Greenhouse Gas Emissions and Infrastructure Investment Decisions

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September 2020

Executive summary

Aims and findings

The Scottish Parliament has committed to achieving net-zero territorial emissions by 2045, as set by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019. Designing and delivering appropriate infrastructure investment will play a large part in achieving this goal.

This report looks at approaches the Scottish Government could use to assess and report on the alignment between its Infrastructure Investment Plan and Scotland's greenhouse gas (GHG) emissions reduction ambitions.

This report is intended to inform the development of the Scottish Government's response to the requirements of the 2019 Act to report on the extent to which its infrastructure plans contribute to meeting the emissions reduction targets. In addition, the Infrastructure Commission for Scotland's *Phase 1: Key Findings Report* recommends that the Scottish Government develop a 'new infrastructure assessment framework and methodology' by 2021. The research presented here is also intended to support the Scottish Government's response to this recommendation.

The Scottish Government's plans and priorities for infrastructure investment are set out in Scotland's Infrastructure Investment Plan, with the latest Plan published in 2015, and a forthcoming Plan due to be finalised later in 2020.

The Scottish Government already uses a range of GHG emissions assessment methods, such as input-output modelling, taxonomies, and integrated assessment modelling, but the Government is also keen to understand emerging practices from other institutions, such as multilateral development banks, green investment banks, other governments, and international agencies and NGOs.

Based on a review of emerging global best practice and interviews with key Scottish Government and international stakeholders, we identify four different types of assessment approach, which each give different information and are appropriate for answering different questions. These approaches and the types of question they answer are:

1. **Absolute emissions methods**: 'How much of Scotland's remaining carbon budget is 'used up' by a particular infrastructure asset?' and 'How much value per unit of carbon budget does this infrastructure asset create?'

2. **Baseline-and-intervention methods**: 'What is the total change in emissions caused by the decision to build this infrastructure asset?'

3. **Gap analysis:** 'What is the gap between current infrastructure plans/spend and what is needed to meet the emission reduction targets?'

4. **Taxonomies**: give a simple categorisation of different types of infrastructure, e.g. as 'low carbon' or 'high carbon', usually for broadly indicating whether an asset is likely to be consistent with reduction targets.

Some of these approaches are relatively simple, such as the taxonomy approach, but there is often a trade-off between the simplicity and the value of information gained through this method. More sophisticated approaches are appropriate for decisions with larger potential impacts.

Methodological development in this area is the subject of live debate. Many of the assessment approaches, particularly those specific to infrastructure, have only recently been developed and there are relatively few examples of detailed implementation. Over time, these methods are likely to become less resource-intensive but initial investment is needed to develop data sets, models and expertise.

From the interviews with stakeholders a number of further important issues were identified. This included the possibility of measuring the wider social and economic benefits from different infrastructure investments, rather than solely the emissions impact. This issue is highly relevant to the Scottish Government's commitment to a just transition and inclusive economic growth, including maximising and capturing the social and economic opportunities associated with decarbonisation.

Conclusions and suggestions

1. A phased approach is needed: Planning and investment in new data and resources is needed to develop a coordinated GHG assessment framework or methodology for infrastructure investments. This will take time.

2. A taxonomy approach could be applied over the short term: In the short run (i.e. for the 2020 Infrastructure Investment Plan), the Scottish Government could continue to use a taxonomy approach to assess the impact of the Infrastructure Investment Plan. An existing approach such as the EU Sustainable Finance Taxonomy or Climate Bonds Initiative taxonomy could be used. To maximise the benefits from any actions taken to enhance the interim use of a taxonomy, priority could be given to actions that will also be useful once a more complete framework is developed. A more complete framework could be developed in 2021, in line with the recommendation from the Infrastructure Commission for Scotland.

3. Applying a gap analysis approach would help build an understanding of the investment required to reach the GHG reduction targets: Over time, estimates for the infrastructure deployment or spend required to achieve the decarbonisation pathway could be developed. This information can then be used to assess how closely this matches with the investment plans set out in the Infrastructure Investment Plan, National Planning Framework, and annual capital budget. Required levels of spend will be particularly useful for comparing to annual budget allocations.

4. A suite of assessment methods could be applied to provide a holistic understanding of the impact of the Infrastructure Investment Plan: A sophisticated approach would incorporate an overall gap analysis as well as a baseline-and-intervention assessment, coupled with estimates of the wider social and economic benefits. However, the resource and analytical challenges of such an approach should not be underestimated.

5. Assessment approaches can be applied to quantify emissions associated with Scotland's infrastructure projects that occur beyond Scotland: Baseline-and-intervention methods could be used to assess the impacts from Scotland's infrastructure that occur outside of Scotland's territorial boundary to ensure that negative impacts are minimised and positive effects are enhanced.

Contents

1 Introduction

1.1 Background context

It is estimated that just over half of annual greenhouse gas (GHG) emissions are associated with infrastructure (Mott MacDonald, 2013). This is either through the building and operation of the assets (16% of the UK's annual total), or through the use of infrastructure (37% of total) (Mott MacDonald, 2013). The F20, a grouping of private foundations that raise awareness of climate change, published a report on infrastructure investment (Bhattacharya et al., 2019) which calls for G20 members to endorse the development of a methodology to track sustainable infrastructure investment and for infrastructure investment to be aligned with the Paris Agreement to limit global average temperature increase to 1.5°C[1]. Aligning current infrastructure decision-making with the Paris Agreement goals is particularly important due to the long-lived nature of infrastructure, and the potential for 'lock-in' to high carbon pathways.

The definition of infrastructure used in this report follows that proposed by the Scottish Government. This includes transport, energy, telecoms, water, waste, flood defences, housing, education, health, justice and culture. The approach proposed can also include the assessment of natural assets such as forests and peatland.

1.2 Scottish context

Last year the Scottish Parliament passed the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 which sets the target of net-zero GHG emissions within Scotland by 2045. This includes interim targets to reduce emissions, compared to a 1990 baseline, by 56%, 75% and 90% by the years 2020, 2030 and 2040 respectively. These targets are for emissions and removals that occur within Scotland. In addition, the Scottish Government is required to report on emissions associated with goods and services consumed within Scotland (whether or not those emissions occur within Scotland).

The Scottish Government (2020) recently reported Scotland's 2018 GHG emissions. This report shows that Scotland's emissions in 2018 increased by 0.6 $MtCO_2e$ (approximately 1.5%) in the previous year to 41.6 $MtCO_2e$. As the latest Climate Change Plan (Scottish Government, 2018) predates the net-zero targets, this plan is currently being updated.

To achieve these targets, significant emission reductions are required across all sectors of Scotland's economy, including the underlying infrastructure upon which these sectors depend. The updated Climate Change Plan will identify the policies and proposals that will deliver the emissions reduction and will provide an indication of the new infrastructure required to help meet these targets.

In recognition of the important relationship between infrastructure investment and the climate change targets, the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 includes a new requirement to assess and report on the extent to which investment in infrastructure is expected to contribute to meeting emission reduction targets. In addition, the Planning (Scotland) Act (2019) requires, as part of the National Planning Framework, 'an assessment of the likely impact of each proposed national development's lifecycle greenhouse gas emissions on achieving national greenhouse gas emissions reduction targets'. It remains to be determined exactly what information should be provided and therefore which type(s) of method will be appropriate.

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[1] The Paris Agreement set the goal of keeping a global temperature rise well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius.

The Infrastructure Commission for Scotland's Phase 1 report (2020) states that the Scottish Government's targets to become a net-zero economy will have significant bearing on the types of infrastructure investment required as well as the way in which decisions are made. The Commission recommends that the Scottish Government develop and publish a new infrastructure assessment framework and methodology to enable system wide infrastructure investment decisions to be prioritised based on their contribution to achieving an inclusive net-zero carbon economy.

The Scottish Government currently has a number of tools for reporting how its investment and Budget decisions are contributing to efforts to reduce GHG emissions, including a carbon assessment of the Budget which is published alongside the other Draft Budget documents[2]. The current assessment includes solely emissions associated with the Scottish Government's purchase of goods and services and does not therefore include the emissions or savings associated with the outcomes arising from Government spending.

Table 1 provides a brief overview of examples of the range of methods used within individual areas, based on discussions with different teams, with more detail given in Section 3.

Table 1: Current approaches used by the Scottish Government.

Area	Methods currently used
Planning	The SPACE Tool has previously been used to give an indication of absolute emissions during the operation and use of an asset. However, its supporting datasets are not current.
Scottish Water	The Capital Carbon Accounting Tool (CCAT) measures whole-of-life emissions from infrastructure. This absolute approach includes both embodied and operational emissions.
	Carbon pricing has also been used to integrate emissions into investment decision-making.
Strategic Environmental Assessment (SEA)	A SEA uses a baseline-and-intervention approach to consider the likely significant environmental impact of plans, programmes and strategies. However, these are typically non-quantified, high level assessments.
Scottish National Investment Bank (SNIB)	Performance and measurement tool based on National Performance Framework indicators ('Carbon Footprint' and 'Greenhouse gas emissions') used for assessing investments.
	Input-Output analysis is used to measure absolute GHG emissions.

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

Emission statistics and Economy-wide emissions modelling	Input-Output analysis is used to assess GHG emissions associated with the Scottish Budget. The TIMES model[3] is used for identifying least-cost abatement pathways. It can also be used for conducting 'what-if' scenarios for assessing the change caused by policies.
Inward Investment	The EU Sustainable Finance Taxonomy is used to assess projects for private investment. BREEAM[4] is used to assess specific building-related projects.
Transport Scotland	EIA is required for certain development proposals, including certain transport projects.
Energy / Industrial Decarbonisation	OFGEM produce impact assessments which account for carbon savings, costs and benefits to society. Industrial decarbonisation is mainly driven by EU Emissions Trading Scheme and the associated reporting mechanisms.
Capital budget	Annual taxonomy-based assessment based on the Low Carbon Infrastructure Task Force (2015) to assess Scottish Budget and spend on low, neutral or high carbon activities.

