Net Zero Accounting for a Net Zero UK

Professor Ian Thomson, Professor Penelope Tuck, Dr Charika Channuntapipat, Dr Robert Charnock, Dr Nana O'Bonsu and Dr Jennifer TyreeHageman.

University of Birmingham, UK.

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Executive Summary and Implications

- Inappropriate GHG accounting choices result in decision makers selecting options they mistakenly ***believe will reduce*** GHG emissions when they will increase global GHG emissions.
- The success of the UK Government Green Industrial Revolution relies on evidence produced from reliable, relevant GHG accounting methodologies that capture life cycle GHG consequences from all programmes, policies, projects and actions
- Concern that the official UK Government GHG accounting methodology could act against the aspirations of the UK Government's Green Industrial Revolution
- There are potential conflicts between the required use of different official ways of calculating GHG emissions, for example DEFRA GHG business reporting guidelines, UK Net Zero protocols and the Green Industrial Revolution. These need to be understood and resolved.
- There is a need to work together. Net Zero will not be achievable from uncoordinated individual choices, but rather from chains of decisions that require collaborative actions from many institutions with different objectives.
- GHG accounts are critical to successfully coordinating these decision chains, but only if the right GHG accounts are used. Therefore decision makers need the expertise to select the right accounting methods so that the whole life cycle of emissions is captured.
- Concerns that decision makers lack the capacity and appropriate levels of climate literacy to make this choice
- What is meant by Net Zero? The term net zero is ambiguous and lacks a robust meaning in all organisations outside government.
- Justification. All decision makers will need to be able to justify their definition of net zero and account for how they are contributing to the UK climate targets and those of international climate conventions.
- Holistic approach. Any GHG accounting that does not tackle climate risk holistically or adequately measures impact on global levels of GHG in the atmosphere only passes the problem somewhere else along the chain and forward in time.

Why accounting?

Imagine if every raw material, product or service came with its own account of greenhouse gases (GHG) as well as a price tag. A GHG account that identified every process, energy use, resource consumed or distance transported across the product lifecycle. Just as with costs, decision-makers need to know the GHG emissions of anything they buy, sell and do as well as understanding how much bigger they could become. Net Zero aspirations require full GHG accountability from all those involved with making decisions including politicians, investors, regulators, tax authorities, business, customers and other stakeholders. Net Zero requires decision-makers to be carbon sensitive and climate literate in order to connect what they plan to do with consequential GHG emissions.

Many organisations have managed to make significant dents in their GHG emissions by using appropriate GHG accounting methods, such as Science Based Targets, that consider the GHG associated with every aspect of their operations. Decision-makers need to account for how every decision drives GHG emissions up or down. These include: what you buy, who you buy from, how it gets to you, what you invest in, how you heat your buildings, how much you waste, how you design your product, how you make, sell and ship your product, how employees get to work, how you finance your operations, how and where you sell your product and what people do with your product.

It's important to identify what increases the GHG emissions of anything you are planning to buy or sell. Think about what has had to be done to transform that 'thing' from its origins somewhere on or within the planet to the 'thing' that turns up at your warehouse, office or shop floor. The decisions taken by you, your suppliers and your customers will impact on the actual GHG emitted into the atmosphere.

There are lots of ways decision-makers can align their decisions with the UK Net Zero strategy and Green Industrial Revolution. These include

- Saving GHG emissions arising from operations within their organisation
- Saving GHG emissions from those involved in the supply of goods / services that they consume
- Saving GHG emissions for those who they provide goods and services to
- Incentivise investments in zero carbon initiatives and businesses
- Enable others to make better decisions and choose more net zero products and services
- Reduce likelihood GHG intensive products / services will be purchased
- Increase likelihood zero carbon products / services will be purchased
- Enable others to consume / use / dispose of products and services in a way that reduces GHG emissions
- Enable others or natural systems to take GHG emissions out of the atmosphere

Net zero will not be achievable from uncoordinated individual choices, rather it requires purposeful decision chains consisting of individuals and institutions with different, potentially conflictual, objectives. For example, it is a positive step to create innovation funds to develop new improved heat pumps, but it is only when consumers actually purchase 'new improved' heat pumps and replace their gas boilers that actual reduction in GHG emissions will begin to accrue. All decisions and actions until that point e.g. public subsidy of new product development, tax subsidy to reduce price, only enable this possible reduction. These antecedents are necessary, but not sufficient to actually reduce the concentration of GHG in the atmosphere.

GHG accounts are critical to successfully coordinating these decision chains, but only if the right GHG accounts are used at the right time. This requires selecting appropriate GHG accounting methods for each decision in a way that aligns all the decisions in a chain. It is important that decision makers are able to make meaningful choices as to which GHG measures to use in different contexts and are aware of the consequences of these choices.

For example, the GHG accounting method designed to monitor UK's compliance with the 2015 Paris Accord (see Figure 1) is inappropriate for consumers choosing how to heat their home and if used in this context is likely to lead to sub-optimal choices. This because this method does not capture the full life cycle GHG emissions of

producing these heating products nor does it include future GHG reductions. As will be explained later it also creates an unintentional bias against products produced in the UK relative to imported products.

Inappropriate GHG accounting choices result in decision makers selecting options they mistakenly ***believe will reduce*** GHG when they will increase global GHG. Given the low levels of carbon literacy of most decision makers, we argue that the choice of how to account for GHG cannot be left to chance. There is a need for urgent research and education programmes to communicate the biases and critical exclusions of different GHG measurements, in order to inform the choice of appropriate GHG accounts in different decision contexts.

Our study identified at least 45 decision contexts connected with the 10 Point Green Industrial Revolution (10GIR)that need to be aligned and co-ordinated through careful GHG accounting choices. There is a clear need for different methods of calculating GHG emissions for different purposes, but there is also a need to ensure the integrity of the decision chains needed to make the necessary reduction of GHG in the atmosphere.

All organisations operating in the UK will need to demonstrate how they plan to go 'net zero'. This will require accurate and comprehensive measures of the size and sources of their GHG emissions, including their cumulative GHG debt and future liabilities. Decision makers at each stage of net zero decision chains will have to be clear what 'net zero' carbon means and include it as a decision outcome. At a National level, net zero is defined by international conventions or legislation, typically using the Paris Agreement definition and the UK Government has chosen to measure this by adapting a well established form of GHG Accounting, which we have labelled NET ZERO UK. NET ZERO UK quantifies the amount of GHG emissions to be balanced by the emissions removed from the atmosphere through carbon capture or off-setting schemes, like storing emissions underground or planting trees. Getting this benchmark wrong means misinforming myriads of other critical decisions.

However, for all others, e.g. businesses, communities and individuals, 'net zero' lacks a robust meaning. Businesses can define 'net zero' to exclude their historic GHG emissions and the current GHG emissions incurred in any raw materials used, existing assets, business investments, purchase of new technology and any carbon emitted after a product is sold. Typically businesses use existing corporate reporting GHG emission protocols, such as DEFRA GHG (2019) or Stock Exchange listing requirements, to define their 'net zero' benchmarks. However, these GHG corporate reporting methods are incomplete and if used inappropriately systematically distort the representation of corporate GHG emissions and any decisions where they are used.

For example, vertically integrated supermarkets like the Co-Op will have higher reported GHG emissions in their Corporate Reports simply because they grow much of their fruit and vegetable rather than buy from independent suppliers. This is because most GHG Corporate Reporting protocols excludes the GHG emissions of purchased goods or services. According to DEFRA GHG if you grow the food you sell, then you have to report it. If you buy in the food you sell, then you don't have to report it regardless of where or how it is produced. Nor do you have to report on the GHG emissions in shipping it to the UK. Even though the Co-Op's business model is more likely to result in lower global GHG emissions, using DEFRA GHG they will report higher GHG emissions than other supermarkets. Paradoxically using DEFRA GHG the Co-Op could ***appear to reduce*** their GHG emissions, by closing down their farms and sourcing all fruit and vegetables from overseas. A course of action that flies in the face of the concepts underpinning 10GIR as well as best practice in the field of net zero carbon management.

Decision-makers need to be able to justify how they measure 'net zero', because powerful stakeholders will start to hold them to account for the consequences of their actions on GHG emissions, including the timeframe of these measurements and to what extent they are paying off their historic GHG debts. These stakeholders will expose politicians, regulators or businesses trying to find 'smart' ways to achieve 'net zero' by employing creative GHG accounting techniques as they perpetuate the global game of GHG pass-the-parcel.

For many NET ZERO UK will be far too low a benchmark, particularly those that accept full or partial responsibility for their historic GHG emissions across their value chain[1]. Going beyond NET ZERO UK is much more likely to future-proof the organisation against the likely introduction of carbon rationing, predicted climate change trajectories and changing social attitudes. Narrowly defined net-zero benchmarks, such as NET ZERO UK or

[1] We use the term value chain to refer to an organisations supply chain – where they source their goods and services - and to their after sale activities – what happens to the goods and services they provide to others.

DEFRA GHG do not differentiate sustainable reductions to the global GHG in our atmosphere from those off-balance sheeting[2] these emissions. The time horizon of any GHG accounts is also critical. Given the planetary climate systems are already on a warming trajectory, stabilising the concentration of GHG emissions at present levels, something that would **not** even be achieved with NET ZERO UK or DEFRA GHG benchmarks, only stops a bad situation getting worse.

To illustrate this we have identified four GHG accounting scenarios that quantify the emissions that need 'zeroing':

1. NET ZERO UK. Narrowly defined annual GHG emissions as per Paris Accord from now onwards, based on a territorial GHG production approach[3].
2. FOOTPRINT UK FROM NOW. Full scope annual GHG emissions using all activities defined in UN GHG Protocol from now onward, based on a consumption footprint approach[4]
3. CUMULATIVE NET ZERO UK. Narrowly defined annual and some historic GHG emissions as per Paris Accord, based on a territorial GHG production approach.
4. CUMULATIVE FOOTPRINT UK. Full scope annual and historic GHG emissions using all activities defined in UN GHG Protocol, based on a consumption footprint approach.

Scenarios 1 & 2 are variants of 'net zero from now' whereas Scenarios 3 & 4 take into account the UK's historic contribution to the GHG that are already in the atmosphere and likely to continue to blanket the Earth for the next 2000 years. Note Scenario 1 best represents the UK Government's Net Zero strategy and targets.

These scenarios assume that this particular GHG accounting is used to judge the acceptability of all policy and regulatory interventions, budget allocation decisions, financing decisions, asset valuations and any investment in specific projects. As per latest IPCC and Governmental assessments, our starting point is that the planet's atmosphere already contains too high levels of GHG concentrations. A useful analogy is to imagine our climate system as an overflowing bath – both taps pumping out greenhouse gasses with the plug in and overflow pipe blocked. We will use this analogy to represent the likely impact of the different GHG accounting scenarios

Scenario One – NET ZERO UK

- Zeroing using a partial measure of annual GHG emissions is the equivalent of turning down one tap a little with no change in anything else. It slows the growth rate of GHG in the atmosphere, but the risk of climate change is still growing and the problem is still getting worse. This scenario has little chance of reducing atmospheric carbon below the critical thresholds to meet the 1.5 or 2 degree warming target.

Scenario Two – FOOTPRINT UK FROM NOW

- Zeroing using a consumption measure of annual GHG emissions is the equivalent of turning off both taps. Stabilising the amount of carbon in the atmosphere but insufficient to prevent the changes in the climate systems in the short to medium term. There is still too much historic carbon in the atmosphere to allow us to meet the 1.5 or 2 degree warming targets.

Scenario Three - CUMULATIVE NET ZERO UK

[2] Off-Balance Sheeting refers to a practice where companies, like Enron, exploited loopholes in Accounting Standards to exclude liabilities from their Financial Report. In the case of Enron not only did they exclude loans from their accounts they misrepresented these loans as income from sales.

[3] This approach measures the GHGs produced in a geographical area, such as a nation. It does not exclude GHG emissions on goods and services produced outside this area but consumed within it (imports). It does however include GHG emissions on goods and services produced in this area but consumed elsewhere (exports).

[4] This approach measures the GHG emissions associated with the goods and services consumed by the residents and businesses located within a specific geographic area. Typically the production approach reports a lower figure for developed nations and a higher figure for developing nations. This is reversed for consumption based approach. Note the difference is substantial. Using UK Official Measures the Production figure was only 60% of the Consumption footprint approach.

