Capacity to Customers (C2C) Carbon Impact Assessment Final Assessment Report

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Capacity to Customers (C_2C) Carbon Impact Assessment *Final Assessment Report*

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C_2C Carbon Impact Assessment Final Assessment Report

Understanding the carbon impact of the C_2C project

1 Introduction

The C_2C project explores a novel means of providing greater capacity from existing distribution assets. The Tyndall Centre for Climate Change Research, at the University of Manchester, has participated in the project to assess its carbon impact, identifying and quantifying the major sources of emissions and areas where C_2C can provide savings and where it may increase emissions.

The C_2C solution has multiple consequences in terms of assets, operation of the network and facilitation of new connections that are different to the existing practices of Electricity North West. A series of reports describe these impacts and the methodology used to assess them. This report is a summary drawing out headline conclusions. For full detail readers should refer to the following:

- *Capacity to Customers (C_2C) Carbon Impact Assessment Whitepaper, June 2014* – describes the approach taken, existing research literature and methodology framework
- *Capacity to Customers (C_2C) Carbon Impact Assessment: Trial Results, Feb 2015* – details the quantification of carbon from assets used to reinforce the network identified from the C_2C trial.
- *Capacity to Customers (C_2C) Carbon Impact Assessment: Carbon Reduction Incentive Review*, *Feb 2015* – discusses key drivers of low carbon technologies relevant to the carbon impact of C_2C.
- *Capacity to Customers (C_2C) Carbon Impact Assessment: Scenario Results, Feb 2015* – collates the results of the scenario exercise examining the carbon impact of the C_2C under different circumstances of load growth, renewable deployment and grid decarbonisation.
- *Capacity to Customers (C_2C) Carbon Impact Assessment: Regional and National Adoption, March 2015* – scales the output of the scenario exercise to ENWL and GB scale.

This research was developed in association with the C_2C Cost Benefit Analysis (CBA) and network modelling work package conducted by Dr Mancarella and Dr Martinez-Cesena at University of Manchester. Readers interested in the identification of capacity constraints, optimal reinforcement, power flows, and losses should refer to this work.

For those unfamiliar with the approach taken sections 1.1 and 1.2 provide useful background, however some readers may wish to skip directly to section 2 on page 6.

1.1 Categorisation of carbon impacts

1.1.1 Asset Carbon Impacts

C_2C requires different combinations of conductors, switchgear, transformers and civil works to traditional reinforcement. The emissions of all greenhouse gases (GHGs) associated with the manufacture and deployment of these materials onto the network are classed as *Asset* carbon impacts.

1.1.2 Operations Carbon Impacts

The emission of all GHGs arising from the generation of electricity that is subsequently lost in transmission through the network is accounted for in the scenario work. Energetic losses calculated using power flow models, developed in the University of Manchester Cost Benefit Analysis work package, for both baseline and C_2C network configurations, have been converted to carbon impact by overlaying further scenarios of power generators in use at the time of consumption. These impacts are classified as *Operations* carbon impacts.

1.1.3 Facilitated Carbon Impacts

Estimating asset and operations carbon impacts will only identify part of the potential of the C_2C solution and not reveal its broader consequences. The rapid delivery of capacity via C_2C suggests that there may be additional indirect emissions reductions due to prompt connection of low carbon technologies (LCT) such as renewable generation, electric vehicles (EVs) and heat pumps (HPs) that might otherwise be delayed by constraints on the network. The incentives that lead to the deployment of these LCTs have been appraised during the C_2C carbon impact assessment. These benefits are categorised as *Facilitated* carbon impacts.

1.2 Scenarios

Scenario methods are used to explore different technical or policy options when future circumstances are unknown and, due to the complexities of human society, unpredictable. Each scenario is not a forecast of a likely future, but rather a plausible and coherent set of future circumstances. Examining the performance of different options against these possible futures allows for more robust decision making.

1.2.1 Drivers of capacity constraint

Five core scenarios of load growth were developed by ENWL and the CBA work package based on regional demand growth forecasts combined with the expectation of change due to policies incentivising low carbon technologies and the transfer of transport and heating energy demand onto the electricity system, specifically DECC's 'low' EV and HP scenarios. Alongside the particular properties of the circuits, it is this that determines the timing and extent of reinforcement and/or C_2C deployment.[1]

[1] Load on all circuits in the scenario study was scaled to varying extents prior to modelling such that all circuits required reinforcement within 3 years. The time frame is therefore not strictly chronological, with the assessment performed over 45 years rather than to 2060.