1.3 Objectives of the study

This report seeks to develop an understanding of the different approaches that can be used to assess and report on the impact of infrastructure investment on GHG emission targets. Specifically, this report will address three primary objectives:

1) To understand approaches that could be applied to assess and report the climate emissions impact of the Scottish Government's Infrastructure Investment Plan; and assess how well aligned the Plan is with Scotland's GHG reduction ambitions[5].

2) To explore approaches that could be used to report on how well infrastructure spending decisions (made as part of the Scottish Government Budget) are aligned with Scotland's GHG reduction ambitions. This aspect of the work would include reviewing frameworks and methods that describe categories of carbon impact associated with infrastructure spend.

3) To identify what indicator, or suite of indicators, may be appropriate for tracking and reporting the carbon impact of infrastructure and investment decisions over time.

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[3] TIMES stands for The Integrated MARKAL-EFOM System, and is an energy systems model.
[4] BREEAM stands for Building Research Establishment Environmental Assessment Method, and is a sustainability assessment method for buildings and infrastructure.
[5] This is the target of achieving net zero emissions by 2045, and interim reduction targets of 56%, 75% and 90% by the years 2020, 2030 and 2040 respectively, compared to 1990 base year emissions.

This report focuses on approaches that could be used to assess and report on the Infrastructure Investment Plan and the annual Scottish Government Budget, but it is recognised that there are also other contexts in which methods are required for assessing the GHG impacts of infrastructure investment decisions, e.g. the National Planning Framework, the Inward Investment Team's Green Investment Portfolio, and the Scottish National Investment Bank's decision-making.

1.4 Research methods and structure of report

To address the objectives of this study the following research activities were undertaken: a desk-based literature review of existing approaches, metrics, methodologies and reports; interviews with experts/organisations within this field (e.g. OECD, Committee on Climate Change, European Bank for Reconstruction and Development); and interviews with relevant teams within the Scottish Government. Details are provided in Appendices 1 and 2.

The remainder of this report is structured as follows: Section 2 provides a framework for categorising the different types of approach/method for assessing the impact of infrastructure decisions on emissions reduction targets, and provides information on the strengths, weaknesses, and data/modelling requirements for each approach. Section 3 provides an overview of the methods currently being used by the Scottish Government to understand the impacts of infrastructure plans or spend on GHG emissions, broken-down by the categories of method identified in Section 2. Section 4 identifies a number of wider considerations related to infrastructure decision-making and climate change. Section 5 concludes and provides suggestions for assessing the climate impact of infrastructure investment decisions.

2 Review of indicators and metrics

A large number of different assessment methods and practices were identified via the desk-based literature review, and these methods and practices are being developed and implemented by a range of different organisations including NGOs, international standard setters, multi-lateral development banks, the EU, and the financial sector. The documents and initiatives reviewed are listed in Appendix 2.

In order to categorise and understand this diversity of practice we developed a framework for grouping the different approaches into four broad types of approach:

- Absolute emissions methods
- Baseline-and-intervention methods
- Gap analysis, and
- Taxonomies

The following sub-section explains the four types of approach, and the subsequent sub-sections then provide more information on each, including their strengths and weaknesses, their data/modelling requirements, and examples.

For simplicity the term 'emissions' is used throughout the report but in most cases this can be understood to refer to both emissions and removals, e.g. absolute emissions methods can be used to quantify absolute emissions and removals. Similarly, baseline-and-intervention methods can be used to assess the change in emissions and removals caused by the decision that is assessed.

2.1 Explanation of the four assessment types

Figure 1 provides a simplified graphical representation of the first three types of assessment method. The bold solid line represents Scotland's decarbonisation target pathway (reaching net zero in 2045) and the area under this line represents Scotland's carbon budget.

Absolute emission methods: the dotted line represents methods that calculate absolute emissions associated with an infrastructure asset, e.g. the emissions from manufacturing the materials used in the asset, and the emissions from the use and decommissioning of the asset. Methods within this category include life cycle assessment, environmentally-extended input-output modelling, and organisational-level value chain accounting. This type of method can provide information on the proportion Scotland's carbon budget that is 'used up' by the decision to build an infrastructure asset.
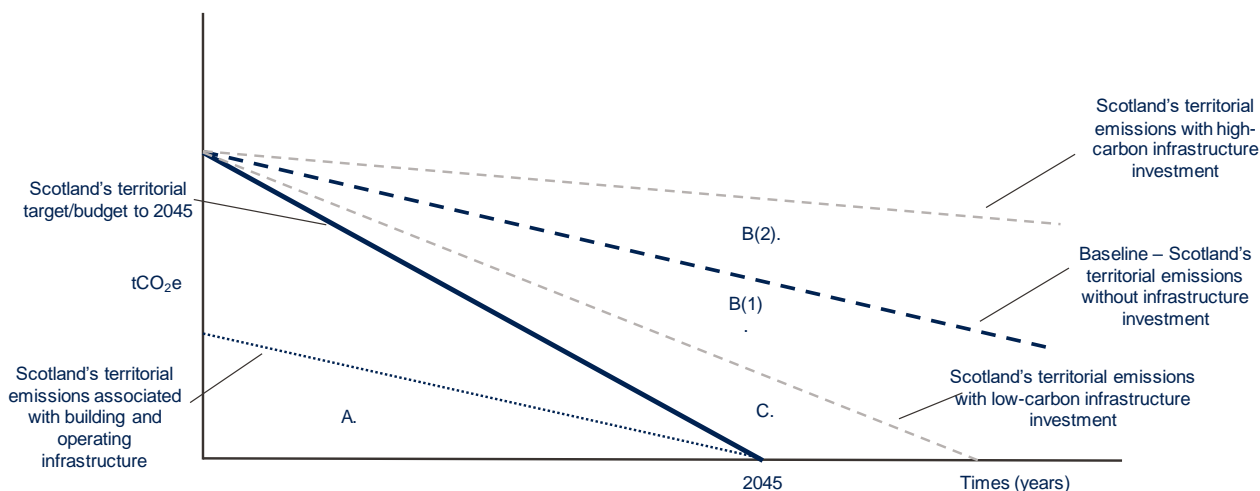

Figure 1: Framework for categorising types of assessment method[6].

Baseline-and-intervention methods: these methods involve estimating what emissions would be in the absence of the decision that is being assessed (called the 'baseline'), and what emissions would be with the decision. The difference between the two scenarios is the change caused by the decision. The baseline is represented by the bold dashed line in Figure 1. A decision that reduces emissions relative to the baseline is represented by area B(1) and a decision that increases emissions relative to the baseline is represented by area B(2). This type of method provides information on the change in emissions caused by an infrastructure investment decision.

Gap analysis: this type of method assesses the difference between planned or implemented interventions and what is needed to meet an established reduction target (the gap is represented by area C). This type of method provides information on additional investment and/or emissions reductions required to meet a reduction target.

Taxonomies: this type of approach categorises types of asset into broad categories such as 'low carbon' or 'high carbon'. This approach is not represented in Figure 1 as it generally does not provide quantified information on the level of emissions associated with an asset, or the

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[6] For simplicity Figure 1 only includes emissions and not removals. If these were included they would be shown as a line below the horizontal axis. Adding emissions and removals (negative numbers) together would give a 'net' emissions balance. It is expected that there will be residual emissions in 2045 from emission sources that are very difficult to abate and so in reality the emissions pathway line will not reach zero. The expectation is that residual emissions will be balanced with removals to achieve net zero.

change in emissions caused by a decision. However, it is important to note that some taxonomies use information on decarbonisation pathways (the bold solid line) as the basis for determining whether an asset is 'low carbon' etc.

A summary of these different types of assessment method, the questions they are appropriate for answering, requirements for implementation, strengths and weaknesses, and examples is presented in Table 2 below. A flow diagram matching the type of assessment method to the type of information required is provided in Figure 2.

Table 2. Summary of the four types of assessment method.

Method	Description	Level of Assessment	Questions answered	Requirements	Strengths	Weaknesses	Examples of use	Tools and resources to help implement
Absolute Emissions	The aggregation of GHG emissions associated with an asset or portfolio.	Project or programme level	What are the life cycle emissions associated with each project in an infrastructure plan? What proportion of Scotland's remaining carbon budget is 'used up' by a specific infrastructure project?	Detailed information on each project or asset in the infrastructure pipeline. Emission factors associated with each element of the project.	+ Shows emissions as proportion of carbon budget.	- Data heavy and resource intensive.	Chang and Kendall (2011) – Life cycle greenhouse gas assessment of infrastructure construction for California's high-speed rail system	FMO (2018) – Absolute GHG Accounting Approach for Financed Emissions PCAF (2019) – Harmonised approach for financial sector IFI (2015) – Harmonised framework
Baseline and Intervention	The change in emissions caused by an intervention compared to a baseline.	Project or programme level	What are the expected changes in emissions caused by an infrastructure investment compared to not investing?	Generally bespoke assessments for individual intervention contexts.	+ Shows changes in emissions caused by a decision as a time series. - Modelling scenarios can be complex and highly uncertain.		Ernst & Young (2012) – Borders Railway Final Business Case VITO (2013) – Towards 100% renewable energy in Belgium by 2050. ADEME (2016) – Quantifying the impact of an emission reduction action on GHGs.	HM Treasury - Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. GHG Protocol Policy and Action Standard ISO 14064-2 IFI (2015) – Harmonised framework
Gap Analysis	Highlights the difference between current investment plans and country's climate targets.	Programme level	What is the gap between current investment plans and what is required in order to achieve GHG reduction targets?	Information on current infrastructure spending on low-carbon projects. Detailed scenario for decarbonisation pathway, including required infrastructure assets and/or spend.	+ Shows shortfalls between investment plans and national GHG reduction targets. - Based on estimates and requires scenario/model for low carbon transition.		I4CE (2019) – Landscape of Climate Finance in France. CPI (2019) – Global Landscape of Climate Finance UNEP (2019) – Emissions Gap Report	Vivid Economics – Net-zero toolkit IEA – TIMES Model SEI Metrics – 2°C Alignment CCC – Net Zero Technical Report
Taxonomies	Categorises activities into broad categories (e.g. 'High carbon' or 'Low carbon').	Project or programme level	What proportion of projects within infrastructure plans are likely to align with GHG reduction targets? What percentage of spend can be considered low-carbon?	Must have suitable taxonomy that covers each sector and project-type.	+ Easy for non-experts to use and to aggregate across a portfolio of projects. - Does not provide information on level of emissions caused by different types of spend.		Green Alliance (2013) – UK Infrastructure Pipeline Green Alliance (2015) – Scotland's Way Ahead S&P Global (2017) – The Carbon Scorecard	CBI – Climate Bonds Taxonomy EU – Sustainable Finance Taxonomy

