



Introduction

The UK has set binding targets to meet net zero emissions by 2050 and transport is one of the key sectors where emissions will have to significantly reduce. While a range of options exist to decarbonise transport, electrification is currently seen as a leading option for private transport in particular. To facilitate the rollout of electric vehicles (EVs), significant electricity network reinforcement is likely to be needed. However, not least because any investment in the electricity network will have to be paid for by consumers through electricity bills, a key question remains as to how this will impact economic prosperity in the long term. This policy briefing builds on a foundation of CEP research,^{1,2} to report on the impacts on wider economy and economic well-being indicators of investing in the electricity network to facilitate the rollout and of the subsequent impact of shifting from conventional vehicles to the extent of 99% EV penetration by 2050.

Our analysis shows that investment in electricity network upgrades and the replacement of conventional vehicles with EVs **can indeed help shift a transitioning UK economy onto a pathway with higher and better quality GDP (ultimately to a level of 0.16% higher than it would otherwise be), employment (+0.12% - up to 30,000 additional full-time equivalent jobs), earnings (+0.22%), labour productivity (+0.04%) and average wages (+0.1%).** In the UK context, the associated shift in fuelling away from using import-intensive petrol and diesel towards the **increased output of the electricity sector, which has relatively strong domestic supply chain content,** along with increased consumer spending (+0.18%), are the key drivers of expansion. However, our research indicates that **consideration should be given to how quickly smart (off-peak) charging is adopted and how both recovery of investment costs and increased demand for electricity generally will affect electricity prices, the Consumer Price Index (CPI) and ultimately exports in different time frames.**

I. Key research questions and findings

Based on the National Grid's Future Energy Scenarios (FES) we model three scenarios where the rate in the uptake of 'smart charging' to an ultimate EV penetration of 99% by 2050 is varied. We use the TIMES energy systems model to estimate the size and timing of the investment that would be necessary to facilitate the EV rollout. This information is used to inform simulation scenarios in the economy-wide UKENVI computable general equilibrium (CGE) model for the UK which captures the potential impacts of electrification of transportation on a range of socio-economic indicators.

Q1 What is the investment requirement and how is this affected by the uptake of smart charging?

An almost full electrification of the private vehicle fleet will undoubtedly increase the demand, and therefore the capacity needed, on the electricity transmission and distribution networks. Depending on how fast consumers adopt smart

charging, we estimate that the necessary electricity network reinforcement may cost between £9.8Bn (fast uptake) and £16.9Bn (slow uptake), with significant variation in how spending needs to be spread among the years until 2050.³ This investment is funded through consumer bills and repaid over a 45-year period.

Q2. What impact does the investment and wider EV rollout have on the wider economy?

Across all three scenarios modelled there is an immediate positive impact on GDP. In the UK context, the associated shift in fuelling away from using import-intensive petrol and diesel towards the output of the electricity sector (with its relatively strong domestic supply chain content) is the key component that results in initial positive gains.

As the EV rollout gains pace, the boost, triggered and driven by more demand for UK electricity and greater consumer/household spending

(ultimately rising to 0.18% higher than it would otherwise be) across a wide range of UK sectors, is likely to be sufficient for many UK industries to enjoy sustained expansion - outside of those supplying conventional vehicles and fuel. In the long-term this leads to net positive effects on employment (+0.12% - up to 30,000 additional full-time equivalent jobs) and earnings (+0.22%) which will ultimately be the key source of a sustained wider economy expansion. The sustained net effect on GDP, is a long-term stabilised increase of +0.16% - after all repayments have been made post 2095.

Q3. What impact does the level and timing of investment have on economic growth?

While across all three scenarios modelled there is an immediate and sustained net positive effect on GDP, we see that the timing and scale of investment required does control how economy-wide impacts materialise. The most positive transitional economic effects on GDP, employment and earnings are seen in the 'Fast' scenario. This is where smart (off-peak) charging is adopted by consumers at a quicker rate and the investment required is limited to £9.8Bn relative to £16.9Bn under the 'Slow' scenario and £10.7Bn under our 'Central' case. Furthermore, in the 'Fast' scenario the investment is spread more evenly in period 2021-2050 which affects how the economy-wide impacts materialise.

Q4. Can network investment and the EV rollout increase the 'quality' of UK jobs and other economic well-being indicators?

Investing in the electricity network to facilitate EVs will have a positive impact on labour markets in a range of sectors - with the largest net gains being in the domestic electricity sector, EV manufacturing sector and in the service sector more generally. This shift has an impact on the overall quality of employment in the UK.

We find that the sustained boost to GDP is proportionately greater than the increase in employment so that labour productivity or the 'quality' (GDP/employee/hour of work) of jobs across the UK economy rises (+0.04%). Sustained gains in earnings from employment also exceed the increase in numbers employed so that the real UK average wage rises (+0.1%).

Q5. What impacts will there be on electricity prices and how does this affect other sectors?

