

LAYING THE FOUNDATIONS FOR A NET ZERO SOCIETY

*Principles and Infrastructure for a Climate Resilient and
Economically Sustainable Recovery*

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UNIVERSITY of STRATHCLYDE
**CENTRE FOR
ENERGY POLICY**

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About

Centre for Energy Policy

*School of Government and Public Policy,
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The Centre for Energy Policy (CEP) was established in November 2014 as a centre of expertise on the macroeconomic modelling of energy and climate policy.

led by Professor Karen Turner, the Centre works with a wide range of partners to bring current research from a wide energy and climate base into the public policy debate.

The global energy landscape is changing fast and this presents challenges to society, industry, commerce and governments as they seek to develop relevant and appropriate strategies. The role of the Centre is to bring evidence based critical thinking to addressing these challenges across all economic sectors.

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Bellona

The Bellona Foundation is an independent non-profit organisation that aims to meet and fight the climate challenges, by identifying and implementing sustainable environmental solutions. Bellona works towards reaching a greater ecological understanding, and the protection of nature, the environment and health. Bellona is engaged in a broad range of current national and international environmental questions and issues around the world. It has offices in Oslo, Brussels, Murmansk and St Petersburg, alongside experts in the U.S. and the UK.

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Foreword

Jonas Helseth - Director, UK and Europe, Bellona Europa.

As the saying goes, in every crisis lies an opportunity. As the world yet again experiences economic downturn, we are once more hearing calls to use this moment to restructure our economies to address the fundamental challenge of climate change.

Just over ten years ago, the UN Environment Programme proposed a Global Green New Deal; to use the economic recovery as a driver for change towards greater sustainability and lower emissions. It is safe to say that the world missed its chance. The half-hearted, 'quick profit' policies put in place then had little consequence for emissions, and got nowhere near to delivering the innovative transformation of the economy we need. We couldn't even sustain economic growth, which should not surprise when sustainability is no priority. Instead of initiating the transition towards a sustainable, more just, but also climate resilient economy, climate action has remained incremental and evolutionary, rather than decisive and revolutionary.

We simply cannot allow this opportunity to pass us by again. If we do, I fear our world will never recover.

As climate change forces us to fundamentally transform our entire economy, we need to understand the implications, interlinkages and opportunities that this transformation brings across that same economy. How public and private investments in climate infrastructures and technologies actually affect consumers, jobs, and business for existing and new industries. And thereby, how such action can deliver both near time positive impacts for the economy and long-term emissions reductions that enable a prospering netzero economy by 2050 in a fair and sustainable way.

In times of populism, extremism, political instability and ideologically driven movements, we need to firmly re-establish science, truth and transparency at the heart of policy making. That is why Bellona is so pleased to be working with the University of Strathclyde and some of its world-leading economists.

This report represents the start of a crucial journey we will be embarking on over the next 2 years to help identify and understand different courses of action to achieving net zero greenhouse gas emissions in an equitable and just way. Our work with Prof. Karen Turner and her team at the Centre for Energy Policy will build on decades of experience and expertise acquired at the University and within Bellona to form the basis of a groundbreaking partnership between civil society and academia.

This paper shows that investing in enabling activities and infrastructures to slash emissions can have substantial benefits for people and the planet. And that this is not only possible in the future, it is possible today. If we can build back better now and recover from this catastrophic shock to society, we will not just help by saving and creating jobs, but we lay the foundations for future climate resilience and help to create a new age where carbon neutrality and environmental sustainability are right at the core of our global economic model.

Whatever we do now to protect and support those worst hit by the Covid-19 pandemic crisis needs to simultaneously render our economy fairer and cleaner. This time, we cannot afford to fail.



Executive Summary

The Covid-19 pandemic brings into sharp focus the need for net zero actions to sustain and contribute to the well-being of the UK economy and society. Now more than ever, it is crucial that what we do to reduce our emissions can deliver both near term and sustained positive impacts across the economy to ensure prosperity and justice in our society.

This special joint paper from the Centre of Energy Policy at the University of Strathclyde (CEP) and the Bellona Foundation considers the design of a Framework for recovery that could align our near-term economic priorities with both short and medium-term climate goals. In doing so, it focuses on three key actions for achieving net zero:



Enabling and realising residential energy efficiency gains



Facilitating the electric vehicle rollout



Investing in Carbon Capture and Storage (CCS) infrastructure to transform process industry.

We show that net zero actions can deliver the type of short term employment, real income and GDP improvements that will be crucial for near term economic recovery from the pandemic. Such actions will simultaneously deliver essential foundations for a sustainable and prosperous transition where sustained economic and societal gains are realised alongside deep emissions reductions.

We demonstrate through rigorous analyses how a combination of public and private sector actions taken now can help put the UK back on a trajectory of competitive economic prosperity. In each case, we apply the CEP Net Zero Principles Framework to develop a common understanding of how decarbonisation actions can deliver economic benefits as well as costs in two distinct stages:

- **Enabling stage – actions and investments in equipment, infrastructure and/or systems capability to enable subsequent emissions reductions.**
- **Realising stage – activities, processes and responses that utilise enabling activities and infrastructure to actually realise emissions reductions through how we live and work.**

Using this framework, and drawing on a foundation of applied economy-wide modelling, we analyse the nature, timing and potential beneficiaries of any sources of net economic gains emerging. We consider how net gains emerging in different timeframes could be used to balance costs accruing to some parts of the economy and to public budgets. Importantly, we highlight the potential unintended consequences of different actions and approaches, with the aim of identifying solutions that ensure the delivery of sustained economic prosperity and a 'just transition'.

1. Improving the energy efficiency of domestic households provides a suite of near and longer term positive economic outcomes on top of a wide range of emissions reduction and health benefits.

Investing in domestic energy efficiency provides potential for near and longer term economic expansion through both the enabling activity of delivering retrofitting projects for efficiency improvements in people's homes and through the real income and spending impacts of households realising energy efficiency gains and lowering their energy bills. Thus, it is an important mechanism in reducing fuel poverty and helping those who may have been worst affected by the Covid-19 slowdown. Ultimately, the UK Government's ECO programme has, in its present form, the potential to deliver a sustained real GDP boost of up to 0.07% (£979million) per annum supporting just over 19,500 full-time equivalent (FTE) jobs across a wide range of sectors, in turn supporting household expenditure in the UK economy. With around £10.9billion spent between 2013 and 2028, this translates to a societal return of 1.8 jobs and £2.3million of cumulative GDP gains (by 2040) per £million spent. Greater net gains could be realised by supporting energy efficiency improvements across more UK households, focussing more ECO funds on projects through the provision of net zero loans and/or government grants. However, this requires that energy bill, loan repayment and/or tax burdens on households do not offset the real income boost that powers a consumer spending driven expansion.

2. Investing in infrastructure upgrades to the electricity network to facilitate the roll out of electric vehicles could stimulate the wider economy over time, while delivering cleaner air and emissions reductions to the transport sector but with energy price rises constraining nearer term expansion.

Investing in the EV rollout can deliver near term and sustained positive effects on real GDP (with gains of up to 0.1%, or £1.4billion per annum) and significant job creation. These gains are driven mainly by increased activity in UK domestic electricity supply chains and by real income gains that allow UK households to spend more money across the wider economy. Enabling even an initial EV rollout projected to 2030, here through £2.7billion spending on electricity network upgrades, could ultimately support up to 3,000 additional jobs in multiple sectors, mapping to around 1.1 FTE job per £1 million spent. However, given the importance of ensuring a 'just transition', a key question for policymakers will be whether any action can be taken to prevent or balance upward pressure on electricity prices, particularly in the near term as investment costs are recovered. Any increase on

bills will disproportionately increase costs on lower income households, as well as constraining the consumer spending driven element of the expansion.

3. Investing in critical CO₂ transport and storage infrastructure provides a transitory stimulus to the wider economy and establishes the foundations for CCS to play a key role in reducing emissions in key high value industries over the coming decades, and to evolve the role of the oil and gas industry.