2.2 Absolute emissions methods

2.2.1 Overview

An absolute GHG accounting approach calculates the emissions (and removals) associated with different stages in the life cycle of an infrastructure asset. For the purpose of the Infrastructure Investment Plan, this approach could be used to calculate the emissions associated with each project, which could then be added together to find the total emissions associated with the Plan. As well as calculating the embodied emissions associated with building the asset, this approach can also include the emissions from the asset's operation and use, giving an estimation of emissions through the asset's lifetime.

There are three main methods that can be used to assess absolute emissions: attributional life cycle assessment (attributional LCA); input-output (IO) analysis; and organisational value chain carbon footprints.

Attributional LCA quantifies the environmental impacts through a product's life cycle from raw material extraction to construction, use and end-of-life (ISO, 2006). This enables a whole-of-life assessment to be performed on each project. LCA uses a 'bottom-up' approach where the emissions associated with each individual component are added together to derive a total for the whole project. Several tools and databases specific to construction/infrastructure have been developed to help practitioners in assessing lifetime emissions. For example, tools such as One-click LCA (Bionova, 2018) and EC3 (CLF, 2020) can be used to generate an assessment using a surveyor's bill of quantities. Databases such as the ICE (Inventory of Carbon and Energy) database (Hammond and Jones, 2008) give embodied carbon emissions for building materials.

A second method is an IO analysis. Rather than the 'bottom-up' LCA approach, an IO analysis uses aggregate sector-level data to measure the environmental impact attributed to each sector of the economy, based on spend. Therefore, on an infrastructure project, by knowing how much money is spent on materials (e.g. steel and concrete), transportation, or construction, average emission factors can be used to estimate total GHG emissions for each project. Each project can then be added together to give the total estimated emissions from the Infrastructure Investment Plan. Standard Industrial Classification (SIC) codes are used to determine industry specific GHG emissions intensity per £ spent. IO analysis can be relatively quick, but there may be a trade-off in terms of accuracy due to the use of average values per £ spent, and aggregation within broad sectors of the economy. Often IO analysis of an infrastructure project will only include the embodied emissions from constructing the asset, but use phase emissions can also be calculated if spend data for use phase energy consumption is included. This requires extra information about each specific capital project and a separate set of estimates of emission impacts that would be added to the EIO estimates.

A final method is a form of organisational value chain assessment. The GHG Protocol *Corporate GHG Accounting and Reporting Standard* divides value chain emissions into three scopes.

- Scope 1 emissions are direct emissions from facilities and vehicles owned and controlled by the reporting entity.

- Scope 2 emissions are from purchased electricity, heating or cooling.

- Scope 3 emissions are from all other sources in the entity's value chain, e.g. 'upstream' emissions from procured goods and services and 'downstream' emissions from the use of products.

This approach has been developed by the International Finance Institutions (IFIs) to assess the absolute emissions from investment projects (IFI 2015). This approach effectively treats an investment project as a reporting organisation, and the use of value chain emissions categories corresponds to the life cycle stages used in LCA.

Each of these approaches could be used to estimate the absolute emissions attributable to the Infrastructure Investment Plan, but to apply these methods detailed information would be needed on each infrastructure asset entailed by the plan. For example, to apply LCA more detailed information would be needed (e.g. number and type of hospitals to be built etc.), or for IO analysis, detailed information on spend in different sectors of the economy.

2.2.2 Example

There are several examples in the academic literature of LCA being used to estimate the absolute emissions of infrastructure projects. A good example is from Chang and Kendall (2011) who assess the life cycle emissions from California's new high speed rail system. Their assessment calculates the absolute emissions associated with the build phase of the project, including emissions from raw material acquisition, refining, manufacturing, production and transport. This found that the total construction emissions would be 2.4 MtCO$_2$e (approximately 3,200 tCO$_2$e/km). From this analysis they found that although bridges and tunnels only accounted for 15% of the total track length, they were responsible for over 60% of emissions. This highlighted areas to address to make emission reductions.

2.2.3 Strengths and weaknesses

Information on the absolute emissions associated with a pipeline of infrastructure projects would allow the emissions to be represented as a proportion of Scotland's carbon budget. In addition, absolute emissions information could be combined with estimates of net-welfare gain for each infrastructure project (e.g. £ welfare gain/tCO$_2$e budget committed), which would allow ranking of projects in an investment pipeline.

Another strength of this approach is that it uses well-known methods, for example ISO 14040, ISO 14044, and ISO 14067 for LCA; the GHG Protocol's Corporate Accounting Standard and Corporate Value Chain (Scope 3) Standard (WRI and WBCSD, 2011); and environmentally-extended IO which is already used by the Scottish Government. Tools and databases exist which give the emission factors required to perform these assessments, if sufficient detail for each asset is available.

There are weaknesses to these approaches too. Building a 'bottom-up' approach from carbon footprint or LCA is very data and resource intensive. An infrastructure project will have thousands, if not tens of thousands, of components which will all require emissions factors to be associated with them. Given the number of projects, compiling this data could take a considerable amount of time. The 'top-down' IO analysis approach may be quicker to implement for large numbers of projects, if sufficient spend data is available, but as noted, the results from this approach may be less accurate.

A further difficulty all of these methods is that information on the geographical location of the emissions within the life cycle/value chain would be needed in order to separately report the emissions occurring with Scotland's territorial boundary, and therefore relevant to Scotland's carbon budget and targets. It is worth noting that this difficulty also arises for baseline-and-intervention methods too. Although in theory it is possible to 'location-stamp' all emissions within an assessment, it adds an additional element of complexity.

2.2.4 Requirements to implement

A bespoke LCA requires detailed information for each project or asset in the infrastructure pipeline, though as highlighted previously, there are several tools and databases available for conducting an LCA of a project. The information required would include the quantities of materials used, as well as plant and labour resources needed for each project. Estimates of operation and use phase emissions would also be required. Alternatively, the results from existing LCA studies could be used to provide proxy estimates for different types of infrastructure asset. For example, numerous LCAs already exist for assets such as wind turbines, roads, rail, etc. and the results of these studies could be used to estimate absolute emissions for future projects. The amount of time required to undertake an LCA depends on the

complexity of the specific infrastructure asset that is being assessed, and the level of detail/specificity aimed for in the assessment. High-level estimates can be undertaken in 1-2 days, and highly detailed assessments can take several months.

IO analysis requires information on the amount of spend to different sectors of the economy entailed by an infrastructure project, for example, how much is spent on concrete, steel, machinery, or the construction process. IO analysis tables can then be used to determine the direct and indirect GHG emissions per £ spent. IO analysis is often used to estimate the embodied emissions from building an asset, but can also be used to estimate use phase emissions if information is provided for projected spend on different types of fuel during the use/operation phase. The IO tables used to perform this type of analysis are already compiled by the Scottish Government, and are used to determine the GHG emissions associated with the Scottish Budget. This same method, albeit at a more granular level, could be used to look at infrastructure investment plans.

2.3 Baseline-and-intervention methods

2.3.1 Overview

Whilst absolute methods estimate the emissions associated with an infrastructure project, a baseline-and-intervention method estimates the *change* in emissions caused by an investment decision. This approach can be used to analyse individual projects within an infrastructure pipeline, or at the programme level by aggregating the change caused by individual projects. The first step is to create a baseline of what emissions would have been without the infrastructure plan or spend that is being assessed. Following this, an 'intervention scenario' is developed to show what would happen to emissions if the infrastructure investment is made. The difference between the two scenarios is the change caused by the intervention or decision, as illustrated in Figure 2.
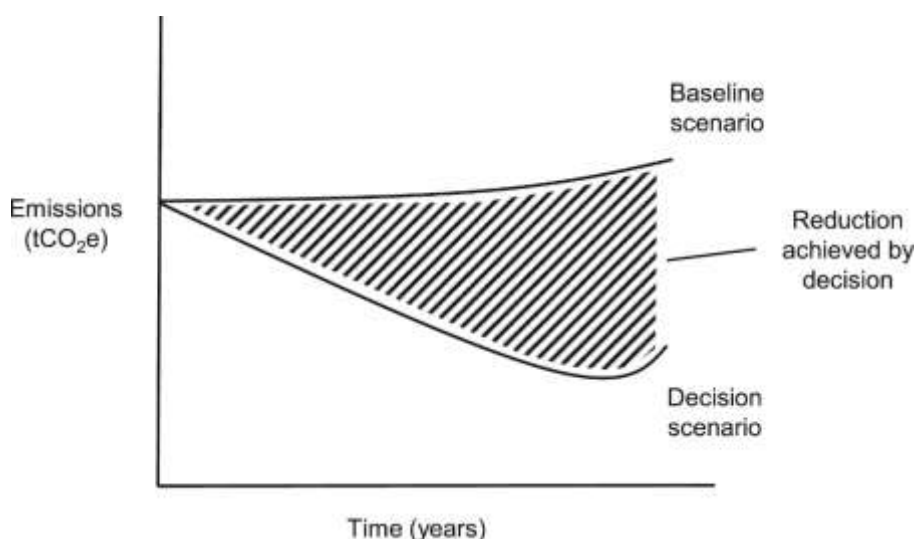

Figure 2: Illustration of the key components of the baseline-and-intervention approach (Source: Brander, 2017).