Our results show that the wider and ultimately demand-driven economic expansion will change the composition of GDP, perhaps most crucially with negative impacts on the competitiveness of export-orientated sectors, where our model shows there is a net contraction (-0.35%) in exports. Generally, it must be recognised that the expansionary power of the economy is constrained both by supply constraints and by the impacts of increased electrification on electricity prices faced by consumers and businesses alike which raise the costs of doing business and dampen real household income growth and spending power.

Our analysis shows that, particularly in the scenario where there is a slow uptake of smart charging and investment repayments are highest, there will inevitably be price pressures (which could be offset or exacerbated by other changes in conditions that are not simulated here). Our scenario results for the 'Slow' scenario suggest a peak 0.35% increase in the price of electricity by 2050. This is a result of both increased electricity demand and the need to repay the costs of network reinforcement, with the latter being a source of pressure that dissipates as investment costs are recovered. The main energy policy implication in this regard is that greater pressure on electricity prices could act to widen real income inequalities, which could become a challenge for policymakers in considering the regulation, planning and timing of other investment by the energy sector that may also impact consumer bills – such as decarbonising heat. However, any price pressures could be of wider policy concern in terms of CPI and competitiveness concerns.

In the subsequent discussion of findings, the following main insights are explored:

1. The uptake of 'smart' charging' has a significant impact on investment requirements
2. Investment in EV infrastructure will facilitate sustained positive economy wide impacts from the EV rollout
3. Network investment to support the EV rollout can facilitate an increase in the 'quality' of UK jobs
4. Consideration must be given to the potential impact on the Consumer Price Index, exports and electricity prices

II. Modelling electricity network upgrades and the EV rollout

As with a number of decarbonisation policies, the electrification of private transportation can be described using the CEP Policy Framework⁴. Following the framework approach we consider the required electricity network upgrade as the key component of the **enabling stage**. In this analysis we do not consider additional costs such as charging point infrastructure. This allows us to focus attention on and isolate the impacts of network upgrades as an enabling action. But this is set against EV rollout in the realising stage. This **realising stage** of the electrification of transportation is the gradual replacement of conventional vehicles with electric ones, until 99% of the vehicle fleet used for private transportation by 2050 consists of EVs.

In order to study the potential individual and joint impacts of each of the stages, we use a combination of two modelling approaches, forming a soft-link between the two models. A more detailed description of the models is provided in the Appendix. The first model we use is TIMES, an energy systems model that allows us to estimate the size of the investment that would be necessary over different time periods so that the energy system can cope with the increased volume of demand. The TIMES simulations not only provide information on the total size of the investment required under different rollout scenarios, but crucially how the total amount needs to be distributed over different time periods.

The underlying assumption of our analyses is that 10% of the EV charging will take place close to the transmission level, while 90% will take place at distribution level. Moreover, by 2030 20% of the private vehicles will be EVs, increasing to 80% by 2040 and 99% in 2050 and thereafter. Those figures are derived from the 2019 Future Energy Scenarios⁵ developed by National Grid (See Appendix for further detail). In the FES scenarios a key assumption is that by 2050, 75% of vehicle charging will be at off-peak times. However, how soon consumers will adopt this behaviour can significantly affect the size and the timing of the investment required. We explore then three scenarios: a 1) Slow 2) Central and 3) Fast where the rate of adoption of 'smart' charging is varied. We consider 'smart' to represent 'off-peak' time charging and 'dumb' to

represent charging at 'peak' hours (see Appendix for more details).

The information on the size and timing of the investment are then used to inform simulation scenarios in the economy-wide UKENVI computable general equilibrium (CGE) model for the UK. The soft-link between the two models reflects the fact that the information from TIMES is not used directly from the CGE model, but are adjusted to match the CGE model requirements, so that the analyses are coherent.

For our economy-wide analysis, we assume the network upgrades take place in 5 year periods, to match the duration of price control periods, starting from 2020⁶. We use the TIMES outputs to identify the amounts that need to be spent by 2030, 2040 and 2050 under the different off-peak charging adoption rates and then the investments are spread evenly across each 10-year period. The results we obtain by simulating the network upgrade in isolation reflect the potential impact of the enabling stage of electrification of transportation. Moving forward, we simulate the rollout of electric vehicles, which is informed by the 2019 FES scenarios. The scenarios only include private transportation (cars and vans). Buses and heavy goods vehicles are not included in these scenarios. The rollout of EVs is assumed to be smooth, meaning that there are no peaks in the way that they are replacing conventional vehicles. Simultaneously, we assume that the efficiency of EVs is improving over the years, reaching a 30% improvement in 2050 compared to before 2020⁷.

