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Abstract

There is much debate around the best way to provide accurate and meaningful environmental footprinting for infrastructure-based businesses; difficulties in scoping and lack of data for assets are just some of the "roadblocks" to a successful outcome. In this paper we will use two case studies (Transit (NZ) and Orion New Zealand Ltd) to illustrate frameworks for environmental profiling for infrastructure projects.

Transit (NZ) plan to determine the environmental footprint of its activities over which it has direct control using a greenhouse gas inventory. Transit wish to respond to government emissions reduction targets in a proactive way. The main confounding factor remains that the environmental impact of the design, construction, operation and maintenance of roading networks is only a small part of the total impact of the roading network over its full life cycle.

We will present options considered to respond to Transits requirements, the difficulties in scoping and how scaleability of solutions is important when dealing with large, multi-site, subcontractor dominated businesses.

Orion New Zealand Ltd has recognised that its corporate responsibility around GHG emissions extends beyond a narrow footprinting exercise. Orion set an ambitious target to measure the footprint of its primary equipment, impact of all its activities and the impact of the subsidiary Connetics.

We will elaborate on the challenges of the project including how the GHG footprint was calculated and the processes involved in setting a meaningful scope. Orions' award winning Asset Management Plan provided detailed data which was converted from the language of an electricity distributor into data compatible with the chosen calculation method – Life Cycle Analysis (LCA). We will discuss why LCA was chosen as the assessment method. The result was an objective, quantified assessment of the GHG

footprint of the network and a document enabling Orion to communicate the findings of the project.

Introduction

Our world is under increasing pressure from a rapidly growing population and resource demand is greater than ever. Accordingly environmental concerns such as resource demand and waste reduction are now of significant interest to stakeholders and communities.

In European countries, many sectors are driven by government targets to assess and reduce their carbon emissions associated with resource use. For example in the United Kingdom, the Water Services Regulation Authority, now requires water companies to quantify the carbon emissions associated with their proposed investments to meet the government targets for carbon emissions reduction.

Investing in a new asset (or improving an existing one) will lead to embodied carbon emissions associated with its construction. As a result of the operation of the asset, the cumulative carbon emissions increase over time, through emissions from energy and from transport movements, for example.

The challenge for companies is to select investment options that over their design life lead to overall emissions reductions. The first step must be to develop a framework for carbon accounting across construction, operation and maintenance. In the United Kingdom for example the UK Water Industry research (UKWIR) has already made significant progress in establishing a standard approach through a suite of projects and MWH has been involved in developing guidelines for estimating embodied carbon and ‘whole life carbon’ accounting.

The embodied carbon emissions associated with a manufactured product life cycle are the direct and indirect emissions of greenhouse gases (GHGs) resulting from all steps from raw material extraction to waste disposal (cradle to grave), expressed as carbon dioxide equivalent (CO_2e). A study of whole life carbon of an asset can identify ‘hot spots ’, which indicate which activities during the asset life cycle contribute the most to carbon emissions (Baumann & Tillman 2004). Companies then need to adapt and apply the carbon accounting guidelines to help develop, promote and implement innovative low carbon solutions to assist in reducing emissions.

In New Zealand, many organizations are interested in developing whole life carbon accounting guidelines for their sectors. MWH is currently working with Orion, one of New Zealand’s largest electricity distributors, to develop a framework for assessing the carbon footprint of the organization, including the embodied carbon of its primary network. This paper will discuss which methodology was used to assess the whole life carbon footprint of Orion's primary network.

Orion's main driver to initiate the carbon footprint assessment is to better understand where it should focus its efforts to achieve the largest carbon emissions reductions. The assessment will also be used to communicate to its stakeholders the nature of their environmental impacts and to quantify them in terms of carbon emissions. Not only will Orion create a key point of difference with this unique reporting approach, but the Government-owned organisation also obtains essential data that provides an informed and quantifiable dimension to its strategic decision-making.