The GHG Protocol Policy and Action Standard (WRI, 2014) and GHG Protocol for Project Accounting (WBCSD and WRI, 2005) both provide framework methodologies for estimating the change in GHG emissions caused by interventions. The Policy and Action Standard could be applied to the Infrastructure Investment Plan or Scottish Budget, whilst the Protocol for Project Accounting would look at individual projects within these plans. The UK Government Green Book is also an example of a baseline-and-intervention type approach, which is already widely applied to appraise policies and projects. ISO 14064-2 (BSI, 2019) also provides a specification

for quantifying, monitoring and reporting GHG emission reductions at a project level. These standards provide a generic framework, and a number of further 'operational' methods can be used within the framework to actually quantify baseline and intervention scenario emissions. Such methods could include consequential LCA, IO analysis, and integrated assessment models.

This type of approach provides different information from the absolute emissions methods. For example, a wind farm built in Poland and Norway would have very similar absolute emissions. However, in Poland the wind farm may be expected to replace coal-fired generation (in the baseline), while in Norway it may replace hydropower (in the baseline). The change in emissions caused by the interventions will be very different, which would be shown by a baseline-and-intervention approach.

2.3.2 Example

At a policy level, the Öko-Institut e.V. undertook an ex-ante (forward-looking) assessment of Germany's Renewable Energy Act. They developed a baseline scenario that assumes there would be no further increase in renewable electricity generation from the 2010 level until after 2020. A policy scenario was developed adding renewable electricity as set out in the Renewable Energy Act. The difference in electricity generation between the two scenarios shows the effect of the policy. It was shown that the policy would reduce emissions by 95 $MtCO_2$ in 2020 and 138 $MtCO_2$ by 2050 (WRI, 2014).

As an example at the project level, Brander (2017) applied a form of baseline-and-intervention method to assess the projected change in emissions caused by a 6MW bioheat plant in Scotland. This showed the importance of modelling the baseline and intervention scenarios as a time series to understand the carbon payback period from using woody biomass.

2.3.3 Strengths and weaknesses

A strength of this type of approach is that it is highly flexible, and it can be used to assess any change, i.e. increases or reductions in emissions. It can also include system-wide change, including market-mediated effects such as indirect land use change. However, a weakness is that modelling scenarios can be complex and highly uncertain, particularly as the baseline is a necessarily hypothetical counterfactual scenario.

Often a baseline-and-intervention approach will be applied at a non-aggregate level, e.g. the baseline and intervention scenarios will not show Scotland's total emissions without and with a specific intervention, but will only show the level of emissions for the sources/sinks affected by the intervention that is assessed. This means that the results from individual assessments need to be coupled with an aggregate level baseline to undertake a gap analysis. For example, a baseline-and-intervention assessment may quantify that a cycle path project reduces emissions by 1,000 tCO_2/yr, but that information needs to be coupled with an aggregate baseline in order to know whether the reduction is sufficient to achieve a decarbonisation pathway (i.e. a gap analysis).

2.3.4 Requirements to implement

Each intervention, whether at a policy or project level, will require a bespoke assessment. Although there are standardised methods for this type of approach, they are mostly high-level generic standards, and there is limited guidance for how to complete an assessment for specific infrastructure/project types. The UK Government Green Book supplementary guidance for greenhouse gas emissions appraisal (HM Treasury, 2020) provides useful resources for undertaking baseline-and-intervention assessments, e.g. a time-series of marginal electricity emissions factors for the UK. However, the guidance is also at a necessarily generic level, and does not include specific rules, e.g. how to estimate the deployment of electric vehicles when assessing transport infrastructure projects.

A GHG assessment is required for both the baseline and intervention scenario, and these can either be created manually using spreadsheets, or using a scenario model. The TIMES model

can be used for baseline-and-intervention assessments, by running the model with and without a specific intervention. However, there are some limitations to the TIMES model, e.g. it does not include the embodied emissions of materials used in infrastructure projects, and it does not include price or market-mediated effects, such as rebound effects from energy efficiency measures.

2.4 Gap analysis

2.4.1 Overview

A gap analysis is a measurement of the difference between current performance and potential or desired performance. An emission-based gap analysis aims to quantify the level of emissions that would be achieved with current policies and highlights the remaining gap to align with an established decarbonisation pathway. Examples include the UNEP's Emission Gap Report (2019) at a global level, and Climate Action Tracker (2019) which gives country specific details.

Building off an emission-based gap analysis, an expenditure-based gap analysis reviews the current planned level of investment on low-carbon activities and compares this to the level of investment required to meet the country's climate targets. From this, it is possible to see if the country is investing enough to meet its emission reduction targets, or highlights the increased investment required to achieve these. Gap analysis reports like this have been performed at a global level, for example the Global Landscape of Climate Finance (CPI, 2019). This report states that to meet the Paris Agreement 1.5^{o}C target, global investment to achieve the low-carbon transition needs to rise from the current $546 billion per year to $1.6-3.8 trillion per year. Similar studies have been performed at a national level, for example in France as detailed in the sub-section below.

2.4.2 Example

The Institute for Climate Economics (I4CE) publish a yearly report on the Landscape of Climate Finance in France (I4CE, 2019). As part of this report, an estimate of the annual investment need is created based on national objectives. National objectives are based on three strategic documents: The French National Low-Carbon Strategy, its Reference Scenario, and Multi-annual Energy Plans. From these documents, I4CE's report identifies the infrastructure/assets that are required to meet the low-carbon targets in each sector. Examples include, the number of electric vehicles on the road, number of building retrofits, or megawatts of new renewable power capacity. To understand the costs associated with the national objectives, I4CE takes the costs observed on similar projects in recent years and then calculates the amount of investment needed to achieve the scenarios described in the strategic documents. The results of this analysis are summarised in Figure 3. These figures can also be broken down to the level of investment required within each sector, for example, transport, buildings or energy.
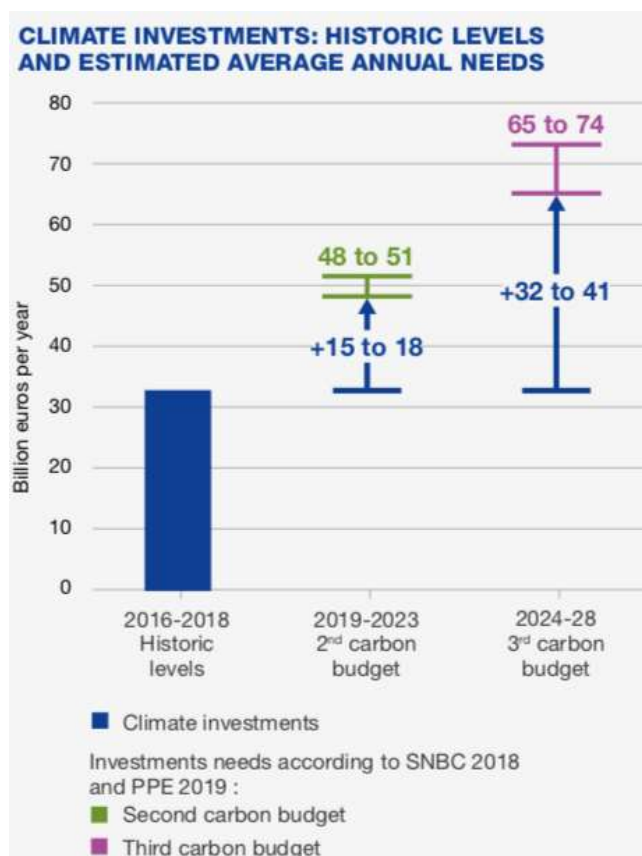
Figure 3: Summary of current spending in France and projected spending gap (Source: I4CE, 2019).

2.4.3 Strengths and weaknesses

The main strength of this approach is that it highlights the shortfalls between current investment plans and national GHG reduction targets and gives a clear metric for measuring compatibility with long term targets. However, there are weaknesses in this approach too. In the I4CE example for France, the costs are based on estimates for similar projects at present. As such, this approach can be open to inaccuracies, particularly as the costs of mitigation will change over time and with higher levels of deployment. For example, tracking the amount of investment in renewables may be misleading if the amount invested declines due to lower costs rather than lower deployment. Another possible weakness is that in order to carry out this assessment, a detailed scenario has to be developed for the decarbonisation pathway, detailing the level of investment required – and the various sources of finance be they public, regulated or private - in order to achieve the target.

A potential weakness with undertaking a gap analysis specifically focused on infrastructure is that it introduces a 'silo' approach, rather than a holistic assessment across the economy as a whole. To understand the gap between current policies and climate change targets it is necessary to consider all aspects of decarbonisation, not just those associated with infrastructure. It is also important that this approach includes information on the contribution to emissions from infrastructure that is not low carbon, e.g. spending on road maintenance.

2.4.4 Requirements to implement

In order to perform an expenditure-based gap analysis, the following information is required:

1) A plan or scenario of how to achieve the 2045 net-zero target at a national level. This should also be broken down by sector. As an example, the Climate Change Plan provides details of the steps required for each sector to meet the net zero targets. Scottish Government uses the TIMES model to support development of sector-level target-consistent emissions –reduction pathways.

2) If undertaking a spend-based gap analysis, estimates of the cost of implementing the measures in the emissions target scenario. This would show the level of investment that is required in order for Scotland to meet its climate goals. This information could be based on the current cost of similar projects, or with projections to account for price changes and technological advances over time.