III. Findings

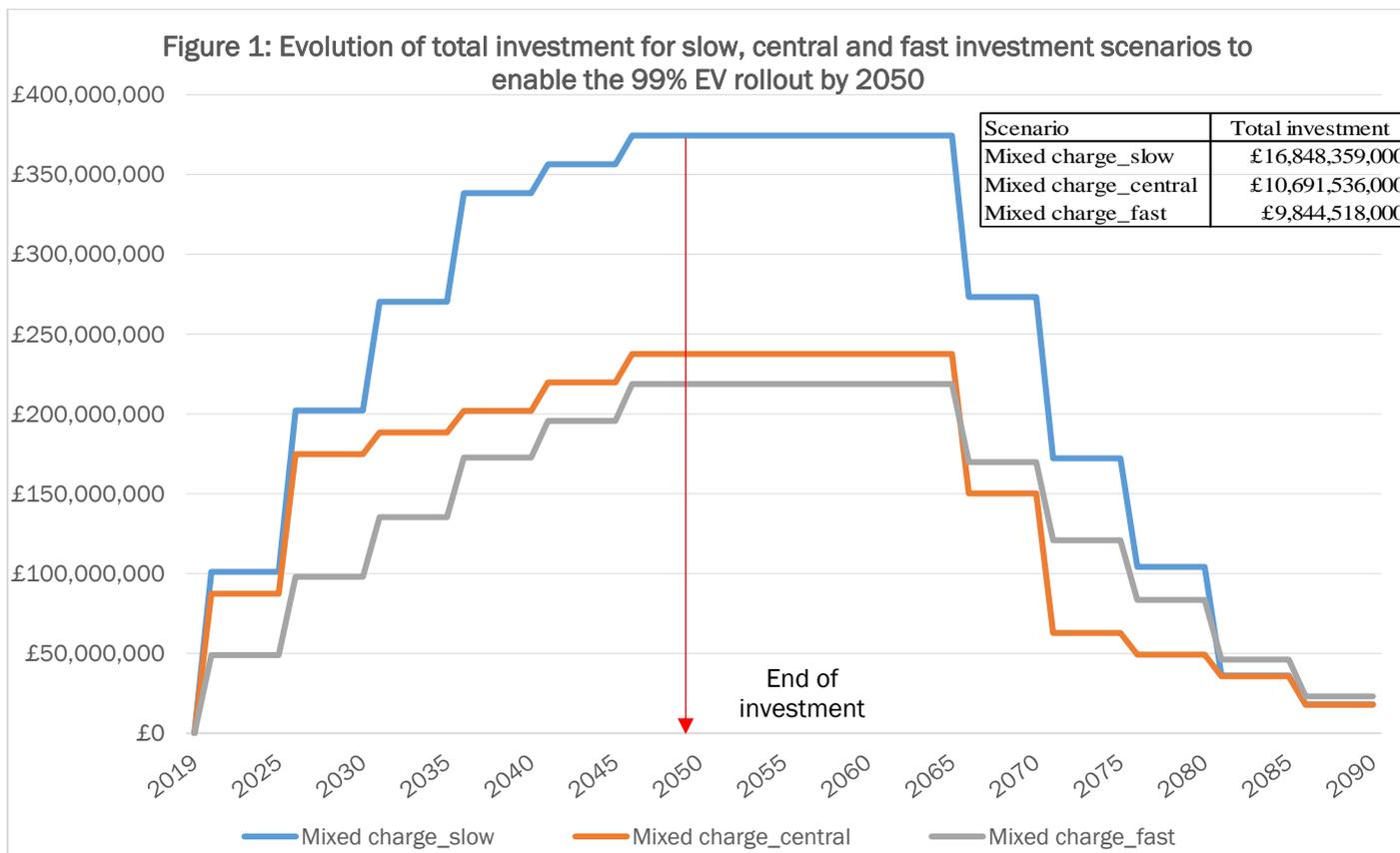
1. The uptake of 'smart' charging' has a significant impact on investment requirements

While investment figures derived from the UK TIMES model may vary from the real-life investments needed at an individual network level and do not include the additional reinforcement that may be needed for the electrification of heat, they do portray some key findings. Our analyses show the 'Slow' adoption of 'smart' charging results in a considerably larger need for network investment. Investment requirements range from £9.8Bn for the 'Fast' uptake of smart charging, £10.7Bn for the 'Central' scenario and £16.9Bn for the 'Slow' uptake scenario (Figure 1). This equates to around a 58% increase between the 'Central'

and the 'Slow' uptake. This is caused by the larger share of 'dumb' charging up to 2040, which increases the pressure on network capacity.

While there is only a small difference in total investment required between 'Central' and 'Fast' scenarios, the timing of these investments is not the same. The 'Central' scenario requires most of the investment to take place by year 2030, whereas the 'Fast' scenario has a more uniform

distribution of investments from 2030 to 2050. The timing and magnitude of investment is a key metric for stakeholders, policy makers and regulators. For example, Ofgem are keen to ensure that network operators do not build assets that are not utilised, whilst also ensuring that network capacity is not a barrier to the wider EV rollout. The macro economic effects of investment timing and magnitude are also important and will be discussed later in this briefing.