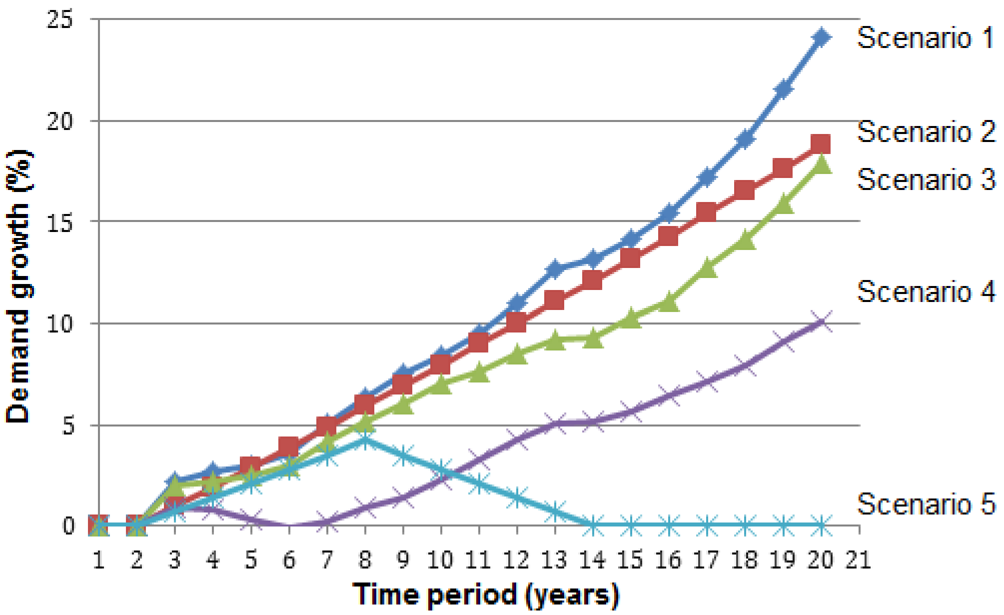


Figure 1

Scenario Number	Growth trend	Increase by 2030 (Year 15)
1	High uptake of LCTs	26%
2	Continuous growth at 1%	20%
3	Initially reduced rate, increasing with time	20%
4	Lag in LCT uptake but increase after Y10	11%
5	Short term peak only	0

1.2.2 Demand growth vs renewable distributed generation

Carbon impact has been calculated both on the basis of demand growth, primarily due to LCTs, and renewable distributed generation. Although the capacity constraints are calculated from the same numerical origin, scenarios 1 to 5 above, there are other implications. Considering losses, the marginal emissions associated with renewable distributed generation are taken to be zero on the basis that they are arising from large scale wind generators operating over multiple decades. The proportion of the power flows and hence losses arising from this generation has been accounted for by the CBA work package model and deducted from the total losses before multiplication with a grid emissions factor.

The choice of demand driven or generation driven reinforcement also determines the basis of the facilitated reduction calculation. In the demand case the electric vehicle methodology is used, in the renewable distributed generation case the grid electricity displacement by wind methodology is used (see the Whitepaper on methodology and the Carbon Reduction Incentive reports for further details).

1.2.3 Grid Electricity Carbon Content

Coincident with the distribution network changes is the decarbonisation of UK electricity supply due to national and international policy. This has relevance to the C_2C carbon impact assessment in that the “carbon content” (grid emissions factor) of the energy consumed as losses may vary substantially over coming years. Five possible scenarios were investigated and three chosen for analysis; the OFGEM CBA approach was taken as a central scenario with Gone Green as the lower bound, and persistent CCGT emissions intensity as the upper bound. Further discussion can be found in the Scenario Results and Carbon Reduction Incentive reports.

