources" (The European Union, 2021b). The circular approach of this Deal was further reinforced when the Circular Economy Action Plan was proposed in 2020 as part of the European Green Deal, which aims to "Make sustainable products the norm in the EU, ensure less waste, focus on the sectors . . . where the potential for circularity is high" (The European Union, 2020).

As another example, the USA also recently announced in 2022 the Inflation Reduction Act (IRA), which on the surface appears to simply be a law to reduce inflation and provide more financial support to USA citizens, especially for working families. Within this law though, there is the aim to increase and create clean energy jobs in efforts to tackle the climate crisis in America, and to

increase sustainable and circular practices in the USA. It is also the largest investment towards tackling climate change in US history (United States of America, 2022a; United States of America, 2022b).

Another international example is Japan's launch of the "Basic Act for Establishing a Sound Material-Cycle Society" in 2000 by the Ministry of Economy, Trade and Industry, in order to change their approach to their waste management systems. This thus lead to the "Fundamental Plan for Establishing a Society" in 2003. Although this appeared on the surface to be a simple change in dealing with waste, this plan lead to the development of a regulatory framework with circular economy principles in Japan (Ellen MacArthur Foundation, 2021).

Overall, more effective ambitions and policies are still needed, with clear action plans into how all of these promises will be achieved. A greater emphasis and focus towards tackling the carbon footprint and impact of chemicals and materials also needs to be placed in future policies (Climate Action Tracker, 2022a).

UK policy post COP26

In terms of post (and current) COP policies, these include (to name just a few) "The 25 Year Environment Plan," "The 10 Point Plan for a Green Industrial Revolution," "The Industrial Decarbonisation Strategy" and "The Net Zero Strategy," as set by the UK Government. Currently, the devolved nations, Northern Ireland, Scotland and Wales, have kept to their policies pre COP26, and are all striving to continually assess, update and evaluate their policies as time goes on.

In 2022, BEIS also launched a policy framework into CCUS technologies, asking for evidence to be submitted on how the UK Government can best support new CCUS technologies from July to October 2022. The framework interestingly stated though that "CCUS refers to dispatchable gas-fired power generation with CCUS. We are engaging separately on bioenergy with carbon capture and storage." Whilst this separate approach is understandable, and helps to define the problem for the consultation, both CCUS for power generation and bioenergy approaches will need to be considered within the context of one another in the future (GOV.UK, 2022a).

The UK also recently completed gathering information *via* consultations for three reports, titled "2030 Strategic framework for international climate and nature action," "Designing a framework for transparency of carbon content in energy products: call for evidence" and "Decarbonisation readiness: call for evidence on the expansion of the 2009 Carbon Capture Readiness requirements." Hopefully, these reports will take a more holistic approach and build CCUS into the UK, especially the chemical sector, with circular economy thinking.

Whilst these policies are all pointing in the right direction, and initial consultations should be launched considering each aspect individually, all approaches must be considered. In the same vein, carbon used in products and the chemical sector must be considered when tackling climate change, not just waste carbon. All technologies and policies must be analyzed in the context of one another. Chemicals were not listed as one of the ten points to tackle in "The 10 Point Plan for a Green Industrial Revolution" (GOV.UK, 2020b). This needs to be reconsidered.

Post COP26 and COP27

At the time of writing this perspective, the COP27 conference came to a conclusion, but how much was achieved between COP26 and COP27, and was COP27 a success?

Between COP26 and COP27, some action was achieved towards delivering on the Glasgow Climate Pact, but much more still needs to be done. In terms of positive aspects, more signatories were obtained for pacts launched alongside the mantra of COP26, but only a few, and more countries submitted their Nationally Determined Contributions (NDCs, a country's contribution to, and/or needs for, dealing with the impacts of climate change) (GOV.UK, 2022b) and National Adaption Plans (NAPs, domestic planning processes that allow a country to identify, address, and review their evolving adaptation needs), in line with meeting the targets of the Paris Agreement and the Paris Rulebook. It is still questionable though whether or not enough action has been performed in this area. For example, out of over 190 counties who attended COP26, only eight developing countries submitted new NAPs between COP26 and COP27 (UNFCCC, 2022). Plans launched from COP26, in regards to implementing a framework to meet the requirements of the Paris Agreement, also indicate that updated and submitted NDCs will not be reviewed until December 2024 onwards (GOV.UK, 2022b). This may be too late.