Ultimately, the long-term GDP boost associated with Government investment in 3 or 4 strategic CCS infrastructure hubs (costing up to a potential £1.75billion) could deliver a short-term wider economy gain of around £0.2million of cumulative GDP per £million spent. Crucially in the post-pandemic economic climate, this investment can lead to the almost immediate creation of between 1,700 and 3,850 new jobs per year over an assumed 6-year investment timeframe. This equates to an average of up to 1.6 jobs per year per £1 million spent. However, the crucial outcome of this early investment will ultimately be the foundations set for the creation of a new large-scale CO₂ management industry that could help sustain and evolve potentially hundreds of thousands of jobs in UK manufacturing and fossil fuel industries.

The key general conclusion emerging is that net zero actions need to be considered in terms of a holistic, economy-wide approach to the recovery that prioritises the transition to net zero emissions. Such a recovery also needs to establish fair and just means for apportioning costs and benefits, and not simply view investments towards net zero as constraints on economic growth.

The policy challenge arising is that different mechanisms for funding net zero activity are shown to have key implications for the nature, extent and equity of economic growth. The research highlights the fact that any up-front investment activity can introduce price pressures and crowd out other activities. In the net zero context, particular attention is required regarding impacts on energy prices, particularly in recovering investment costs. This is both in terms of potential near term impacts on those least able to pay, and on how the consumer spending driven element of the resulting stimulus may be affected. Thus, a crucial consideration is setting foundations for a just and prosperous transition around which societal consensus can build.

Introduction

The Covid-19 pandemic has caused unprecedented worldwide economic disruption with nations, communities and entire industries brought to a standstill. Faced with the prospect of its most significant recession ever,ⁱ the UK government responded with a rescue package designed to keep businesses and jobs secure whilst the worst impacts of the virus hit the economy.

Now, as attention moves from the initial rescue to longer-term recovery and reform, focus is also shifting back to the other great economic and societal challenge of our time: climate change and the transition to a net zero economy.ⁱⁱ Within this, key questions must centre around whether and how the recovery can be designed to simultaneously service the need to reform the nature of economic activity in the UK and put us on a sustainable, prosperous and just pathway to our mid-century net zero goals.

Drawing on results and analysis from economy-wide computable general equilibrium (CGE) simulation modelling, this special joint paper from the Centre of Energy Policy at the University of Strathclyde (CEP) and the Bellona Foundation considers the design of a framework for recovery that could align our near-term economic priorities with both short and medium-term climate goals. The latter includes the UK's broader 2050 target for net zero greenhouse gas emissions. The paper demonstrates, through rigorous analysis of three examples of net zero activities currently under consideration for deployment (enabling residential energy efficiency, the EV rollout and infrastructure development for CO₂ transport and storage), how policy decisions taken now can put the UK back on a trajectory of competitive GDP, income and employment growth. In doing so, it presents a model to inform economic decision making, which could be taken forward, for example as part of Her Majesty's Treasury's ongoing review on Net Zero planning and principles.ⁱⁱⁱ



How can enabling and realising net zero actions contribute to stimulating the economy?

In February 2020, CEP published the first iteration of a Net Zero Principles Framework that set out the need to consider the challenge of meeting the UK's ambitions of a carbon neutral economy by 2050 in terms of the policy, political economy and societal consequences of any decarbonisation action. Crucially, the Framework^{iv} was grounded in the premise that the wider economy consequences of achieving net zero emissions across the UK (including indirect and supply chain impacts on both activity levels and competitiveness) must be understood and addressed if the permission and participation of citizens, politicians, businesses and financiers is to be secured and sustained.

Moreover, consideration of economic consequences cannot be limited to GDP and employment impacts, but must encompass the quality of expansion (e.g. the labour productivity underpinning GDP expansion and real earnings/wage premia associated with employment) and the public budget impacts, alongside other non-economic variables (such as health) that can be expected to at least indirectly impact our economic wellbeing (e.g. through NHS spending).

A key element in addressing these challenges is the need to identify the nature, timing and potential beneficiaries of any sources of net economic gains potentially emerging from net zero actions and how they are enacted, and to consider how these could be used to balance costs accruing to some actors in areas of the economy and to public budgets.

This is important in terms of the fact that any action will involve both costs and benefits.^v In this context it is also important to recognise that not all net zero actions can be expected to independently deliver net economic gains in their own right, but could still play an important role in sustaining key sectors of the economy, particularly those that support high value supply chains across the UK economy. This perspective is also necessary in order to understand and secure different types of returns for those being asked to bear near term costs.

In developing a common understanding of how decarbonisation actions can deliver economic costs as well as benefits, this paper builds upon the initial Framework developed by CEP and categorises activities into two stages:

1. Enabling stage:

First, before any emissions reductions can begin, there is a need to invest in, install and facilitate operation of new equipment, infrastructure and/or systems capability to enable emissions reduction. This can provide a source of wider economic stimulus, depending on the supply chain activity required, but could also 'crowd out' activity and competitiveness in other areas of the economy, depending on resource constraints and consequent pressure on prices.

2. Realising stage:

Second, with this capacity and capability in place, the UK can actually realise emissions reductions by drawing on this new capacity in how people live and work, with particular attention to how such sustained changes may trigger ripple effects that could impact not only the composition of our GDP generation and employment across different industries and supply chains, but the quality and competitiveness thereof.

Both of the stages above will involve costs but, crucially, can also generate economic gains that ripple across the wider economy. In order to do that though, it is important to recognise two key points:

First, activities that create capacity and/or involve operating new equipment/systems are economic activities and can therefore (e.g. through building infrastructure) create economic value even if only on a transitory basis. A critical question here is how this is paid for, by whom and when.

Second, once society begins to live and work with emissions reducing technologies, this will affect how much we can do with the resources we access and pay for. For example, replacing heating systems with ones that enable people to heat their homes and businesses at a lower cost per hour can increase economic efficiency as well as carbon efficiency^{vi}. On the other hand, if people need to use more equipment to do the same things as before, but with lower emissions – for example if industries need to introduce 'end of pipe' carbon capture equipment - economic efficiency may fall as carbon efficiency increases^{vii}. It then becomes crucial to consider how the competitiveness of those industries can be sustained as they deliver the emissions reductions required for a net zero society.

The extent and evolution of any net gains, how they are distributed across industries, households and the public purse, and how they may balance against unavoidable costs, will depend very much on how activity at each stage is planned and conducted.^{viii} This will include factors such as the extent to which the skills, capacity and infrastructure already embedded in UK supply chains can be utilised – and/or the extent to which domestic content can quickly evolve or develop – rather than relying on importing goods and services to enable and realise emissions reductions.

Maximising domestic content, where possible to do so, provides a basis for boosting the wider economic returns that can be set against the total costs that must ultimately be recovered from UK citizens and businesses^{ix}. It also makes more important the need to identify sources of near term net economic gains that could be used to offset both upfront capital costs and any continued implications for the costs of operating in the UK. In circumstances such as those we face now, identifying sources of near term economic gains from net zero actions can also translate to contributing to the wider recovery of the economy following a crisis like the Covid-19 pandemic.

In short, there are opportunities that come with investing in both enabling and realising net zero actions both in terms of our economic recovery, but also to smooth the transition back onto the net zero path as decarbonisation programmes build the economic and fiscal basis to effectively pay for themselves in a sustainable way.

This approach can put money 'back in the pockets' of those whose incomes, and ability to earn incomes, have been impacted by the crisis. It also helps sustain the contribution of high value and strategically important energy intensive industries as we move towards living and working in a net zero economy and society.

Particularly in the current uncertain international economic and policy landscape, acting now to assure firms of the longer-term benefits of doing business in the UK, will also be a crucial element of any successful stimulus framework.