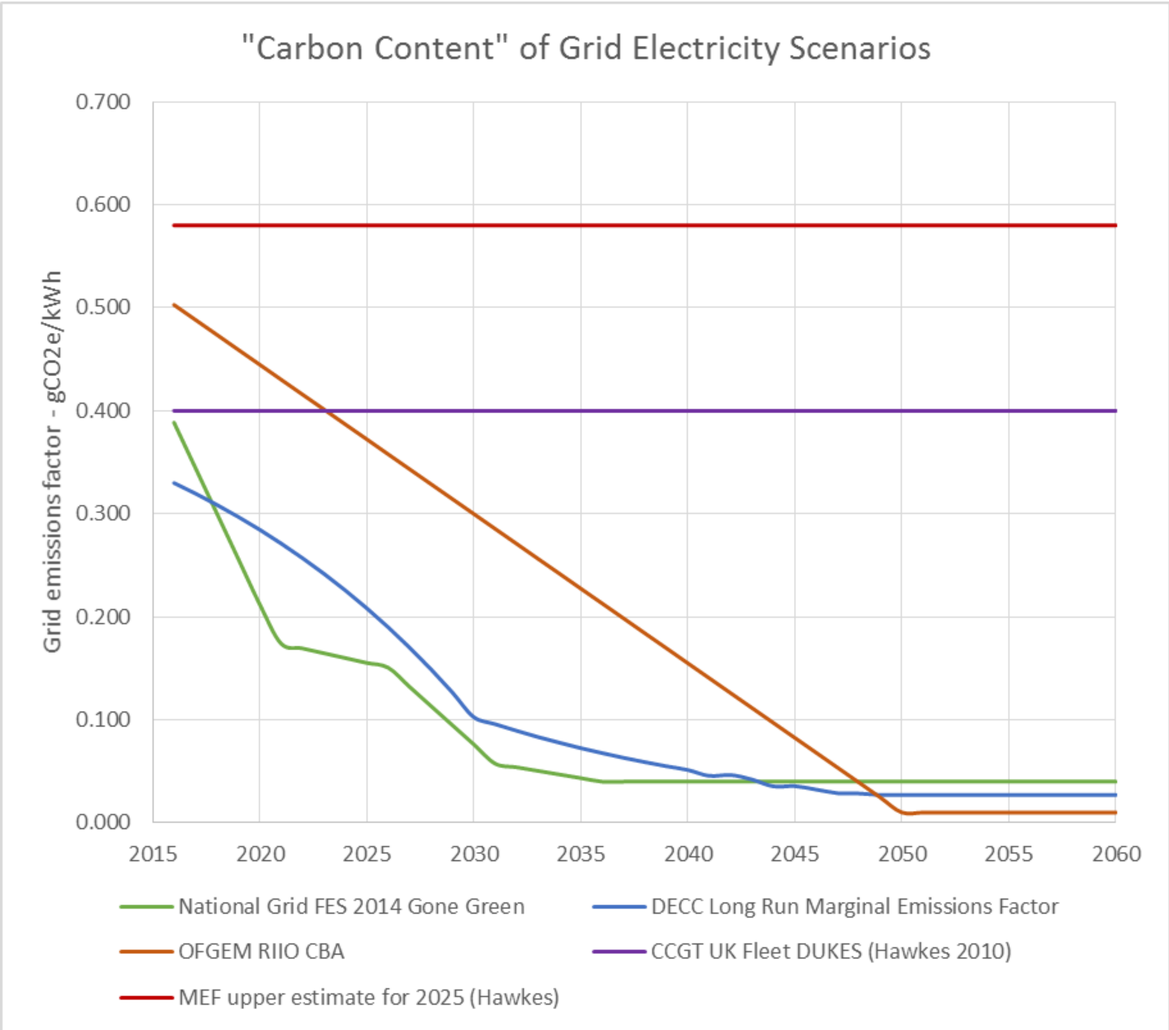


Figure 2

2 Key Findings

As well as developing and demonstrating a novel approach to carbon assessment that may be replicated by other distribution network projects, the C_2C Carbon Impact Assessment has identified a number of findings relevant to both ENW, and the engineering and academic communities developing smart grids and low carbon energy policy.

2.1 C_2C substantially reduces the immediate carbon impact of additional network capacity, potentially up to 250 tCO2e per circuit

C_2C provides new capacity with negligible additional asset cost unlike traditional reinforcement. This can lead to savings of up to 250 tCO2e per circuit. The box plot below displays the results for the 36 modelled circuits with the box representing the central 50% of circuits, the line within it the median, and the 'whiskers' the full range. For approximately 8% of cases the same physical investments as traditional reinforcement are required to deliver the necessary capacity but at a later date.

