Open Risk White Paper

Sustainable Portfolio Management

Attribution and Allocation of Greenhouse Gas Emissions

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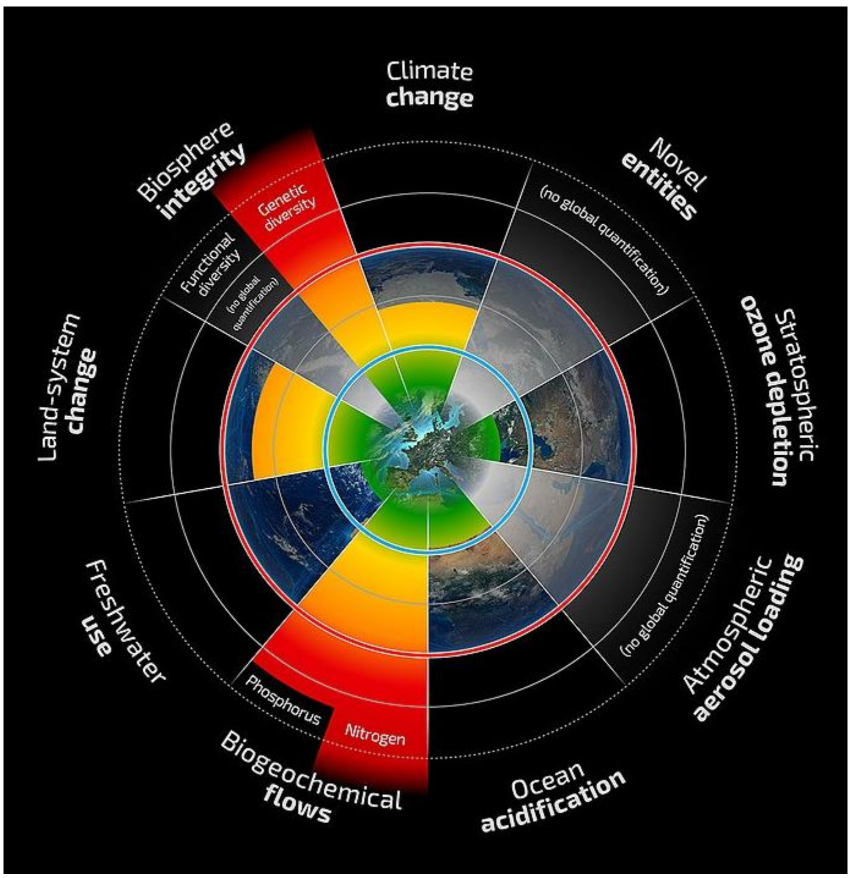

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Contents

1 Sustainability Constraints and Portfolio Management **4**
1.1 Motivation and Current Scope 4
1.1.1 The physical basis of emissions 5
1.1.2 Kyoto Protocol Gases 5
1.1.3 Global Warming Potential 5
1.2 The GHG emissions constraint 6
1.2.1 Coupled Model Intercomparison Projects 6
1.2.2 Integrated Assessment Models 6
1.2.3 The Kaya Identity 6
1.2.4 Global GHG Constraints 7
1.2.5 Mitigation Pathways and Science Based Climate Targets 7
1.3 Sustainable Portfolio Management - A sketch 8
1.3.1 GHG Portfolio Types 9
1.3.2 GHG Portfolio Emissions Scopes 9
1.3.3 Portfolio Management Activities 10
1.3.4 Data Infrastructure and Analytics / Measurement Tools 10
1.3.5 Issues and Challenges 11

2 Attribution of GHG Emissions **12**
2.1 GHG Emission Sources and Sinks 12
2.1.1 Directly Measured Emissions 13
2.1.2 Indirectly Measured Emissions 13
2.1.3 Emissions Factors (EF) 14
2.1.4 The EFDB Database 16
2.2 The Emissions Portfolio: GHG Inventory 16
2.2.1 Physical Asset Inventory 16
2.2.2 Example: City-wide Inventory 17
2.2.3 Calculation Workflow 17
2.3 Slicing and Dicing 17
2.4 Aggregating Emissions Intensities 18
2.4.1 Example: Emissions Intensity of Steel Production 18
2.4.2 Effective Sectoral Emissions Intensity 20
2.5 Attribution of Indirect GHG Emissions 20
2.5.1 Scope 3 Portfolio Management Contexts 20
2.6 The Attribution of Indirect Emissions 21
2.6.1 Financed Balance Sheet Approach 22

3 Mitigation of GHG Emissions **25**
3.1 GHG Mitigation Projects 25
3.1.1 GHG Project Activity 25
3.1.2 Quantifying GHG Reductions 25
3.1.3 Baseline Scenarios 27

4 Allocation of GHG Emissions Budgets **28**
4.1 Portfolio Steering Tools and Limit Frameworks . . . 28
4.1.1 Portfolio GHG Limit Frameworks . . . 28
4.2 Portfolio Emissions Projections . . . 29
4.2.1 Model Approaches . . . 30
4.2.2 Emissions Projections . . . 31
4.2.3 Example: Sectoral Decarbonization Approach . . . 31
4.2.4 Integrated Validation Metrics . . . 32
4.3 Measuring Portfolio Limit Alignment . . . 32
4.3.1 Example: SDA Emissions Alignment . . . 32
4.3.2 Asset Specific Emissions Alignment . . . 33
4.4 Indirect Emissions Portfolios . . . 33
4.4.1 Financed Emissions Projections . . . 34
4.4.2 Measuring Financial Portfolio Alignment . . . 34
4.4.3 Example: The PACTA Methodology . . . 34

Abstract

We develop an analytic framework that synthesizes current approaches to sustainable portfolio management in the context of addressing climate change. We discuss the different required information layers, approaches to emissions accounting, attribution and forward-looking limit frameworks implementing carbon budget constraints. The focus is on identifying the necessary ingredients for a coherent representation, recognizing that practical implementations require a large amount of specific detail.

Objectives and Structure of this White Paper

In this white paper we aim to setup a analytic framework synthesizing various existing GHG accounting, attribution and allocation approaches that have been proposed in recent years. The aim is to develop a common language for i) GHG accounting approaches of direct emissions, ii) GHG mitigation analysis of sustainability oriented projects, iii) portfolio level GHG emission *attribution* approaches when managed emissions are indirect (such as financial portfolios) and finally iv) portfolio level GHG *budget allocation* approaches when financed emissions are indirect. The white paper serves also as a first installment of the mathematical documentation of the Equinox software platform [1], [2] .

- The first chapter 1 reviews and summarizes the context and need for sustainable portfolio management. The current scope is limited to discussing Greenhouse Gas (GHG) emissions: the global carbon budget concept, how this is estimated and how it cascades into portfolio level management constraints and limits.
- The second chapter 2 goes over concepts and practices of GHG inventories and GHG accounting, which involves the attribution of emissions to concrete physical assets and processes. Many different methodologies are available and our approach here parameterizes the enormous variety of low-level measurement approaches and emission factors and focuses on constructing informative portfolio views and representations of the key drivers. We cover separately the attribution of direct emissions and the challenge of attributing indirect emissions such as those influenced by financial portfolios.
- The third chapter 3 is a brief excursion into the most fundamental aspect of the sustainability transition, the active management of emissions at the asset level in the context of concrete projects.
- The fourth chapter 4 discusses another important aspect of portfolio management, namely the forward-looking setup of targets for portfolio steering and alignment. We elaborate here on proposed limit frameworks to guide portfolio development that are based on cascading global and nationally determined contributions to the sectoral and portfolio level.

Credits

The frontpage graphic is adapted from Steffen et al. "*Planetary Boundaries: Guiding human development on a changing planet*". Science (2015)

Chapter 1

Sustainability Constraints and Portfolio Management

1.1 Motivation and Current Scope

> *"We study the natural world in relation to the many other assets we hold in our portfolios, such as the vehicles we use for transport, the homes in which we live, and the machines and equipment that furnish our offices and factories. But like education and health, Nature is more than a mere economic good. Nature nurtures and nourishes us, so we will think of assets as durable entities that not only have use value, but may also have intrinsic worth. Once we make that extension, the economics of biodiversity becomes a study in portfolio management."* - The Dasgupta Review

The quote from the recent Dasgupta review [3] on the economics of biodiversity comes at a time of increased awareness of the (un)sustainability of the human economy as it has been rapidly growing in the last century. The economic thinking that dominated this period, whether normative or explanatory, was imbued with a sense of perceived abundance of key natural resources. Pollution and carbon emissions were assumed contained or irrelevant. The broader impact of humanity on Nature went largely unaccounted for in economic and financial thinking and practice. Current financial theory does not acknowledge natural resources beyond near term cash flows and a potential depletion of resources or adverse environmental outcomes are ignored. These mental models are deeply ingrained and still widely used but are no longer viable. New fields such as *sustainability economics* and *sustainable finance* that were until now rather niche schools of thought are now becoming more mainstream [4].

A powerful though framework found in sustainable economics and finance is to *expand the economic universe* to include relevant aspects of the natural world. To be clear, in some cultures the very idea that we manage Nature as a "portfolio" would seem alien, if not sacrilegious. *Managed Nature* implies also a level of hubris that - for now at least - does not seem warranted. One need look no further than the pandemic experience to understand that we are not yet the almighty self-appointed *managers* of Nature but an integral part of the biosphere and we are in constant interaction with it - just like any other species. Yet in the short term, and given the complete lack of developed and workable alternatives, we are obliged to utilize the portfolio management machinery (among other existing tools) as a vehicle towards adaptation in directions that are more sustainable.

In this work on *sustainable portfolio management* we think of sustainability primarily in the context of environmental sustainability and, more specifically, climate change. While much current work aims to integrate a variety of wider sustainability concerns under the so-called "ESG" banner, the loose definition and unclear conceptual links of the three ESG pillars (Environment, Society and Governance) means that such a general framework is by structure very qualitative.

Transitioning to a lower-carbon economy (which is one of the preconditions of sustainability) will entail extensive policy, legal, technological, and market changes to address mitigation and adaptation requirements posed by climate change. Depending on the nature, speed, and focus of these changes, transition risks create varying levels of both financial and reputation risk to organizations. A comprehensive analysis and thought framework to systematically identify risk and opportunities associated with climate change has been presented in [9],[10]. A subset of climate change risks and impacts are often measured using aggregate economic indicators, such as gross domestic product (GDP) or aggregate income. Estimates, however, are partial and affected by important conceptual and empirical limitations [6]. Mapping climate-related metrics and the potential financial or other impacts to an organization's portfolio is not straightforward. There is already significant work towards combined transition and physical risk methodologies to provide a complete picture of climate-related risk [5]. The field does see rapid development: In [7] they review no less than 16 climate transition risk tools. A regulatory discussion paper [8] identifies various methodological approaches to assessing climate risk and integrating into the origination and portfolio management of banks.

The first order of business is to take stock of GHG emissions. Early initiatives such as IPCC [34] / GHG Protocol [23] set measurement standards for GHG emissions with specialized frameworks targeting projects, sectors, cities, products, financial institutions etc. GHG inventories do not provide guidance on *how* to design mitigation goals, nor how to assess and report *progress* toward achieving them.[1] Forward-looking portfolio management tasks differ from GHG inventory and accounting (2.1) in essential ways. Tools like the application of scenario analysis to climate-related issues are a relatively new phenomenon but there is significant precedence e.g., with financial institutions conducting scenario analysis to test the resiliency of their portfolios in economic terms. A general process for applying scenario analysis to Climate-Related Risks and Opportunities was illustrated in [11].

1.1.1 The physical basis of emissions

The physical basis of GHG emissions is the list of sources and sinks which extends anywhere where human activity is material. Gas emissions from Earth's surface mix quickly into the atmosphere but also into other components of the biosphere (oceans, soil, biological matter) in what are complicated *carbon cycles*. GHG cycles exist independently of anthropogenic (human made) intervention but are driven by human influence into new configurations. Solar and volcanic activity can also influence climate states and dynamics. Human activity that is notable in this context includes the burning of fossil fuels (which shifts reservoirs of carbon from underground to the biosphere). This is an *energy generation process* where low entropy reservoirs are converted into high entropy (heat) and in the process (em)power human activity. Other examples of important GHG emissions are industrial processes or changing vegetation patterns (deforestation, agriculture/aquaculture etc). Those are chemical or biochemical processes different from combustion.

1.1.2 Kyoto Protocol Gases

Increases in GHG concentrations since around 1750 are unequivocally caused by human activities [12]. Since 2011 (measurements reported in AR5 [6]), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 ppm for carbon dioxide (CO2), 1866 ppb for methane (CH4), and 332 ppb for nitrous oxide (N2O) in 2019. The seven gases (species) mandated under the Kyoto Protocol to be included in national inventories under the United Nations Framework Convention on Climate Change (UNFCCC) are:

- carbon dioxide (CO2)
- methane (CH4)
- nitrous oxide (N2O)
- hydrofluorocarbons (HFC's)
- perfluorocarbons (PFC's)
- sulphur hexafluoride (SF6)
- nitrogen trifluoride (NF3)

GHG missions are generally measured in tonnes. Hence the unit **tCO2** denotes *one tonne of CO2 gas*. Larger emission amounts use *unit prefixes* (e.g.,MtCO2) to denote multiples of tonnes (kilo for a thousand, mega for a million etc.).

