Bridging sustainability scales, from global frameworks to operational methods for sub-level actors: focus on climate change mitigation strategies for organizations

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Et surtout, un merci infini à toi, Lucie, pour tout ce tu m'apportes chaque jour et depuis tant d'années.

EPIGRAPH

« If we wait for the governments, it'll be too late; if we act as individuals, it'll be too little; but if we act as communities, it might just be enough, just in time. »

— Rob Hopkins

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INTRODUCTION

In December 2019, Antonio Guterres, Secretary General of the United Nations, issued a call to urgent action to address the climate crisis and acknowledge a climate emergency (United Nations, 2019). At the same time the collaborative writing of this PhD proposal began. This thesis comes at a time when the responsibility of human activity in climate change, and more broadly in the environmental crisis, is no longer up for debate, as recalled in the latest IPCC synthesis report (IPCC, 2023a). The year 2023 has been marked by numerous extreme events all around the world, whose frequency and amplitude are exacerbated by global warming (IPCC, 2023a). Heatwaves, floods, droughts, glacier melt, among others, are the warning signs of a warming trend already well advanced, now reaching a global 1.15 degrees Celsius increase compared to pre-industrial levels (Forster et al., 2023), and 1.9 in France (Haut Conseil pour le Climat, 2023), in terms of mean surface temperature for the most recent decade (2012-2022).

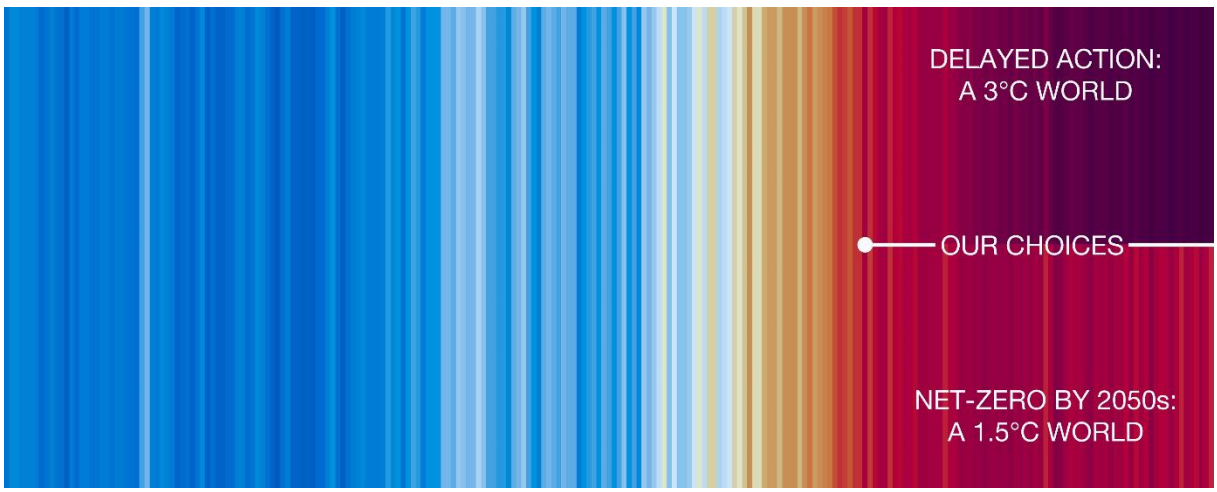
Now, perhaps more than ever, the issue of social justice is at the heart of the matter. Because no region is spared by these impacts, the most vulnerable are often the least responsible. Therefore, climate change mitigation and adaptation must be considered as part of integrated strategies that also include social equity considerations and other planetary limits, with action needed at all levels (IPCC, 2023b). In this light, as Valérie Masson-Delmotte, co-chair of IPCC Working Group 1, emphasized at the French inter-ministerial seminar in August 2022, every decimal degree makes a significant difference, every ton of carbon dioxide equivalent matters, and every decision, at every scale, counts (Masson-Delmotte, 2023). It is no longer time to shift the burden of inaction between different players, but rather to coordinate all stakeholders and recognize the importance of action and synergies at multiple levels towards a common sustainable future.

This transdisciplinary thesis embraces the importance of multi-scale climate action to achieve a global carbon neutral world by 2050, and to transform our systems and economies towards a safe and just world. The main issue dealt with in this work lies in bridging scales through global sustainability frameworks that need to be downscaled and operationalized, in order to define what absolute sustainability means at different levels. In other words, what should the contribution of each player be at each scale to the transformation towards a sustainable world, and how can the effort be shared fairly with sufficient ambition?

This thesis has been written as an article-based PhD and therefore in English, notably to ensure that research results are enhanced and widely disseminated, both in the private sector among sustainability players and in the academic world. In this context, four partners, i.e. one company, two research units in France and Denmark including three supervisors, and one PhD student, jointly investigate methodological issues of bridging global absolute sustainability frameworks to sub-scales. TOOVALU SAS is a 30-person company based in Nantes, which provides support, training and software for organizations in the areas of corporate climate change mitigation and CSR. It is a French 'entreprise à mission' (purpose-driven company) and a "benefit corporation" (B-Corp), whose raison d'être is to "engage decision-makers in integrating climate change and more broadly sustainability issues, into the heart of their organizations' strategy (Toovalu, 2023). Since 2021, Centrale Nantes has been a signatory to the Grenoble agreements (CTES, 2023) and adopted a sustainable development and corporate social responsibility action plan for the years 2021-2025, (Centrale Nantes, 2023). One axis aims at aligning research themes with international and national sustainable development objectives (Centrale Nantes, 2021a). In this light, the Research Institute in Civil and Mechanical Engineering (GeM) research unit at Centrale Nantes has taken an increased interest in sustainability science, notably in sustainable industrial strategies, carbon accounting and CSR (Auger et al., 2021; Centrale Nantes, 2021b; RIODD, 2015). At the Denmark Technical University, the Quantitative Sustainability Assessment section is a research pioneer in terms of

sustainability assessment models, conducting research notably on the integration of scientific sustainability frameworks, e.g. planetary limits, into operational tools such as life cycle assessment; the aeronautics sector; or development policies (DTU, 2023). The multiple stakeholders involved in this PhD build a link between the private sector, the research on sustainability science in Denmark, and the more general engineering research in France.

In Section **1.1** of the introductory chapter, the theoretical background of this PhD is outlined, presenting both global sustainability frameworks and issues, the importance of underlying distributive justice considerations when translating global goals to sub-scales, and some sub-scales initiatives to contribute, fairly or not, to climate change mitigation. This overview shows the need for bridging local and global sustainability scales, as captured in Section **1.2** of this introductory chapter, which introduces the research problem, the research objectives, and the article-based thesis plan.



Adapted from Ed Hawkins, National Centre for Atmospheric Science, https://showyourstripes.info/

CHAPTER 1

Need for bridging sustainability scales: introductory chapter

1.1. Theoretical background

1.1.1. Global sustainability frameworks: the absolute perspective

1.1.1.1. Thriving in a stable world, a common objective: defining sustainability

Since the industrial revolution, ever-increasing anthropogenic pressures on the Earth system have been jeopardizing the 10,000-year-long climate stability of the Holocene, the current geological epoch so profitable for humans to prosper (Rockström et al., 2009). This destabilization may push the Earth system into a new state that is less suited for sustaining current human societies and economies (Steffen et al., 2015). Thus, actions towards avoiding a destabilization of the Earth's state are urgently needed, that can be called 'sustainable' actions. Sustainability is defined in the 1986 United Nations' Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations Brundtland Commission, 1987). Human needs are therefore embedded in the primary definition, as also captured by the widely recognized framework of the Sustainable Development Goals (SDGs), adopted by all United Nations (UN) Member States in 2015. This framework sets 169 targets with 232 indicators and defines a 15-year plan from 2015 to achieve global goals and cover environmental issues such as climate, biodiversity, energy, water but also social and need-related issues such as poverty, gender equality, economic prosperity or peace, access to food or education (United Nations, 2018).

Three criteria are proposed to further define sustainability (Ruggerio, 2021): "a) account for the complexity of socio-ecological systems (SES) by encompassing economic, ecological, social and political factors, b) account for intergenerational and intragenerational equity and c)

address the hierarchical organization of nature, i.e. acknowledge the feedback between the SES and their surrounding". Here, we consider that the sustainability doughnut theory, introduced in the next sub-section, provides a conceptual framework that meets these criteria and captures an "absolute" perspective. The notion of "absolute sustainability" entails defining what is good enough to maintain a stable state for present and future generations (Hauschild et al., 2020). This concept is opposed to relative sustainability, which capture merely what is better according to a set of environmental or social criteria, e.g. in eco-efficiency practices (Bjørn & Hauschild, 2013). While relative sustainability is the main approach used in engineering methods to date, scholars call for absolute environmental sustainability assessment (AESA) to be incorporated in target-driven life cycle engineering, e.g. in the metrics of the Planetary Boundary framework (Bjørn et al., 2015; Hauschild et al., 2020; Nunes et al., 2016; Ryberg et al., 2018a). In AESA, such approaches refer to "downscaling" the Planetary Boundaries, i.e. operationalize absolute sustainability frameworks to sub-levels by allocating a share of a global boundary to an actor or activity (Ryberg et al., 2020). This thesis falls within the scope of these attempts to downscale absolute sustainability frameworks at different scales, with a view to going beyond this merely top-down approach with a more hybrid one including bottom-up initiatives.

Many alternative definitions of sustainability or sustainable development can be found in literature, which either clarify the terms "meeting the needs" stated in the 1987 Brundland report or broaden the moral community and ethical subjects concerned, e.g., whose needs are referred to as "present needs", and who comprise "future generations". While less Western-centric or anthropocentric alternatives (e.g., Leopold, 1949; Naess, 1973; Descola, 2005; Latour, 2018) are crucial in contemporary debates, they fall outside the scope of this thesis, which takes as its starting point the more widely adopted global framework of the Sustainable Development Goals (United Nations, 2015).

1.1.1.2. Planetary Boundaries and Doughnut theory, absolute sustainability frameworks

The Planetary Boundaries (PBs) framework is developed to frame the challenge of maintaining the Holocene state, by identifying nine key Earth system processes and associated absolute boundaries (i.e. the PBs), important for regulating and maintaining the Earth system in a stable state, (Rockström et al., 2009; Steffen et al., 2015). They delimit a 'Safe Operating Space (SOS)' for humanity, which should be respected to minimize the risk of destabilizing the Earth system. As assessed in 2023 in the third framework update, a total of six boundaries is transgressed, namely Climate change, Biosphere integrity, Land-system change, Biogeochemical flows (phosphorous and nitrogen), Introduction of novel entities and Ocean acidification, while the current value for control variables of Freshwater use, Stratospheric ozone depletion, and Atmospheric aerosol loading are still within the safe operating space, i.e., below the absolute thresholds (Richardson et al., 2023). Additionally, the PB framework has been recently updated to include justice considerations and propose new safe and just Earth systems boundaries (Rockström et al., 2023).

In this light, a transdisciplinary systemic approach must be taken to avoid burden shifting between the different dimensions of sustainability, and to address the interdependence of environmental, economic and social issues in indicators and assessment methodologies. The Safe and Just Operating Space (SJOS) for humanity, or "doughnut theory", expands the framework of planetary boundaries with a human needs approach, as conceptualized by Kate Raworth to provide a systemic framework to maneuver within, ensuring that humans' rights are respected while safeguarding environmental limits (Raworth, 2012, 2017). In line with the SDGs, it brings together in a doughnut-shaped framework, an environmental ceiling framed by the PB and a social foundation for everyone to live a decent life (see **Figure 1.1**).

At different scales, relating to these absolute thresholds can help to define if a system, country or product, for example, are truly sustainable, and to facilitate sustainability-oriented decision-making. To this end, quantitative and qualitative methodologies are needed to operationalize the PB into frameworks at state and non-state levels, (Bjørn, 2018; Bjørn et al., 2015, 2017; Boutaud & Gondran, 2023). It is necessary to allocate a share of planetary limits – in other words, allowances for impacts that should not be exceeded in terms of sustainability – at different scales, while taking human needs and social standards into consideration. Such allocation approaches entail ethical considerations with underlying sharing principles, as further presented in Section **1.1.2.**

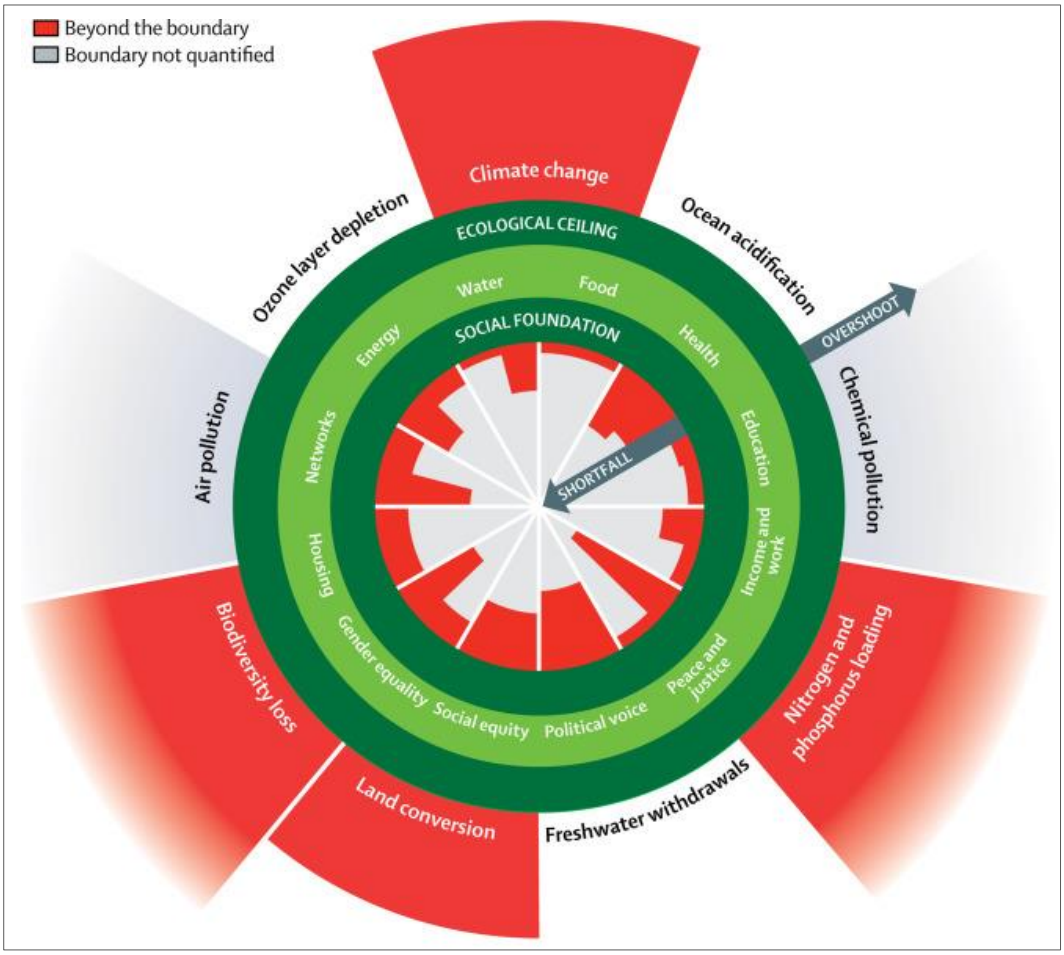


Figure 1.1: Illustration of the conceptual framework of the doughnut theory[2].

[2] The green area shapes a Safe and Just Space for humanity, defined by the environmental ceiling in on the outer circle and a social foundation on the inner circle. Red areas depict current values that exceed thresholds. Source: (Raworth, 2017)

In this PhD, we adhere to the requirements for absolute sustainability approaches in engineering methods and to the need for transdisciplinary research (Pohl & Hirsch Hadorn, 2007) within sustainability challenges. The focus of this thesis has gradually shifted to the single planetary boundary of climate change, due to the growing global recognition of the climate emergency including in the private sector (Aggeri & Cartel, 2017; Cadez et al., 2019; Persson & Rockström, 2011), to the legal international framework defined at global level by the Paris Agreements (presented below), to its universal dimension (i.e. one ton of CO_2e has the same climate change impact anywhere on the planet) and its central importance. Indeed, climate change, along with biosphere integrity, is one of the two core PB (Steffen et al., 2015). While trade-offs (i.e. transfer of negative impacts) exist between climate change mitigation options and sustainable development such as framed by the SDGS, climate actions often result in co-benefits on other planetary boundaries or social equity issues (IPCC, 2018b; IPCC WG III, 2022; Pörtner et al., 2021). In addition, a number of initiatives to downscale or allocate part of the planetary boundary of climate change emerged over the last two decades, as described in section **1.1.3**. These initiatives should be compared and reviewed, in terms of their transparency and operationality as well as in relation to their underlying ethical principles, as described in section **1.1.2**.

1.1.1.3. Focus on climate change

The Intergovernmental Panel on Climate Change (IPCC) highlights that exceeding the 1.5°C global temperature rise compared to pre-industrial levels threshold strongly increases the risk of much more severe climate change impacts, including more frequent and severe droughts, heatwaves and rainfall. In its Special Report on Global Warming of 1.5°C, the IPCC presents four illustrative model pathways with no or limited overshoot of 1.5°C (IPCC, 2018a) in terms of global total net GHG emissions. As an order of magnitude, in all of them, global net anthropogenic CO_2 emissions decline by at least 45% from 2010 levels by 2030 to reach zero in 2050. Along the same lines, aggregated GHG emissions (targeted by the Kyoto-

protocol) decline at least by 80% by 2050 in all four scenarios. To align with this trajectory, a drastic systemic change within a decade is needed. Such a paradigm shift towards a low-carbon, just and sustainable society is referred to by the Climate Action and Transparency Initiative (ICAT) as "transformational change" (Olsen et al., 2018).

To achieve this transformation, the Paris Agreement is a significant milestone in the multilateral climate action, as it constitutes a binding agreement uniting most nations together to tackle climate change and adapt to its effects. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015, with the ultimate objective to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels." (UNFCCC, 2015).

A crucial question concerns the voluntary or regulatory (un)fair contributions of each signatory, and subsequently of subscale actors. Sharing the mitigation efforts required to limit global warming to below 1.5°C compared to pre-industrial levels, i.e. how GHG emissions allowances are allocated between the various players, is a question that raises ethical and philosophical issues (Caney, 2011; Knight, 2014; Robiou Du Pont et al., 2017), prior to imply necessary technical and engineering issues. The next section **1.1.2** focuses on these philosophical issues, which cover the field of distributive justice.

1.1.2. Ethical principles underlying the allocation of planetary boundaries to sub-global scales

1.1.2.1. Concept of downscaling planetary boundaries to sub-scales

Absolute sustainability has been defined on a global scale, but most sustainability assessments operate on sub-global scales, be they territorial, organizational, at a product or individual levels. In such cases, how can absolute sustainability be defined, in other words, whether an environmental or social impact is considered acceptable, or whether an action to reduce the impact is sufficient, at these scales?

From an environmental standpoint, absolute environmental sustainability is often defined through PB framework, whose thresholds need to be operationalized using appropriate methodologies (Diamond & Hauschild, 2015). This process is called "downscaling", and these methodologies lie on "downscaling principles" (Ryberg et al., 2020), a key concept of this thesis. **Figure 1.2** illustrates a possible process of downscaling global environmental goals as depicted by Planetary Boundaries, in particular the global climate change boundary, to the organizational level, potentially through intermediate steps such as the national and sectoral levels, without neglecting social equity issues as characterized by the doughnut framework. This figure shows a possible linear downscaling path, when several other alternatives are possible. For example, a share of a global limit could be first allocated at the individual level, and then reallocated, i.e. upscaled, accordingly at organizational level (Hjalsted et al., 2021).

For the social dimension, absolute assessment methods are not as mature, notably because dimensions, thresholds and assessment methods are both more difficult to translate and adapt to local levels, and thus sometimes are deemed more arbitrary (Desmoitier et al., 2023; Häyhä et al., 2016). No further interest is taken in the theoretical background associated with absolute social sustainability assessments here, as **Chapter 2** of this thesis focuses on this issue on a national scale.

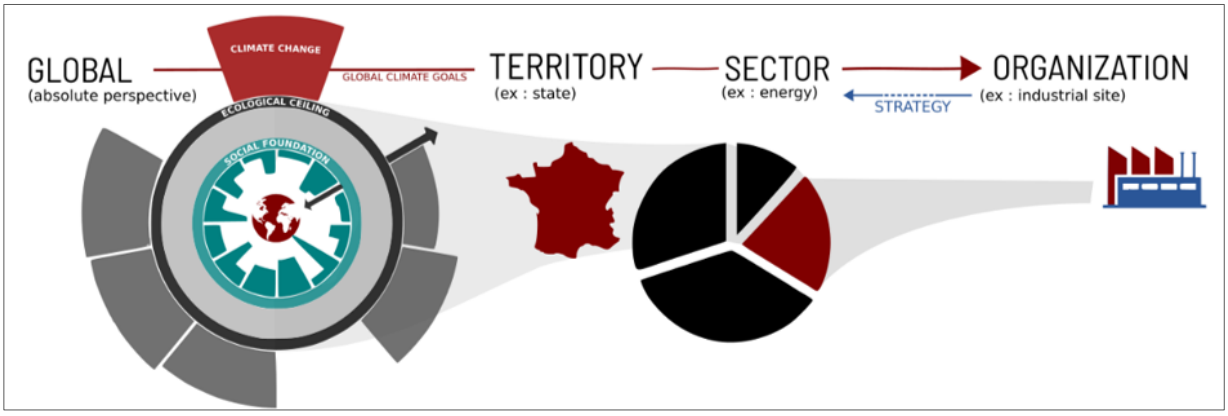


Figure 1.2: Illustration of downscaling global sustainability to organizations with an absolute perspective [3].

1.1.2.2. A philosophical approach to define downscaling: ethical allocation principles in relation to distributive justice

The overall goal of this PhD is to contribute to bridge sustainability scales, between the climate change planetary boundary and corporate levels, with robust and transparent methodologies. Before exploring methodological and operational considerations, this section summarizes the ethical issues underlying PB downscaling processes, crucial to an in-depth understanding of the subject.

Downscaling of planetary boundaries leads to the distribution of associated resources, e.g. GHG emission allowances for climate change, among different players. Different dimensions are considered when downscaling, such as temporal and geographical scopes, the target of distribution, i.e. between whom the distribution occurs who, and the pattern of distribution (Lippert-Rasmussen, 2016; Ryberg et al., 2020). The latter refers to the method and rules the distribution should follow, sometimes complemented with specific clauses or constraints (Ryberg et al., 2020). They are also referred, in AESA literature, as allocation, sharing, ethical, or distributive principles (Chen et al., 2021; Hjalsted et al., 2021; Ryberg et

[3] The climate change PB, is downscaled to the organizational level as depicted in red on the figure, with the implication of different intermediate sub-scales. The inner part of the doughnut, in green on the figure, is highlighting the need for social equity and distributive considerations when allocating the global emission budget to sub-levels.

al., 2020). Most of the time, these allocation principles are based on distributive justice theories, widely studied in social sciences and philosophy, mentioned hereafter.

Distributive justice is generally concerned with the "fair distribution of the burdens and benefits of social cooperation among diverse persons with competing needs and claims" (Kaufman, 2012). The distribution involves a “currency of justice”, which is a metric that provides a way to determinate who should be fortunate and who should not (R. Arneson, 2000). This distribution is done on the basis of principles of distributive justice, not to be confused with the allocation principles defined above which refer to operational methodologies in EASAs. In political philosophy studies, those principles of distributive justice are the subject of considerable debates and multiple schools of thought, e.g. in (Forsé & Parodi, 2006; Kaufman, 2012; Knight, 2016; Menell, 2001), the main ones being outlined in the following sub-section.

Three fundamental criteria, on which a fair distribution can be made, emerge clearly from these studies: absolute equality, i.e. an equal distribution of the resources, equity, which rewards individual merits and introduces relative equality, and the satisfaction of needs, in which those who are most in need receive the greater share, at least in terms of basic human needs (Wright & Boese, 2015). In all three cases, a clearer definition is required of what must be equal, what kind of merit is involved, and what the basic needs are, all of which have given rise to several schools of thought. However, the diversity of these criteria and approaches to distributive justice is considered legitimate, depending on the nature of the conflicts involved and their context. According to Deutsch, equality is preferred when the goals are cooperation and harmony in social relations, satisfaction of needs when the goals are social welfare and responsibility, and equity in economic and competitive contexts (Deutsch, 1975). However, based on a study from 1999 and repeated in 2004 and 2005, in which nearly 30,000 individuals in Europe were asked about these three justice values, the guarantee of basic needs was overwhelmingly recognized as essential for a just society, in the first place before equality and equity, with similar trends observed in 2004 and 2005 (Forsé & Parodi, 2006).

The various theories of distributive justice can be linked to one or a combination of these three criteria of justice and they are discussed in the following section.

1.1.2.3. Presentation of the four main theories of distributive justice

In the distributive justice literature, four main theories stand out: egalitarianism, prioritarianism, utilitarianism and sufficientarianism (Knight, 2014), which are introduced below.

For egalitarianism, the distribution of resources must be based on the criterion of equality, although different definitions of equality can be used, e.g., equal sharing of resources or equal sharing of well-being (Knight & Albertsen, 2018).

Luck egalitarianism introduces luck as a clause, recognizing individual responsibility. This means that inequalities are justified if they result from intentional choices, but must be remedied if they are related to non-controlled choices or in other words to "brute bad luck" (Lippert-Rasmussen, 2016; Tinghög et al., 2017). This position has the advantage of taking individual responsibility into account, unlike the three other theories. But it ignores both the position of the most disadvantaged and the aggregate levels of individual advantage (i.e. the total level of summed advantage).

For prioritarianism, the distribution must favor the position of the most disadvantaged. This view has the advantage of taking into account the position of the worst-off, but it may neglect individual responsibility as well as aggregate benefit levels (Knight, 2016).

Utilitarianism is defined in relation to people welfare, which leads to many interpretations. It argues for a distribution that maximizes the aggregate level of welfare of the members of a society, i.e. the greatest good for the greatest number (Audi, 2007). It overlooks the distribution between members, and therefore the situation of the most disadvantaged, as well as individual responsibility (Knight, 2016).

Sufficientarianism aims to provide people with enough in a distribution based on meeting basic needs for all (Gosseries, 2011), as the Brundtland report imprecisely requires for current and future generations in its definition of sustainability (United Nations Brundtland Commission, 1987). This position has the advantage of considering fundamental human rights by giving enough to all to develop basic autonomy, but it appears to its objectors as too vague or arbitrary on how to place thresholds linked to needs (Knight, 2016).

Multiple-threshold sufficientarianism (Huseby, 2019), defines at least one additional threshold defining an upper bound, e.g., a point of contentment. This approach combines sufficientarianism with a more recent view called limitarianism, stating that it should not be permissible to have too much of the currency of distributive justice (e.g. material resources or emission quotas) (Hickey, 2023; Robeyns, 2017). This theory addresses another common limitation of sufficientarianism named the "indifference objection", which stresses that for sufficientarians, once needs have been met, significant or even avoidable inequalities in the currency of justice are not problematic (Shields 2020). A parallel can be drawn between the multiple-threshold sufficientarianism, or combined sufficientarianism-limitarianism approach, and the doughnut theory framework. Indeed, in a finite world, as characterized by the framework of planetary boundaries, an upper limit in a resource distribution frame would seem logical, along limitarianism. On the other hand, the doughnut's social foundation ensures a decent standard of living for everyone and sets minimum thresholds to be reached by everyone, in line with sufficientarianism.

1.1.2.4. Sharing emission allowances, other specific principles

In the context of this PhD, the currency of justice that needs to be distributed among various actors is GHG emission rights. In this case, other common views can be found, namely status quo rights or grandfathering, its opposite approach, historical responsibility, as well as the capability approach. While not directly derived from the four main distributive justice theories or explicitly providing one, they are presented in this section as widely adopted in emission

allowance distribution ethical discussion (Knight, 2016; Meyer & Roser, 2006) or in AESA (Chen et al., 2021; Ryberg et al., 2020).

The principle of status quo rights argues that emissions rights should be allocated, not on the basis of justice criteria as defined in the previous section, e.g. equity, but rather by preserving the status quo distribution (Caney, 2011; Meyer & Roser, 2006). Grandfathering falls within this theory, as a principle that allocate future emissions (seen as burden-sharing in terms of emission reductions) based on past emissions. This principle may be seen as an approach derived from utilitarianism, in which the welfare value to be optimized would be the total cost for emissions reduction, or each actor's current contribution to global GDP. These values are indeed generally higher for wealthier – and often higher-emitting – countries or companies, which would therefore benefit from preserving the status quo. However, using these economic proxies to define welfare is widely criticized in literature e.g. (Chancel et al., 2013; Hickel, 2018a; D. W. O'Neill et al., 2018). Although often criticized as unfair as it tends to reward the polluters that would have a right to the status quo (despite their large contribution to the problem as opposed to the polluter-pay principle), it is nevertheless a widely applied principle in practice (Caney, 2011). Looking for a pragmatic explanation, grandfathering might be the starting point for getting the main players and the biggest emitters to sign up to binding agreements, with the possibility of subsequently discussing the definition of fairer distribution and updating the commitments made with other principles of distributive justice (Caney, 2011). For example, it was one of the factors that led the United States to oppose the Kyoto agreement in 2000, deploring the injustice of certain emitters not carrying a reduction burden (Meyer 2006). In this light, Knight argue that in some cases, the main distributive justice principles might gain benefit if they incorporate moderate grandfathering (Knight, 2014).

An alternative and opposing view is the historical responsibility approach, which requires the highest emitters to further reduce their emissions, and therefore that past emissions result in lower emission allowances due to their accountability (Robeyns, 2018).

Eventually, the capability approach does not define an entire theory of distributive justice, but it is another principle widely used for emission allowances, arguing that the distribution should be made as a function of "functionings" and/or capabilities, which are respectively various states that a moral agent can undertake (e.g. being educated for a person, being within high-income countries for a nation), and freedoms or opportunities (R. J. Arneson, 2010; Robeyns, 2018). In other words, the capability approach tends to focus on what people, or moral agents considered in a distribution process, are able to be and to do.

Finally, many academics and thinkers of distributive justice argue for currency pluralism or/and principle pluralism, i.e. a combined vision of distributive principles (Caney, 2011; Gosseries, 2005; Knight, 2016). These pluralistic visions may help to overcome the limits of each of the main principles, to accommodate with trade-offs and to accept the relative importance of the others, e.g. with combined prioritarian sufficientarian views (Shields, 2020). In AESA, it is rarely straightforward to associate an operational method for downscaling a given global limit, through a distribution approach, with a single theory of distributive justice. These operational methods depend on numerous parameters, they are often composed of several steps and draw inspiration from several schools of thought or from other practical considerations. However, it is interesting to analyze them through the lens of these philosophical theories, to question and highlight the underlying, often hidden, values and principles.

In this thesis, we focus on the case of climate change, applied to the organizational and intermediate scales, analyzed notably in terms of their fair contributions to the objectives of the Paris agreements. This section outlines the main principles of distributive justice, the existence of pluralistic visions, and some of the associated debates that are currently taking place in the academic community. This variety of principles and interpretations results in a large number of possible methods for allocating planetary boundaries at different scales (Chen et al., 2021; Ryberg et al., 2016, 2020). Some principles have been widely applied and others

neglected, and there is often a limited transparency regarding underlying distributive justice principles. For this reason, it seemed important in this thesis to begin with a theoretical foundation for distributive justice, before turning to operational methods applied to the case of corporate climate change mitigation strategies.

The following section looks at the case of intermediate scales, up to and including the organizational level, and some associated attempts to contribute, according to these actors, in a fair way to climate change mitigation.

1.1.3. Sharing the global budget, the climate case: world, state and non-state actors fair contributions to Paris agreement goals

This section deals with the planetary boundary of climate change, whose currency of distributive justice is emission allowances from the global GHG emission budget. The Paris Agreement's objective of limiting the global temperature increase to 1.5°C above pre-industrial levels implies a global GHG emissions reduction target, i.e. a global emissions budget of 500 $GtCO_2$ for a 50% likelihood of limiting global warming to 1.5°C (IPCC, 2023b). This global budget must consequently be divided among lower levels, such as states, regions (Schulan et al., 2023) and possibly companies and individuals. In the light of the principles of distributive justice, the examples of international negotiations at the global level and of a region of the world with the European Union are considered in section **1.1.3.1**, and at the national scale with France example in section **1.1.3.2**. Before moving to the organizational level in the last section **1.1.3.4**, the question of the relevance and meaning of bringing organizations into the moral community that benefit from distributive processes is raised in section **1.1.3.3.**

1.1.3.1. From global to organizational scales in terms of fair emission allowances

The principle of common but differentiated responsibility and respective capabilities (CBDR-RC), inscribed in the Paris Agreements, clearly shows that distributive justice issues are considered in the breakdown of efforts to be made to mitigate climate change (UNFCCC, 2015). However, the debate is still crucial today as the sum of all members Nationally Determined Contributions (NDC), i.e., self-defined national climate pledges under the Paris Agreement, is not enough to ensure a world below 2°C, let alone 1.5°C . To that extent, while unambitious contribution pledges of high-emitting actors are not illegal under the Paris Agreement, they may appear to be immoral in terms of various distributive justice principles (Robiou Du Pont et al., 2017; Schulan et al., 2023).

Divergent points of view therefore emerge on how to determine what constitutes a fair share, which can be read through the prism of the principles of distributive justice. Schematically, high-emitting states (e.g. the US) argue for emission reductions based on current levels (reflecting grandfathering or utilitarian principles), while small island developing states (e.g. Tuvalu) argue for the need to finance the severe impacts of climate change (historical responsibility and capabilities principles), the very-low income countries claim conditional emission reductions subject to adequate financing for their transition and development (prioritarianism or sufficientarianism principles), and some countries align their emission targets with a global decarbonization trajectory according to their population (equal per capita methods, following an egalitarian principle).

The European NDC, updated in 2019 through the implementation of the European Green Deal, involves reducing its net domestic GHG emissions by 55% by 2030 compared with 1990 levels (European Commission, 2019). However, the official NDC publication does not explicitly explain how this target is “fair and ambitious” (European Union, 2020) as

required by the NDC framework. It may be seen sufficiently ambitious in a grandfathering, and in some egalitarian perspectives, where all countries equally reduce their emissions, as the IPCC indicates that a 43% reduction in global emissions is needed between 2019 and 2030 to limit global warming to 1.5°C (IPCC, 2022). However, like the United States and China, the European NDC falls far short of the emission reduction ambition when viewed through the prism of historical responsibility or economic capabilities (Davide et al., 2017).

