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Using proxies to calculate the carbon impact of investment into electricity network assets

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HIGHLIGHTS

- Proxies are developed to estimate embodied carbon impact of network assets (kg/£).
- Regional proxies are developed for the GB network as a case study.
- Proxies are applied to GB data to show embodied carbon impact of RIIO-ED1 investment.
- Results show RIIO-ED1 investment could contribute 10,000 T CO_{2eq} in one GB region.
- It is shown that DG could save carbon if it defers investment in network assets.

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ABSTRACT

Replacement and upgrading of assets in the electricity network requires financial investment for the distribution and transmission utilities. The replacement and upgrading of network assets also represents an emissions impact due to the carbon embodied in the materials used to manufacture network assets. This paper uses investment and asset data for the GB system for 2015–2023 to assess the suitability of using a proxy with peak demand data and network investment data to calculate the carbon impacts of network investments. The proxies are calculated on a regional basis and applied to calculate the embodied carbon associated with current network assets by DNO region. The proxies are also applied to peak demand data across the 2015–2023 period to estimate the expected levels of embodied carbon that will be associated with network investment during this period. The suitability of these proxies in different contexts are then discussed, along with initial scenario analysis to calculate the impact of avoiding or deferring network investments through distributed generation projects. The proxies were found to be effective in estimating the total embodied carbon of electricity system investment in order to compare investment strategies in different regions of the GB network.

1. Introduction

It is estimated that the transition to a low carbon electricity system for the GB electricity network could require investment of 8.8 bn GBP in reinforcements on the Transmission Network (Tx) [1]. These network investments would have embodied carbon impacts due to the materials and construction activities associated with network assets, such as the installation and upgrade of cables and transformers. Investments in new network assets will aid and enable the transition to a low carbon electricity supply but their associated emissions should be quantified and taken into consideration when deciding on investment strategies.

The impact of Demand Side Management (DSM) or Distributed Generation (DG) projects on Network Investment has been investigated by a number of researchers, each taking a different focus, due to the number of ways that DG can affect the network. These impacts include minimising losses [2] and potentially deferring network investment by reducing peak demand [3], and the financial impact associated with Network Investment Deferral has been calculated [4,5] in several local models and the possibility of DSM and DG contributing to reduced investment costs and therefore emissions is discussed in several papers. However, there is often no attempt to quantify this environmental impact. For a DG owner or DSM project operator, assessing the environmental impact of

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Nomenclature

PD_{Dx}	change in peak demand at distribution level over RIIO-ED1 (kW)
AEF	Average Emissions Factor
C_{DG}	Distributed Generation capacity (kW)
CRC	Carbon Reduction Commitment
CSR	Corporate Social Responsibility
DG	Distributed Generation
DGE	Displaced Grid Emissions (kg)
DNO	Distribution Network Operator
DSM	Demand Side Management
Dx	Distribution Network
EE_{Dx}	Distribution Network embodied emissions due to RIIO-T1 investment (kg)
EE_{Tx}	Transmission Network embodied emissions due to RIIO-T1 investment (kg)
EF_{DG}	Distributed Generation emissions factor (kg/kW)
EF_G	grid emissions factor (kg/kW)
EP_{Dx1}	Distribution Network emissions proxy Method 1 (kg/£)
EP_{Dx2}	Distribution Network emissions proxy Method 2 (kg/£)
EP_{Tx}	Transmission Network emissions proxy (kg/£)
$I_{RIIODx1}$	RIIO-ED1 investment Method 1 (£)
$I_{RIIODx2}$	RIIO-ED1 investment Method 2 (£)
I_{RIIOTx}	RIIO-T1 investment (£)
IP_{Dx}	Distribution Network Investment Proxy (£/kW)
L_{OHLDx}	length of overhead line in Distribution Network (km)
L_{OHLTx}	length of overhead line network in Transmission Network (km)
L_{UGCDx}	length of underground cable in Distribution Network (km)
L_{UGCTx}	length of underground cable network in Transmission Network (km)
LCA	Life Cycle Assessment
$LRI_{RIIOED1}$	RIIO-ED1 load related investment (km)
NCR_{OHL}	RIIO-ED1 new cable requirements for overhead lines (km)
NCR_{UGC}	RIIO-ED1 new cable requirements for underground cables (km)
OE_{DG}	operational emissions of Distributed Generation (kg)
OHL	overhead lines
OHL_{CO_2}	carbon intensity for overhead lines (kg/km)
OHL_{GBP}	investment intensity for overhead lines (£/km)
PC_{OHL}	asset proxy component for overhead lines (£/kg)
PC_{UGC}	asset proxy component for underground cables (£/kg)
PEF	Peak Emissions Factor
SG	standby generator
SO	System Operator
T_{DG}	run hours of Distributed Generation (hr)
Tx	Transmission Network
UGC	underground cables