Nonetheless, given the depth of the economic crisis triggered by the Covid-19 pandemic, and the need to secure a rapid and resilient recovery of the economy and the ability of business and citizens to 'make a living', it is crucial that any net zero actions included in a recovery package can perform against criteria that any other stimulus action would be assessed on. For this reason, it is important to identify comparative metrics, such as performance on key indicators (e.g. jobs, GDP in different time frames) per £1 million of stimulatory spending. However, this must be set in the context not only of our need to prioritise the need for deep emissions reductions but also in setting the foundations for what we want and need our economy to look like going forward through the transition and beyond.



Simulating the economy-wide impacts of enabling and realising activities: the economic benefits of investing in domestic energy efficiency, electric vehicles and CCS infrastructure

Our approach

In showcasing the potential application of the CEP Net Zero Principles Framework we have drawn evidence from three pieces of ongoing research in areas which are already the focus of net zero policy planning. These are (with endnote references to the underlying research and methodology):

- 1. Residential energy efficiency delivered through the Energy Company Obligation^x
- 2. Reinforcing the electricity network to facilitate high EV penetration^{xi}
- 3. Enabling CCS in the UK through investment in CO₂ transport and storage infrastructure^{xii}

The evidence is generated from application of our multi-sector economy-wide CGE simulation model, UKENVI. CGE models are already used in policy analysis, including by HM Treasury in the UK.^{xiii} The key benefit of the CGE approach in contributing to the policy discourse is that it captures wider economy impacts triggered by a given disturbance in any one sector or area of the economy (e.g. investment spending, export demand, resource efficient, tax rates etc.) and these transmit through responses to changes in prices, incomes, demand and supply in all sectors and markets.

It is important to note that CGE is a scenario simulation framework. It is most commonly used for 'what if' or ex ante analyses, with results most usefully considered in terms of what qualitative and quantitative changes in the economy may be expected with all other things remaining as they were before, rather than somehow projecting or forecasting economic development more generally. The specification, configuration and assumptions depend on the questions being asked and focus of the analysis. The core structural database is a social

accounting matrix that incorporates, where possible, industry-by-industry input-output (Ixl IO) accounts produced as part of national accounts.^{xiv}

Our UKENVI model is currently calibrated on a 2010 SAM. While it is currently being updated to incorporate newly published Ixl IO data for 2016, the state of the economy in 2010 (following the 2009 financial crisis) may be a useful benchmark given the current Covid-19 contraction. However, this means that any £ results reported here must be considered in terms of those 2010 prices.

As outlined in Section 2, the CEP Framework involves considering impacts at both enabling and realising stages of any net zero action. The three examples selected, and the order they are presented in, are useful in considering the different ways and context that the Framework can be applied, and showcase the opportunities that come with investing across a range of net zero activities.

Energy efficiency delivered through ECO constitutes an example where both enabling (retrofitting) and realising (households enjoying energy efficiency gains) are, in practise, both in progress now. This allows our simulation work to draw on real data to inform both stages, with consideration of how any new stimulus element could involve a limited adjustment in policy approach.

In terms of the required EV rollout, electricity network operators are currently considering reinforcement



and upgrade requirements required to support this (via Ofgem's RII0-2 Price Control process^{xv}). While the rollout has begun, both enabling and realising activity are at an earlier stage, but with sufficient projected/projectable data to consider the types of impacts that may emerge at both stages, how they may interact, and where policy attention may be directed to improve evolving outcomes.

Finally, although CCS deployment in the UK is at a very early stage, information on the size of the CCS Infrastructure Fund and previous government-funded research into the characteristics of different geological CO₂^{xvi} storage sites, is sufficient to begin considering the potential nature and magnitude of wider economy impacts emerging at this enabling stage. In the future, any return generated through actually realising an operational CCS industry in the UK (e.g. through investment in CO₂ capture and creating investable business models for CCS projects) should ultimately aim to offset such upfront investment and generate sustained economic and societal value. That is, one aim may be for such a 'CO₂ Mangement' industry to become part of our transitioning economy.

In the subsequent three sub-sections, we take each of the three cases in turn, first examining the economic nature of the enabling and realising stages of the net zero action, how it is or can be funded, and how these factors may be simulated in the CGE framework. We then report and analyse the modelled outcomes and their relative performance as potential post-Covid stimulus package activities, before considering the policy implications and challenges arising from the type of impacts on economic well-being and distribution of net costs/benefits that are observed.



Enabling and realising residential energy efficiency gains

Supporting household energy efficiency improvements is widely recognised as a source of sustained wider economy gains. This is because it enables households to use less energy, thereby reducing their required spending on energy bills and increasing real disposable incomes that can be spent on other goods and services.^{xvii}

CEP research^{xviii} produced in collaboration with the BEIS Clean Growth team in 2019/2020 focussed on how the sustained wider economic expansion triggered by the Energy Company Obligation (ECO) policy for domestic energy efficiency could be sustained and potentially justify continued public spending support. Whilst ECO only funds a sub-set of energy efficiency projects in UK households, with private loans being the dominant source of finance, the research brought attention to the potential expansionary power of different funding mechanisms, albeit in the context of the scale of the current ECO programme.

The work showed that retrofitting activity (and the installation of new boilers) supported by ECO (what we define as the 'enabling' stage) in itself has the potential to deliver a GDP expansion of up to 0.02% above what it would otherwise be, and to support a peak of just under 6,500 full-time equivalent (FTE) in 2023, even if no efficiency gains were actually realised. This assumes that ECO only runs for the 16 years, from its inception in 2013 to 2028, with the implication that these wider economic gains are transitory and begin to erode at the end of this timeframe.

However, from the outset, households actually begin realising energy efficiency gains that equate to each beneficiary household using, on average, 17.2% less energy to heat their homes at the current level. This releases more disposable income to spend on other things, triggering further expansion across the economy. It is this realising stage that delivers sustained economic expansion driven by shifting and increasing consumer expenditure. The research found that, by enabling energy efficiency gains across more UK households equating to a 2.4% energy saving across the entire household sector, ECO in its present form has the potential to deliver a sustained GDP boost of up to 0.07% per annum (see Figure 1), supporting just over 19,500 full-time equivalent (FTE) jobs across a wide range of sectors supporting household expenditure in the UK economy.

The analysis shows that spending approximately £10.9 billion on ECO between 2013 and 2028 would translate to a societal return of 1.8 jobs and £2.3million of cumulative GDP gains (by 2040) per £million spent.

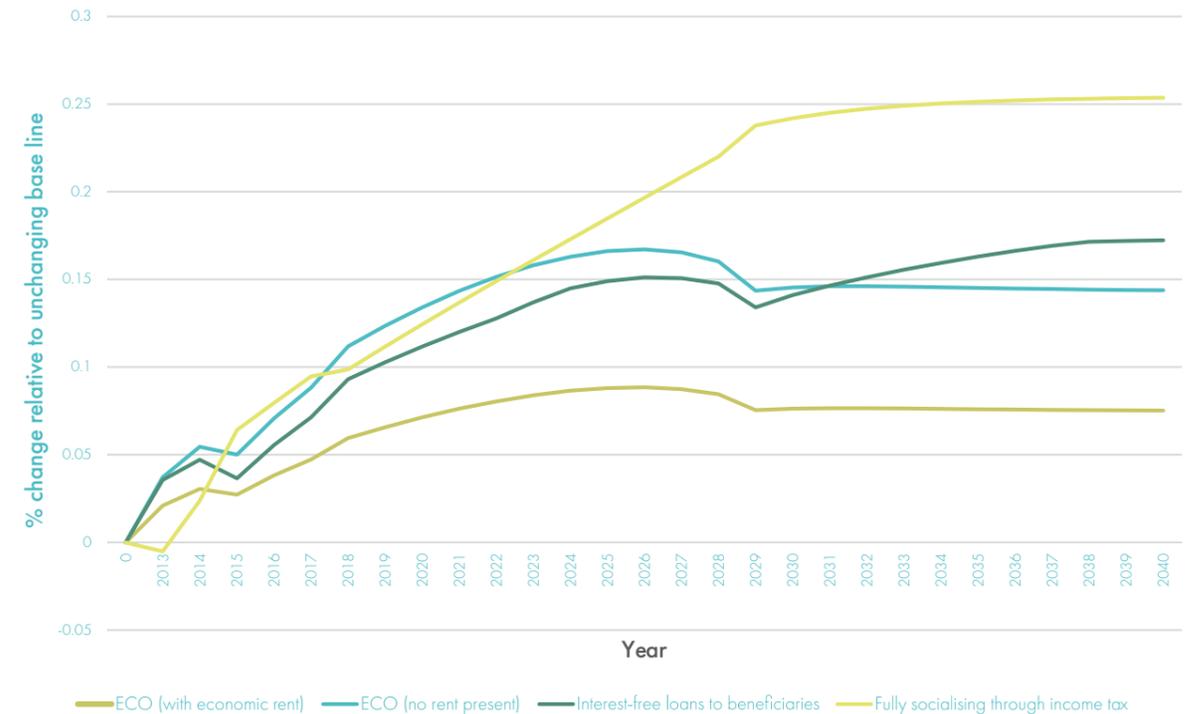
Sustained economic gains are mainly concentrated in, and driven by, those sectors where households