1.1.3 Global Warming Potential

A simplifying tool for managing emissions across the above seven gas species is the concept of *CO2 Equivalent*. This simplification is in wide use, obviously when the specific distribution of gas emissions is not a critical consideration. The CO2 equivalent is the amount of CO2 that would cause the same integrated radiative forcing (a measure for the strength of Climate Change drivers) over a given time horizon as an emitted amount of another GHG or mixture of GHGs. The CO2 equivalent is a sort of universal unit of measurement to indicate the Global Warming Potential (GWP) of each greenhouse gas, expressed in terms of the GWP of one unit CO2 and can be used to evaluate different greenhouse gases against a common basis.

[1] This is analogous to how the financial reporting of a company is focused on establishing the current state of an entity.

1.2 The GHG emissions constraint

1.2.1 Coupled Model Intercomparison Projects

Focusing first on the relevant climate modeling insights, the Coupled Model Inter-comparison Project (CMIP) was established by leading climate-modeling groups around the world in 1995 to promote a set of coordinated climate model experiments. The CMIP Phase 5 project provided key results and access to data from 28 modeling centers that underpinned the IPCC 5th Assessment Report, generating projections of future climate change. CMIP helps evaluate how realistic the models are in simulating the recent past. It provides projections of future climate change on two time scales: near term (out to about 2035) and long term (out to 2100 and beyond). It also helps understand some of the factors responsible for differences in model projections, including quantifying key feedback mechanisms such as those involving clouds and the carbon cycle.

The CMIP6 models considered in the last IPCC report [12] have a wider range of climate sensitivity than CMIP5 models. These CMIP6 models show a higher average climate sensitivity than CMIP5. The higher CMIP6 climate sensitivity values compared to CMIP5 can be traced to an amplifying cloud feedback that is larger in CMIP6 by about 20%. The evolving best estimates highlight the ongoing fine-tuning of climate models which over time will further reduce forecast uncertainty.

1.2.2 Integrated Assessment Models

Climate models must be complemented with economic models to assess the range of plausible outcomes (After all it is the economy that creates the additional emissions!). Over the past decades so-called *Integrated Assessment Models* (IAM's) have been developed to estimate the impact of (further) economic development on the environment. This category of models includes e.g., the seminal DICE models [13]). Importantly, IAMs lie also at the basis of the assessment of *mitigation pathways*: Climate decarbonization scenarios developed by IEA and IPCC that aim to suggest mechanism to halt and avert the damage from GHG emissions induced climate change.

Recent integrated economic models introduce ever more enhanced realism integration of the physical and economic and financial sphere. For example DEFINE [14] incorporates explicitly the laws of thermodynamics, the carbon cycle, climate change damages, waste generation process, the endogeneity of money and the impact of finance on economic activity. The literature of IAM's and in particular stock-flow consistent variants provides a list of relevant macro variables that can characterize a sustainability transition. Such complete physical/economical models capture GHG concentrations in all the major carbon reservoirs (atmosphere, biosphere and ocean layers) and consistently represent physical flow matrices, along with financial transactions and balance sheets. Reviewing in detail such models is out of scope but the following discussion should give a flavor of the complex dynamics involved.

1.2.3 The Kaya Identity

The Kaya identity [15] is a useful tool for understanding some of the factors relevant in understanding the economic context of climate change and in particular for sustainable portfolio management discussion. It is an equation that disaggregates (energy related only!) GHG emissions into macro-level *emission drivers*: population, GDP per capita, energy intensity of GDP, and emissions intensity of energy consumption:

$$E_T = N \times (\frac{A}{N}) \times (\frac{J}{A}) \times (\frac{E_T}{J})\,, \tag{1.1}$$

where

- N is a measure of system size (e.g., population),
- A is a system economic activity measure (GDP) and A/N is GDP per capita,
- J is a system energy use measure and J/A is a measure of energy intensity of GDP,
- E_T are the total GHG emissions of the economy and E_T/J is the emissions intensity from energy.

By pointing out the overall drivers of GHG emissions on a macro physico-economic level this equation provides a rough structure of the movable levers that can affect GHG emissions and thus increase the sustainability of the energy system[2].

[2]Obviously other sustainability aspects besides energy induced GHG emissions are not captured

The Kaya identity was used to develop business-as-usual trajectories by the IPCC to develop the mitigation pathways presented in IPCC AR5. This assessment suggested a *remaining carbon budget* of about 420 GtCO2 for a two-thirds chance of limiting warming to 1.5°C, and of about 580 GtCO2 for an even chance (medium confidence).

Physical, Economic and Financial Intensities

While we saw that emissions are extensive properties measured in tonnes there are three distinct types of *intensities* that will be defined more precisely and used extensively in the sequel:

- **Physical Emissions Intensity**. This is the normalization of emissions by any extensive variable that expresses another physical aspect (e.g., amount of fuel burned). Managing portfolios using physical emissions intensities focuses on the *physical reality of the emissions processes* as opposed to any economic and financial arrangements.
- **Economic Emissions Intensity**. This is a normalization using a monetary unit of account (currency) that captures some *real economy activity* (e.g., revenue from a production process, or possibly the value of a facility). Managing portfolios using economic emissions intensities focuses on *economic linkages and exchanges* irrespective of financial system structure.
- **Financed Emissions Intensity**. This is a normalization that uses as denominator the monetary value of *financial instruments* (e.g., loan amount).

1.2.4 Global GHG Constraints

In the Paris Agreement signed in 2015, 196 countries agreed to set long-term goals to reduce national GHG emissions and adapt to the impacts of climate change. Expressed in terms of *average global temperature* the ambition is to be well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

The recent Glasgow Climate Pact [16] expressed alarm and utmost concern that human activities have already caused around 1.1 °C of warming to date, that impacts are already being felt in every region, and that *carbon budgets* consistent with achieving the Paris Agreement temperature goal are now small and being rapidly depleted. GCP also recognized that limiting global warming to 1.5 °C requires rapid, deep and sustained reductions in global greenhouse gas emissions, including reducing global carbon dioxide emissions by 45% by 2030 relative to the 2010 level and to *net-zero* around mid-century, as well as deep reductions in other greenhouse gases.

The *global carbon budget* is defined as the cumulative CO2 emissions from the start of 2018 until the time of net-zero global emissions.[3]. Simply put, the carbon budget effectively rations GHG emitting economic activity. It is a simplified measurement of the additional emissions that any economic sector or entity or city or country etc can still emit if the world is to limit global heating to 1.5°C. Nationally determined contributions (NDCs) are at the heart of the Paris Agreement. Each country's NDC reflects its ambition for reducing emissions, taking into account domestic circumstances and capabilities. The NDC's are ultimately also the legally binding framework that set the perimeter for sustainable portfolio management as we will discuss it in this paper.

1.2.5 Mitigation Pathways and Science Based Climate Targets

Given a global landscape how carbon budgets are allocated to countries (NDC) sectors, cities, companies etc will vary based on many complex aspects, indicatively:

- **Responsibility:** GHG emissions, particularly CO2 emissions, accumulate in the atmosphere over time. Many industrialized countries have been the main source of carbon emissions for the past 200 years. These past emissions are termed *historical emissions*. Other countries are still developing their economies and are permitted to peak their emissions later. These are called *late emissions*. Allocated carbon budgets take into account historical emissions and late emissions, tasking those countries, companies and cities who are most responsible for global CO2 accumulation with reducing their emissions.
- **Capacity:** It is acknowledged that different sectors, cities and countries have varied capacities to respond to the challenge of climate change based on their respective levels of socio-economic development, technological maturity etc.

[3]Remaining budgets applicable to 2100 would be approximately 100 GtCO2 lower than this to account for permafrost thawing and potential methane release from wetlands in the future, and more thereafter

- **Inter-generational Justice:** Present generations have certain duties towards future generations, in terms of decreasing climate change risks, increasing the availability of natural resources and the health of the planet's ecosystems.

The menu and possibilities of climate change mitigation actions is enormous and varied. Broad and overlapping drivers that can contribute to mitigation of climate change include:

- Less rapid population growth.
- Technological progress (more energy efficiency, improved agricultural techniques).
- Environmentally oriented behavioral changes (land use, resource-efficient lifestyles).
- Higher productivity.
- Higher human development (access to education, high quality jobs, financial inclusion).
- Economic convergence and global cooperation.

A narrower subset of mitigating actions that is relevant for sustainable portfolio management is built around *science-based targets* (SBTs). These are measurable and actionable environmental targets, aligning action with sustainability goals and the biophysical limits that define the safety and stability of earth systems. Targets adopted by companies / sectors, cities, countries or any other entity to reduce GHG emissions are considered *science-based* if they are in line with the level of decarbonization required to keep global temperature increase below 2°C compared to pre-industrial temperatures, as described in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [6]. Science-based climate targets should be bound by the following principles: they must be science-driven, equitable and complete. *Science-driven* means led by the latest climate science. *Equitable* means they take into account the different historical contributions to levels of carbon dioxide in the atmosphere and take into account socio-economic development. *Complete* means that these targets are robust and comprehensive taking into account inventory-wide emissions from a variety of sources [17]

A central theme of science based targets that is close to the role and responsibility of portfolio management are considerations around the *technology mix*, the set of technologies (in the broadest sense) that determine forms of energy supply and use (in industry, buildings, transport etc) but also land-use transitions and changes in e.g., agriculture. A simplifying classification is to characterize technologies and practices as *high carbon technologies* or *low carbon* (or no carbon) and aim to transition from the former to the latter. Yet technological adoption involves a complex mix of availability, cost and adoption processes. Even within this narrowly defined problem scope sustainable portfolio management faces fairly unique challenges.

1.3 Sustainable Portfolio Management - A sketch

Sustainable Portfolio Management (SPM) denotes a set of principles, tools, processes that underpin the management of *Portfolios* while incorporating sustainability constraints. A portfolio is formed as a collection of distinct "interests" (ownership, control, investments, contracts, relations etc.) in various economic settings. These components have broadly similar set of characteristics and evolve (change over time) in a common context. Sustainable portfolio management involves making comparisons and evaluations that integrate both economic / financial and sustainability criteria. For example analyzing the change to a portfolio brought by a decision at a point in time. Such evaluation is necessary because the portfolio manager would not otherwise know whether the proposed portfolio change is desirable according to defined sustainability criteria and objectives. A sustainable portfolio manager is a portfolio manager that incorporates sustainability as measurable objective *alongside* their pre-existing objectives.

A particular type of evaluation is cost-benefit analysis, or project evaluation, which offers a methodology for evaluating investment projects from a sustainability angle. The exercise involves evaluating alternative uses to which capital resources can be put. Another type of comparison involves valuing the change a portfolio displays over time. This answers questions as, is the country, or city more prosperous today than it was a year ago, where prosperity is taken to mean, for example, quality of life that preserves natural capital. For our current purposes a sustainable portfolio manager has an externally defined *carbon budget* over a period of time. This a significantly reduced mandate and scope: In the first instance it focuses on *environmental sustainability* as a subset of broader sustainability considerations (sometimes bundled under the "ESG" acronyms). Next, it isolates green house gas emissions induced climate change as an important subset of many other environmental impacts (other air pollution, soil contamination, water use, habitat destruction / biodiversity loss from deforestation etc). We also adopt (as the vast majority of current work) the IPCC identified gases as an adequate proxy for material emissions impact. Finally, various methodologies we discuss are in practice limited to specific critical sectors (energy, transport etc). The skill-set, toolkit and models used by sustainable portfolio managers is likely to evolve over the next years and decades. During what appears to be a long transition period, portfolio management will need to incrementally incorporate constraints and considerations that where heretofore ignored.

1.3.1 GHG Portfolio Types

A sustainable portfolio manager is acting on the behalf of an agent. That agent can be an individual, a corporate entity, a city, a nation state or, indeed, the entire human enterprise as represented e.g., by the United Nations. The portfolio management mandate is *augmenting* other objective functions with sustainability constraints and aims to use available tools towards optimizing the portfolio in this new framework. Thus sustainable portfolio management strategies must be informed by the very diverse context, governance, decision-making processes and pre-existing objective-setting mechanisms. Starting in a top-down fashion we can enumerate a number of natural "portfolio management" contexts (the references point to corresponding GHG accounting frameworks):

- National GHG Inventories [19] that concern sovereign level aggregation and disclosure
- City GHG Inventories [20] that targets the very Community-Scale where 70% of all emissions happen
- Corporate GHG Inventories [21],[22] that are maybe the most significant "hot-spot"
- Project GHG Inventories [23] that cover the very important dedicate project class (e.g., wind turbine installations)
- Financial Intermediary GHG Inventories, e.g., banks (Scope 3 Category 15 of [22])

Choosing a portfolio that optimally satisfies sustainability constraints among all the portfolios that are attainable requires concrete and quantitatively oriented information technology tools. An essential feature of sustainable portfolio management is that it involves distinct information layers that interact closely and are of very different intrinsic nature. This layered structure appears as a considerable complication over the more traditional portfolio management focus which optimizes under purely *financial constraints*, e.g., optimal allocation or risk capital. These distinct information layers are as follows:

- **The physical asset layer**: This is the set of identifiable physical artifacts that both enable economic activity and create GHG emissions. Physical assets have (in general) also a defined *spatial profile*.
- **The technology portfolio or mix**: This denotes the collection of specific processes (including physical/chemical processes, information flows and human effort) that are associated with generating economic value from physical assets. Technologies are variably linked to physical assets and, crucially, have variable environmental impact through emissions.
- **The financial or contractual portfolio**: This is the collection of legally enforceable contracts (ownership deeds, credit contracts, shareholding contracts, leases, procurement contracts, derivatives contracts etc) that embed the two previous layers into a formal financial system.
- **The stakeholder portfolio**: This is set of entities that may have a stake (have an interest or are affected by) the physical asset portfolio, its technology mix and GHG emissions. This may include any entity involved in the supply or value chain of a physical element: Government Entities (State, City), Companies and Organizations of various sizes types (SME's, Corporations, Non-Profits), Households and last but not least, Financial Intermediaries of various types (Banks, Pensions Funds, Insurance providers etc)

The precise shape and interaction of those layers is context dependent and thus shapes also the portfolio management mandate and contours. For example, cities may manage local government emissions as a physical portfolio, implement procurement policies as a financial portfolio, as well as developing building and energy-efficiency codes or rules, that can lead to changes within city-wide supply-chains that effectively decrease GHG emissions [18].