- Zeroing using a partial measure of present and historic GHG emissions, cumulated say since the 1970s is the equivalent of turning off one tap and pulling out the plug for a short period of time. This slows the growth rate of GHG in the atmosphere and begins to deal with our carbon debt. Over time it could reduce atmospheric GHG to below certain critical thresholds but this may well be too slow a process to meet the 2 degree warming target.

Scenario Four – CUMULATIVE FOOTPRINT UK

- Zeroing using a full life cycle measure of present and historic GHG emissions is the equivalent of turning off both taps and pulling out the plug until the bath drops to a sustainable level. Only once the bath is not overflowing can we manage its level through intelligent co-ordinated operation of both plug and taps. This scenario has the best chance of reducing atmospheric GHG below certain critical thresholds to meet the 1.5 or 2 degree warming target.

It is also necessary to consider the social consequences of the achievement (or otherwise) of UK Net Zero, because reducing carbon emissions isn't just about avoiding climate collapse in the near future, but tackling social inequality now. While the air pollution associated with GHG emissions and climate change affect the health and environment of everyone, air pollution impacts the poorest most severely. The majority of the 8 million deaths each year from air pollution are in developing countries, which also have the least resources to cope with extreme weather events.

Moreover, notwithstanding that the increase in atmospheric carbon dioxide since the 18th century is attributed to the mass industrialisation of the affluent Western countries, the world's richest 10% are still responsible for more than half of all GHG emissions through consumption today, while the poorest 50% create just 10%. The impacts of those emissions are felt unequally across countries with differing GDPs and across different income groups within a country.

Given this it is somewhat paradoxical that the compliance with international climate change conventions is measured using protocols that do not account for the consumption of goods and services. These compliance GHG accounts measure the production of GHG within national geographical territories. This tends to under-represent the GHG impact of those living in richer countries and over-represent the GHG emissions of those poorer countries producing the goods the rich consume. Much of this disparity comes about through an 'out of sight, out of mind' attitude to GHG emissions. GHG are largely invisible and their source difficult to prove, unlike physical waste such as plastic. There is no such thing as throwing 'away' a GHG. It all has to go into the atmosphere where it remains until it is removed and stored in natural carbon sinks. And while South East Asia might be far enough out of sight for the Global North not to worry about plastic pollution, the interconnectedness of life and its many systems – ecological, financial and socio-political – means we can never fully escape the consequences of emitting more than our fair share of GHG.

If governments and businesses keep playing pass-the-parcel with their climate change risks by exporting or outsourcing their GHG, we will not make sufficient inroads towards a net zero world. Even though creative GHG accounts may show we are making a difference, we are really stoking the flames for when the impacts of 'off-balance sheet' emissions return to bite governments, businesses and communities, whether directly or indirectly. Any net zero solutions or GHG accounting that doesn't tackle climate risk holistically only passes the problem somewhere else along the chain and forward in time. And we have run out of space and running out of time.

2. Net Zero and Green Industrial Revolution

UK Government and devolved administrations have ambitious plans for a radical reduction of the UK's contribution to climate change, with targets reported as beyond the reduction needed to hold global average temperature rise to below 2°C. This commitment is embedded within a nexus of international conventions, Global Goals, national and regional strategies, specific policy initiatives, existing regulations and voluntary frameworks. In May 2019 the Committee on Climate Change recommended a new emissions target for the UK: net-zero greenhouse gases by 2050[5]. Underpinning this aspirational target is an assemblage of policy interventions, taxation and subsidies, investment incentives, infrastructure plans and behavioural change projects, summarised in UK Government's 10 Point Plan for a Green Industrial Revolution (10GIR) and presented in Exhibit One.

Exhibit One – Summary of UK Government 10 Point Plan for a Green Industrial Revolution[6]

1. Advancing offshore wind
2. Drive growth of low carbon hydrogen
3. Delivering new and advanced nuclear power
4. Accelerating the shift to zero-emission vehicles
5. Green public transport, cycling and walking
6. Jet zero and green ships
7. Greener buildings
8. Investing in carbon capture, usage and storage
9. Protecting our natural environment
10. Green finance and innovation

10GIR stated intention is to accelerate the UK down a 'net zero' path. It describes a series of interconnected projects that are dependent on robust and meaningful evaluation of their GHG consequences, resource requirements and impacts on socio-ecological systems. Our analysis suggests that achieving net zero through 10GIR is reliant on the quality of evidence produced by GHG accounting systems. However, we have identified systemic misalignments between different GHG accounting methods, 10GIR and the UK's Net Zero aspirations Plans, leading to concerns over the fitness for 'net zero' purposes of certain GHG accounting methods. In addition to the completeness of GHG measures, these concerns include how effectively these accounts model future GHG emissions and incorporate advances in climate science, technology, conventions and regulations.

Our research suggests that decision outcomes are highly sensitive to choices in the application of different GHG accounting methods. The assumption that all GHG accounting methods produce reliable, certain, relevant, comprehensive or comparable figures is highly problematic. Prior research suggests that different actors in different 'net zero' implementation decisions are likely to use different ways of measuring GHG emissions or evaluating climate risks, which could distort decision outcomes. This problem is compounded by decision-makers' limited levels of climate literacy and lack of transparency as to what categories of GHG emissions, the accounting entity, and timescale are included in any calculations. This creates major risks of misinterpretation or misapplication of GHG emissions data in critical decisions.

[5] https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

[6] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution/title

Table 1 – UN GHG Protocol Categories.

Scope 3 upstream	Scope 2 purchase of energy	Scope 1 direct operational emissions	Scope 3 Downstream (after sale)
Purchased goods & services	Purchased electricity	Company facilities	Transportation & Distribution
Capital goods	Purchased Gas	Company Vehicles	Processing of product
Fuel & Energy	Purchased Heating	Fugitive Emissions	Use of product
Transportation & Distribution	Purchased Steam		End of life disposal
Waste from operations	Purchased Cooling		Leased assets
Business Travel			Franchises
Employees commuting			Investments
Leased Assets			Sale of renewable energy

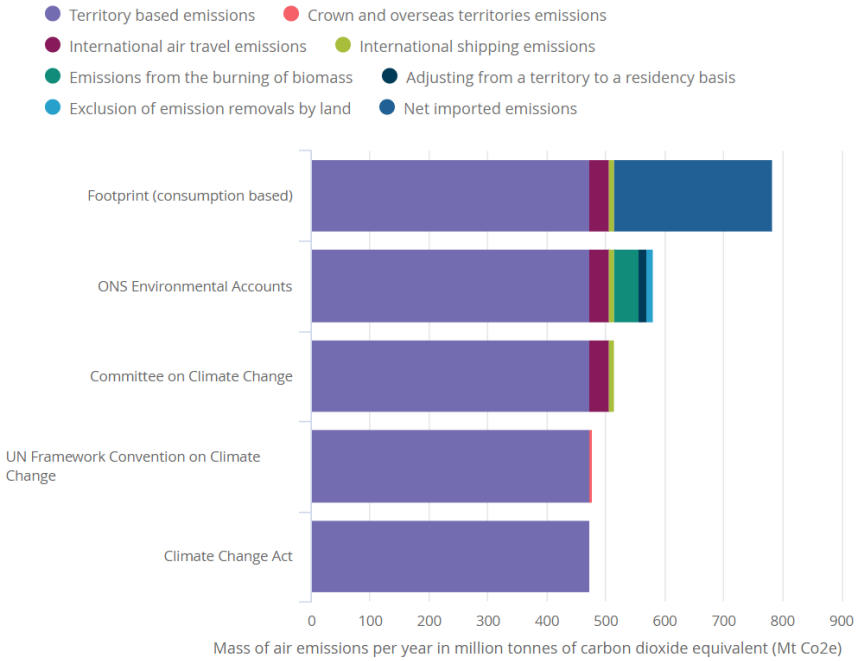
Our review concludes that GHG accounting methods that represent the life cycle consequences across all of the GHG categories specified in UN GHG Protocol (See Table 1) were more likely to provide appropriate evidence for 'net zero' and 10GIR decisions. However, even using all these GHG categories requires complementary evidence of its impacts on other systems (e.g. using the UN SDGs) and measures of the capacity of natural systems to remove atmospheric GHG. Without all this evidence it would be difficult to conclude that proposed 'net zero' solutions were sustainable and did not simply transfer climate risks onto other social or ecological risks.

3. Which Net Zero? 5 Official Measures: All different but none complete

While 'net zero' works wonderfully as a soundbite, it is difficult to operationalise at the different levels of analysis and decision contexts associated with 10GIR. The Office of National Statistics produce 5 official measures of UK Greenhouse Gas Emissions[7] used for different regulatory and policy formulation processes. These are illustrated in Figure 1, which also demonstrates the range of GHG emissions data, which could be used as the benchmark for balancing off or 'zeroing' GHG emissions. Four of these measures adopt a territorial production approach to attributing GHG to the UK with relatively minor variations. One of these measures (FOOTPRINT consumption based) calculates UK GHG emissions based on the UK's consumption of resources i.e. imports of goods and services adjusted for UK exports.

In 2016 the smallest measure was 473 million tonnes of CO2e and the largest was 784 million tonnes of CO2e. This equates to 66% difference in one year. Even FOOTPRINT UK is incomplete as it excludes emissions from the burning of biomass and emissions captured by UK based natural systems, such as forests or peatlands. The UK Government chose to adopt the smallest GHG measure, labelled in Figure 1 as Climate Change Act, as their 'net zero' benchmark.

Figure 1 – Official Estimates of greenhouse gas emissions according to different domestic and international bases, UK 2016 – source ONS 2019



Officially 'net zero' is defined as the UK's GHG emissions would be equal to or less than the emissions the UK removed from the environment either by putting less emissions produced in the UK into the atmosphere or by increasing the amount emissions removed in the UK from the atmosphere. The amount of GHG to be zeroed will be determined by the emissions produced in the UK from:

- businesses based in the UK regardless of where in the world they are registered
- the activities of people that live in the UK as well as non-UK visitors
- land such as forest, crop or grazing land

UK Net Zero does not include emissions or removals from:

- international air travel
- international shipping

7 https://www.ons.gov.uk/economy/environmentalaccounts/articles/netzeroandthedifferentofficialmeasuresoftheuksgreenhousegasemissions/2019-07-24

- UK residents abroad
- UK Crown dependencies and overseas territories
- the burning of biomass such as wood, straw, biogases and poultry litter for energy production
- land such as peatland
- production of goods and services that the UK imports from other countries.

The Committee on Climate Change [8] note that production based GHG accounts such as NET ZERO UK allow the possibility of the transfer of GHG emissions rather than an absolute reduction, and as such should be subject to constant review with further research on improving consumption based measures. Our analysis suggests that none of the 4 production based UK GHG emission measures adequately model the GHG consequences of the decision chains associated with 10GIR. Of the 5 options the FOOTPRINT UK offers the greater potential to model the GHG emissions the UK is responsible for.

Let us consider how a UK vehicle manufacturer that successfully developed an Electric Vehicle with a zero carbon battery with near 100% recharging efficiency with zero carbon charging infrastructure and this business became a global market leader, would be accounted for under the UK's chosen 'net zero' benchmark – NET ZERO UK.

- All GHG emissions relating to all imported components or raw materials production and their shipping (up to UK national border) would be excluded from the NET ZERO UK Accounts.
- Any GHG emission saving from the procurement or component re-design or the adoption of low carbon shipping would be excluded from NET ZERO UK Accounts.
- All GHG emissions relating to production activities and UK based construction will increase the NET ZERO UK Account in the year they are incurred.
- Reductions in GHG emissions from sales to UK customers will be recognised in NET ZERO UK Accounts over the life of the EV.
- All international shipping GHG emissions for exports will be excluded from NET ZERO UK Accounts.
- The GHG emissions of EV's exported from the UK would remain in NET ZERO UK
- Reductions in GHG emissions from use of exported EVs will not be recognised in NET ZERO UK Accounts.

This simple analysis explores how this global GHG reducing product would show up in the NET ZERO UK Accounts. It demonstrates a number of problematic misrepresentation of the actual GHG emissions. In this scenario this global GHG reducing product is likely to be recorded as increasing NET ZERO UK emissions until a breakeven period some time in the future. All of the red impacts would not form part of any evaluation using NET ZERO UK Accounts. There is a clear risk that a substantive contribution of UK business to reducing global GHG would be rejected if it relied on its representation in NET ZERO UK Accounts.