their projects could become vital as carbon footprint reporting becomes mandatory. It is especially important for certain DG owners such as owners of standby generators (SG), which are often diesel fuelled. Diesel generators are the most commonly installed DG technology worldwide and are often used for network support through contracts with the SO to run at time of peak demand. Running diesel generators emits carbon locally, which can have a negative brand impact or financial impact depending on the company size and regulatory framework. The carbon emitted locally is higher than the average grid emissions factor in the GB electricity system. An average diesel generator emits 700 g CO_2/kW h, whereas average grid emissions factors range from 430 g CO_2/kW h to 520 g CO_2/kW h [6]. It is therefore important to consider the long term impacts of running diesel generators in supporting the electricity network.

Assessing the impact of Network Investment and Network Investment Deferral is challenging for an individual project-by-project basis as a Life Cycle Assessment (LCA) would need to be carried out, which is a data-intensive and time-consuming process. However, applying a proxy, or emissions factor, provides an estimate that could be used to evaluate and compare a range of different project options. A proxy is a factor used to convert one unit to another. Being able to apply a proxy to convert between investment and investment deferral to the amount of embodied carbon associated with that investment would allow for an estimate to be generated based on data that is readily available to either the Transmission Network System Operator (SO) or Distribution Network Operator (DNO).

It is therefore the aim of this paper to identify an appropriate proxy that can be used to estimate the embodied carbon associated with network assets, given either network investment or increase in peak demand over a given time, in order to consider the total carbon impact of running a DG unit in support of the electricity network. The GB system is used as a case study given the availability of peak demand data and investment data over a set period of time. The GB SO, National Grid, have contracts with owners of 743 MW of diesel generators for network support [7], which are regularly used in times of peak demand. National Grid have recently acknowledged the importance of calculating the carbon associated with network support [8]. These calculations are not complete without an assessment of the embodied carbon impact of delaying network investment.

2. Motivation

There are two key benefits of the proxy described above for the SO and DNO: they can calculate the embodied carbon cost of peak demand growth under current investment strategies; and they can use the proxy to assess other options for peak load reduction for potentially lower carbon solutions.

At present in the GB system, the second benefit may be more applicable to the SO due to the fact that the DNO cannot arrange contracts for ancillary services like the SO can. However, in the future, DNOs may have some control over using different methods to manage their network investment requirements and they may wish to evaluate the carbon impacts of several options before deciding on an investment strategy. In addition to this, DG owners may wish to understand the carbon impact of running their DG on the network as part of their CSR policy or environmental strategy,

The use of DG and DSM is likely to increase as the transition to a low carbon electricity supply progresses. The running of company owned DG and SG may be incentivised inherently by the electricity pricing structure, as is the case in the GB electricity market [9], or through formal contracts with the SO in times of extreme peak demand. However, when running different forms of DG, in particular SG, carbon emissions may be emitted locally. The associated carbon emissions can have a branding impact as well as a financial impact for the DG owners. Although the contracts and inherent incentives are designed to cover fuel costs, they are not designed to cover the cost of emissions to the DG owner. For example in the UK, larger electricity consumers on a half hourly metered tariff pay the Carbon Reduction Commitment (CRC) at 16.40 GBP per