1.3.2 GHG Portfolio Emissions Scopes

In a modern economy with different entities producing and consuming goods and services in complex supply and ownership structures attributing emissions is highly non-trivial. For each physical asset or entity in the portfolio, emissions associated with its operations can be categorized as *direct or indirect emissions*. The GHG Protocol has introduced the extremely important concept of emission *scopes* [21].

- *Scope 1*: **Direct GHG emissions** are those that occur from sources owned or controlled by the entity mandating the portfolio manager. For example emissions from combustion in owned or controlled buildings, plants, vehicles, etc or emissions from sources located within the GHG inventory boundary.

- *Scope 2*: **Indirect GHG emissions** that are from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the entity mandating the portfolio manager. Scope 2 emissions physically occur at the facility where the electricity, steam, heating, or cooling is generated.

- *Scope 3*: All **Other indirect GHG emissions** (not included in Scope 2) that occur in the value chain of the entity mandating the portfolio manager. Scope 3 can be broken down into upstream emissions that occur in the supply chain (for example, from production or extraction of purchased materials or procured services) and downstream emissions that occur as a consequence of using the organization's products or services. Importantly, Scope 3 emissions include both purchases of goods and services (upstream emissions) and investments (downstream emissions).

Example Contexts

For a company the GHG inventory and its Scope decomposition may involve, depending on its business model and sector, any distribution of emissions around Scopes 1, 2 or 3. For energy intensive sectors Scope 1 might be of paramount importance. The portfolio manager can pursue projects activities that modify technologies, adjust suppliers etc. For public sector entity (e.g., a city) the inventory may involve Scope 1 emissions from property and land, Scopes 3 through the public procurement process etc. For a bank or other financial intermediary, the inventory concerns the financed emissions portfolio of assets belonging to other entities (companies, households) tt will thus be primarily of Scope 3. The portfolio manager can for example engage with clients about their sustainability strategy, or adjust investments to rebalance the technology mix of the portfolio.

1.3.3 Portfolio Management Activities

The SPM function has both a business steering aspect and a risk management aspect. We expand now in some detail on the range of sustainable portfolio management activities:

- *Portfolio Monitoring*. Providing *complete portfolio information* (help assess the current state of the portfolio) along both the financial and sustainability dimensions (2.1, 2.6). This involves data collection and processing and new data sources. At this stage of SPM development this aspect is possibly the most vital contribution on which other tasks depend.

- Helping guide the *origination of assets* (help shaping a future portfolio) that is aligned with sustainability objectives. In particular with the formulation of portfolio-wide baseline scenarios (3.1.3), establish consistent comparisons of project impact. Steer the pricing of assets (where applicable), identify diversifying investments and, if needed, divestment.

- Improve portfolio structure and reduce *concentration risk*, both climate and transition risk concentrations. Set (allocate) and monitor limits and carbon budgets. More broadly, help managing risk appetite (setting and monitoring relevant risk limits), including physical risk and transition risk appetite.

- Perform *stress testing* and sensitivity exercises in a sustainability context.

- Support with external (sustainability) *reporting*.

- Overall *portfolio optimization*, including developing internal measures for holistic evaluation of risk return. Ultimately support the holistic management of both financial capital and natural capital.

1.3.4 Data Infrastructure and Analytics / Measurement Tools

Sustainable portfolio management calls for a number of additional data infrastructure and analytics tools

- *Position Data*: Integrating both financial and GHG accounting snapshots of the current state of the portfolio

- *Historical Data*: Track record and metrics at asset, counterparty, regional/sectoral level

- *Scenario Analysis and Stress Testing*: For risk horizons and addressing dimensions relevant for sustainability

- *Risk-based Measures*: Developing a holistic valuation toolkit
- *Quality Assurance*: Backtesting, verification and validation of inputs and assumptions

Improving transparency on the models and underlying assumptions used in sustainable portfolio management is of some importance. Currently, models are often too much of a black box [24]. There is a growing number of open data sources and open source tools that help with accounting and managing GHG emissions in the context specific projects, cities or financial portfolios [25],[26],[27],[28]. These projects span a range of online databases, spreadsheets and R libraries and oriented both towards city or financial institution portfolios.

1.3.5 Issues and Challenges

Sustainability related risks are still poorly understood. Sustainability risk break with the prevalent linear/additive view of risks and portfolio management that looks to optimize value in splendid isolation. As can be seen already in the above emissions scope discussion, considerations like Scope 3 emissions require analysis of the entire network of economic relations in a significantly more comprehensive way than what is customary.

For many organizations sustainable portfolio management comes as a new and multi-dimensional constraint. It is a consideration on top of pre-existing portfolio management approaches. It must thus satisfy pre-existing requirements even while addressing new requirements. While sustainable portfolio management will eventually come to be practiced by a wide range of organizations and deploying a full range of tools at present the conceptual frameworks, data sources and tools are limited to a few pioneering initiatives.

The ambiguity, multiplicity of concepts, difficulty of validation and potential conflicts with purely financial considerations may open the door to green-washing practices, rules arbitrage and the eventual discrediting of practices. For example, a list of challenges towards a climate neutral and circular procurement system for local government includes [29]

- Prioritization of focus and resources to have an impact is unclear (80/20 rules).
- Tools and databases are not yet widely available.
- Data requested and supplied by/to market actors / counterparties too limited.
- Aggregation of effects on the scale of the organization not yet possible.
- No consensus on uniform framework of sustainable indicators.

Integrating broader sustainability issues beyond climate impact of GHG emissions adds complexity to an already complicated landscape. In this work we focus on portfolio management in the context of GHG emissions. Finally, equity questions are deeply related to what type of accounting is used as a basis to set targets: production-based or consumption-based accounting, which lead to very different views for any given territory in terms of climate responsibility.

Chapter 2

Attribution of GHG Emissions

Let us examine in more detail GHG emissions sources and how they can be measured (accounted for). Accurate, complete, trusted, measurement and reporting of all material emissions is a prerequisite for the global effort towards climate change mitigation as part of the sustainability transition. *GHG Accounting* (also named Carbon Footprinting) is a quantification process that aims to integrate a number of analytic approaches towards an objective enumeration of anthropogenic GHG emissions (and absorption). Such an exercise is, in principle, independent of any financial, economic or jurisdictional considerations and must reflect the granularity, stability, reliability that is appropriate to inform decisions. GHG "accounting" is currently primarily a best-effort process of identifying and attributing the low-level physico-chemical processes creating GHG emissions. Notably on November 2021 the IFRS Foundation Trustees announced the creation of a new standard-setting board, the International Sustainability Standards Board (ISSB) to create formal accounting standards for high quality, transparent, reliable and comparable reporting by companies on climate and other environmental, social and governance (ESG) matters [30].

In the current context we will use prominently the term *attribution* rather than accounting. As we will see in detail, when quantifying indirect (Scope 3) emissions, an attribution process is a key component of the quantification methodology and alternative choices are equally plausible. For direct emissions as well, in the vast majority of cases emissions and activity numbers are inferred rather than measured. Thus emissions are effectively being attributed via other, directly measurable, economic activities (e.g., production).

2.1 GHG Emission Sources and Sinks

Emission sources or sinks can be classified and grouped in various ways. From a physical mechanisms perspective, GHG Emissions are produced due to (bio)chemical processes that take place while in contact with the atmosphere (emissions diffuse and mix immediately) or through leaks of previously generated and stored gases, or through changing land use that changes the role of vegetation in its natural carbon emission and absorption cycle.

In turn, the relevant chemical processes can be classified as either i) *fuel combustion*, where the primary aim is energy generation and ii) *industrial process* emissions, where the primary activity is a chemical or mechanical transformation process. In turn combustion can be classified as either *stationary*, where the combustion process takes place in a geographically fixed facility or mobile combustion, where combustion happens in transit (e.g., in the context of transport of people or goods using cars, ships or planes). The precise taxonomy for classifying sources varies slightly by framework (e.g., [31],[21]). An example would be:

- Stationary Combustion: combustion of fuels in stationary equipment such as boilers, furnaces, burners, turbines, heaters, incinerators, engines, flares, etc.
- Mobile Combustion: combustion of fuels in transportation devices such as automobiles, trucks, buses, trains, airplanes, boats, ships, barges, vessels, etc.
- Electricity Use.
- Non-electric Energy Use.
- (Industrial) Process Emissions: emissions from physical or chemical processes such as CO2 from the calcination step in cement manufacturing, CO2 from catalytic cracking in petrochemical processing, PFC emissions from aluminum smelting, etc.

- Fugitive Emissions: intentional and unintentional releases such as equipment leaks from joints, seals, packing, gaskets, as well as fugitive emissions from coal piles, wastewater treatment, pits, cooling towers, gas processing facilities, etc.

As a separate category, *carbon sinks* are processes that absorb GHG. Carbon sinks are an important and distinct consideration: The residual terrestrial sink is finite but substantial and is affected by economic activities such as changes in land management practices and/or fertilization effects leading to increased vegetation and soil carbon [32]. A more precise categorization of sources/sinks will not be important for our present purposes as we will parameterize an abstract collection of emission sources. An important sub-categorization that is very relevant in practice concerns the *fuel* that is involved in energy production.

2.1.1 Directly Measured Emissions

GHG emission or absorption can in principle be measured directly locally by placing a sensor near the emitting source. Emissions may be measured directly through systems that monitor the concentration of the GHGs and output flow rate [31]. In chemical processes, stoichiometry refers to the quantitative relationship between reactants and products in a chemical reaction. A stoichiometric ratio is used to determine the amount of carbon dioxide (CO2) released per unit of carbonate input, and can be expressed as the molecular weight of CO2 divided by the molecular weight of carbonate.

Direct measurement may be relevant for facilities using *Continuous Emissions Monitoring Systems* (CEMS), such as power plants, industrial facilities with large stationary combustion units, or landfills with landfill gas collection systems. In certain cases it may possible to directly detect certain GHG emissions from satellite data [33].[1] While possibly the most accurate and unbiased approach, direct measurement will obviously not be practical as the sole emissions attribution approach. Current GHG accounting frameworks envision a menu of further possibilities which we briefly discuss next.

2.1.2 Indirectly Measured Emissions

There is a hierarchy of recognized GHG measurement methodologies that, in the IPCC nomenclature [34] are called Tier 1, Tier 2 and Tier 3 methodologies. Tier 1 uses default (generic) data and simple equations, while Tiers 2 and 3 are each more demanding in terms of complexity and data requirements. Tier 1 methods are meant to be the simplest to use, rely on globally available sources of activity data estimates. Tier 2 methods generally apply emission and stock change factors that are based on country or region specific data while Tier 3 involves the most specific, project-level, activity data and emission factors. The hierarchy of specificity from highest to lowest depends on the context. For a manufactured product it may look like:

- Product-level: GHG emissions for the product of interest.
- Production line-level: GHG emissions and/or activity data for the production lines that produce the product of interest.
- Facility level: GHG emissions and/or activity data for the facilities or operations that produce the product of interest.
- Business unit level: GHG emissions and/or activity data for the business units that produce the product of interest.
- Corporate-level: GHG emissions and/or activity data for the entire corporation.
- Sectoral-level: GHG emissions based on sector averages.

All non-directly measured emissions are inferred or deduced from proxy *activity* data which are converted to emissions following the general linear equation[2]. For calculating emissions, activity data are multiplied by a corresponding *GHG Emission Factor* to derive the GHG emissions associated with a process or an operation as illustrated:

$$E[t, t+1] = f \times A[t, t+1] + C \tag{2.1}$$

where E are emissions over a time period $[t, t+1]$, measured in CO2 units. A is an activity measure *over the same period* and f is an emissions intensity measure that converts the activity to emissions. C is an (optional) fixed offset that might be adding a degree of accuracy in some circumstances (e.g., fixed overhead emissions that do not scale with activity level).

Activity Data are quantitative measures of the level of activity that results in GHG Emissions. Activities producing emissions will in general be associated with some type of formally recognized economic activity. *Primary* activity data may

[1] An example of so-called fugitive emissions

[2] In practice the actual equation may include a number of more detailed calculations in a multiplicative or additive way

be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, mass balance, stoichiometry, or other methods for obtaining data from specific activities in the company's value chain. *Secondary* activity data includes industry-average-data (e.g., from published databases, government statistics, literature studies, and industry associations), financial data, proxy data, and other generic data. In certain cases, one may use specific data from one activity in the value chain to estimate emissions for another activity in the value chain. This type of data (i.e., proxy data) is considered secondary data, since it is not specific to the activity whose emissions are being calculated. These different data input options may get assigned different *Data Quality* scores as they embed varying degrees of uncertainty.