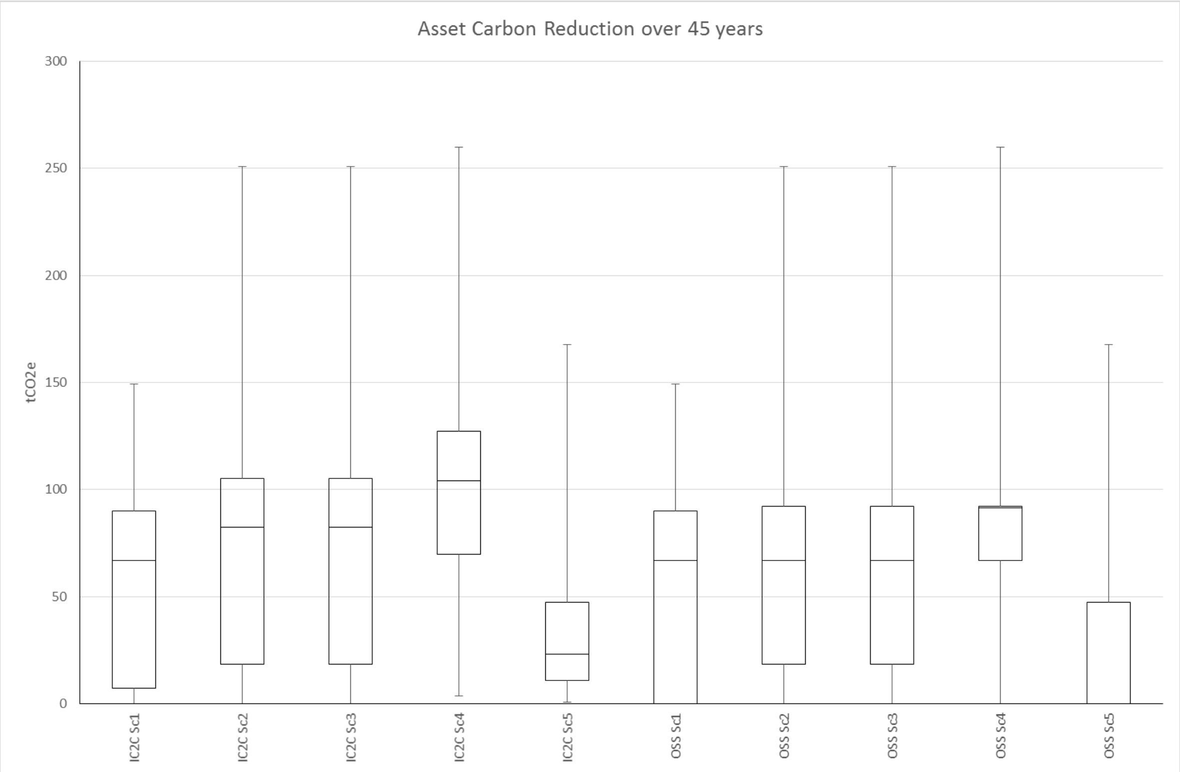


Figure 3

2.2 Savings of up to 55% of carbon impact over a 45 year time frame are observed in some circuits, although the median benefit is ~10%

Relative carbon impacts, both reductions and increases, summed over 45 year period are modest, typically ±10%, and vary substantially between circuits. Figure 4 illustrates the absolute total carbon impact for all circuits under the central scenario, 3, modelled for traditional reinforcement (base), interconnected C_2C (IC_2C) and optimal investment to minimise total social cost (OSS) when driven by demand growth.