Let us now consider the same scenario if the Net Zero GHG benchmark was calculated using FOOTPRINT UK.

- All GHG emissions relating to all imported components or raw materials production and their shipping would be included in FOOTPRINT UK.
- Any GHG emission saving from the procurement or component re-design or the adoption of low carbon shipping would be included in FOOTPRINT UK.
- All GHG emissions relating to production activities and UK based construction will increase the FOOTPRINT UK Account in the year they are incurred.
- Reductions in GHG emissions from sales to UK customers will be recognised in FOOTPRINT UK Accounts over the life of the EV.
- All international shipping GHG emissions for exports will be included in FOOTPRINT UK.

[8] See recommendation page 9 CCC (2017) Quantifying Greenhouse Gas Emissions…
Government should continue to monitor consumption-based GHG estimates and support continued research to improve methodology and reduce uncertainty in these estimates. Unlike production emissions estimates, consumption-based estimates take account of emissions embedded in the goods and services the UK imports or exports. Consumption emissions are more uncertain than production estimates, but are important to monitor to ensure that measures to reduce territorial emissions do not lead to increased global emissions.

- The GHG emissions of EV's exported from the UK would reduce FOOTPRINT UK
- Reductions in GHG emissions from use of exported EVs will not be in FOOTPRINT UK.

Re-visiting this example using FOOTPRINT UK demonstrates a significant reduction in the scope of misrepresentation of global GHG emissions. A summary of the accounting differences is presented in Table 2. In this scenario this GHG reducing product is likely to be recorded as reducing FOOTPRINT UK. Only the reduction in GHG from the use of the exported vehicles will not be captured by FOOTPRINT UK, but the GHG attributed to the EVs exported will be deducted from FOOTPRINT UK. This project with its substantive contribution of UK business to reducing global emissions is far more likely to be accepted using FOOTPRINT UK than NET ZERO UK.

Table 2 Comparison of NET ZERO UK and FOOTPRINT UK Accounting

	NET ZERO UK	FOOTPRINT UK.
GHG emissions relating to all imported components or raw materials production and their shipping	**Excluded**	**Included**
GHG emission saving from the procurement or component re-design or the adoption of low carbon shipping.	**Excluded**	**Included**
GHG emissions relating to production activities and UK based construction.	**Included**	**Included**
Reductions in GHG emissions from sales to UK customers. ***(over life of EV)***	**Included**	**Included**
All international shipping GHG emissions for exports	**Excluded**	**Included**
GHG emissions adjusted for the production of EV's exported	**Excluded**	**Included**
Reductions in GHG emissions from use of exported EVs. ***(over life of EV)***	**Excluded**	**Excluded**

4. Non- Governmental Net Zeros?

While the UK Government has five official GHG emission measures, other institutions such as businesses are largely free to choose their own methods of calculating and disclosing GHG emissions. GHG accounting and reporting has been critiqued as producing inconsistent and irreconcilable numbers and narratives with the potential to undermine the confidence in actions intended to address climate change[9]. A major concern of this research is that the selective attribution of GHG to corporations does not measure all the GHG emissions resulting from corporate actions. There are numerous GHG accounting protocols that have been developed for the reporting of organisational GHG emissions. See Table 3.

Table 3 – Examples of GHG Emission Reporting Protocols or Standards

UN GHG Protocols	Carbon Disclosure Project	Science Based Targets
Climate Disclosures Standard Board	Task Force for Carbon Disclosures	Department of Environment, Food and Rural Affairs
Global Reporting Initiative	EU Non-Financial Reporting Directive	EU Taxonomy
FTSE	2 degree Investing[10]	World Resources Institute
Carbon Tracker Initiative	World Benchmarking Alliance	ACCA
OFWAT / WRI		

Each method was designed for a particular purpose aimed at a particular type of organisation with a specific group of stakeholders or users – e.g. DEFRA to help investors, FTSE for compliance with listing requirements, TFCD for the banking and finance sector, OFWAT/WRI specifically for the regulated UK Water and Sewage sector. They were never intended to be used outwith this decision context nor were they intended to be a complete representation of the GHG emissions an organisation was responsible for[11]. Each of these protocols has specific rules and flexibility as to what is included and excluded in their GHG emission calculation, which was based on what was deemed appropriate for their original purpose. Problems arise when a GHG accounting method or measure is used for a purpose or decision it was never intended for.

Large UK businesses[12] are required to calculate and report their annual GHG emissions using DEFRA GHG protocols, e.g. DEFRA (2019). The UK Government defined the purpose of these compulsory disclosures as a "vital first step for companies to make reductions in these dangerous emissions" as they "will enable investors to see which companies are effectively managing the hidden long-term costs of GHG emissions" (DEFRA, 2012). However, others have more problematically suggested that this very selective measure of GHG emissions could be useful for other decision makers and stakeholders, such as NGOs, customers, employees and regulators[13]. Our research notes that many of the businesses making net zero pledges are using DEFRA GHG to calculate their net zero benchmarks, a purpose for which it was not designed.

A pilot study of reported GHG emissions of Standard and Poor 500 firms over the period 2015-19 suggests that DEFRA GHG excludes at least 77%[14] of annual corporate GHG emissions. The types of emissions excluded from

[9] Kolk et al., 2008; Andrew and Cortese, 2011; Sales de Aguiar and Bebbington, 2014; Comyns, 2018; Comyns and Figge, 2015; Liesen et al., 2015; Ascui and Lovell, 2011; Lovell, 2014; Haslam et al., 2014

[10] 2° Investing Initiative. (2013). "From Financed Emissions to Long-Term Investing Metrics: State-of-the-Art Review of GHG-Emissions Accounting For The Financial Sector." available here.

[11] Brander, 2016; Liesen et al. 2015; Comyns and Figge 2015.

[12] In 2013 the UK Government legislated that all quoted companies must include GHG emissions data in their Annual Report and, more recently in 2018, this legislation was extended to also apply to large unquoted companies and limited liability partnerships.

[13] ACCA, 2007; Deloitte, 2010; Kauffmann et al., 2012; ACCA and GRI, 2009.

[14] Most corporate reporting standards only require companies to disclose Scope 1 and 2 emission. The 77% figure comes from all S&P500 companies who voluntarily disclosed Scope 1, 2 and partial 3 emissions in the period 2015 to 2019, based on 915 observations from 230 companies. Thanks to Ewan Thomson for this analysis.

DEFRA GHG are presented in Table 4. DEFRA GHG and many of the others listed in Table 3 are considered inappropriate as they are too incomplete to meaningfully inform decisions that will actually reduce global GHG emissions. There is a real risk that if businesses used DEFRA GHG to make GHG related evaluations it would break 10GIR decision chains in many places.

All of the organisational GHG protocols listed in Table 3 build from the UN GHG Protocol, which identifies 24 categories of GHG grouped into four scopes[15] of a business's carbon emissions; upstream supply chain activities; purchase of energy; direct emissions, downstream activities relating to the delivery, use and disposal of a product (see Table 1). It is possible to use the framework of UN GHG Protocol to evaluate the completeness[16] of different GHG accounting standards.

For example, DEFRA GHG only includes Scope 1 and Scope 2 emissions and does not include any Scope 3 upstream or downstream emissions. The shaded cells in Table 4 identifies the categories that are included in DEFRA GHG. Whereas NET ZERO UK is restricted to GHG emissions arising from activities within UK territory, corporate GHG emissions are calculated for all Scope 1 & 2 emissions of the corporations regardless of where they are emitted. It would be wrong to assume the DEFRA GHG emissions of a UK Corporation relates to GHG emissions in the UK or measures the global GHG emissions that arise from their operations.

Table 4 – UN GHG Categories included in DEFRA GHG for all global businesses owned by the corporation – shaded cells.

Scope 3 upstream	Scope 2 purchase of energy	Scope 1 direct operational emissions	Scope 3 Downstream (after sale)
Purchased goods & services	Purchased electricity	Company facilities	Transportation & Distribution
Capital goods	Purchased Gas	Company Vehicles	Processing of product
Fuel & Energy	Purchased Heating	Fugitive Emissions	Use of product
Transportation & Distribution	Purchased Steam		End of life disposal
Waste from operations	Purchased Cooling		Leased assets
Business Travel			Franchises
Employees commuting			Investments
Leased Assets			Sale of renewable energy

For example, vertically integrated supermarkets like the Co-Op include the GHG emissions of the fruit and vegetable they grow on their farms in their DEFRA GHG account. Because they own these farms these emissions are counted as direct emissions (Scope 1). Whereas the GHG emissions of any goods purchased from independent suppliers are considered Scope 3 Upstream and are excluded from DEFRA GHG. Applying DEFRA GHG correctly, if you buy in the food you sell, then you don't have to report it regardless of where or how it is produced, nor do you have to report on the GHG emissions in shipping it to the UK.

Even though the Co-Op's business model is highly likely to result in lower global GHG emissions, all other things being equal using DEFRA GHG they will report higher GHG emissions than other supermarkets. Paradoxically using DEFRA GHG the Co-Op could ***appear to reduce*** their GHG emissions, by closing down their local farms and sourcing all fruit and vegetables from overseas. A course of action that flies in the face of the concepts

[15] Rather confusingly the Protocol refers to Scope 1, Scope 2 and Scope 3 emissions, with scope 3 divided into Scope 3 Upstream activities (before sale) and Scope 3 downstream (after sale).

[16] We recognise that the current version of the UN GHG Protocol is under development due to the need to include GHG removals through nature based solutions see GHG Protocol (2020) *Carbon Removals and Land Sector Initiative - Project Overview*..

underpinning 10GIR as well as best practice in the field of zero carbon management. It is measures like DEFRA GHG that allow Multinational Oil Companies to legitimately claim to be 'net zero' while excluding the GHG emissions from the use of their product.

Same company different 'net zeroes'?

Businesses will be subjected to multiple demands for GHG accounts calculated using different protocols, depending on their risks, stakeholders, customers and regulatory regimes. This often results in multiple disclosed measures of GHG emissions, which complicates the usability of corporate GHG disclosures. Take for example the water and sewage companies in England and Wales. These businesses are regulated by OFWAT who have developed their own specific way of calculating GHG emissions that reflects some of the unique characteristics of this sector, for example their ability to generate renewable energy from sewage treatment plants (see Table 5). The water and sewage companies that are also quoted UK Corporations are also required to disclose DEFRA GHG emission data (see Table 4) which covers all corporate operations, not just their regulated water and sewage businesses.

However, OFWAT GHG only relates to their regulated activities in England and Wales but for a wider set of GHG categories. This situation is further complicated when these companies are part of international groups, privately held or listed in overseas capital markets. These companies are subject to other listing requirements or national GHG regulations and so are required to disclose GHG emissions that are likely to be calculated differently from OFWAT and DEFRA GHG[17]. While each measure fulfils a specific purpose it is important that users do not confuse or conflate these different measures when making decisions.

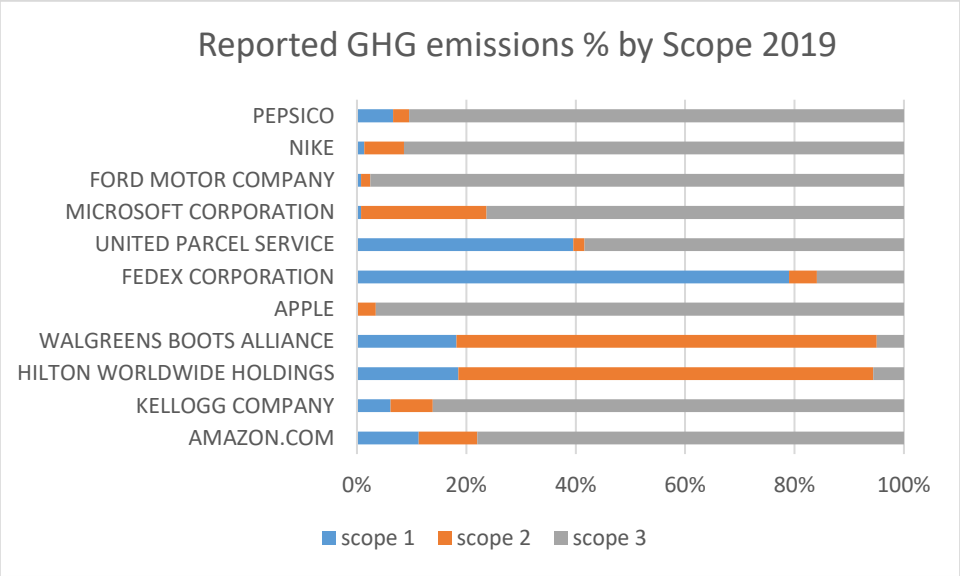
Table 5 – UN GHG Categories included in OFWAT GHG restricted to regulated water and sewage activities– shaded cells.