2.1.3 Emissions Factors (EF)

Emission Factors linked to activities are maybe *the* central organizing concept in GHG emissions management. They encapsulate the rate at which an economic activity produces emissions. They are a tangible representation of the *technology mix* and (when multiple alternatives exist for the same ultimate activity) illustrate concrete possibilities for decarbonisation. The portfolio technology mix involves a collection of such emissions factors and the sustainability transition (in very simplified terms) implies a rebalancing of economic activity between these factors. Technological innovation means *materializing new factors* that do not exist in the current toolkit. Emission factors are by convention positive for produced emissions and negative for sequestered (removed) emissions (sinks) [3].

The categorization of activities is adapted to the nature of the emission processes. Different activities get quantified in different ways and the associated unit depends on the type of activity. For example:

- Kilowatt-hours of electricity used.
- Quantity of fuel used.
- Output of a production process (numbers of widgets, volumes or weight of substance etc).
- Hours some equipment is operated.
- Distance traveled by a vehicle.
- Floor area of a building.
- Revenue from some service provision.
- Value of assets providing a defined service.

Corresponding to the categorization of activities, there are various categorizations of emission factors: physical emission factors are emission factors associated with a lower-level physical activities. Emission Factors are at the most fundamental level *technology dependent physical parameters*. Verified emission factors expressed per physical activity (e.g., tCO2eq/MWh) are issued or approved by a credible independent body such as the International Energy Agency (IEA). Some illustrative examples:

$$E_1 = \text{Energy Consumption} \times f_1 \tag{2.2}$$

$$E_2 = \text{Production} \times f_2 \tag{2.3}$$

$$E_3 = \text{Revenue} \times \frac{\text{Sectoral Emissions}_s}{\text{Revenue}_s} \tag{2.4}$$

$$E_4 = \sum_a \text{Fuel}_a \times f_a \tag{2.5}$$

$$E_5 = \sum_b \text{Distance}_b \times f_b + C \tag{2.6}$$

where E_1 are emissions from a physical activity based on energy consumption with factor f_1 expressing emission per energy unit, E_2 are emissions from production with f_2 expressing emissions from production unit. E_3 is an example of proxying emissions from a sectoral profile of sector s and associated revenue figures for the sector and the activity respectively. As another example of incremental specificity, in the context of mobile combustion (CO2 from road transport), the GHG Protocol Tier 1 approach calculates CO2 emissions by multiplying estimated *fuel sold* with a default CO2 emission factor.

[3] Land use categories may also have removal factors i.e., the amount of CO2 removed from the atmosphere per unit of activity data (often expressed in hectares)

The Tier 2 approach uses fuel-based emission factors specific to vehicle subcategories E_4. Further complications may involve multiple fuels and fixed offsets (e.g., cold start emissions) E_5.

Further categorizations of EF's follow from the nature of activities and we discuss some important cases next:

Material or Product Emissions Factors

For manufacturing activities that involve material / chemical transformations GHG emissions will be captured by corresponding material or product emissions factors. These can be either [35]:

- *Life cycle emission factors* that capture emissions that occur at every stage of a material/product's life, from raw material acquisition or generation of natural resource to end of life.
- *Cradle-to-gate (or upstream) emission factors* that include all emissions that occur in the life cycle of a material/product up to the point of sale by the producer.

Energy Emission Factors

Another specific example are energy emission factors:

- *Combustion emission factors*, which include only the emissions that occur from combusting fuel
- *Life cycle emission factors*, which include emissions that occur from combusting the fuel and all other emissions that occur in the life cycle of the fuel such as emissions from extraction, processing, and transportation

Which factor is suitable in each instance depends on the scope of attributed emissions.

Economic Activity Emissions Factors

The physical activity-based emissions estimates (material, energy) we saw above are based on physical activity data collected directly (e.g., quantity of fuel consumed or megawatt-hours of electricity produced). For example 3.0 tCO2eq/tonne crude oil or -200 tCO2eq/hectare forest. *Economic activity based emission factors* are, in contrast, expressed in terms of a less directly attributed economic activity, e.g.,100 gCO2eq/mln of sales. Emissions data can be estimated at the macro level using e.g., official statistics data and acknowledged EEIO tables providing region or sector-specific average emission factors expressed per economic activity (e.g., tCO2eq/€ of revenue or tCO2eq/€ of assets). Yet it should be obvious that economic indicators also encompass larger possibility for errors, biases, volatility, blind spots, arbitrage or even fraud.

Revenue, in particular, is a widely applicable means to integrate emissions from diverse activities, given that any economic activity is (in-principle) translated into a monetary flow as follows:

$$E[t, t+1] = f \times A[t, t+1] \tag{2.7}$$

$$E[t, t+1] = f \times \frac{A[t, t+1]}{R[t, t+1]} \times R[t, t+1] \tag{2.8}$$

$$E[t, t+1] = f' \times R[t, t+1]\,, \tag{2.9}$$

where $R[t, t+1]$ is revenue during a period from a given activity and $f' = f \times \frac{A[t,t+1]}{R[t,t+1]}$ is an emissions factor adapted to using revenue as activity data to obtain emissions.

Temporal Characteristics

The fundamental equation 2.1 is an *emissions rate equation* applied to a given period. Emissions might be constructed e.g., with reference to calendar years. From an accounting perspective, activities have intrinsically a *flow nature* (what is recorded is the amount of activity *during* a measurement period). Stock variables (Such as floor area or value of assets) can also be used as a proxy for an underlying economic or physical flow variable that might be less easily measurable. For example using the floor area of a building together with the energy requirement to heat over a period produces an *implicit flow activity*. Mathematically this is expressed as follows:

$$E[t, t+1] = f \times \frac{SA[t, t+1]}{A} \times A = f' \times A \tag{2.10}$$

where the "shadow" activity SA that is actually producing emissions is bundled in a new emissions factor f'. In various portfolio management contexts finer temporal granularity might be desirable but this puts more pressure of data quality. Economic activity (and hence emissions) exhibits strong temporal patterns (daily, weekly, seasonal) that might requires proper treatment before being used to support portfolio management decision making. A methodology for aggregating quarterly activity data at national level is provided in [36].

Gas Species Aggregation

A given amount of economic activity A may involve a range of technologies and each may produce a range of gas emissions. As discussed already in (1.1.3), one can aggregate emissions using global warming functions. For a set of GHG species g (e.g., CO2, N2O and CH4) and a technology τ (e.g., the diesel engine) the accounting equation is:

$$E_T = \sum_{g,\tau} f_{g,\tau} \times \text{GWP}_g \times A = \sum_g E_g \times \text{GWP}_g \,, \tag{2.11}$$

where E_g are emissions in a particular gas species g and GWP_g the conversion factor to a CO2 equivalent. The resulting amounts are then quoted as tCO2eq (CO2 equivalent tonnes). Hence the total GHG Emissions E_T from a source is the sum-product of an Emissions Factor $f_{g,\tau}$ for this gas and technology times the Economic Activity Indicator A, converted to CO2 equivalent.

Carbon Intensities

Emissions normalized using economic indicators are frequently named *carbon intensities*. While the term carbon intensity and emissions factor are sometimes used without distinction we will only use the former in the context of portfolio management of indirect emissions where the intensity refers to an economic value of the *relationship* (e.g., face value of a financial contract)

2.1.4 The EFDB Database

The Emissions Factor Database (EFDB) is a database on various emission factor parameters that can be used in the calculation of anthropogenic emissions by sources and removals by sinks. The EFDB at present contains the IPCC default data (Revised 1996 IPCC Guidelines, IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry, 2006 IPCC Guidelines for National Greenhouse Gas Inventories and 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands), and data from peer-reviewed journals and other publications including National Inventory Reports (NIRs). Indicatively, the EFDB database contains circa 18000 distinct activity / factor entries.

2.2 The Emissions Portfolio: GHG Inventory

2.2.1 Physical Asset Inventory

Calculating a GHG emissions baseline snapshot of the portfolio is the first step of any portfolio management activity. The GHG inventory helps prioritize actions (e.g., mitigation projects, investments) and policies as it highlights *emissions concentration*. The inventory is also the baseline to measure future progress. A physical asset inventory is a database of all relevant physical assets e.g., oil and gas extraction facilities, coal mining, power generation plants, car manufacturing factories, aviation and shipping transport infrastructure, cement and steel manufacturing etc. Each asset is characterized by a number of technical and physical characteristics (the technology used, its production capacity) that determine applicable emission factors and production volumes. Geospatial data such as coordinates may allow representing assets on maps to establish also their geographical concentration density. In turn physical assets are linked to direct owners (e.g., companies) via specific ownership deeds. Further up the portfolio management layer, assets may be linked via financial contracts and instruments to investors and other stakeholders.

Calculating a GHG inventory requires portfolio-wide data and access to such data can be a barrier that either prohibits completing the inventory or reduces data quality in the portfolio overview it produces. In general a portfolio manager will have easiest - in principle - access to Scope 1 data, that is data relating to GHG emissions from assets that the entity controls directly. If the portfolio being managed concerns Scope 3 emissions (e.g., a procurement portfolio or a financial investment portfolio), the data must be provided through clients, providers or counterparties. This raises the bar as to cost, availability, consistency, completeness and other data quality criteria.

2.2.2 Example: City-wide Inventory

Economic activities within an urban area that may contribute to GHG emissions include: energy production (from oil & gas or other fossil fuel source), residential / commercial heating, transportation (road vehicles of various types / energy sources, boats, trains, airplanes etc), industrial activity, waste and wastewater management, fugitive emissions, agricultural activity and even forestry or other land use that is within the city boundaries. Each physical asset may generate emissions of different types: e.g., a hybrid automobile will generate greenhouse gas emissions from the combustion of fossil fuels and indirectly from by the electricity that has been used to charge its battery. The quantity of GHGs emitted by transportation within a city depends on applicable transportation modes, fuel types, fleet age and prevalent technology and of-course the total activity measured in actual kilometers traveled, number of passengers (occupancy rate) or goods carried etc.

2.2.3 Calculation Workflow

The steps to create an emissions baseline, or inventory involve, broadly speaking, the following:

- Defining the portfolio boundaries (what is in scope) and the economic activities that will be tracked
- Collecting and collating activity data for the portfolio, e.g., amounts energy production or consumption
- Cleaning and normalizing data and finalizing emissions factors methodologies and/or proxies
- Calculating individual and aggregate emissions by applying the emissions factors to activity data

The result of this workflow is a list of emissions contributions from portfolio elements expressed as pairs (f_i, A_i) and a total sum of emissions attributed to the entire portfolio:

$$E_T = \sum_i f_i \times A_i \tag{2.12}$$

In practice GHG inventory methodologies will also support defining *subsets* of emissions defined by filtering on various characteristics. In the following section we discuss some useful examples.

2.3 Slicing and Dicing

Segmenting the portfolio along various dimensions provides deeper insights over the potentially large and difficult to inspect catalog of portfolio elements. Conceptually this can be expressed as filtering a catalog of indexed contributions, where the various dimensions are depicted as indexes $(ijkl\ldots)$ and the desired *portfolio subset* is denoted as "S":

$$E_S = \sum_{ijkl \in S} f_{ijkl} \times A_{ijkl} \tag{2.13}$$

By Emissions Scope

The decomposition by emissions scope is maybe the most important dimension from a portfolio management perspective because it determines responsibility (attributability of emissions) and the ability to influence transition pathways via various incentives or other tools. Delineating the appropriate emissions scope (1.3.2) (direct versus indirect) can be complicated, both conceptually and in terms of data requirements. In the current context for brevity of exposition we will assume that a portfolio manager either manages a Scope 1 portfolio of directly controlled emissions *or* a Scope 3 portfolio of indirect emissions.

By Economic Sector

Segmenting the inventory by *economic activity sector* is maybe the next most important slice because activities and emission factors will in general be more homogeneous within sectors and the dynamics of transition pathways follows sectoral paths. Any sector classification can be used for that purpose, either a standard one (NACE, ISIC, BICS, GICS, etc.) or the portfolio manager's internal classification. One difficulty is that entities may be active across multiple (sub)sectors; e.g., some oil gas companies are transitioning into renewable energy production. It is therefore important to account for this granularity when it is present. Indicatively the most relevant top-level GHG sectors according to IPCC are: Electricity and Heat; Industry; Transport; Buildings; Other Energy; AFOLU (Agriculture, Forestry and Other Land Use). A sectoral classification will be important for setting forward looking portfolio management targets. We will see, though, in (4.1) that aggregation of cross-sector alignment metrics is not straightforward.

By Geography

When the portfolio concerns a legal entity with defined geographical perimeter (country borders or municipal government boundaries) the concept of a *spatially defined GHG inventory* is an insightful way of cataloging, processing and reporting emissions related information. For example the administrative city boundaries can be represented on a map and various assets, technologies, emissions profiles and financial information can be added as overlays. A geospatial catalog means that each source or sink is linked with a defined physical asset geometry. Geographical segmentation is also necessary to address correctly different local technology conditions (e.g., electricity in some area produced by a power plant).