spend their money, while shorter term gains are also spread over the construction supply chains that deliver retrofitting projects. Despite upward pressure on prices in a constrained economy, the simulations suggest that the only UK sectors that ultimately suffer net losses as a result of this consumer spending driven expansion are in the energy supply industries, where demand for output falls with efficiency gains, albeit with some offsetting stimulatory power as the wider economy expands. In the shorter term, price pressures from increased demand may crowd out some activity in more export-orientated industries.

Moreover, there is potential for even greater gains. The centralised nature of the current ECO programme means that there is significant rent extraction (e.g. through charging of standard per project prices where many individual projects can in fact be delivered at lower than average costs). The implication is that only £4.2billion of the total £10.9billion may actually be spent on retrofitting activity. The research estimated that if rent extraction could be reduced, this would enable efficiency gains in a larger number of UK households, potentially almost doubling total energy savings and emissions reductions, and raising real average income and spending gains to power a larger sustained expansion. This could ultimately equate to the sustained societal return per £million of ECO spending reaching 3.4 FTE jobs and £4.4million in additional (cumulative) GDP by 2040.

ECO is funded through the energy bills paid by all residential consumers (households), and there remain critical questions about the validity and fairness of this approach of paying for the low/net zero transition through a 'socialisation of costs'^{xix}. Therefore, the CEP research also considered other approaches to funding the retrofitting activity that could enable residential energy efficiency gains and the resulting economic stimulus triggered by reduced spending on energy bills. Specifically, the research focussed attention on the role of zero interest loans or grants funded by income tax (another but more progressive approach to socialising costs) to allow households to design and contract their own retrofitting (and/or boiler purchase) projects. Such a decentralised system would have a lower overall cost, estimated at £9.8billion in the timeframe to 2028.

Figure 1: Comparison of shifting UK GDP trajectories enabled by UK residential energy efficiency programmes running 2013-2028 under different funding schemes



We found that, on the basis of greater energy efficiency gains actually realised and, thus, more consumer spending power freed up to drive wider economy expansion, either approach would enable greater GDP and employment gains over time. See Figure 1 for the simulated GDP trajectories under the different funding models considered. In the scenario simulations, the tax-funded approach is assumed to be self-contained in that future revenue gains can be redistributed via income tax reductions to further power a consumer driven expansion. On this basis, it has the potential to deliver the greatest expansionary power, but is an approach not currently in practice in at UK national level.

Loans, on the other hand, are already a prevalent source of finance for enabling energy efficiency increases in the UK household sector. In the scenarios, we consider zero interest loans only, which ultimately deliver sustained GDP gains of 0.17% per annum over what they would otherwise be and employment gains that equate to 4.6 FTE jobs per £1 million of spending. This is more than double the estimated long-term employment return for the current ECO programme (1.8 jobs per £1 million spent), and more than could be achieved if there were no rent extraction issues (3.4 jobs per £million).

However, in the nearer term, particularly with higher income (and higher spending) households

facing loan repayments and/or higher tax bills, the expansionary power of these alternative funding mechanisms is more limited.

The research also considered the impacts in the first years after investment (given the recovery context of this paper) if energy efficiency gains do not actually transpire. This involved considering the enabling stage of retrofitting alone in isolation to assess what may happen if efficiency enhancing equipment is not used in a way that realises all potential efficiency gains, or if real income gains are otherwise offset.

The latter could transpire, for example, if energy bills rise to cover the costs of other net zero actions, such as in the EVs case below. We found that under such circumstances, either a loan or taxpayer-funded approach to supporting residential energy efficiency could actually deliver some net negative jobs impacts per £1 million of spending in some years. This would occur as the recovery of costs through increased income tax or loan repayments begins to build alongside more energy efficiency projects completing in a larger number of UK households. Ultimately, this could depress the consumer spending driver of the wider economy expansion triggered by residential efficiency gains.

1.

Improving the energy efficiency of domestic households can provide a suite of economic benefits on top of the recognised emissions reduction and health benefits. From the outset, the retrofitting process generates GDP accompanied by jobs and growing wage incomes. Crucially, the interaction of enabling and realising energy efficiency actions ultimately deliver key benefits that allow people to reduce household bills, thereby raising real incomes and spending power that can be directed to other goods and services produced in the UK economy. This could be an important mechanism for reducing fuel poverty and helping those who may have been worst affected by the Covid-19 slowdown.

2.

The results show that the positive economy wide impacts of energy efficiency investments ultimately have real potential to more than offset the costs of the current ECO programme. This, in turn, means that successfully enabled and realised residential energy efficiency projects within the scale of the current ECO programme could shift the UK economy onto a trajectory with up to 0.25% per annum GDP gains (depending on the mix of funding mechanisms going forward which would need to extend beyond ECO to include more loan-finance and/or government grants).

3.

In summary, ECO is only relevant for a subset of residential energy efficiency actions; if other funding mechanisms could come into play in different timeframes to fund more energy efficiency projects, the expansionary power of energy efficiency policies could be further enhanced. Our research identifies zero (or even low) interest loans as an existing approach that could markedly increase GDP and jobs 'return' per £1 million.

4.

There is a need for careful consideration of how alternative funding mechanisms may impact household real incomes and spending power in the near term, particularly where the impacts of the Covid-19 slowdown are still being felt. Energy efficiency actions funded by loans can ultimately provide sustained GDP and employment gains per £1 million spent that are at least double what can be achieved via the current ECO programme (depending on interest rates, where our 4.6 jobs per £1 million spent applies to zero interest loans). However, particularly in the near term, anything that substantially affects the realisation of real income gains and the increased consumer spending that powers wider economy expansion could lead to net negative impacts on GDP, employment and other wider economy gains in a manner that is not observed under ECO.

5.

In terms of ensuring a sustained economic recovery, where this type of net zero action can continue to pay for itself – and potentially help support other actions – another key concern for policy makers must be to ensure that any funding gaps are bridged in the near term and that private sector lenders are encouraged to provide zero or low interest loans. This is important not only in the context of the Covid-19 pandemic but also in relation to the UK exit from the European Union, where CEP research funded by UKERC has indicated (in a Scottish context) that Brexit may also pose a significant risk to the availability of funding for domestic energy efficiency retrofit programmes^{xx}.

Enabling the EV rollout through electricity network upgrades

The rollout and uptake of EVs is seen as a key component of achieving deep emissions reduction in private transport and facilitating the transition to a net zero economy. The research reported in CEP's paper published in Energy Policy, and a linked policy brief, demonstrates that it too can deliver both near and sustained longer term economy-wide gains.