Scope 3 upstream	Scope 2 purchase of energy	Scope 1 direct operational emissions	Scope 3 Downstream (after sale)
Purchased goods & services	Purchased electricity	Company facilities	Transportation & Distribution
Capital goods	Purchased Gas	Company Vehicles	Processing of product
Fuel & Energy	Purchased Heating	Fugitive Emissions	Use of product
Transportation & Distribution	Purchased Steam		End of life disposal
Waste from operations	Purchased Cooling		Leased assets
Business Travel			Franchises
Employees commuting			Investments
Leased Assets			Sale of renewable energy

The corporate GHG accounting research literature concludes that narrowly defined GHG emissions are problematic for most business decision making processes. Imagine an investor looking to rebalance their portfolio towards low carbon businesses making their decision based on DEFRA GHG emissions, which only account for around 1/3 of emissions and excludes the main drivers of climate risks. It would be like valuing a business without taking account most of their costs, the assets they own, their investments, their products, their sales, their customers or future liabilities. To illustrate this, the figure below presents the percentage 2019

[17] At the risk making it more complicated the infrastructure required to satisfy regulators means that Water and Sewage companies effectively include GHG emissions from upstream and downstream Transport and Distribution (pipe network) as well as end of life disposal (sewage treatment plants). This makes it very difficult to benchmark their performance against industries.

reported GHG emissions of 10 S&P 500 Companies by Scopes 1, 2, & 3. The use of DEFRA GHG would mean making decisions on the GHG performance of each company by ignoring all the grey bars!



The same research is broadly supportive of the use of GHG Accounting that captures as much of the consequential GHG emissions from a decision. Brander (2016) demonstrated that narrowly defined GHG accounting methods, which do not capture all the GHG consequences can increase rather than decrease GHG emissions. In most cases choosing a life cycle consequential calculation will improve the chances of making decisions that will reduce emissions.

DEFRA GHG, 10GIR and perverse Incentives to increase GHG emissions.

To illustrate the problems of inappropriately calculated GHG emissions for 10GIR decisions, this section presents how a business working in partnership with a local authority to reduce GHG emissions by encouraging employees to commute using active travel and rewilding their car park, building safe storage facilities and staff changing rooms would be measured by DEFRA GHG.

The first problem for this business is that employee commuting is not included in their DEFRA GHG accounts (see Table 4). This means that any reduction in these GHG will not impact on this figure as it is effectively off-balance sheeted. This also means that any business decision that is likely to increase GHG from commuting such as changing shift patterns are also excluded. DEFRA GHG assumes that businesses are not accountable or responsible for how their employees get to work.

Using DEFRA GHG this active travel project would be measured as

- Existing GHG emissions from employees driving to work are excluded from DEFRA GHG
- Investments and building work by business for bike storage, changing rooms or rewilding to encourage active commuting are excluded from DEFRA GHG
- Additional energy usage for showers or changing rooms are included in DEFRA GHG
- Saving in GHG emissions by employees not using cars to drive to work are excluded from DEFRA GHG
- Any GHG emissions removed from the atmosphere due to the car park rewilding will be excluded from DEFRA GHG.

Overall, this active travel project is likely to result in a slight increase in the DEFRA GHG measure, resulting in a negative appraisal of its GHG impact. This is despite this project actually reducing GHG emissions as measured by NET ZERO UK and FOOTPRINT UK. In this case the evaluation of the project is highly sensitive to the choice of GHG accounting used. If the decision makers in this company trust the DEFRA GHG figures they have to use for corporate disclosure purposes then there is a risk they would reject this proposal. This risk will be amplified if their bonus or performance appraisal is dependent on reducing DEFRA GHG, rather than reducing global GHG.

The ultimate success of this active travel project is dependent on the daily decisions of each employee. At present there is no official GHG account that an individual can use to evaluate this type of decisions or that holds them accountable for their actions, other than voluntary use of carbon footprint calculators[18]. However, this surprisingly complex daily decision will be affected by multiple factors specific to each individual and there is clear need to develop some form of incentives to help individuals prioritise active travel.

[18] https://transportation-forms.stanford.edu/cost/; https://calculator.carbonfootprint.com/calculator.aspx?tab=6

5. 10GIR, GHG Reducing Behaviours, Decision Contexts and Accounting

Our review of 10GIR identified a number of ways proposed actions could result in reducing the GHG emissions the UK, through its businesses, institutions and citizens, is at least partially responsible for. Achieving Net Zero through the 10GIR will require careful coordination across the lifecycle of all these activities, including appropriate evaluation of the GHG impact at critical points in decision chains. Understanding how, where, when and which GHG emissions are affected by 10GIR is an important first step in selecting appropriate GHG accounting techniques. This means for each 10GIR action determining

- How GHG emissions are intended to be reduced?
- Where in the world are the GHG emissions intended to be reduced?
- When will these GHG emissions be reduced?
- Which GHG emissions are intended to be reduced?

Examples of 'how, where, when and which' include

1. Saving carbon emissions arising from operations within their organisation in the UK, and in the rest of the world (for how long into the future).
2. Saving GHG emissions from those involved in the supply of goods / services that you consume in the UK, and in the rest of the world (for how long into the future).
3. Saving carbon emissions for those who you provide goods and services to in the UK, and in the rest of the world (for how long into the future).
4. Enable others to make better decisions and choose more net zero products and services in the UK, and in the rest of the world (for how long into the future).
5. Incentivise investments in zero carbon initiatives and businesses in the UK, and the rest of the world (for how long into the future).
6. Reduce likelihood carbon intensive products / services will be purchased in the UK, and in the rest of the world (for how long into the future).
7. Increase likelihood zero carbon products / services will be purchased in the UK, and in the rest of the world (for how long into the future).
8. Enable others to consume / use / dispose of products and services in order to reduce GHG emissions in the UK, and in the rest of the world (for how long into the future).
9. Enable others or natural systems to take GHG emissions produced in the UK, and in the rest of the world out of the atmosphere in the UK and in the rest of the world (for how long into the future).

As demonstrated earlier NET ZERO UK effectively excludes any of 'the rest of the world' GHG emissions, whereas FOOTPRINT UK captures more of the global emissions, but excludes measures of GHG emissions removed from the atmosphere. It is difficult to how DEFRA GHG could be meaningfully used to support any of these routes to GHG emission reductions, including the one it was designed for – *Route 5- incentivising investment in low carbon projects and businesses*

Our analysis suggests that the most commonly used forms of GHG accounting would only provide useful information for part of the first solution *Route 1 Saving carbon emissions arising from operations within their organisation in the UK* (but not in the rest of the world). For all other routes to net zero, narrowly defined GHG accounts, can be problematic, likely to distort individual decision processes and break essential decision chains. The choice of which GHG account and how it is applied must adequately represent how, where, when and which GHG emissions are expected to be impacted by the decision, if we are to reduce the risk that 'GHG-reducing' solutions don't increase global GHG.

GHG Accounting to connect across scales and actors.

Achieving UK Net Zero will not depend on single institutions or emerge from independent decisions. It will require coordination of interconnected decision chains across different institutional scales and involving different actors. As noted earlier UK Net Zero commitment is part of a global effort to tackle climate change and needs to rise to prominence in the agendas of business, finance, civil society, and governments at all levels.

These levels include: global institutions, national governments, regional governments, planning and regulatory institutions, business development and innovation institutions, financial markets, supply chains, business sectors, individual businesses, academic and research institutions, communities, citizens and consumers.

Achieving Net Zero UK and 10GIR requires the integration of GHG consequences into every decision process, ranging from government taxation and spending priorities to daily decisions on how to get the kids to school. Table 6 contains a list of over 40 decision contexts associated with the 10GIR, a list, which is by no means exhaustive.

Table 6. Examples of 10GIR Decisions requiring GHG Accounting Input

Categories	Decisions		
Business Investment and budgeting	Infrastructure Investment Appraisals	Business Assets Purchase and replacement decisions	New product development evaluation
	Non-domestic building choices (purchase, lease, refurbishment)	Project / programme budget allocation	Evaluation of new financial products / services
	Business energy choices	Land use appraisals	Research and Development budget allocations
Business Model and Strategy	Evaluation of financing options	Business Model Evaluation	Product / service Pricing decisions
	New market developments		
Supply Chain and Production	Procurement and Supply Chain	Scaling up production levels	Structuring of UK supply chain
	Incentivising low carbon and UK purchasing	Exporting products, services and intellectual capital	
Government funding and public resource allocation	Funding of conservation and nature enhancement plans	Funding of adaptation and mitigation programmes	Public expenditure allocation decisions
	Public sector decarbonisation choices	Sectoral subsidy and support evaluations	Overseas development funding
	Transport infrastructure appraisal	Planning Appraisals	Allocation of scientific research funding
	Tax and subsidy evaluations		
Compliance/Certification	Compliance with international conventions or accords	Product standards and certification decisions	Evaluating regulatory frameworks

	Compliance with national level standards	Accountability, assurance and transparency processes	
Personal consumption	Consumer purchase decisions	Individual transport choice	Housing choice decisions (purchase, lease, refurbishment)
	Household energy choices		
Others	Evaluation of training and education changes	Future scenarios and forecast models	Welfare system reforms
	Share / portfolio valuations	Valuing nature and natural systems	

All these decisions are subject to formal and informal evaluation practices that have evolved over time, reacting to different events, risks and opportunities, developing a vast array of individual and institutional solutions. In most cases this will ***not*** have involved reducing GHG emissions. Other than when complying with specific regulations or standards, these decisions have not taken account of the contribution to atmospheric concentrations of GHG or their impact on natural carbon sinks. It is this systematic exclusion (for whatever reason) of climate related consequences in decision-making is partly responsible for the current climate emergency.

Addressing this systematic exclusion through the application of GHG accounting methods fully aligned with international goals and national aspirations is therefore a priority. GHG accounting is required to provide appropriate evidence to inform all the actors involved in these different decisions and to co-ordinate / align all their desired outcomes, priorities and resources with long term global Net Zero goals. Getting both right is critical to the success of UK Net Zero plan, but this is far from a trivial task. There is an extensive research literature that reports on how inappropriate accounting techniques distort decision making processes. These distortions include; privileging outcomes that can be easily measured or valued, creating perverse incentives, incorrectly labelling unsustainable solutions as sustainable, incorrectly labelling sustainable solutions as unacceptable decisions and using performance measures that inhibit progress against agreed outcomes, to name but a few. Despite these problems it is clear that **not accounting for climate consequences** or **poorly accounting for some climate consequences** is not working.

6. GHG Accounting for Decision Chains.

Previous sections have established that there are different ways to measure GHG accounting, different ways to reduce GHG emissions, different institutions responsible for reducing GHG emissions and different decision contexts. They have also discussed the importance of co-ordinating these issues across decision chains, noting the risks associated with breaking these chains. This section pulls these issues together and explores the GHG accounting challenges from these decision chains.

Generic Decision Chain

Typically, each of the 10 action points from 10GIR describes a multi-stage, multi-level, multi-actor strategy, which we have represented in Table 7. This table illustrates a top-down process originating with a government initiative that cascades down to other institutions passing through key project gateways and critical evaluation stages. As each stage is 'passed' the project evolves with different actors, criteria, priorities and conflicts becoming involved. A decision chain can be seen to consist of GHG reduction enabling stages and GHG reduction stages with high levels of interdependencies between these project life cycle stages.

It is worth noting that in most decision chains meaningful reductions in GHG emissions only begin to occur after the new product has been sold. Even if there has been substantive GHG reductions in the supply chain, production and delivery phases – unless the product is bought, used appropriately (e.g. plug in hybrid vehicles that are actually plugged in) and sustainably disposed of – there will be no reduction in GHG emissions. Before passing successfully through the purchase and consumption gateways, any GHG reduction remain as possibilities. If any product remains unsold and unused, then it has incurred GHG emissions for no purpose!