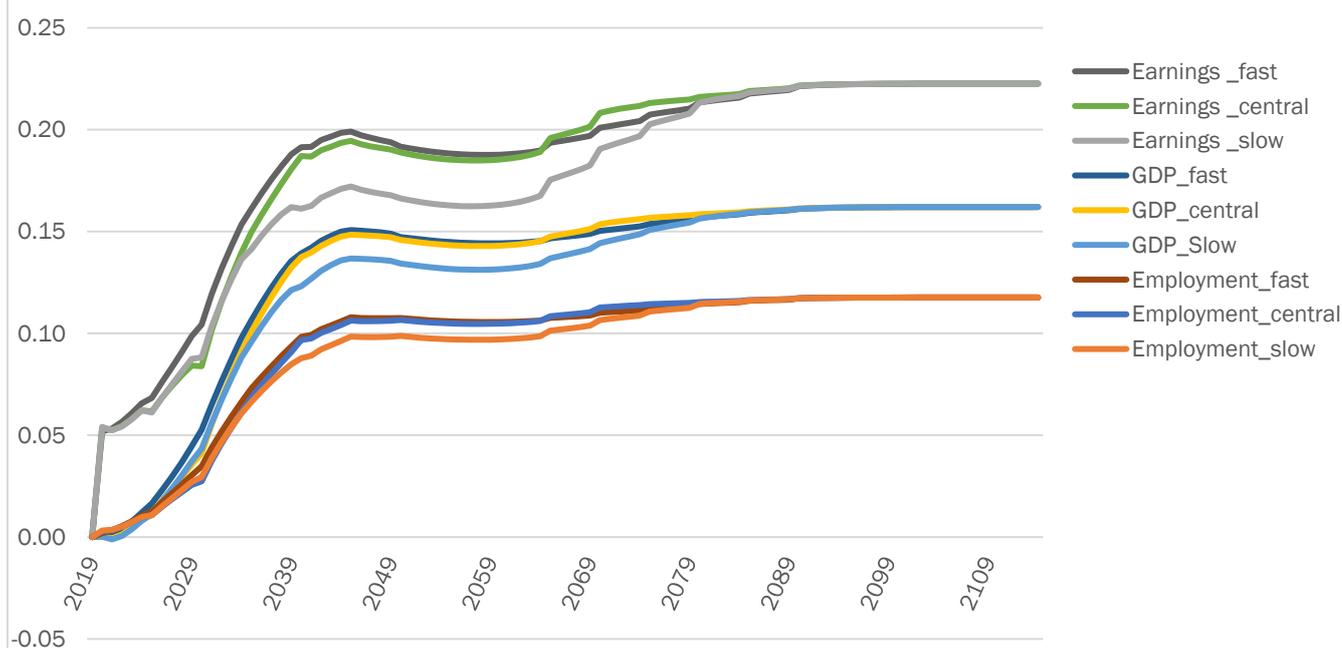
2. Investment in EV infrastructure will facilitate sustained positive economy wide impacts from the EV rollout

Our findings show that across all three scenarios modelled there is an immediate net positive effect on GDP (Figure 2). In the UK context, the associated shift in fuelling away from using import-intensive petrol and diesel towards the output of the electricity sector (with its relatively strong domestic supply chain content) is the key component that results in positive gains in activity levels in many sectors of the economy.

Over time, the EV rollout will gain pace, accompanied by associated efficiency gains in delivering private transport and fuel shifting to reliance on domestically sourced electricity. This is what can be expected to deliver larger and

clear sustained net economic gains that substantially offset the wider economy costs associated with paying for network upgrade activity. The boost, triggered and driven by more demand for UK electricity and greater consumer/household spending (+0.18%) across a wide range of UK sectors, is likely to be sufficient for many UK industries to enjoy sustained expansion, outside of those supplying conventional vehicles and fuel. In the long-term this leads to net positive effects on employment (+0.12% - up to 30,000 additional full-time equivalent jobs) and earnings (+0.22%) which will ultimately be the key source of a sustained wider economy expansion, where a long-term stabilised increase of +0.16% can be seen - after all repayments have been made post 2095 (Figure 3).

Figure 2. Evolution of net impacts (% change relative to base year values) on UK GDP, employment and earnings from employment for slow, central and fast investment scenarios to enable the 99% EV penetration by 2050



While our findings show that across all three scenarios modelled there is an immediate and sustained net positive effect on GDP, we see that the timing and scale of investment required does have a control on how economy-wide impacts materialise. The most positive transitional economic effects on GDP, employment and earnings are seen in the 'Fast' scenario where the investment required is limited to £9.8Bn and is spread more evenly in the 2021-2050 period. For example, in the 'Fast' scenario, 91% of the long-run GDP expansion is achieved by 2050. In contrast, in the 'Slow' scenario, 83% of the long-run GDP expansion is achieved by 2050. Earnings growth is even more subdued, with 75% of the ultimate 0.22% gain achieved by 2050 in the 'Slow' scenario, compared to 86% where consumer responses enable the more gradual and overall lower cost investment in the 'Fast' scenario. This may be a result of the more moderate increases in the price of electricity seen in this scenario which act as less of a constraint on growth.