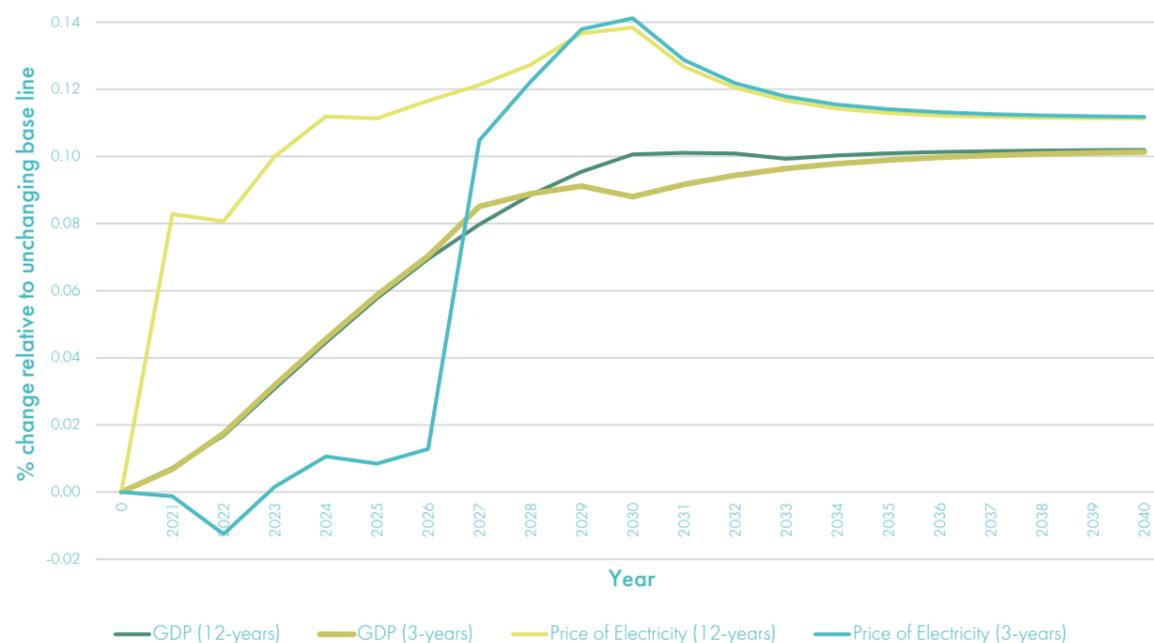
An important finding emerged from this work in that, while any increased efficiency in fuel costs per mile travelled will have positive wider economy impacts, the real driver of sustained gains from shifting to EVs is strong UK supply chain activity driven by powering vehicles with electricity. Put simply, fuelling vehicles using petrol and diesel relies heavily on imported supply chain content while the UK electricity industry tends to have strong domestic supply chain linkages, for example supporting up to as many as three times more jobs per £1 spent on fuelling.^{xxi}

The dual challenge in the current Covid-19 recovery context concerns: (a) the speed at which particular private households will actually switch to EVs, fuel their cars with electricity, and respond to 'smart

charging' capability^{xxii}; and, (b) the need to deliver large-scale infrastructure upgrades in incremental stages to enable significant levels of EV penetration. The latter is particularly important in the UK regulatory context, where Ofgem's Price Control mechanism constrains investment planning to ensure that consumers do not pay (via energy bills) for capacity building ahead of demand actually transpiring.

Indeed, in all of the scenarios examined in CEP's research, the combined impact of cost recovery and rising demand for electricity constitutes the main constraint on the wider economy expansionary power in all timeframes that is triggered by enabling potential gains from the shift to EVs and electric fuelling.

Figure 2: Impacts on GDP and the price of electricity of 20% EV penetration by 2030 and required electricity network investment (alternative scenarios with £2.7billion investment spread over 3 years 2027-2029, or 12 years 2021-2032)



The existing CEP research^{xxiii} focussed on the potential economy-wide impacts of both enabling (through electricity network upgrades) and realising (through EV uptake and operation) stages of a 20% penetration of EVs in the private fleet by 2030^{xxiv}. This is estimated to require a £2.7billion investment by 2030, which does not necessitate any direct government spending as all costs are recovered by electricity network operators through both business and residential consumer bills over the average 45-year lifetime of assets created.

Crucially, current conditions dictate that electricity network operators are likely to import two-thirds of the total investment requirement, with only £0.9billion spent within the UK, mainly on construction rather than equipment requirements.^{xxv} This equates to limited expansionary power from investment spending where the full costs are recovered through the electricity bills of all system users.

The net long run impact of investing in electricity network upgrades to support the EV rollout is positive, with GDP per annum shifting to a trajectory that, by 2030, could be 0.1% higher than it would otherwise be. It is important to note, however, that the simulations suggest a slight contraction in GDP around this time if investment activity has to be condensed in the 3 years immediately prior to this crucial projected demand/rollout stage (as currently required under Ofgem's regulatory framework). This is due to the impact of price pressures and 'crowding out' of domestic and export demand components of GDP.

The expansion triggered by the EV uptake that is enabled by investment to facilitate the projected rollout (which will, in practice, not be limited to electricity network upgrades) ultimately supports up to 3,000 more FTE jobs across the UK economy. This maps to just under 1.2 FTE jobs per £1 million spent. It compares to the minimum 1.8 FTE jobs per £1 million in a more constrained ECO case (where, as discussed in section 3.2, significant rent extraction erodes funds actually directed at enabling efficiency gains, with potential refinement of ECO and/or other funding approaches providing potential to increase the per £1 million and total wider economy gains).

In terms of what industries gain and lose, there are some similarities with the case of enabling and realising energy efficiency in that, while construction supply chains enjoy a large share of gains in the near term, the ultimate 'winners' are likely to be those

sectors that (directly or indirectly) support consumer spending. However, the key difference in the EVs case is that the switch to electric fuelling of vehicles means that the electricity industry and its strong domestic supply chain share substantially in the gains.

Again, and despite general price pressure from what is essentially domestic demand driven expansion, the only sectors that ultimately suffer net losses over the longer term are those supplying conventional vehicles and fuel. These industries are likely to suffer losses regardless on the journey to a net zero economy. Of course, this then raises another challenge for policymakers considering a potential acceleration of activity to enable the EV uptake: ensuring that gains from switching to EVs can offset losses in these sectors and their supply chains (and provide alternative employment for workers and capacity) in the near term. That is, more generally ensuring a smooth and just transition for firms and workers in those sectors supporting conventional vehicles and fuelling.

The source of the more constrained expansion in the EVs case (relative to that of energy efficiency) is specific to the enabling element considered in CEP's research, and particularly the need to recover electricity network investment costs through consumer bills. This is reflected in the higher level results illustrated in Figure 2. Here, the analysis shows that the real expansionary power of enabling the EV roll-out lies in the uptake of the vehicles themselves and, more specifically, in the shift to fuelling using electricity rather than petrol or diesel. It is then the timing and timepath of electricity network investment that generates some disruption.

On the one hand, spreading investment over a longer timeframe enables a smoother adjustment of the wider economy. On the other, earlier investment requires an earlier triggering of the process of recovering costs through energy bills. Thus, there is a trade off. The 3-year case in Figure 2 shows that allowing the EV rollout to begin by making more use of existing infrastructure – as required under the current regulatory environment – may enable a transitory decrease in electricity prices (all other things remaining equal). This introduces a range of transitory price pressures around 2030. Results for the 12-year case show that upfront investment would resolve the latter problem, but at the cost of putting upward pressure on electricity prices from the outset, which could be counter-productive in the current Covid-19 environment.^{xxvi}

In this regard, the findings are consistent with the perspective of the current regulatory model, where meeting the requirements of demand anticipated in 2030 cannot be brought forward within the current RII0-2 Price Control business planning process. Thus, the 3-year timepath in Figure 2 is the more relevant under the current regulatory model, but does not offer any potential for the electricity network investment to provide any additional near term expansionary power on top of what the EV rollout itself supports (noting that the expansionary power of such investment is constrained by the need to begin recovering the costs of the investment through electricity bills from the outset). Of course, this may be less of an issue in the context of other activities (e.g. investing in public charging infrastructure) to enable the EV rollout, where investment activity could introduce net additional expansionary potential. The crucial question is how costs are recovered, as with the case of retrofitting to support energy efficiency, where ECO also involves recovery of costs through energy bills. The crucial question is whether the cost recovery factor is sufficient to offset any net gains that the investment activity itself can support.