The carbon inventory for Orion has largely been developed based on the methodology that MWH in the United Kingdom developed for the water industry, however the methodology has been tailored for electricity distribution. The carbon footprint assessment of Orion is underway and is expected to be completed at the time of this conference; hence, this paper will limit discussion to the overall methodology for carbon emissions estimation for asset planning associated with electricity distribution, and further results will be presented at conference.

Transit's main driver for planning a greenhouse gas inventory framework for the network was to take a proactive approach to achieving government targets around greenhouse gas profiling and be able to respond in a pragmatic and timely fashion to new regulatory initiatives.

What follows are details of the two very different approaches taken by Orion and Transit to achieve their objectives of environmental profiling and what was learned in each case.

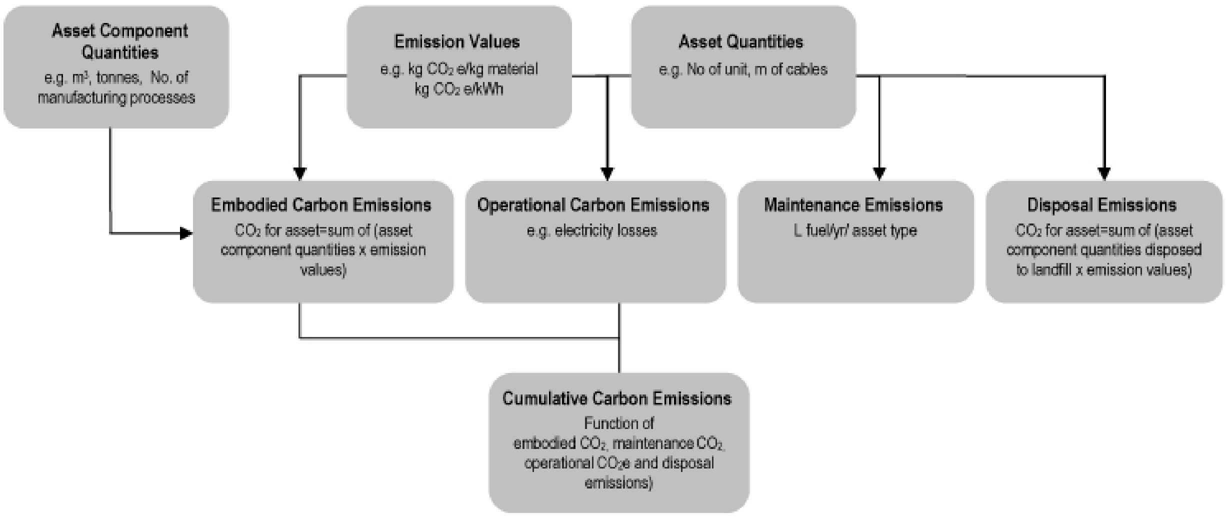
Methodology

Orion Carbon Accounting

The methodology chosen for carbon accounting depends upon the desired outcome an organisation wants to achieve. For example, the tools developed by MWH for the UK Water Industry aimed to make the future net damage costs of climate change from carbon emissions evident in investment decisions and to help drive sound investment choices that have lower carbon emissions.

For Orion, a similar methodology was selected, and to attain a 'whole life carbon' assessment for its infrastructure, many aspects of their assets needed to be included in the study. These are summarised in Figure 1.

Figure 1. *The whole life carbon emissions are a function of: the embodied emissions from any initial construction or components of assets installed, emissions from operational and asset maintenance, asset design life and emissions associated with waste disposal.*



The methodology used for carbon accounting for Orion is based on the pragmatic principle that whole life carbon accounting should follow the same principles as cost accounting and, as far as possible, use the same asset input data. This means that embodied carbon estimation for construction aims to use the same structure and input data as cost estimation for construction. For assets which are manufactured from several raw materials, the estimation is based on information provided by the suppliers. In general, accounting boundaries for whole life carbon costing follow the same rules as those for Capex and Opex costing. Orion wanted to focus on assets which are currently installed into the network and the assessment included any assets which were added to the network during the financial year of 2007.Based on the principles of Figure 1, whole life carbon can be split into 5 key elements as described below;