The evaluation of impacts from each of the investment scenarios also allows consideration of the issue of 'stranded assets' - where infrastructure is built and paid for without ever being used. This is a continued concern for regulators. Our results show that while the investment scenario that requires the most limited amount of spend produces the most positive macro-economic impacts, net positive

economic effects are realised even when the total investment is over 50% greater in the 'Slow' scenario where the uptake of smart charging is slower. However the wider economic benefits seen rely on the high uptake and use of EVs and may not be seen if EV uptake was considerably limited. Consideration should also be given to the impact this greater investment will have on the price of electricity which may impact low income households who are in fuel poverty.

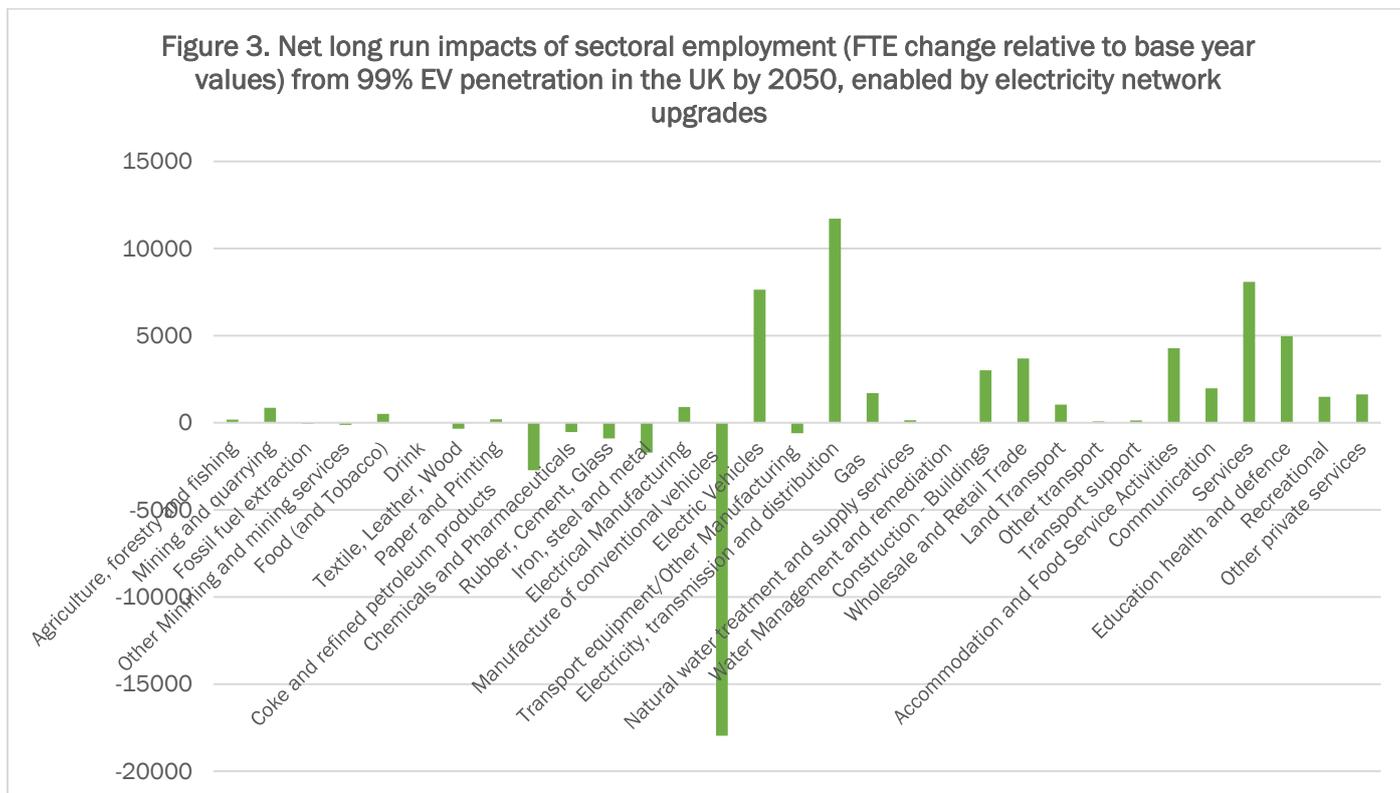
3. Network investment to support the EV rollout can facilitate an increase in the 'quality' of UK Jobs

Our results show that investing in the electricity network to facilitate EVs will have a net positive impact on labour markets with gains in employment seen in a range of sectors - most notably in the domestic electricity sector, EV manufacturing sector and in the service sector more generally. However some negative trends are seen most notably in the 'Manufacture of conventional vehicles' and 'Coke and refined petroleum products' sectors (Figure 3). The net effect translates to a positive shift in jobs to sectors with a higher average wage than the base case scenario where no EV uptake is assumed.

The sustained boost to GDP is also proportionately greater than the increase in employment so that labour productivity or the 'quality' (GDP/employee/hour of work) of jobs

across the UK economy rises (+0.04%). Sustained gains in earnings from employment also exceed the increase in numbers employed so that the real UK average wage rises (+0.1%).

This not only has a positive impact on those employed, but also has important implications for the UK budget where the increase in tax revenue could be used to offset the costs of other net zero actions.