Physical assets can quite generally be classified as *Point Sources* (e.g., power plants), *Linear Sources* (e.g., transport systems) or wide *Area Sources* (e.g., residential blocks, agricultural areas, forests). The appropriate geometry choice depends on spatial resolution (e.g., houses as point sources or aggregated as an area) [4].

By Jurisdiction

Closely linked but in many cases distinct from geography is the segmentation by *legal jurisdiction.* All physical assets operate under *some* jurisdiction. National boundaries are significant for portfolio management purposes as they define: applicable laws, financial and taxation systems, policies (including e.g., subsidies), and, critically, the top-down defined carbon budgets (NDC). A national budget might be further decomposed into sub-national level contributions. A multi-national portfolio spanning multiple jurisdictions might have to cope with complex and inconsistent aggregation challenges.

2.4 Aggregating Emissions Intensities

The consistent measurement and reporting of GHG emissions profiles at higher levels of aggregation is of obvious importance for portfolio management but is non-trivial as will be illustrated by the following example following [37].

2.4.1 Example: Emissions Intensity of Steel Production

The iron and steel sector is highly energy and emissions-intensive, accounting for 8% of global final energy use and 7% of global direct energy-related CO2 emissions (including its industrial process emissions). Producing a tonne of crude steel results on average in 1.4t of direct CO2 emissions and 0.6t of indirect CO2 emissions on a sectoral basis. This is the relevant sectoral *aggregated emissions intensity* expressed in terms of the core production activity of the sector. How is this metric produced?

Defining the Sectoral Boundary

The first question is what is meant by ”sector” in this instance (the sector boundary). Broadly speaking iron and steel production falls within Section C (Manufacturing) of the NACE classification. Within Manufacturing, it falls within Division C.24, (Manufacture of Basic Metals), further, in Group C.24.1, (Manufacture of basic iron and steel) and of ferro-alloys and ultimately, Class C.24.10 that focuses exclusively on the *production* of steel as opposed e.g., to casting, drawing and related activities (including also metals such as copper and aluminum). An example of how a *legally binding sectoral boundary* might be specified is provided by the EU's proposed green taxonomy [38]. The taxonomy is proposed (as of 2021) regulation that aims to establish technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives. In our example case the EU taxonomy stipulates that manufacture of iron and steel is classified under NACE codes C24.10, C24.20, C24.31, C24.32, C24.33, C24.34, C24.51 and C24.52. Indicatively, the taxonomy classifies this activity as ”green” when the iron and steel with GHG emissions calculated in accordance with Regulation (EU) 2019/331 is lower than the following values applied to the different manufacturing processes:

- (i) hot metal = [xxx] tCO2e/t product;
- (ii) sintered ore = [xxx] tCO2e/t product;

[4] As the spatial resolution of the inventory becomes finer various complications and alternatives emerge, namely there is discretion where emissions should be attributed to. For example, the emissions of a ferryboat could be spatially located where they physically occur (a linear asset describing the ferry path), at the office of the operating company, at the harbor where the boat takes on fuel, or at the terminals it operates picking up passengers or goods!

- (iii) coke (excluding lignite coke) = [xxx] tCO2e/t product;
- (iv) iron casting = [xxx] tCO2e/t product;
- (v) electric Arc Furnace (EAF) high alloy steel = [xxx] tCO2e/t product;
- (vi) electric Arc Furnace (EAF) carbon steel = [xxx] tCO2e/t product,

where in the above, [xxx] denotes the average value of the top 10% of installations based on the data collected in the context of establishing the EU ETS industrial benchmarks for the period of 2021-2026 and calculated in accordance with the methodology for setting the benchmarks set out in Directive 2003/87/EC. It is thus a *relative* target / threshold on the basis of sectoral data.

Accounting Low-level Emissions Factors

The activity metric *tonnes of crude steel* and the corresponding emissions intensity is rolling-up a number of contributing sources as summarized below from the IEA analysis. A list of actual physical processes involved in iron and steel production would include (from the detailed NACE Class Description):

1. operation of blast furnaces, steel converters, rolling and finishing mills
2. production of pig iron and spiegeleisen in pigs, blocks or other primary forms
3. production of ferro-alloys
4. production of ferrous products by direct reduction of iron and other spongy ferrous products
5. production of iron of exceptional purity by electrolysis or other chemical processes
6. remelting of scrap ingots of iron or steel
7. production of granular iron and iron powder
8. production of steel in ingots or other primary forms
9. production of semi-finished products of steel
10. manufacture of hot-rolled and cold-rolled flat-rolled products of steel
11. manufacture of hot-rolled bars and rods of steel
12. manufacture of hot-rolled open sections of steel
13. manufacture of sheet piling of steel and welded open sections of steel
14. manufacture of railway track materials (un-assembled rails) of steel

There are three categories of CO2 emissions attributed to the iron and steel sector in its technology roadmap: direct energy-related emissions, process emissions and indirect emissions. Direct energy-related emissions are the CO2 emissions generated from fuel combustion in the iron and steel sector. The energy used in blast furnaces and coke ovens are merged to form the sectoral boundary which includes also finishing processes, ferro-alloy production and other ancillary processes. Fuel is consumed to produce heat and electricity on site.[5]. The energy intensity of blast furnaces is an indicative *low level emission factor*. This energy accounting methodology results in an average energy intensity of crude steel of 19 GJ/t (2019 data).

Process emissions include those arising from the use of lime fluxes and from ferro-alloy production. Indirect emissions are those attributable to electricity generation. The CO2 intensity of electricity must be calculated on a regional basis for imports from the grid, depending on the power generation technology mix. Aggregating the above and examining existing alternative options the IEA Sustainable Development Scenario stipulates that the average direct CO2 emission intensity of steel production must decline by 60% by 2050, to 0.6 tonnes of CO2 per tonne of crude steel relative to today's 1.4 level.

[5]fuel used to generate heat or electricity that is sold is accounted for in the fuel transformation sector, and is therefore not included within the iron and steel sector boundary

2.4.2 Effective Sectoral Emissions Intensity

Schematically, aggregating a sectoral profile means developing a concrete aggregation equation (2.12) by summing up emissions from within the sectoral boundary and its relevant technologies and activities to a total sectoral emission E_S, *effective sectoral intensity* and measurable sector level activity A_S:

$$E_S = \sum_i f_i \times \mathrm{A}_i = f_S \times A_S \,, \tag{2.14}$$

where f_i, A_i are the input data for low level activities and intensities leading to the end product activity A_S and f_S is the implied intensity of the entire input-output process. The example should be make it clear that this aggregation process is highly sector specific and requires both deep expertise and independent audit to properly serve its purpose.

2.5 Attribution of Indirect GHG Emissions

Scope 2 and Scope 3 indirect emissions are ubiquitous in the sense that any entity compiling an inventory of its emissions will have at least *some* emissions attributable to its electricity use or upstream / downstream emissions. Scope 3 emissions become particularly relevant for an entity that manages a large portfolio of *indirect relations with other emitting entities*. We will denote all such entities involved in the Scope 3 portfolio as *relations*. This type of configuration occurs frequently in an economy where large centralized entities form complex financial / economic relations with other economic actors. Sustainable portfolio management of such indirect emissions introduces an additional layer of complexity and data requirements that we sketch next.

2.5.1 Scope 3 Portfolio Management Contexts

Examples of situations where Scope 3 portfolio management is important include the following:

- Corporate entities with large physical supply / value chains where Scope 3 emissions (upstream and/or downstream) are relevant
- Public sector entities providing financing, guarantees or procurement contracts for goods and services to a large number of counterparties
- Commercial banks and related credit institutions that intermediate credit financing to clients with substantial GHG emissions
- Investment banks and asset managers intermediating equity and debt financing of clients via securities issuance or investments
- Insurers and other intermediaries that underwrite risk transfer contracts with counterparties involved in significant GHG emissions

The portfolio management needs and practices of different indirect emissions portfolios vary significantly because of:

- Different *business models*, e.g., public sector, non-profit, short term / trading market, mid-term (1 - 5 years contracts), or long term contracts
- Different *optimization objectives*, e.g., different sensitivity to climate risk (physical and transition), different charters of constitution
- Different contractual or business relations and hence *varying ability to control* or influence counterparty activities e.g., companies, small and large, households.
- Different *specificity of instruments* and contracts that define the relationship, e.g., a general purpose loan versus specific project finance.

Diving deeper into the specific instruments that comprise a Scope 3 portfolio, the following is an indicative list:

- **Project Finance.** This asset class includes all loans or equity investments to finance projects for specific purposes (i.e., with known use of proceeds as defined by the GHG Protocol). The financing is for a defined activity or set of activities, such as the construction and operation of a gas-fired power plant, a wind or solar project, or energy efficiency improvement projects. It is thus, from a sustainable finance perspective, a portfolio with the most clearly delineated boundary for the use of proceeds and attributed emissions impact.
- **Residential / Commercial Real Estate or Auto Loans.** This set of asset classes is also characterized by known use of proceeds: loans for specific corporate purposes, namely the purchase and refinance of commercial real estate; for the purchase and refinance of residential property, including individual homes and multi-family housing; and loans and lines of credit for used to finance one or several motor vehicles. While the primary purpose of these assets might not be sustainability related, the attribution process is still clear-cut.
- **General Purpose Loans.** This asset class comprises for example business loans. Business loans include all loans and lines of credit for general corporate purposes. This implies *unknown use of proceeds.* Attribution is in this case less clear-cut and requires an additional methodological layer that will attempt to properly apportion the correct fraction.
- **Securities.** This asset class includes listed corporate bonds and listed equity for general corporate purposes (i.e., unknown use of proceeds as defined by the GHG Protocol) that are traded on a market and are on the balance sheet of the financial institution.
- **Risk Management Contracts.**: Derivatives and Insurance portfolios may provide explicit support for GHG emitting entities. In terms of attribution clarity, they may be directly linkable (e.g., when used to manage risk in project finance structures) or general purpose (as when a corporate manages its general interest rate or foreign exchange risk exposure).
- **Procurement Contracts.** Contracts to obtain capital goods, purchased services and similar is an example of upstream Scope 3 portfolio that may have varying degrees of ”attributability”.

2.6 The Attribution of Indirect Emissions

The linkage of the universe of financial contracts and relationships with the physical assets responsible for GHG emissions is denoted the *attribution of financed emissions.* The central concept here is the portfolio of *Financed GHG Emissions.* The question is how to attribute the, once-separated, economic and emissions activity of relationships (the companies, clients, suppliers etc. with their physical assets and their GHG emissions) to the financial instrument or activity. It concerns the attribution to a particular portfolio element (contract) the GHG emissions of entities that *benefit* from that relationship, contract or financing. This stage can be referred to as the *attribution rule.*

Quite generally, if E_i are the measured emissions of a relation that are in Scope 3, and v_i an indicator of economic value associtated with the contract (financing, procurement value etc.) the financed emissions are obtained via an *attribution factor* a_i. Which metric of the financial portfolio ”corresponds to” and thus must be assigned the emission metric is denoted as the ”accounting challenge” [39]. It can be expressed as the choice of scaling factor S and the corresponding financed emissions intensity g_i in the following constituent equations:

$$F_i = a_i \times E_i = \frac{v_i}{S} \times E_i \tag{2.15}$$

$$g_i = \frac{F_i}{A_i} = \frac{v_i}{S} \times f_i \tag{2.16}$$

$$e_t = \frac{F_T}{V_T} = \frac{\sum_i F_i}{\sum_i v_i}\,, \tag{2.17}$$

where F_i are attributed emissions to a contract of value v_i, V_T is the total portfolio value and e_T is the global financial emissions intensity metric. The precise meaning and implication of alternative attribution approaches depends on the choice and meaning of the scaling measure S and it must be stressed that there are no right or wrong approaches but rather approaches that are more or less useful and adapted to portfolio management objectives.

Measuring financed emissions in absolute terms (i.e., linked to the absolute emissions E_i of a project or company i) provides a portfolio manager with the necessary baseline for climate action to align with the Paris Agreement. The financed *carbon footprint* [6] is the sum of financed emissions F_T (e.g., in annual tons of CO2 equivalents invested in). When

[6] Carbon footprint is an alternative expression for absolute GHG emissions

benchmarking or comparing companies, sectors, or portfolios with each other, some normalization is required, in order to bring out features that are independent of the size of a relationship. Absolute financed emissions at a portfolio level are not a useful metric in this case, due potential differences between portfolios in terms of size, product portfolio, exposure to sectors and regions, etc. For better comparability and benchmarking, absolute financed emissions are translated into *emissions intensity metrics* (emissions per a monetary unit).

The financed emissions intensity (or carbon intensity) expresses the amount of annual GHG emissions which are attributed per million invested in a portfolio and is therefore an intuitive metric available at portfolio level. A financed emissions intensity can be derived from absolute financed emissions by dividing with the monetary amounts representing the investment or other economic interest. It is the ratio $e_T = F_T/V_T$ where V_T is the value of the entire portfolio. Such emission intensities might be expressed at portfolio level, asset class, sector level etc. in metric tonnes of carbon dioxide equivalents per million euro or dollar invested or loaned: tCO2eq/M€ or tCO2eq/M$.