3) Information on the current, or planned level of spend of low-carbon projects. This data could be extracted from the Scottish Government's Infrastructure Investment Plan or the Scottish Budget.

Similar steps would be required for a 'deployment'-based gap analysis, but with information on the quantity and types of assets deployed, e.g. kilometres of railway line electrified, number of homes retrofitted, capacity of carbon capture and storage pipeline installed etc. This information is also regularly reported within the Climate Change Plan monitoring framework.

2.5 Taxonomies

2.5.1 Overview

Taxonomies gives a broad indication of whether an asset or expenditure is likely to be aligned with a decarbonisation pathway. Taxonomies generally use broad 'directional' categories such as 'green' or 'brown', or 'high', 'neutral' and 'low' carbon. For example, in the power sector, fossil fuel-based generation projects may be classified as 'high carbon' whereas renewables projects may be classed as 'low carbon'. Examples for other sectors are given in Table 3. A pipeline of projects can be assessed either by the percentage of projects, or percentage of spend, that fall into each category.

Table 3: Examples of green and brown projects. Adapted from 2ii (2015).

	Brown	Green
Oil, Gas and Coal	• Share of high-cost capital expenditure • Share of unconventional (e.g. tar sands, deep water) oil in production mix	• Share of carbon capture and storage • Share of renewables in R&D and capital expenditure
Power sector	• Share of high-carbon electricity generation • Estimated remaining lifetime of power plants	• Share of renewables in electricity generation, installed capacity, and capital expenditure
Automobile manufacturing	• Average fuel economy of car fleet	• Share of sustainable propulsion technologies in sales
Industry	• Energy and carbon intensities	• Share of zero-carbon manufacturing • Relative investment levels in green manufacturing R&D or deployment

Cross-sector	• Share of oil and gas in sales / revenues • Share of coal in revenues	• Share of green technologies (e.g. low-carbon economy) in sales / revenues

A taxonomy is not necessarily binary and variants may only designate what is 'green' without specifying what is 'brown', or may include more than two categories. In the case of the Climate Bonds Taxonomy (CBI, 2019), a traffic light system is used to identify a project or asset's compatibility to the 2°C target set in the Paris Agreement (UN, 2015). Similarly, Germanwatch and New Climate Institute (2018) set out three categories for grouping investment decisions: 'Paris-aligned' which are investments that fully support the achievement of the Paris Agreement's temperature goals, 'misaligned' which undermine the Paris Agreement, and 'conditional' investments, which only align to the Paris Agreement under certain conditions.

Another example is the Sustainable Finance Taxonomy (EU, 2019) which lists economic activities according to performance criteria for six environmental objectives including climate change mitigation, adaptation, and transition towards a circular economy. An economic activity is included in the taxonomy if it makes a substantial contribution to at least one of the environmental objectives and does no significant harm to any of the others. As well as highlighting activities that are already low carbon (for example, zero emission transport, renewable energy or afforestation), the EU Sustainable Finance Taxonomy also highlights activities that will aid transition to a net zero economy by 2050. This could be building retro-fits, electricity generation less than 100 gCO_2/kWh, or cars less than 50 gCO_2/km. Over time, these intensity measures are reduced to keep aligned to the targets.

2.5.2 Example

Green Alliance (2013) prepared a policy insight report for the UK Government on infrastructure investment based on the 2012 infrastructure pipeline. This highlighted that just over 70% of UK Government infrastructure spending was designated for 'low carbon' projects. This figure was derived using a taxonomy created by Vivid Economics to categorise projects as low, neutral or high, depending on their carbon impact. This exercise has been repeated in subsequent years and shows that the percentage of infrastructure spend on low carbon projects has fallen in recent years (Green Alliance, 2016), shown in Figure 4 below.
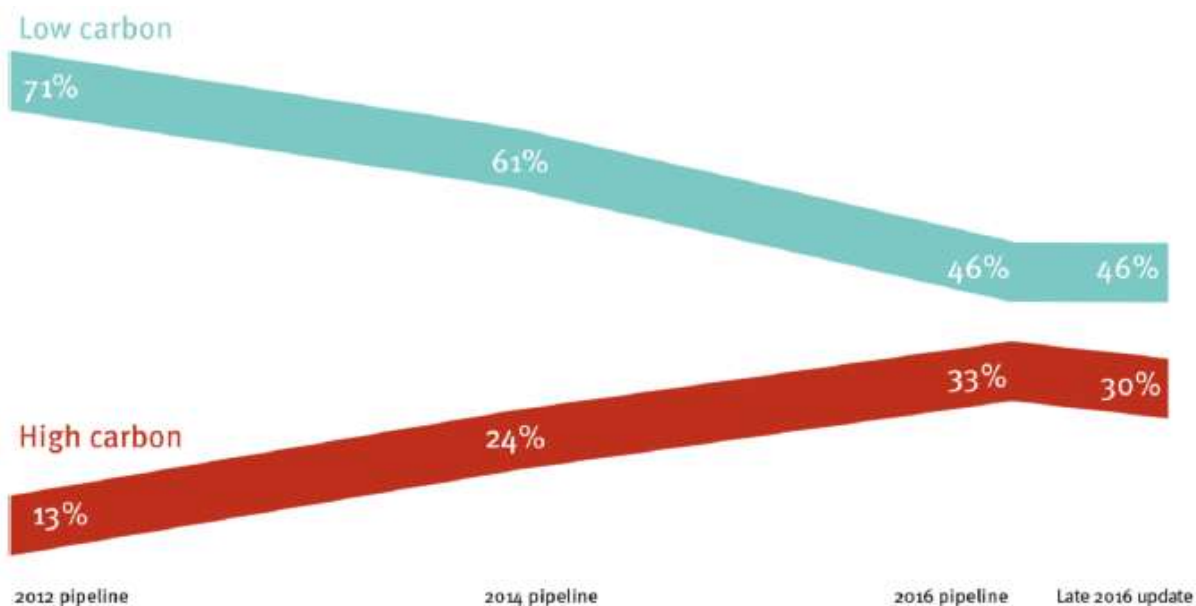

Figure 4: Percentage of UK infrastructure spend on high and low carbon projects (Source: Green Alliance, 2016).

2.5.3   Strengths and weaknesses

The main benefit of using a taxonomy is the ease of implementation, if an appropriate taxonomy is available. However, there are weaknesses or limitations to this approach. A key weakness with taxonomies is that they do not provide quantified information on the amount of emissions caused by different projects, nor the change in emissions caused by infrastructure projects, plans, or spend. For example, 80% of projects may be 'green' but may not lead to substantial emission reductions, whilst the remaining 20% of projects may be carbon intensive and lead to significant increases in GHG emissions, meaning the portfolio will not be aligned with the country's reduction targets. In addition, the use of intensity metrics, as used in the EU Sustainable Finance Taxonomy, will not be an accurate indicator of sustainability if the absolute level of activity is higher than projected. For example, an individual power generation facility with emissions below $100gCO_2/kWh$ will not be aligned with the decarbonisation pathway if large numbers of similar facilities are also built, and collectively they exceed the available carbon budget.

A further issue is that although a taxonomy may give a correct 'directional' signal for asset types that are clearly low or high carbon, there may be categories of Government spending that are more difficult to categorise. For example, capital expenditure within the health service may be for highly efficient or inefficient buildings, and therefore additional information will be needed in order to meaningfully categorise such expenditure within a taxonomy.

Another issue to be aware of is the applicability of a taxonomy to the specific GHG targets set by Scotland. For example, the EU Sustainable Finance Taxonomy is designed for the EU pathway of decarbonising by 2050. As such, using this taxonomy may misinform decisions that are required to achieve net zero emissions in Scotland by 2045. To overcome this, a taxonomy must be chosen that is in line with Scotland's targets.

2.5.4   Requirements to implement

The application of a taxonomy is relatively straightforward, simply matching projects in the Infrastructure Investment Plan or Scottish Budget with the taxonomy. However, information is required on the nature of individual projects/assets within broad categories of spending, e.g. detail is needed on what spending on 'Health services' entails. At present, this would be classified as 'neutral' but if it is investing in an energy efficient heat source for a hospital this would be 'low carbon'. Some taxonomies require more detailed information for projects that are not obviously within a 'low' or 'high' category, e.g. whether non-renewable power generation has emissions below $100gCO_2/kWh$. A number of taxonomies already exist, or are in development, which can be used to fulfil the function of providing broad 'directional' information. If a taxonomy is used as an interim method before developing a more complete approach, it may not be worth spending a significant amount of time developing or enhancing the taxonomy. With this in mind, using a simple but relatively comprehensive existing taxonomy, such as the Climate Bonds Initiative Taxonomy, may be most appropriate approach. In order to maximise the benefits from any actions taken to enhance the interim use of a taxonomy, priority could be given to actions that will also be useful once a more complete framework is developed. For example, collecting data on the nature of capital projects would be useful for categorising expenditure within a more detailed taxonomy and for implementing a gap analysis.

3   Scotland's current approaches

As highlighted in Section 1.2, the Scottish Government already use a range of approaches to capture information on GHG emissions. These instances can be classified using the four assessment categories discussed in Section 2. In this section, a brief overview of these examples is provided to highlight where the Scottish Government already has capabilities to undertake these assessments. We also suggest what would be required to extend these

assessments to fully understand the impact of infrastructure investment on GHG emission reduction targets.

3.3.1 Absolute emissions methods

Several methods have been used to calculate absolute emissions. At a country-wide level, each year since 2010, the Scottish Government have published a high-level carbon assessment alongside the Scottish Budget. This Environmental Input-Output assessment raises awareness of the carbon impact of spend in different areas, giving the direct and indirect effects of each industry group per million pounds spent. Using this approach, it was estimated that emissions resulting from the 2019-20 Budget would be 7.3 $MtCO_2e$ (Scottish Government, 2019). However, the IO assessment currently only includes the embodied emissions associated with the infrastructure spend.