4. Consideration must be given to the potential impact on the Consumer Price Index, exports and electricity prices

The nature of the wider economic expansion described here is likely to carry two main costs. The first arises from the fact that any expansion involving a boost to consumer spending will put upward pressure on prices across the economy (the Consumer Price Index - CPI), particularly where there are lasting constraints on labour supply. This will be exacerbated by higher levels of investment spending. Any expansion that is essentially demand driven in the presence of even transitory constraints on labour and capital, is by some extent characterised by reduced competitiveness in export-orientated industries.

Our results show that – depending on the sensitivity of export demands to higher output prices in manufacturing industries – there is a net contraction (-0.35%) in exports. This inevitably leads to an expansion in GDP that is both constrained and changing in its composition.

The second type of cost relates specifically to the price of electricity. The main source of expansion

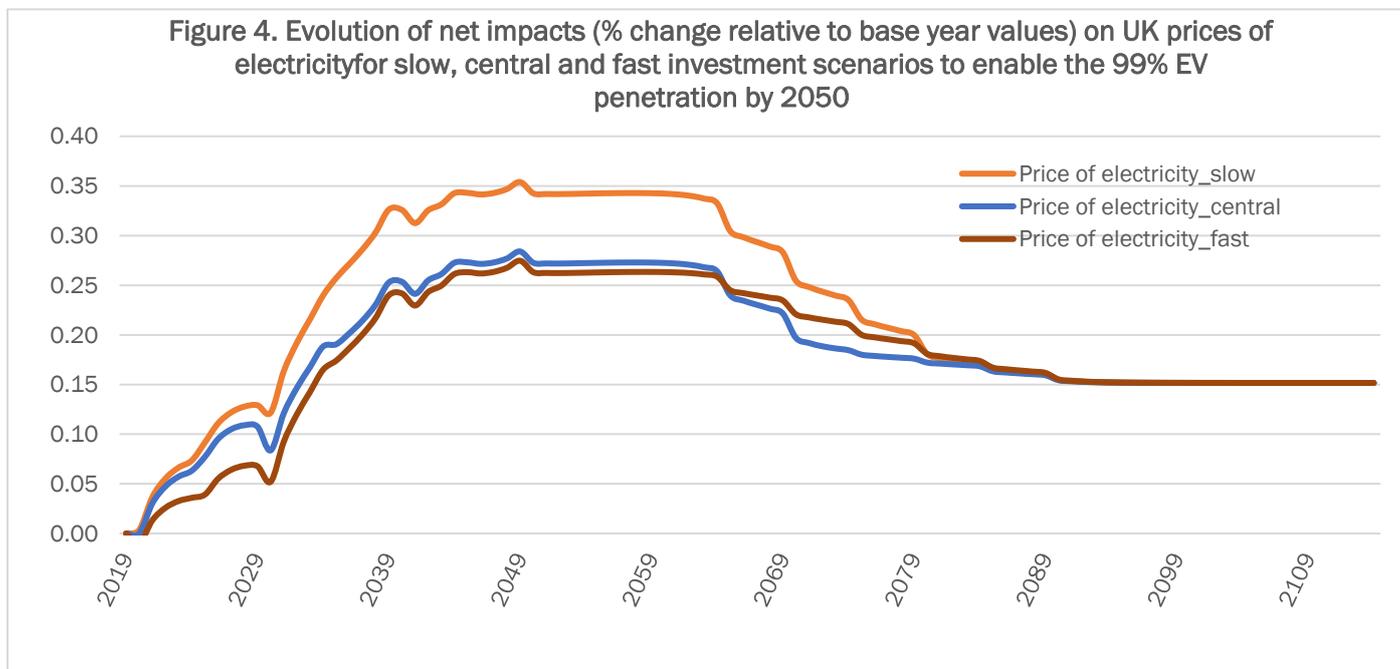
in the scenarios considered in our analysis is the increased demand for UK electricity to fuel transport. Even where the industry response is a competitive one, such an expansion is likely to drive a sustained upward pressure on the price of electricity faced by UK businesses and consumers. This demand-driven market pressure will exacerbate the impacts of the costs of the required network upgrade investment continuing to be recovered through the electricity bills of all users over the (45 year) lifetime of those assets. Our model shows a peak 0.35% increase in the price of electricity by 2050 in the ‘Slow’ scenario where the cumulative effect of repayments is highest (Figure 4).

The combined impact on electricity prices will act as a source of constraint on wider economic growth by acting to raise the costs of doing business and dampening real household income growth and spending power. It must be noted however that the scale and timing of investment has a control on the price of electricity, with the ‘Fast’ scenario resulting in a more moderate increase in the price of electricity (Figure 4). This leads to higher net positive economic effects

than the other scenarios through the period to 2050.

While a distributional analysis of the impact of increased electricity prices on different consumer groups has not been undertaken in this study, further research could be undertaken

to explore this and the impact on general poverty levels. This may be particularly important as certain societal groups may be less likely to benefit from the growth in economic activity described. This may be of particular interest to policymakers who are looking to deliver a 'Just Transition' to net zero.