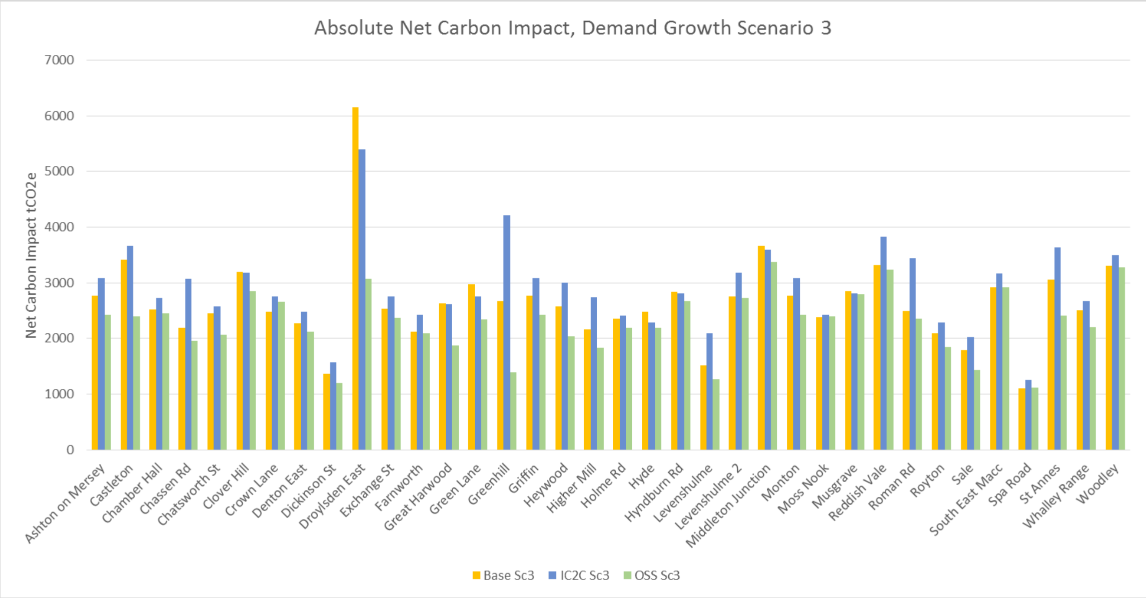


Figure 4

2.3 Optimum reinforcement with a combination of C_2C and traditional asset upgrades would be least cost and deliver a lower carbon system than C_2C alone

The carbon impact of C_2C and the OSS strategy, relative to traditional reinforcement, under five different scenarios of load growth was summed over a 45 year time frame. With the mean circuit carbon impact scaled to ENWL's network, and the ratio of demand growth to renewable deployment taken as 30% to 60% with 10% of load growth allocated to background demand, we can see that whilst C_2C has the highest asset carbon reduction in each scenario, the greatest net benefit is realised when it is deployed in association with some traditional reinforcement in the OSS strategy, to alleviate points of network congestion and minimise losses.