Understanding the whole decision chain as well as the key factors at each evaluation gateway is an important part of GHG accounting choices. This allows greater insights into how GHG are intended to be reduced, where the GHG are intended to be reduced, which GHG are intended to be reduced, when GHG reductions are likely to accrue and who else does this GHG reduction depend on. As a project has to successfully pass through all gateways, it is important to actively manage the intersection of different disciplines, institutions, priorities, values, culture and desired outcomes. Holding this chain together will need meaningful estimates of future global GHG emissions as a consequence of these chained decisions, which in turn are dependent on GHG accounting choices.

Take for example the use of taxation systems to incentivise the purchase of zero carbon products. There is research that supports the use of taxation to reward 'net zero' activities or punish 'high GHG' activities. However, how GHG emissions are calculated will significantly affect the effectiveness of taxation reforms. Using thresholds based on NET ZERO UK to exempt products from VAT could result in imported goods being exempt from VAT, whereas the price of identical goods manufactured in the UK could be up to 20% higher. This is because NET ZERO UK does not recognise the GHG of imports so would attribute no GHG emissions to these goods. But NET ZERO UK attributes GHG emissions to all goods produced in the UK, so locally produced products would have higher attributed GHG emission, even though the UK products could have lower global GHG emissions. Using NET ZERO UK for this purpose creates a VAT system intended to reward UK low carbon products that perversely incentivises the purchase of high GHG imported products. This problem could be mitigated by using CONSUMPTION UK as the 'net zero' benchmark for VAT thresholds or other taxation reforms.

This example demonstrates the dependency of 10GIR on aligned and coordinated decision making by many different individuals and organisations whose operations are currently misaligned and uncoordinated. Without mechanisms in place to ensure this alignment, the risks of uncompleted decision chains are much higher.

Table 7 Illustration of 10GIR Decision Chain (probabling better presented as a diagram)
Note shaded cells indicate when actual reductions in GHG occur

Stage	Levels and Actions	Decisions and GHG Accounting
Establish Government Project Development Fund	National or Regional level entities	Public sector budget allocation decision (Including estimate of carbon consequences) Public Sector Financing decision (Including estimate of carbon consequences) Future public funding projections and Carbon Emission forecasts
Preparing Bid for project development funding	Multiple proposals from individual businesses, social enterprises, public service organisations	Project budget allocation decision (including estimate of carbon consequences) evaluation of viability of project bid (Including estimate of carbon consequences) Estimate of impacts across whole project life cycle, including raw materials, procurement, logistics, production, distribution, use and disposal. Business strategy alignment, carbon emissions forecasts and scenarios
Project Bid evaluation and award process	National or Regional Level	Project appraisal decision, including ranking against carbon consequence criteria Determination of funding process and desired outcomes Prediction of likely impact on existing carbon emissions forecasts
Implementing Project Development	Multiple winning businesses, social enterprises, public service organisations	R & D budget allocation decision Collation of project costs and carbon emissions Project value engineering / functional analysis Pricing, marketing forecasts Project funding updates to funders End of project viability assessments including funding production and scale ups
Financing Project Implementation or Scaling Up	Multiple winning businesses, social enterprises, public service organisations, financial institutions, capital markets	Strategic and operational plans for new product Internal Funding proposal plans External funding proposal plans Funding package evaluation plans
Delivering Project / new product	Winning business, social enterprises, public service organisations with viable new product with finance package	Procurement decisions Capital Expenditure evaluations Process and Production changes & budgets Marketing plan evaluation Target markets (including delivery logistics and sales channels) End of life evaluation
Consumer Purchase Decision	Multiple consumers (individuals, businesses or institutions) domestic and/or global	Packaging and 'carbon' labelling Product ranking information Availability of complementary services and infrastructure Marketing campaigns and point of sale information Media coverage and social acceptability norms
Consumer Use / consumption decisions	Multiple consumers (individuals, businesses or institutions) domestic and/or global who purchased product or used service	Instructions, availability of complementary services / infrastructure, training and education, ability to repair, etc.
End-of-life decisions	Individual consumer, recycling businesses, public sector infrastructure providers, based on location of final consumer	Investment in on-site recycling system, Disposal options

Already multiple GHG Accounts out there.

The last decade has seen a massive growth in the number of different GHG accounting methods and climate risk modelling. However, their adoption and integration has been patchy, lacking cohesion or standardisation. GHG accounting has already infiltrated a number of different decision processes, but often as a secondary consideration to well established evaluation systems. For example, the latest version of the UK Treasury Green Book outlines how the climate risks[19] of all Central Government projects should be evaluated. The problem is often not the absence of GHG accounts, but how to cope with the contradictions arising from multiple GHG accounts.

Let us explore some of the problems when different GHG emission accounts intersect or overlap in the case of a Regional Transport Authority deciding whether to replace its fleet with Hydrogen Powered buses.

1. Establishing GHG Baseline and Future Projection of Current Fleet

The first stage of this project would involve establishing a GHG emission baseline, measuring existing public transport services, adjusting these for planned demographic changes, developments in Regional strategic plans, other transport infrastructure developments and general trends. Transport authorities are required to undertake sustainability impact assessments[20] [21] for this type of project, which contain specific guidance on how to evaluate the GHG emission impact.

These evaluations typically focus on GHG emissions from the operation of vehicles and the building of any new infrastructure. These are similar to Scope 1 emissions, as per UN GHG Protocol, and do not take into account historic emissions or emissions embedded in existing bus fleet, fleet replacement, current infrastructure or emissions in the disposal of the existing fleet. It is also does not take account of GHG emissions attributable to the production of diesel or any other Scope 3 upstream or downstream emissions. Best practice would be to establish multiple baselines based on a range of plausible future scenarios.

This approach is in line with NET ZERO UK calculations. This projected baseline establishes a GHG emission benchmark against which any new proposals are evaluated. Note the focus on Scope 1 emissions means this is a narrowly defined GHG measure.

2. Predicting GHG of Hydrogen Fleet

Hopefully using the same assumptions and scenario used to calculate the Projected Baseline above, an estimate is made of the GHG emissions of a hypothetical hydrogen fleet of buses, which may not actually be available to purchase. It is highly unlikely that the Regional Transport authority would have the same level of detailed operational data of these new buses. This projection is likely to focus on the projected Scope 1 emissions of the new fleet and is used to determine the GHG saving envelope for all subsequent stages of the evaluation.

Sometimes other GHG emissions (Scope 3) maybe introduced in this projection, e.g. GHG associated with the purchase of the new buses. However, this can distort the GHG saving envelope as you are comparing Status Quo Scope 1 with Hydrogen Scope 1 & 3, effectively discounting all Scope 3 emissions accruing from the Status Quo.

However, this Scope 1 focus substantively underrepresents the impact on global GHG emissions of this project. The GHG emissions associated with the production of two different types of fuel – diesel and hydrogen - are not taken into account. Neither are GHG emissions arising from differences in the production, maintenance and possible re-use of diesel and hydrogen buses. It is possible that the scope 1 savings associated with the running of hydrogen buses is offset by shorter operational life requiring a more frequent replacement of buses over a 50 year period.

[19] ww.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020#valuation-of-costs-and-benefits

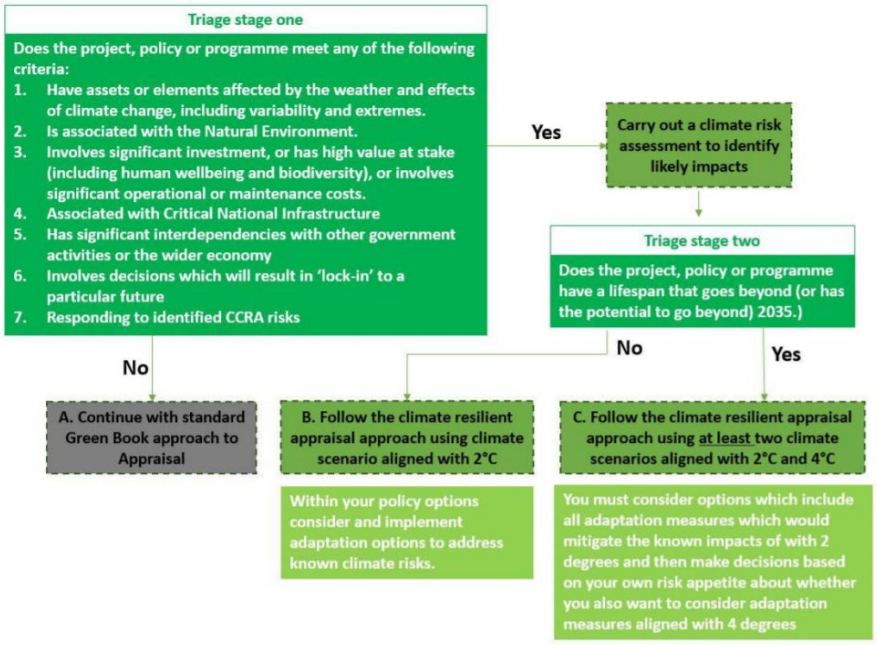
[20] https://www.gov.uk/guidance/travel-plans-transport-assessments-and-statements

[21] Transport.gov.scot/media/4589/planning_reform_-_dpmtag_-_development_management__dpmtag_ref__17__-_transport_assessment_guidance_final_-_june_2012.pdf

3. Value for Money Evaluation – Taking Account of Climate Risk.

Public expenditure on large-scale transport projects are normally subject to stringent cost-benefit analysis using procedures similar to that outlined in the Treasury Green Book. This includes detailed guidance on how to measure the climate impact of this project[22] . This process requires a comprehensive consideration of climate risks across the project life cycle that differs substantially from the focus on Scope 1 emissions

Figure 2 Outlining a proportionate approach to accounting for the effects of climate in appraisal
Source Treasury (2020) page 7.



This approach provides a very different form of analysis that should complement the other ways of accounting for GHG emissions. While Figure 2 describes a process that is more aligned with FOOTPRINT UK rather than NET ZERO UK, it does not specify how or whether the GHG consequences should be calculated and input in any evaluation process. This creates the possibility of different evaluations of the same project. The Hydrogen Bus project could demonstrate overall GHG savings, but not be considered value-for-money when taking into account climate risks.

4. Alignment with Strategic and National Plans

In addition this proposal will also need to be evaluated relative to national, regional and local authority strategic plans, as well as their climate mitigation and adaptation plans, including predicted performance against key performance indicators. As mentioned earlier the UK Government has determined that NET ZERO UK is the default official measure to be used in any net zero evaluation, which has trickled down to other institutional performance measures and regulatory mechanisms. Therefore, the GHG emissions of this project will be evaluated in terms of its impact on:

- businesses based in the UK,
- the activities of people that live in the UK as well as non-UK visitors,
- land such as forest, crop or grazing land.

22

Assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/934339/Accounting_for_the_Effects_Of_Climate_Change_-_Supplementary_Green_Book_.._.pdf

This will require producing estimates of the project's annual net GHG impact similar to step 1. However, if the key performance indicators are set using NET ZERO UK, then it will be necessary to undertake an additional evaluation translating the initial GHG estimates into NET ZERO UK, only taking into account all of the possible impacts on NET ZERO UK factors. The outcome of this analysis could result in a medium term increase in NET ZERO UK GHG emissions, especially if the hydrogen, buses and any infrastructure are sourced and manufactured in the UK.

The NET ZERO UK GHG profile could be radically different if any of the hydrogen, buses and any infrastructure are sourced and manufactured outside the UK and thus would have not any attributed GHG emissions. It is as if the buses and hydrogen appeared by magic, in the same way as imported diesel used by existing buses appears free of any embedded GHG emissions! Evaluating this project through NET ZERO UK will produce another set of project GHG emissions to input into other decision processes.

This project when combined with all other NET ZERO UK measures of the activities of the local authority or transport authority, could tip them over critical thresholds for a substantial period of time. Even though in the long term this project could save global GHG emissions or NET ZERO UK emissions, the time taken to breakeven creates potential problems and possible sanctions due to short to medium breach of targets, regulations or stakeholder pressure. This could result in political pressure to reject this project due to its short to medium term impact rather than its whole life cycle GHG impact. Paradoxically this pressure will be greater if the hydrogen, buses and infrastructure are produced in the UK. However, if the hydrogen, buses and infrastructure are produced outside the UK, there is a risk this project could reduce NET ZERO UK but increase global GHG emissions. This is possible because NET ZERO UK excludes any imported GHG resulting in project evaluations that only show UK GHG and thus overstate the GHG reductions.