Another instance of the use of IO assessment is by the Scottish National Investment Bank (SNIB) to measure the embedded carbon of their investments. SNIB has identified this method for reporting against the National Performance Framework indicators for GHG emissions.

Within Planning, the SPACE (Spatial Planning Assessment of Climate Emissions) Tool has been designed to help planners make informed decisions about the GHG implications of planning policies, primarily focused on buildings. The tool does not provide an overall quantity of emissions for a plan (for example, embodied emissions associated with the build of the project are not considered) but provides likely emissions relating to energy use, transport use, waste and land use change. However, since its development in 2012, the underlying datasets have not been updated, meaning there could now be inaccuracies in the results. If the datasets could be updated, and embodied carbon emissions integrated, this could be a good way of creating a whole-of-life carbon assessment for buildings. More development would be needed to include the assessment of other types of infrastructure asset.

At a project level, Scottish Water has a whole-of-life carbon calculator that is used to inform investment decisions. The Capital Carbon Accounting Tool (CCAT) (see Scottish Water, 2018) has been developed to enable monitoring and reporting of whole life carbon associated with capital investment and to optimise projects for whole life carbon through the project development process. By bringing together embodied carbon in the building of the asset, along with the net operational emissions (for example, consumption of energy from renewable sources or grid electricity, or consumption of fuels), the tool can give an estimate of absolute emissions through each asset's lifetime. Each project can then be assessed to see how it aligns to Scottish Water's target of being net-zero by 2040.

3.3.2 Baseline-and-intervention methods

Strategic Environmental Assessment (SEA) is a method for considering the likely impact of a public plan, programme or strategy on the environment. If undertaken during the plan's preparation then the information gained from the SEA can be used to inform alternative options to avoid or minimise any negative environmental impacts and, where appropriate enhance positive effects (Scottish Government, 2009). To establish the current characteristics of the environment a baseline is created. Baseline data can be quantitative or qualitative and can be collected from a range of sources, including environmental reports, previous studies and consultation or environmental groups. This baseline is then used to look at likely changes if the plan is implemented. Although SEA has the structure of the baseline-and-intervention approach it generally only provides directional qualitative information, rather than a quantification of the magnitude of change.

Transport Scotland's Scottish Transport Appraisal Guidance (STAG) also uses a broad baseline-and-intervention structure that covers a wide range of social and environmental indicators, but does not necessarily provide a quantitative assessment of emissions in the baseline and intervention scenarios. The Transport Scotland team mentioned that the Department for Transport is currently developing a new assessment method.

The TIMES model is a high-level strategic model that covers the entire Scottish energy system, as well as non-energy sectors such as agriculture, waste and forestry. The model uses engineering data and economic data to identify cost effective emission reduction measures in order to transition to a low carbon economy (Scottish Government, 2016). The model can be used to generate 'what-if' scenarios (i.e. intervention scenarios) to quantify the change in emissions caused by specific policy interventions, and therefore provide a baseline-and-intervention approach.

3.3.3 Gap analysis

The Climate Change Plan (2018) provides a detailed analysis of annual emissions targets to 2032. It highlights the changes required in key sectors in order to achieve the Government's climate change targets. These figures could be used to assess the level of spend specifically on infrastructure required to meet Scotland's targets. For example, the number of homes that require energy efficiency measures, or the number of charging points for electric vehicles. This could then be assessed against current spending plans to see the gap in spending across infrastructure.

In addition, the TIMES model can be used to estimate what emissions will be, given current policies, and therefore the size of the emissions gap. The TIMES model includes details for many current and future technologies, but can also be complemented with higher resolution models for specific sectors to give more precise estimates of infrastructure and investment needs.

3.3.4 Taxonomies

The Green Alliance (2015) published Scotland's Way Ahead on behalf of Scotland's Low Carbon Infrastructure Taskforce. This report categorised the projects outlined in the 2011 Infrastructure Investment Plan into 'low carbon', 'neutral' and 'high carbon' categories. This was based on categories defined by Green Alliance for the UK Infrastructure Pipeline in 2013 shown in Table 4. This categorisation states that low carbon projects are 'seen as necessary to the low carbon transition', neutral 'do not represent substantial carbon efficiency gains in their own right but are consistent with low carbon ambitions', and high carbon projects are 'relatively carbon intensive'.

Table 4: Classification of low, neutral and high carbon activities (Source: Green Alliance, 2015).

Category	Examples
Low carbon	Transport – rail and ferry
	Energy –all renewable generation and electricity transmission and distribution
	Rural affairs and the environment – waste
	Housing – energy efficiency programmes
Neutral	Rural affairs and the environment – all non-waste
	Housing – all non-energy efficiency
	Water
	Digital
	Health
	Schools
	Culture and heritage

	Regeneration
	Justice
High carbon	Transport – roads and airports
	Energy – fossil fuel generation

Based on this categorisation, the report found 52% of capital spend was on low carbon projects. Using the same approach, the Scottish Government used the Taskforce's categories to perform an analysis of planned infrastructure spend for individual years. This found that in 2017-18, and 2018-19 the percentage of Scottish Government infrastructure spend on low carbon projects was 21% and 29% respectively, in line with the Government's commitments to increase the level of spend on low carbon projects year-on-year. As part of the budget scrutiny process, in 2018, the ECCLR Committee commissioned SPICe to analyse the carbon impact from capital spend. This report used the same methodology as detailed above, finding that planned spending on future low carbon projects in the infrastructure pipeline was considerably lower, with only 7% of spend in the low carbon category.

This high-level categorisation gives an estimate of the percentage of spend on low carbon projects. If a taxonomy is to be used, we would recommend using one that is directly linked to the Scottish targets. For example CBI's Climate Bond Taxonomy (CBI, 2019) states which projects are aligned to achieving a 2°C target, whilst the Sustainable Finance Taxonomy (EU, 2019) sets limits on emissions for each asset to fall under certain categories. The Scottish Government's Inward Investment team is using the EU Sustainable Finance Taxonomy to rate low-carbon projects as it aims to secure private investment to boost Scotland's low-carbon infrastructure. A further ratings method used by the Inward Investment team is the Building Research Establishment Environmental Assessment Method (BREEAM) assessment method for buildings, which provides broad categories of performance rather than quantified emissions information.

4 Wider considerations

Through the course of the research a number of further issues related to infrastructure and climate change were identified. These are summarised in the sub-sections below.

4.1 Territorial, consumption-based, and system-wide emissions

Scotland's net zero target for 2045 relates to Scotland's territorial emissions, and so does not include 'upstream' emissions (e.g. from the manufacture of materials imported into Scotland from other countries) or 'downstream' emissions from the use of products exported from Scotland (e.g. from the combustion of North Sea oil and gas sold to other countries). Moreover, the Scottish Government's infrastructure plans and Capital Budget may have other indirect or market-mediated effects, beyond the direct value chain of the assets built in Scotland. Increases in emissions outside of a designated boundary, caused by actions aimed at reducing emissions within the boundary, are also referred to as 'carbon leakage'. In order to have full information on the impact of the Scottish Government's infrastructure plans and spending it is necessary to quantify the total system-wide change in emissions caused by infrastructure decisions regardless of where those emissions occur.

Although reporting on the location of emissions adds additional complexity, the approaches discussed in Section 2 are capable of providing this information, e.g. IO analysis, LCA, the GHG Protocol *Policy and Action Standard* etc. Information on absolute 'upstream' emissions is

also needed for reporting on Scotland's consumption-based emissions, which is a requirement of the Climate Change (Scotland) Act (2009).

4.2 Broader positive influence on mitigation

Closely related to the issue of emissions occurring outside of Scotland's territorial boundary, some interviewees discussed the importance of considering the broader positive influence Scotland can have through its infrastructure plans. The suggestion arose partly because Scotland's direct territorial emissions are a small proportion of global emissions, but Scotland's ability to influence emission reductions in other countries is potentially much larger.

One example of broader influence is through the supply of renewable electricity to other countries, e.g. the rest of the UK, Netherlands, Germany etc. The renewable infrastructure would be installed in Scotland, but the emission reductions (through displacement of fossil generation) would be reflected in the national GHG inventories of other countries. The use of a baseline-and-intervention type method could be used to quantify and report the beneficial reduction in emissions enabled by Scottish infrastructure.

Another example of broader influence is through innovation and learning that is enabled or promoted by Scotland's infrastructure investment, e.g. decreasing the levelised cost of offshore wind energy due to deployment in Scotland. Innovation and reduced costs of technologies may have transformational effects which greatly exceed the scale of Scotland's direct territorial emissions. Estimating such effects is highly uncertain, particularly as any transformational change is by definition unlike historic trends. In principle, a baseline-and-intervention structure provides a generic framework that can be used for estimating such changes.

4.3 Carbon lock-in

An issue raised by a number interviewees is how to assess and avoid 'lock-in' from infrastructure decisions. This issue is particularly relevant to infrastructure investment decisions given the long-lived nature of many infrastructure assets. Many of the methods identified in Section 2 can present emissions as a time-series and therefore give information on the on-going level of emissions a decision entails. Baseline-and-intervention methods explicitly model emissions as a time-series. Traditional LCA generally does not provide information on the temporal distribution of emissions, but the development of 'dynamic' LCA is intended to provide this information.

A more complex form of lock-in occurs when a decision may not directly entail an on-going level of emissions, but may obstruct other infrastructure options which would have achieved overall lower emissions. For example, high-speed rail may itself fit within a net zero scenario but may obstruct the achievement of the scenario overall, e.g. by using limited public budgets which are then not available for other interventions. Again, in principle, a baseline-and-intervention type-method provides a high-level structure for assessing such effects. The TIMES model can be used to avoid budgetary lock-in, as it optimises for all technologies over all time periods.