1.1.3.2. Downscale global emission budget to the national level, the illustrative case of France

At national levels within the European Union members, the respective effort of each member state to the European NDC is still under negotiations, also bringing distributive justice debates and studies (Steininger et al., 2022). Taking the example of France, the National Low-Carbon Strategy (SNBC) reflects its national climate plan. This strategy was established in 2015, revised in 2019 and 2023. It defines national territorial GHG emission reduction trajectory until 2050 and sets short- and medium-term objectives, in alignment with France's NDC (MTES, 2020). Its first NDC implied to reduce domestic gross GHG emissions by 40% in 2030 compared to 1990. This objective was updated in September 2023 "taking into account the raising of the European target" (French ministry on ecological transition, 2023), and aligning with a 55% reduction in domestic net GHG emissions (French Government, 2023a). In a further downscaling process, national emissions budgets are then allocated to the French sectors, namely transport, buildings, agriculture, industry, energy and LULUCF[4]. These budgets are differentiated so as to minimize marginal abatement costs, i.e. the cost of reducing GHG emissions. This approach falls within the framework of utilitarianism, with the welfare value to be optimized being the marginal abatement costs.

In several respects, from the point of view of distributive justice, this target lacks ambition. Firstly, it was 15% below the target of the European Green Deal for three years, which quite

[4] Land use, land-use change, and forestry

trivially seems inadequate in terms of its fair contribution, and for this reason the "Haut Conseil pour le Climat", an independent French consultative body reporting to the French Prime Minister, recommends at least a 50% reduction between 1990 and 2030 in its last two annual reports (Haut Conseil pour le Climat, 2022, 2023). However, this objective has been revised in 2023. Secondly, several scientific studies have investigated ambitions at national level according to different principles of distributive justice, with some minimum reduction rates of 68% by 2030, using a combination of historical responsibility, egalitarianism and capability principles (Robiou du Pont & Meinshausen, 2018) and up to 168% considering historical responsibility (Holz et al., 2019). Last but not least, currently France fails to meet its current (fair or unfair) NDC, as acknowledged in the litigation case lost by the French government on this matter (Cournil et al., 2019) and by the governmental Council of State (Conseil d'Etat France, 2022).

1.1.3.3. A matter of meaning: should organizations be included in distributive justice considerations

One might question whether the fair allocation of a burden of benefit holds any meaning at the level of an organization. Definitions of organizations are numerous, but most of them encompass four elements: two or more members, one or more guiding objectives, distinct roles assigned to members, and an accepted system of authority and governance (Tolbert & Hall, 2016). Therefore, the main difference with other scales is that organizations are not defined by the individuals who make them up, unlike a country or territory which are often defined in terms of the languages, interests and traditions of their inhabitants. In the principles of distributive justice presented earlier, the moral community eligible for distribution was made up of individuals, or territories composed of individuals, with discussions centered on the needs, equality, equity between these individuals. In a fundamental principle of universal human rights, it is deemed natural to attribute to every human being an inherent right to exist, and therefore to take part in distributions of resources.

When it comes to organizations, then, questions are legitimate as they do not have an inherent right to exist or thrive, nor do they have moral rights. In a market context with open competition, companies are constantly disappearing, merging, being created and evolving. One could argue that, within the rules of the economic game, companies should simply comply with the regulations applicable in their territories, and that these should constrain them. Regulators might then be expected to change the rules of the game, particularly with respect to emissions allowances, as it is the case for certain sectors in Europe with the Emissions Trading System (EU ETS), for example (Engels, 2009). Along the same lines, companies could only be expected to innovate widely to develop the necessary social, systemic and technical solutions linked to the low-carbon transformation of our society.

While it may not appear trivial to decide on the philosophical question of whether a company should be concerned by distributive justice applied to climate change, we argue here that it is essential to include them, for at least five reasons. Firstly, if approaching distributive justice through the prism of burden distribution (duty to reduce emissions) rather than benefit distribution (right to emit), then it seems important to be able to hold companies accountable for doing their part in the low-carbon transition. Indeed, 164 cases climate change litigation cases against companies have been retrieved solely in 2023 outside the US (Climate case chart, 2023). Secondly, regulations are gradually moving in this direction, with for example the introduction of the European Corporate Sustainability Reporting Directive (CSRD), which by 2028 will progressively require most European companies to share publicly a set of structured information relating to their extra-financial strategies (EFRAG, 2022). This reporting framework will notably include targets for reducing GHG emissions across the value chain, with related methodologies being developed, which is driving the need for scientific transdisciplinary review and allocation discussions. Another sectoral example concerns the French emission target set for the building sector and consequently the RE2020 standard, which sets intensity targets in terms of results rather than means, requiring organizations to work

toward this outcome (French Government, 2023d). Thirdly, this may also be a survival issue for companies, both in terms of climate-related risk anticipation (World Economic Forum, 2022), strategic aspects like resilience and adaptation (e.g. to supply chain disruptions and dependence on fossil fuels) or reputation (customers, value chain stakeholders, employees and talent acquisition) (TCFD, 2015). Four, the increasingly popular concept of Corporate Social Responsibility (CSR) and emerging concepts such as the status of mission-driven companies under the PACTE law in France (Government of France, 2019a), or benefit corporations with the B-Corp label, show that societal responsibility and long-term vision perspectives can be attributed to companies, going beyond regulation (Segrestin & Parpaleix, 2019). In this light, the PACTE law specified in the French Civil Code that "a company is managed in its corporate interest, taking into consideration the social and environmental challenges of its activity (Government of France, 2019a). Finally, from a pragmatic standpoint, the scale of the transformation linked to climate change and the global ecological crisis leaves no choice: the private sector has an essential role to play in mitigating climate change, and organizations also have a climate duty to reduce their emissions – if not a moral one for the individuals who constitute them.

1.1.3.4. Organizational level: the current distribution of emission allowances

Personn and Rockström highlighted the crucial interdependence between the international climate negotiations, domestic level and the private sector: progress at one level depends on action at the other (Persson & Rockström, 2011). Thus companies have a fundamental part to play to contribute to Paris agreement goals. Over the last three decades, climate change progressively came to the agenda of corporation strategies, in regards to GHG emissions mitigation, climate risks as well as climate adaptation (Aggeri & Cartel, 2017; Iken et al., 2019; World Economic Forum, 2021, 2022). In the last 5 years, acceleration have gained momentum, as shown by a study on the progress of European companies reporting climate-related information through CDP questionnaires, which cover around three quarters or the total market

capitalization of European companies. In 2022, 47% of them reported absolute reduction emission targets, against 14% in 2019 (CDP, 2023a). This acceleration is also reflected in regulatory evolutions (e.g. ADEME, 2020; European Commission, 2020; Government of France, 2019b; U.S. Securities and Exchange Commission, 2022).

However, scholars have shown that in some cases, voluntary corporate environmental programs may tend to dissuade other actors that usually demand environmental regulations (voters, activists and official members of government) from implementing more drastic measures (Malhotra et al., 2019), especially when these are multi-stakeholder initiatives such as industrial coalitions. In other words, given the positive public opinion regarding actors who take environmental actions, self-defined voluntary environmental programs with modest ambitions could end up being lobbying strategies to influence government policies in the direction of statu-quo preservation and climate inaction. These results underline the need for regulatory approach, in particular on the corporate reduction target definition, without dependence on self-proclaimed fair contributions. We argue that voluntary environmental programs are also needed, including business model transformations, social and technical innovations, investments, and emissions targets. Anyway, both regulatory and market incentives induce the adoption of climate action plan at the scale of organizations. These voluntary bottom-up approaches, notably through enhancing innovation, are complementary to top-down normative and independent regulatory approaches.

However, it is also noteworthy to mention that the efficiency and integrity of corporate sustainability strategies is subject to question. In 2022, in relation to their own developed criteria, CDP outlined that G7 companies were on path to a 2.7°C temperature increase, based on the targets of the companies that reported to this initiative (CDP, 2022b). In addition, the Corporate Climate Responsibility Monitor 2023 analyzed 24 major multinational companies reporting roughly 4% of global 2019 emissions and outlined that pledges are often ambiguous, with limited implementation of emission reduction measures, resulted in 15 out of 24 low to

very low climate strategy integrity (Day et al., 2023). This shows that claiming reduction targets 10 years ahead does not necessarily transform the companies that set them, nor does it secure sufficiently ambitious climate change mitigation actions or associated strategies. This may be partly due to a lack of methodological standards for the latter two elements, which could undermine the possibility of holding organizations accountable.

In AESA literature, several attempts with various methodologies have been made to downscale planetary boundaries, at territory levels (including national, regional, urban, biogeographical) (e.g. Acosta, 2022; D. W. O'Neill et al., 2018; Turner & Wills, 2022), fewer at company levels (Chen et al., 2021; Hausdorf & Timm, 2023; Hjalsted et al., 2021; Ryberg et al., 2018b). Among methodologies to define corporate climate-related targets, the Science-Based Targets initiative (SBTi) methodology is gaining interest on the international scene, with more than 5,000 companies adhering to the initiative, which represent one third of the global market capitalization. This methodology is of particular interest in this thesis, as it aims at providing standardized guidance and a validation process for organizations, to define their emission budget to contribute to Paris goals. This methodology is mostly based on the underlying principle of grandfathering (all emitters being required to lower their emissions with the same rate, as in the SBTi Absolute Contraction Approach (ACA) method) or utilitarianism (with welfare defined as the economic value added of companies or the optimized mitigation cost, as in SBTi GHG emissions per Value Added (GEVA) or Sectoral Decarbonization Approach (SDA)) (Bjorn et al., 2021). SBTi methods, further analyzed in this thesis, overlooks other theories such as sufficientarianism or proritarianism, while we could argue that they might be of interest, for instance, for G7 companies with expected large capabilities in high-income countries.

1.2. Scope of the PhD: bridging sustainability scales

1.2.1. Problem statement

There are many approaches to ecological transition with a strongly top-down perspective, such as ecological planning (by states or a potential world government) e.g., (French Government, 2023c), the energy approach (cost-optimization, energy specialist problems e.g., (Jacobson et al., 2017; Krabbe et al., 2015; SBTi, 2015)), the macro-economic approach (price regulation, border and domestic carbon taxes) e.g.,(Paroussos et al., 2019). While these approaches have their advantages and are useful to investigate, they also have their limitations, such as inefficiency (e.g. current policies), low social acceptance and lack of involvement of both individuals and organizations. In addition, attention on the international climate scene tends to shift from top-down discussion of global emission reduction targets to bottom-up self-determined contributions (Steininger et al., 2022). Here we aim at investigating how scales can be connected back together, i.e. how to fairly downscale global sustainability goals such as the global emission budget to state and sub-state actors, and how to ensure absolute or good enough perspective in voluntary or regulatory initiatives at local scales, i.e., in bottom-up approaches.

We argue that all these top-down approaches are perhaps necessary but not sufficient, and that combined with bottom-up approaches, they may complement binding top-down targets, enable maximum mitigation of climate change, and more broadly contribute to the maintenance of our global system in a just and safe operating space for humanity. The hypothesis supported in this thesis is that sub-state actors have a crucial role to play in the low-carbon transition and the definition of a sustainable society, as well as a responsibility and the means to act (financial, technical, skills), with different responsibilities for different players. Therefore, there is a need from the research community to dive into the topics of corporate climate-related strategies and sub-state actors' fair contribution to the Paris Agreement mitigation goals and consequently propose context-based recommendations to support decision-making at their level. The

ultimate goal of this research is to help to bridge the gap between Paris Agreement objectives and operational methodologies for organizations. In other words, we aim at contributing to methods for downscaling the global emission budget to national, sectoral and then organizational levels in an absolutely sustainable way, while considering human needs and distributive justice.

To this end, the overarching problem of this PhD is: **What methods can state and non-state actors implement to contribute to the ecological transformation of our society, and how can these sub-scales be bridged to global sustainability frameworks?** We investigate how diverse actors can build credible, robust and operational strategies to align with global sustainability issues such as framed by the Paris Agreement, including social equity as framed by the Safe and Just Operating Space.

1.2.2. Research questions and PhD objectives

Two underlying concerns emerge from this problem statement. From a top-down perspective (Research Question (RQ) 1), how to fairly downscale global sustainability goals, such as the global emission budget, to state and sub-state actors, notably in relation to distributive justice and ethical considerations. From a bottom-up perspective (RQ 2; 3; 4), how to ensure absolute perspective, i.e. good enough, in voluntary or regulatory organizational climate change mitigation strategies.

Research questions

1. RQ 1: How to downscale global sustainability goals to sub-scales?
2. RQ 2: How to define climate change mitigation trajectories at the organizational level?
3. RQ 3: What framework to derive organizational climate change mitigation strategies (OCCMS) from global goals?
4. RQ 4: How do existing methods align with global goals and scientific literature?

To contribute to scientific progress in relation to these research questions, the objectives of the PhD are to:

i) Analyze the existing global sustainability frameworks and the existing downscaling methods at diverse sub-scales, with a focus on a need-based approach at the national level
ii) Review existing OCCMS methods and tools for organizations, highlight associated research gaps and challenges
iii) Identify the challenges to downscale global carbon budget at corporate level and provide methodological recommendations, notably in regards to the increasingly popular SBTi methodology
iv) Build an operational comprehensive methodological framework to define a low-carbon strategy for an organization
v) Test the methodology on a case study, to support decision-making at company-level, to make organizations accountable, and to set the research agenda for the definition of robust OCCMS

1.2.3. Article-based thesis outline

The top-down and bottom-up complementary approaches to bridge sustainability scales organize this thesis into two stages.

The first stage deals with need-based distributive justice and associated operationalization of the doughnut theory at national levels, as a first step of the downscaling process toward organizations. **Section 1.1.2** shows that the sufficientarianism principle in distributive justice is overlooked in absolute sustainability assessment and that one common related objection is arbitrary social thresholds. In this light, we show the relevance of a need-based approach within the global doughnut framework as we develop a method for characterizing and assessing the social impact of an action or a policy on a system, at the national level. This method is presented in **Chapter 2**, with a first research article as a result.

The second stage of this thesis is oriented to address specifically the issue of bridging the climate change Planetary Boundary to the organizational level, notably to take advantage of the industrial partnership at the heart of this PhD (CIFRE agreement) and the access to the corporate world, cases and data. Thus, after recognizing the ethical principles of distributive justice underlying environmental engineering methods, the scope is narrowed to the scientific development of organizational climate change mitigation strategies (OCCMS) and trajectories in a second phase. A specific in-depth literature review is subsequently conducted along these lines, leading to a second research article and a novel OCCMS framework, as presented in **Chapter 3**.

This review identified a number of scientific gaps, one of them being the lack of scientifically reviewed methodologies that go beyond carbon accounting and the definition of GHG reduction targets, as well as the lack of associated case studies to illustrate the applicability of OCCMS. A third article is presented in **Chapter 4** to address this gap, with the in-depth 3-year case studies of 10 companies defining their OCCMS. In a collective and

territorial format, these companies were the first to follow the Assessing Low-carbon Transition Step-by-step (ACT-S) methodology, which is identified in **Chapter 3** as a promising method to contribute to OCCMS definition.

As identified theoretically with the review article presented in **Chapter 3** and confirmed empirically in **Chapter 4**, there is a there is a clear lack of transparency in the way in which companies set their reduction targets, both in the underlying assumptions used in their definitions and in their reporting. This is true even with SBTi's widely recognized methodology and validation process. In particular, this lack of transparency leads to a risk of carbon imbalance, i.e. exceeding the global carbon budget defined by summing up individual targets. In a final article presented in **Chapter 5**, we cross-reference several databases and recover emissions data and SBTi targets from over 3,000 companies between 2015 and 2021. This demonstrates this risk of carbon imbalance and cherry-picking, through the example, previously unstudied, of the influence of the choice of base year when defining emission targets. This data analysis and the lack of transparency identified in SBTI's reporting and validation process also led me to contribute as a co-author to a comment published in the journal Nature Climate Change, calling for greater transparency to ensure effective, credible and robust SBTi targets (see Annexes **A.2**).

Below is a summary of the articles that compose this article-based PhD thesis, with their status at the moment of writing:

1. Methods for assessing social impacts of policies in relation to absolute boundaries. Published in Environmental Impact Assessment Review, Volume 101, 2023, 107098, ISSN 0195-9255, https://doi.org/10.1016/j.eiar.2023.107098. Co-authors are, in order, Mathilde Kolenda, Karen Olsen and Morten Ryberg.
2. Methods for defining climate change mitigation strategies at organizational level: review and outlook, Submitted to Business strategy and the environment on 07/09/2023, under review. Co-authors are, in order, Jean Roman, Benoit Hilloulin, Emmanuel Rozière and Alexis Laurent.
3. How to define climate change mitigation strategies at organizational level: lessons learnt from 10 organizations in France. To be submitted to Business strategy and the environment. Co-authors are, Marie Gaborit, Benoit Hilloulin, Emmanuel Rozière, and Alexis Laurent.
4. Do base years matter? Exploring the links between Corporate Science-Based Targets and corporate GHG emissions. To be submitted to Environmental Research Letters. Co-authors are, in order, Anders Bjorn, Benoit Hilloulin, Emmanuel Rozière, Alexis Laurent.
5. Comment **as a co-author** (not included in the chapters of this thesis): Increased transparency is needed for corporate science-based targets to be effective. Nature Climate Change, 13(8), 756–759. https://doi.org/10.1038/s41558-023-01727-z. Authors are, in order, Bjørn, A., Matthews, H. D., Hadziosmanovic, M., Desmoitier, N., Addas, A., & Lloyd, S. M.

CHAPTER 2

Methods for assessing social impacts of policies in relation to absolute boundaries

This chapter is based on the article entitled "Methods for assessing social impacts of policies in relation to absolute boundaries", published in *Environmental Impact Assessment Review* (Desmoitier et al., 2023). The approach taken in this article is intended to give a broader scope to the thesis, before focusing on climate change mitigation strategies at the organizational level. This chapter underlines the importance of international climate justice, with differentiated challenges across regional boundaries. In this thesis, the emphasis is on the needs-based development of the method, using a simple case study for illustrative purposes, and further details on the case can be found in the supplementary information of the published version of the article (Desmoitier et al., 2023).

Abstract

There is an urgent need for designing truly sustainable policies supporting transformational change, and consequently for integrated tools to avoid burden shifting from different dimensions of sustainability. The Safe and Just Operating Space concept holds potential to support sustainable design of policies and decision making, using both the planetary boundaries framework and key social dimensions on an absolute perspective. Yet there is a lack of associated quantitative social assessment approaches. A new methodology is developed to evaluate the social sustainability of a policy against absolute boundaries. First, the methodology quantifies the state of a system, in 15 social dimensions defined systematically. Second, it estimates the social impacts of a new policy and observes if it will contribute to reduce the social shortfall. A geothermal energy development policy in Uganda is taken as an illustrative example for proof-of-concept. In the metrics of the Social Foundation of the Just Operating Space, the implementation of the policy would substantially improve the social performance of Energy and Health. Conclusively, this methodology holds potential to help early-phase policy design that do not unintentionally shift burdens between social dimensions, albeit further work remains to test the methodology and apply it in absolute integrated assessments.

Keywords

Social impact assessment; Absolute sustainability; Safe and Just Operating Space; Social foundation; Sustainability assessment framework.

2.1. Introduction

Anthropogenic pressures on the Earth System (ES) are starting to jeopardize the stability of the Holocene state that has been so important for humans to prosper (Rockström et al., 2009). These pressures risk pushing the ES into a new state that is less suited for sustaining current human societies and economies (Steffen et al., 2018). Thus, drastic systemic actions are needed within the next decade to avoid a potential destabilization of the ES and safeguard human and planetary health (Masson-Delmotte et al., 2018). Future business-as-usual trends fail to eliminate social shortfalls, while worsening the ecological crisis (Fanning et al., 2021). Thus, policymaking has a key-role to play in designing transformational policies that enable a disruptive shift from unsustainable practices to zero carbon and sustainable societies in line with the objectives of the Paris Agreement and the United Nation's global Sustainable Development Goals (SDGs) (K. H. Olsen & Singh, 2020).

Furthermore, transformational policies need to address the interdependence of environmental, economic and social issues. It is important to develop policy- and decision-support methods and tools that cover all three sustainability dimensions to promote synergies and avoid simply shifting the burden from one dimension to another (Sala et al., 2015). Acknowledging the interdependence of the socioeconomic and environmental issues, Raworth coined the concept of the Safe and Just Operating Space (SJOS) for humanity to maneuver within, ensuring that humans' rights are respected while safeguarding environmental limits (Raworth, 2012, 2017). On the one hand, the environmental limits are expressed by the Planetary Boundaries (PBs) framework (Rockström et al., 2009; Steffen et al., 2015), which identifies and defines boundaries for nine key ES processes, considered essential for maintaining the ES in a Holocene-like state. Hereby, the PBs delimit a 'safe operating space' for humanity. On the other hand, the social dimensions in the SJOS are covered by a set of social categories, which altogether form a 'Social Foundation' (SF), below which exists

unacceptable human deprivation (Raworth, 2012). The SJOS defines a space for humanity to act within to be both environmentally and socially sustainable.

To operationalize the underlying concepts of the SJOS framework, methods assessing if a product or system is environmentally sustainable across its life cycle in absolute terms relative to the PBs, have recently been developed (e.g. Algunaibet et al., 2019; Li et al., 2019; Ryberg et al., 2018c).

As for the SF of the SJOS, studies have sought to assess social sustainability in relation to absolute boundaries, with no consensus in the literature on operational frameworks (e.g. Acosta, 2022; Fanning et al., 2021; Hickel, 2018; Luukkanen et al., 2021; D. W. O'Neill et al., 2018; Randers et al., 2018). These studies have tried to operationalize the global SJOS for humanity to sub-levels (national or regional scales) to support and influence the decision-making process. It can serve as a communication tool (Dearing et al., 2014), as a tool to define the 'national safe and just spaces' (Cole et al., 2014a) or as a comparative tool to quantify the resource use associated with meeting basic human needs across countries (Fanning et al., 2021; D. W. O'Neill et al., 2018). The definition of the social foundation can be challenged: are the sets of dimensions, indicators and thresholds used so far relevant? So far, methodologies were based on practical considerations rather than theoretical ones and consequently showed little consistency (Häyhä et al., 2016). Besides, when trying to set social thresholds, arbitrary and disputable decisions were made (D. W. O'Neill et al., 2018; Raworth, 2017). Rather, a more systematic approach is needed for identification and definition of indicators and boundaries.

This study aims at reviewing the social framework and implementing a more systematic approach to frame the social foundation. The purpose is to develop a method for defining social boundaries and setting minimum targets with regards to social sustainability. The method is intended for application as part of policy assessment to provide an indication of the social impacts of a policy on a system in relation to the social dimensions of the SJOS. Therefore, to illustrate the applicability of the method, it is applied to a simple illustrative case of a draft

policy in Uganda. This is used to assess the social impacts of a policy on the construction of a geothermal plan that provides 1,500 MW additional energy to Uganda by 2040, as described in a real Ugandan policy case study (Kolenda & Desmoitier, 2019).

2.2. Methods

2.2.1. Defining the social foundation

To assess impacts of policies relative to absolute boundaries, it is first required to investigate the current system's social performance in relation to the defined absolute boundaries, i.e. the 'baseline scenario'. The sustainability performance refers to the capacity of a system to maneuver within the SF of the SJOS. Then, the methodology deals with assessing impacts assigned to a specific policy with a forward-looking vision and in relation to the baseline results (referred to as the 'policy scenario'). The SF of the SJOS relies on the concept of 'deprivation' (Raworth, 2012; Townsend, 1987). Deprivation is defined in relation to the multiple facets of poverty: "Individuals, families and groups in the population can be said to be in poverty when they lack the resources to obtain the types of diet, participate in the activities, and have the living conditions and amenities which are customary, or at least widely encouraged or approved, in the societies to which they belong" (Townsend, 1987). In that respect, this study takes an individual perspective and has a focus on individual well-being. Ensuring that basic humans' needs (represented by the dimensions of the SF) are met is embodied in the definition of the 'just space' of the SJOS. To consistently define the SF-framework, we propose three main steps, sequentially aiming at i) defining the SF dimensions, ii) selecting the indicators to represent the SF dimensions, and iii) setting absolute boundaries for the selected indicators.

2.2.1.1. Definition of the Social Foundation dimensions

The dimensions of the SF were defined based on a literature review of studies operationalizing the SJOS framework, the SDG framework (United Nations, 2018), the original SJOS concept (Raworth, 2012, 2017) and the underlying reports, namely the theory of basic needs (Doyal & Gough, 1991), and the RIO+20 countries priorities (Raworth, 2012).

As for the literature review, the following search strategy *(TS=("donut economic*" OR "doughnut economic*" OR "social foundation" OR "just operating space" OR ("safe and just" NEAR/2 space))) AND TS=(thresholds Or indicators OR operational* OR metric* OR measure OR downscal* OR dimensions)*, with restrictions to research articles written in English between 2009/01/01 and 2022/30/11, generated 49 results on the search engine 'Web of Science'. The search criteria did not explicitly encompass the term SDGs, as research studies utilizing the Donut economics are themselves based upon the SDG framework. Eventually, screening and assessment of the results left 11 studies for comparison and definition of the SF dimensions (Acosta, 2022; Capmourteres et al., 2019; Cole et al., 2014a; Dearing et al., 2014; Fanning et al., 2021; Hickel, 2018b; Luukkanen et al., 2021; D. W. O'Neill et al., 2018; Randers et al., 2018; Roy et al., 2021; Y. Zhang et al., 2022) (see Supplementary Material (SM) in section **3** for details). Defining the dimensions has comprehensively been based on the existing dimensions of the literature (see section **A.3.1** for more details). As a result, 15 dimensions were found to be constitutive of the SF (see **Table 2.1**).

2.2.1.2. Selection of the indicators

Based on the 225 indicators identified in the literature review of dimensions of the SF, a selection process was developed to systematically select and assign one indicator per social dimension. All indicators retrieved from the reviewed literature were classified according to the social dimensions they relate to (gathered in Supplementary Data, by social dimension). Hereafter, each indicator was ranked based on its relevance to the social dimensions. The ranking was based on four criteria of different importance, presented here from most to least

important: 1) Relevance, 2) Classification of the indicator in the UN Tiers, 3) Frequency, 4) Alignment with the SDGs (see Section S2.3 for more details on the definition of the four criteria). First-ranked indicators for each dimension were selected as SF indicators as depicted in **Table 2.1**.

2.2.1.3. Absolute boundaries definition

In this study, a socially sustainable state is defined when 'no deprivation to humans' is observed. There is no consensus for defining a boundary for expressing an absolute social sustainable state and such boundary is potentially normative. Thus, the dimensions were divided into three tiers, depending on the degree of certainty, credibility or scientific support with which the boundary for each SF indicator can be defined. Tier 1 includes dimensions, whose indicator directly measures deprivation or needs fulfillment (i.e. anti-deprivation) and the absolute boundary is, accordingly set to 100% or 0%, respectively. Tier 2 relies on existing research studies in which there is sufficient evidence to define a boundary. Tier 3 refers to dimensions, where there are few previously published studies and where the definition of absolute boundaries involves ethical, social or cultural perspectives. Thus, absolute boundary definitions for Tier 3 were based on empirical data and the Human Development Index (HDI), particularly with countries classified under the group 'very high' human development (see **Appendix A.3.1** for details). Absolute boundaries for all 15 dimensions are presented in **Table 2.1**.

The 15 social dimensions and their respective associated indicators define the social state of the system before the implementation of the assessed policy. By comparing this state with the absolute thresholds defined in this study, the absolute social performance of the system in the reference scenario is obtained. Then, social impacts of the assessed policy need to be quantified in the metrics of the indicators defined in this section and compared to the baseline scenario.

Table 2.1: Overview of the 15 social foundation dimensions, their associated top-ranked indicator and absolute boundary.

Tier	Dimension	Indicator	Absolute boundary
Tier 1	Food	Fraction of population undernourished (%)	0%
Tier 1	Water	Fraction of population using safely managed drinking water services (%)	100%
Tier 1	Sanitation	Fraction of population with access to improved sanitation (%)	100%
Tier 1	Housing	Fraction of urban population living in slums, informal settlements or inadequate housing (%)	0%
Tier 1	Income	Fraction of population living below the national poverty line (%)	0%
Tier 1	Education	Children aged 12-15 out of school (%)	0%
Tier 1	Energy	Fraction of population with access to electricity (%)	100%
Tier 1	Safety and Justice	Number of victims of intentional homicide per 100,000 people	0
Tier 1	Networks	National average of binary responses to the question "If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?"	100 % of 'yes'
Tier 2	Work	Unemployment rate by sex, age and persons with disabilities (%)	5%
Tier 2	Gender Equality	Share of women in national parliaments (%)	50%
Tier 2	Life Satisfaction	Cantril life ladder (from 0 to 10)	6.5
Tier 3	Health	Life expectancy at birth (years)	75
Tier 3	Social equity	Palma ratio	1.2
Tier 3	Democratic rights	Voice and Accountability index	1.0

2.2.2. Ex-ante social impact assessment of a policy

The policy scenario consists of assessing the impacts associated with the implementation of a policy and of adding the impacts of the policy results to baseline scenario impact scores. Only impacts associated with the policy are considered in the comparison between the baseline and the policy scenario. All other conditions that might affect the scores of SF dimensions are kept constant, except for population growth, which is accounted for via population projections.

As opposed to environmental impacts which are governed by laws of physics well studied cause-effect mechanisms, social impacts are affected by human behavior, which can be unpredictable and irrational (Sircova et al., 2015), and quantitative social impact assessment models are less developed as they highly depend on cultural and regional context. The novelty of this study is to contribute to the development of a methodology for ex-ante social impact assessment of policies, as standardized methods for assessing social impacts in the context of the SJOS framework are lacking (Raworth, 2012). Several disciplines have developed to answer specific needs, such as Social Life Cycle Assessment (SLCA) with a focus on assessing social impacts from products and services (UNEP/SETAC Life Cycle Initiative, 2009) or Social Impact Assessment (SIA) to analyze, monitor and manage the intended and unintended social consequences of planned interventions (Esteves et al., 2012) (see article Supplementary Material, **section 2.7** for more details). Drawing on these disciplines, a method for quantitatively assessing the social impacts of policies in relation to the SFs was developed. The method consists of three main steps, which are detailed in the next sections: impacts identification; significance assessment; and impact quantification.

2.2.2.1. Impact identification

The impacts identification (Step 1) relates to the identification of the potential positive and negative impacts that might arise from implementing the policy. This method draws on the method developed by Terrapon-Pfaff et al., 2017, which applies a participatory approach for

identifying impacts. The process includes the following steps: (i) Identify relevant stakeholder groups impacted by the policy; (ii) build a diverse and comprehensive panel of people representing different groups affected by the policy; (iii) conduct surveys among this panel to list potential impacts. If i), ii), iii) cannot be performed, an alternative is to (iv) scan existing literature on similar implemented projects in similar conditions to list potential impacts. Lastly, it is needed to (v) classify all identified impacts within the dimensions of the SF.

2.2.2.2. Significance assessment

Step 2 aims at increasing the efficiency of the assessment and only focusing on important social impacts. Accordingly, a significance assessment is carried out to identify significant impacts. The significance assessment is based on four criteria on a five-point scale: Likelihood, Intensity, Geographic extent and Duration (Terrapon-Pfaff et al., 2017), and is used to estimate a final significance score for each identified impact (see Appendices, section **A.3.2** for more details). The final significance scores are, hereafter, ranked and classified as being either 'very low', 'low', 'moderate', 'high' or 'very high'. Impacts classified as having a 'moderate', 'high' or 'very high' level of significance are selected and must be quantified. There may be cases where numerous impacts with 'very low' or 'low' significance all affect one specific SF dimension and, thereby, altogether have a significant impact. To avoid overlooking such cases, significance scores are summed per SF dimension and converted into an aggregated significance level per dimension. Here, dimensions with a 'moderate' or higher level of aggregated significance are included as part of the impact quantification step (referred to as 'relevant dimensions') (see SM, section **A.3.2,** for specific details).

2.2.2.3. Impact quantification

In Step 3, the impacts identified in Step 1 and Step 2 are quantified to facilitate a comparison between a policy scenario and a baseline scenario. Hence, the objective of Step 3 is to draw 'social impact pathways', that represent a range of causal relationships between

indicators in an area of protection (Jørgensen et al., 2009) to quantify both significant impacts and overall impacts on relevant dimensions. Quantifying social impact pathways requires establishment and quantification of causal links between the policy outcomes, the significant impact(s) of the dimension and the associated social foundation indicator. However, in case mechanistic models could not be developed due to the complexity and non-linear characteristics of social behavior, it is recommended to use statistical correlations to express the relationship between different indicators on the social impact pathway and between different SF dimensions. A set of validation conditions were defined to judge if the correlation between e.g. two indicators is sufficiently strong, including a coefficient of determination (r^2>0,5) and a statistically significant correlation coefficient (p-value < 0.05) (see SM, section **A.3.2,** for specific details).

2.2.3. Illustrative case: assessment of a Geothermal Energy Development Policy in Uganda

The methodology presented in Sections **2.2.1** and **2.2.2** is applied in a simple case study as a proof of concept to show the applicability of the methodology in practice and indicate the added value in terms of supporting policymaking. The case study is on the Geothermal Energy Development Policy in Uganda aiming at developing additional 1,500 MW generated from geothermal energy by 2040.

2.2.3.1. Baseline scenario

Data for expressing the social status of Uganda was collected and compiled to construct the 'baseline scenario', where 2018 was selected as reference year. Thus, data for 2018 was prioritized and latest available data was used as a proxy if data from 2018 was not available (see **Table 2.1** in **Section 2.6** for the overview of data sources used to construct the baseline scenario for social impacts). All dimensions were assessed except for *Sanitation*, due to lack

of data, but this does not hinder the demonstration of the proof of concept as energy policy is not likely to have substantial effects on sanitation.

2.2.3.2. Policy scenario

The identification Steps i, ii and iii (see **Section 2.2.2.1**) involving stakeholder participation has not been performed for this illustrative case. To support decision-making in policy design, taking a participatory approach with the application of these steps would be necessary. In this study, as the policy only aims at being a proof of concept, the alternative option of performing a scan of existing literature on similar implemented projects was conducted, based on reports from the African Geothermal Inventory Database (UNEP AGID, 2014) in Uganda and neighboring countries (Bw'obuya, 2002; Mwangi-Gachau, 2011; Namugize, 2011; Oduor, 2010; Shortall et al., 2015; Zakkour & Cook, 2016). As a result, 51 potential impacts were identified (see the article supplementary material (SM) in **Section 2.7** for details). Similarly, the significance assessment and impact quantification were carried out by the authors of this study to illustrate the applicability of the methodology. Six impacts were found to be significant: four in the *Energy* dimension (*Decreased levelized cost of energy and electricity*; *Increased energy security, national independence and stabilization*; *Increased access to energy in households, public infrastructures, etc.*; *Increased share of clean energy*), one in *Income (Increased salaries for directly or indirectly involved employees)*, one in *Health* (*Decentralization of energy systems and health centers)*, plus one other relevant dimension, *Work*, for which the aggregation of numerous impacts with 'Low' or 'Very low' significance was found significant (see the article Supplementary Material in **Section 2.7** for details).