1. Embodied Carbon Emissions ('cradle-to-site')

For Orion, the embodied emissions components to be estimated include:

- Extraction and processing of raw materials, which make up asset components or construction material used
- Manufacturing of final asset/product (if applicable)
- Transport from supplier to site

The emissions arising from the extraction and processing of raw materials are commonly quoted in terms of the ‘cradle-to-gate’ boundary condition. Adding the emissions from the transport of materials to the ‘cradle-to-gate’ emissions gives an estimate of ‘cradle-to-site’ emissions.

A product such as a transformer or underground cable may be made up of several different materials, each of which undergoes some processing before assembly into the component. Emission factors were used for raw materials and since these factors generally only cover the emissions associated with each particular raw material, an allowance was added for the energy used in manufacturing the product and its transport to site to calculate the carbon emissions associated with that particular asset. An emissions value is the amount of carbon emissions per unit quantity.

In determining quantifiable impacts of raw materials, it is very important to have access to reliable and relevant emissions factors. There are relatively few emission factors calculated for New Zealand and the calculations of Orion’s carbon footprint often used data from a European database that contains harmonised industrial international LCA data.

Excluded emissions comprise any emissions associated with the manufacture of plant used for extraction and processing of raw materials, as well as any emissions associated with the construction of factories and the manufacture of factory equipment.

2. Embodied Carbon Emissions (‘Site-to-built asset’)

To estimate the carbon emissions related to the installation and on-site construction (if applicable) of the assets, Orion will utilise the capex costs which have been estimated for this stage of the asset life cycle. These are accurately calculated since Orion has contractors installing and servicing their entire network. Off-site disposal of any waste created from the installation/construction is also estimated.

When installing an underground cable, the emissions will for example include those resulting from trenching, transport of backfill and disposal of any excavated soil off site.

There are also emissions associated with design and project management before and during the construction process, which result from the heating and lighting of staff offices, travel for meetings and site visits, use of computers and consumables such as paper. These emissions will only be accounted for under Orion’s office related emissions and will not be allocated to individual asset types.

3. Operational emissions

The main operational emission related to electricity distribution is ‘distribution losses’ which are simply the difference between the electricity entering the network and that leaving the network excluding any electricity consumed internally by the network company. Orion has recorded an average annual network loss of 4.9%. The exact methodology to account for these losses has not yet been determined. Depending on the accuracy of data available, it may be possible to calculate operational emissions per asset type.

4. Maintenance emissions

Orion has several contractors responsible for servicing the network. For overhead lines, the contractor is for example responsible for tree cuttings to maintain clearance around the line and safety inspections of towers and lines, etc. There are maintenance schedules outlined for all of Orion's assets together with detailed opex cost estimations. The carbon footprint calculations are based on this source of information.

5. Demolition and disposal of asset at end of life ('built asset-to-grave')

At this point in time, it has not been agreed how the emissions associated with the decommissioning and disposal of an asset at the end of its life, will be estimated. It is dependent on the level of details that the contractors can provide, since they are accountable for any disposal. Many of Orion's assets contain metals, e.g. circuit breakers, cables, lines, transformers, and the majority of this is currently recycled. The average design life span of Orion's assets is approximately 40 years. Given the long timescales and the considerable uncertainties associated with any future use, reuse and disposal of an asset, there is likely to be limitations to the accuracy of this part of the carbon footprint assessment.

To summarise, the embodied CO2e emissions associated with one unit of a particular construction item or asset (such as 1 metre of 33kV Copper Underground Cable or one unit of a 33/11 kV Circuit breaker) is defined as the sum of the emissions from the raw materials, manufactured products, in-situ construction activities, off-site removal of waste necessary to create that one unit, asset specific maintenance and operational losses and the emissions from disposal of the asset at the end of its life.