2.6.1 Financed Balance Sheet Approach

One class of attribution methodologies is to assign emissions to financial instruments *proportionally* to the fraction of financing or other *enabling capacity* that is provided by the portfolio manager. This is a linear approach by construction where it is implied that a larger amount is proportionally more enabling or emissions.[7] The portfolio manager might account for the portion of emissions of the financed relation as the ratio between the outstanding financed amount (numerator) v_i and the total financing of the project $S = V_i$ (denominator). The attribution factor a_i is thus not fixed in time even if the emissions are fixed, but may evolve as the economic structure changes (changing V_i).

The financing amount v_i in the numerator is a *financial exposure indicator*. It can be for example the amount of debt or equity provided or the size of a procurement contract. In the case of debt, the amount might be defined as the value of the outstanding debt the borrower owes to the lender (i.e., disbursed debt minus repayments). In the case of equity, the amount is the outstanding value of equity the financial institution holds in the project. Depending on the contract, the relevant amount can be measured using a variety of more elaborate financial tools, such as accounting or risk-adjusted indicators. For example a bank loan facility that allows additional (a-priory not fully known) draw-downs at client discretion may use gross commitment or exposure-at-default as a proxy for v_i:

$$\text{Gross Commitment} = \text{Drawn Amount} + \text{Confirmed Undrawn Amount} \tag{2.18}$$

$$\text{Exposure at Default} = \text{Drawn Amount} + \text{Confirmed Undrawn Amount} \times \text{CCF}\,, \tag{2.19}$$

where CCF is the so-called credit conversion factor that estimates an expected additional drawn amount in case of default.

The denominator V_i may be the total value of the company being financed, or the value of a property in the case of commercial or residential real estate. In this approach, if an entity is financed by multiple parties, the entity emissions are implicitly apportioned pro-rata to the participation share. Putting everything together we have from (2.12) that in a balance sheet attribution approach

$$F_i = \frac{v_i}{V_i} \times E_i = \frac{v_i}{V_i} \times f_i \times A_i \tag{2.20}$$

$$g_i = \frac{F_i}{A_i} = \frac{v_i}{V_i} \times f_i \tag{2.21}$$

$$F_T = \sum_i F_i = \sum_i a_i E_i = \sum_i v_i \frac{A_i}{V_i} f_i \tag{2.22}$$

$$e_T = \frac{F_T}{V_T} = \sum_i \frac{v_i}{V_T} \frac{A_i}{V_i} f_i = \sum_i w_i e_i f_i\,, \tag{2.23}$$

where w_i is the portfolio weight, $e_i = A_i/V_i$ is a measure of economic efficiency (activity per total asset value) and f_i is the physical emissions intensity. Hence the portfolio carbon intensity is the weighted sum-product of economic and physical efficiencies. We note that carbon intensity as defined above increases with the physical emissions intensity f_i of the invested projects as expected but it also increases with the economic intensity $e_i = A_i/V_i$ of the relation (the amount of production activity per invested amount).

[7] More precisely, the relevance and impact of a marginal monetary amount of financing the corresponding emission is assumed to be the same irrespective of the level of the financed amount. This is clearly not the case in general. Depending on the activity being financed and the nature of the market (oligopoly, oligopsony) there may be thresholds effects for a project or company to get started. While the linear attribution assumption may appear "logical", it is primarily a practical choice. In edge cases this effect may introduce biases and wrong incentives.

Example: The PCAF Methodology

The PCAF methodology [40] can be considered as a specialization of [22] for entities that manage portfolios of *financial instruments*. The PCAF Methodology covers a number of different financial contracts. For example, the Project Finance methodology is specifically for accounting and reporting GHG emissions linked to Project Finance such as energy, power, industrial, infrastructure, and agricultural projects that rely primarily on the project's cash flow for repayment. This asset class includes all loans or equities to GHG projects for specific purposes (i.e., with known use of proceeds as defined by the GHG Protocol) that are on the balance sheet of the portfolio manager. The financing is designated for a defined activity or set of activities, such as the construction and operation of a gas-fired power plant, a wind or solar project, or energy efficiency projects. The PCAF attribution methodology is a balance sheet approach. The total financed emissions are, in general, determined by the formula:

$$F_T = \sum_i F_i = \sum_i a_i E_i = \sum_i \frac{v_i}{V_i} E_i \,, \tag{2.24}$$

where

- The index i of a financed project or company or contract.
- F_i is the financed emission of an element in the portfolio.
- v_i is a measure of economic interest in the underlying asset (e.g., loan or contract amount).
- V_i is a measure of the total interest in the underlying asset (e.g., total economic value).
- a_i is the attribution factor which here we take to be v_i/V_i.
- E_i are the aggregated absolute emissions of the entity i.

Alternative calculations in the same spirit might be required when detailed data are not available, for example using sector based revenue figures:

$$F_i = v_i \times \frac{\text{Asset Turnover Ratio}_S}{\text{Revenue}_S} \times E_S \,. \tag{2.25}$$

Financed Intensity or Portfolio Weight Approach

Another approach, termed the portfolio-weighted approach, is to take the scaling factor S to represent the total value in the managed portfolio ($V_T = \sum_i v_i$). Effectively this attributes GHG emissions from relations in roughly the same proportion as the allocation of economic resources by the portfolio manager[8].

$$g_i = a_i \times f_i = \frac{v_i}{V_T} \times f_i \tag{2.26}$$

$$F_i = g_i \times A_i \tag{2.27}$$

$$F_T = \sum_i F_i = \sum_i \frac{v_i}{V_T} \times f_i \times A_i \tag{2.28}$$

$$e_T = \frac{F_T}{V_T} = \sum_i \frac{v_i}{V_T} \frac{A_i}{V_T} f_i = \sum_i w_i e_i f_i \,, \tag{2.29}$$

where g_i is the financed emissions intensity which is converted into absolute financed emissions using the activity indicator A_i where the corresponding economic intensity $e_i = A_i/V_T$ is the amount of the financed activity in relation to the portfolio.

The convenience of working with intensity indicators is that there is no need to find the share of the activity that is being financed. For example, a company's power production has an average physical emission intensity of 500gCO2e/kWh. Whether a financing bank granted a €1, €10 or €100 million loan to this company, the physical emission intensity of the company remains the same and this value can be attributed to the financial instrument as a financed emissions intensity. The assumption in this approach is that the act of financing Scope 3 emissions has no influence on those emissions happening.

[8] It is only "rough" because the actual allocation decision may have involved many other considerations and risks

Financed Market Share Approach

Yet other weighting approaches are possible. For example in a procurement context, the denominator S may denote the value of the entire market (total activity indicator) A_T for a sector, product or service. Thus v_i is scaled in this case with the fraction of that market product is being financed or procured.

$$F_i = \frac{v_i}{A_T} \times E_i = \frac{v_i}{A_T} \times f_i \times A_i \tag{2.30}$$

$$g_i = \frac{F_i}{A_i} = \frac{v_i}{A_T} \times f_i \tag{2.31}$$

$$F_T = \sum_i F_i = \sum_i \frac{v_i}{A_T} \times f_i \times A_i \tag{2.32}$$

$$e_T = \frac{F_T}{V_T} = \sum_i \frac{v_i}{V_T} \frac{A_i}{A_T} f_i = \sum_i w_i e_i f_i \,, \tag{2.33}$$

where $e_i = A_i / A_T$ is the market share of the activity that is being financed.

In summary, within a linear attribution logic, there are a number of different possibilities for scaling emissions by a measurable scalar S that determines attributable absolute and relative emissions F_i, g_i where the corresponding economic intensity e_i acquires different meaning depending on that normalization: it can be the amount of activity given total financial resources of the asset, total activity of the market or total resources of the portfolio.

Chapter 3

Mitigation of GHG Emissions

Any and all action taken to mitigate climate change consists ultimately of concrete *individual interventions* that modify the emissions profile of some of the sources or sinks in existing GHG inventories. Mathematically, reduced GHG emissions means i) reduced activity, ii) reduced emissions intensity or iii) both. We will touch now the topic of evaluating *GHG project* activities. A GHG project is any well defined set of actions that intentionally leads to a modification of the GHG emissions profile of a physical asset or collection of assets.

We use here the terms "action" and "project" only in connection with direct modifications of Scope 1 emissions. Strictly speaking the standalone analysis and evaluation of such individual projects might not in the scope of sustainable portfolio management activitie (that focus on portfolio level strategies, policies and tools). It is more typically a task for the individual asset manager, owner or other stakeholders to pursue the detailed analysis of a focused project. Nevertheless, the portfolio management function will be responsible to assess the impact of such proposed project activity on a *portfolio basis*. Hence a consistent framework that aligns individual project analysis with portfolio level analysis is indispensable.

3.1 GHG Mitigation Projects

3.1.1 GHG Project Activity

A *GHG Project Activity* is a specific action or intervention targeted at changing GHG Emissions, removals, or storage. It may include *modifications* to existing production facilities, manufacturing processes, consumption patterns, service provision, delivery or management systems, as well as the introduction of *new systems* that enable the adoption of different technologies. The GHG Project *effect* captures the changes in GHG Emissions, removals, or storage caused by a GHG Project Activity.

A Project i might involve one or more activities a. The GHG Protocol [23] recognizes two types of GHG effects: Primary GHG Effects and Secondary GHG Effects. A *Primary GHG Effect* is the *intended change* caused by a project activity in GHG emissions, removals, or storage associated with a GHG source or sink. Each project activity will generally have only one primary effect. A Secondary GHG Effect is an *unintended* change caused by a GHG Project Activity in GHG Emissions, removals, or storage associated with a GHG source or sink. This differentiation between intended and unintended consequences is an example of the non-linear complexity associated with the sustainability transition and the inter-connectedness (implying second and third order effects) that must be taken into account. A more general example of the need for such holistic policy approaches is the *Do No Significant Harm* principle introduced in the EU Taxonomy [38].

3.1.2 Quantifying GHG Reductions

Primary effects must be identified and quantified for each project activity. The primary effect is defined as a change relative to *Baseline Emissions* which must be determined using a suitable baseline methodology. The baseline methodology is a scenario aims to represent what GHG emissions would have been in the absence of a mitigating GHG project activity. It is thus a hypothetical *reference case* that best represents the conditions most likely to occur in the absence of a proposed GHG project.

Time Horizon

Generally, the further out into the future one tries to project what would have happened, the more uncertain this projection becomes. For this reason, any particular baseline scenario is valid for a finite period of time. After a certain period, either no further GHG reductions can be reliably forecast for the project activity, or a new (revised) baseline scenario must be identified. The length of this period may vary, depending on technical and policy considerations. In any case the scenario methodology introduces the forward-looking time horizon concept T that sets an outer boundary.

Absolute Emissions Reduction

Absolute emissions changes are the GHG emissions that are generated, reduced or sequestered etc. as a result of a project, expressed in tonnes CO2 eq. For example the GHG emissions due to an expansion of a farm, the construction emissions due to the placement of a wind turbine or the sequestration of greenhouses gases by growing biomass. As stressed in [41] considering absolute emissions reductions are critical in managing a portfolio in the context of a carbon budget and focusing exclusively on intensity metrics may work against the overall objective.

Avoided Emissions

Avoided emissions are the emissions that are avoided as a result of a project (when compared to the baseline scenario), for example emissions avoided by additional renewable energy capacity that is assumed to replace future fossil fuel-based power plants, or emissions avoided through the protection of forests against illegal logging.[1] In a GHG project evaluation context absolute emissions can be mapped as generated emissions or negative emissions linked to the project. A project is most clearly identifiable in the context of Project Finance where there is a specific earmarked investment but corporate investment activity (CapEx) can also serve as a basis. The procedure for compiling and reporting an aggregate GHG reduction from a GHG Project following the GHG Protocol for Project Accounting [23] highlights the following:

- Estimate the absolute baseline E_i as the business-as-usual emissions of an asset. The standard reporting unit is tonnes of CO2 equivalent, denoted as (tCO2eq).
- Estimate the absolute project emissions $\bar{E}_i$ as a result of a project which encompasses a number of activities a.
- Each activity will have at least one primary effect (index p) and possibly secondary effects (index s).
- Calculate the emission reduction from each project activity a as ΔE_a incorporating all primary and secondary effects.
- Calculate the total GHG reduction for the project as the sum of annual GHG Project Activity reductions ΔE_a (for the time horizon T of the project).

Baseline and Project Activity Emissions from primary or secondary effects are computed via the corresponding emissions factors as usual, e.g.,

$$E_a = f_a \times A_a = \sum_p E_a^p + \sum_s E_a^s \tag{3.1}$$

$$\bar{E}_a^p = f_a^p \times A_a^p \tag{3.2}$$

$$\bar{E}_a^s = f_a^s \times A_a^s \,, \tag{3.3}$$

where E_a, f_a are the absolute emissions and factors respectively of project activity a, and $A_a^{p/s}$ is the quantitative measurement of some physical or economic activity and $f_a^{p/s}$ are the corresponding emissions factors. The total Primary Effects reduction is the delta on absolute reduction from baseline emissions induced by the project activity emissions:

$$\Delta E_a^p = E_a - \bar{E}_a^p \,, \tag{3.4}$$

where $\bar{E}_a^p$ is the primary emissions profile of an activity a. Secondary effects are correspondingly computed from secondary activity emissions reduction:

$$\Delta E_a^s = E_a - \bar{E}_a^s \,. \tag{3.5}$$

[1]The GHG Project *Additionality* is a concept relevant in distinguishing a GHG Project Activity from its GHG Baseline Scenario. The difficulty is that many projects that reduce GHG Emissions (relative to historical levels) would happen regardless of the existence of the GHG reduction activity (and without any concern for climate change mitigation).