Based on the policy documentation and related literature (UNEP AGID, 2014), it was possible to construct and quantify impact pathways for the significant impacts pertaining to the *Energy* dimension and for the overall impact on the *Work dimension*. A correlation between the social foundation indicators of *Energy* and *Health* was built and validated to quantify the impact of the policy on the *Health* dimension. For the significant impact in the *Income*

dimension, it was not possible to develop the impact pathway due to lack of data. Instead, a correlation between the social foundation indicators of *Energy* and *Income* was tested. Particularly, data points are scattered and no visible correlation can be observed when the 'Proportion of population living below the national poverty line' is plotted as a function of the 'Fraction of population with access to electricity'. Such correlation was found too weak, thus impacts on the *Income* dimension could not be quantified in this case (see the article Suppelmentary Material, **section 2.7** for details on the case-specific impact quantification).

2.3. Results on an illustrative case

The results of the assessment are given in **Figure 2.1** in their normalized form (see **Table 2.2** in **Section 2.6** for all social scores; see Appendices section **A.3.3** for details on normalization method). **Figure 2.1** shows Uganda's current performance in the baseline scenario (colored areas) and the additional social impacts associated with implementation of the geothermal energy policy (grey areas). Notably, the theoretical fraction of the Ugandan population with access to electricity is estimated to significantly rise from 19% to 57%, while life expectancy increases from 57.0 to 66.1 years. *Work* dimension did not show noteworthy changes, as unemployment rate decreased from 9.4% to 9.33%. Lastly, impacts on the *Income* dimension were not considered as they could not be quantified due to limited information to define the causal chain and a lack of correlation between the dimensions *Income* and *Energy* indicators.

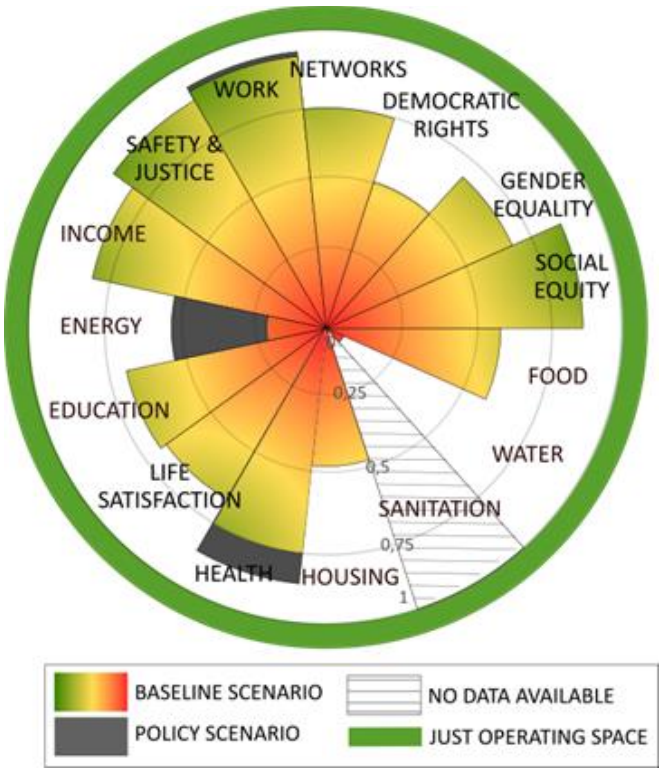


Figure 2.1: Visualization of the current status of Uganda, i.e. the baseline and the social impact of the assessed policy[5].

[5] The results are plotted in their normalized form for each social dimension. Results for social foundation dimension Sanitation are not shown as relevant indicators and impact assessment model could not be derived.

2.4. Discussion

2.4.1. Illustrative case in Uganda as a proof of concept

2.4.1.1. Social impacts of the Geothermal Energy Development Policy in Uganda

The methodology developed in this study, applied on the illustrative case of the Geothermal Energy Development Policy in Uganda, provides an assessment of the baseline scenario (Uganda country) in relation with the SF of the SJOS, and of the impacts on this policy on that system. The results show that Uganda is currently maneuvering in a high state of social deprivation (i.e. no absolute social boundary is met), particularly, within the *Energy* and *Water* dimensions. The introduced policy would improve the performance for four SF dimensions: *Energy, Health, Work, Income*, and significantly on *Energy* and *Health* dimensions. It appears logical that a net-increase in energy generation will have a positive impact on *Energy* in terms of the share of Ugandan population with access to electricity. However, the indirect increase in *Health* expressed as life expectancy is also an important benefit of the policy.

As a result, the policy is found to enhance social standards in Uganda and this benefit should be compared with potential further exceedance of the assigned share of the safe operating space in the metrics of the Planetary Boundaries. The impact assessment methodology presented in this study allows for evaluating social impacts of policies, or other large-scale changes in relation to absolute social boundaries. Here, results allowed for identifying the potential social impacts of implementing the policy and how this would affect the current performance of the country. Indeed, being able to indicate the direct and indirect social effects of introducing a policy is an important contribution to better decision-making. Also, the qualitative assessment, i.e. impact identification and significance assessment, can already highlight what potential impacts would be significant in a policy scenario. This methodology and the visualization of the results could serve as a decision support tool to

quickly assess the social impacts of a policy on a system in early-phase design and to prioritize subsequent in-depth studies.

2.4.1.2. Uncertainties

All types of impact assessments are subject to inherent uncertainties stemming from various sources, such as the selection of models and parameters used as input for the chosen models (Huijbregts, 1998). For example, parameter uncertainty is introduced for the social results from the significance levels defined by expert judgement. Uncertainty due to value choices is seen in the definition of the absolute social boundaries; and model uncertainty is introduced via the selection of models for quantifying social impacts. It is important to identify the various sources of uncertainty and quantify their contribution to the results. This is needed to provide results with confidence intervals and to take measures to reduce their overall uncertainty. It is common practice to provide policymakers with scientific results and their associated uncertainty for political decisions to be made accordingly (Masson-Delmotte et al., 2018). Considering the potentially high uncertainty of the results, it is recommended to use the developed methodology as an initial screening to make informed decisions and allocate resources in key areas, for which more specific assessments should be conducted. For instance, in the proof of concept, the Ugandan policy leads to substantial impacts on the *Health* dimension. However, quantitative results should be examined cautiously since no participatory approach was adopted and no quantification of the sensitivity nor uncertainty has been carried out in this study, and these areas should undergo further investigations. It is therefore recommended to complete the quantification with a participatory approach to corroborate the results including surveys, interviews or panel discussions for example.

2.4.2. Added value and potential of the developed methodology: holistic assessment of social impacts to support better policy making

2.4.2.1. Absolute perspective

The methodology presented in this study facilitates systemic assessment with the development of a framework for social impact assessment in the metrics of the SF of the SJOS. A novel aspect of the SJOS is to bring an absolute perspective when assessing systems' social performance, by defining boundaries for all social foundation indicators. The use of absolute boundaries allows for identifying if the evaluated policy is sufficient for increasing social dimensions to above the boundaries or if additional policies are required to reach a socially sustainable level. This is very relevant for policymakers as it allows for evaluating the efficiency of policies and, thus, designing policies or a suite of policies that are sufficient for making e.g. a country, sustainable in an absolute sense. Also, the consideration of all dimensions of social sustainability allows to highlight benefits and burdens across different social categories, i.e. potential trade-off. This study provides a first take on defining and operationalizing holistic assessments of social impacts relative to absolute boundaries and illustrate the potential of the approach to produce evidence-based and comparable assessment results. This type of approach can help reverse the logic by designing policies with the intention to be sustainable, i.e. use absolute boundaries as targets for policy definition.

2.4.2.2. Potential for early-stage policy development

This methodology holds potential to support decision-making in the design of policies seeking to raise social standards, with an effective visualization and a holistic approach. The qualitative phase of impact identification allows for prioritization of specific impact quantifications, resulting in a relatively quick initial assessment of the policy which can be useful in early phases of policy design. In addition, this methodology could be used to compare

the effects of several policies that are not necessarily related as well as to identify priorities: for example, the social impacts of a food policy could be compared with those of an energy policy. By extension, the combined effects of several policies and the degree they allow to stay within the Safe Operating Space could also be studied using this methodology.

2.4.2.3. Potential use in integrated absolute assessments

This methodology allows for contribution to design policies on an informed basis, where unintentional social burden-shifting can be avoided. It shows a great potential for supporting decision-making and early-stage policy development, especially if combined with an absolute environmental sustainability assessment. Indeed, there is a need for applying systemic approaches that cover both environmental and social aspects to address major challenges such as climate change, social (in)justice and economic growth (Daly et al., 2017). The ability to comprehensively evaluate a policy across a suite of social and environmental indicators is important to avoid unintentional burden-shifting of impacts among the social and environmental indicators. This is important to avoid cases, where policies that focus on improving a single, or a set of, environmental or social aspects have unintended negative impacts on other aspects and to evaluate trade-offs, where such negative impacts occur.

For instance, in Uganda, D. O'Neill, 2018 shows that "only" one of the seven PB covered in its study, namely *Land-system change,* is found to be transgressed in the baseline scenario. This is due mainly to Uganda's large agricultural sector where forest has been converted into arable land (Obua et al., 2010). For all other PB, Uganda operates within its assigned SoSOS. Thus, there is not a large need for introducing policies aiming at reducing environmental impacts because Uganda is generally acting within its assigned SoSOS. Instead, the focus of Ugandan policies should be to improve social conditions while not further exceeding the environmental ceiling.

2.4.3. Limitations and further work

The assessment methodology developed in this study shows potential for supporting policy-related decisions on the social aspect. Still, several challenges must be addressed and are subject to further work, to improve the applicability and robustness of the methodology. It is also recommended to test the methodology via application on different types of policies with stakeholders' engagement to detect potential dead-ends and other improvement needs. The methodology developed in this study could also be further investigated at sub-state levels, e.g. in relation to organizations.

2.4.3.1. Limitations in defining the Social Foundation

Defining boundaries for the SF comes with the underlying assumption that such universal standards exist. However, most choices, when defining boundaries, are normative and influenced by values, which are in turn context and time dependent. Therefore, it is essential to be transparent in the definition of boundaries. In this regard, the tiered classification of dimensions gives insights on which absolute boundaries are more consensual than others. Moreover, the definition of the SF's dimensions does not prevent potential overlaps between dimensions, which may result in over-representation of certain issues (e.g. *Housing* with *Water*, *Sanitation* or even *Energy*). Dimensions are also considered equally important, when it can be argued that some (e.g. *Food*, *Water*, *Health*) represent basic needs that are essential to fulfil, while others (e.g. *Democratic rights*, *Social equity*) are higher psychological needs, based on Maslow's hierarchy (Maslow, 1943). Further research could investigate if core social dimensions might be defined and might be given greater weight. It is important that the methodological limitations and the importance of value-based choices are further investigated, notably through stakeholders' engagement and participatory approaches, to increase the robustness of the methodology. Further research could also examinate the definition of the social foundation based on sufficiency, deprivation and human needs in different geographical and cultural contexts.

2.4.3.2. Further development of the SJOS impact assessment method

This methodology is developed with a focus on systems that have not reached the social foundation and probably nor overshoot the environmental ceiling, such as for low-income countries. This choice is reflected in the definition of indicators and the normalization of social scores, aiming at enhancing social standards. Practically, focusing on depicting the reduction of deprivations for all means overlooking what happens on the 'other side' of the social foundation. Therefore, it proves to be less adequate for systems that have high social standards (beyond the social foundation) at the expense of the PBs that might already be transgressed. Such trends are common patterns of 'high income countries' (D. O'Neill, 2018). Subsequently, other indicators would be required in order to reveal 'the social standards surplus' (what happens once the SF is met). For example, the indicator "% of population undernourished" of the *Food* dimensions could be changed to "Obesity rate". This approach would then serve a different purpose, aiming at granting a 'social budget', i.e. a maximum decrease or stagnation in social standards, for each reduction of environmental stress. It poses the following question: How to maintain good living standards, while drastically decreasing anthropogenic environmental pressures? To address this issue, the methodology could be adapted to not only look at minimum social foundations but also to account for excessive social conditions, and then compare with results of an absolute environmental sustainability assessment. This question is found to be highly normative though critical with the planetary state as expressed by the Planetary Boundaries framework. Further research could investigate the relation between the absolute social thresholds and their potential exceedance while maintaining our Earth System with Planetary Boundaries.

Even though the social assessment embraces socio-economic considerations through the *Work* or *Income* dimensions, it does not evaluate the performance of the economy at the system level. This simplification hides important parameters that could influence the sustainability performance of a system, as no sustainable state can be reached without levers to be pulled in

the economic playing field (Biermann et al., 2012). While the end-goal of absolute social sustainability is people welfare, it is deemed interesting to take process-goals into consideration as levers to reach social sustainability, including large-scale economic variables, such as GDP or income distribution, to represent the response of the social states of a system to its economic evolution.

2.5. Conclusion

This study developed a novel methodology for evaluating the social impacts of policies in relation to absolute boundaries for social deprivation. The methodology allows for defining the social sustainability state of a system in 15 social dimensions and quantifying associated social impacts. It was tested on an illustrative example of a Geothermal Energy Development Policy in Uganda. The results identify the social impacts of implementing the policy for Uganda and to which extent the policy contributes to achieving social sustainability. Thus, we see that the methodology has the potential to express the effects of a policy on social conditions. This allows for gauging and evaluate the effect of future policies and designing policies or policy sets that allows for achieving social sustainability. This has the potential to be combined with assessments of environmental sustainability to evaluate to which extent policies contribute to staying within the Safe and Just Operating Space. Still, future work is needed on quantifying and indicating uncertainty of the results as well as further testing of the methodology in more case studies to detect potential needs for improvements. Nevertheless, transformational policies are required to address both environmental and social problems and it is imperative that environmental sustainability is not achieved at the expense of social sustainability. Thus, methods for assessing social sustainability of policies in an absolute perspective are needed to provide a holistic evaluation of policies to avoid potential burden shifting between environmental and social aspects. We see this method as an important aid for decision-makers as part of policy making and evaluation to ensure the development of policies that can provide

the transformational changes needed for making humanity navigating within the Safe and Just Operating Space.

2.6. Chapter appendix 2A: Supplementary Material

Supplementary information associated with this article can be found in https://ars.els-cdn.com/content/image/1-s2.0-S0195925523000641-mmc1.xlsx

2.7. Chapter appendix 2B: Supplementary Data

Supplementary data associated with this article can be found in https://ars.els-cdn.com/content/image/1-s2.0-S0195925523000641-mmc2.docx

2.8. **Chapter appendix 2C:** Detailed scores for social assessment

Table 2.2: Scores for Uganda for each dimension of the social foundation for both the baseline and policy scenarios. n.a. stands for 'non-applicable', norm.score for 'normalized score'.

Dimension	Indicator	Absolute boundaries	Baseline scenario			Policy scenario	
			Score	Norm. score	Year and Source	Score	Norm. score
Food	Fraction of population undernourished (%)	0 %	41.4 %	0.586	2016; (FAO, n.d.)	41.4 %	0.586
Water	Fraction of population using safely managed drinking water services (%)	100 %	6.44 %	0.0644	2015; (WHO/UNICEF, 2017a)	6.44 %	0.0644
Sanitation	Fraction of population with access to improved sanitation (%)	100 %	No data	n.a.	n.a.	No data	n.a.
Housing	Fraction of urban population living in slums, informal settlements or inadequate housing (%)	0 %	53.6 %	0.464	2014; (United Nations, n.d.-a)	53.6 %	0.464
Health	Life expectancy at birth (years)	75 yr	57.0 yr	0.762	2012; (WHO, n.d.)	66.1 yr	0.884
Income	Fraction of population living below the national poverty line (%)	0 %	19.7 %	0.665	2012; (World Bank, n.d.-a)	19.7 %	0.665
Work	Unemployment rate, by sex, age and persons with disabilities (%)	5.0 %	9.40 %	0.927	2017; (ILOSTAT - LFS, n.d.)	9.33 %	0.928
Education	Children aged 12-15 out of school (%)	0 %	31.4 %	0.686	2008; (UNESCO - Institute for Statistics, n.d.)	31.4 %	0.686
Energy	Fraction of population with access to electricity (%)	100 %	19.0 %	0.190	2016; (IEA, 2017)	56.8 %	0.568

Safety and Justice	Number of victims of intentional homicide per 100,000 people	0	11.5	0.890	2014; (United Nations, n.d.-b)	11.5	0.890
Networks	National average of responses to the question "If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?"	100 % 'yes'	74 %	0.740	2014; (Helliwell et al., 2019a)	74 %	0.740
Gender equality	Share of women in national parliaments (%)	50 %	34.3 %	0.686	2018; (Inter-Parliamentary Union (IPU), n.d.)	34.3 %	0.686
Social equity	Palma ratio	1.2	2.0	0.862	2017; (UNDP, 2018a)	2.0	0.862
Democratic rights	Voice and Accountability index	1.0	- 0.6	0.518	2017; (World Bank, n.d.-b)	- 0.6	0.518
Life Satisfaction	Cantril life ladder	6.5	4.3	0.665	2018; (Helliwell et al., 2019a)	4.3	0.665

CHAPTER 3

Methods for defining climate change mitigation strategies at organizational level: review and outlook

This chapter is based on the article entitled "Methods for defining climate change mitigation strategies at organizational level: review and outlook", submitted to Business Strategy and the Environment on the 7th of September, 2023, currently under review.

Abstract

The private sector has a pivotal role in contributing to the objective of the Paris Agreement and its 1.5-degree target. However, there is a lack of a comprehensive framework to define and implement climate change mitigation strategies in organizations. The current study fills this gap and aims to perform a critical review of existing methods that can make a partial contribution to the definition of such strategies. We found 25 methods and evaluated them based on 15 criteria developed for this study. No method fulfills all the criteria, but significant differences are observed between them, ranging from 0% to 80% of the criteria met. Based on this analysis, we propose a first harmonized 5-step iterative framework to define organizational climate change mitigation strategies. Eventually, the results of the review and the framework proposal draw up a research agenda to derive robust, credible and operational climate strategies at organizational levels.

Keywords

Corporate climate change mitigation strategy; non-state climate action; climate change mitigation; climate strategy framework; methods evaluation; environmental management

3.1. Introduction

To limit global warming to well below 2°C and pursuing efforts to limit it to 1.5°C, a drastic systemic change within a decade is needed (IPCC, 2018a). Antonio Guterres, Secretary General of the United Nations, issued in 2022 a call for urgent actions to address the climate crisis (UNEP, 2022). In response, states and sub-states actors including the private sector must take ambitious climate measures, with mutual influence on each other (Chan et al., 2018; Persson & Rockström, 2011; Rashed & Shah, 2021). The legislative sphere is driving efforts to frame and regulate corporate climate disclosure (European Parliament, 2020, 2022; U.S. Securities and Exchange Commission, 2022). For instance, the European Commission adopted in July 2023 the European Sustainability Reporting Standards (ESRS), acknowledging that climate change has wide-ranging impacts across the economy and that it should systematically be a priority issue for organizations (European Commission, 2023). From 2024 the CSRD has planned to progressively require large European companies to disclose their transition plan for climate change mitigation, policies, actions, targets and resources related to climate change mitigation and adaptation as well as their GHG emissions, energy metrics and internal carbon pricing, among others (EFRAG, 2022).

The private sector and sub-state entities play a pivotal role in implementing innovation and incorporating Corporate Social Responsibility (CSR) and Environmental, Social and Governance (ESG) metrics into their core strategies (Barre-Bon et al., 2017; Busch, Barnett, et al., 2023). In this regard, for the last decades, corporations have increasingly recognized the importance of climate change in their strategic planning, focusing on greenhouse gas (GHG) emission mitigation, climate risks, and adaptation (Aggeri & Cartel, 2017; Iken et al., 2019). However, there are concerns that the efforts made by various organizations may not be efficient, sufficiently ambitious or transparent (T. N. Hale et al., 2020), as demonstrated by findings of Carbon Disclosure Project (CDP) 2022 report. It revealed that among the 18,000 organizations

that disclosed information through the Climate Change questionnaire, only a small proportion (3%, 4%, and 7%) met the CDP disclosure criteria for financial planning, targets, and strategy, respectively (CDP, 2022a). In addition, a report by NewClimate Institute shows that out of 24 leading global companies assessed on their criteria, fifteen demonstrated low or very low integrity in their climate strategies (Day et al., 2023).

Two major obstacles to broader and bolder climate actions at organizational level can be identified: i) the inconsistent accounting of GHG emissions and associated trajectories, ii) the lack of standardization in corporate low-carbon strategy development (World Economic Forum, 2021). In a systematic literature review focused on carbon accounting, Marlowe et al. highlighted that, though corporate climate strategies are much broader than GHG emission accounting, very few articles have addressed strategic considerations, decision-making, transition pathway or corporate climate operational action at the organizational level (Marlowe et al., 2022). These studies have focused mainly on GHG emissions accounting, analysis of corporate climate disclosure (Demastus & Landrum, 2023; Kang & Kim, 2022; Köves & Bajmocy, 2022), the influence of climate reporting on financial performance (Castilho & Barakat, 2022; Grishunin et al., 2022; Park, 2023), carbon accounting performance indicators (Daimi & Rebai, 2022), or climate change mitigation targets (Andersen et al., 2021; Bjørn et al., 2017; Bjorn et al., 2021; Faria & Labutong, 2019; Giesekam et al., 2021a; Rekker et al., 2022; Ryberg et al., 2018a; SBTi, 2019c; Walenta, 2019). In the scientific literature, there is currently a deficiency of guidelines for sub-state actors on how to formulate a comprehensive climate change mitigation strategy. However, in the grey literature, numerous methods have been devised to partially address different aspects belonging to a potential corporate climate transition plan (CDP, 2021). Synergies, complementarities, and barriers between these methods need to be understood to ensure consistency and credibility as well as to develop a comprehensive methodology.

The emergence of multiple climate commitments among various actors requires the development of such methods that can help subnational actors to contribute to close the emissions gap (United Nations Environment Programme, 2016). Here, we define an organizational climate change mitigation strategy (OCCMS) as a time-bound set of means and ends an organisation makes use of to achieve goals that are intended to mitigate the impacts of climate change in its value chain. OCCMS are also commonly called climate transition plans, climate strategies, low-carbon strategies, which typically constitute a crucial component of broader transition initiatives encompassing climate change adaptation and other environmental impact mitigation. While some scholars tried to build theoretical frameworks for corporate sustainability (Imbrogiano & Nichols, 2021; Molin et al., 2022; Sanchez-Planelles et al., 2021), no study has been directed to a comprehensive OCCMS framework, specifically addressing climate change from corporate levels. No academic review nor harmonization of these methods have been conducted, thus preventing such understanding and the adoption of standardized complete OCCMS framework. This article provides a full overview of all these methods as well as what elements they address, and use them to define and recommend a comprehensive OCCMS methodology.

The present study focuses on the critical review of existing methods that address some elements of a potential OCCMS. It aims (i) to perform a critical review of existing methods in terms of the core principles of scientific integrity, as well as (ii) to provide recommendations for the development of a harmonized, robust and transparent OCCMS framework allowing to consistently derive climate strategies at organizational level.

3.2. Methods

3.2.1. Research methodology overview

Figure 3.1 presents the steps of the review. A number of steps are defined to frame an OCCMS, which are used to categorize methods (**Section 3.2.2)**. Then relevant methods were identified from both grey and scientific literature (**Section 3.2.3**). Evaluation criteria are then defined (**Section 3.2.4**) to evaluate OCCMS methods based on semi quantitative scale (**Section 3.2.5)**. This methodology highlights the complementarities and gaps between methods and lays the foundations of a methodological framework for defining an organization-wide climate change mitigation strategy.

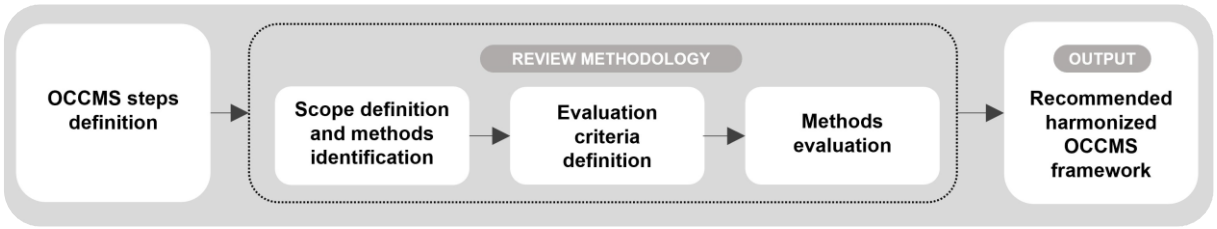


Figure 3.1: Overview of the methodology and the different stages of the review. OCCMS: organizational climate change mitigation strategy.

3.2.2. Required steps for an OCCMS

To facilitate and harmonize the review, different steps of a comprehensive OCCMS methodology were developed and used as a categorization frame for classifying the retained methods. This categorization is documented in **Figure 3.2.**

The first step proposed here for defining an OCCMS is to frame the strategy, in the form of a goal and scope definition, as it is a prerequisite for every assessment project or strategy development, including Life Cycle Assessment for example. Then, measuring through GHG emission accounting is essential for obtaining a comprehensive quantitative understanding of

critical issues and dependencies related to GHG emissions and fossil fuels. Next, an analysis of the current situation should include strategic aspects, consider the current strategy of the organization, while also integrating key aspects such as governance, management, influence, levers, and barriers. Subsequently, a commitment is necessary to formulate quantitative and qualitative targets, aiming to anticipate and align with the goals of the Paris Agreement and a low-carbon economy. Lastly, implementation is essential to ensure consistency between the preceding steps and achieve trajectory success, involving operational actions with different stakeholders. Lastly, reporting is crucial to ensure the transparency and credibility of the overall strategy and we recommend an iterative process, including measurement at least once a year. This process facilitates the evaluation of consistency between accounted GHG emissions, the climate action plan, and projections, enabling adjustments to the OCCMS.

Figure 3.2: *Overview of the different steps of an OCCMS, used to categorize the methods OCCMS: organizational climate change mitigation strategy.*

3.2.3. Scope definition and method identification

All selected methods were conditioned to address one or several of the steps of the OCCMS required structure. They need to target the organizational level as opposed to national or territorial levels, to be publicly available, to include a translation in English or French (French language was additionally considered as it is mastered by the author team). Methods for specifically adjusting organizational strategies to the current and future effect of climate change, i.e., climate change adaptation, for developing strategies to limit the pressure on other environmental aspects than climate change, or for taking exclusively energy transition issues into organizations strategies, are not included within the scope of this study.

The identification of the relevant studies was done by searching the Web of Science database (Web of Science, 2023). The following search query was used: *(TI=(company OR companies OR corporate OR corporation OR industry OR organization* OR organisation* OR "private sector")) AND (TI=("low-carbon" OR "low carbon" OR climate OR carbon OR "GHG emissions" OR mitigation OR "planetary boundary" OR "planetary boundaries" OR sustainability OR decarbonization OR decarbonisation)) AND (TI=(strateg* OR method* OR tool OR instrument OR process OR framework))* with restrictions to research articles before 2023/03/31. In total, the search generated 946 results, which were filtered on for relevance, according to the review scope. As many methods to provide organizations with guidelines in their climate mitigation strategies are available among institutional and private sector documents, a grey literature search using the Google search engine was additionally conducted, complemented with combined academic and industry experience from the authors including French literature.

Some methods precisely address specific elements of OCCMS, some serve as guidelines for monitoring and reporting, others are more general and cover a large part of an OCCMS. Therefore, they are categorized according to the steps of an OCCMS defined in **Section 3.2.2.**

In addition, methods are also categorized by whether they target specifically financial organizations (such as investors, banks, funds, their portfolios, etc.) or any organization, as many methods are designed for the financial sector.

3.2.4. Evaluation criteria definition

Here, evaluation criteria are defined to define the key principles of a method addressing one or several steps of an OCCMS. They are chosen based on previous scientific works that conducted reviews of environmental sustainability assessment methods such as GHG emission accounting or life cycle assessment (CDP, 2021; EC-JRC, 2010; Eleftheriadis & Anagnostopoulou, 2017; Faria & Labutong, 2019; T. N. Hale et al., 2020). That led to include the 5 following criteria: multi-level applicability; scope; scientific robustness; accessibility and adoption; stakeholders' involvement. A number of sub-criteria were additionally developed to specify each criterion, as depicted in **Table 3.1**.

3.2.5. Methods evaluation

For all sub-criteria, we propose a semi-quantitative scale to assess how a given method can contribute to the definition of an OCCMS, on a three-tier scale level. This choice of three levels was made with the objective to answer the question "does this method fully meets this criterion?". Level 2 corresponds to a method that fully meets the criterion, level 1 partially and level 0 not fulfilling it. For example, a method will get the higher score (level 2) in the sub-criteria *Adaptability to all sectors* if it has specific methodological development for precise sectors (e.g. retail), a medium score (level 1) if it has specific methodological development for the three economic sectors (primary, secondary, tertiary) or other macro sectors, and the minimum score if it has no specific sectoral development (level 0). Further details on sub-criteria are available in **Table 3.4** in this chapter appendix (**Section 3.6)**. Each of the 25 methods was reviewed, by analyzing the available background documents against the 15 evaluation sub-

criteria, as outlined in supporting information. In addition, scientific articles published on certain methods were used to assist in their evaluations.

Table 3.1: Overview of the assessment criteria, sub-criteria, and their definitions.

CRITERIA	SUB-CRITERIA	DEFINITION
Multi-level applicability: quality of the method to be able to be applied or adapted to different situations	**Adaptability to all sectors**	Method specificity for different professional sectors, with differentiations for each sector
	Applicability to all sectors	Method applicability to all professional sectors
	Adaptability to all sizes and types	Method adaptability to all organisations size and types
Scope: boundaries and extent of the method within the organization	**Climate-associated risks and opportunities**	Consideration of the multiple risks (physical, political, environmental, economic, social, reputational) involved in a climate transition
	Consideration of the initial organizational climate context	Consistency with the operational context of the organization and its initial situation in terms of GHG emissions and associated climate change mitigation strategy
	Inclusion of all organisation activities	Implementation of the climate mitigation strategy within the organization in all departments, at all levels including governance, and consideration of the value chain
Scientific robustness: ability to integrate scientific approach and up-to-date science	**Uncertainty assessment**	Assessment of uncertainties in the scientific quantitative data and information provided by the organization
	Consideration of other sustainability parameters	Consideration of other environmental or social indicators (e.g. carbon footprint, impact on biodiversity, chemical pollution, resources, etc.), in order to avoid burden shifting.
	Scientific review of the method	Peer-review process in the method definition and publication in scientific journals, norms or standards
Accessibility and adoption: clarity of the method, accessibility to information and adoption by organizations	**Accessibility of the method**	Possible access for all to every information and hypothesis of the different case studies and methods
	Usage by organizations	Number of organizations that have already used the method
	Existing public case studies	Number of available case studies and business cases
Stakeholders' involvement: Participation of various external stakeholders in the method processes	**Involvement of multiple stakeholders in the processes**	Need to involve external partners (e.g. customers, suppliers) in the method application
	Support for organizations	Possibility for the organization to be assisted from qualified experts, to have trainings and capacity building
	Alignment with recognized authorities and policies	Alignment of the method with political targets (national, EU, NDC, etc.) and mention of the method in an official regulations or statements

3.3. Results and Discussion

3.3.1. Overview of OCCMS methods

A total of 25 methods could be retrieved from both grey and scientific literature with a view to help define an OCCMS. They originate from various sources such as NGOs, trade associations, scholars, and institutions, with a majority (72%) developed in 2015 or later, and all of them have been updated after 2015. **Table 3.2** summarizes all methods and their associated stage in OCCMS, and whether they target financial organizations and those targeting non-financial organizations (referred to as "all organizations"). The detailed evaluation of each method can be found in supporting information. Out of the 25 methods, 56% target all types of organizations and 44% are aimed specifically at financial organizations. The focus on finance may be attributed to its recognition as a key tool for achieving global climate goals, increasingly after the adoption of the Paris Agreement in 2015 (Berrou et al., 2019). 10 out of 11 financial methods were developed after this date, alongside other initiatives like the European Commission's publication of the first Action Plan for a Greener Economy in 2018 (European Commission, 2018).

The trend of the methods developed over time shows an emphasis on GHG emission accounting in the early years and a shift towards climate change mitigation targets definition in more recent times. The other steps of the OCCMS framework are less represented, suggesting that the progress in addressing these phases might still be in its initial stages. While all steps are covered by at least one method, none addresses all the steps of an OCCMS, which is to be expected due to the lack of framework in the literature. About 84% of the methods address multiple objectives of an OCCMS definition; 60% address two objectives. Five methods (20%) address three objectives, 3 of them targeting financial organizations, in addition to the TCFD which is finance-oriented but still concerns all organizations and to the GHG Protocol whose

main aim is GHG emission accounting. One method is targeting 4 objectives, namely Assessing Low-carbon Transition Step-by-step (ACT-S), which include in its scope a goal and scope definition of the OCCMS, a strategic analysis of the current situation, the definition of climate change mitigation targets, and the definition and deployment of an action plan.

More than half of the methods include a goal and scope definition phase in their objectives (67% for generalist methods, 30% for financial methods), as this step in important in any strategic development to frame the approach. Yet there are no method only aiming at defining the goal and scope of the corporate climate change mitigation strategy, which does not make this category a goal, but rather a prerequisite. In the following, this step is not considered for extensive analysis as no methods are targeting it specifically.

Table 3.2: *Identified methods that contributes to define an organizational climate change mitigation strategy (total of 25 methods)*[6].