For example, using 1 metre of 33 kV Copper Underground cable as a working example, the embodied emissions include:

CO2e (unit) = one metre of 33kV Copper Underground cable

CO2e (material) = Raw materials which makes up an asset, e.g. Copper conductor and XLPE insulation.

CO2e (products) = E.g. Manufacture cable from component materials and transport of asset to site.

CO_2e (in-situ works) = On-site temporary works to install asset, e.g. trenching for cable, transport of backfill to site and of waste from site. The emissions will also include those created from construction waste after disposal.

CO_2e (maintenance) = Any scheduled maintenance associated with the underground cable.

CO_2e (waste) = Emissions produced at the end of asset life, e.g. disposal of non-recyclable components of the asset.

Transit Greenhouse Gas Inventory Framework Planning

Transit is a complex business and developing a brief for a greenhouse gas inventory across the key phases of state highway operations namely; route option analysis, design, construction, operation and maintenance, proved challenging.

The complex nature of state highway design, construction, operation and maintenance suggested a wide range of approaches could inform Transit's activities as they related to carbon emissions. Examples include;

International best practice
A review of other road controlling authorities' practices could inform an overview of how others assess, reduce, monitor and benchmark the GHG implications of their activities as they relate to:

1. Route option analysis: implications of highways on local road networks, public transport, walking and cycling, induced travel

2. Design: embodied energy of aggregate materials (recycled versus raw), whole of life cycle costs, lighting specifications, planting

3. Construction: transporting material and labour to, around and from site, haulage vehicles causing adverse effects in already congested areas, biofuels on site

4. Operation: traffic counts, levels of service (free flow versus congestion)

5. Maintenance: fuel use, material use, replanting and offsetting

GHG implications of route options
The analysis of route options within the investigation and reporting phase of scheme assessments could pay closer attention to the carbon dioxide emission effects of different schemes. Transport modeling software assesses the impact of road design on traffic patterns, fuel usage and therefore carbon dioxide emissions. Currently, GHG emissions are assigned a monetary value for cost benefit analysis. Transit could consider a review of scheme assessment processes to ensure the inclusion of global warming effects from a broader sustainability perspective rather than just the current economic focus.

Design
Transit may request detailed analysis of GHG implications of design considerations as part of pavement and lighting specifications. Over time, specifications may enable benchmarks to be set for embodied energy requirements of pavement materials. Transit's own technical specifications could be reviewed to calculate the likely carbon footprint of various materials, which would be a useful industry standard for reporting and design comparison purposes. Transit's Guidelines for Highway Landscaping may be strengthened by encouraging low maintenance vegetation that will enhance GHG offset opportunities.

Construction
A GHG footprint methodology during construction could be based on:

- Journey to and from work for labour
- Transport of materials
- Fuel use on site, amount and type

A toolkit of things to consider to reduce the footprint of each site could also be developed. A review of Transit's leading project practices, contract proforma and contract management review processes to ensure GHG footprints were a mandatory component of environmental management plans for future works is also a possibility.

Operation
GHG emissions profiles could be established for each region based on fuel use, congestion factors and travel mode splits.

Transit (NZ) could work collaboratively with territorial local authorities and regional councils to assess the risk profiles of communities' access to key destinations in future scenarios that incorporate fuel shortages.

Maintenance
The operational GHG template developed for existing Transit (NZ) networks in the regions could be used to calculate the fuel usage profile of each region, reduction strategies and offset options.

Results

At the time of the conference, MWH will have results from assessing embodied carbon emissions of Orion's electricity network. A selection of examples will be presented as a case study of pragmatic carbon accounting for Orion's infrastructure. Planning of the Transit (NZ) greenhouse gas inventory framework remains at the proposal stage, the presentation will advise on which (if any) options become implemented.