The reduction enabled by each activity is decomposed into primary and secondary effects,

$$\Delta E_a = \sum_p \Delta E_a^p + \sum_s \Delta E_a^s \,. \tag{3.6}$$

The total reduction of a project is the sum of its contributing activities:

$$\Delta E_i = \sum_a \Delta E_a \,. \tag{3.7}$$

Putting everything together in terms of equivalent end-product activity A_i we have a new emissions intensity f_i'

$$E_i = f_i \times A_i \tag{3.8}$$

$$\bar{E}_i = \bar{f}_i \times A_i \,. \tag{3.9}$$

3.1.3 Baseline Scenarios

Defining a baseline scenario is a non-trivial exercise and there are various approaches and recommendations depending on context [23],[42],[43]. The baseline setting is aimed at identifying the most feasible and realistic alternative scenario to a mitigation project. In many cases it is an alternative that can provide the same product or service within the same timeframe. The baseline scenario may involve more than one feasible alternative. These are denoted as *baseline candidates* and must each be evaluated separately. The eventual selection should be the most conservative, namely the one producing the lowest absolute emissions. The nature of the baseline scenario depends on the context of the project mitigation activity (project finance, corporate activity etc):

- The baseline may be simply the *status quo scenario*. In this case there will be already attributed GHG data which can be projected into the future making e.g., activity forecasts using standard values that are determined based on current legislation or regulations and average values of goods or services in the relevant industries.
- The baseline may be a *theoretical business-as-usual scenario* that captures what would have occurred had the project not been pursued. The theoretical scenario is used when assessing the benefits of a new development where an actual project baseline does not exist. The project's environmental benefits are compared against a counterfactual business-as-usual scenario.

Concretely, for each project i the benchmark baseline scenario is quantified through the projection of emissions factors and activities for the relevant horizon T:

$$\{f_i^t, f_i^{t+1}, \dots f_i^T\} = \text{Baseline Emission Factors} \tag{3.10}$$

$$\{A_i^t, A_i^{t+1}, \dots A_i^T\} = \text{Baseline Activities} \tag{3.11}$$

$$\{E_i^t, E_i^{t+1}, \dots E_i^T\} = \text{Baseline Emissions} \,. \tag{3.12}$$

The above vectors, together with the corresponding project activity based scenarios will for the quantitative basis to evalution a project's emissions impact.

Portfolio Level Baseline Scenarios

When evaluating a large number of actions in a portfolio context it is important that baseline scenarios for different projects are consistent. At a given time point this implies e.g., similar assumptions about available technologies. For longer horizons, sectoral level baselines must be established, a process that involves significant model assumptions about technology developments (4.2.3). At the macroeconomic level the baseline scenario represents a business as usual pathway where the global economy continues to expand and climate mitigation efforts are minimal. It is also termed a "no transition" scenario. This projection translates into a static pool of emissions factors and a more-or-less increasing loading on activity indicators. Clearly the validity of a baseline scenario must be revisited with the passage of time to account for developments: e.g., already realized behavioral changes and substitutions (changes in activity), technological availability and updated cost structures which redraw the contours of what is "business-as-usual".

Chapter 4

Allocation of GHG Emissions Budgets

We formalized already the process of mitigating GHG emissions one project at a time but the task of the sustainable portfolio manager is to provide the portfolio context and overview in which such project proposals can be evaluated. It is a central role of SPM to evaluate and report how the *aggregated* (in sectoral and temporal terms) portfolio activities fit with overall sustainability constraints. The outline of such evaluation frameworks is the subject of this chapter. We focus first on notation and considerations most applicable to portfolio of Scope 1 (direct) emissions. Allocation of budgets for indirect (Scope 3) emissions such as financial portfolios is discussed next in (4.4)

4.1 Portfolio Steering Tools and Limit Frameworks

A forward portfolio planning methodology must use the variables and metrics of GHG accounting as the starting point and develop concrete qualitative and quantitative metrics that can help the organization pursue its activities within a desired envelope. The challenge is that forward-looking sustainable portfolio management operates at an aggregated and conceptual level that can be abstract (we have already encountered this issue as the counterfactual baseline scenario). It does not concern the direct evaluation of presently available options but rather the steering of a (potentially large) collection of assets spanning temporal and sectoral dimensions. The larger the perimeter of the portfolio the larger the number of complications, such as potentially interacting elements.

A further complication is the task of managing multiple value dimensions. As discussed in the introduction the efforts to translate the sustainability question into a purely financial question or, starting from a different moral universe, expand the notion of value and capital is ongoing. This is a process that is currently still in its infancy. The need to adopt sustainable portfolio management as soon as possible prompts developing frameworks that are *preliminary building blocks* towards more integrated approaches.

The most important such building block in the context of climate change is arguably the concept of *carbon budget allocation*. Portfolio level allocated carbon budgets aim (ultimately) to *steer* the development of *absolute GHG emissions* at the portfolio level to remain within the a prescribed global carbon budget. Steering can be achieved at portfolio level by developing approaches that are applicable to *homogeneous classes of assets*, that is, sub-segments of the portfolio, by sector, jurisdiction or geography.

How can one practically implement portfolio GHG steering? This depends on the context in which a sustainable portfolio manager operates: The nature of the physical and/or financial assets (direct or indirect emissions), the portfolio management mandate and any constraints and available tools. Portfolio management tools may include for example the redefinition of the portfolio scope (divestment from certain sectors), or a general class of approaches that comes under the banner "limit frameworks". It may also involve indirect actions such as purchases and sales of transferable emissions units (such as offset credits and allowances).

4.1.1 Portfolio GHG Limit Frameworks

A limit framework is a set of policies that aims to steer (in an organized quantitative manner) the distribution of portfolio characteristics. Tailored to GHG mitigation this technique translates into a set of GHG emissions portfolio constraints (limits) that define a perimeter against which all portfolio adjustments must be assessed. The general idea behind proposed limit frameworks is to start with global carbon budgets (1.2.4) and cascade more detailed internal portfolio constraints and objectives.

A limit framework is quantitatively translating the *risk appetite* of an institution to assume certain risks into operating boundaries. In this case the risk is that attributed GHG emissions will not comply with explicit or implicit constraints. The operating assumption is that staying *within* an indicated limit as defined by the framework is consistent with the degree of risk the firm is willing to accept while pursuing its operations and other objectives. Limit *utilization* is at the same time a business enabler. Ceteris-paribus, the institution is incentivised to use the allocated budget to achieve its other objectives. Importantly, whether binding or not, the GHG budget constraint is specified *externally* without the institution being able to affect it.

Limit frameworks are used extensively in financial institutions as a means to allocate risk bearing capacity (financial risk capital). In a sustainability risk context the proper concept might be the optimization of *natural capital*. Nevertheless at this stage as discussed above, the focus is on more directly observable metrics, namely absolute emissions and emissions intensities. Fortunately, in the case of of GHG emissions, there are quantitative measures that are in principle available to play this role (GHG emissions are tangible). This might not be true for other sustainability constraints. Importantly, though, as we have seen with examples, GHG emissions metrics concern *low level physical aspects* that may be quite removed from the typical portfolio management context[1]. In particular the relationship of these GHG constraints with other institutional risks and opportunities might not be directly or easily visible.

By examining the gaps between the current portfolio and climate benchmarks interpreted as limits, the portfolio manager can use the available portfolio management options to re-align a portfolio so that it stays on track with the trajectory. Obviously these limits, targets and benchmarks need to be set so as to be consistent with the Paris Agreement's goals and their updates. The methodology must be able to link distinct sector specific approaches in a consistent way, as it will otherwise skew the portfolio in ways that ultimately do not reconcile to the overall constraints.

A limit framework in the context of distributing a given "carbon budget" has the objective of *allocating* the available emissions capacity or allowance to activities at portfolio, sub-portfolio or individual entity level. It is thus a *normative framework*, indicating what "good", or at-least acceptable, looks like on a forward-looking basis. Importantly, while a GHG inventory will typically cover the full range of a portfolio's emissions a limit framework may focus on sectors and assets that concern a *subset of total emissions*. Reasons for this reduced scope may include the materiality of emissions, the ability to steer (e.g., locked-in emissions) etc.

Sector-specific targets that isolate important emitting sectors are motivated for many reasons: i) as an application of the 80%/20% rule, ii) because of the low-level specificity of technological options and iii) to avoid obfuscating critical performance aspects within more general targets. This latter aspect is particularly true if measured on normalized basis: Adding "green assets" in a portfolio can improve the overall carbon intensity however it does not help to reduce emissions.

Limit Alignment Approaches

Benchmarks can in principle be constructed and set as limits on i) absolute emissions E_i (total GHG volumes), activity data A_i (production capacity, say barrels of oil), or emissions intensities f_i. The scope of emissions to be included in a limit framework varies. Scope 3 emissions are the most important for financial intermediaries and other portfolios managing indirect emissions.

A special characteristic of the GHG budget is that it is *cumulative* and defined over a *very long horizon* rather than point-in-time and short term. This means that the appropriate model is that of an ongoing *convergence path*. This approach still leaves open the question of whether convergence should be in levels or rates. The first approach creates a *convergence benchmark* in which portfolio performance is measured against benchmark average *emissions levels*. The convergence approach requires that portfolio converges to a benchmark at the end-point of the scenario. The second approach is to create a *rate-of-reduction benchmark* in which portfolio performance is measured against benchmark average *emissions reduction rate*. The trajectory approach requires the same rate of change as the top-down climate scenario.

4.2 Portfolio Emissions Projections

The develop an emissions limit framework we need to *project* portfolio emissions for a sufficient time period forward. This must incorporate meaningful and adapted planning and risk horizons e.g., five-year production and investment plans. NB: A 5-Year Horizon is aligned with the five-year cycle of determining NDC.

[1]This *remoteness* is, ultimately, the result of historical behaviors that focused on financial accounting and ignored environmental externalities

4.2.1 Model Approaches

GHG emissions projections must be modeled in some way [44]. Such models require input data and assumptions and provide estimated projections of future emissions. They indicate, for example, the required technology shift rates to remain with a scenario envelope. Within that horizon the available technological options are assumed given. Updating the carbon budget framework may be necessary for a number of reasons:

- When the GHG inventory methodology or boundary has changed materially
- To reflect technology or climate model updates, e.g., IPCC and IEA update their pathway scenarios (6-7 years and annually respectively).
- To reflect strategic decision changes

Models may be complex algorithms that develop baseline scenarios based on projections of economic activity, sectoral and economy-wide activity data, and assumptions about future changes in emissions intensities. Less complex approaches may rely on extrapolations of historical emissions trends and/or key drivers such as gross domestic product (GDP) and overall emissions intensity. There are three major classes of models. Top-down, bottom up, or hybrid. The terms top-down and bottom up refer to the basic modeling approaches used to examine the linkages between the economy and specific GHG emitting sectors such as the energy system. The terms top-down and bottom-up are, ultimately, just shorthand for models derived from aggregated or dis-aggregated data [45]. Top-down models evaluate the system from aggregate economic variables, whereas bottom-up models consider technological options or project-specific climate change mitigation policies.

Top-down Models

Top-down models focus on projecting overall economic output and the emission intensity of that output based on forecasts of simulated economic interactions between sectors, taking into account their effect on GDP, consumption, and investment. Top-down models mainly focus on energy supply sectors and their interaction with other economic sectors. They model technology through the degree of substitution possibilities of production inputs and the shares that these represent of the purchase of intermediate inputs. Top-down models may include simple extrapolations of historical trends as well as complex computable general equilibrium (CGE) models such as ENV-Linkages and SGM.

Bottom-up Models

Bottom-up models use dis-aggregated data on specific technologies to produce detailed projections of energy use by type and sector, based on assumptions about structural and/or policy developments in each sector and/or optimal behavior for economic agents. Bottom-up models typically do not capture the economic linkages across sectors and represent a sector from an engineering perspective, focusing on end-use technologies.

Construction of the sectoral benchmark

There are various ways to extract a normative sector level benchmark from climate scenarios. The first is to select the respective sector's emissions pathway from a single, most applicable, scenario. The second is to develop a statistical function that describes the central tendency of a given sectors' emissions pathway across a wide range of different climate scenarios (referred to as the *warming function* approach). An important element of the sectoral benchmark is the technology mix (as it influences the forecast available emission factors). Sectoral approaches rely on the development and use of emission-based physical intensity metrics forecasts, namely energy or carbon intensity metrics that use a physical unit denominator and are applicable to a specific sector (e.g.,kgCO2/MWh for the power sector and MWh/m2 for real estate), always on the basis of *existing technologies*. The uncertainties surrounding paths means that attention is focusing on key sectors, and in fact even just key segments within the value chains of sectors (e.g., upstream oil & gas, coal mining, power generation, car / steel / cement manufacturers and transport operators).

Locked-in Emissions

The projection may need to split-out emissions that cannot be mitigated. Namely, to the extent that in a certain sector physical assets will be in operation for many years into the future, the associated CO2 emissions are often considered to be *locked-in*. Locked-in emissions are emissions that will necessarily be emitted due to the existing and planned assets hence their inclusion in the limit framework complicates assessing actual portfolio management performance.