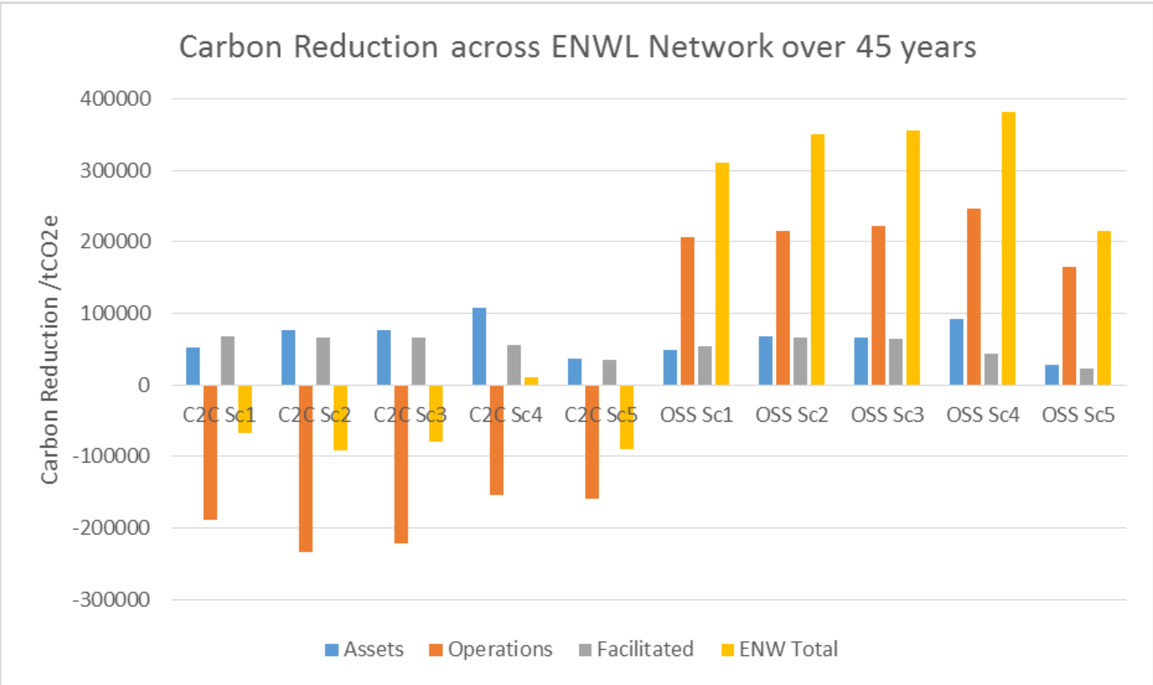


Figure 5

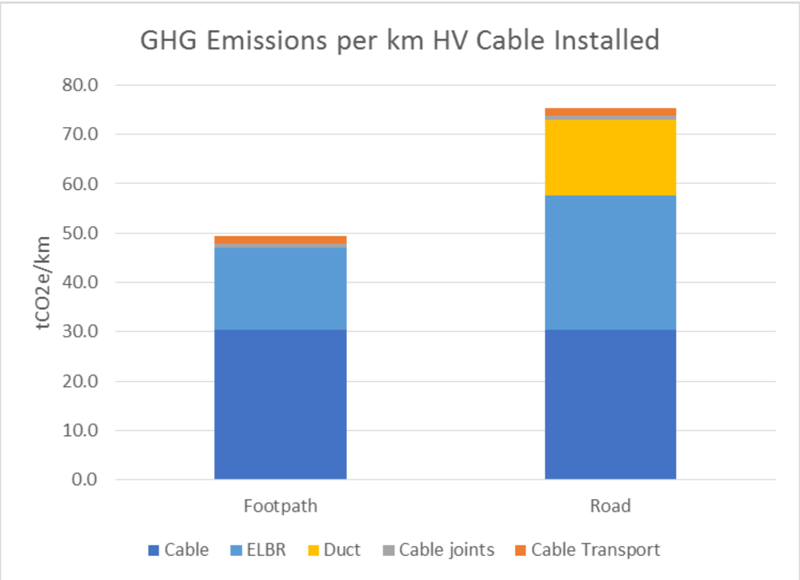
2.4 Facilitated reductions can be substantial but are usually smaller than benefit of losses reduction

If it is assumed that the IC_2C solution facilitates the connection of growing demand four months quicker than traditional techniques, and that this demand is from EVs and wind turbines that connect as soon as the capacity is available, then there is the expectation of additional emissions reductions. In formal carbon accounting methods these benefits would not typically be attributable to ENWL as an organisation, however, for the scope of this project they are relevant. The impacts are greatest when connecting wind turbines, and for electric vehicles are invariably smaller than the benefits from losses reductions.

With this detail and understanding we see that simple “capacity release” measures of carbon benefit do not provide a complete picture.

2.5 Asset carbon impacts from traditional cable reinforcements are greater than reported in the current academic literature

Summing the C_2C emissions factors for cables, joints and installation, we found the composite emissions factor for traditional reinforcement to be between 49 tCO2e/km and 75 tCO2e/km. These estimates are especially high relative to those published within electricity network LCA studies, at least seven times greater than Turconi et al’s (2014) estimate of ~7 tCO2e/km and far in excess of the small allowance for limestone aggregate suggested by Jones and McManus (2010). The notable development in the C_2C case was the inclusion of detailed assessment of civil engineering works required to lay the cable, especially under carriageways.



2.6 Connection of renewable distributed generation substantially reduces operations carbon impact by changing power flows and carbon content of losses

For our sample of 36 circuits, operations carbon impacts vary substantially. This depends on the distribution of existing load (symmetric/asymmetric) and current assets installed. Traditional reinforcement typically provides a greater reduction in carbon from losses for scenarios driven by demand growth than C_2C but not for renewable distributed generation.

For the renewable DG scenarios, losses were allocated separately to DG power flows (zero carbon emissions) and grid power flows (at grid emissions factor). Figure 6 below illustrates this.