Name (Acronym)	Founder(s); year of creation; year of last update	Targeted user		Categorization						Reference
		All Organizations	Financial organizations	Goal & Scope definition	GHG emission accounting	Strategic analysis of current situation	Climate change mitigation targets	Action plan definition and deployment	Monitoring of progress, reporting and verification	
Assessing Low-Carbon Transition, Assessment (ACT-A)	CDP (Carbon Disclosure Project); ADEME (Agence De l'Environnement et la Maitrise de l'Energie); 2015; 2019	(Y)	(N)	(Y)	(N)	**(Y)**	(N)	(N)	(N)	1
Assessing Low-Carbon Transition, Step-by-step (ACT-S)	CDP (Carbon Disclosure Project); ADEME (Agence De l'Environnement et la Maitrise de l'Energie); 2015; 2019	(Y)	(N)	(Y)	(N)	(Y)	**(Y)**	**(Y)**	(N)	2
Bilan Carbone (BC)	ADEME (Agence De l'Environnement et la Maitrise de l'Energie); ABC (Association Bilan Carbone); 2002; 2022	(Y)	(N)	(Y)	**(Y)**	(N)	(N)	(N)	(N)	3
B-Impact Assessment (BIA)	B Lab; 2006; 2019	(Y)	(N)	(N)	(N)	(N)	(N)	(N)	**(Y)**	4
CDP Questionnaire; CDP-Climate Change (CDP-Q)	Carbon Disclosure Project; 2011; 2022	(Y)	(N)	(N)	(N)	(Y)	(N)	(N)	**(Y)**	5
Climate Action 100+ : Net zero company benchmark (CA100+)	AIGCC (Asia Investor Group on Climate Change); Ceres; IGCC (Investor Group on Climate Change); IIGCC (Institutional Investors Group on Climate Change); PRI (Principles for Responsible Investment); 2017; 2021	(N)	(Y)	(N)	(N)	**(Y)**	(Y)	(N)	(Y)	6
Climate Bonds Standard version 3.0 (CBI)	Climate Bonds Initiative; 2011; 2019	(N)	(Y)	(N)	(N)	**(Y)**	(N)	(N)	(N)	7
Climate Safe Lending Network: Taking the Carbon Out of Credit (CSLN)	Climate Safe Lending Network; 2020; -	(N)	(Y)	(N)	(N)	(N)	(Y)	**(Y)**	(N)	8
Recommendations and Guidance on Financial Institution Net-zero Transition Plans (GFANZ)	Glasgow Financial Alliance for Net Zero; 2021; -	(N)	(Y)	(Y)	(N)	(N)	**(Y)**	(N)	(N)	9
Global Climate Insights / Climate plan voting guidelines (ACCR)	Australasian Centre for Corporate Responsibility; 2021; -	(Y)	(N)	(N)	(N)	(N)	**(Y)**	(N)	(N)	10
Greenhouse Gas Protocol (GHGP)	WRI (World resources Institute); WBCSD (World business Council for Sustainable Development); 1998; 2015	(Y)	(N)	(Y)	**(Y)**	(N)	(Y)	(N)	(N)	11
GRI 305 : Emissions (GRI)	Global Reporting Initiative; 2016; -	(Y)	(N)	(Y)	(N)	(N)	(N)	(N)	**(Y)**	12
The Investor Climate Action Plans (ICAPs) Expectations Ladder and Guidance	The Investor Agenda (7 founding partners: AIGCC (Asia Investor Group on Climate Change); CDP (Carbon Disclosure Project); Ceres; IGCC (Investor Group on Climate Change); IIGCC (Institutional Investors Group on Climate Change); PRI (Principles for Responsible Investment) and UNEP Finance Initiative; 2021; -	(N)	(Y)	(Y)	(N)	(N)	(Y)	**(Y)**	(N)	13
ISO 14064:2018 - Greenhouse gases and ISO 14069 ; (ISO 14064)	ISO (International Organization for Standardization); 2006; 2018	(Y)	(N)	(Y)	**(Y)**	(N)	(N)	(N)	(N)	14
Net Zero Initiative (NZI)	Carbone 4; 2018; 2020	(Y)	(N)	(Y)	(N)	(N)	**(Y)**	(N)	(N)	15
Oxford Martin Principles for Climate-Conscious Investment (OMPCCM)	Oxford Martin School / University of Oxford; 2018; -	(N)	(Y)	(N)	(N)	(N)	**(Y)**	(N)	(N)	16
Paris Aligned Investment Initiative : Net Zero Investment Framework (PAII)	IIGCC (Institutional Investors Group on Climate Change); 2019; 2021	(N)	(Y)	(N)	(N)	(N)	**(Y)**	**(Y)**	(N)	17
Quanti GES (Q-GES)	ADEME (Agence de l'Environnement et la Maîtrise de l'Energie); 2015; 2021	(Y)	(N)	(Y)	(N)	(N)	(N)	**(Y)**	(N)	18
Recommendations of the Task force on Climate-related Financial Disclosures (TCFD)	TCFD (Task force on Climate-related Financial Disclosures); 2017; 2021	(N)	(Y)	(Y)	(N)	**(Y)**	(Y)	(N)	(N)	19
Say on climate (SOC): guide for companies	CIFF (Children's Investment Fund Foundation); 2020; -	(N)	(Y)	(N)	(N)	(N)	**(Y)**	(Y)	(N)	20
Science Based Targets initative : Net-Zero Standards - Standard ; (SBTi NZS)	CDP (Carbon Disclosure Project); WRI (World Resources Institute); WWF (World Wildlife Fund); UNGC (United Nations Global Compact); 2020; 2021	(Y)	(N)	(N)	(N)	(N)	**(Y)**	(N)	(N)	21
Science Based Targets intiative (SBTi short-term)	CDP (Carbon Disclosure Project); WRI (World Resources Institute); WWF (World Wildlife Fund); 2015; -	(Y)	(N)	(N)	(N)	(N)	**(Y)**	(N)	(N)	22
Sustainable finance plan of the International Capital Market Association (ICMA)	International Capital Market Association; 2018; 2021	(N)	(Y)	(N)	(N)	(N)	**(Y)**	(Y)	(N)	23
Système de Management des Gaz à Effet de Serre (SM GES)	ABC (Association Bilan Carbone); 2012; 2015	(Y)	(N)	(Y)	(N)	(N)	(N)	**(Y)**	(N)	24
Transition Pathway Initiative (TPI) methodology and indicators report, v3	Church of England National Investing Bodies (Church of England Pensions Board; Church Commissioners and CBF Funds); Environment Agency Pension Fund; 2017; 2020	(N)	(Y)	(Y)	(N)	**(Y)**	(N)	(Y)	(N)	25

[6] (Y) corresponds to methods that meet a column condition, (N) those that do not. In the method categorization, dark green is used when the intended use is the main one, and light green when a method covers a purpose complementary to the main one. Full references of the methods can be found in Appendices, section **3.5**.

3.3.2. Criteria-based method evaluation

The evaluation of all 25 methods is presented in **Figure 3.3**, showing a comprehensive review of methods across all criteria, evaluated against each criterion using a three-level color-coding system. The method fulfilment of the different criteria varies across criteria (see supporting information for more details). It can be observed that no method fulfils all sub-criteria and criteria in any category of a comprehensive OCCMS.

3.3.2.1. Multi-level applicability and accessibility of the existing methods

Overall, with regards to the multi-level applicability criteria, the retrieved methods exhibit a high degree of flexibility and are well-suited to specific sectors and compatible with organizations of all sizes and sectors, with 68% fulfilling both adaptability and applicability to all sectors, and 84% being adaptable to different sizes and companies. In terms of accessibility and adoption, the majority of the methods are publicly available (68% fulfilling the accessibility criteria), but there is often a lack of transparency regarding how organizations use them and limited existing case studies (52% were identified to present case studies). One of the consequences is the difficulty to analyze the results, the effectiveness of methods, and the impact in terms of climate change mitigation.

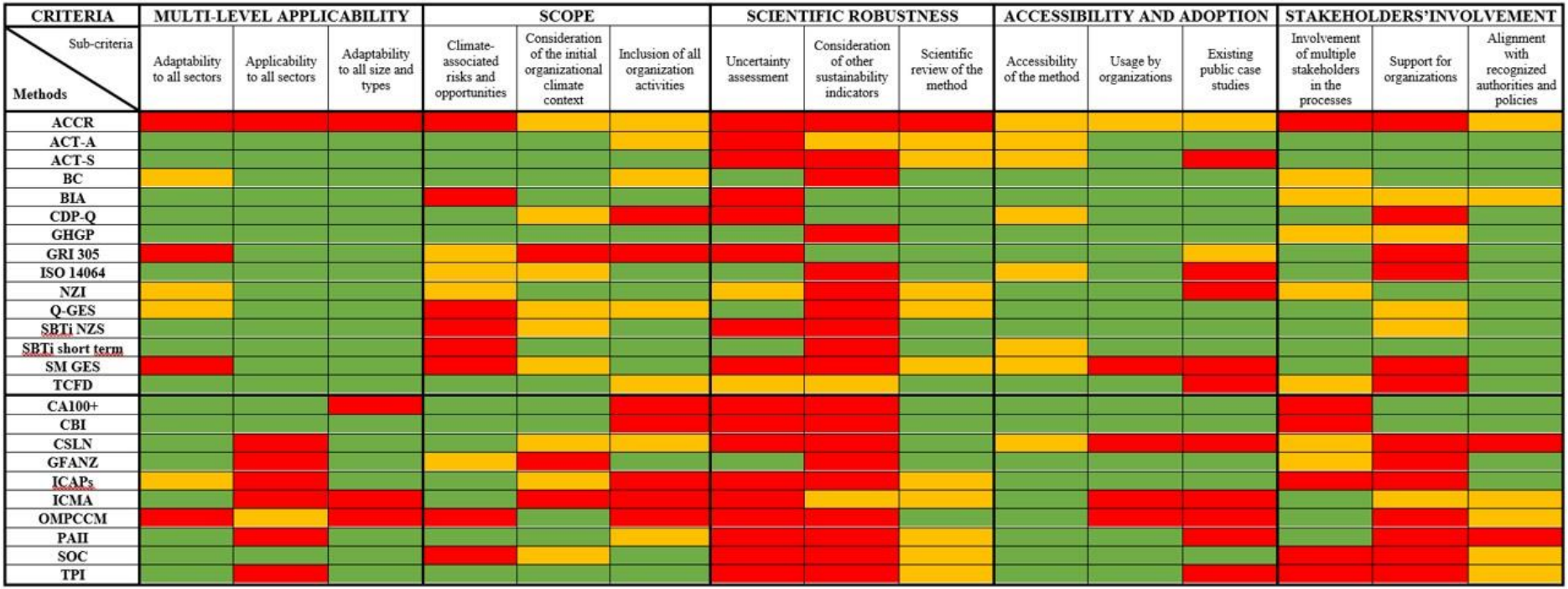


Figure 3.3: *Review matrix representing the evaluation of retrieved methods for contributing to the definition of organizational climate change mitigation strategy (OCCMS)*[7].

[7] The color green is used when a method fully meets the criterion (level 2 of sub-criteria evaluation), red when it does not meet the criterion at all (level 0), and orange when it partially addresses issues related to the criterion but does not go into sufficient detail to consider that it fully meets it (level 1). The methods are arranged in alphabetical order, beginning with those targeting all types of organizations, followed by those targeting financial organizations. Full names of the methods can be found in **Section 3.5** and the definition of sub-criteria evaluation method in **Section 3.6**.

3.3.2.2. Various involvement of internal and external stakeholders

The results for the scope criteria are varied (between 44% and 52% of fulfilment for the three sub-criteria), with only a few methods requiring participation and commitment from governance, except for initiatives from financial trade associations that necessitate communication and disclosure (CA100+, GFANZ, PAII, TPI) and ACT-S. In the category of Acceptance and usage, the involvement of external stakeholders and support for organizations in applying the methods are not commonly practiced (48% of the methods fulfil the sub-criterion of multiple stakeholder's involvement in the OCCMS process) and only 28% of the methods facilitate the support of companies in their implementation through extensive guidelines or qualified experts. This may be attributed to the prevalence of methods sourced from grey literature, often proprietary to companies with potential biased interests. This lack of involvement is detrimental, since systemic or transformational change needs to involve the organization's governance and key stakeholders (Lopes de Sousa Jabbour et al., 2020).

3.3.2.3. Lack of scientific robustness in the methods

About 56% of the methods included a scientific peer-review in the method definition, with most methods being based on grey literature. In addition, only 24% of the methods consider the management of uncertainties in their processes, precisely all 3 methods for GHG emission accounting in addition to QUANTI-GES and Science-Based Target short-term. This is especially critical given that the uncertainties surrounding GHG emissions in organizational value chains are frequently high, notably for Scope 3 emissions which are usually often the most significant (Klaaßen & Stoll, 2021). GHG emission accounting methods fulfil sub-criteria of scientific robustness, given their uncertainties management and scientific review. However, this rigor is not extended to other quantitative steps, such as target definition or the quantification of mitigation potential in the action plan definition phase. Conversely, for qualitative and operational stages, such as strategic analysis or action plan deployment, offering a method to

quantify uncertainties is needed to integrate them in reporting and publish transparent and credible analysis.

The potential for burden shifting across environmental dimensions is also overlooked, which is not surprising since the methods examined in this study are designed specifically for climate change mitigation strategies. Yet, it is important to mention the limitations of the mono-criteria approach in the methods and to build in links with other methods as impact categories, as environmental impact categories (e.g., related to planetary boundaries) are often interdependent (Steffen et al., 2015).

3.3.3. OCCMS steps analysis

Figure 3.4 shows the performance of methods regarding evaluation criteria, within the different categories of methods. The scores for each sub-criterion cannot be directly summed up within and across the different criteria because weighting across them would yield too much uncertainty. Consequently, the results of the evaluation should be interpreted as a hotspot study to identify the strengths and weaknesses of the different methods and not as an overall comparison across the different criteria, while comparison across methods for one criterion is possible. In the following, each step of OCCMS is analyzed individually. Prominent methods, those performing the best from the review in terms of number of sub-criteria met, are identified for each step to feed into OCCMS recommendations. In average, similar trends are observed for the steps of climate change mitigation targets definition and action plan definition, both fulfilling less criteria than other categories (see **Figure 3.4**). This reflects a lower maturity in these methods, possibly as they are more recent and less widespread in organizations. On the contrary, GHG accounting methods and strategic analysis methods seems to be more mature.

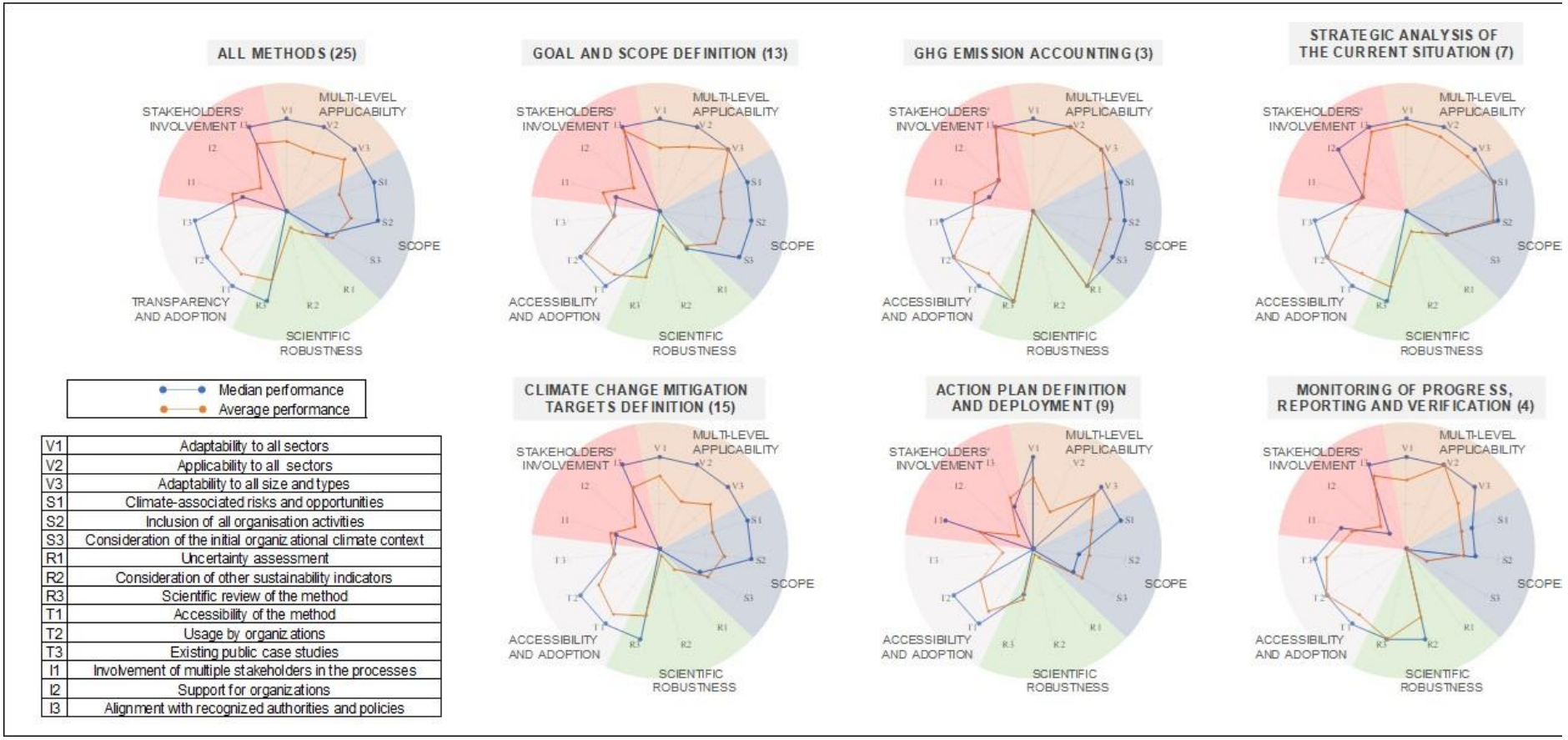


Figure 3.4: *Performance of methods to fulfill the key principles of an organizational climate change mitigation strategy (OCCMS), by intended use related to the steps of the strategy*[8]

[8] *Each radar plot represents the average and median score for all sub-criteria. Radially, the central point corresponds to methods which do not meet the sub-criterion (level 0 of the evaluation), the middle point corresponds to methods which partially meet the sub-criterion (level 1) and the point at the end of the radius corresponds to methods which meet the sub-criterion (level 2).*

3.3.3.1. GHG emission accounting

Three methods focus on GHG emission accounting, but they only address this objective without any further developments in the OCCMS definition in their processes. No new methods within this category have been established since 2006 with the adoption of the ISO standards, that built atop the GHG Protocol standards. This is possibly because of widely accepted norms governing GHG emissions accounting, that render further methodological developments less necessary for these categories. Yet these methods are updated regularly and the related research agenda remains relevant (Marlowe et al., 2022). The absence of methods addressing GHG emission accounting for financial organizations may be due to the well-established methods being also applicable to the finance sector.

Regarding the 3 methods identified for GHG emissions accounting, the international standard of GHG Protocol is the recommended method for this specific step. It was found to satisfy the most criteria among all 25 methods, fulfilling 80% of them and partially fulfilling 13%. The only criterion not satisfied was the consideration of other environmental indicators, which is beyond the scope of this study but would worth mentioning in the method's recommendations. The engagement of external stakeholders across the value chain to enhance data transparency and accessibility, along with clear processes on supporting companies, represents two sub-criteria that are only partially met within the GHG protocol. Yet this standard stands out as the most mature method among the 25 methods, signifying that GHG emission accounting is a well-established step of OCCMS.

3.3.3.2. Strategic analysis of the current situation

About 36% of the 25 methods are designed to include a strategic analysis of the current situation. Average performance is high for all criteria but scientific robustness, which may be explained by the field of strategic analysis going beyond climate change mitigation, and the

private sector being used to this practice. Yet, uncertainties and consideration of other sustainability issues are rarely mentioned in these methods.

The method ACT-A is found to be the method that meets most sub-criteria within this category, with 67% of the sub-criteria fulfilled and 27% being partially fulfilled. Therefore, this method is recommended for the step of strategic analysis of the current situation. However, it does not fulfil either the sub-criterion of considering uncertainties of the responses. This can be attributed to the fact that ACT-A relies mostly on qualitative information, which makes it challenging to quantify uncertainties. We recommend including uncertainty management approach in the assessment performed in ACT-A, with for example the evaluation of the strategy to address and mitigate uncertainties in the OCCMS. This could range from a low-maturity level, where uncertainties are not accounted for, to a high-maturity level that involves reporting, managing, and formulating strategies to minimize uncertainties.

3.3.3.3. Climate change mitigation targets definition methods

About 56% of the methods include the definition of climate change mitigation targets. All methods, apart from the GHG protocol, have emerged since 2015, which might be related to the ratification of the Paris Agreement that same year and the contribution of the private sector to reach its objectives thereafter. This is also possibly due to the escalating inclination within the private sector to commit in climate change mitigation targets notably with the Science-Based Target Initiative (SBTi) created in 2015. The importance attached to setting reduction targets may be linked to financial sector-specific requirements and to the growing expectations of financial structures and investors regarding their portfolios and stakeholders, particularly with the creation of the Task Force on Climate Related Financial Disclosures (TCFD, 2015).

Even if average fulfilment of sub-criteria is lower in this category, the SBTi short-term method meets 80% of the criteria and is the recommended method. The GHG Protocol, which also provides guidance for establishing GHG targets and meets a greater number of sub-criteria, is not considered within this context as it is not the primary focus of the method. Yet this GHG accounting standard can be used complementarily with SBTi-short term method, as recommended in SBTi criteria (SBTi, 2023b), because it provides guidance to set and report corporate climate change mitigation targets as well as the choices to be made and their implication. More recent that GHG Protocol, SBTi short-term method is now widespread in the world and recognized as an example of integrity in corporate climate actions, e.g., by the United Nations or the White House (SBTi, 2022b; The White House, 2022). Yet, the SBTi method failed to fulfil the consideration of transition risks. This is an important factor when setting corporate-level climate mitigation targets, to anticipate necessary changes in a company's activities or business model or to evaluate the targets credibility. Despite the wide accessibility of SBT methodologies and associated resources, the accessibility sub-criterion was only partially met as a lack of transparency is observed in assumptions and choices for disclosed SBTi data of organizations with validated targets (Bjørn, Matthews, et al., 2023). Lastly, the SBTi recommends that companies include the level of uncertainty in their climate reporting reduce them as far as practicable (SBTi, 2019c), which partially fulfils the uncertainty sub-criterion. However, making uncertainty management a mandatory and transparent step in the SBTi target definition and validation would enhance the scientific robustness of the method. In spite of these limitations, which should be addressed in future works, the SBT short-term method is still recommended for the step of targets definition as it remains more consistent than the others.

3.3.3.4. Action plan definition and deployment

Around 36% of the methods are designed for the action plan definition and deployment, which is the category for which methods fulfil the least number sub-criteria, with an average of 44% of sub-criteria met. This is possibly related to a slower and more recent adoption, as well as to the lack of consensus around strategy, action plans definition methods in OCCMS. Assuming equal weighting between sub-criteria, the method ACT-S fulfils the highest number of sub-criteria (67%) for action plan definition and deployment. Three sub-criteria were not met, namely the consideration of uncertainties, the consideration of other sustainability parameters and the absence of public case studies. The lack of mention of uncertainties (quantitative and qualitative) is an issue as uncertainties are often important in corporate GHG emissions (Klaaßen & Stoll, 2021). The relatively recent development of the method since its origin in 2020 could explain the lack of case studies. Nonetheless, the corporate and scientific communities would benefit from accumulating experience, e.g. through public case studies. Two criteria were only partially met: while ACT-S is mentioned in the scientific literature (Blin-Franchomme, 2017; Pesqueux, 2021; Rekker et al., 2022; Vargas-Gonzalez, 2018), it has not been published in scientific journals with peer-review. Likewise, while the method is available online, associated tools are not. In the same category, the method QUANTI-GES fulfils less sub-criteria but include uncertainties, accessibility to all resources and published case studies. This method has a narrower focus compared to ACT-S, as it aims to quantify a particular climate change mitigation action within an organization. It could therefore be utilized in conjunction with the action phase of ACT-S, providing a more robust quantification of GHG emission reduction.

3.3.3.5. Monitoring of progress, reporting and verification

About 16% of methods aim at monitoring of progress, reporting and verification, i.e, four methods. Of these, two methods, the CDP Climate Change questionnaire for all types of organizations and CA100+ for financial organizations, met 67% of the criteria and therefore are the recommended methods for this step. The 3 methods targeting any type of organization in this category (namely CDP reporting, GRI 305, and B Impact Assessment) are the only ones fulfilling the sub-criteria of the consideration of other sustainability indicators out of 25 methods. However, all methods lack specific guidelines for the scope of companies' governance involvement, and importantly for mandatory quantification of uncertainties linked to the disclosed information. In reporting frameworks, we recommend including the disclosure of governance approach to tackle climate-related concerns. For instance, a demonstration could be reported on how the integration of climate change mitigation occurs within decision-making processes and strategic levels. Additionally, mandatory reporting of uncertainties and strategies to manage them, is recommended.

3.3.4. Toward a comprehensive OCCMS methodological framework

3.3.4.1. OCCMS framework

Build on the previous analysis, we present a first OCCMS framework to harmonize the methodology, with available methods as complementary starting points, examples of operational elements for each step, as well as with key aspects to be careful about integrating throughout the strategic development. **Figure 3.5** lays the foundation of an OCCMS framework, with an emphasis directed towards a comprehensive approach applying for all types of organizations. The initial step of goal and scope definition is regarded as a preliminary stage within the framework, akin to similar approaches in impact assessments or strategic developments. However, no corresponding method is delineated for this first step, as the review

did not identify methods specifically serving this purpose. Although no method across any category fully satisfies all sub-criteria for scientific integrity, certain methods outperform others and are therefore depicted in the framework as starting points, to consolidate best practices.

This framework shows potential to aid robust organizational transition plans to make organizations accountable. OCCMS extend beyond GHG emission accounting and climate change mitigation target formulation, which are commonly but wrongly perceived as comprehensive corporate climate strategy (Kuramochi et al., 2020). The proposed OCCMS framework include strategic considerations, complementary qualitative and quantitative approaches, involvement of stakeholders, among other factors. Moreover, the review methodology presented in this article can be used to evaluate and compare upcoming methods, while also highlighting gaps in their development. It also parallels ongoing institutional efforts to establish initial reporting standards and therefore holds the potential to function as a methodological framework for facilitating corporate information reporting.

The proposed framework constitutes an initial step towards standardizing and consolidating OCCMS methods within a comprehensive and robust approach, addressing a literature gap. However, it presents certain limitations and holds potential for further development. Firstly, its current scope encompasses generic methods, yet sector-specific adaptations capturing unique attributes would be required across sectors. Secondly, it should be noted that some of the methods discussed in this study, which are not recommended in the OCCMS framework, could still be highly relevant in other contexts as they have a wider scope than just climate change mitigation. For instance, the Net Zero Initiative (NZI) framework and the B Impact Assessment (BIA) are respectively addressing the contribution of companies in reaching global carbon neutrality, and the sustainability and CSR performance of companies, which are relevant, albeit being outside the scope of this study. Thirdly, areas for attention vary according to the steps of an OCCMS as depicted in the right column of **Figure 3.5**, and further

specific research is required for each of them. For instance, uncertainty management emerges as pivotal for quantifying GHG past and future emissions, in the steps of GHG emission accounting and climate change mitigation target definition.

3.3.4.2. Research agenda for further development of OCCMS methods

This review indicates whether methods adhere to the basic principles of an OCCMS. There are still gaps in research and methods for all steps of an OCCMS, as they have specific objectives that may require additional criteria to be considered. For instance, Marlowe et al. specifically examined carbon accounting methods and associated research gaps (Marlowe et al., 2022), while other authors focused on climate mitigation target-setting methods (Bjorn et al., 2021; Faria & Labutong, 2019; Krabbe et al., 2015). Such specific complementary studies are needed for the step of action plan definition and deployment in an OCCMS. This includes inductive approaches with case studies and in-depth analysis of certain methods (e.g., ACT-S). This is particularly relevant in the areas of strategic planning, low-carbon management and climate mitigation action plan definition, which are currently underrepresented in scientific literature. Lastly, the implementation of the consolidated methodology necessitates testing and validation procedures in published case studies.

Further research, categorized in **Table 3.3,** is therefore needed in all steps of an OCCMS and associated methods, in order to build a harmonised, robust and comprehensive climate change mitigation framework for organizations.

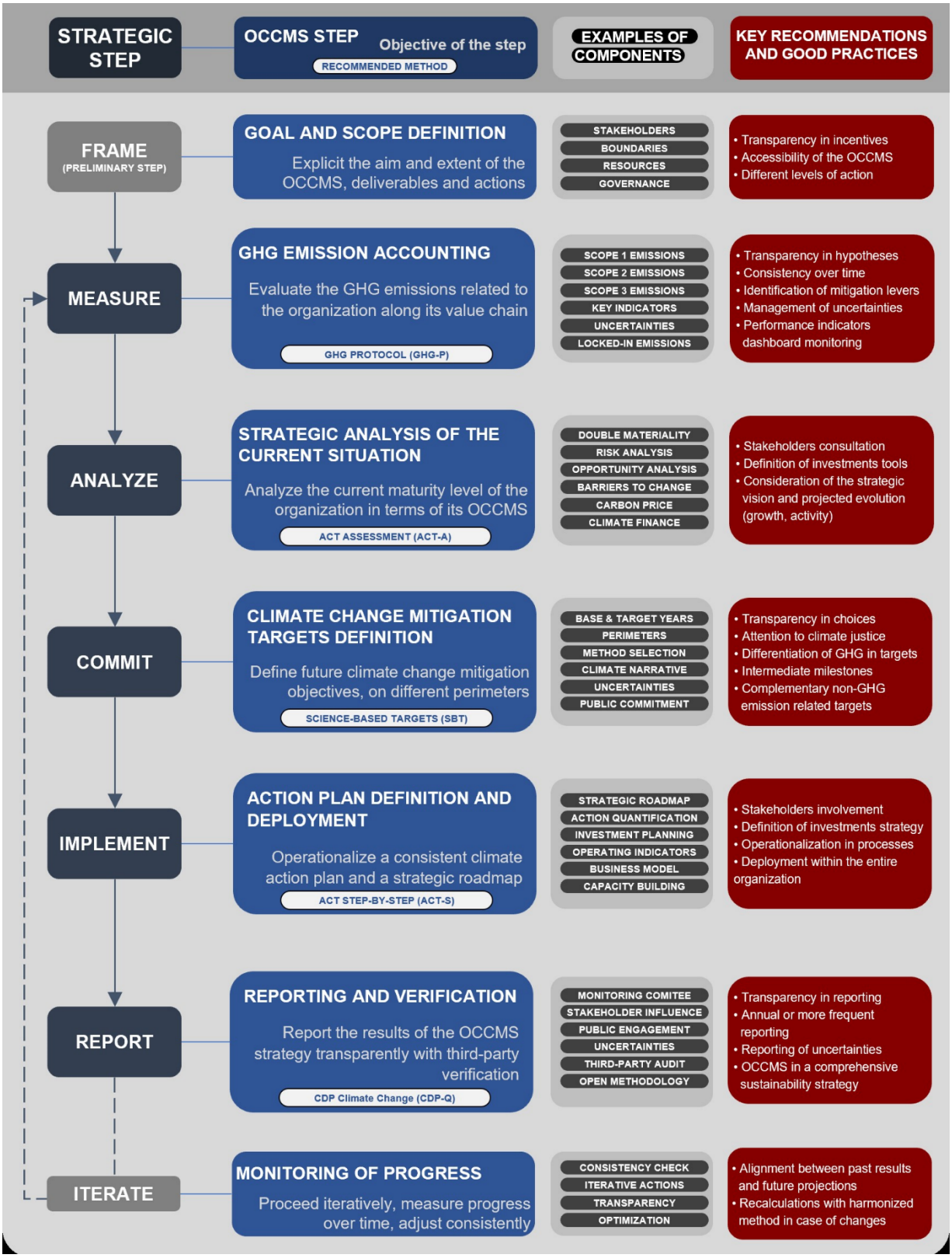


Figure 3.5*: framework for the definition of organizational climate change mitigation strategies*[9].

[9] *Regarding strategic steps, the dark blue segments denote the central elements of an organizational climate change mitigation strategy (OCCMS), which is an iterative process. The recommended methods, depicted in white boxes, are the one that fulfils most sub-criteria in the evaluation developed in this study, for each step.*

Table 3.3*:* research agenda on OCCMS[10], step by step.

Step of OCCMS	Challenges, gaps and needs for further research
MEASURE GHG emission accounting	Large uncertainties in corporate GHG emissions, jeopardizing the consistency, harmonization and accuracy of the assessments
	Incompleteness of GHG emission accounting exercises with lack of justifications and transparency
	Lack of data among the value chain for Scope 3 emissions
	Lack of consolidated harmonized observatory of corporate GHG emissions, preventing bridges between corporate value chain GHG emissions and other scales (regional, sectoral, national, global)
ANALYZE Strategic analysis of the current situation	Lack of guidelines to link OCCMS with other climate-related issues (e.g., climate change adaptation, avoided emissions, global net-zero)
	Lack of guidelines to link OCCMS with other corporate sustainability issues and associated methods (e.g. with Science-Based Targets for Nature, the Global Biodiversity Score, or with the Doughnut theory at the corporate level)
	Lack of guidelines to define climate change mitigation-related monitoring indicators at organizational level (intensity, sectoral indicators, avoided emissions, operational indicators, etc.)
	Lack of comprehensive study on the relation between distributive justice and corporate climate-related strategies depending on countries, sectors, type, size of organizations
COMMIT Climate change mitigation targets definition	Lack of complete methodological framework and decision-making tools for downscaling global climate-related goals to the corporate level (as well as national, regional, sectoral levels), that take climate justice and ethical allocation principles into consideration
	Lack of recommendations and transparency regarding all parameters of climate change mitigation targets, lack of sensitivity analysis of these parameters (e.g., the influence of the base year on climate change mitigation trajectories)
	Lack of study on the relation between SBTi targets, carbon imbalance and market laws (e.g., newcomers, B2B, B2C, evolving activities, innovation, etc.)
	Is the process of setting targets efficient? Re-evaluation of SBT companies progress after the new 1.5°C criteria is adopted, analysis of imbalance between aggregate company targets and global emissions
IMPLEMENT Action plan definition and deployment	Lack of case studies on OCCMS, lack of methodological framework on the action plan definition and deployment step of OCCMS (e.g., lack of studies on ACT-S methodology)
	Lack of scientific guidelines and comprehensive standards to structure OCCMS for organizations to define low-carbon strategies
	Lack of studies about the role of the private sector regarding CO_2 removal and CO_2 offsets in corporate targets and strategies, in relation with CO_2 emissions reduction
	Lack of analysis of public data, observatory of corporate climate-related actions and relation with other scales (global, national, sectoral)
REPORT Reporting and verification	Incompleteness of most of the GHG emission accounting exercises
	Lack of transparency in the definition of the system boundaries and difficult comparison between corporate GHG emissions
	Lack of study on the additionality of the published targets, past and current GHG emissions, and different projected future emissions scenarios
	Lack of structured guidelines related to transparency in choices, hypothesis, perimeters, parameters of OCCMS strategy

[10] *Organizational climate change mitigation strategies*

3.4. Conclusion

To address the need for a robust and standardized methodology to derive climate change mitigation strategies at organizational levels, this study conducts a meticulous assessment of methods that can potentially contribute to the definition of such strategies. We define 15 sub-criteria based on established scientific methodologies and use them to evaluate 25 methods in terms of fundamental principles of scientific integrity. Based on this review, we proposed a first framework to define climate change mitigation strategies in businesses and drew up needs for further research for each step.