5. Procurement Decisions – Which Bus to Buy?

Assuming suitable Hydrogen Buses exist, specific decisions on which type of bus to purchase will be impacted on by manufacturers data on the GHG emissions, some of which will be subject to industry standards or if the supplier is an overseas company subject to national guidance. We all need to remember the fallout of VW's Dieselgate when relying on manufacturer's data. This data is likely to be restricted to 'tailpipe' GHG emissions[23] rather than GHG lifecycle footprint of the bus. It is possible that voluntary information on the GHG life cycle footprint of this bus, or similar products, may be available from manufacturers, researchers or NGOs, but this is unlikely to be the case. If the procurement decision is to be aligned with reducing global GHG emissions, then decision makers should be informed by full scope GHG lifecycle footprint measures rather than comparison of tailpipe emissions.

However, given the UK government's adoption of NET ZERO UK, it is more likely that the procurement decision will be evaluated using NET ZERO UK, which will be affected by where the buses, their fuel and their components are sourced. NET ZERO UK is therefore problematic when applied to procurement decisions.

6. Time Scale – Not in My Term of Office.

In the short term, this type of project is likely to result in a substantial increase in NET ZERO UK emissions, particularly if the buses are produced in the UK (as envisioned in 10GIR). This front-end GHG emission increase is typical of many infrastructure or capital expenditure projects. This short term increase in GHG is expected to payback over time as these buses come into operation and replace the diesel ones.

The payback period may be very long say 10-20 years, which creates a potential political problem. How likely is it that a council, who are elected every five years, agree to a project that will substantively increase NET ZERO UK emissions in their term of office? Even though it paybacks over the long term.

A strict interpretation of NET ZERO UK may require unnecessary carbon offsets charged to this project in the early stages, even though it is net zero over the project life cycle. From a climate change perspective this is not

[23] Tailpipe emissions refer to the GHG emissions from driving a vehicle – similar to Scope 1 emissions.

necessarily a bad thing, but the additional and unnecessary costs charged to this project may make it less attractive relative to other projects with a shorter payback period but lower absolute GHG emission reductions.

Summary – So What?

This simplified presentation of the different evaluations of a project envisioned by 10GIR demonstrates some of the ways in which different ways of accounting for GHG and climate risks can break the chain and acts against the alignment and coordination of the different actors upon which 10GIR depends. There is a need for further research into complex decisions, such as in this case, to determine the appropriate application of GHG accounts, particularly in representing the future GHG consequences of a decision chain.

7. Accounting for Future GHG Emissions and Climate Scenarios

Understanding historic emissions is important in respect of quantifying how much GHG we need to remove from the atmosphere, but this is only part of becoming a Net Zero nation in a Net Zero world. Relying on backward looking accounts of GHG emissions is unlikely to resolve our current climate crisis and impending climate emergency. The 10GIR is forward looking and therefore requires predictive GHG accounting, GHG Accounting that estimates the future GHG consequences of our current activities and our decisions intended to resolve the climate crisis. One approach to do this involves the use of climate scenarios.

Scenario analysis attempts to represent a diversity of future possibilities, in order to challenge decision makers to consider plausible futures they might choose not to take into account. A scenario is often based on complex data sets and system thinking, but it transforms these relationships and mass of evidence into compelling narratives that form the backdrop to evaluate different actions or strategies. Scenarios are designed to disrupt *business-as-usual* thinking and to be used when it is difficult to predict with certainty system behaviour. Climate scenarios are therefore narratives of possible futures based on assumptions of the consequence of different levels of GHG emissions. For example, the IPCC has developed a range of scenarios based on a range of different climate models,

'A climate scenario is a plausible representation of future climate that has been constructed for explicit use in investigating the potential impacts of anthropogenic climate change. Climate scenarios often make use of climate projections (descriptions of the modelled response of the climate system to scenarios of greenhouse gas and aerosol concentrations), by manipulating model outputs and combining them with observed climate data.' https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-13.pdf page 741

The Task Force for Climate-Related Disclosures (TCFD) recommendations include climate scenario analysis as a technique underpinning how companies can test their business models against multifaceted climate impacts. Its uptake has been driven by announcements regarding impending mandatory reporting requirements linked with the TCFD recommendations. For example, the UK Government intends to make TCFD-aligned disclosures mandatory by 2025[24]. These regulatory changes are interconnected with growing investor interest in ESG (Environmental, Social and Governance) and, specifically, climate risk. Companies therefore face rapidly increasing regulatory and investor pressure to analyse business model resilience to climate change.

Climate scenario analysis supports decision making within uncertain conditions, structuring the way companies explore alternate possible futures. It guides a collaborative process across multiple business functions, aimed at considering how numerous climate drivers—such as Social, Technological, Economic, Ecological and, Political/Legal (referred to as STEEP) drivers (Haigh 2019)—may impact their assets, operations and supply chains.

In doing so, scenario analysis builds capacity for anticipating surprises and remaining resilient throughout the low carbon transition. However, climate scenario analysis is not a forecasting technique. Instead it pushes companies to think beyond day-to-day concerns and to embrace the idea that the future will be different, and that it could be different in many alternate ways. It is by engaging in this structured imagination that participants come to change how they understand the present (Cunha 2004).

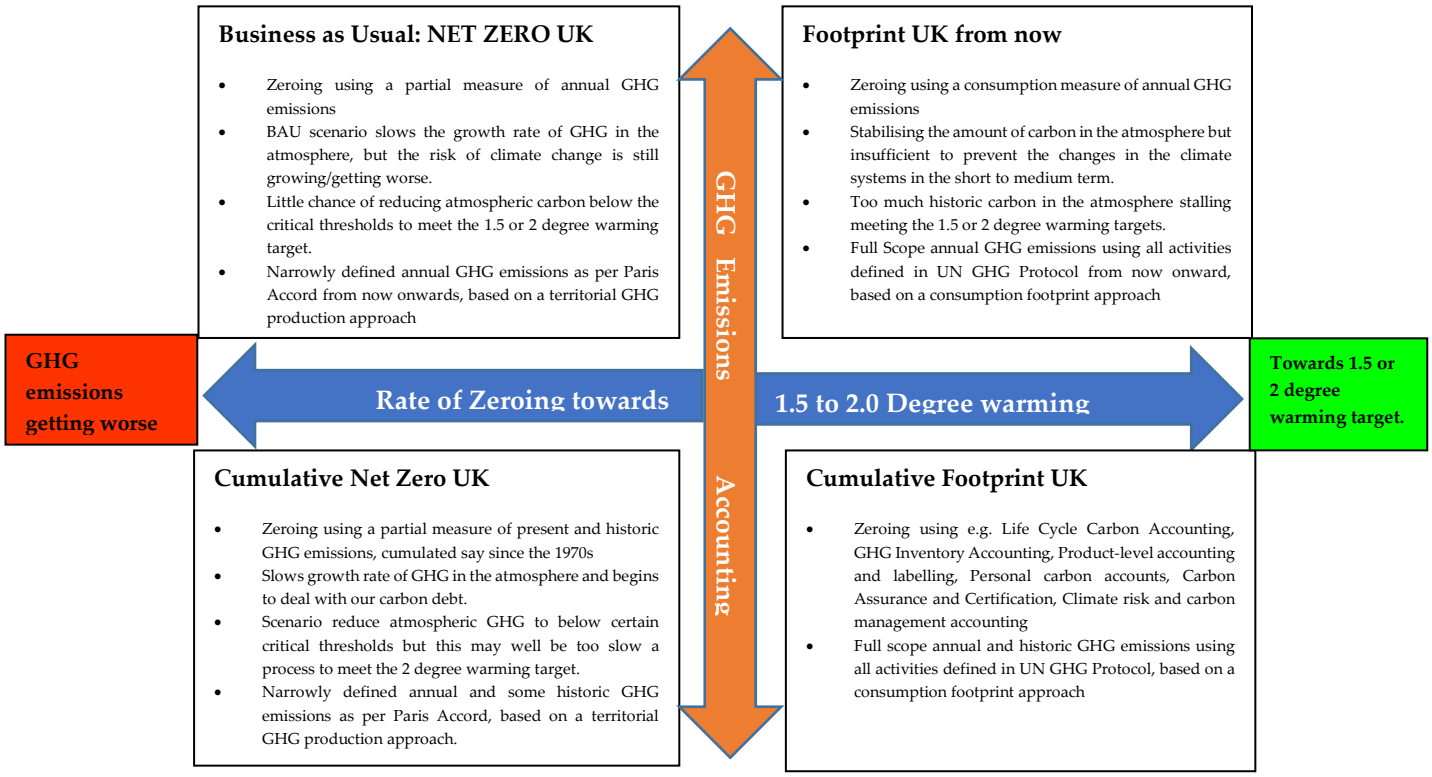
Any scenario analysis should build the capabilities companies need to navigate the many ways in which climate change may shape the future. So these discussions should be directed at opening up debate on alternate futures and not on reaching a consensus viewpoint on how what the future will hold (Cairns and Wright 2017). Research suggests that companies should draw on four alternate scenarios for their analysis. While using three scenarios is commonplace, using four mitigates the tendency to become overly focussed on a middle ground.

[24] https://www.gov.uk/government/publications/uk-joint-regulator-and-government-tcfd-taskforce-interim-report-and-roadmap

It does so by allowing for two 'middle' scenarios, each of which focuses on a different range of climate drivers (Haigh 2019).

To illustrate this approach, we used 2 scenario axes to explore the factors influencing the climate systems and institutional responses, in particular choices in how to account for GHG. This created four scenarios distinguished principally by divergent futures associated with two highly influential and uncertain drivers. Our team ensured each scenario deals with internal logic questions, i.e. if logically possible (without reference to likelihood), these events and trends could indeed unfold in reality. If not, what part of the story needs to be changed? What features could not possibly occur, given the way climate change systems works and the antecedent parts of the story?

For the purposes of this short section, we do not fully discuss all of the STEEP influencing factors (Haigh 2019), rather we adopt the narratives contained in earlier IPCC reports in relation to the rate of zeroing required by 1.5 and 2-degree warming forecasts. Figure 3 below summarises the scenarios.



As discussed earlier these 4 scenarios accept that a particular GHG accounting is used to judge the acceptability of all policy and regulatory interventions using the 10GIR decision chains and decision contexts identified in previous sections. These scenarios create possible consequences of related decisions, using a loose form of if..then..thinking.

If we use Net Zero accounting, then how will this determine the quantity of GHG to be removed from our atmosphere. These consequences can be compared with the possible consequences of using Footprint UK to make the same decision. These consequences can then be constructed into possible narratives that intersect with the latest IPCC and Governmental climate change projections. Earlier we used the overflowing bath analogy to simplify the climate system and to represent the likely impact of the different GHG accounting scenarios. This analogy can be usefully further developed by including other STEEP factors, trends and events at the global, national and sub-national levels, that act as climate change system drivers.

Scenario One – NET ZERO UK

- Zeroing using a partial measure of annual GHG emissions is the equivalent of turning down one tap a little with no change in anything else. It slows the growth rate of GHG in the atmosphere, but the risk of climate change is still growing, and the problem worsens. This scenario has little chance of reducing atmospheric carbon below the critical thresholds to meet the 1.5 or 2-degree warming target.

Scenario Two – FOOTPRINT UK FROM NOW

- Zeroing using a consumption measure of annual GHG emissions is the equivalent of turning off both taps. Stabilising the amount of carbon in the atmosphere but insufficient to prevent changes in the climate systems in short to medium term. There is still too much historic carbon in the atmosphere to allow us to meet the 1.5 or 2-degree warming targets.

Scenario Three - CUMULATIVE NET ZERO UK

- Zeroing using a partial measure of present and historical GHG emissions, say since the 1970s is the equivalent of turning off one tap and pulling out the plug for a short period. This slows the growth rate of GHG in the atmosphere and begins to deal with our carbon debt. Over time it could reduce atmospheric GHG to below certain critical thresholds, but this may well be too slow a process to meet the 1.5 or 2-degree warming target.

Scenario Four – CUMULATIVE FOOTPRINT UK

- Zeroing using a full life cycle measure of present and historical GHG emissions is the equivalent of turning off both taps and pulling out the plug until the bath drops to a sustainable level. Once the tub is not overflowing, we can manage its level through the intelligent coordinated operation of both plug and taps. This scenario has the best chance of reducing atmospheric GHG below certain critical thresholds to meet the 1.5 or 2-degree warming target.