IV. Conclusions and policy implications

Our simulated scenario analysis suggests that investment in electricity network upgrades to support the EV rollout can indeed help shift a transitioning UK economy onto a pathway with **higher and better quality GDP and employment, as reflected by the impact on labour productivity, earnings and average wage levels.** If realised, these wider economy benefits could ultimately offset the costs associated with upgrading the electricity network.

Positive net expansionary activity across the economy will allow Government to begin to accumulate gains in revenue and the public budget balance. This is important in a UK policy context, where identification and tracking of such outcomes is crucial in enabling public budget decision makers to consider what the most beneficial way of using any additional budget savings in the wider context of the transition to net zero, including how to address losses in fuel duties.

Results show that the scale and timing of investment does have an important causal impact on just how positive the net economic

effect is. The most positive transitional economic effects are seen where smart charging is taken up by consumers at a quicker rate and investment requirements are reduced. **Policy makers should assess the feasibility and consumer appetite for smart charging and consider whether action should be taken to speed-up its uptake.**

The wider and ultimately demand-driven economic expansion described in this paper will change the composition of GDP, with potential negative impacts on the competitiveness of export-orientated sectors. Generally, it must be recognised that the expansionary power of the economy is constrained both by supply constraints and by the impacts of increased electrification on electricity prices faced by consumers and businesses alike.

Greater pressure on electricity prices could act to widen real income inequalities. This could become a challenge for policymakers in considering the **regulation, planning and timing of other investment by the energy sector that may impact consumer bills – such as decarbonising heat.**

Policymakers and regulators should consider how energy and absolute poverty levels may be affected, given that low income households – which tend to receive relatively small shares and absolute levels of income from employment and wages - are least likely to benefit from any type of economic expansion that could offset a rise in electricity bills.

Acknowledgements

This project is specifically funded by Scottish Power Energy Networks (SPEN) and is part of a wider portfolio of research projects funded by the EPSRC National Centre for Energy Systems integration (CESI) (EPSRC grant ref: EP/P001173/1). We also acknowledge the support of ClimateXChange, the Scottish Government- funded Centre for Expertise in Climate Change, whilst noting that any opinions in the paper expressed are those of the authors, and not necessarily those of SPEN, ClimateXChange or the Scottish Government. Responsibility for the design, conduct and reporting of the research lies with the authors.

Contact

For more information on the research reported here, and to discuss potential future research, please contact Professor Karen Turner, Director of the Centre for Energy Policy at the University of Strathclyde, or other members of the CEP project team at cep@strath.ac.uk

About the authors

Professor Karen Turner, Director of the Centre for Energy Policy (CEP). Principal investigator and research lead on this project and others at CEP. Member of the Scottish Government's Just Transition Commission and member of the Committee on Climate Change Advisory Group on the Costs and Benefits of Net Zero.

Dr Oluwafisayo Alabi, Co-investigator, hands-on modeller/researcher on economy-wide modelling and analyses on the crucial question of 'Who Ultimately Pays for low carbon solutions and the transition to a low carbon future'.

Dr Christian Cavillio, Co-investigator, TIMES energy systems modeller and Scottish Government, ClimateXChange (CXC) fellow on 'Energy System Impacts of Energy Efficiency' project.

Dr Antonios Katris, Co-investigator, economy-wide CGE modeller and researcher on UKERC funded project: 'The Impact of Multi-level Policymaking on the UK Energy System'.

Dr Jamie Stewart, Deputy Director at the Centre for Energy Policy. Senior Knowledge Exchange Fellow.

Constantin Broad, Graduate Research Assistant with a research interest in social-Cost-Benefit frameworks to demonstrate the net benefits of the outcomes delivered by different policy actions.

Appendix

Energy system model (UK-TIMES)

We have used the UK TIMES (UKTM) energy system model to assess the level of investment required by a large-scale rollout of EVs in the UK. The TIMES modelling framework has been used widely to analyse different policy questions including the energy system impacts of specific technologies and policies or decarbonisation scenarios.

UKTM is a single region bottom up techno-economic energy system wide model of the UK. We develop further the model to analyse the impacts of EV penetration, following the work presented in (Calvillo and Turner (2020)).⁸ UKTM models all areas of the energy system. The model inputs (exogenous variables and parameters) are: energy service demand curves (i.e. end user demand), supply curves (e.g. primary energy resources such as wind power or availability of imports), and techno-economic parameters (e.g. technology efficiencies and availability factors, investment cost per capacity unit, O&M cost per unit of production, etc.). The outputs of the model (endogenous variables) include: energy and commodity flows, marginal costs, technology installed capacities, greenhouse gas emissions, etc.

The time horizon in UKTM runs until 2050, with time periods of 5 years, and taking 2010 as the base year. UKTM considers 16 representative time-slices that work as an average of that time period. These 16 time slices consist of four seasonal divisions (spring, summer, fall and winter), and four daily divisions (night, day, evening peak and late evening) within each season.