4.4 Mitigation vs. adaptation

The present report is focused on assessing infrastructure plans/spend and the fulfilment of climate change mitigation goals. A separate important issue is how to assess whether an infrastructure asset is adapted or resilient to the physical risks from a changing climate, and/or how it contributes to adaptation needs. One interviewee highlighted the importance of assessing infrastructure decisions against both mitigation and adaptation objectives. For example, the mitigation value of forestry creation may be undermined if the forest is not adapted to extreme weather events. Equally, adaptation projects should be assessed for their alignment with mitigation goals (e.g. concrete flood defences may aid adaptation to extreme

weather events but may not align with mitigation goals). Moreover, some infrastructure can achieve both mitigation and adaptation goals, e.g. forests which sequester carbon and contribute to flood prevention.

4.5 Risk

A prominent area of activity within the financial sector is the development of methods for assessing climate-related financial risk. A key initiative within this area is the Taskforce on Climate-related Finance Disclosure (TCFD), which was established by the Financial Stability Board in 2015, and has published guidance on climate-related financial disclosures. It is useful to understand the focus of this initiative as it differs from the purposes of the assessment methods identified in Section 2, it is important not to confuse the assessment of climate-related financial risk and the assessment of alignment between investment decisions and mitigation goals.

The assessment of climate-related financial risk generally takes the perspective of a private investor, where the primary interest is risk-adjusted financial returns rather than the fulfilment of mitigation targets. For example, a private investor may be able to reduce their exposure to climate-related risk by moving investments to jurisdictions which have less climate-related regulation. This may reduce exposure to climate-related regulatory risk but may not support climate change mitigation at a global level. Managing risk can be aligned with mitigation goals, e.g. if an investment manages climate-related regulatory risk by investing in low-carbon technologies, but climate-related risk management and climate change mitigation are not necessarily aligned.

4.6 Wider costs and benefits

One interviewee discussed the possibility of combining an assessment of absolute emissions with an assessment of net welfare gain (noted in Section 2.2.3 above). This would allow different proposed infrastructure projects to be ranked in terms of £ of net welfare gain per tonne of carbon budget 'used up'. Such an approach aligns with the Infrastructure Commission for Scotland's dual focus on achieving net zero emissions and inclusive economic growth, and the Scottish Government's interest in maximising and capturing the social and economic opportunities associated with decarbonisation and securing a just transition.

Methods already exist for this type of analysis, for example, marginal abatement cost curves provide information on net costs per tonne of CO_2e abated (with negative net costs denoting a positive net benefit). Calculating net costs (costs minus benefits) is simply the reverse of calculating net benefits (benefits minus costs), and detailed guidance exists on how to estimate social costs and benefits, e.g. the UK Government's Green Book (HM Treasury, 2018). A complete analysis would aim to include all social, economic, and environmental costs and benefits, e.g. reduced fuel poverty, job creation, biodiversity benefits etc. It is also worth noting that as well as presenting net costs (or benefits) per unit of carbon budget (using an absolute assessment method), net cost (or benefits) can also be presented per unit of change in emissions (i.e. using the results from a baseline-and-intervention assessment). This latter approach is essentially that used for calculating marginal abatement costs. However, the complexity and uncertainties associated with such calculations can render such an analysis to be misleading or only able to partially assess the costs and benefits.

4.7 Wider applicability of the framework

As noted above (Section 1.3), this report focuses on approaches that could be used to assess and report on the Infrastructure Investment Plan and the annual Scottish Government Capital Budget, but it is recognised that there are also other contexts in which methods are required for assessing the GHG impacts of infrastructure investment decisions, e.g. the National Planning

Framework, the Inward Investment Team's Green Investment Portfolio, and the Scottish National Development Bank's decision-making. The categorisation framework presented in Section 2 (i.e. absolute methods, baseline-and-intervention methods, gap analysis, and taxonomies) may be useful for guiding the selection of the appropriate assessment method for the information required.

For example, the Planning (Scotland) Act (2019b) requires 'an assessment of the likely impact of each proposed national development's lifecycle greenhouse gas emissions on achieving national greenhouse gas emissions reduction targets'. If the aim is to understand the extent to which individual national developments increase or decrease emissions, then a baseline-and-intervention assessment is needed. If additional information is required on whether national developments are sufficient or consistent with a decarbonisation scenario then a gap analysis is required.

Alternatively, in the context of the Inward Investment Team's Green Investment Portfolio, it might be sufficient to know broadly whether specific projects in the portfolio are low-carbon, particularly if the individual projects are relatively small and the costs of undertaking a quantified assessment are disproportionately high. In this situation a taxonomy approach could be appropriate.

The key point is that it is essential to select the correct method for its appropriate purpose, as different methods provide different information, and have different resource requirements. The information provided by the different types of method are shown in Figure 5 below.
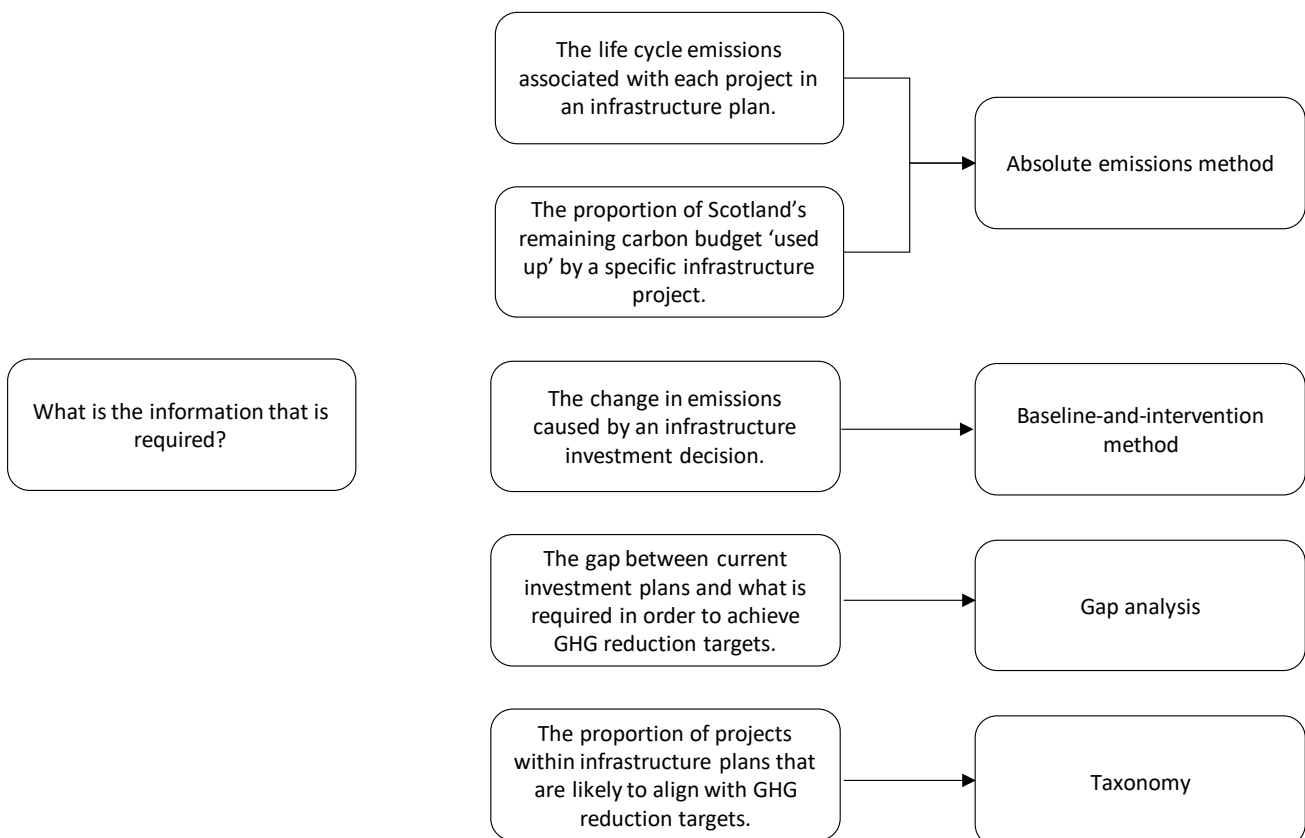

Figure 5. Flow diagram matching methods to the information that is required.

5 Conclusion and suggestions

There are a number of key conclusions and suggestions from the research undertaken:

1. A phased approach is needed: Planning and investment is needed to develop a coordinated GHG assessment framework/methodology for infrastructure investments, and a phased approach is appropriate as this will take time to implement.

2. Potential application of a taxonomy approach over the short-term: Given the limited time before the publication of the 2020 Infrastructure Investment Plan, and the forthcoming National Planning Framework, the focus should be on the use of existing methods. In relation to the IIP, methods such as the EU Sustainable Finance Taxonomy or the Climate Bonds Initiative taxonomy could be used in the short-term. Although consideration could be given to enhancing the current taxonomy to separate out 'neutral' activities into those that are likely to help reduce emissions and demonstrate alignment with the Climate Change Plan and TIMES modelling, other limitations with a taxonomy approach will remain. For example, using a taxonomy will not provide quantified information on absolute emissions or change in emissions caused by the Plan, or information on whether the projects within the Plan are sufficient to meet Scotland's targets. In order to maximise the benefits from any actions taken to enhance the interim use of a taxonomy, priority could be given to actions that will also be useful once a more complete framework is developed. For example, collecting data on the nature of capital projects would be useful for categorising expenditure within a more detailed taxonomy and for implementing a gap analysis. Careful consideration on the public presentation of the taxonomy and its limitations would be needed when producing the carbon assessment of the 2020 Infrastructure Investment Plan. A more complete framework could be developed in 2021, in line with the recommendation from the Infrastructure Commission for Scotland.