Other possibilities for the vertical axis could include; changes in global GHG regulations post COP26; different business zero carbon strategies; new zero carbon technology roadmaps; development of GHG contingent cost of capital; changing social acceptability of different products or sectors; changes in carbon assurance and certification schemes; different regional policies and development models.

Climate change is a systemic source of uncertainty intersecting with all socio-ecological systems. Decision-making will be enhanced by exploring multiple scenarios that represent the possible influencing factors.

8. A Review of GHG Accounting and Finance Research[25]

GHG accounting and finance has been subject to considerable inter-disciplinary research activity. For example, Appendix 1 lists of over 150 scientific articles or policy reports. Getting to grips with GHG accounting, finance, taxation and assurance research is complicated because it draws on many disciplines and is a dynamic, continually evolving research field. In 2012 Carbon accounting was defined as:

'the non-monetary and monetary evaluation and the monitoring of greenhouse gas emissions on all levels of the value chain and the recognition, evaluation and monitoring of the effects of these emissions on the carbon cycle of ecosystems.' (Stechemesser and Guenther 2012, p. 35).

In the 9 years since this systematic review, many new topics have been added to this definition, including estimating changes in emissions caused by specific actions, climate scenarios, personal carbon accounts and the removal of GHGs from the atmosphere. Definitions of GHG accounting have changed over time and will continue to change. This is one field where it is important to keep up to date with the latest science and thinking. This section will provide an overview of this emerging field and briefly outline key issues and terminology that we consider relevant to achieving a Net Zero UK and the 10GIR. It is structured into a number of different topics, which are:

- What is GHG Accounting
- Science-based target setting
- Life Cycle Carbon Accounting
- Product-level accounting and labelling
- Carbon Assurance and Certification
- Accounting for GHG Emission Rights
- GHG Accounting for the Earth and international climate governance
- Carbon Taxes and government Interventions
- GHG Inventory Accounting
- Personal carbon accounts
- Climate risk, carbon management accounting and regulatory guidance.
- Accounting for negative emissions technologies

What is GHG Accounting?

Ascui and Lovell (2011) list a range of GHG accounting practices, identifying the importance of different scales and entities e.g. global and national inventories down to corporate or product-level assessments, and different purposes, such as compliance, research, marketing, product design, financing and risk management. Achieving a Net Zero UK, in a net zero world, requires the application of context appropriate GHG accounting practices that connect relevant accounting with how the decision could reduce GHG emissions. GHG accounting choices should be informed by a theory of change that connects the specific decision with Net Zero outcomes, i.e. how will this decision contribute to progress towards Net Zero. There is a need for greater knowledge of the range of carbon GHG methods, in particular their strengths, weaknesses and appropriate applications.

Research suggests that GHG accounting should not be restricted just to decisions pigeon-holed as GHG reducing. For example in the past the Scottish Government shown a selective spotlight on a number of key projects with the potential for substantial GHG emission reductions. However, these projects only constituted a small percentage of their annual budget and an evaluation of the whole budget revealed that 97% of their expenditure was likely to increase GHG emissions. To address this, for at least the last 10 years The Scottish Government produces a GHG estimate of their whole expenditure plans which is submitted to Parliament to be scrutinised alongside the financial numbers[26].

[25] Summary of Brander, Charnock and Schneider (2021) Carbon in Routledge Handbook of Environmental Accounting, with some additional material.

[26] https://www.gov.scot/publications/carbon-assessment-budget-2020-21/

GHG accounting should apply to all decisions, especially those with the potential to increase carbon emissions. It is difficult to envision how the selective application of GHG accounting to a small subset of decisions, preselected based on prior assumptions they will reduce carbon emissions will bring about the radical transformation expressed in the UK Net Zero aspiration. Returning to our overflowing bathtub this would be like carefully monitoring and managing the flow from one tap, ignoring the amount of water already in the bath while allowing the other tap to do what it wants and guessing whether the plug is in or not.

GHG Accounting for the Earth and International Climate Governance.

This category of GHG accounting is dominated by natural sciences, particularly geosciences, climate science, and ecology, focussing on the global carbon cycle. For example, Liu et al. (2010) explore the magnitude of CO2 removals from the atmosphere by aquatic organisms. This work led to the development of the "carbon budgets" concept – identifying maximum levels of carbon emissions, in total and allocating this budget to different nations and/or activities e.g. domestic heating or industrial sectors such as cement or transportation (Rogelj et al. 2016.) This research is still experimenting with GHG accounting methods. There is not a single standard universally accepted approach to GHG measurement, resulting in many ways to 'account' for global and local carbon cycles as well as different methods to allocate 'carbon budgets'. Even the IPCC has been criticised for the inconsistent use of carbon budgeting. However, we need to recognise this experimentation and innovation is a normal feature in social systems. We rarely criticise software companies for continually improving their products, or vehicle manufacturers for consistency in product design or athletes for not pushing their performance. What is wrong with striving to improve how we account for GHG, particularly when those undertaking this momentous task are aware of their limitations.

Typically this type of GHG accounting works well with high level / macro entities (globe, country, sector) and feeds into determining appropriate levels of emissions based on different scenarios and desired outcomes, as well as global conventions, carbon rationing, carbon trading schemes and can be used as a trigger for enforcement sanctions or to monitor compliance. Most other GHG accounting systems derive from these scientific programmes, either conceptually or directly apply their measurement protocols, for example, CDP or Science Based Targets.

When the Paris Agreement was reached in December 2015 it marked a fundamental shift in climate governance towards a decentralised "pledge and review" system (Charnock and Hoskin 2020; Falkner 2016). This raised significant and pressing questions, such as how nations are held accountable for their pledges, how to ensure financial flows are consistent with the Paris goals, and whether GHG accounting methods for national GHG inventories are fit for purpose. We have already discussed how GHG Accounting approaches (e.g NET ZERO UK) that designed for compliance monitoring can be problematic in other decision contexts, including the transparency of international flows of climate finance, technology and information (Weikmans and Roberts 2019). Indeed, there is also a growing need for the social sciences to engage with bodies such as the IPCC, whose highly influential synthesis reports are now looking beyond the natural sciences (Charnock and Thomson 2019). Research is needed to evaluate the alignment of different GHG Accounting approaches alongside investigations into the suitability and effectiveness of different policy approaches to specific aspects of the climate agenda, such as regional, sectoral and institutional impacts and risks.

Science-based Target (SBT)

This type of GHG accounting tends to operate, below the level of national governments, in "non-state spaces" – for example, regional governments, non-governmental organisations (NGOs), businesses and public bodies with an interest in climate change mitigation (Bebbington and Harrison 2017). Science-based targets (CDP et al. 2015) involves setting sector or business level reduction targets that are consistent with the Paris Agreement. SBT is a form of allocating the global carbon budgets to specific social or economic actions, e.g. generating energy, human mobility, constructing buildings or products, such as steel or cement. The underlying concept is to re-design these systems, sectors or product within these allocated GHG budgets. However, SBT is a voluntary initiative and lacks regulatory sanctions or enforcement mechanisms, but it is regarded as one of the most

systemic and comprehensive approaches in the GHG accounting 'market'. The effectiveness of SBT is largely determined by addressing concerns as to whether the budgets determined by science-based target-setting methods are genuinely aligned with below 2°C pathways and whether voluntary initiatives can shape organisational activity and influence regulatory agendas.

Carbon Taxes and government Interventions

There are a range of government interventions to reduce GHG emissions that are connected to accounting and finance. These interventions include financial subsidies to encourage the expansion of renewable energy technologies and legal obligations to reduce carbon usage in buildings, cars and appliances (Bowen and Fankhauser, 2017). However, these interventions may not be sufficient and a form of carbon pricing may need to be introduced which will create financial incentives to reduce emissions and additionally generate revenue for governments. There are two main approaches to carbon pricing: emissions trading systems (ETS) and carbon taxes; both of which put a price on carbon. However, there is no standard way of implementing both these forms of carbon pricing and each territory can choose different aspects of them with different rules. 21.5% of global GHG emissions are covered by carbon pricing instruments in 2021, and 22 of the 29 countries which have adopted net zero targets have carbon pricing (World Bank, 2021).

ETS which are sold by governments are market-based instruments which aim to control GHG emissions through two methods: cap and trade; or baseline and credit system. In a cap and trade system the particular government decides on a limit for emissions (the cap) in a particular period and allowances are either auctioned or allocated. Under a baseline and credit system, GHG emission baselines are set for regulated emitters. Emitters with emissions above this base line need to surrender credits to make up these emissions. The particular regulator will set a limit of the amount of emissions for a particular sector of the economy. A monitoring system on usage is set up and if these limits are exceeded then penalties are imposed by way of fines. Companies who do not use their allowances by reducing their emissions can trade their allowances with other emitters who may exceed their allowance, thus creating an ETS market. In summary, to function effectively ETS require a market structure, enforcement, auditing, fraud prevention and mechanisms to control pollution (Andrew et al. 2010). The effectiveness of an ETS depends on the level of emissions permitted and the subsequent price of GHG (mainly carbon).

Alternatively, a carbon tax sets an exact price on carbon by specifying a tax rate on GHG emissions. This tax is charged on the polluting company with the aim that the polluting company will strive to lower their emissions to reduce their tax burden. There are a number of complexities with carbon taxes: the tax base (i.e. on what the tax is charged on); when the tax becomes chargeable and the particular rate of tax.

The UK approach.

In the summer of 2020, the UK government consulted on the potential implementation of a carbon emissions tax (HM Treasury, 2021). The UK Emission Trading system was introduced from 1 January 2021. An ETS (cap and trade system) approach was favoured to a carbon tax and a carbon tax would only have been enacted if the UK left the EU without a deal. This did not happen. The cap was introduced which was set at 5% below the EU ETS cap. Businesses covered by an ETS must buy a 'permit' or 'allowance'. The particular ETS scheme applies to energy intensive industries, power generation and aviation. The first auction of ETS permits took place in May 2021.

Life Cycle GHG Accounting

Within the GHG field a large body of research finds that GHG accounts that capture life cycle GHG emissions as a consequence of a decision are more likely to be aligned with actions that support reductions in global GHG. The implication of this research is that Life Cycle GHG accounting should be the default approach, rather than narrowly defined attributional methods. Life Cycle methods calculate GHG emissions (and other forms of environmental impact) across all stages of a product's life cycle. For example, Eide (2002) studies the environmental impacts from industrial milk production, including agricultural emissions, processing,

consumption, and the waste management of packaging. Typically this type of GHG accounting is used at a very granular level, such as products or projects. It's strength is that it measures cumulative GHG emissions from 'cradle to grave'. It provides useful input into product design, project evaluation, pricing, procurement and consumer purchase decisions. Given the required depth of analysis and customised nature of this type of accounting it is often very difficult to use for comparison purposes, benchmarking or for regulatory compliance monitoring.

GHG Inventory Accounting

This type of GHG accounting uses a list of carbon emission categories and then attributes GHG emissions to these categories. The inventories are normally constructed by experts, regulators or politicians to resolve a specific problem. Previous sections have discussed the limitations of GHG Inventories such as DEFRA Corporate Disclosures, OFWAT and stock exchange listing requirements. In principle their main advantage is in providing consistent, reliable accounts that can be linked to regulatory enforcement mechanisms. GHG Inventory Accounting is most common approachto measure and report corporate greenhouse gas emissions and is favoured by regulators. In this context they can and do operate effectively, but as discussed earlier they are often co-opted for purposes they were never designed for. And this creates major problems as attributional inventory accounting can produce meaningless numbers that seriously distort many decision making process, particularly when individuals mistakenly trust the construct validity[27] of these numbers and consider they produce relevant evidence of GHG consequences.

GHG Inventory Accounting is applied in many different contexts – e.g. National GHG accounting, local communities or even individual projects. It is attributional in nature in that these GHG accounting categories are pre-determined and standardised. Any GHG measure is constrained by these categories and the choices made as to which inventory items to include for specific decisions. Meaningful application of a GHG Inventory requires re-assessing the relevance of the inventory to individual decisions contexts and how the decision is expected to impact GHG emissions BEFORE applying it. Problems arise when GHG inventories as used in a box-ticking manner.

The research into GHG Inventory accounting is dominated by studies on corporate accounting and disclosure, rather than national-level governance (e.g. Harris and Symons 2013; McGlade and Ekins 2015; Charnock and Hoskin 2020). Research into corporate GHG emissions reporting has found such high levels of inconsistent use of categories combined with a very narrow selection of inventory items and a lack of transparency on methods that these corporate disclosures cannot be meaningfully analysed or evaluated.