4.2.2 Emissions Projections

Irrespective of how they are produced, emissions projections are captured quite generally as a set of metrics:

$$\{f_i^b, f_i^{t+1}, \dots f_i^T\} = \text{Asset Level Emission Intensities} \tag{4.1}$$

$$\{E_i^b, E_i^{t+1}, \dots E_i^T\} = \text{Asset Level Emissions} \tag{4.2}$$

$$\{f_s^b, f_s^{t+1}, \dots f_s^T\} = \text{Sector Level Emission Intensities} \tag{4.3}$$

$$\{E_s^b, E_s^{t+1}, \dots E_s^T\} = \text{Sector Level Emissions}\,, \tag{4.4}$$

where

- the time horizon is $t = T$ and the base year is $t = b$,
- the asset, sector indexes are (i, s) respectively,
- asset / sectoral emissions are denoted E_i, E_s respectively,
- asset / sectoral emissions intensities are denoted f_i, f_s respectively.

Selecting Emissions Targets

Selecting a concrete set of targets must address a number of options:

- **Production (Activity) Trajectories**. Targeting the alignment of production volumes / activities that lead to emissions. Changes in production volumes from expansion of production using given technology.
- **Absolute Emissions Trajectories**. Absolute emissions targets aim to reduce a specified quantity of GHG emissions from the base year to the target year. For example, an absolute target may be a 20% reduction in an asset's scope 1 emissions from 2021 to 2030. Absolute reduction targets are the most meaningful in reducing global total atmospheric emissions and the least likely to suffer reconciliation issues. Thus they may be more future proof and less prone to shocks but are more challenging to disentangle from activity growth or decline.
- **Emission Intensity Trajectories**. Normalizing CO2 by economic activity output isolates the effect of the technology mix. Emissions intensity targets, also known as normalized targets, are emissions per unit of economic output (e.g.,unit of production, number of employees, or value-added). For example, an intensity target might be a 35% reduction in tCO2eq emissions per unit of value-added from 2021 to 2030. The implication of using emissions intensity targets is that if activity remains the same for the same "economy" there will be fewer emissions. Unlike absolute emissions, there is no guarantee that emissions to the atmosphere will be reduced: Reduced emissions intensity coupled with an increased activity may exceed absolute emissions budgets. This aspect of emissions intensity targets may make them more susceptible to regulatory risks or other surprises.

4.2.3 Example: Sectoral Decarbonization Approach

Despite the relatively nascent status of this field, various approaches are being developed to define and set the underlying science-based portfolio targets [46]. The Sectoral Decarbonization Approach (SDA) is a scientifically-informed method for *companies* active in certain sectors to set GHG reduction targets necessary to stay within a 2°C temperature rise above pre-industrial levels [47]. The SDA is designed for homogeneous and energy intensive sectors by SBTi [47] and applies a focused sub-sector level approach and a global "least-cost" mitigation perspective. SDA results and assumptions are based on mitigation potential and cost data from the IEA's **TIMES model** 2°C scenario, which identifies the least-cost technology mix available to meet final demand for industry, transport, and buildings services. The SDA sets carbon-intensity reduction targets based on sectoral carbon budgets. Even after adopting SDA as the backbone of a forward looking limit framework there are many other design options before one has concrete metrics to report and use in decision support [48].

4.2.4 Integrated Validation Metrics

Multiplying the projected carbon intensity by the activity leads back to the absolute emissions pathway per sector. The metric used for translating sector budgets into asset targets can be double-checked by performing a validation. For an incremental (per annual period) test alignment requires that:

$$\sum_{s}(A_s^t \times f_s^t + O^t)\, dt \leq \text{Emissions}_{2^\circ C}^t \,, \tag{4.5}$$

where the Emissions refer to any specific year t. For a cumulative test extending to the 2050 the requirement is that:

$$\sum_{s}\sum_{t}(A_s^t \times f_s^t + O^t)\, dt \leq \text{Budget}_{2^\circ C}^{2050} \,, \tag{4.6}$$

where

- A_s^t is the activity of sector s in year t,
- f_s^t is the emissions intensity of sector s in year t,
- O^t are other GHG emissions in year t that are not captured in the sectoral budgets,
- Budget is the cumulative carbon budget 2011-2050 compatible with a below 2°C scenario.

4.3 Measuring Portfolio Limit Alignment

GHG mitigation projects are pursued in the context of a very diverse mix of policies, fiscal and structural reforms (e.g., labor markets), public procurement, carbon pricing, more stringent standards, information schemes, technology adoptions, fossil-fuel subsidy removal, climate risk disclosure, land-use, transport planning etc. After all is said and done, the tangible manifestation of success is to demonstrate "alignment". The key principle is for the institution (and other stakeholders) to establish how "far" or "close" portfolios are from globally agreed sustainability targets. Looking specifically at climate targets and GHG emissions this approach outlines how much an institution would need to change its portfolio and activities in order to align with the Paris Agreement 2 °C scenario. A portfolio is considered *aligned* if the level of the relevant indicators is below the benchmark originally set. This can translate into a number of questions:

- How congruent is an institution's portfolio of assets relative to global sustainability targets?
- What is the new proportion of climate relevant sectors and technologies of a given portfolio?
- How did the prevalence of climate relevant technologies of the assets in the portfolio change over time?
- How did the aggregated CapEx plans of assets align with climate scenarios?

4.3.1 Example: SDA Emissions Alignment

Continuing with the SDA example, the SDA method assumes that the emissions intensity for assets in all homogeneous sectors tends to converge in 2050. This convergence is represented by an index of the sector's *decarbonization*, being equal to 1 in the base year and 0 in 2050. The decarbonization index p^t is calculated as follows:

$$p_s^t = \frac{f_s^t - f_s^{2050}}{f_s^b - f_s^{2050}} \,, \tag{4.7}$$

where

- p_s^t is the decarbonization index of the sector s in year t,
- f_s^b, f_s^t, f_s^{2050} are the emissions intensities of the sector s in base year b, year t, 2050 respectively.

4.3.2 Asset Specific Emissions Alignment

A lower-level, asset specific, carbon intensity trajectory is derived from the sector-specific intensity trajectory. It depends on the initial performance of an asset and its expected future share of emissions. The initial performance is defined as the difference between emissions in the base year and the sector carbon intensity in the year 2050:

$$d_i^b = f_i^b - f_s^{2050}\,, \tag{4.8}$$

where

- d_i^b is initial asset performance in the base year relative to the 2050 sector target (tCO2e/activity),
- f_i^b is the emissions intensity of the asset in base year b (tCO2/activity),
- f_s^{2050} is the emissions intensity of the sector s in year 2050 (tCO2/activity).

The expected future activity of the asset is combined with the sector's expected activity levels to calculate the asset's *sector share* parameter for any given year following equation:

$$a_i^t = \frac{A_i^b}{A_s^b} / \frac{A_i^t}{A_s^t}\,, \tag{4.9}$$

where

- a_i^t is activity (market) share parameter in year t (%),
- A_i^b, A_i^t activity of the asset i in base year b / year t respectively,
- A_s^b, A_s^t activity of the sector s in base year b / year t respectively.

Combining the asset's initial performance parameter d_i^b with its sector share a_i^t and the sectoral decarbonisation index p_s^t for year t results in an asset intensity target for any year t between the base year and the target year 2050:

$$d_i^t = d_i^b \times p_s^t \times a_i^t + f_s^{2050}\,, \tag{4.10}$$

where d_i^t is the intensity target of the asset i in year t expressed in tCO2eq/activity.

4.4 Indirect Emissions Portfolios

Portfolio targets and steering via allocation of budgets or limits are also applicable to portfolios of indirect emissions. Target setting and limit frameworks are already widely used in financial portfolio management. In this context the core question becomes: How congruent is an institution's portfolio of *financial assets* relative to global sustainability targets? As discussed in the section of indirect portfolio attribution (2.6) this step involves an *additional* layer of analyses, data sets, methodologies and assumptions. In addition, just like the management and mitigation of Scope 1 emissions is entangled with the broader economic objectives in which such entities are operating, the management and mitigation of Scope 3 portfolios is linked to the economic objectives and mandates of portfolio managers. A fundamental reality of managing indirect emission portfolios is that the principals that are able to affect GHG mitigation are once-removed relations. They can only indirectly be influenced as part of their relationship with the portfolio manager (bank, asset manager, public entity procurement agent etc).

Given an allocation framework, through examining the gaps between the Scope 3 portfolio and climate benchmarks, the portfolio manager can reorient their available instruments to stay on track with the desired trajectory. Such steering can be achieved at portfolio level, either by engaging with existing relations to align their own activities, or by adjusting the set of relationships. Alignment in principle can be targeted at portfolio but also lower level sector, relation or even individual contract level. As with the steering of Scope 1 emissions, alignment indicators might track either alignment level or alignment rate.

Consistency Requirements

Forward-looking Scope 3 portfolio targets must be bootstrapped using the same modeling and projection approaches as for the underlying sectors (4.2)[2]. The forward looking allocation of emissions budgets must also mirror the attribution methodology applied to the base situation (2.6) if one wants to transparently *explain* an evolving portfolio footprint.

[2]Over the long term, the influence and role of intermediaries such as the financial sector may have material impact through feedback effects - which may or may not be captured in models

4.4.1 Financed Emissions Projections

A limit framework that is adapted to financed Scope 3 emissions *augments* the one already described in (4.2.2) with contractual value indicators and financed intensity indicators:

$$\{g_i^t, g_i^{t+1}, \dots g_i^T\} = \text{Asset Level Emission Intensities} \tag{4.11}$$

$$\{v_i^t, v_i^{t+1}, \dots v_i^T\} = \text{Asset Level Financing Volumes} \tag{4.12}$$

$$\{g_s^t, g_s^{t+1}, \dots g_s^T\} = \text{Sector Level Emission Intensities} \tag{4.13}$$

$$\{v_s^t, v_s^{t+1}, \dots v_s^T\} = \text{Sector Level Financing Volumes}\,, \tag{4.14}$$

where v_i, v_s are financial indicators capturing the economic relationship with individual assets (projects, companies, contractors etc) and the corresponding sectors. These values constitute effectively the relevant absolute limit framework for the portfolio manager as they have no direct influence on the underlying physical emissions. Alternatively, the intensities g_i, g_s create a limit framework based on normalized metrics. As already discussed, there is no unique way of defining those but they must be adapted to the use case at hand.

4.4.2 Measuring Financial Portfolio Alignment

In analogy with the measurement and reporting of the alignment of a physical emissions portfolio (4.3) one might pose similar questions for the alignment of a financial portfolio. There are many conceivable approaches depending on the context and portfolio data used. E.g., regulated bank entities may be required to report a green asset ratio [49] based on the EU Taxonomy [38]. In analogy with alignment at the physical emissions portfolio we illustrate one approach to measure alignment. Importantly, there is no mechanism to conceptually validate a set of such projections or budgets against global targets in the manner of (4.2.4) because mitigation pathways and sectoral decarbonisation approaches do not constraint financial portfolio allocations. A general setting irrespective of attribution approach that is built on top of sectoral decarbonisation scenarios looks as follows. We start with the asset level alignment indicator d_i^t already discussed and we create a *financed intensity alignment indicator* g_i^t using a scaling factor as before:

$$d_i^t = d_i^b \times p_s^t \times a_i^t + f_s^{2050} \tag{4.15}$$

$$g_i^t = \frac{v_i^t}{S^t} \times d_i^t\,. \tag{4.16}$$

We can illustratively work out the implication in a market share attribution approach, where $S^t = A_s^t$ is the total market for a sectoral activity:

$$g_i^t = \frac{v_i^t}{A_i^t} \left(p_s^t \times d_i^b \times \frac{A_i^b}{A_s^b} + \frac{A_i^t}{A_s^t} \times f_s^{2050}\right) \tag{4.17}$$

This expression decomposes the targeted financed intensity at the asset level into a sectoral performance p_s^t and the asset market share A_i^t/A_s^t, amplified by the production financing ratio v_i^t/A_i^t.

4.4.3 Example: The PACTA Methodology

A publicly released tool detailing a portfolio alignment approach is the Paris Agreement Capital Transition Assessment (PACTA) tool developed by the 2 Degrees Investing Initiative (2DII) [27]. For climate scenario analysis the tool is used by some banks to quantify a financial portfolio's exposure to a 2°C benchmark in relation to a series of climate-related technologies. The tool combines portfolio information on exposures, a database on the technology mix and production plans of individual companies and technology mix scenarios developed by the International Energy Agency (IEA) in order to assess a portfolio's alignment with the Paris Agreement Targets.

At the financial portfolio level, each client exposure is matched with the 2DII database[3] on firms and their forward-looking production profiles is created. Individual institutions can then be assessed in how far the clients they finance are aligned to the IEA targets. The technology mix scenarios define pathways for CO2 emissions for certain technologies and industries, under various climate target scenarios, implying certain required technology mixes in the energy sector. Production plans by individual firms together with the envisaged scenarios' pathways for different sectors are combined to assess the alignment of each firm's production plan to the scenarios developed by the IEA.

[3] The 2DII database holds information on the production plans of individual firms for the period 2019-2024 for climate relevant sectors.

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