UKTM is a partial equilibrium model-generator, using linear-programming and assuming perfectly competitive markets and full foresight. The model uses demand projections as the main driver of the energy system, finding the least cost energy system configuration (technology mix and energy flows) to meet the expected demand.

UKENVI Modelling strategy and development

The UKENVI model, is informed using the information on estimated extra investment requirement for network upgrades under each scenario, projected EV penetration and EVs efficiency improvement by 2050 produced from the UKTM model as discussed in previous section. There are four main modelling strategies, assumptions and narratives/perspectives employed.

First, for any one of the investment scenarios or pathways' (i.e. slow, central and fast) it is assumed that only one third of investment spend occurs in the UK through an increase in exogenous final demand for construction sector output. While, the remaining component of the investment spend occurs abroad in the purchases of other necessary materials in the form of imported goods and services required to upgrade the UK network. However, UK consumers will pay the total investment cost via higher electricity bills. Thus, the UK investment cost is spread by planning blocks or per price control period (assumed here to be 5 years).

Secondly, the repayment value (i.e. the total investment cost) is spread over the lifetime of the asset (assumed to be 45 years) and occurs per planning period to account for and/or allow for renewal of assets to meet increasing demand on the energy system.

Thirdly, we assume a fixed labour supply (where flow in migration cannot dampen wage pressures as unemployment falls) and allow for wage bargaining in the model to take account of the impacts of longer timeframes for projected EV rollout and the length of investment and repayment activity. Fourth, we take account of the evolution and impacts of EV penetration and efficiency improvement to 2050 to reflect impact of using electricity to deliver same number of miles per physical unit of electricity (growing to 30% by 2050).

EV Scenarios modelled

Three EV charging scenarios are analysed using the UK TIMES model, based on National Grid's Future Energy Scenarios (FES) 2019 (National Grid, 2019).⁹ We extend the analysis in Calvillo and Turner (2020)¹⁰ in two ways. First, we assume a large EV penetration reaching 99% EV penetration and a 75% of smart charging by 2050. Secondly, we consider scenarios that capture the impacts of different rates of smart charging adoption in terms of the level and timing of the transmission and distribution network investments, required to accommodate the increasing EV demand over time.

In addition, we consider that EV charging behaviour could be done in a 'Dumb' or 'Smart' way. Where 'Dumb' charging take place between 17h and 20h (peak hours), when people come back from work and electricity demand is highest, and 'Smart' charging only occurs when it is cheaper to do so (off-peak times) to reduce the stress on the network and the need for reinforcements. It is important to note that the smart charging profiles are not static, as they are likely to change with the increase of EV penetration and other demands for electricity. This flexibility of smart charging is important to consider to avoid concentrating demand and creating a new 'peak time', defeating the purpose of smart charging.

The three scenarios simulated are:

- Mixed charge slow: the adoption of smart charging takes longer, with only 15% of all EVs doing smart charging by 2030, 30% by 2040, then increasing rapidly to 75% by 2050.
- Mixed charge central: this scenario shows a steadier adoption of smart charging, with 20% smart charging by 2030, 60% by 2040 and 75% by 2050.
- Mixed charge fast: smart charging is adopted faster by EV users, with 45% smart charging by 2030, 70% by 2040 and 75% by 2050.

The results of the different scenarios are compared across one another with a 'No EV uptake' scenario. Note that the lack of EV use is the only difference between this benchmark scenario and the three described above. Note that the slow adoption of smart charging results in a considerably larger need for network investments (around 58% more than the Central scenario). This is caused by the larger share of 'dumb' charging up to 2040, which increases the pressure on network capacity.

Endnotes

¹ In 2019 CEP published a policy brief ‘Who Ultimately Pays for and Who Gains from the Electricity Network Upgrade for EVs?’ This work focussed on the economy wide impacts of the EV rollout to 2030. It is available at this link: <https://strathprints.strath.ac.uk/67741/>. Full details of the research are available at <https://doi.org/10.1016/j.enpol.2019.111117>

² Analysing the Impacts of a Large-Scale EV Rollout in the UK – How Can We Better Inform Environmental and Climate Policy? Christian Calvillo and Karen Turner, Energy Strategy Reviews July 2020 <https://doi.org/10.1016/j.esr.2020.100497>

³ Our modelling does not consider specific network factors which may impact the scale of these figures, for example, location of chargepoint installation, network conditions, existing load etc.

⁴The policy briefing detailing the Policy Framework has been published by Turner et al. and can be found at this link: <https://doi.org/10.17868/71580>

⁵ National Grid Future Energy Scenarios 2019 <https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2019-documents>

⁶ There are no strict restrictions regarding which will be the first year. In this work 2020 is used for narrative purposes but it is possible to use a different starting year to match the beginning of the next transmission or distribution price control periods. However, under a different starting year the simulated scenarios would need to be revisited.

⁷ TIMES assumes this improvement of the EVs’ efficiency in that time period. We use the same assumption in our CGE model to ensure that the insights from both models are compatible and complementing each other.

⁸ See Endnote #2

⁹ See Endnote #5

¹⁰ See Endnote #2