The proposed framework, presented in **Figure 3.5,** is organized around the various stages of a transition plan, allowing for tailored recommendations depending on organizations' maturity levels. These review and framework highlight further research needs, depicted in **Table 3.3**. The results of this study can be used to evaluate existing and future methods, to assess existing corporate climate strategies or to assist organizations in their climate mitigation efforts and hold them accountable.

We recommend that method developers, whether in the private sector or in academia, consider and use the framework proposed here in their future work on climate change mitigation strategies, in order to be transparent about the strategic step and the gaps they address as well as to take a further step towards the standardization of corporate climate strategy methods. For corporate stakeholders, the results of this article can serve as a guideline for assessing the maturity level of their organizations, for considering climate change in their decision-making processes, and for enhancing the robustness of their climate change mitigation strategies.

There is a need to move beyond necessary yet insufficient corporate emission measurements and commitments, shifting focus towards comprehensive corporate climate strategies that also integrate climate-related action plans, influence strategies, and model transformations. This

study paves the way to build scientific guidelines to structure robust and credible organizational climate change mitigation strategies, and to set the research agenda in this area.

3.5. Chapter appendix 3A: List of OCCMS methods and sources

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3.6. Chapter appendix 3B: Detailed definition of sub-criteria

Table 3.4: Definition of sub-criteria and associated three-level assessment method.

Category	Criterion	Commentary & Explanation	Evaluation		
			Not fulfilling	Partially fulfilling	Fulfilling
Multi-level applicability	**Quality of the method to be able to be applied or adapted to different situations**				
	Adaptability to all sectors	Method specificity for different professional sectors, with differentiations for each sector	Only a general decarbonization tool or no information	Specific for general sectors (purchase of goods, purchase of services)	Specific for precise sectors (auto, retail, etc.)
	Applicability to all sectors	Method applicability to all professional sectors	Only applicable to a precise sector (industry, finance, etc.) or no information	Only applicable for a general sector (purchase of goods, purchase of services)	Applicable without any sectoral exclusion
	Adaptability to all sizes and types	Method adaptability to all organisations size and types	Only applicable to a specific organisation size or no information	Applicable to almost all company sizes, but with at least one exclusion	Applicable to all company sizes
Scope	**Boundaries and extent of the method within the organization**				
	Climate-associated risks and opportunities	Consideration of the multiple risks (physical, political, environmental, economic, social, reputational) involved in a climate transition	No consideration nor mention of transition risks and opportunities in the method	Mention of transition risks and opportunities in the method but indirect use	Consideration and use of transition risks and opportunities in the method
	Consideration of the initial organizational climate context	Consistency with the operational context of the organization and its initial situation in terms of GHG emissions and associated climate change mitigation strategy	No consideration of the current strategy or operational context in the method	Partial consideration of the current strategy in the strategy creation (e.g. only a part of the strategy)	Consideration of the current strategy and maturity of the organization in the method
	Inclusion of all organisation activities	Implementation of the climate mitigation strategy within the organization, at all levels and in all departments	No consideration or implication of all departments nor governance specified in the method	Partial consideration or implication of departments or governance specified in the method	Consideration of all department and governance specified in the method
Scientific robustness	**Methods ability to integrate scientific rigor and up-to-date science**				
	Uncertainty assessment	Assessment of uncertainties in the scientific quantitative data and information provided by the organization	Uncertainty of data is not taken into consideration in the method	Uncertainty of data is partially included in the method (not all data or no mention)	Uncertainty of data is taken into consideration
	Consideration of other sustainability parameters	Capacity to conduct systemic analysis considering other environmental or social indicators (e.g. carbon footprint, impact on biodiversity, chemical pollution, resources, etc.), in order to avoid burden shifting. This criterion has been added to take into account the systemic and interdependent nature of earth processes (characterized, for example, by the framework of planetary boundaries), as well as the links between climate issues and societal issues.	The method does not mention other sustainability indicators or impact categories than climate change mitigation	The method mentions other sustainability indicators or risk of burden shifting (e.g. in recommendations)	The method takes other indicators into consideration (e.g. qualitatively)
	Scientific review of the method	Peer-review process in the method definition and publication in scientific journals	No scientific review from a third-party	Method cited in research articles or scientific committee	Method peer reviewed in scientific journals
Accessibility and adoption	**Clarity of the method and its outputs**				
	Accessibility	Possible access for all to every information and hypothesis of the different case studies and methods	Impossible access or no case study	Partial access to summary versions, without all calculations, hypothesis, tools or information	Total access
	Usage by organizations	Number of organizations that have already used the method	None or no information	Between 1 and 10	More than 10
	Existing public case studies	Number of available case studies and business cases	None	Between 1 and 5	More than 5
Stakeholders' involvement	**Participation of multiple stakeholders in the method**				
	Involvement of multiple stakeholders in the processes	Need to involve external partners (e.g. customers, suppliers) in the method application	None or no mention	Method mentions stakeholders' involvement, but do not include associated processes	Stakeholders' involvement is possible and encouraged in the method
	Support for organizations	Possibility for the organization to be assisted by experts, to have trainings and capacity building	None or no information	Possibility to be helped by trained external expert, but no database	Database and processes for trained external expert (e.g. potential financial or technical)
	Alignment with recognized authorities and policies	Alignment of the method with political targets (national, EU, NDC, etc.) and mention of the method in an official regulations or statements	No link with regulations and no mention in official recommendations	The method does mention relations with regulations	The method is mentioned in official texts or recommendations

CHAPTER 4

How to define climate change mitigation strategies at organizational level: lessons learnt from 10 organizations in France

This chapter is based on the article entitled “How to define climate change mitigation strategies at organizational level: lessons learnt from 10 organizations in France”, submitted to Business Strategy and the Environment in December 2023. ADEME is gratefully acknowledged for partially funding the project. The project was also funded through the contribution of the participating companies.

Abstract

Voluntary and regulatory initiatives seek to engage organizations in climate change mitigation strategies. However, the associated methodologies rarely go beyond carbon accounting and setting emission reduction targets. The strategic and operational dimensions of means and implementation are not integrated. The Assessing low-Carbon Transition step-by-step method, or ACT-S, provides a process for organizations to define their climate strategy in up to three years. Although the potential of this method has been recognized in literature, no case studies exist to date. This study aims to draw lessons from the application of this methodology to 10 French companies, first organizations applying the metho from 2020 to 2023. On this basis, we propose improvements points in the application of ACT-S as well as recommendations for defining comprehensive climate change mitigation strategies for organizations.

4.1. Introduction

In June 2023, United Nations Secretary-General Antonio Guterres called on international leaders to submit transparent and credible climate transition plans in the shortest possible time (United Nations, 2023). In France the government has encouraged companies of all sizes to align their strategy and governance with international commitments on climate, by complying with existing regulations or through voluntary commitments (French Government, 2017, 2023b). Such voluntary initiatives may be prompted by stakeholder pressure (Alsaifi et al., 2020; Cadez et al., 2019; Chithambo et al., 2020) or by strategic risk issues (World Economic Forum, 2021, 2022, 2023). However, despite an increasing number of companies with voluntary climate commitments, very few show credible and transparent climate transition plans (CDP, 2022a; Day et al., 2022, 2023). In this context, several studies have raised doubts about the effectiveness of voluntary corporate programs in taking ambitious action on climate change (Newell & Paterson, 2010), arguing that they may hinder the development of more ambitious regulations (Malhotra et al., 2019). While a common regulatory system is essential, hybrid systems (binding and voluntary) could enhance the contribution of companies in achieving the Paris goals (Lee et al., 2023). We argue that regulatory and voluntary approaches should not be opposed, but rather complementary: even with binding constraints, organizations still need methods and frameworks to achieve the legal objectives. From a regulatory perspective, the European Corporate Sustainability Reporting Directive (CSRD) is a further step in this direction, requiring most European companies to report their emissions, their reduction targets, and their action plans and policies to achieve them by 2028 (EFRAG, 2022). In this context of mixed market and regulatory incentives, how to define sufficiently fair, robust and ambitious climate change mitigation strategies?

Several studies have examined the incentives behind voluntary programs (Tavakolifar et al., 2021; Wakabayashi, 2013), and how companies report and comply with established

frameworks (Demaria & Rigot, 2021; Dias et al., 2023; Ruiz Manuel & Blok, 2023). As for climate change mitigation strategy methodologies, studies mainly focus on greenhouse gas (GHG) emission accounting (Le Breton & Aggeri, 2018, 2020; Marlowe et al., 2022) or emission target setting (Andersen et al., 2021; Bjørn, Lloyd, et al., 2023; Giesekam et al., 2021a; Krabbe et al., 2015; Moshrefi et al., 2022; Walenta, 2019), which are only a part of comprehensive strategies (Desmoitier et al., forthcoming; Iken et al., 2019; Imbrogiano & Nichols, 2021). In **chapter 3**, an extensive literature review of 25 existing methods related to businesses' contributions to climate change mitigation was conducted (Desmoitier, forthcoming). A number of 15 review criteria were accounted for, revealing that no existing method met all of them but a handful of methods were demonstrated to be promising in specific aspects of corporate strategy for climate change mitigation. In this review, the Assessing low-Carbon Transition Step-by-step (ACT-S) methodology was shown to be promising, specifically for strategic analysis as well as for action plan definition and deployment. (Desmoitier, forthcoming). ACT-S actually provides a methodological framework for "developing and implementing voluntary business low-carbon strategies" (ADEME & CDP, 2022) through 5 gradual steps involving cross-functional teams and several strategic levels.

The Assessing low-Carbon Transition initiative (ACT) is part of the Global Climate Agenda of UNFCCC secretariat (UNFCCC, 2023) and is a joint voluntary initiative of the French Agency for Ecological Transition (ADEME) and CDP (former Climate Disclosure Project), with the overall objective of "fostering climate action by organizations around the world" (ADEME & CDP, 2022). A preliminary study to frame the ACT-S methodology was published in April 2020 (Marcus et al., 2020) and the full publication of the methodology was in January 2021 (Marcus et al., 2021). However, very few scholars have considered ACT-S in their research. In 2018, Vargas-Gonsalez mention ACT methodology and highlight its holistic view, allowing to help companies with their business model, investments, operations and GHG emissions management (Vargas-Gonzalez, 2018). However, this is only based on the pilot

phase of the methodology. In 2020, Pesqueux mentionned ACT as a promising methodology in a lecture given on the state of CSR after Paris Agreement and COVID pandemic (Pesqueux, 2021). In 2020, Blin-Franchomme mention ACT as a methodology to measure companies' engagement into GHG emissions mitigation as well as to rethink their business models (Blin-Franchomme, 2017). Rekker et al. highlight a limitation of the ACT methodology regarding the carbon budget methodology, which align with the SBTi methodologies, only picturing ACT with the carbon budget aspect rather than seeing it as a comprehensive framework for decarbonization strategy, which is quite restrictive (Rekker et al., 2022). The most advanced analysis of low-carbon strategy at corporate level is the discussion paper of climate bonds (Creed & Horsfield, 2021). Though it is not a peer-reviewed academic paper, it uses different methodologies to eventually propose five hallmarks for a credibly transitioning company: Paris-aligned targets, Robusts plans, Implementaiton action, Internal monitoring and External monitoring. ACT is mentioned in the target-setting hallmark, in the external reporting, acknowledging that policy engagement is included in ACT.

Desmoitier et al (review paper, forthcoming) highlight that there is a need to further investigate ACT-S method, which is outlined as one of the most suitable method for the step Action plan definition. Also, it insists on the need for case study to show the applicability of the method. ACT-S is often limited to a simple mention in much broader studies, and there are no case studies available or empirical feedbacks in either the academic or grey literature. Thus there is a lack of feedback on the use of ACT-S method in the literature to date, addressing its pros and cons and enabling progress to be made on a standard methodology for corporate climate strategy definition.

In an intervention-oriented research approach (see Aggeri, 2016), this study aims at providing experience feedback on the application of the ACT-S methodology, to discuss its advantages and disadvantages and lead the discussion on what is required to define a relevant

method for defining corporate strategy for climate change mitigation. The objectives are (i) to illustrate a 3-year process to define climate change mitigation strategies for 10 companies based in France, (ii) evaluate the applicability of the ACT-S methodology for defining corporate strategic plans for climate change mitigation with the first companies experimenting with this method, and iii) use the feedback from these multi-case applications to provide recommendations on how to further refine the ACT-S methodology and support the development of a comprehensive framework and guidance for defining climate change mitigation strategies in organizations.

The number and the nationality of participants (i.e. 10 organisations in France) is related to the frame provided by the French Agency for Ecological Transition (ADEME) for this first ACT-S implementation. The organizations were selected by the company Toovalu, who has coordinated the study (see **Appendix A.1.1** for further details on Toovalu). This study is based on the very first companies that applied the ACT-S methodology, in order to define their "low-carbon strategy", also called transition plan (CDP, 2022a), or more broadly climate change strategies (Cadez et al., 2019; Gasbarro et al., 2017). We suggest a more precise term, that covers the scope of ACT-S: organizational climate change mitigation strategy (OCCMS). OCCMS has been defined in **Chapter 3** as a time-bound set of means and ends that an organization uses to achieve goals aimed at reducing its GHG emissions and associated risks throughout its value chain, thereby contributing to climate change mitigation (Desmoitier et al., forthcoming). OCCMS are typically a critical component of broader transition initiatives, outside the scope of this study, that include climate change adaptation and other environmental impact mitigation measures.

4.2. Methods

4.2.1. Overall approach

Figure 4.1 provides an overview of the approach used to define climate change mitigation strategies for the 10 companies, derived from ACT-S. Firstly, company selection is described, on the basis of the ACT-S prerequisites and additional criteria set for this study (section **4.2.2**). Next, the scope of the study is defined, in terms of timeframe and stakeholders involved (section **4.2.3**). The 15 sub-steps of the ACT-S methodology are then applied to the 10 selected companies (section **4.2.4**), in a hybrid process between collective and individual working sessions, which is specific to this study. This results in 10 climate change mitigation strategies defined with the participant organizations, that are analyzed to evaluate the ACT-S methodology and contribute to the standardization of ambitious and robust climate change mitigation strategy definition (section **4.3**).

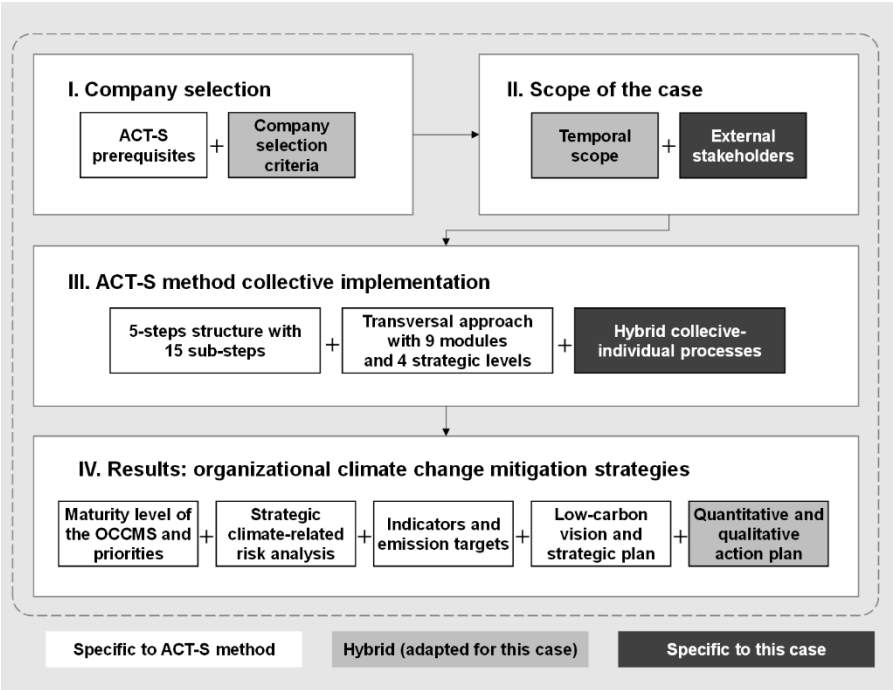


Figure 4.1: overview of the methodology of this study, with specificity compared to ACT-S.

4.2.2. Company selection

4.2.2.1. ACT-S prerequisites

ACT-S methodology is designed as a progress-oriented process, regardless of the initial situation of organizations (Marcus et al., 2021), meaning that there are no prerequisites in ACT-S related to the maturity of the existing climate strategy. However, to apply the ACT-S methodology, organizations must have conducted at least one organizational GHG inventory that covers all GHG emission sources. Emissions shall include Scope 1 (direct GHG emissions), Scope 2 (indirect GHG emissions from consumption of purchased electricity) and Scope 3 (other indirect emissions).

Additionally, governance involvement, e.g. with the board of directors, is required from the beginning of the project. In this regard, ACT-S required in-house contributors, including a "sponsor" and a "coordinator". The sponsor must be a member of the board of directors, who may have decision-making power and significant influence within the company to implement the OCCMS. The coordinator ensures the application of the ACT-S methodology within its company, and must be trained by the French Agency for Ecological Transition (ADEME), co-developer of the ACT-S methodology. Furthermore, ACT-S recommends, but does not require, the involvement of a cross-functional team representing most of the functions of the organization, such as the finance department for the investments required for the low-carbon transition, the executive committee for the business model decarbonization, or the marketing and communication department for the customer influence or policy engagement.

An external "advisor" may be involved in the process to provide expertise on climate change or on the company's sector decarbonization, but this is not a mandatory criterion. Advisors were involved for this study, as described in section **4.2.3**.

4.2.2.2. Company criteria selection

In addition to the ACT-S criteria, the selection process for this study was carried out among a territorial employer association in western France, in 2020. This association, anonymized for this study, was selected as they set a collective objective in 2020 to halve cumulative GHG emissions of its members between 2019 and 2030. The 137 member companies, through their CEOs, have therefore defined a collective emission target to contribute to climate change mitigation, but they had no company-specific GHG emission reduction trajectory, nor structured strategy to achieve them. Within the employer association, companies that meet the ACT-S criteria were selected on a voluntary basis. The CEOs who volunteered to take part in the experiment had already established a Corporate Social Responsibility (CSR) strategy for their company. **Table 4.1** describes the 10 companies selected to participate in the first ACT-S implementation.

4.2.3. Scope of the case

ACT-S can be applied over a period of one to three years. This first trial of the ACT-S methodology took place between February 2021 and June 2023. The implementation of ACT-S with the 10 organizations is the result of a tripartite initiative. ADEME participated in the experimentation as co-founder and co-financer, and provided expertise during collective training sessions. The 10 organizations, with the employer association, were involved as key actors and co-financer, building their OCCMS using the ACT-S methodology. The company Toovalu, has coordinated the project and supports the 10 companies with “advisors” (i.e. consultants) in applying ACT-S and defining their strategies. In addition to Toovalu, other ACT-S "advisors" were involved, among Vertuel, Evea and Espère companies. As required by the ACT-S methodology, all the advisors have been trained by ADEME beforehand.

4.2.4. ACT-S methodology implementation

4.2.4.1. 5-steps structure

The ACT-S methodology framework consists of steps, actions, strategic levels that together describe a standardized strategic process for the structuration of an organization climate change mitigation strategy (Marcus et al., 2021). The methodology is composed of 5 steps, namely Current situation, Issues and challenges, Vision, New strategy, Action plan, adapted from the Plan-Do-Check-Act (PDCA) approach (Deming, 1994). Each step is composed of several sub-elements, resulting in a number of 15 sub-steps in total (see Appendix **A.5.1** for more details). **Figure 4.2** illustrates the 15 sub-steps of ACT-S, categorized according to the 4 strategic levels as well as the collective and individual sessions.

Step 1, 'Current Situation', consists of a series of questions for which the organizations positioned themselves on a 5-grade scale (sub-steps 1A and 1B), which resulted in maturity levels and average relative importance for each ACT module. The levels range from "Basic" (compliant with regulations and state of the market), "Standard" (aligned with CSR standards), "Advanced" (ahead of the market), "Next practice" (among the best on the market) to "Low-carbon aligned" (aligned with the Paris Agreement). In addition, each module is assigned with an organization-specific relative importance, derived from the sector and the GHG emission profile of the organizations (Marcus et al., 2021).

Table 4.1: description of the 10 companies in the case study[11].

	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 4	COMPANY 5	COMPANY 6	COMPANY 7	COMPANY 8	COMPANY 9	COMPANY 10
LEGAL STATUS	Joint-stock company	Joint-stock company	Industrial group	Public establishment	Mutual company	Industrial group	Joint-stock company	Joint-stock company	Joint-stock company	Joint-stock company
HEADCOUNT	50	1100	1500	21	5000	1800	1100	900	600	800
REVENUE (K€)	5 500	97000	280000	NA	2 800 000	180 000	140 000	55 000	60 000	70 000
SECTOR OF ACTIVITY (ISIC[12])	Legal and accounting activities	Legal and accounting activities	Manufacture of structural metal products	Other monetary intermediation	Insurance, reinsurance and pension funding, except compulsory social security	Warehousing and non-refrigerated storage	Manufacture of lifting and handling equipment	Restaurants and mobile food service activities	Consultancy	Software publisher
ACTIVITY DESCRIPTION	Accounting expertise, delegation of HR administrative management, business development and financing, tools to simplify day-to-day management	Consulting, auditing, accounting, social and legal expertise	Industrial group specializing in housing envelopes, producing several ranges of doors, windows, solar panels, insulation and ventilation solutions in France.	Financial institution focused on social missions, based on pawnbroking, microcredit and overindebtedness management	Its services include supplementary health, prevention, provident and savings plans. It serves individuals, civil servants, self-employed professionals and companies.	The group deploys its expertise in several service offerings: industrial logistics, industrial packaging, healthcare logistics, site logistics, industrial transport, bulk logistics, maritime and port services.	tractor loader manufacturer	Collective catering	territory planning	specialized in software publishing, custom digital solutions integration, information systems outsourcing and cloud solutions
SHARE OF EMISSIONS IN % (SCOPE 1)	16%	4%	5%	<1%	<1%	47%	4%	3%	2%	2%
SHARE OF EMISSIONS IN % (SCOPE 2)	1%	1%	<1%	<1%	<1%	1%	1%	0%	4%	117%
SHARE OF EMISSIONS IN % (SCOPE 3)	84%	95%	95%	100%	99,00%	52%	95%	97%	94%	95%

[11] For confidentiality reasons, companies are referred to as Company 1 to Company 10. Values indicated in the table refer to the year 2021 and are rounded.
[12] The International Standard Industrial Classification of All Economic Activities (ISIC) is the international reference classification of productive activities(UN Stats, 2008)

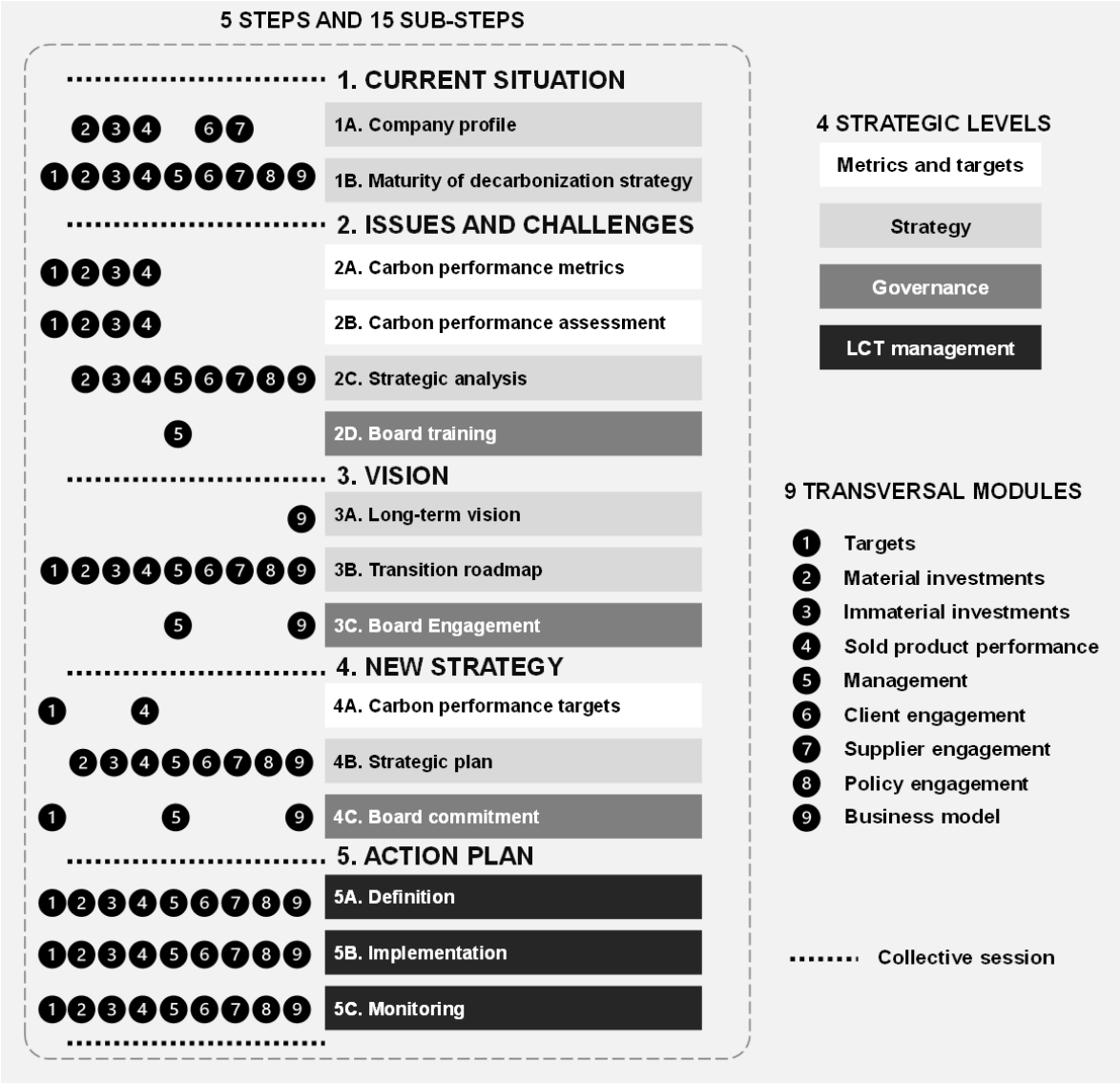


Figure 4.2: structure of the ACT-S methodology and the overall approach that is applied to the 10 organizations of this case study[13].

Step 2, 'Issues and challenges', is composed of the identification of relevant metrics and indicators (sub-steps 2A and 2B), and of a risk analysis (sub-step 2C) based on the Task Force on Climate Related Financial Disclosures (TCFD) risk and opportunity categorization (i.e. policy and legal, technological, market, reputational, acute physical, and chronic physical risks) (TCFD, 2015). Semi-quantitative analysis using scales graded from 1 to 5 are also used in this

[13] The sub-steps are numbered in the order in which they were applied, and categorized according to the ACT-S 4 strategic levels. For each step, we propose a list of ACT-S modules involved, indicated by black numbers. Depending on the company, the modules involved may vary.

step, to evaluate the likelihood and magnitude of impacts associated with climate-related risks and opportunities.

Step 3, ‘Vision’, along with one sub-step of step 4, are designed to establish a company's low-carbon vision (sub-step 3A) and an associated strategic plan (sub-steps 3B and 4B), i.e. the means to achieve the targets. The purpose of the vision stage is to answer the question: what place will the company have in a carbon-neutral world in 2050, and what role will they take in the transition? In addition, the vision step adds short-term (2025) and medium-term (2030) milestones. In this way, organizations build a non-quantified narrative to outline a new value proposition viable in a carbon-neutral world according to their own scenario.

In step 4, ‘New strategy’, a strategic plan breaks down the previously defined vision into several pillars (sub-step 4B). It also includes a complementary quantitative sub-step with the definition of emission targets (sub-step 4A), for which Science Based Targets Initiative (SBTi) methods (SBTi, 2023b) are recommended (Marcus et al., 2021).

Step 5 of ACT-S, ‘Action plan’, aims to define and implement an action plan to operationalize the vision and strategic plan defined in the previous steps (sub-steps 5A, 5B and 5C). It focuses mainly on operational dimensions, with a detailed description of each action, including the person(s) responsible, monitoring indicators, sources of funding and a GHG emissions target, among 17 descriptive fields. In addition, it proposes 9 criteria to validate that an action is operational for an organization and relevant from a climate change mitigation context.

In addition, the board of directors is involved at least three times along the ACT-S process, for a climate-related training in step 2 (sub-step 2D), for the engagement in a low-carbon vision in step 3 (sub-step 3C), and for the validation of a strategic plan in step 4 (sub-step 4C).

The ACT initiative, through ADEME, provides spreadsheets for companies applying ACT-S, with the condition of prior training. These spreadsheets are thus not publicly accessible, yet they follow the ACT-S methodology (Marcus et al., 2021). In this study, those spreadsheets were used for all stages, as a means for providing ACT-S deliverables, i.e. OCCMS strategies for the 10 companies. Complementary methods were defined for some sub-steps due to a lack of specific guidance in the methodology (see SI for more details).

4.2.4.2. Transversal perspective with 9 modules and 4 strategic levels

The actions that compose ACT-S steps involve different aspects of a strategy. They are classified across four strategic levels, namely Metrics and targets; Strategy; Governance; Low-carbon transition (LCT) management. They were formalized based on the classification of the TCFD recommendations (TCFD, 2015). In addition, ACT-S uses a total of 9 performance modules, i.e. thematic pillars of a climate change mitigation strategy (ADEME & CDP, 2022), namely Targets, Material investments, Immaterial investments, Sold product performance, Management, Client engagement, Supplier engagement, Policy engagement, and Business model.

4.2.4.3. Hybrid collective-individual processes

A specific aspect of this case study, not covered by ACT-S, is the collective approach, with a succession of training and sharing collective sessions, held to structure the process, encourage momentum and synergies among the participants. The purpose of the collective sessions was to physically bring together several employees and CEOs from each company, as well as the advisors, to enhance capacity building related to ACT-S, exchange best practices and to dynamically launch each new ACT-S step. In addition, regular operational meetings between all coordinators and advisors were held to continue sharing best practices and obstacles to the implementation of the ACT-S methodology. Individual working sessions, specific to each company and potentially including advisors, were necessary to collect data, carry out in-house

group work sessions, analyze results and define the new strategy. Lastly, at the end of each step, a collective interview was held with the coordinators of all companies to provide feedback and identify the obstacles and levers encountered during the application of the step. These interviews were conducted in an unstructured way and they provide the opportunity in this study to add the companies' perceptions, as well as to formulate further recommendations.

4.3. Results and discussion

This section is organised around the deliverables of ACT-S for each step (as depicted in **Figure 4.1**), which show essential elements of a climate change mitigation strategy (see **Figure 4.2**). The first deliverable, maturity levels and priorities (section **4.3.1**), corresponds to those of the first step of ACT-S. Next, strategic climate-related risk analysis (section **4.3.2**), are the deliverables linked to the Strategy level of the second ACT-S step. Emission targets (section **4.3.3**) are presented afterwards, corresponding to the Metrics and targets level deliverables for step 4. Given their interdependence, section **4.3.4** groups together the deliverables of ACT-S stages 3 and 4, linked to the Strategy level. Finally, section **4.3.5** presents the action plans, related to ACT-S step 5 deliverables.

4.3.1. Maturity level of the OCCMS and priorities

ACT-S step 1, current situation, describes the initial maturity of the organizations' climate change mitigation strategies. **Figure 4.3** shows the results for the diagnostic of the initial maturity in terms of OCCMS for the 10 companies (sub-steps 1A and 1B). Results reveal different maturity level of the climate change mitigation strategy depending on the modules. 7 modules (78%) show a median maturity lower than 1, one module (11%) between 1 and 2 (management) and only one module between 2 and 3 (policy engagement). On average, the organizations demonstrate a maturity score of 0.77 on a scale from 0 to 4, considering the relative importance of each module. This finding indicates that most organizations included in the study showed a relatively low level of maturity in their strategies for mitigating climate

change. This observation aligns with studies showing low consistency and robustness in climate change mitigation strategies based on public data and reporting (Day et al., 2022, 2023). ACT-S does not aim at communicating or reporting, but rather provides a step-by-step approach to improve this maturity level. Significant heterogeneity is observed, as scores above 2 are observed for all modules, in the same time as minimum scores below 0.5 are observed for all modules except policy engagement.

In relation to the heterogeneity, the comparability of results may be biased by questions that sometimes appeared too arbitrary. The nuance between levels for several questions was reported by participants as sometimes difficult to appreciate, varying only by one word for example. This is particularly true in modules with more qualitative questions (business model, customers, suppliers, for example). Heterogeneity can therefore also be a sign of differences in understanding. For example, in the target module, the question on existing emission reduction targets covering the long term and intermediate milestones is very precise. It ranges from level 1, no target or no quantitative target covering the next 5 years, to level 4, targets covering the next 15 years and a period lasting at least the average lifespan of the main product or asset, with milestones at least every 5 years. On the other hand, in the performance of sold products module for instance, a question is asked about the proportion of low-carbon products sold. Although the answer is quantitative, what is deemed "low-carbon" may be difficult to assess. Finally, in the supplier module, the difference between "few actions", "actions" and "major actions" is subject to interpretation. Therefore the results of this initial climate strategy maturity should not primarily be used to compare against other companies, but rather to track progress along the way. This is a relative company-specific assessment, which must be carried out with rigorous transparency and using the same criteria over time. Given the wide diversity of companies (sectors, type, size), it seems acceptable to have very broad criteria that cover a large perimeter and sometimes require interpretation. However, some questions would benefit from more

precise criteria, or more guidance, so that they can be answered with the least subjective approach possible.

Similarly, the knowledge of contributors within companies could be checked at the start of this ACT-S step, or at the start of the project. Accordingly, complementary capacity building or resources could be useful in overcoming potential information bias. Nevertheless, this step with all its questions and level descriptions enables the participating companies to realize the extent of the gap with ambitious climate strategy implementation, to identify what the maximum maturity levels corresponded to for each question, and to understand the different elements of a climate strategy.