Key policy implications: electric vehicles

1.

The rollout of EVs is not only essential to achieving net zero emissions and reducing air pollution, but can also provide strong opportunities for wider net economy gains. Our research has demonstrated that there could be up to 3,000 additional FTE jobs associated with even the initial stage of enabling the UK EV rollout up to 2030.

2.

It is crucial for policy makers to consider issues around the type of investment activity that requires recovery of costs via energy bills. In the case examined here, the full costs of electricity network upgrades have to be recovered from consumers (albeit over an extended time period) which combines with a significant increase in demand for electricity that could drive up energy bills for all consumers, and constrain the wider economy expansion.

3.

Enabling a greater share of investment with UK content (we model 1/3rd) could provide greater expansionary power to offset costs. However, it is unlikely that this could be achieved in the near term timeframe that is so important in terms of the Covid-19 recovery (and where the current regulatory approach does not permit significant investment ahead of need in any case). On the other hand, public investment in other enabling activities (e.g. greater provision of public charging infrastructure) could be designed to incorporate greater reliance on domestic supply chains in the near term and, thus, increase expansionary power.

4.

More generally, where upfront investment in net zero infrastructure has implications for real household spending power through increased energy bills or taxes, this can constrain near term expansionary power of the associated net zero action, as well as having implications for the public perception and reality of whether a 'just transition' is being delivered. This issue is not specific to the EV context in which we raise it. Indeed, the trade-offs involved in considering the impacts of large upfront investment in reinforcing electricity networks are perhaps even more pressing and relevant in the context of electrifying heat.

Public investment to enable Carbon Capture and Storage in the UK

The third and final example presented here focuses on the potential wider economy impacts of initial enabling stage work for carbon capture and storage (CCS) infrastructure, where the UK Government has allocated funds from existing budgets, thus removing the need for immediate cost recovery via taxation or energy bills. At present, £800million is allocated to developing CO₂ transport and storage capacity under the CCS Infrastructure Fund as a first stage to deploying CCS in the UK.

The Committee on Climate Change has identified CCS as an essential component in delivering the deep decarbonisation necessary to achieve mid-century net zero ambitions.^{xxvii} Economy-wide simulation work reported in a recent CEP policy brief has demonstrated how this could provide a transitory but importantly near term stimulus to the UK economy that has positive impacts on GDP, employment and household real incomes and spending.

For the purposes of this analysis, two scenarios have been considered using the UKENVI CGE model, both involving development of pre-identified potential CO₂ storage sites.

The first scenario involves the development of 4 storage sites (Hamilton, Captain X, Viking A and Bunter 36) with a total estimated cost of £1.75billion.^{xxviii} Whilst it is highly unlikely that all four of these storage sites would be developed by the first candidate CCS projects in the UK, the total investments required, and the characteristics of the stores in terms of their capacity and ability to service the needs of industrial clusters in line with a smooth transition to net zero, are broadly in-line with what will be required to enable deep decarbonisation across major UK industrial clusters such as Teesside, Merseyside, Grangemouth, the Humber region and south Wales.

The second scenario focuses on the development of only Captain X and Viking A with a total cost of £755million. Again, these two stores were not chosen because they would necessarily be the first two stores developed in the UK, but because their characteristics and costs are indicative of what could be funded under the Government's existing commitments under the CCS Infrastructure Fund.

In the absence of specific information, but informed by previous studies and analysis by the Bellona Foundation,^{xxix} it was assumed that around 80% of the total investment spending is likely to be made within the UK, spread across a range of upfront (first year) activities and others spread over a six year period from 2021. The upfront spending (23% of total spend) involves site surveys, well appraisals, engineering and design, and securing licences and permits. The latter involves a range of design, procurement and fabrication activities (pipelines and transport and storage facilities, including repurposing of drilling platforms), construction and commissioning activities.

Figure 3 demonstrates that the outcome of investment in CCS infrastructure is a transitory stimulus to the wider economy. These results emphasise the impacts of the larger investment programme, but we note that the impacts of the more limited £800million investment are roughly half the size of those of the £1.75billion programme (so that the per £1 million results discussed below are broadly similar). Given the much smaller stimulus, the GDP per annum gains will naturally be small relative to those reported in Figures 1 and 2 for the energy efficiency and EVs cases. The key point to note is that the GDP impact is positive throughout the 6 year investment period, maximised at 0.01% (£126.4million) in the first year (2021) where there is concentrated up-front spending on key administrative and survey activities. The annual GDP boost then settles at around 0.005%-0.006% (£70million-£73million per annum) in the three year period between 2022 and 2024, before tailing off.

It is important to exercise caution in considering how the end of a relatively large but time limited investment could cause a slight contraction in subsequent years as resources reallocate. In particular, given that what is considered here is a first stage in enabling CCS, such a down turn may not occur/be delayed, depending on what may be planned for subsequent stages and progress in delivering the realising stages of CCS (i.e. investable business models and policy for CO₂ capture and the operation of a transport and storage system in the context of an emerging CCS industry).

Additional job creation associated with the expansion (facilitated by an existing pool of unemployed labour) is seen across the 6-year project timeframe, requiring an additional 3,850 full-time equivalent (FTE) workers in the first year, between 2,250 and 2,670 additional FTE jobs in each of the subsequent 4 years, and 1,700 workers in 2026. Given the relatively limited scale of investment spending involved, these figures compare favourably with total jobs estimated of 12,000 direct and indirect jobs associated with the construction of Hinkley point, and around 6,500 jobs projected for a single pumped hydro station in Scotland in other CEP research.^{xxx} However, we would note the jobs impacts of both these power system developments were estimated using simple economic multipliers, which do not take any account of the type of price and crowding out pressures considered in our CGE simulations here.

Figure 3: Impacts on GDP from public investment on CCS transport and storage infrastructure (comparison of 4 sites and 2 sites scenarios)



In terms of what areas of the economy are likely to benefit, the greatest job gains are observed in the sectors that directly service the spending outlined above, with the UK construction sector and manufacturers of fabricated metals and transport equipment enjoying gains sustained throughout the project period. Due to price pressures triggered by the time-limited investment, the simulation results suggest some crowding out of export demands in other manufacturing sectors, but not enough to generate job losses. Crucially, our results show that the employment and wage income gains trigger gains in consumer spending by UK households that are proportionately greater than the GDP boost illustrated in Figure 3.

The research has only considered early stage projected investment spending in physical infrastructure for CCS and, thus, it is useful to consider the policy implications in terms of two important questions at this stage.

First, how does the initial investment activity simulated here compare with enabling stage activity in the other two cases considered in this paper? It is important to emphasise that any subsequent realising of emissions reducing activity is not simulated here – for example, information is not available on the operation of the transport and storage capacity created, or contributed to, via this initial investment. Second, what lessons can be learned in terms of what

the realising stage of CCS in the UK would have to deliver to 'make the case' for the sustainability of a CCS sector in the UK economy as it moves through the net zero transition?

Taking the former first, overall, our results suggest that the cumulative employment impact of the £755million or £1.75billion investment activity in creating CO₂ transport and storage capacity as outlined above is the transitory creation (respectively) of an average 1.6 or 1.5 one additional jobs per year per £1 million spend (with both spending and job creation limited to the 6-year project timeframe). Table 3 shows that this is markedly more than the combined (long-run) enabling and realising outcome reported for the EVs scenario above (1.15 jobs per £1 million).

A comparable outcome cannot yet be projected for CCS, given the lack of firm planning to date as to how industrial scale activity in managing CO₂ through CCS services could evolve through further enabling and, ultimately, realising stages. While the minimum 1.8 jobs per £1 million outcome for energy efficiency (for the current ECO programme) is clearly a strong benchmark, it must be remembered that this is also sustained long-run impact, which reflects both enabling activity and the full realisation of emissions reductions and expansionary processes triggered by initial investment activity.