Conclusions

Orion's carbon footprinting initiative is believed to be the first of its kind in New Zealand amongst electricity distribution companies. The science of carbon accounting is developing and the proposed methodology used for this project together with the emissions values chosen are considered to be preliminary and subject to advances in this evolving field.

The study is Orion's first step in addressing climate change issues associated with its business and in determining the extent of GHG emissions the company is effectively responsible for as a result of the annual expansion and maintenance of the network. Orion initially hoped to measure the embodied carbon footprint of their entire network. The project scope was narrowed and defined to only assess its annual emissions as Orion realised the complexity of the task. It was decided to mainly focus on the asset types which are currently used in the network and how these impact the environment. The assessment will guide Orion's decisions on which types of assets to install. The scope was adjusted since Orion has no plans to replace any historic assets until these have reached their end of life and are due to be replaced, even if they prove to have a significant carbon footprint. The study will become the first step in achieving a more environmentally conscious decision-making process when planning for network expansion and replacement of historic assets.

The electricity sector is principally driven by local government and legislation to provide a network to support community growth. It is important to remember that Orion is restricted by the regulatory framework and will often not have many options to choose from when selecting the nature of transmission infrastructure. For obvious reasons, Orion owns many assets which are made of metals with an inherently high carbon footprint. By taking a life cycle approach, the study will evaluate the potential global warming effects that an asset has on the environment over the entire period of its life cycle. Orion wants to find out where there are improvement possibilities during the life cycle of the assets in its primary network.

The accuracy of the footprint is dependent on various factors, such as available data from suppliers, contractors and internally within Orion. Accessing suitable emission factors is also challenging and since most assets are purchased from Europe, America or Asia, there may be no emission values estimated for some of these countries. Where possible, emissions factors will be chosen based on the geographic location. When emissions occur in New Zealand, e.g. transport to site, excavation, and waste disposal, local emission factors will be applied.

At the time of the conference, further key learning from this carbon accounting project will be presented and discussed.

Further Work

Orion Carbon Accounting

As a result of this initial assessment of the carbon footprint of its primary network, Orion wishes to explore opportunities to reduce its emissions. This may include developing tools to assist its strategic planning process and decision making towards more environmentally preferable choices. The information gained can help to assess the environmental impacts when Orion is planning for replacements and growth of its network. The tools should complement Orion’s existing methodology for planning of network expansions. The next phase will include further detailed study on carbon footprint impacts from various options which are feasible. At the time of the conference, further thoughts about additional work will be discussed.

The assessment of Orion’s carbon footprint is a first attempt of its kind in New Zealand and better methodologies will be refined over time when more New Zealand specific data becomes available.

Transit Greenhouse Gas Inventory Framework Planning

Once Transit has reached a decision on its preferred approach for implementation of a New Zealand wide greenhouse gas inventory, the project will proceed. It is likely that the project will start with a pilot trial on a single regional network project, before implementing it on a national scale.

Further Research

Life Cycle Analysis and carbon footprinting is a rapidly emerging field in New Zealand. There is already agreement regarding many local emission factors relating to stationary combustion of fuels, transport fuels and electricity for example, however there is a need to also assess emissions factors for common processes and products in New Zealand. With increasing amounts of benchmarked LCA studies for key infrastructure assets that are in common to private and government owned organisations, there will be more thorough methodologies defined.

In the future we may see a regulatory framework that has the ability to be able to incorporate true life cycle costs into legislative drivers.

References

Baumann. H., & Tillman. A-M., (2004) The Hitch Hiker's Guide to LCA: An orientation in life cycle assessment methodology and application. Studentlitteratur AB, Lund.

Salem, O., Abourizk, S., & Ariaratnam, S. (2003). Risk-based life-cycle costing of infrastructure rehabilitation and construction alternatives [PDF], Journal of Infrastructure Systems, 9(1), 6-15 .

Zou, P.X.W., Wang, S., & Fang, D. (2008). A life cycle risk management framework for PPP infrastructure projects [PDF], Journal of financial management of property and construction, 13(2) 123-142.