This type of GHG Inventory approach forms part of sustainability reports and/or mandatory company reports. Carbon disclosure requirements are becoming increasingly prevalent, via securities regulation and an array of laws that especially target large emitters (Schneider et al. 2018). GHG Inventory accounting looks to provide a standardised and comparable measures of GHG emissions, but in doing so it often problematically feeds into investor decision making, stakeholder activism or management decision making. It has the potential to be used in effectively in conjunction with carbon budgeting for regulatory and performance management purposes. However, it is important to ensure that the same categories are used in constructing the budget and measuring emissions, but this can mean that the GHG figures produced are relevant for regulation and problematic for decision making.

Product-level accounting and labelling

Many people argue that 'carbon' will be the next currency replacing or complementing the price tag, in the same way as 'traffic light' labelling informs healthy choices in food products. Product-level GHG accounting and

[27] the degree to which a calculative device measures the characteristic of concern or the extent to which conceptual definitions match the calculative protocols.

labelling provides information to aid consumers' purchasing decision. The label will act as important final information disclosures that the consumers will see; however, it is important that the GHG accounting behind the label is visible and clear to the consumers. This labelling should apply to all purchase decisions including Business-to-business procurement as well as personal consumption.

One of the questions here is that how the consumers make sure that the carbon information of the same product types from different brands are comparable or subject to the same standard? The carbon information is dependent on the complex and ambiguous chain of calculations and number allocations from the production stage to consumption and disposal stages. Although this is a consumption-based carbon accounting that has a potential to consider the GHG emission thought the product life cycle, the calculated carbon information for a unit of certain product might be "counter-factual" (Ormond and Goodman 2015) and challenge pre-existing norms and assumptions of low-carbon choices. Although the calculation of product-level carbon footprint entails a number of issues, this practice will raise the awareness of GHG emission throughout the supply chain activities, which potentially lead to the emergence of related GHG reduction activities through "cost-carbon efficiency, market-led innovation and consumption-driven change" (Ormond and Goodman 2015, p. 129).

The effectiveness of retail GHG labelling is complex and is being extensively research. In 2019 researchers in France set up an experimental grocery store with 300 products, which either had no GHG label, a traffic light labels for GHG (red high, amber medium, green low) or stated the number of kilometres a car would need to drive to produce the equivalent level of emissions. This labelling did have a significant impact on the levels of purchase of lower GHG items, regardless of the format of the GHG labels. This was replicated in a Belgian supermarket. Whereas in a study in China products labelled with carbon calculators, showing the percentage of the price going towards carbon off-setting schemes, were less effective than a more ostentatious environmental label. In the US rhe more the label showed the personal impacts of sustainability, the more favourably the product's ethical credentials were viewed. But a very clear finding was credibility, reputation and transparency of the company making the product and those producing the label. Researchers have found third-party certification schemes are important way of ensuring consumer confidence in any eco-labels but the source of those endorsements is also key. While labelling schemes run by governments and environmental NGOs were most trusted by consumers, those developed by business organisations were deemed untrustworthy unless audited by credible third parties.

Personal carbon accounts

Personal carbon accounts have become more important for the race to Net Zero. The report "Achieving Net Zero Forty-Sixth Report of Session 2019–21" by House of Commons Public Accounts Committee highlighted that "there was a disconnect between people's concern about climate change and their understanding of what is required to achieve emissions reductions in the UK". In addition, The Climate Change Committee (CCC) estimated that as much as 62% of the future emission reduction will rely on individual choices and behaviours. This leads to the need for problematization of carbon emission responsibility of individuals. One of the main challenges to govern Individual actions related to carbon emission is to make them aware of the problem, understand the issues and relate the numbers from carbon accounting practices to their actions and behaviours (Miller and Rose 2008).

Paterson and Stripple (2010) mentioned five practices of carbon accounting at the individual levels. Those include footprinting, offsetting, dieting, rationing and creating personal allowance and trading systems. These practices create accounts that make individual to be "responsible subject" of carbon emitters (Paterson and Stripple, 2010), rather than territorialized the calculation of carbon that mainly focuses on the production-based emission. Different practices also form different identities of the adopters, including carbon counters, displacers, dieters, communitarians or market citizens.

Actionable carbon accounts at this level, which is largely voluntary, therefore, depend heavily on the individual understanding and willingness to make decisions that lead to reduction in carbon emission. Although, there has been attempts by the UK government in April 2020 to establish a behaviour change and public engagement team

for net zero to begin designing a public engagement strategy and share good practice across government, it was not yet providing an integrated accounts of public engagement and that there was more work it needed to do to address this gap in 2021. The translation of our daily activities into meaningful numbers relevant to this national and global aspiration are not so visible and tangible that the public could see the scale and the significant of the changed behaviours to help achieve the goal.

Carbon Assurance and Certification

As can be seen from the previous sections, GHG accounting is beset with a number of issues, which affect the quality of these GHG emission accounts. A growing trend has been to get these 'accounts' audited, certified or assured, increased the perceived quality of the GHG accounts. However, these auditing standards introduce a number of new GHG Accounts, including different quality certification schemes or compliance audits. At present these audits have to interpreted in the context of different GHG Accounting practices. The audit is often customised to specific issues and has to be understood in that context. There is no generic form of audit or assurance that transcends different GHG Accounting. Its role is largely confirming that the general protocols of a chosen GHG Accounting process have been reasonably applied, not that the GHG emission data is the most appropriate for different decision contexts. These particularly relate to "hard" targets set by the firm or regulators , not to the appropriate accounts to achieve Net Zero. Green,Taylor, and Wu (2017, p. 31) state that "there is a clear and defined set of disclosures of measurable parameters", arguing that this implies more similarities with a financial audit.

GHG assurance of GHG corporate disclosures is dominated by the big four auditing firms (KPMG 2017), but there is the emergence of many carbon counters, carbon counters and carbon assurers, each with a preference for different GHG accounting measures and with expertise in a particular dimension of GHG emissions. These GHG 'accountants' tend to derive their practices from their knowledge/experience of the scientific, engineering or technical aspects of GHG reductions rather than accounting or auditing

Climate risk, carbon management accounting and regulatory guidance.

There has also been a substantial rise in regulatory guidance on carbon disclosure, both regarding environmental risk and disclosure (e.g. CSA 2019; BIS 2020; SEC 2010). With both the regulatory and real effects of climate change becoming manifest, GHG accounting is now a material item for investors and thus falls under the continuous disclosure regulations underlying all major stock exchanges, or is specifically mandated by securities regulations (Bebbington et al. 2020; Schneider et al. 2018). Climate risk has recently attracted increasing attention within academic research about GHG accounting. Since the landmark 2015 Paris Agreement on climate change, governments and practitioners have become increasingly concerned about the physical, market and regulatory risks that climate change could pose to business and finance.

These risks are not entirely new to social and environmental scholarship. By the mid- 1990s a range of primarily qualitative studies – drawing on interviews, case studies and documentary analyses – were already highlighting the litigation risks of environmental disasters (Coulson and Dixon 1995) and how climate change could be factored into risk management practice. However, there is renewed interest in this space, across academia, industry and policymaking. Where physical risks arise through the impacts of climate change, the market and regulatory risks are now seen as stemming from the prospect of a "carbon- constrained future" (Bebbington and Larrinaga-González 2008) and a global transition away from fossil fuels.

There is a need to e should develop conceptual insights on how to operationalise the low-carbon transition through CAPEX decisions – mitigating locked-in emissions, the stranding of assets as well as the stranding of liabilities – from many studies (Larrinaga-Gonzalez and Bebbington 2001; Cushen 2013). Additional challenges are emerging in managing operations and measuring performance in organisatios, adding to interest in the dynamics between accounting and organisational action on climate change. For example, what is the likely impact of integrating GHG metrics into remuneration, incentives or sanctions. This is an area where valuable conceptual insights can be drawn from leading performance management scholarship (e.g. Chenhall, Hall, and Smith 2013).

This type of GHG Accounting focuses on changes in management practices (Kumarasiri and Jubb 2016) that help highlight more carbon-intensive aspects of production (Cadez and Guilding 2017) and supply chain hot spots (Acquaye et al. 2014) that require action or interventions. These management-oriented techniques offer valuable insights into the interplay between national policies, corporate strategies, carbon management accounting (Bui and Fowler 2019) and the emergence and development of new practice that seek to operationalise GHG management as reported by Gibassier and Schaltegger (2015).

Bebbington et al. (2020) provided a recent example by exposing the (in)adequacy of current reporting practices within the fossil fuel sector. The study is based on the concepts of unburnable carbon, stranded assets and the risk of stranded liabilities that question whether existing fossil fuel resources can be burned if climate change goals are to be met. The authors used a multi-methods approach, combining a survey of accounting disclosure rules for fossil fuel resources, accounting disclosures made by fossil fuel firms, and stock market participants' views on stranded asset risk. This type of study demonstrate the urgent need for making sense of shifting climate risk perceptions and regulatory agendas, as well as proposing climate- related applications for existing accounting techniques.

We are likely to see greater penetration of GHG accounting into the management accounting in organisations. We have noted how Global GHG Budgets have led to National GHG Budgets to sector GHG Budgets and this trend is already being extended into departmental GHG budgets, product GHG budgets. Performance measurement systems are integrating GHG measures and it is feeding into investment decisions and pricing. It is critical that we make use of the existing scientific research into effective accounting to make sure that our hybridised GHG accounting systems don't replicate the problems of conventional accounting that we already know about!

Accounting for GHG Emission Rights

This GHG accounting emerged as a consequence of market based or trading approaches to control GHG emissions (Bebbington and Larrinaga-González, 2008; Mete et al. 2010, McNicholas and Windsor 2011, McKenzie, 2009) These trading schemes attempt to construct a market for GHG emissions with companies placing a value on these emissions, and managing their emissions through the buying or selling of 'rights to emit GHG'. This has led to debates on how to account for these rights and how to value them. If you have purchased the right to emit x tonnes of GHGs, then is this really an asset to include in the Balance Sheet. Questions remain as to whether emission rights are a financialisation of the atmosphere and that market-based solutions are inappropriate for a problem caused by markets. With the proliferation of carbon markets around the world, these debates and accounting treatments are far from settled (see Jotzo et al. 2018). What is of concern in this area is when inappropriate accounting for these emission rights perversely incentivise increases in GHG emissions or inappropriately represent the connection between the value of emission rights and climate change.

Accounting for negative emissions technologies

An interesting observation is that most of the research in GHG Accounting is that they focus on measuring emissions. Most of these accounts don't even include categories for reducing emissions. This includes the UN GHG Protocol that forms the foundations of most GHG Accounts, however this is something that is currently under review. This is the equivalent of preparing a Cost Benefit analysis but only including costs. Net zero strategies depend on the removal of GHG from the atmosphere in addition to emitting less GHG. Many of the nature-based solutions to climate change are legitimated by their capacity to transform atmospheric GHG into more benign forms, locking them in carbon sinks such as peatlands, oceans or forests. Yet accounting for the removal of GHG is one of the most under-developed areas in GHG accounting.

Negative emissions technologies (NET) that remove GHG from the atmosphere, such as bioenergy with carbon capture and storage (BECCS), afforestation, and direct air capture and storage, need to be robustly evaluated based on consequential GHG emission measurements. Such technologies are required to achieve targets such as the UK government's pledge to achieve net zero emissions by 2050 (UK Parliament 2008), and also for dealing with an emissions "overshoot" if warming exceeds 2°C (Smith et al. 2015). Many of these technological solutions are controversial and their merits challenged by powerful stakeholders. These technologies pose distinct

accounting challenges, such as how to support NETs within existing incentive mechanisms, and how to allocate responsibility for historic contributions to cumulative emissions.

Concluding Comments

This section has provided a brief summary of a rich, dynamic and interdisciplinary field of practice and research. As we type and you read this new research will be emerging, new experiments undertaken and innovations in practice. The nature of the climate emergency is such that we have a responsibility to ensure that any GHG accounting used is aligned with the latest thinking and research in this field. The underlying message of this whole report is that how GHG is measured and accounted for matters. It is not trivial, geeky or unimportant. It is something we need to constantly strive to ensure we get it right as often as possible. The consequences of getting this wrong are potentially catastrophic.

Appendix 1. Carbon Accounting, Reporting and Finance Themed Reference List

Carbon Accountants and Carbon Accounting Practices

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