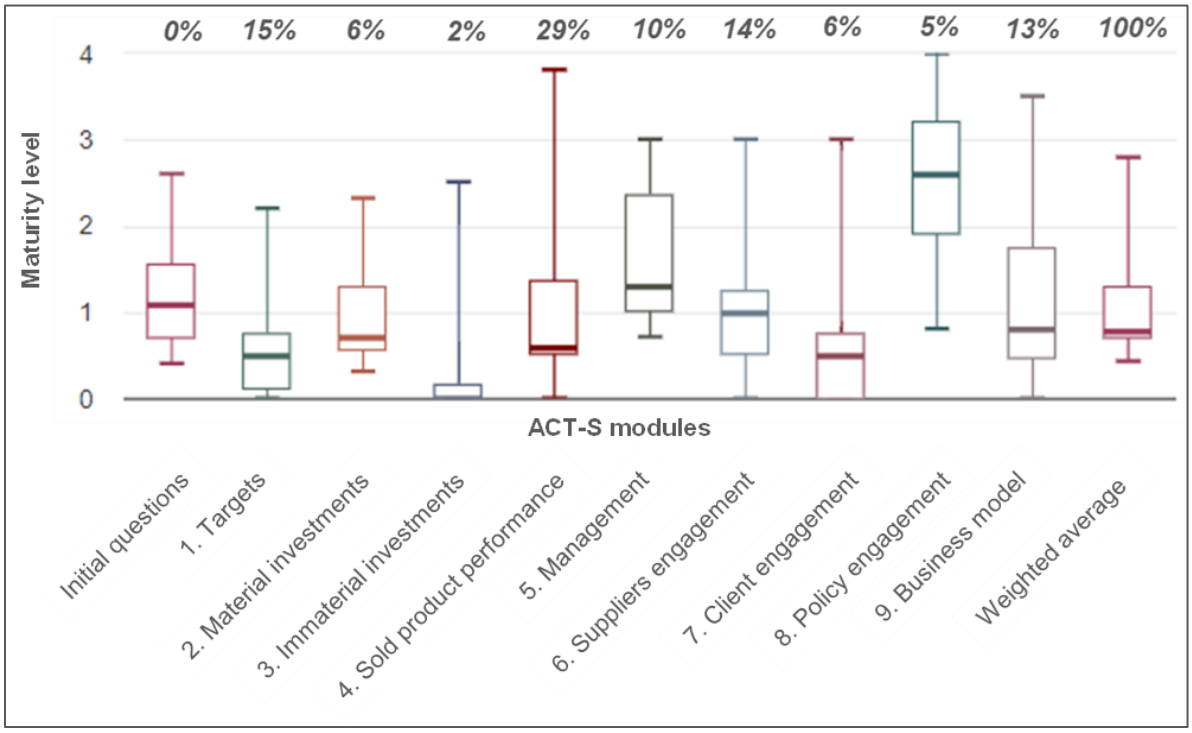


Figure 4.3: Maturity score per module and for the weighted average of each of the 10 companies[14].

4.3.2. Strategic climate-related risks analysis

Figure 4.4 shows the aggregated materiality matrix for the 10 companies, derived from the climate-related risk analysis (sub-step 2C). It can be observed that the most frequently cited

[14] Maturity levels for the 9 modules (numbered from 1 to 9 on the x-axis) are evaluated on a 5-grade scale from 0 to 4, with specific progress questions for each module. The 0 for each of these modules, box plots outline the median indicated by thick line, whiskers indicates first and third quartiles, and high and low ends, maximum and minimum values. Percentages on the top of each module indicate their average relative importance.

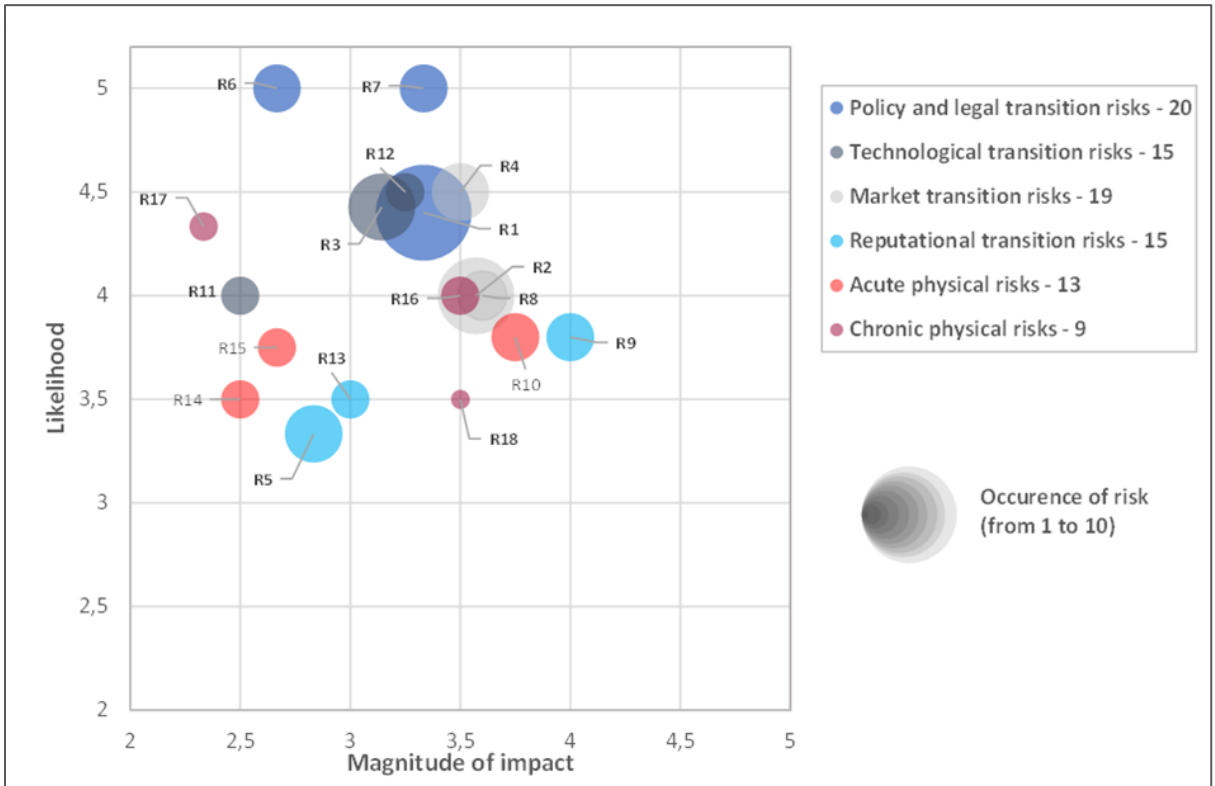
risks fall into the regulatory (20 out of 33 possible occurrences) and market (19 out of 33 occurrences) categories, while physical risks are less frequently cited (13 occurrences for acute and 9 for chronic out of 33 in total). This may be linked to recent changes in French and European regulations concerning non-financial reporting obligations e.g., (ADEME, 2020; EFRAG, 2022), and therefore to participants' greater knowledge and vigilance on this subject, often included in strategic risk evaluations. In contrast, risks related to physical impacts may be new to such analysis, and potentially not as familiar.

In addition, this step may relate to double materiality, i.e., an issue is considered "material" if it has a major impact on social or environmental aspects, or on the company's economic performance, or on both. Identifying priorities with a double materiality lens is increasingly recommended (La Torre et al., 2020), although not yet fully operationalized (De Cristofaro & Gulluscio, 2023). More guidance is needed, both in the ACT-S methodology and in international standards and regulatory frameworks, to ensure that this dual approach is considered and harmonized.

Furthermore, this step takes a comprehensive perspective in terms of climate-related risks and implies a wide range of stakeholders in the company. To take advantage of this structured and comprehensive approach, other environmental or social issues could also be included, at least in qualitative terms, to identify potential hotspots in terms of transferring impact to other sustainability issues. Although outside the ACT-S framework, the methodology could, for example, rely on the impact categories defined as part of the materiality exercise in CSR practices, e.g. in the Sustainable Development Goals (United Nations, 2018) or in the doughnut theory (Raworth, 2017).

Lastly, this sub-steps and participant feedbacks reveal that climate-related perspective in strategic risk analysis may be uncommon in the corporate world and requires a good knowledge of both climate and company-specific sectoral issues, especially when only using the TCFD's

risk categories as a starting point. Mobilizing experts is therefore important to ensure that certain risks (e.g. physical risks) are not overlooked due to a lack of knowledge. Also, a more extensive risk bibliography could facilitate the process and increase the likelihood of obtaining a more complete analysis. Here, we propose an initial basis for such a library, in the supplementary information (see section **0** in Annexes), and call on future research to complete and systematize it.



Description of the risks (from most to least frequent)

R1	Introduction of a mandatory carbon tax / green taxonomy / emission quotas	R10	Impact of natural disasters on infrastructures/buildings/sites
R2	Poor anticipation of climate-related changes in supply and demand, and stakeholder expectations	R11	Difficulty in introducing digital sobriety or optimizing energy use
R3	Dependence on resources and energy for the development of digital and business activities in companies	R12	Financial difficulties for the necessary technological transition (stranded assets, investments)
R4	Shortage of components and raw materials (scarcity or geopolitical tensions/privileges)	R13	Impact on corporate image with investors
R5	Difficulty of climate-related communication, negative image of an ineffective climate strategy (e.g. speed, ambitions, impacts)	R14	Extreme and frequent meteorological crises that would paralyze production
R6	Regulatory changes linked to buildings/land, energy performance	R15	Risk of supply chain disruption & rapid rise in raw material prices
R7	Evolution and obligation of carbon-related reporting and disclosure	R16	Loss of productivity due to extreme heat and rising temperatures
R8	Insufficient involvement and availability of stakeholders in transformations	R17	Major increase in insurance costs (buildings and activities) due to climate impacts
R9	Employer brand: loss of attractiveness	R18	Increasing impact on people's environmental health, epidemic risk

Figure 4.4: Top 3 climate-related risks for the six categories of ACT-S[15].

4.3.3. Indicators and emission targets

Based on sub-steps 2A and 2B, the carbon performance targets step (sub-step 4A) quantitatively define the company's emission allowances over a time horizon circa 10 years. **Figure 4.5** shows the 10 trajectories defined by the companies in this study, normalized according to their base year emissions. After the 4th step of ACT-S, 3 organizations defined differentiated targets for Scope 1 and 2, and for Scope 3 (figure **4.5a** and **4.5b**); and 7 organizations defined their targets on all emission scopes (figure **4.5c**).

Companies numbered 2, 7, and 10 (with differentiated targets for scope 1, 2 and 3) followed the SBTi method (SBTi, 2019c, 2023b), one of the options recommended in ACT-S methodology for emission target setting. For Scope 1 and 2 emission targets, a linear annual reduction rate of 4.2% corresponds to the minimum ambition, using SBTi Absolute Contraction Approach (ACA) 1.5°C method (SBTi, 2023b). For specific Scope 3 targets, only intensity targets are defined, which are difficult to compare as they are highly dependent on forecasts for the physical or financial indicators used.

The others defined their targets in relation to other benchmarks such as national or sectoral or network trajectories, sometimes more ambitious than SBTi methods. Five companies out of seven have set a target of halving emissions between 2019 or 2020, and 2030. This corresponds to the overall employer association emission target. One company has also set this 50% target, but with a longer timeframe. Finally, one company has set a less ambitious target, following the

[15] The figure shows 18 most cited risks, represented with their average likelihood and magnitude impact on the company, according to the 10 companies of the case study. Size of datapoints represents the occurrence of the risk. The cumulative number of occurrences for the top 3 risks in each category is shown in the legend at top right. Probability and magnitude of impact are shown on the ordinate and abscissa respectively, on a scale of 1 to 5. Probability is indicated semi-quantitatively, from "not likely at all" (level 1) to "certain" (level 5). Impact magnitude ranges from 1. very low to 5. Very high. The table on the bottom details the name of the risks.

national trajectory for its sector (agri-food and agriculture), which takes into account more difficult reduction levers (MTES, 2020).

This stage was perceived as simpler for companies as it involves the definition of quantified targets, which companies are more used to doing. Also, the application of this step was facilitated by the collective commitment made in 2019, aiming to reduce the employer association companies' cumulative emissions by 50% between 2019 and 2030. For most companies, this step was therefore a way of specifying GHG emission reduction targets.

As the ACT-S methodology recommends the use of SBTi methods, the SBTi limitations apply to ACT-S when setting emission targets (Bjorn et al., 2021; Bjørn, Matthews, et al., 2023; Tilsted et al., 2023). In this light, ACT-S deliverables and tools could facilitate an increased transparency when setting and reporting emission targets, notably on the underlying assumptions. In this light, additional parameters could also be integrated in ACT-S emission target definition step, such as the uncertainty of emissions, the shape of the trajectory, or climate justice considerations (see **Chapter 1**).

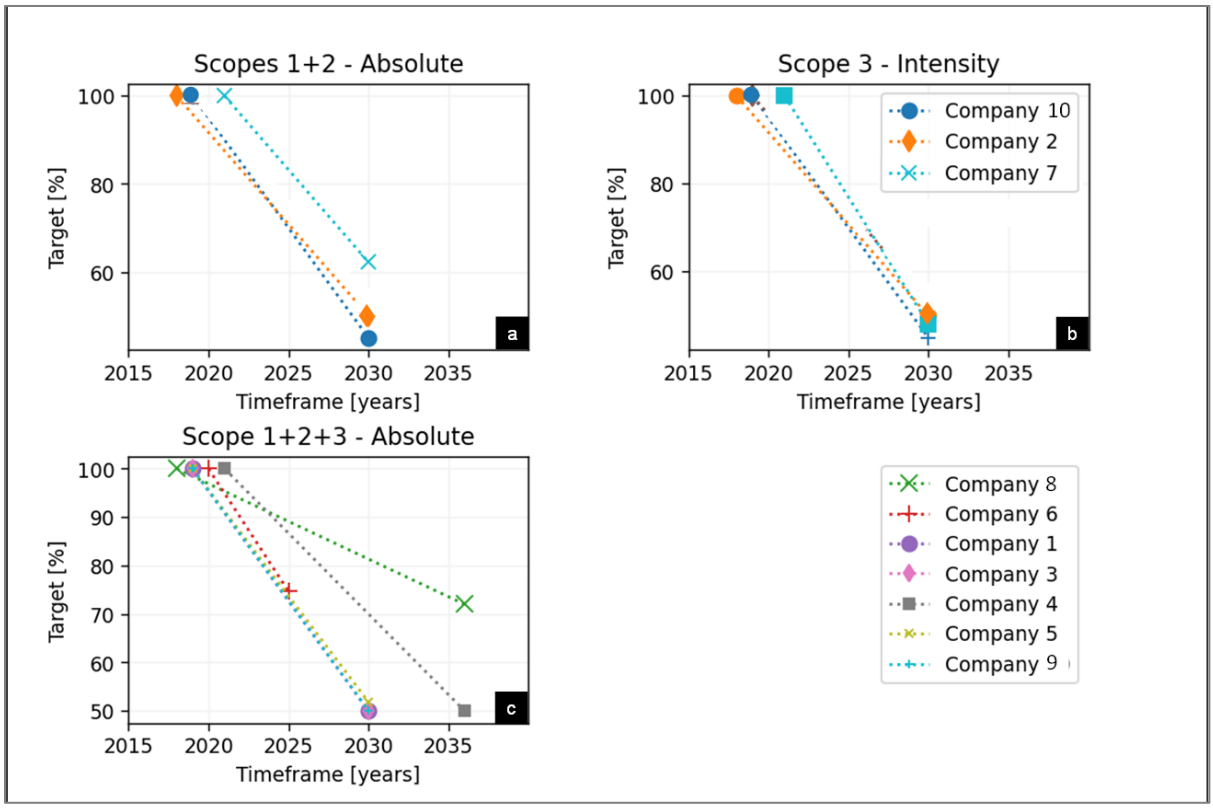


Figure 4.5: Emission targets defined by the 10 organizations on their Scope 1, 2 and 3 GHG emissions.

4.3.4. Low-carbon vision and strategic plan

Step 3A aims to develop narratives for the long-term vision of organizations in a low-carbon world, with milestones for 2025, 2030 and 2050. For the 10 organizations in this case study, this step resulted in a cumulative total of 426 words for 2025, 273 words for 2030 and 1028 words for 2050. Step 3 of ACT-S is crucial to ensure consistent and robust transition plans (defined in steps 4 and 5), yet complex. The first steps of ACT provide valuable insights to prepare step 3, both quantitative (e.g. performance indicators) and qualitative (e.g. risk analysis and new narrative). The experimentation showed that it is important to rely on both the identified risks and the initial maturity analysis, so that the visions defined can integrate the priorities established in step 1 and overcome the major risks identified in step 2. Feedback from

participants highlighted that to be successful, the vision step needs to be carefully prepared, as the process of envisioning a company into 2050 can be difficult.

However, step 3 application is described very briefly in the methodology, which may be due to a lack of precise guidelines in literature, or to the fact that each company is given the freedom to define its own strategy and business model. Specifically in this study, the definition of the vision during step 3 was facilitated by a full-day collective workshop. The process of this workshop is detailed in annexes, section **0**, and we recommend that future users of the ACT-S methodology follow a similar workshop or be transparent about the processes followed, so as to be able to refine the ACT-S methodology.

Based on these visions outlined in step 3A, strategic plans with thematic pillars were defined to categorize the axis of the strategic plan (sub-steps 3B and 4B), as shown in **Table 4.2**.

A generalization of what can make up a complete strategic plan for a company in terms of climate change mitigation is inductively generated. Therefore, we propose 7 strategic axes, that should be defined and adapted with a cross-functional team, validated at board level and then implemented operationally within the company. These 7 strategic axes are

1) Develop a low-carbon offer and generate positive-impact projects;

2) Take action on direct emissions in an exemplary manner;

3) Increase positive influence on the territory and value chain;

4) Transform professional practices for employees;

5) Rethink governance and business model;

6) Tackle major indirect emissions (e.g. digital technology, transport, raw material, etc.);

7) Manage and promote low-carbon performance.

These 7 axes can be used as a basis for structuring a climate change mitigation strategy, and although they may not be systematically relevant to all organizations, they could be relied upon to ensure that no strategic aspect has been overlooked.

Table 4.2: Strategic plans defined by companies in ACT-S 4th step [16].

	Develop low-carbon offers and generate positive-impact projects	Take action on direct emissions in an exemplary manner	Increase positive influence on the territory and value chain	Transform professional practices for employees	Rethink governance and business model	Tackle major indirect emissions (e.g. transport, material)	Manage and promote low-carbon performance
COMPANY 1		Energy - heating	Inputs - CSR criteria	Digital - GreenIT best practices and fixed assets		Transportation - electrification and soft mobility	Communication - GHG vision and strategy
COMPANY 2	Economic - Investments, partnerships and virtuous offerings	Environment - controlled impact and stakeholder involvement	Territory - Responsible and local purchasing, territorial involvement	Social - employee commitment and reinvented work organization	Governance - Virtuous business model and value sharing		
COMPANY 3	Developing low-carbon offerings	Energy consumption - reduction and self-generation	Reducing the carbon impact of inputs			Reduce the amount of waste sent to landfill	Tracking their positive impact (avoided emissions and carbon sinks)
COMPANY 4	Responsible Products	Buildings & Energy-saving practices	Responsible Purchasing & Food	Changing practices	Responsible Investment	Soft mobility	Green IT
COMPANY 5	Designing low-carbon, eco-incentive products and services for customers		Involve stakeholders in climate actions and become a major player in one health approach	Integrate an ecological and sober approach into professional practices	Incorporating the challenges of transition into our business model		Reducing the carbon footprint of the investment portfolio
COMPANY 6	Invest in our low-carbon offer	Optimizing energy consumption	Positively influencing our stakeholders	Optimizing employee travel	Promoting innovation for transitions		Playing an active role in the region's energy transition - ENR and forestry heritage
COMPANY 7	Low-carbon solutions and the circular economy	Energy transition		Innovation and collective intelligence for transitions		Reconciling and aligning the value chain - travel and freight	
COMPANY 8	Developing a pleasurable and committed healthy diet	Freeing ourselves from fossil fuels				Reduce waste and turn it into resources	Managing climate performance
COMPANY 9	Positive impact project - offering and customer impact	Group exemplarity - direct leverage	Responsible purchasing			Low-carbon mobility - travel and freight	Digital sobriety
COMPANY 10		The impact of Company - operations and energy consumption	Customers and ecosystem - Responsible and local purchasing and stakeholder involvement	Employees - commitment and value sharing	Governance - a virtuous business model for sustainable performance and rethought work organization		

[16] . Each company defines between 4 and 7 strategic pillars, based on the major direct and indirect GHG emissions, the diagnosis carried out in step 1, the risks identified in step 2, and the vision defined in step 3. The pillars were automatically translated and anonymized. They were categorized by generic strategic axis, which were developed by comparing them with each other.

4.3.5. Quantitative and qualitative action plan

Table 4.3 shows the number of actions identified by each company, as well as the number of fields completed in ACT-S step 5 to characterize operational actions. A total of 359 actions were defined for all companies, with the number varying across them. This may reflect upstream prioritization and very precise specification for the deployment of prioritized actions. For example, Company 4 defined 9 actions, with a high level of detail (i.e. all fields were filled to characterize the 9 actions). Company 7, on the other hand, defined 77 actions, but only partially filled in 14 out of 26 fields, with, for example, only 7 actions with a monitoring indicator or planned coordination.

This may be linked to the different uses of ACT step 5, such as prioritizing actions, using the 9 validation criteria, planning actions, using the operational fields, or simulating an action plan, using the specific GHG emission targets, for example. The advantage of this action plan format is that, unlike the actions that result from a carbon accounting exercise, this framework accommodates actions of means, which cannot be quantified in terms of direct GHG emissions reduction, although they may be of similar importance, and complementary.

In addition to the ACT-S methodology framework for action plan definition, we recommend indicating the purpose for which the action plan step is being carried out, as well as the status of each action (committed, validated, started, in progress, or completed, for example). In addition, it might be useful to indicate mandatory fields (e.g., description of the action, a monitoring indicator, the start and end year, and a target, whether in terms of GHG emissions or other) and optional fields to be completed in certain cases to be specified. It might also be useful to provide two different templates for actions involving means or which cannot be quantified in terms of GHG emissions reduction, and for actions whose results can be quantified in terms of GHG emission reductions. This second type would include mandatory fields such as CO2e target and type of reduction. In this case, it would also be advisable to add the relevant

emissions and associated uncertainties. Also, obstacles and levers for each action could also be identified and filled in the description of the action.

In addition to the action plan definition step, a visualization of the actions as well as a quantification, when possible, of the GHG emissions reduction potential was added to the ACT-S methodology in the case of this study. **Figure 4.6** shows an illustration of this visualization. We recommend including such a tool in the ACT-S methodology in the step 5 deliverables, that could rely on existing methods (e.g. (ADEME, 2022)). Although it is important to include qualitative actions of means, and that such quantification is often associated with high uncertainties, this additional step can help to judge the consistency between the defined action plan and the emission targets defined in step 4. This quantification allow assessing the orders of magnitude of the emissions covered by the action plan, as well as on the overall ambition of the action plan.

Table 4.3: Number of identified climate-related actions for the 10 organizations of this case study, with number of fields completed to describe them[17].

	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 4	COMPANY 5	COMPANY 6	COMPANY 7	COMPANY 8	COMPANY 9	COMPANY 10
Strategic pillar and action name (total number or actions)	43	29	19	9	36	30	77	51	16	49
Action number (ID)	0	0	10	9	35	30	15	51	16	49
Action description	43	29	19	9	13	30	77	51	16	49
CO2 Target	43	0	19	9	32	30	75	24	16	49
Unit	43	0	19	9	14	30	77	28	16	49
Target Year	43	0	19	5	27	30	46	51	16	49
Base Year	43	0	19	9	30	30	77	0	16	49
Reduction type	43	0	18	8	2	0	65	0	16	49
Intensity unit	0	0	1	9	9	0	0	0	16	0
Monitoring indicator	0	0	19	9	27	0	7	0	16	49
Coordination and organizational structures assigned	34	0	19	9	29	0	7	3	16	49
Human and time needs for planning	0	0	19	9	31	0	0	0	16	49
Human and time needs for implementation	0	0	15	9	31	30	0	0	16	49
Overall budget for planning and implementation	0	0	19	9	30	0	0	0	16	49
Financing sources	0	0	19	9	31	0	0	0	16	49
Stakeholders involved	31	0	19	9	33	0	0	0	16	49
Level of involvement	0	0	9	4	32	0	0	0	16	0
Specific	0	0	19	9	33	30	0	51	16	49
Measurable	0	0	19	9	33	30	0	51	16	49
Achievable	0	0	19	9	33	30	0	51	16	49
Realistic	0	0	19	9	33	30	0	51	16	49
Time based	0	0	19	9	33	30	0	51	16	49
Climate impact	0	0	19	9	33	30	5	51	16	49
Acceptable	0	0	19	9	33	29	46	51	16	49
Transformative	0	0	19	9	32	29	37	51	16	49
Engaging	0	0	9	9	33	29	36	51	16	49

[17] The color code is specific to each column, and represents, for a given cell, the proportion of actions for which the field has been filled in. A field filled in for 0% of the actions identified by the company will be dark red, while a field filled in for 100% will be dark green, with a progressive shade between the two.

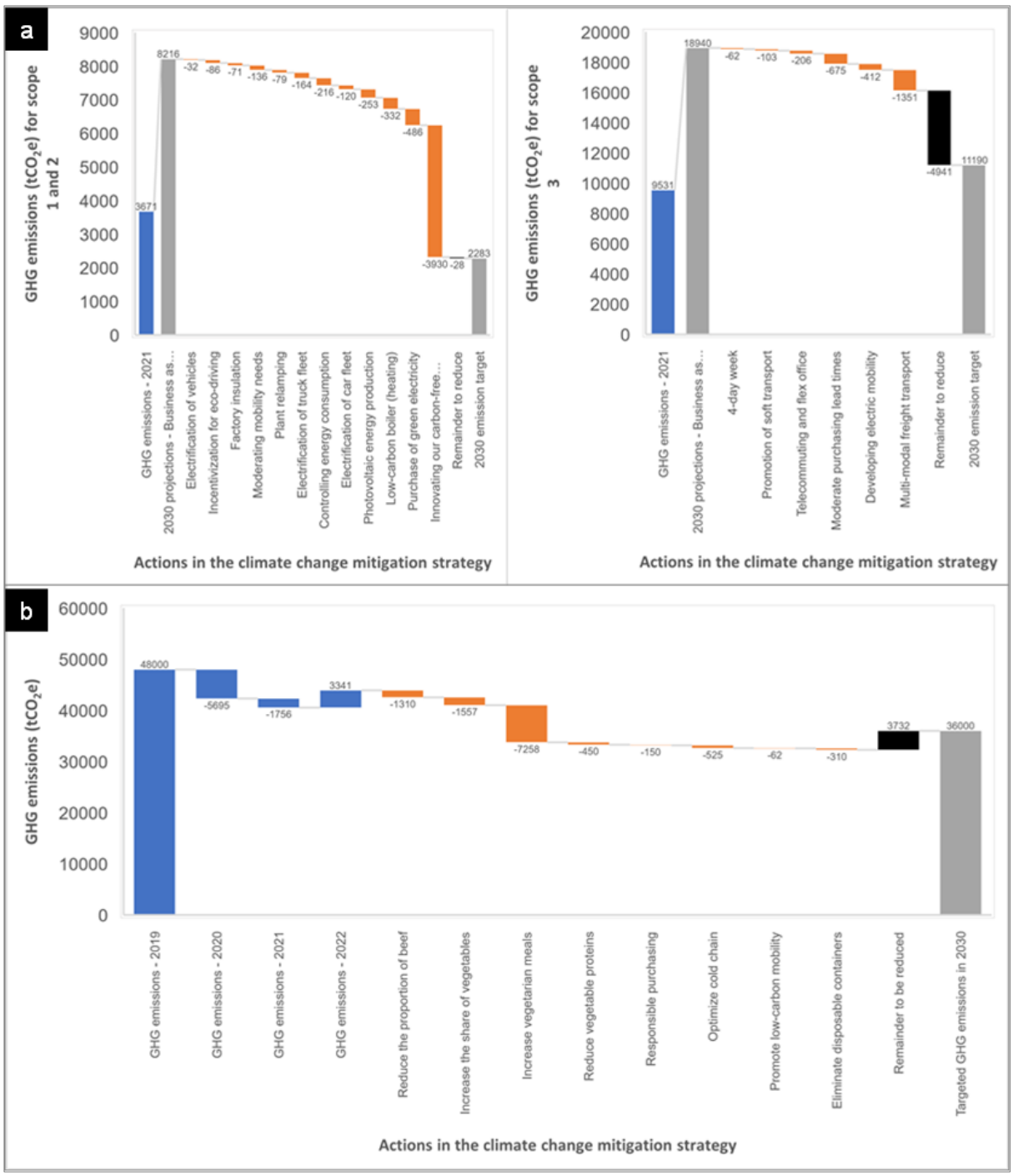


Figure 4.6: Illustration of quantitative complements for ACT step 5 on action plan visualization, for two companies of this case study[18].

[18] Figure 4.6a corresponds to a company with SBT emission targets differentiated according to scope 1 and 2, and scope 3. Figure 4.6b represent a company that defined a single target for all its emissions. The blue bars represent measured emissions, the orange bars simulated actions, the grey bars projections for 2030, and the black bars the difference between the cumulative emissions of the action plan and the target for 2030.

4.3.6. Toward an upgraded ACT-S framework

Based on the first application of the ACT-S methodology and feedback from participating companies, this section presents an improved ACT-S framework with recommendations for improvements. **Figure 4.7** provides a visualization of these recommendations.

Firstly, several modules could be added or could complement the 9 existing ACT modules. A point not addressed in ACT yet potentially critical to the deployment of OCCMS is the financing of the strategy and the investment for climate action (Adhikari & Safaee Chalkasra, 2021). A module could be added, focusing for example on the internal price of carbon, the shadow price of carbon, other sources of financing, or investments on climate action both within and outside the value chain. Next, a module linked to the quality of measurement of GHG emissions and other quantitative indicators could be added, as uncertainties and lack of harmonization in GHG emissions is a major issue of corporate carbon accounting (Adhikari & Safaee Chalkasra, 2021; Klaaßen & Stoll, 2021). Such a module could include the strategy for managing uncertainties, the completeness of the scope of carbon accounting, and elements on transparency. One of ACT's prerequisites is the completion of at least one GHG emissions assessment, but this does not necessarily mean that the quality is sufficiently high. In addition to involving governance in the ACT-S methodology, a module could also be added to address the governance of the OCCMS, covering decision-making processes and the establishment of a strategy steering committee with external stakeholders. These elements could also be included in the current Management module. Finally, elements on communication and influencing the general public could be added, either in the policy engagement module, or in a new module.

Secondly, complementary tools could be added to make some steps more operational. This study and the feedback it provides enable to suggest such elements, which could be a basis for future work on integrating them into the ACT-S methodology or into methodologies for defining OCCMS. In this light, to enhance the definition of robust OCCMS, ACT-S tools could also be publicly available. For example, a risk library, initiated in section **0** (annexes) and

completed progressively and collectively, could be added to step 2C, a vision workshop format (such as defined in SI) could be specified in step 3A, a strategic plan template could be proposed in step 4B (e.g. with the 7 pillars proposed in section **4.3.4**), and a visual quantification of the action plan and overall coherence could be integrated into step 5 (as proposed in section **4.3.5**).

Thirdly, the action plan stage could be initiated before the four first steps have been completed, so as not to wait a year before implementing the first incremental actions before proceeding to deeper, cross-functional actions. This does not prevent this step from being carried out in the same way once the first four steps have been completed.

Finally, it is important to integrate ACT in broader organizational strategies, ranging from OCCMS to CSR strategies to overall corporate strategies. ACT-S can be used to carry out a strategic analysis, define reduction targets and implement an action plan, but as shown in **Chapter 3**, there are other elements involved in a complete OCCMS. For example, it is important to make the link with carbon accounting methods (e.g. GHG protocol) and monitoring, reporting and verification standards (e.g. CDP). Beyond climate change mitigation, it is also important to integrate ACT-S into strategies that also take into account adaptation to climate change, the development of carbon sinks, or the climate transition financing. More broadly, to break free from the climate change tunnel vision (Deivanayagam & Osborne, 2023) (i.e. overlooking other sustainable impacts than climate change), it is necessary to consider how ACT-S interact with other key environmental and social issues, such as biodiversity or social justice, among others.

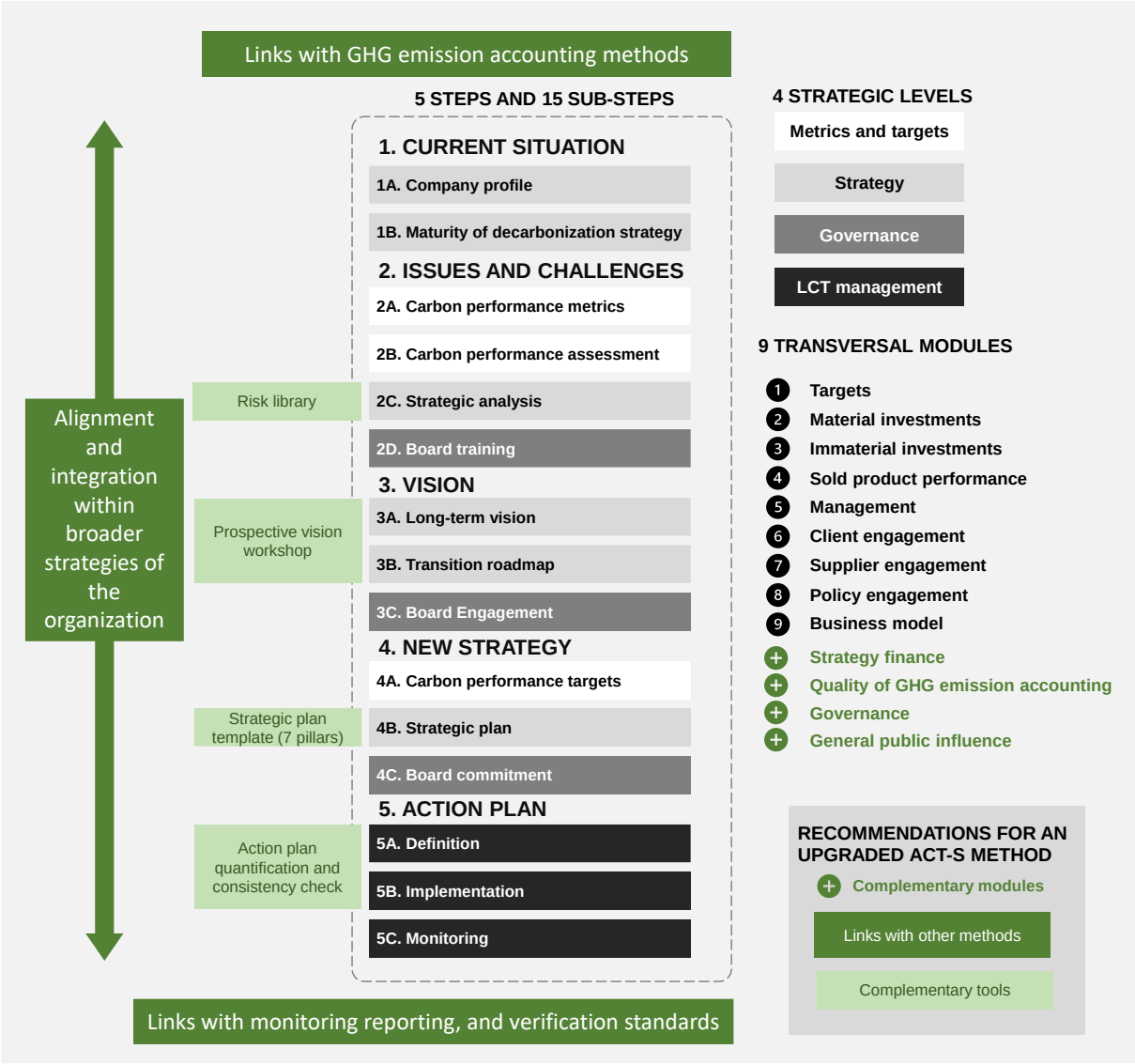


Figure 4.7: overview of an upgraded ACT-S methodological framework based on the learnings from this case study

4.4. Conclusion

The private sector must contribute to achieving the objectives of the Paris agreements, but there is a lack of methodology for defining comprehensive and robust climate change mitigation strategies for all types of organizations as well as a lack of case studies demonstrating attempts to implement such strategies. The ACT Step-by-step (ACT-S) methodology holds potential to meet this gap, going beyond the necessary yet no sufficient notions of carbon accounting and emission target setting. However, no case study related to ACT-S was ever published, possibly due to its recent nature. Through a multi-case approach, this article responds to this need and reveals the first 10 companies to have ever applied this method.