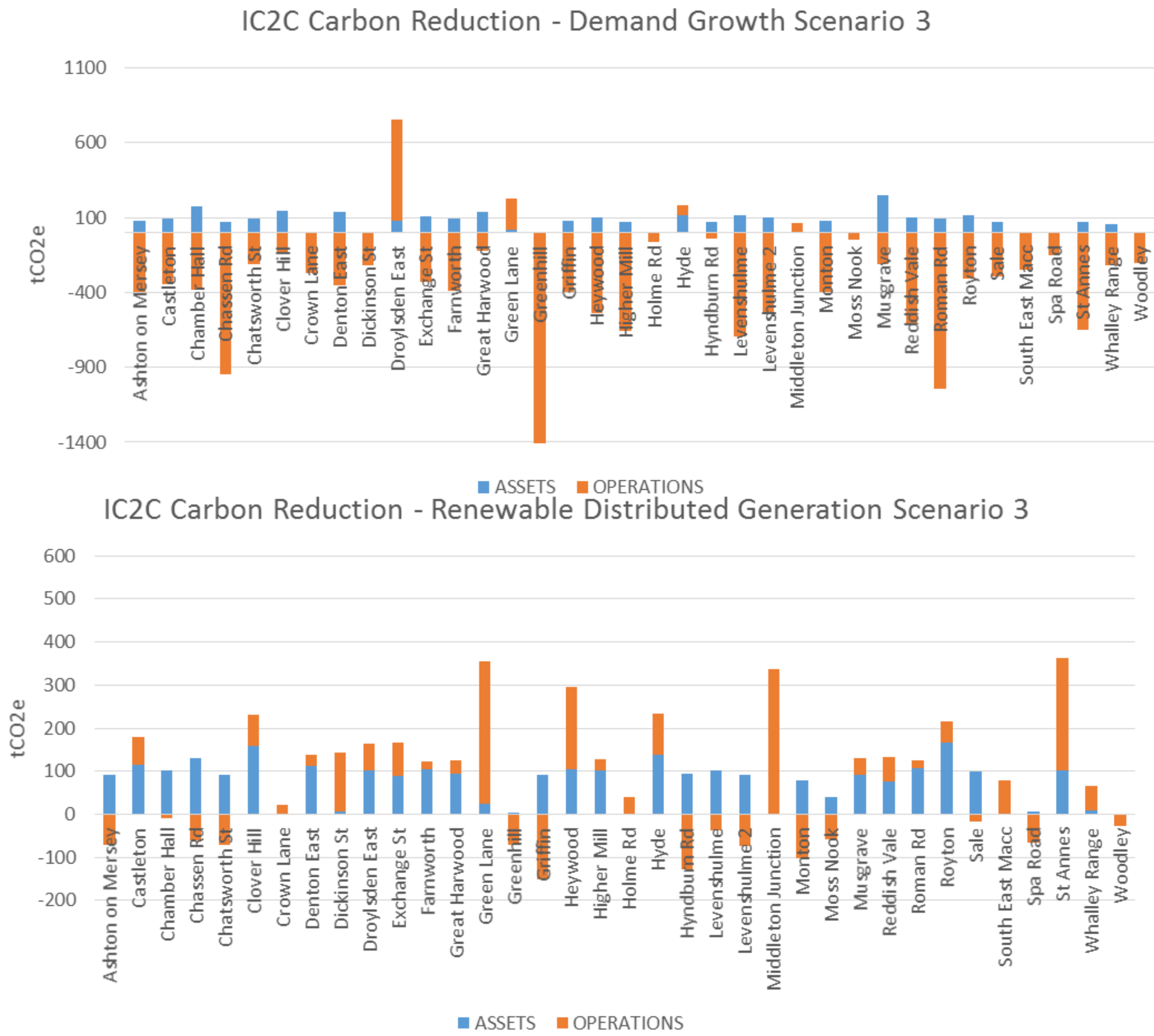


Figure 6

2.7 Grid emissions factors assumptions make a larger difference to net carbon impact than the variation between growth scenarios

The composition of the UK grid could vary substantially over the coming decades, as could the marginal plant that provides the final unit of electricity consumed as losses and hence their carbon content. This can make a major difference to the quantitative and qualitative outcomes by altering the balance between assets and operational carbon. As Figure 7 illustrates, if we assume that combined cycle gas turbines are the marginal generator over the 45 years considered then losses become a more significant issue. The OSS optimisation method is also therefore favoured.