Table 1: Comparison of FTE jobs per £million spent

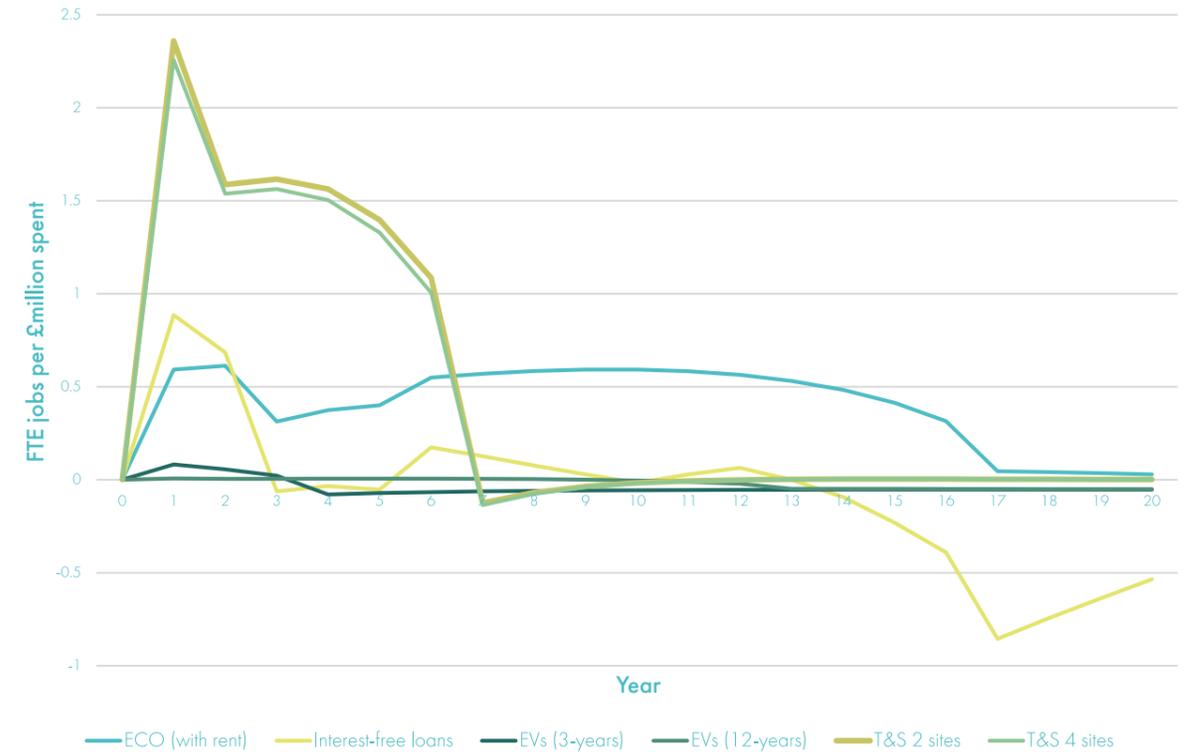
	Average Enabling Stage (only) Impacts Across Project Timeframe	Enabling Stage Peak (Year within specific project time frame)	Sustained Enabling and Realising Stage Impacts
EE - ECO (with rent)	0.50 (16 years)	0.61 (Year 2)	1.80
EE - Interest-free loans	0.07 (16 years)	0.89 (Year 1)	4.60
EVs (3-years)	0.05 (3 years)	0.08 (Year 1)	1.15
EVs (12-years)	0.00 (12 years)	0.01 (Year 1)	1.15
CO ₂ T&S – £0.8bn	1.60 (6 years)	2.36 (Year 1)	To be determined
CO ₂ T&S – £1.75bn	1.53 (6 years)	2.26 (Year 1)	To be determined

In terms of the near term year-on-year jobs impacts from enabling activity alone, Table 1 shows that these are small for both EVs scenarios examined above, and for loan finance of energy efficiency. Even retrofitting activity under the current ECO programme (which is projected to support a peak of 6,500 UK jobs in 2023) does not perform as well as either CCS investment in terms of average jobs per year for every £1 million spent. Indeed, while masked by the average figures in the first column of Table 3, our research shows that network upgrades to support EV roll-out may actually generate negative jobs per £1 million spent in some periods, as could energy efficiency actions funded through taxation or loan finance (albeit with these losses ultimately offset by realising stage gains).

Crucially, while with network upgrades and CCS investment some negative impacts may be observed after the end of the investment programme, loan finance could in fact drive negative impacts within the duration of the programme and some years beyond the end. That is, until the repayment period ends (see Figure 4). However, it is important to note that all of these results will be sensitive to the question of ‘who pays’, with the costs of ECO and electricity network upgrades to support EVs both recovered through energy bills, while the CCS transport and storage capacity investment modelled here is assumed to be covered by current government budgets.

The challenge, then, becomes one of using near term investment to lay foundations for the realising stage of CCS, which may involve a new, potentially internationally competitive CCS industry to deliver similarly strong returns. In previous work, CEP has identified a key comparator – given the similarity in capital intensive activity – to be the UK Oil and Gas industry and the ‘employment multiplier’ of 9 or 10 UK-wide jobs per direct industry job that it has supported in recent years. Such ambition will be important, not least given the challenges of how carbon capture costs to industry can be met without reducing the competitiveness and sustainability of high-value manufacturing in a number of regional clusters across the UK economy^{xxx}. In this regard, the crucial outcome of this early investment could ultimately be the creation of a new large scale CO₂ management industry that could help sustain and evolve potential hundreds of thousands of direct and indirect jobs currently associated with our emissions intensive UK manufacturing and fossil fuel industries.

Figure 4: Comparison of societal returns of enabling stage of different decarbonisation actions (FTE jobs per £million spent)



Key policy implications: CCS

1.

Increasing the CCS Infrastructure Fund to £1.75 billion can not only enable the development of CO₂ transport and storage infrastructure for all major industrial regions of the UK but can deliver a higher level of total transitory economy wide benefits compared to the planned investment of £0.8 billion to support CCS in just one or two industrial clusters.

2.

The nature of spending under the CCS Infrastructure Fund is likely to create near-term job and growth opportunities. While the initial investment analysed here only provides a transitory stimulus, this should be expected to extend and evolve at subsequent stages of delivering a CCS industry in the UK through greater investment under the CCS Infrastructure Fund. This could play a key role in delivering a ‘just transition’ for workers currently employed in fossil fuel industries.



Conclusions

The case examples examined in this paper show that a combination of policy interventions, regulatory changes and government investment could be used to stimulate activity and investment in the UK economy. Our findings highlight that different net zero actions can contribute in complementary ways, for example providing GDP expansion, peak job creation and income returns at different times throughout the mid-century transition timeframe. This can both aid near term economic recovery while also putting the UK on a sustainable and resilient path to net zero. Thus, net zero actions need to be considered in terms of how they can be combined to maximise economic benefits in a stimulus context, and not be seen as a constraint on economic growth.

Our analysis shows that the mechanism of funding net zero activity has key implications for the shape, extent and equity of resultant economic expansion. The research highlights the challenge that, as for any stimulus action, enabling/up-front investment actions can introduce price pressures and crowd out other activities. In the net zero and particularly the energy system context, careful attention must be given to how energy prices may be affected by the design of net zero actions and the need to recover costs over different timeframes. This is crucial, both in terms of potential near term impacts on those least able to pay, and on how the consumer spending driven element of the resulting stimulus may be affected.

Consideration of, and finding solutions to, this issue is key in ensuring that the full potential of net zero actions - in both aiding our near term economic recovery and setting crucial foundations for the transition ahead - can be realised in a manner that is considered just and acceptable by the UK population and electorate. CEP's research has also extended to how understanding of economy-wide impacts and consequences can help build consensus in the policy discourse and the policy making process for the transition to a net zero economy and society.^{xxxii}

The key economic proposition we outline in each case helps us begin to identify and understand the near and the longer-term consequences of changing the way people live, earn and spend money, and how businesses and industry operate. This may in turn rely on further policy interventions and, importantly, consumer and private sector buy-in. However the actions we analyse here – as just a subset of potential net zero actions that must be analysed – not only lay foundations for net zero emissions but could play a key role in shaping the wider UK economy in the coming decades.