This study demonstrates the applicability of the ACT-S methodology to companies of different sizes and sectors. It also emphasizes the comprehensive, cross-functional nature of the methodology, covering both quantitative and qualitative aspects, in relation to an organization's carbon performance, strategy and governance. Also, this 3-year experimentation with 10 diverse organizations contributed to the definition of more ambitious and robust climate change mitigation strategies in an intervention-oriented research perspective. Crucially, such initiatives need to be supported both by standardized reporting frameworks that promote transparency and accountability, and by legislators who enforce the development of ambitious decarbonization practices and innovation in the private sector.

Some adjustments and additions to the methodology were made, enabling to highlight some shortcoming and to provide recommendations for further improvement of the methodology. Firstly, the collective operation format, with alternating times for group and individual work, brought together 10 companies from a territorial employers' network. This enabled a mutually reinforcing dynamic among the companies involved in defining their climate change mitigation strategy, getting both managers and employees to participate, and sharing best practices within the same territory. Secondly, operational tools and workshops have been added to the ACT-S

methodology, to strengthen participants' knowledge or to reinforce the overall consistency of the approach.

This study helps to cross the boundaries between innovative methods of the private sector for climate change mitigation strategy definition, and the academic sphere, with a field approach. It is actually the first academic review of a methodology to define organizational climate change mitigation strategies that goes beyond quantification, including also strategic and governance levels. It is also the first inductive research approach proposing case studies and data for such strategy development. This 3-year inductive approach allows suggesting some improvements and recommendations in the ACT-S methodology, and more generally in the definition of corporate climate change mitigation strategies. Additional methodological development needs have been highlighted, which may be both relevant to method developers and future research. Overall, this study contributes to developing the standards needed to define credible, robust and sufficiently ambitious climate change mitigation strategies.

CHAPTER 5

Exploring the links between corporate "Science-Based Targets" and corporate GHG emissions: focus on base year

This chapter is based on the article entitled "Do base years matter? Exploring the links between Corporate Science-Based Targets and corporate GHG emissions", to be submitted to Environmental Research Letters in November, 2023. The format of the article for submission is a letter (i.e. less than 4000 words). The version presented in this thesis is longer as it covers a broader work including further analysis and recommendations to make the recognized Science-Based Targets initiative (SBTi) more relevant and reliable. This chapter includes a focus on the need for greater transparency in the way SBT emission reduction targets are defined, validated, and then reported with SBTi. The latter point was featured in a comment in Nature Climate Change I co-authored in July 2023(Bjørn, Matthews, et al., 2023).

Abstract

The Science-Based Targets initiative has become increasingly popular for companies committed to reducing their greenhouse gas emissions. A lack of transparency can be observed about the choices, assumptions and justifications made in the target-setting process. This study sheds light on one important choice, namely the selection of the base year when defining corporate science-based targets, and investigates its relative importance and influence on GHG emission reductions. By cross-referencing actual emissions and target data from over 500 companies and 800 approved targets, we show that there is a tendency that companies cherry-pick their base year, so as to minimize the reduction burden in the target year. This finding implies that the aggregated actual emission reductions associated with the implementation of science-based targets are lower than intended. To ensure robust and ambitious corporate climate mitigation trajectories, we therefore recommend to the Science-Based Targets initiative stakeholders to select transparently the base year when setting emission reduction targets and when reporting annual emissions. Here, we provide guidance documenting the information to be reported in order to prevent base year cherry-picking, for emission targets to be effective.

Keywords
Science-based targets; Corporate emissions; Emission pathways; Climate action and transparency; Climate change mitigation;

5.1. Introduction

The Paris Agreement and its 1.5°C targets impose stringent constraints on global GHG emissions over the coming decades (IPCC, 2018a; UNFCCC, 2015). To accommodate these reduction needs, both states and non-states actors, including within the private sector, are increasingly committing to ambitious climate actions (Chan et al., 2018; Persson & Rockström, 2011; Rashed & Shah, 2021). As part of the corporate-wide climate effort, emission targets are defined as planned reductions in companies' GHG emissions (absolute or per unit of production) between a historical base year and a future target year (SBTi, 2019c). An organization can thus define several targets, according to emission scopes using different available approaches or methods (Andersen et al., 2021; Bjorn et al., 2021; Giesekam et al., 2021a; Krabbe et al., 2015; SBTi, 2015, 2019b; Walenta, 2019).

Since 2015, the Science-Based Target initiative (SBTi), founded by CDP (former Carbon Disclosure Project), the United Nations Global Compact, World Resources Institute and the World Wide Fund for Nature, has provided guidelines and a validation process for companies to set such targets, allegedly "in line with the latest climate science" and "with a 1.5° future" (SBTi, 2023e). Organizations can use these available methodologies to define their "science-based targets" (SBTs) and submit them to the SBTi which then approves and publicly publishes the targets if they meet a set of SBTi criteria (SBTi, 2023b). As of 30 June 2023, more than 5,500 companies committed to set targets with a rapidly increasing trend, representing a third of the global market capitalization, among which more than 3 000 companies already have approved targets by SBTi (SBTi, 2023c). The initiative is presented as a reliable methodology for ensuring integrity of targets by institutions (United Nations, 2022) and by governments (The White House, 2022).

This growing interest has also led researchers to scrutinize the scientific foundation of the methodology, its processes, governance and reporting mechanisms (Bjørn, Matthews, et al., 2023; Tilsted et al., 2023). First, there is a lack of transparency in the process to set and validate climate targets through SBTi, notably on underlying choices (e.g., transparency in hypothesis and scopes, projected company activities, feasibility of the trajectory, and monitoring of progress) (Bjørn, Matthews, et al., 2023). Second, there are multiple parameters that organizations can use and adjust to define their targets, such as base year, target year, temperature alignment scenario, emission indicator, scope (SBTi, 2019b). Without stricter method guidelines and documentation requirements, the current SBTi target-setting flexibility might lead to a carbon imbalance between global and downscaled climate goals (Bjorn et al., 2021). Third, all existing SBT methods rely (fully or partially) on emissions grandfathering, meaning that the allowable emissions in the target year are proportional to the emissions in the base year (Bjorn et al., 2021). Thus companies can, in theory, maximize their future emission allowances by choosing a base year with relatively high emissions. The selection of the base year can therefore be determining in the accounting of corporate emission reductions. But to what extent? In this light, the 2022 climate monitor found some evidence of base year cherry picking for a small number of 25 companies, meaning emissions in base year being extraordinarily different from other years (Day et al., 2022). Despite these shortcomings, no study has examined the influence of the base year on the GHG emission targets defined with SBTi methods.

This article aims at empirically studying the influence of the choice of base year on future emission allowances for a large sample of companies with approved SBTs worldwide. Specifically, it tends to i) investigate trends in the choice of base year for validated SBTs in terms of GHG emissions relative to neighboring years, ii) evaluate the relationship between the selected base years and the defined pledges for individual companies iii) quantify the combined effect of companies´ potential base year cherry-picking on aggregate emission reduction

commitments. By addressing these questions, we aim to gain insights into the decision-making process of companies when setting their targets, to investigate the impact on the total projected GHG emission reduction, as well as to provide recommendations for more robust target setting methodologies and reporting.

5.2. Methods

5.2.1. Overall approach

This study aims at exploring what would have happened if each company with one or more SBTi-approved targets had chosen different base years with the same annual reduction rate. First, it is required to define the company and target sample, and build the dataset to link the approved SBTs with GHG emissions for the base year and neighboring years **(section 5.2.2)**. Then, different indicators are developed to analyze trends in base year selection as well as variations in GHG emissions between base years and neighboring years (**section 5.2.3).** Finally, several possible scenarios compliant with SBTi criteria are defined for every target, each with a different base year for which GHG emissions are retrieved, to observe the sensitivity of this parameter and the impact on cumulative GHG emission reductions (**section 5.2.4**).

5.2.2. Sample definition and dataset construction

Figure 5.1 illustrates the target selection and dataset creation process. As of 30/06/23, the SBTi dashboard (SBTi, 2023f) covered 11047 data, including 6156 validated targets for 3033 companies, which are the focus of this study, and 4891 commitments, i.e. companies aiming to submit reduction targets over the next 2 years. First, near-term targets are retained, as opposed to long-term or net zero aiming towards 2050. Targets are categorized notably according to sectors, world region, target scopes, i.e. combinations of Scope 1 (direct emissions), Scope 2 (indirect emissions from consumption of purchased electricity) and Scope 3 (other indirect emissions). To ensure comparability, and since financial or physical corporate

data are often not available, only absolute emission reduction targets are taken into account. Absolute targets are opposed to intensity targets (relative to an economic or operational variable) and maintenance targets (that do not require further emission reductions). These criteria (stages 1 to 3 in **Figure 5.1**) applied to the SBTi dataset led to the removal of 37% of the targets (from 6156 to 3890 targets), but only 4% of companies (from 3033 to 2917 companies). This reveals that companies with SBTi long-term, net-zero and/or intensity targets are usually defined after absolute near-term targets.

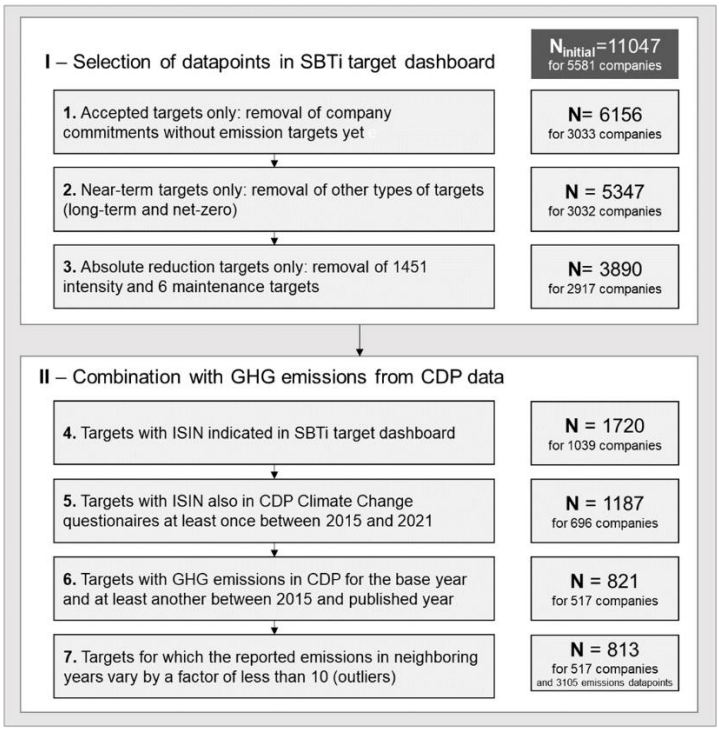


Figure 5.1: step-by-step method to build the dataset of SBTi-approved targets combined with historical GHG emissions. N = number of targets.

For each target, the associated emissions for the base year and neighboring years on the same scope are retrieved from CDP Climate Change questionnaire (CDP, 2023b). As company names in SBTi and CDP are not always consistent, potentially due to errors or different administrative nomenclatures, International Securities Identification Numbers (ISIN) have been used to link the two datasets as unique international identification numbers. However, not all companies indicate ISIN in SBTi reporting system, notably SMEs. SBTi criteria require base years to be set for 2015 or later, therefore ISIN has been searched in CDP Climate Change

questionnaire from 2015 to 2021. Moreover, only targets for which GHG emissions are available for the base year and at least for one more year were retained in the dataset. Also, to simulate only the choices available to companies at the time of target definition, only emission data prior to or equal to the year of publication of each target have been included.

Lastly, as some GHG emissions reported in CDP Climate Change vary extraordinarily from one year to another, outliers were removed based on the relative variation in reported emissions. A threshold of 10 was applied, for the variation in GHG emissions between base year and another year. The choice of this tolerance threshold removes 8 targets out of 821 and 123 datapoints (i.e. emissions data for one company at a given year) out of 3228 and it is further analyzed in Appendices (see **Figure A.13**). It could be valuable to investigate the systematic treatment of temporal variations in GHG emissions in available databases, which is outside the scope of this study. To assess whether this sample is representative or if there is a bias, e.g. towards big and publicly traded companies, a comparison is performed between the target sample and all targets approved by SBTi, in terms of sectors, emission scopes, GHG emission covered, and cumulated projected emission reductions (see **Appendix A.6.2**).

5.2.3. Development of indicators to analyze trends in base year selection

To analyze trends in base year selection, the noise in the data linked to the different publication years needs to be removed. Therefore, trends in choosing the base year for targets within the sample are analyzed by delay, with delay (D) for a given target T being defined as in **Equation 1**.

$$\textbf{Equation 1: } D(T) = Y_p(T) - Y_b(T)$$

where $Y_b(T)$ is the base year for target T, from which future emissions are reduced and compared against, and $Y_p(T)$ is the year of publication of the target, once approved by SBTi.

To discount scaling effects between companies' emissions, normalization of GHG emissions data is carried out for each target datapoint in relation to base year emissions, as depicted in **Equation 2**.

$$\textbf{Equation 2: } NE\ (\mathrm{Y},\mathrm{T}) = \frac{E(Y,T)}{E(Y_b,T)}$$

where NE(Y,T) is the base year-related normalized emissions of year Y for the company having set the target T; E(Y,T) is the GHG emissions for year Y of the company that set the target T, on the same scope as the target.

5.2.4. Simulation of emission reduction targets using other base years

As part of the analysis, we use the allowed GHG emissions (i.e. targeted emissions) to compare the gaps in 2030 between scenarios with different base years. The year 2030 was chosen because more than 75% of companies in the sample use 2030 as target year (see **Figure A.12**). To this end, for each target, it is investigated what the GHG emission trajectory would have been from using alternative base years, with no other parameters changed.

For consistency and compliance with SBTi criteria, two exceptions to above approach are made. First, for targets that are defined earlier than 2030, to avoid potential negative values by projecting up to 2030, we consider the overall targeted reduction rate equally applied to all alternative base years. In other words, it is assumed that if other base years had been chosen, the overall reduction rate would have been the same until the target year, and that emissions would have been stable thereafter. In a few cases, this may not be in line with SBTi criteria (for example, if the target year is prior to 2030, and the annual reduction rate falls below 4.2% for Scope 1 for companies covered by the ACA 1.5 method and the overall equivalent reduction rate is inferior to 90%). This choice has been made so as not to assign more ambitious commitments to companies that have set a target year lower than 2030. This limit does not hinder the aim of the study, as it still enables to observe the influence of the choice of base yearr, and as less than 5% of the targets in the sample are concerned. Also, in line with SBTi maintenance targets, that do not require further emission reductions for rare companies that have already significantly cut their emissions, the same rule applies if the product of the target annual reduction by the difference between 2030 and the alternative base year is greater than 1, which would mean a reduction percentage greater than 100%. Second, for potential base years after 2020, an adjustment related to the SBT criterion "minimum ambition threshold" is applied, meaning that the emissions must be reduced by at least the same amount as with a 2020 base year, to avoid favoring late emission target-setting companies (SBTi, 2023d). As there are no base year in the sample after 2020, there is no need to further adjust target ambitions according to already considered “minimum ambition threshold” rules.

So, the annual linear reduction rate AR(T) is defined in **Equation 3**.

Equation 3: $$AR(T) = \frac{R(T)}{Y_t(T) - Y_b(T)}$$

where $Y_t(T)$ is the target year until which the projected GHG emission reduction of target T is defined, and R(T) is the targeted total percentage reduction in GHG emissions communicated by SBTi for the target T between its base year $Y_b(T)$ and target year $Y_t(T)$.

Then, for a target T and for an alternative base year Y, projected emissions for 2030 are defined in **Equation 4**.

Equation 4:

$$E_{2030}(Y,T) = \begin{cases} E(Y_b(T),T) \times (1 - AR(T) \times (2030 - \min(2020,Y)), \ if\ Y_t(T) \geq 2030\ and\ if\ AR(T) \leq 1 \\ E(Y_b(T),T) \times (1 - R), \ if\ Y_t(T) < 2030\ or\ if\ AR(T) > 1 \end{cases}$$

where E_{2030} (Y,T) represent the projected emissions in 2030 for the company that set the target T, with Y as a base year and with the same trajectory used for target T; and $(2030 - \min(2020, Y))$ represents the timeframe between 2030 and the alternative base year, that defines the number of years the annual reduction rate will be applied, with the minimum value between 2020 and Y representing the "minimum ambition threshold" SBTi criterion.

To analyze the carbon imbalance between different scenarios depending on base year selection, the total aggregated projected emission reduction is calculated for three different cases, namely the 'real' case (with all targets official base years as communicated on SBTi target dashboard), the 'worst' case (i.e., the sum of all maximum projected 2030 values for each target, meaning that the reduction brings less constraints to the company in terms of emission reductions) and the best case (i.e., the sum of all minimum projected 2030 values for each target, meaning that the emission reduction is the most ambitious one), as follows:

$$E_{2030_{total_{real}}} = \sum_{i=1}^{N=813} E_{2030}\,(Y_b(T_i), T_i)$$

$$E_{2030_{total_{min}}} = \sum_{i=1}^{N=813} E_{2030\_min}\,(T_i)$$

$$E_{2030_{total_{max}}} = \sum_{i=1}^{N=813} E_{2030\_max}\,(T_i)$$

where $E_{2030\_min}(T)$ and $E_{2030\_max}(T)$ are respectively the minimum and maximum values of $E_{2030}(Y,T)$ between all years Y available in terms of GHG emissions in CDP questionnaires, for the company that set the target T; and where the sum is used to represent respectively the real, maximum and minimum cumulated GHG emission projections for all 813 targets in the sample of this study.

A comparison is conducted between these three scenarios in relation to their 2030 projected GHG emissions.

Figure 5.2 shows an illustrative fictive example to represent the different variables introduced for this study, and **Figure 5.3** provides an illustrative case with four fictive companies.

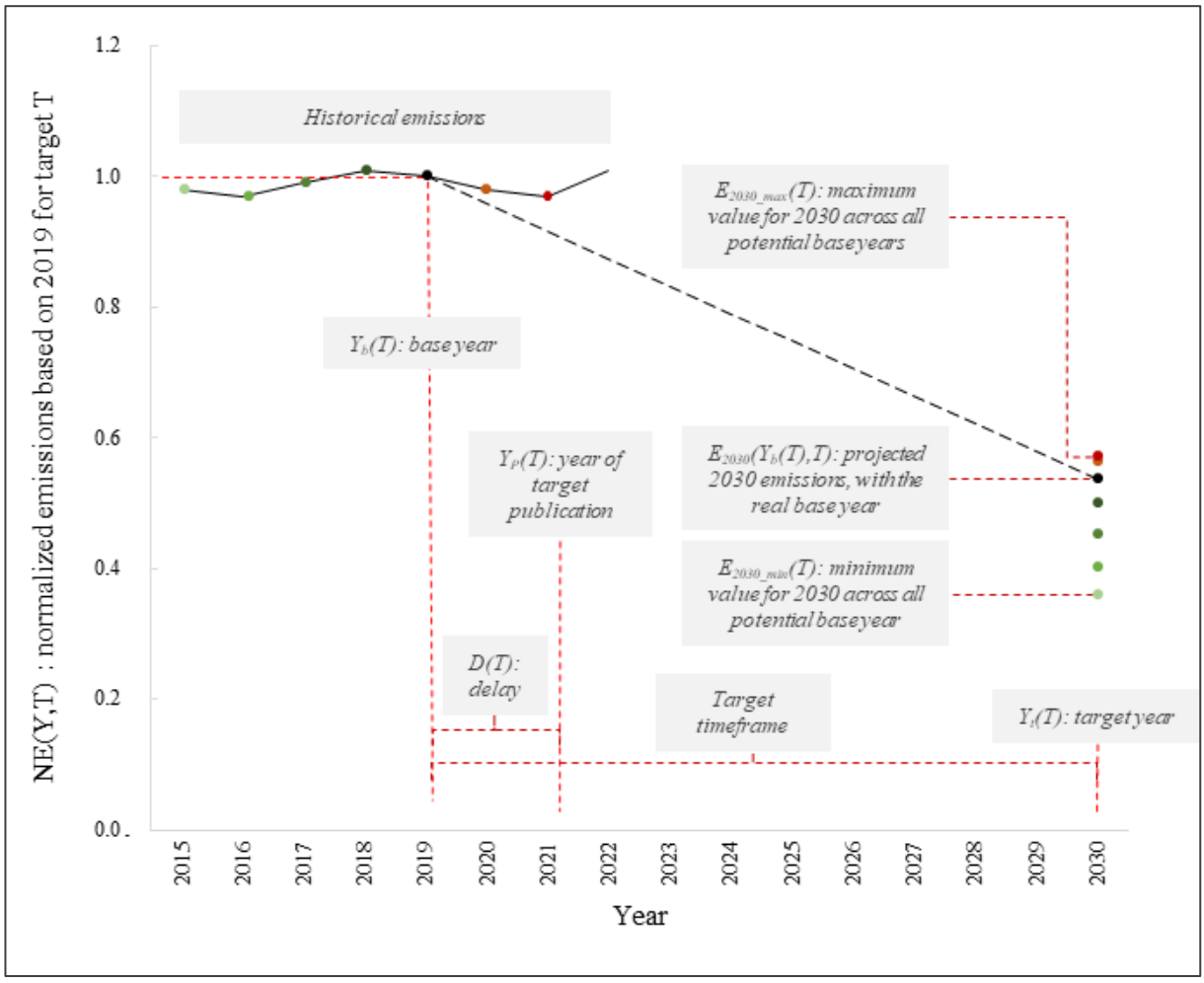


Figure 5.2 : Illustrative example for with one fictive SBTi-approved target T, with historical GHG emissions in full line, 2030 projected reduction in dashed line, and the 2030 colored points representing the different 2030 projections using different base year scenarios[19].

5.2.5. Illustrative example with fictive companies' archetypes

To illustrate the influence of the base year, 4 fictive cases have been considered, with a target published in 2021, between 2019 and 2030 with a 4.2% linear reduction (i.e. the SBTi Absolute Contraction Approach aligned with 1.5°C (ACA 1.5)), which represents a common case for Scope 1&2 targets, as SBTi ACA 1.5 is the most common acceptable method for Scope 1&2, and as 2019 is frequently chosen as a base year due to COVID-19 perturbations in 2020 and

[19] In this example, T is a 4.2% annual linear reduction of GHG emissions on Scope 1+2, between 2019 and 2030. From 2020 onwards, the projected trajectories are defined by a linear trend starting from the base year and leading to a 42% reduction in greenhouse gas (GHG) emissions by 2030, as with a 2020 base year as defined in the last SBTi criteria.

2021. The difference between the 4 illustrative companies is the trend in their historical GHG emissions between 2015 and 2022 (see **Table 5.1**). 2015 is chosen as the earliest year in this example as it is now the earliest year that can be defined as base year (SBTi criteria April 2023).

- Fictive company 1 has increasing GHG emissions of approximately 10% per year, with a slower growth rate in 2020 and 2021, due to the COVID-19 sanitary crisis. For example, it can be representative of fast-growing company in the Information and Communications Technology (ICT) sector.
- Fictive company 2 has reached a peak in GHG emissions in 2019 and an increase in GHG emissions arises in 2022. It can be representative of a tertiary company whose activity was impacted by COVID-19 crisis and changed its practice in terms of employee commuting for example.
- Fictive company 3 has decreasing GHG emissions. It can be representative of a company that deployed energy saving and efficiency measures (Scope 1 and 2) and is an early-adopter of climate change mitigation measures.
- Fictive company 4 has stable GHG emissions. It can be representative of an established secondary sector industrial company with difficult climate change mitigation leverage points because of the dependency on strategic suppliers from the primary sector.

Trajectories projected until 2023 are established for each year between 2015 and 2022, involving two distinct phases. For the years up to 2020, a 4.2% linear annual reduction is applied i.e. following the SBTi ACA 1.5°C method. From 2020 onwards, the trajectory is defined by a linear trend starting from the base year and leading to a 42% reduction in greenhouse gas (GHG) emissions by 2030. This alignment with the most recent Science-Based Targets initiative (SBTi) criteria, as of April 2023, aims to prevent any advantages gained by late adopters due to delayed definition of a SBT target.

Table 5.1: Fictive trajectories for 4 company types, with GHG emissions normalized with 2019 as a base year. Historical values are assigned for years 2015 to 2022, and projections for each company type are calculated for each potential base year from 2015 to 2022.

Reporting year	**Fictive company 1:** GHG emissions peak in 2019	**Fictive company 2:** Fast increasing GHG emissions	**Fictive company 3:** Stable GHG emissions	**Fictive company 4:** Decreasing GHG emissions
2015	0.70	0.68	0.98	1.15
2016	0.80	0.75	0.97	1.08
2017	0.90	0.83	0.99	1.05
2018	0.95	0.91	1.01	1.01
2019 (real base year)	1.00	1.00	1.00	1.00
2020	0.95	1.05	0.98	0.95
2021	0.94	1.10	0.97	0.92
2022	0.96	1.21	1.01	0.92

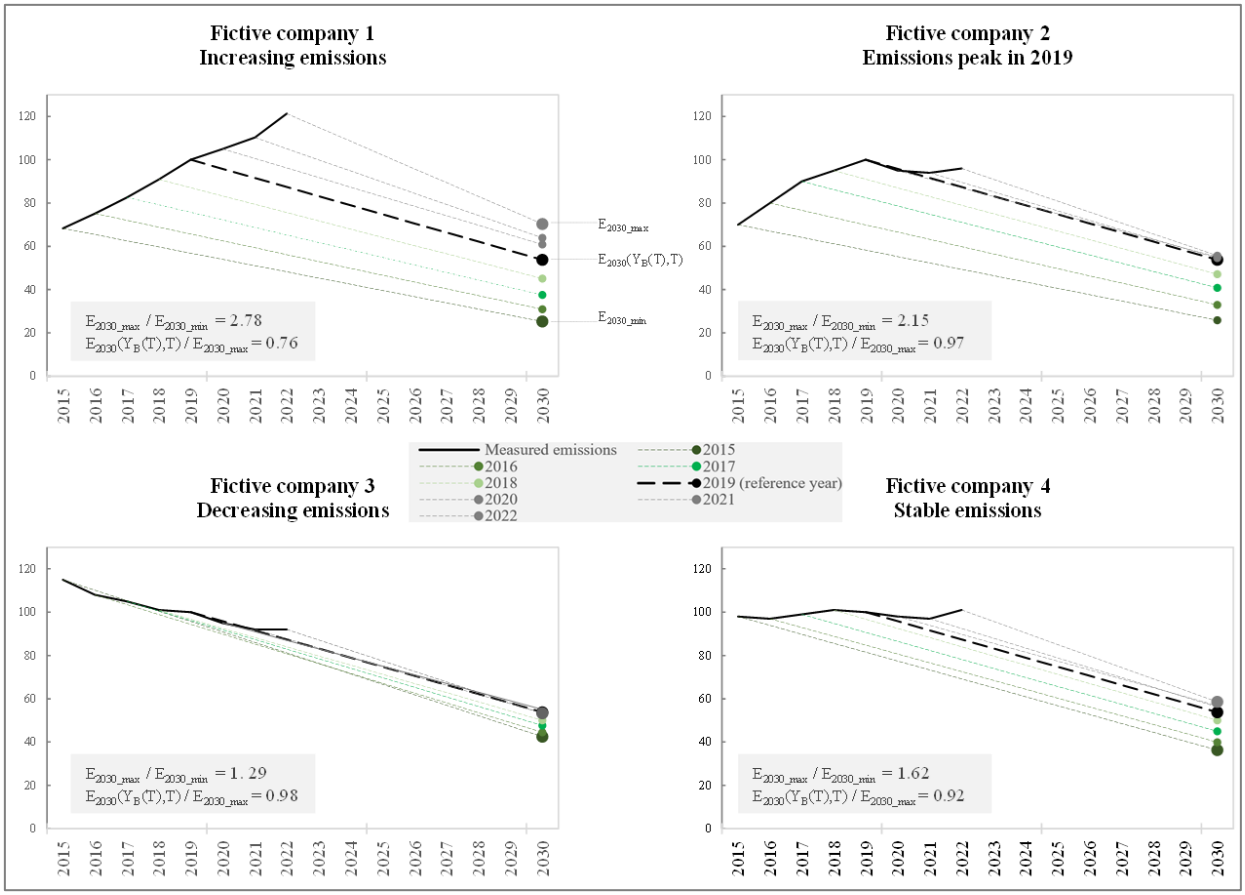


Figure 5.3: Trajectories in four different fictive company types, depending on the base year. In all cases, 2019 is the base year, 2030 the target year, and the ACA 1.5°C trajectory of SBTi is used, i.e. 4.2% linear annual reduction for years before 2020, or a reduction equivalent to 42% until 2030 for year after 2020.

The four fictive cases show that the choice of the base year leads to significant variation in the amount of GHG emissions reduced and in the projected emissions for the target year. Indeed, the ratio between the maximum and the minimum values for projected emissions vary from 1.29 (in the decreasing emissions case) to 2.78 (in the increasing scenario case). In this illustrative case, this means that for a validated SBTi absolute target, the level of GHG emissions at the target year (here 2030) may increase from 29% to 178% depending on the choice of the base year (between 2015 and 2022).

5.3. Results and discussion

5.3.1. Analysis and representativeness of SBTi-validated absolute emission reduction targets

Figure 5.4 shows the descriptive analysis of absolute reduction targets for which emissions have been retrieved in CDP Climate Change questionnaires. The final dataset is composed of 813 targets, i.e. about 20% of the total absolute SBTi-approved targets, for 528 companies and 3105 GHG emission data. Therefore, for each target, in addition to base year emissions, there is an average of 2.8 other GHG emission data items available that can be tested as potential alternative base years. As represented in **Figure 5.4b,** similar sectoral distributions of targets in the sample and in the total SBTi dataset are observed. Main differences may stem from some sectors being dominated by SMEs, who are less likely to have international identification numbers and report to CDP.

The total GHG emissions in base years covered for 813 targets represents 8.18 $GtCO_2e$, equivalent to about 14% of the global net anthropogenic GHG emissions in 2019, estimated to be 59 ± 6.6 $GtCO_2e$ (IPCC, 2023a). Targeted emissions reduction represents 2.4 $GtCO_2e$, corresponding to a 29% emission reduction and 4.1% of the global net anthropogenic GHG emissions for 2019. For Scopes 1 and 2 emissions, the covered emissions represent 0.77% of 2019 global net anthropogenic emissions or 453 $MtCO_2e$, which is considerably less but still

substantial in terms of GHG emissions. As 95% of the GHG emissions in the sample falls within Scope 3 targets, it is likely that double-counting between projected reductions for Scope 3 occurs between companies, meaning that the total emission reduction potential of the sample companies is likely smaller than the sum of their targets. Overall, the proportion of global emissions covered by the sample, and its adequacy in relation to the total number of absolute SBTi-approved targets, make it a suitably representative sample for this study.

With regards to emission scopes, about 55% of the targets address a combination of scope 1 and 2, and 45% are covering scope 3, sometimes associated with scope 1 and/or scope 2. The aggregated reduction for scopes 1 and 2 is of 46%, whereas it is of 28% for targets including Scope 3, as shown in **Figure 5.4a**. This can be explained by differentiated minimum ambition levels in SBTi criteria for Scope 1 and 2, compared to Scope 3. The commonly applied SBTi method for absolute targets, namely the ACA, impose a minimum linear reduction of 4.2% per year compared to the base year for Scope 1 and 2, and of 2.5% for Scope 3. Using this study sample average target timeframe of 11.1 years, i.e. the difference between the target year and the base year, with ACA minimum annual reduction rate would result in total reduction of 46.7% for Scope 1 and 2, and 27.8% for Scope 3, which are very close to those mentioned here. This suggests that companies often stick to these minimum ambition thresholds.