3. Applying a gap analysis approach would help build an understanding of the investment required to reach Scotland's GHG reduction targets: Over time, estimates for the infrastructure deployment or spend required to achieve the decarbonisation pathway could be developed in order to allow a gap analysis for the Infrastructure Investment Plan. This would involve a more detailed assessment of the balance of public and private investment required to deliver the Climate Change Plan. This requires the development of a decarbonisation scenario, with detailed information on the necessary amount of infrastructure deployment (e.g. homes retrofitted, railway lines electrified etc.) and/or level of spend on low-carbon infrastructure deployment. The decarbonisation scenario would also need to specify the carbon budget available for infrastructure that is not low-carbon. This information for the decarbonisation scenario can then be compared to the planned deployment or spend within the Infrastructure Investment Plan, National Planning Framework, and annual capital budget. Required levels of spend will be particularly useful for comparing to annual budget allocations.

4. A suite of assessment methods could be applied to provide a holistic understanding of the impact of the Infrastructure Investment Plan: Given the strategic nature of the Infrastructure Investment Plans and National Planning Framework, and the longer timeframe for undertaking GHG assessments (compared to the annual budget), it would be beneficial to employ a number of different GHG assessment methods in future assessments (i.e. those undertaken beyond 2021). This suite of assessment methods would likely incorporate:

1) a gap analysis (on a consistent basis to that described above) to understand whether planned infrastructure deployment is consistent with the decarbonisation pathway;

2) baseline-and-intervention methods for large infrastructure projects to assess the change in emissions (positive or negative) they cause; coupled with

3) an assessment of the net welfare gain/loss from each large project in order to rank potential projects in terms of £ value/tCO_2 abated/increased.

This would allow a more holistic understanding of the alignment of the plan with the infrastructure required for meeting emission reduction targets. However, the resource and analytical challenges of such an approach should not be underestimated.

5. Assessment approaches can be applied to quantify emissions associated with Scotland's infrastructure projects that occur beyond Scotland: Scotland's infrastructure investment can have GHG emissions impacts outside of Scotland's territorial boundary, both positive and negative. For example, importing cement and steel from other countries for infrastructure assets in Scotland will increase emissions from the production of the materials in those countries, and this will not be reflected in Scotland's territorial GHG inventory. Conversely, Scotland can make infrastructure decisions, e.g. to permit an interconnector to be built with mainland Europe and export electricity from renewables, which will reduce emissions in other countries, but this will also not be reflected within Scotland's GHG inventory.

Baseline-and-intervention methods could be used to assess the impacts from Scotland's infrastructure that occur outside of Scotland's territorial boundary to ensure that negative impacts are minimised and positive effects are enhanced.

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7 Appendices

7.1 Appendix 1 – Methodology

To identify methods and approaches for assessing the impact of infrastructure decisions on GHG emissions a three-step methodology was used for this report. First a desk-based literature review was performed. Reports, standards and methodologies were reviewed that were related to climate/GHG emissions and infrastructure, and climate/GHG emissions and investment. Literature sources included financial institutions, government agencies, NGOs, standard-setters and academia. From this review, the framework (shown in Figure 1) was created.

Following this initial literature review, a series of interviews with practitioners and experts were undertaken to sense check the proposed framework and to identify any further reports not already included in the initial literature review. This helped us to refine the framework and gave insights into the strengths and weaknesses of each approach, as well as practical examples of some of the methods. A full list of the organisations interviewed is given in Table 5.

Table 5. List of interviewees by organisation represented and job title.

Organisation	Role
European Bank for Reconstruction and Development (EBRD)	Associate Director
World Resources Institute (WRI)	Senior Associate
Committee on Climate Change (CCC)	Senior Analyst
Green Investment Group (GIG)	Senior Manager / Policy Researcher and Advisor
Institute for Climate Economics (I4CE) (x2)	Senior Advisor / Project Manager
Organisation for Economic Co-operation and Development (OECD)	Senior Advisor (Environment)
French Environment and Energy Management Agency (ADEME)	Project Manager
Green Finance Initiative (GFI)	Director

A final step was to liaise directly with the Scottish Government to understand current practices and reporting methods. Interviews were undertaken with members of 9 teams. An overview of the methods currently used is given in Table 1 of the report, and a more detailed discussion of the findings from the interviews is given in Section 3 above. As well as identifying current practices, we also asked for information on data and resource availability for implementing different types of assessment approach.

7.2 Appendix 2 – Carbon accounting initiatives for banks and investors

Several international initiatives have been developed that relate to carbon accounting for investments. A non-exhaustive summary of these initiatives is given in Table 6 below.

Table 6: Initiatives for carbon accounting and investment decisions.

Initiative	Coordinator	Description
Investor Agenda	UNEP FI et al.	Set of climate actions for investment aimed at keeping global warming within 1.5°C.
Harmonised Approach to GHG Accounting	IFI	Framework for GHG accounting methodologies for financial institutions.
Partnership for Carbon Accounting Financials (PCAF)	Navigant	Industry-led collaboration to measure and disclose GHG emissions from portfolios.
Taskforce for Climate-related Financial Disclosure (TCFD)	FSB	Disclosure framework for climate-related financial risk.
Paris Agreement Capital Transition Assessment (PACTA)	2dii	Framework measuring alignment of financial markets with climate goals and scenarios with 5-year timeframe.
Paris Aligned Investment Initiative	IIGCC	Concepts and methodologies to test portfolios with alignment to the Paris Agreement.
Landscape of Climate Finance	CPI	Overview of global climate-related primary investment.
Science Based Targets for Financials	SBTi	Aid financial institutions align investment portfolios to the Paris Agreement.
CDP Financial Services Sector Disclosures	CDP	Questionnaires to focus on financing and investing initiatives.
Climate Bonds Taxonomy	CBI	Identification of assets and projects needed to deliver a low carbon economy consistent with a 2°C global warming target.
Sustainable Finance Taxonomy	EU	Tool to enable capital markets to identify and respond to investment opportunities that contribute to environmental policy objectives.

7.3 Appendix 3 – Related reports

Table 7: Related reports. *Report types Legal (L), Standards (S), Methods (M), Examples (E) and Reports (R).

Author (Year)	Report name	Type*
Absolute emissions methods		
IFI (2015)	Framework for a Harmonised Approach to GHG Accounting	M
FMO (2018a)	Absolute GHG Accounting Approach for Financed Emissions	M
WRI (2004)	A corporate accounting and reporting standard	S
Germanwatch (2018)	Aligning investments with the Paris Agreement temperature goal	M
I4CE (2017)	How should financial actors deal with climate-related issues in their portfolios today?	M
PCAF (2019)	Accounting GHG emissions and taking action: a harmonised approach for the finical sector in the Netherlands	M
2ii (2015)	Climate strategies and metrics: exploring options for institutional investors	M
WRI et al. (2018)	Exploring metrics to measure the climate progress of banks	M
Baseline-and-intervention		
WRI (2014)	Policy and Action Standard	S
WRI (2003)	The GHG Protocol for Project Accounting	S
ISO (2019)	ISO 14064-2 – Specification with guidance at the project level for quantification, monitoring and reporting of GHG emission reductions and removal enhancements	S
IFI (2015)	Framework for a Harmonised Approach to GHG Accounting	M
2ii (2015)	Climate strategies and metrics: exploring options for institutional investors (Annex 3)	M

ADEME (2016)	Quantifying the impact of an emission reduction action on GHGs	M
VITO (2013)	Towards 100% renewable energy in Belgium by 2050	E
PCAF (2019)	Accounting GHG emissions and taking action: a harmonised approach for the financial sector in the Netherlands	M
Gap analysis		
I4CE (2019a)	Landscape of Climate Finance in France	E
Hainaut and Cochran (2018)	The Landscape of domestic climate investment and finance flows: Methodological lessons from five years of application in France	M
CPI (2019)	Global Landscape of Climate Finance	M / E
UNEP (2019)	Emission Gap Report	R
Taxonomies		
CBI (2019)	Climate Bonds Taxonomy	M
EU (2019)	Sustainable Finance Taxonomy	M
Green Alliance (2013)	Infrastructure investment and the UK's economic renewal	E
Green Alliance (2016)	The UK's Infrastructure Pipeline	E
Germanwatch (2018)	Aligning investments with the Paris Agreement temperature goal	M
I4CE (2017)	How should financial actors deal with climate-related issues in their portfolios today?	M
S&P Global (2017)	The Carbon Scorecard	E
2ii (2015)	Climate strategies and metrics: exploring options for institutional investors	M
WRI et al. (2018)	Exploring metrics to measure the climate progress of banks	M

Other relevant reports		
CLIMACT (2013)	Low Carbon Scenarios for Belgium by 2050	E
Vivid Economics (2017)	Net-zero in New Zealand: Scenarios to achieve domestic emissions neutrality	E
HSBC (2018)	Low-carbon transition scenarios: Exploring Scenario Analysis for Equity Valuations	M
F20 (2019)	Aligning G20 Infrastructure Investment with Climate Goals and the 2030 Agenda	R
FMO (2018b)	Deriving a 1.5°C Pathway for a Financial Institution	M
Germanwatch (2018)	Aligning investments with the Paris Agreement temperature goal	M
NCE (2016)	The Sustainable Infrastructure Imperative	R
I4CE (2019b)	A framework for alignment with the Paris Agreement	M
IIGCC (2019)	Paris Aligned Investment Initiative	M
ISO (2019)	ISO 14097 – Framework including principles and requirements for assessing and reporting investments and financing activities regarding climate change	S
OECD (2017)	Infrastructure for climate and growth (Chapter 3 of Investing in climate, investing in growth)	R
2ii (2019)	PACTA – Taking the temperature of financial assets	M
PRI (2016)	French Energy Transition Law (Article 173)	L
WWF (2018)	Keeping it cool: How the UK can end its contribution to climate change	R

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