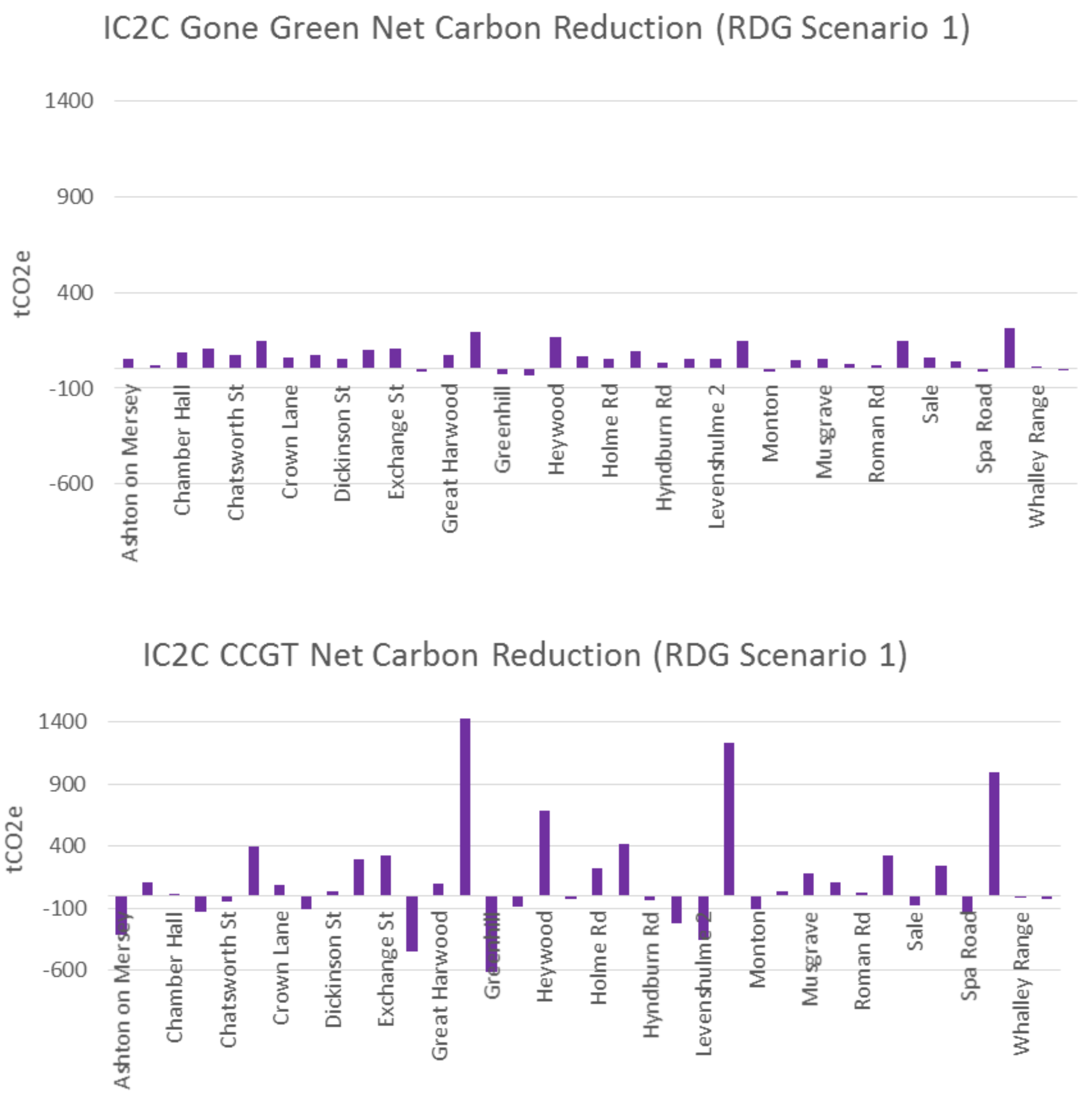


Figure 7

2.8 The net impact is highly diverse with respect to the circuit that C_2C may be deployed on.

For the set of scenarios where increases in network demand are simulated, traditional reinforcement triggered by capacity constraints can lead to a substantial network losses improvement. The use of DSR and interconnection in the C_2C method does not trigger such investments and increases utilisation of existing assets. This results in a lost opportunity to reduce operations carbon impact which the OSS algorithm identifies. Such modelling approaches applied to the roll out of C_2C could lead to significant benefits.

3 Further Discussion

As well as the specific outcomes in relation to the C_2C trial, this carbon impact assessment has identified a number of important issues in the consideration of the carbon impact of smart grid solutions.

1. A new method for estimating emissions reductions from direct and indirect sources has been demonstrated including a means of calculating short term facilitated carbon reductions, a novel impact category in the GHG accounting literature. Trial scale and future scenarios have been defined, boundaries clarified, baselines established and data sources identified.

2. Capacity released is a poor proxy for net carbon impact. Facilitated reductions are highly conditional on assumptions, vulnerable to double counting, and for the demand growth set of scenarios examined, substantially lower than the absolute changes identified in assets and operations carbon.

3. A demand growth trend increases the losses in all circuits as they approach their firm capacity. In the base case this phenomenon is partially offset by a reduction in losses that accompanies the introduction of traditional reinforcement assets, however, smart solutions such as C_2C will enable greater utilisation of assets and defer capital network investment at the expense of comparatively higher losses. The balance depends upon the carbon content of these losses.

A final caveat on both operations and facilitated impacts should also be borne in mind. Carbon emissions arising from the EU power sector are capped by the operation of the EU Emissions Trading Scheme (ETS) up to 2020 and there is the expectation that this will carry over to 2030. As a result, whilst changes in energy consumption are always well defined, the ultimate effect on emissions may not be. The GB grid is supplied almost entirely by installations regulated under EU ETS caps and any savings of electricity do not affect the final volume of emissions from the sector as a whole; the same quantity of permits persists and may be surrendered elsewhere rather than being used by GB generators. Nonetheless, the period is short relative to the lifespan of the assets involved and estimating potential emissions savings is valuable for comparing different technical interventions.

4 Acknowledgements

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- Dr Rita Shaw, ENWL first proposed the analytical framework and provided some emissions factor.
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