As detailed in the "COP26 Presidency Outcomes to document," the UK "responded to the Glasgow Climate Pact by revisiting our 2030 NDC and strengthening it with information on delivery of our target to reduce all greenhouse gas emissions by at least 68% by 2030 compared to 1990 levels" (GOV.UK, 2022b). However, in October 2022 (shortly before the start of COP27), Climate Action Tracker, a joint venture between Climate Analytics and NewClimate Institute to provide independent scientific analysis on government track records towards climate action and measures, stated "The UK's climate action is not consistent with the Paris Agreement. While the UK's NDC and long-term targets are broadly aligned with cost-effective domestic pathways, they do not represent a fair share of the global effort to address climate change. The UK's current approach is therefore incompatible with the principles of equity and common but differentiated responsibilities which are central to the Paris Agreement" (Climate Action Tracker, 2022b). It is therefore clear that the UK needs to do more, sooner and now.

In terms of COP27 itself, there was little focus again on the carbon footprint of materials and the issue around circularity of chemicals, and thus on reducing the carbon footprint of the chemical sector. Deep divisions occurred on providing funding towards poorer countries dealing with the effects of climate change, with some countries willing to providing more funding for "loss and damage," whereas others were reluctant. A final deal was struck though in the last moments of the conference, where promises were made to provide funding for loss and damage, something that has never happened at COP before (Harvey, 2022).

Discussions around phasing out coal were discussed again, with some countries such as India pushing for all fossil fuels (i.e., coal, natural gas and oil) to be phased out (McGrath and BCC news, 2022). This was met with resistance from Saudi Arabia, whose economy heavily relies on oil and gas, with the Saudi energy ministry official and COP27 negotiator, Khalid Abuleif, stating that new rules and promises could "demonise" the fossil fuel industry (Abnett et al., 2022).

Debates about the ability of Africa to use their huge gas reserves in order to economically develop further also occurred. One side argued that keeping global warming to below 1.5°C will not be possible if these gas reverses are used, whereas the other side stated it was socially unfair to stop developing countries from undergoing the same level of industrialisation the West experienced Centuries ago. Africa will also require large investments and financial aid to resource renewable energy sources if these gas reverses cannot be used (Okereke et al., 2022).

Another concern of COP27 was the lack of commitment of some countries to work towards limiting global warming to 1.5°C, with countries such as India and China stating this goal is no longer scientifically feasible. Whilst this task will be hard to achieve, undoubtedly, efforts to strive towards this goal should not be diminished (Harvey, 2022; McGrath and BCC news, 2022). Ultimately COP27 was seen as a step backwards, as pledges towards 1.5°C were and few and far between, with the COP26 president Alok Sharma damning the results of COP27 (Cabinet Office and The Rt Hon Alok Sharma MP, 2022) and reports suggesting that policies of the conference will let our global annual average temperature rise by 2.7°C (Sharp and BBC News, 2022).

Conclusion

Overall, it is still clear that more action is needed to develop more effective and systematic policies to tackle CO_2 emissions more sustainably in the UK, and indeed globally. The UK chemical sector cannot be ignored, and carbon emissions from materials must be accounted for more in the future. This will need not only policy changes but also behavioural changes across society.

Ultimately, there is always a tricky balance between creating policies that are green and can also stimulate innovation, investment and competitiveness for those investing and operating in the UK. Any transition from current fossil carbon technologies and energy supplies must occur urgently, even though this transition will be complex, difficult to manage, and presents many hurdles. Job losses, economic uncertainty and energy supply instability could all arise from this transition. This does not mean the transition should not happen, but if the transition is not managed successfully, confidentially and effectively, it will be difficult to sell to the public and could be met with resistance.

Large-scale CCUS implementation across the UK has still not occurred and has only been pursued when it was of political relevance, rather than arguably a matter of global urgency. Fully and accurately tracking the full route of carbon, or any chemicals, throughout the UK chemical sector and beyond, whether the chemicals are recycled or not, will be difficult regardless of the technologies employed. This difficulty and complexity however cannot be ignored and must be enacted upon sooner rather than later. The importance of the circular economy in helping the UK to defossilise, as well as decarbonise, in conjunction with CCUS technologies, cannot be understated.

The vision of COP27 in Egypt was to turn the Glasgow policy outcomes into action, with the ultimate aim to "commence implementation of climate change adaption, mitigation and financial strategies." This sadly appears to still be a goal or ambition that COPs are yet to achieve. Let us hope that after the Glasgow and Egypt COPs, the implementation of required polices and technologies comes to fruition, as after 27 editions of COP, the time for turning ambition into action is now, if it is not already too late. This raises a question as to the effectiveness of COPs on an annual cycle. There is insufficient time for any policies to be formulated, let alone enacted, within 12 months. Perhaps it is the time to rethink their frequency to at least occur biannually and perhaps more realistically every 3 or 4 years. This will not only give time for significant advances to be made, but also reduce the considerable carbon intensity that results from staging and travelling to COPs around the globe.

Data availability statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

Author contributions

KL was lead author, and contributed original ideas. PS was Principal Investigator, research supervisor and read and checked the manuscript, whilst also contributing original ideas.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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