If delivered in the right way, net zero actions such as these could play a key role in ensuring that the UK delivers a prosperous, equitable and world leading economy.



Endnotes

- i. The recent (June 2020) OECD Economic Outlook estimates a GDP drop for 2020 between 11.5% and 14% depending on the progress of the pandemic. The report can be accessed here: <http://www.oecd.org/economic-outlook/june-2020/>
- ii. There is precedence in the practice of introducing 'green' measures in stimulus packages following an economic crisis. A joint discussion paper by the European Commission and the International Institute for Labour Studies explores the measures that a number of countries introduced following the 2009 economic crisis. The paper is available here: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---inst/documents/publication/wcms_194185.pdf
- iii. See <https://www.gov.uk/government/publications/net-zero-review-terms-of-reference>.
- iv. See CEP Policy Brief A Net Zero Principles Framework: Fundamental questions for public policy analysis <https://doi.org/10.17868/71580>
- v. This is an important discussion that is currently missing in published work. For instance, a recent Oxford Smith School working paper (<https://www.smithschool.ox.ac.uk/publications/wpapers/workingpaper20-02.pdf>) and a McKinsey Quarterly article (<https://www.mckinsey.com/business-functions/sustainability/our-insights/addressing-climate-change-in-a-post-pandemic-world#>) discuss the importance of using climate change policies in the post-Covid stimulus packages but there seems to be little consideration of the associated costs
- vi. See for example Open Access Energy Policy paper available here: <https://doi.org/10.1016/j.enpol.2017.09.028> (which also includes a review of the relevant literature). Notable examples include this paper by Thomas and Azevedo: <https://doi.org/10.1016/j.ecolecon.2012.12.002> and this led by Rosa Duarte: <https://doi.org/10.1016/j.apenergy.2015.09.101> which uses the same methodological approach as the one we employ here. More recently we produced an extended policy briefing of our recent work alongside BEIS Clean Growth team available here: <https://doi.org/10.17868/71454>
- vii. CEP has published a relevant policy briefing available here: <https://doi.org/10.17868/71454>. CEP has also provided written evidence to the House of Lords: <https://committees.parliament.uk/work/55/level-playing-field-and-state-aid/publications/written-evidence/>. Further examples of how 'end-of-pipe' technologies can affect the wider economy can be found in this paper led by Panida Thepkhun: <https://doi.org/10.1016/j.enpol.2013.07.037> and Wei Li: <https://doi.org/10.1016/j.energy.2016.11.059>
- viii. This is something CEP explored in a recent Energy Policy paper available Open Access at: <https://doi.org/10.1016/j.enpol.2019.111117>. Also see the policy briefing in collaboration with BEIS: <https://doi.org/10.17868/71454>
- ix. See the 2018 Energy Policy paper: <https://doi.org/10.1016/j.enpol.2018.05.011> and a more recent (2020) Energy Policy paper (focussing on enabling the EV rollout) on the issue of potential impacts of switching towards industries with stronger domestic content: <https://doi.org/10.1016/j.enpol.2019.111117>
- x. See CEP policy brief at <https://strathprints.strath.ac.uk/71454/>. This work resulting from a collaborative EPSRC Impact Accelerator project (linking to EPSRC grant ref. EP/M00760X/1, <https://gtr.ukri.org/projects?ref=EP%2FM00760X%2F1>) in partnership with the BEIS Clean Growth Team.
- xi. See paper published in the journal Energy Policy, available Open Access at <https://www.sciencedirect.com/science/article/pii/S0301421519307049> and a linked CEP policy brief at <https://strathprints.strath.ac.uk/67741/>. This work results from a Flexible Fund project conducted within the EPSRC National Centre for Energy Systems Integration (EPSRC grant ref. EP/P001173/1, <https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/P001173/1>)
- xii. See CEP policy brief at <https://doi.org/10.17868/64609>. This is part of ongoing work in the project being conducted in partnership between the Centre for Energy Policy at the University of Strathclyde and the Bellona Foundation, with funding from the Childrens Investment Fund Foundation (CIFF). See project information at <https://strathprints.strath.ac.uk/70760/>, and work to date on the wider economy impacts of CCS, focussing on operational carbon capture in industry, at <https://strathprints.strath.ac.uk/72094/>.
- xiii. For example, HMT apply CGE methods to analyse the impacts of fuel duty reductions in a paper published at <https://www.gov.uk/government/publications/analysis-of-the-dynamic-effects-of-fuel-duty-reductions>. Full model documentation on the CGE model used by HMT can be found at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/263652/CGE_model_doc_131204_new.pdf.
- xiv. For the type of input-output national accounting data used as the structural database of CGE models, see <https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetaild>.
- xv. <https://www.ofgem.gov.uk/network-regulation-riio-model/network-price-controls-2021-riio-2/what-riio-2-price-control>.
- xvi. ETI Pale Blue Dot – <https://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal>
- xvii. A review can be found at this 2013 paper: <https://dx.doi.org/10.5547/01956574.34.4.2>. More recent examples can be found at this Energy Policy paper: <https://doi.org/10.1016/j.enpol.2017.09.028> and this Regional Studies paper: <https://doi.org/10.1080/00343404.2018.1490012>. Yushchenko and Patel have conducted a similar analysis for Switzerland: <https://doi.org/10.1016/j.apenergy.2015.12.028>, while we can find a Spanish focus in this study led by Rosa Duarte: <https://doi.org/10.1016/j.enpol.2018.03.065>
- xviii. <https://doi.org/10.17868/72886>
- xix. See for example the UKERC report at <https://ukerc.ac.uk/publications/funding-a-low-carbon-energy-system/>
- xx. See the UKERC report at <https://ukerc.ac.uk/publications/brexit-energy-efficiency-scotland/>.
- xxi. See paper published in journal Energy Policy, available Open Access at <https://www.sciencedirect.com/science/article/pii/S0301421518303033>. This work results from a project funded by the EPSRC SuperGen Hydrogen and Fuel Cell Hub (EPSRC grant ref. EP/J016454/1, <https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/J016454/1>)
- xxii. In the context of CEP's work, 'smart charging' is charging off peak demand. This is important to keep in mind as researchers often refer to grip-to-vehicle solutions when talking about 'smart charging'.
- xxiii. CEP is in the process of preparing new papers/reports emerging from a subsequent round of research in this area, which extends focus on electricity upgrade requirements to support the fuller EV rollout to 2050. Work has also just begun on another EPSRC CESI project considering a wider range of potentially important determinant of outcomes, including limited EV uptake in low income households and constraints on manufacturing capability to produce vehicles in line with rollout projections and requirements.
- xxiv. The CGE model scenario simulations were informed by UK TIMES energy system analyses of investment requirements and fuel cost efficiency gains implied by National Grid's (2018) Future Energy Scenarios (FES), at <http://fes.nationalgrid.com/media/1363/fes-interactive-version-final.pdf>.
- xxv. CEP's research was informed in this regard through discussions with Scottish Power Energy Networks.
- xxvi. Current research at CEP, focussing on investment requirements for the fuller EV rollout to 2050, emphasises this finding.
- xxvii. CCC Net Zero Technical Report – <https://www.theccc.org.uk/publication/net-zero-technical-report/>
- xxviii. Strategic UK CCS Storage Appraisal, specifically storage development plans D10, D12, D13 and D14
- xxix. See the report titled "A UK Vision for Carbon Capture and Storage" (Orion Innovations for the CCSA and the TUC) available to download here: http://www.ccsassociation.org/index.php/download_file/view/750/76/
- xxx. See CEP policy brief at <https://strathprints.strath.ac.uk/71142/>.
- xxxi. See analysis of this issue in the CEP policy brief at <https://strathprints.strath.ac.uk/72094/>.
- xxxii. See CEP research paper published in the Journal of European Public Policy paper, available Open Access at: <https://doi.org/10.1080/13501763.2020.1742774>

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