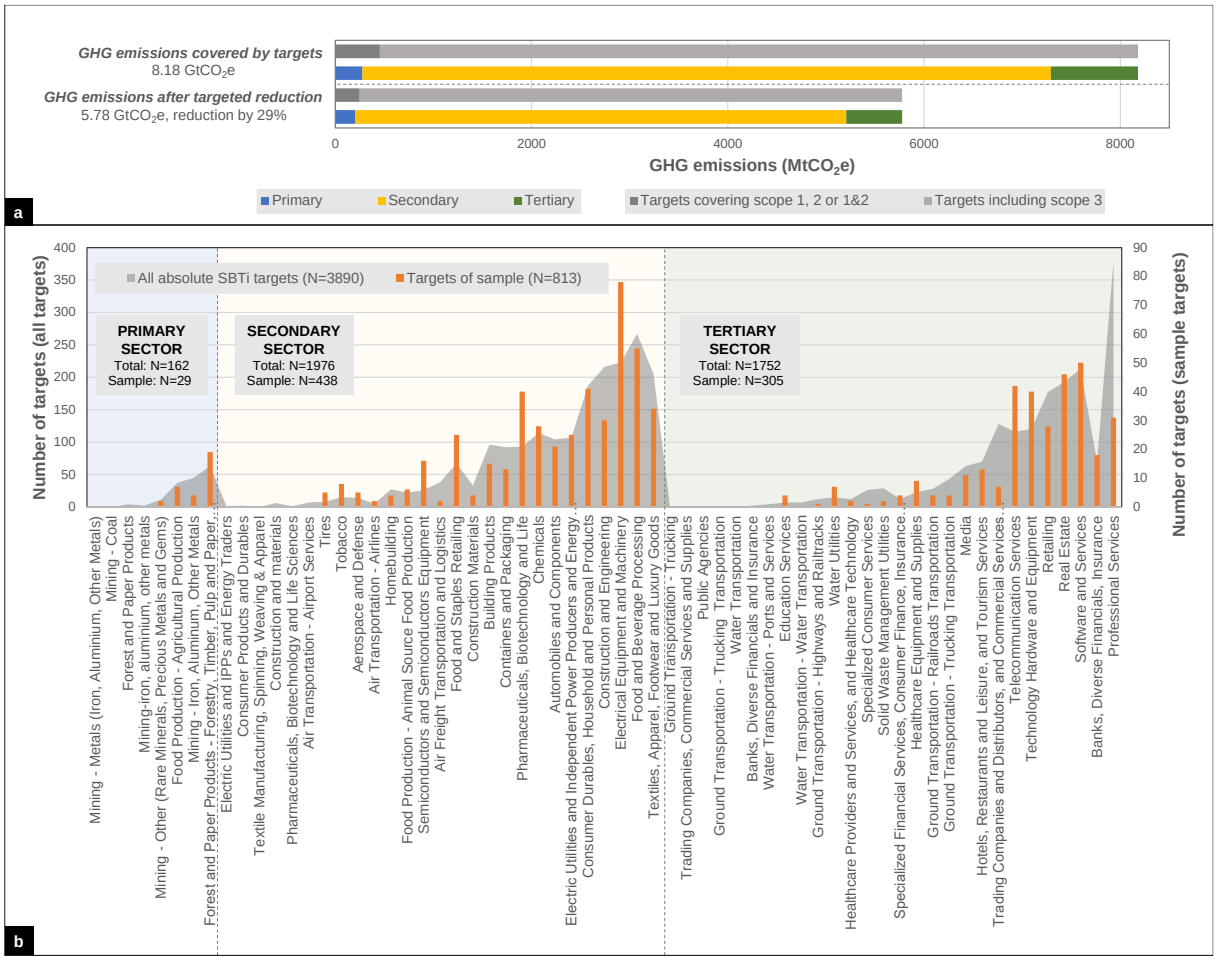


Figure 5.4: analysis of validated SBTi targets in the sample of this study[20].

5.3.2. Trends in selecting base years for setting emission reduction targets

Figure 5.5 shows trends in selecting base years for SBT in the sample of this study. 15% of the targets show a delay of one year. Yet in 2019 and 2020, this number goes up to 37% and 40%, respectively, meaning that the most common practice in base year selection was to set the year immediately preceding the year in which these targets are made public (see **Figure 5.5a)**. This is an expected delay since corporate carbon accounting usually synchronizes with the most recent completed financial year, often one year earlier, and that SBTi recommends this approach. However, the majority of companies (38%) have established their base year two years

[20] Figure 5.4a: cumulative GHG emissions covered and cumulated projected reductions for all 813 sample targets of this study, by macro-economic sector and by emission scopes.
Figure 5.4b: number of targets by sector for the 813 targets in the sample of this study (left y-axis) and for the overall 3890 SBTi-approved absolute reduction targets (right y-axis)

prior year of publication (see **Figure 5.5c**). In addition, about 47% of the emission reduction targets have base years that fall within the range of 3 to 5 years prior to their publication, which adds relevance to this research since a wide range of practices is observed in base year selection.

This variation may be attributed to several factors, such as a progressively increasing time in the review process for SBTi to validate submitted SBTs, especially since the increasing popularity of the initiative. As shown in **Figure 5.5a**, the trend in increasing delay is especially pronounced from 2021 onward, possibly due to the global COVID-19 pandemic, as companies may have sought to enhance the accuracy and relevance of their targets by considering a year before the onset of the pandemic. Similarly, no base year was found in the sample for 2021 and 2022, i.e. COVID-19 years. This pattern might also be related to a bias in data selection, given that the GHG emissions retrieved via the CDP files end in 2021, meaning that there are no targets in the sample with base year in 2022 and few in 2021, due to not available base year emissions. The COVID hypothesis is confirmed by a similar analysis carried out on all SBTi absolute targets, which shows that 2019 (i.e. the most recent pre-COVID year) is still the most selected base year, despite a trend towards the number of targets validated by SBTi doubling each year between 2017 and 2023 (see **Appendix A.6.1** and **Figure A7** for further details).

Regarding base year selection, the SBTi only requires the base year not to be earlier than 2015 (criterion C13 of SBTi criteria), and that it leads to a minimum forward-looking ambition (criteria C14), i.e. that targeted emissions are not already achieved (SBTi, 2023b). The choice of the base year may depend on business representativeness of a year (acquisition, business model evolution, inorganic growth, geographic changes, etc.) and on climate actions undertaken in the past to account for already engaged reduction. In addition, for target updates, base year emissions must be recalculated in some cases (e.g. change in the carbon accounting boundaries or methodology). Nonetheless, SBTi provides further valuable recommendations, but that are not mandatory. In this light, it recommends i) that verifiable data on scope 1, 2 and 3 exist for the base year, ii) that the base year is representative of a company's typical GHG profile, iii)

that companies use the same base years for all near-term targets, and iv) that companies with approved SBT report, among others, the target coverage of base year emissions, absolute emission reductions (in tCO_2e) (SBTi, 2023a). We align with these recommendations, but still we would point out that the problem is twofold. First, there is no transparency about how companies set their base year and how SBTi reviews targets (Bjørn, Matthews, et al., 2023), so it is not possible to determine whether these recommendations have been met, even if they have. Second, there is a major distinction between "should", "may", or "recommend", and "shall", "must" or "require", as stated in SBTi criteria. There is no indication that companies are following these recommendations, and one might legitimately assume that if a particular target meets SBTi criteria, leading to already binding emissions reductions, then the company might pick the method - and in this case the base year - that is least binding, i.e. the one that leads to the highest emissions allowance in the target year. Next sections **5.3.3** and **5.3.4** investigate such potential cherry-picking trends in selecting base year when setting emission targets.

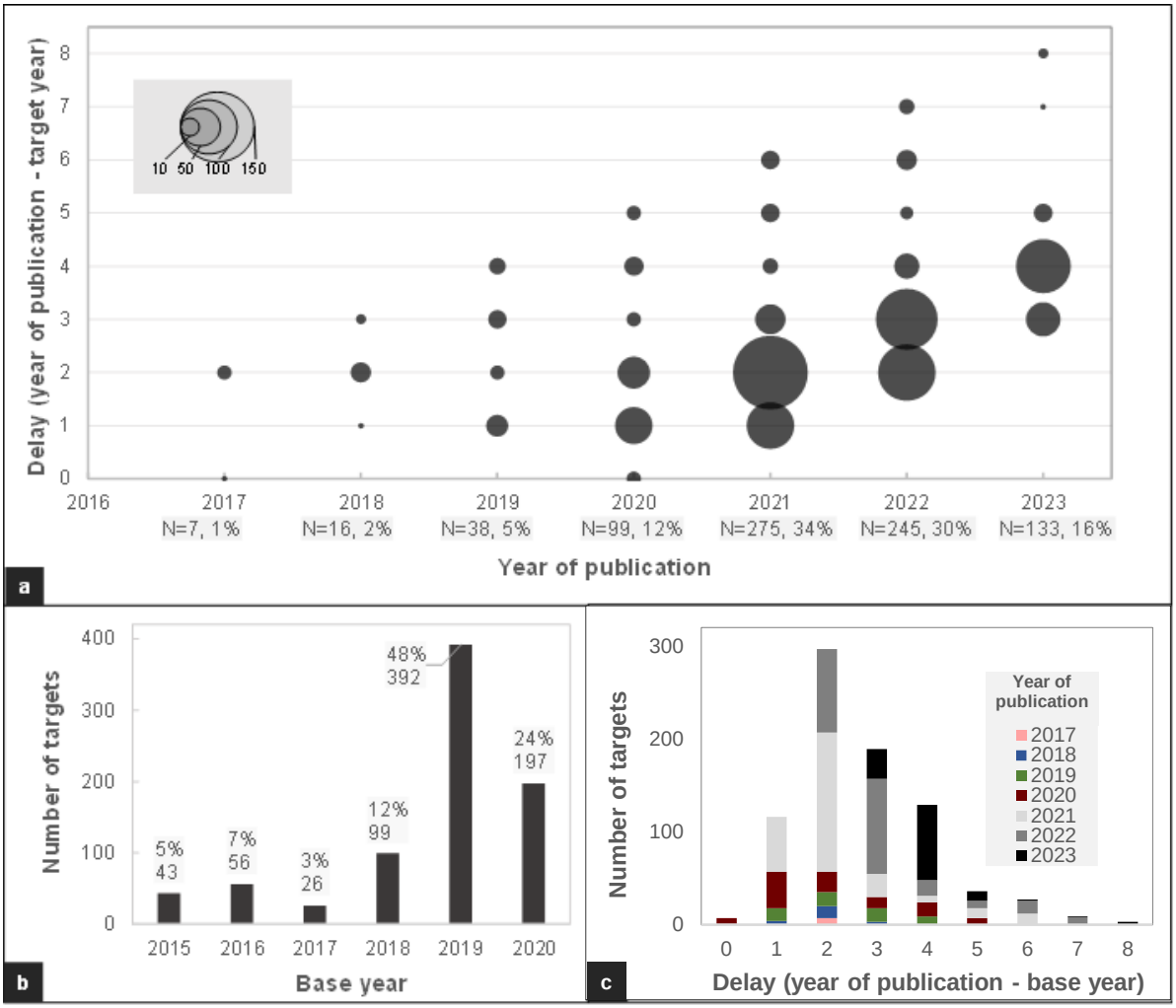


Figure 5.5: analysis of trends in selecting the base year[21].

5.3.3. Variation in historical GHG emissions across years compared to the base year

Figure 5.6 shows the variation in emissions between base years and neighboring years for the 813 absolute reduction targets of the company sample. Important variation in GHG emissions across years are observed in **Figure 5.6**. For example, about 33% of the datapoints available for the year before the base year (BY-1) show a variation of more than 20% compared to base year emissions, and 31% for the year after (BY+1). This finding seems to be surprising, as it is commonly recommended to recalculate base year or previous year emissions when there

[21] Figure 5.5a: delay between year of publication and base year, as a function of year of publication. The grey box below the x-axis indicates the number of validated targets for each year, and their relative share within the sample, and the 2023 point corresponds to the situation at mid-year (as of 06/30/23). Figure 5.5b: distribution of base year for the 813 targets of the dataset. Figure 5.5c: analysis of trends in selecting base year with the delay of publication.

is a 10% or more variation in GHG emissions between two years, which is the case for more than 46% of datapoints in this study (GHG Protocol, 2004). We acknowledged this practice in this study, as most recent reporting years were prioritized to retrieve GHG emission data.

An overall decreasing trend can be observed, with higher emissions before the base year and lower after, which is deemed logical as only GHG emissions of companies with validated SBTi targets are represented, and as companies with SBT tend to reduce their emissions (Giesekam et al., 2021a; SBTi, 2023c). However, the shape of reduction does not appear to be linear, as GHG emissions are rapidly decreasing just after the base year and are relatively stable in the next years from 2 to 5 years after (i.e. levels of black lines in **Figure 5.6**).

Considering the delay between deciding on a climate change intervention and realizing its intended emission reductions, the abrupt emission reduction in the year after the base year are likely related to decisions made prior to the setting of the SBT. Following that possible explanation, it would mean that companies merely may take advantage of the SBTi to formalize emission reductions that they had already planned, hence questioning the actual impact of the SBTi on curbing corporate GHG emissions at the global scale. However, considering that uncertainties, which may be source of major variation in emissions across years (Klaaßen & Stoll, 2021) are not reported, both increased transparency and further research are needed to confirm this hypothesis. The drop in GHG emissions after the base year on **Figure 5.6** may also be related to a COVID-19 noise in the dataset, for which 2019 is the most widely adopted base year.

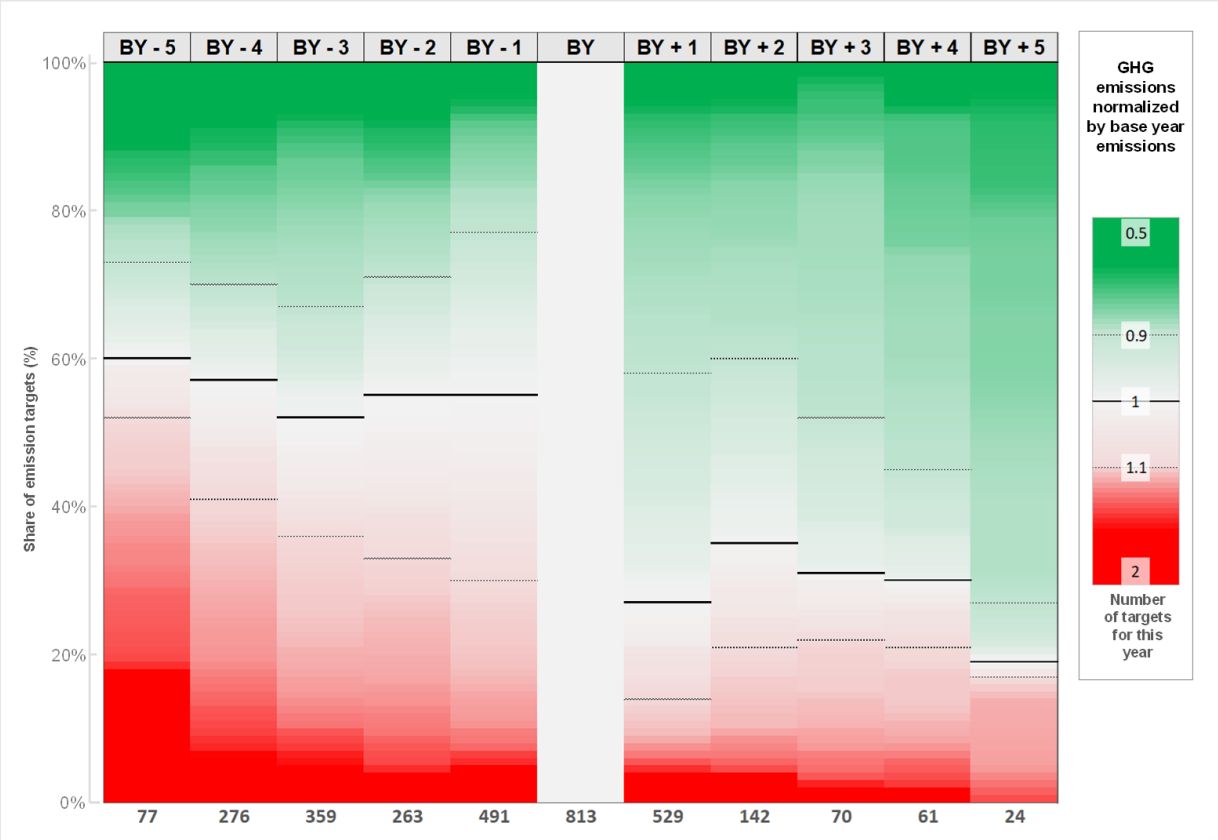


Figure 5.6: Analysis of the variation in normalized GHG emissions of different reporting year compared to the base year, per centile[22].

5.3.4. Impact on total GHG emissions reduction for 2030

Considering all options that a company with a target validated by SBTi would have had for choosing its base year, the choices resulting in (i) the lowest emissions in 2030, i.e. the greatest reduction in the 'best' case, and (ii) the highest emissions in 2030, i.e. the least reduction in the 'worst' case, compared to (iii) the projected emissions, i.e. the 'real case', have been compared. These three values are estimated and summed for all 813 targets to obtain a total cumulative projected emissions value in 2030, compared against the sum of all base year emissions, as shown in **Figure 5.7**. It is noteworthy that the cumulative baseline scenario does not represent emissions for a given year, since the base year varies (as highlighted in **Figure 5.5b**), but it

[22] BY indicates the base year. Color coding is used to indicate whether reported GHG emissions for a year are higher (in red) or lower (in green) than the GHG emissions for the base year. The number of datapoints for each year prior to or after the base year is shown at the bottom of each column.

reflects the sum of all base year emissions, i.e. a situation equivalent to the starting point of all companies, regardless of time.

The analysis of results in **Figure 5.7** shows substantial variations in reduced GHG emissions depending on selected base years. In the 'real' case, the emissions targeted in 2030 result in a 28.9% reduction compared with cumulative baseline emissions. This is very close to 29.3% which is the cumulative emission reduction targeted (considering all diverse target years). As shown in **Figure 5.7**, this is also very close to the "Well-below 2°C" (WB2C) ACA 2.5% annual reduction calculated with the average sample target timeframe of 11.1 years. One could argue that for comparison with SBTi ACA methods, it would have been better to calculate the cumulative percentage ACA reduction (for 1.5 and WB2C) based on the actual specific base years of companies (i.e. the real case) rather than using the average timeframe of 11.1 years. A verification was carried out to validate this choice of using average timeframe. ACA 1.5 method (i.e. annual linear reduction of 4.2%) applied to all base years and projected to 2030 results in a total emission reduction of 47.28%, and ACA WB2C (annual linear reduction of 2.5%) to a total reduction of 28.14%. In comparison, with the average timeframe of 11.1 years, these are 46.62% and 27.75%, i.e. nearly equal, which validates this methodological choice. It may seem logical given that 95% of covered emissions represent Scope 3 emissions for which WB2C is the minimum ambition accepted by SBTi for absolute non-sector-based targets (SBTi, 2023b). These consistent findings help to validate the assumptions made in the method presented in Section **5.2.4**. The alignment with WB2C also supports cherry-picking trends (WB2C being the least restrictive method for scope 3, for companies not subject to a sector-based methodology).

Then, when looking at the 'best' and 'worst' cases, projected 2030 emissions result in reductions of 59% and 11%, respectively. In other words, there is a factor greater than 5 in the cumulated emission allowances, between the worst and best cases. The 'best' case is far more ambitious than the most ambitious minimum threshold of SBTi absolute methods, i.e. equivalent to a 4.2% annual reduction. The real case is far from the worst case (i.e. lead to a

28% reduction compared to a 11% reduction). It is possible that cherry-picking may be one of the main reasons of this important variation between the real case and the best case, rather than the official SBTi recommendations (i.e. emission data verifiability, base year representativeness, and sufficient forward-looking ambition).

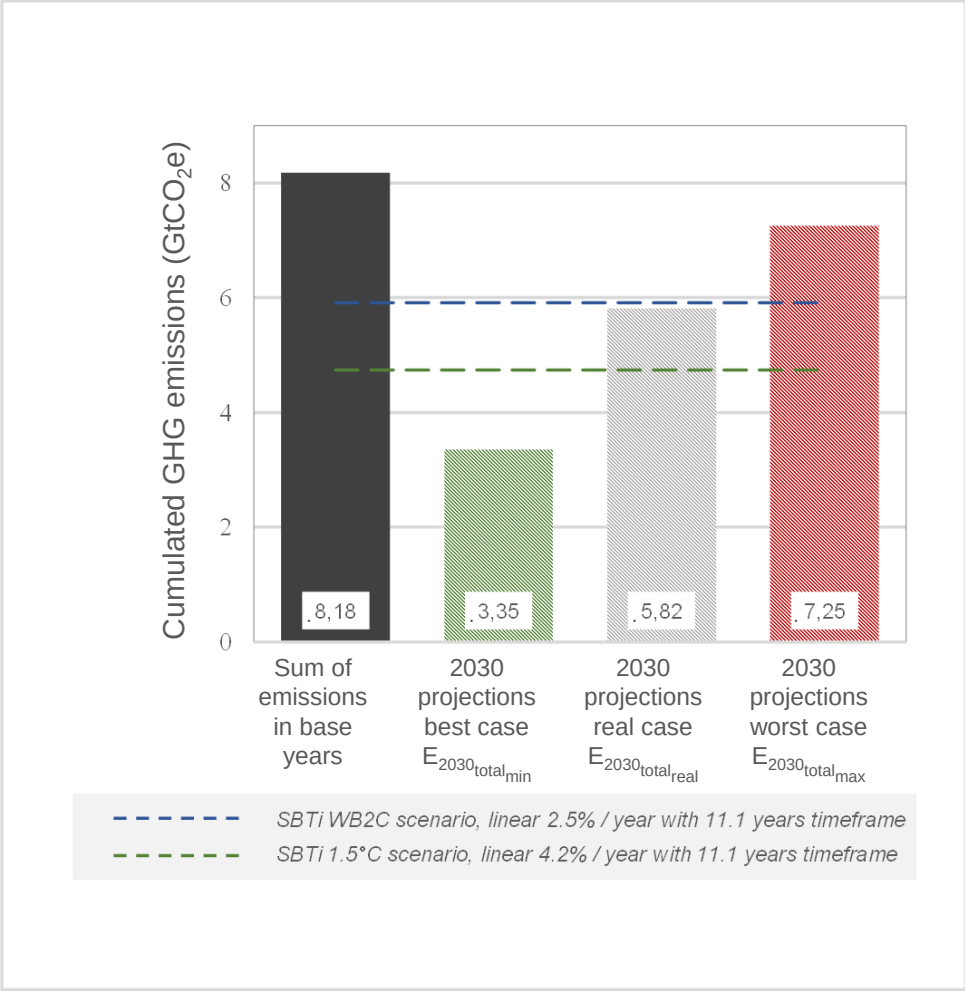


Figure 5.7: Projections of cumulative 2030 GHG emissions in different scenarios, depending on the selection of the base year for each target[23].

[23] The reductions in the 'best', 'real' and 'worst' cases are compared with two absolute non-sectoral SBTi pathways, namely the 1.5°C and WB2C scenarios, with their annual reduction rate multiplied by the average difference between target and base years in the sample, 11.1 years.

5.3.5. Recommendations for reliable base year selection

As all other target-related parameters remain unchanged, this significant variation reflects the variation in GHG emissions compared to base years as shown in **Figure 5.6**. This result reveals that base year is a key parameter to consider when setting emission reduction targets, and therefore that further guidance and transparency are needed to ensure robust emission targets. In some rare cases, important deviations in GHG emissions across year are justified in reporting systems, in auditing processes or in internal monitoring, as recommended by the GHG Protocol or in the SBTi corporate manual (GHG Protocol, 2004; SBTi, 2019c, 2023a). More transparency on the reasons of major variations in historical GHG emissions would allow to take organizations accountable and to conduct further research to evaluate the effectiveness of corporate emission targets in contributing to climate change mitigation.

Therefore, in addition to the valid SBTi recommendations on the choice of base year, we recommend the default approach for base year selection to be systematically the most recent available year. If not, the SBT initiative could enhance its guidelines and methods, increase transparency in its target dashboard, and impose a reporting framework that demonstrates greater transparency on assumptions and on the target review process. For example, the justification of the choice of base year, or the variation of emission quotas defined according to the base year, could be included in mandatory SBTi reporting.

Secondly, SBTi methodology and criteria could be reviewed under the prism of critical cases (i.e. which could threaten the overall emissions budget). When the base year is not the most recent year available, we recommend companies to disclose the underlying reasons for the choice of the base year and that SBTi systematically include mandatory rationale for transparency purpose as a condition of target validation. This latter recommendation could be extended to other target parameters, while ensuring sensitive corporate information protection. We also recommend established and harmonized guidance to set the base year based on a

number of criteria/reasons. We propose the following justifications, to select and transparently disclose especially when picking another base year that the most recent one:

i) to take into consideration progress and actions engaged in the past;

ii) to increase representativeness of the base year with another year (e.g. COVID-19);

iii) to tackle methodological issues found in the most recent year (e.g. no data available);

iv) to have least constraint in GHG emissions reduction for another year in the past;

v) or any other reason to specify.

Also, a sensitivity analysis could be required when setting and submitting SBT, and if base year selection leads to important variation in emission allowances, a multi-year average base year method, or a rolling target base year (i.e. emission reductions compared to the X previous years), may be required, as described in the GHG protocol chapter on base year selection (GHG Protocol, 2004). In the same line, to increase transparency and strengthen further analysis, SBTi could require companies with approved targets to report systematically the variations in GHG emissions on the scopes of their targets, with compulsory questions and quantified answers. In line with the GHG protocol, GHG emission variation could be quantified and categorized according to i) change in methodology (selection among inventory boundaries, methods, data, emission factors ii) structural changes (selection among acquisitions, divestments, mergers, outsourcing and insourcing of emitting activities), iii) discovery of significant errors (data incompleteness, calculations errors, incorrect assumptions, uncertainties mismanagement) iv) organic evolution (selection among actual decarbonization actions, change in production and economic outputs, changes in product mix, closure and opening of operational units) v) real reductions (selection among efficiency improvements, material or fuel substitution, decarbonization of business model).

Drawing on the findings of this study, **Table 5.2** summarizes the recommendations for base-year selection when setting emissions reduction targets, from the perspective of both companies, the SBTi initiative, and corporate climate-related reporting systems such as CDP Climate Change questionnaires.

Table 5.2: Recommendations for increased robustness and transparency in base year setting for GHG emissions reduction targets

ACTORS INVOLVED IN CORPORATE TARGET SETTING	RECOMMENDATIONS FOR ROBUST AND TRANSPARENT CORPORATE EMISSION REDUCTION TARGETS
Companies, that set emission reduction targets	Systematically include Scope 3 targets in addition to Scope 1 and 2 targets, with potentially differentiated ambitions
	Use most recent year as target base year when possible and relevant
	Justify the choice of other base year if not the most recent
The Science Based Targets initiative, that provides guidance, review and validation process for targets	Provide a framework for companies to disclose base year justification with prelisted rationales
	Ensure enough capacity to have independent and robust SBT validation process, with attention towards the base year, and increase the transparency of the review process
	Require companies to publicly disclose annual GHG emissions, reasons for variations, and progress as well as main target hypothesis, as a condition to validate SBT
Reporting system makers and regulators, that increase transparency towards targets hypothesis and progress, perhaps in binding ways	Integrate target-related transparency elements within reporting frameworks (e.g., share of scope 3 emissions, GHG emission variation explanations, target-related hypothesis)
	Include uncertainties reporting and management strategies for both target and emission reported data
	Enhance at least annual reporting of target progress (e.g., relevant recalculations, foster sharing of best corporate climate practices) and call for regulators to adopt such measures

5.4. Conclusion and recommendations

While the Science-Based Targets initiative is becoming widely and internationally recognized as a method to set corporate emission reduction targets, and that such an incentive for the private sector to engage in the fight against climate change can only be welcomed, studies show that there are still hurdles to overcome, both in terms of associated methodology and reporting. Notably, the flexibility that businesses have in setting such targets might lead to heterogeneous climate ambitions. There is a need for increased transparency in methods and reporting regarding emission targets, particularly with regard to the choices made to set the targets parameters including base year.

This study focuses on the influence of the base year on absolute reduction targets validated by the Science-Based Targets initiative (SBTi). To this end, we used SBTi and CDP databases to collect data linked to companies' emission targets and their GHG emissions, and retrieve GHG emissions of over 500 companies with over 800 SBTi-validated targets covering 8GtCO_2e. The successful cross-referencing of emissions data and targets across dataset, and the good representativeness of the sample add relevance to this study. The sensitivity of the base year parameter on emission targets has been highlighted, simulating what would have happened if companies had chosen a different base year (from 2015 to 2021) for each target in our sample. These emissions were projected to 2030, using the same parameters as the validated targets and following the SBTi criteria. This shows the importance of the choice of base year for total committed emission reductions, ranging from a 59% reduction from an average base year and 2030 in the most ambitious case to 11.3% in the least ambitious case. The actual cumulative projection with official SBT used in this study is a 29% reduction. These significant variations in GHG emissions between years, compared to the base years, demonstrate the importance of rigorously updating emissions data, as well as the need to transparently report and manage uncertainties.

The results suggest that it is possible that companies cherry-pick their base years when setting emission targets, while COVID years avoidance, base year representativeness of the company activity, and the (poor) quality of carbon accounting are likely to play a role as well.

Finally, the choice of base year must be made transparently and rigorously, by finding the right trade-off between the representativeness of the selected exercise, the quality of carbon accounting, the management of uncertainties and the consideration of previous initiated corporate climate actions. We recommend full transparency on the assumptions made in the methodological definition of targets with SBTi, as well as rigor and transparency in reporting, as addressed in **Table 5.2**. Additionally, our results reveal that companies may select base years aligned with already defined GHG emission reduction strategies, hence questioning the actual impact of SBTi. This possibility enhances our call for more harmonized and consistent guidelines to justify the base years, as proposed in this study guidance that we recommend to implement in SBTi processes. In this light, a particular focus is needed on the evolution of GHG emissions, the associated uncertainties, and the progress made in following the emission targets defined with SBTi. These elements are crucial to ensure fair climate ambitions and scientific robustness at the corporate level, and enable the private sector to play its part in the necessary path toward a low-carbon economy.

CONCLUSION AND PERSPECTIVES

This thesis focusses on methods that state and non-state actors can implement to contribute to the ecological transformation of our society, and subsequently to building bridges between global absolute sustainability frameworks and climate change mitigation strategies at local levels. Four research questions narrow down this overall problem statement. In this conclusion, I look at these research questions and approach them through my research contributions in this PhD.

The first research question considers how global sustainability frameworks can be applied at sub-scales. It leads to a published article on the territorial scale and the doughnut theory. This article proposes an innovative methodological development and recommendations for stakeholders. The next two research questions concern existing methods and an overall methodological framework for defining a climate change mitigation strategy at the organizational level, in a bottom-up approach. Two articles provide an answer, offering a review of existing methods, a methodological framework for corporate climate strategies, and a multi-case study involving 10 companies in an intervention research perspective. The final research question focuses on a top-down approach, looking at how to allocate to an organization a share of the global carbon budget, defined, for example, using the planetary boundaries framework. This PhD's contribution to this question extends to the need for greater transparency and integrity in the processes through which voluntary climate targets are set by organizations. A scientific article results, showing in particular the importance of the choice of the reference year.

First, the principles of distributive justice are presented as well as their application to the distribution of efforts in the fight against climate change. A lack of transparency can be identified on the principles underlying various downscaling methods in absolute impact assessments, notably via the planetary boundaries framework. We have shown that the

sufficientarianism principle and its variants, which are concerned with satisfying minimum needs for all, are hardly applied in regulatory or voluntary methods for distributing efforts to achieve the objectives of the Paris Agreement. In the first article, a need-based method was thus developed for assessing the social impacts of an action on a system at national level. We then focused more closely on the level of organizations, in terms of their fair and ambitious contribution to climate change mitigation. This focus combined top-down approaches with the question of the fair allocation of GHG emission quotas to organizations with the widely used SBTi methodology, and bottom-up voluntary strategies notably with the ACT-S methodology. Through a theoretical review and a case study based on field experience, this research has demonstrated that climate change mitigation strategies for organizations can, and should, go far beyond carbon accounting and the definition of emission reduction targets. Our approach calls for and contributes to the development of methodological standards for building comprehensive climate strategies, which integrate both qualitative and quantitative dimensions, both incremental and transformative perspectives. Through this theoretical approach combined with a fieldwork experience, the thesis succeeded in achieving the objectives.

In addition, the CIFRE partnership established between Toovalu and two complementary research laboratories enabled me to carry out transdisciplinary work, and to adopt, as anthropologists do, a posture of participant observer, to meet the needs of the field while shaping scientific thinking. In this light, this work serves to provide recommendations at several levels, for defining fair and ambitious climate change mitigation strategies. Firstly, for methodology developers, this thesis highlights the need to develop rigorous standards in co-construction with the scientific community, to frame transparency processes, and to develop methods based on various principles of distributive justice. For companies, we emphasize the need for greater ambitions and transparency in terms of incentives, methodologies (including justifications for choices) and reporting. We also invite them to consider several principles of distributive justice when defining their ambitions to contribute to climate change mitigation.

Finally, there is a need from regulators to develop consistent, objective and ambitious binding frameworks, which takes account of climate justice and scientific knowledge. These different needs must be addressed with the support of future transdisciplinary scientific work and public-private collaborations.

This thesis is primarily concerned with climate change mitigation strategies at the organizational level, from the perspective of reducing GHG emissions. Taking a step up, it is essential to note that the latter are sub-strategies that need to be part of broader climate strategies, including, for example, contributions to climate change adaptation, carbon sink development or avoided emissions. A further step up, in line with Toovalu's mission to place meaningful impacts at the heart of organizations' strategies, corporate climate strategies need to be anchored in wider corporate strategies, which integrates other environmental, social and business issues that would drive companies' future. In this light, further research could investigate the operationalization of the systemic frameworks of planetary boundaries and doughnut theory at organizational levels, to ensure that there are no burden shifting from the different categories of sustainability.

Taking another step up the ladder, the work of this thesis also outlines that further research is needed on the responsibility of companies in achieving the objectives of the Paris Agreement, and consequently on the role of a company in a carbon-neutral world. A number of private-sector initiatives have emerged along these lines, notably in France. For example, the "Convention des Entreprises pour le Climat" (CEC) offers a process for companies to define a transformative and regenerative narrative for their transformations (CEC, 2023). The Net Zero Initiative framework proposes three pillars for a climate strategy, comparing emissions induced, avoided and absorbed by companies (NZI, 2023). Another indicator has been proposed to evaluate the Paris Agreement Compatibility Score (SCAP) (Carbone 4, 2022). In the academic sphere, the "closing worlds initiative" invite companies to enter a new paradigm that succeeds CSR, to "ecologically redirect" their models (Landivar et al., 2022). From these perspectives,

where and how does an organization stand in a safe and just space for humanity (Raworth, 2017) or in a post-growth society (Méda et al., 2018)? These initiatives and this essential question deserve further attention of the academic world.

Finally, reaching the top of the scale to be bridged, the question of an organization's fair contribution to mitigating climate change raises ethical issues that would be worth exploring in greater depth. Firstly, what is the meaning and raison d'être of a company, and to what extent should it be granted a right to emit, or to exist? This ethical question could be addressed from the perspective of the principles of distributive justice, including sufficientarianism that is often overlooked in operational methods. These discussions, which fall within the field of political philosophy, appear to be important since, although rarely transparent, they underlie all operational methodologies for defining an actor's fair ambition to contribute to meet the objectives of the Paris Agreement. In this light, multidisciplinary work is needed to coordinate all stakeholders and recognize the importance of actions and synergies at multiple levels towards a common sustainable future.

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APPENDICES

Appendices presents additional information, to ensure transparency in the overall methodology. Section **A.1** details the actors involved in this PhD thesis. Section **A.2** presents a comment published in Nature Climate Change in July 2023 in which I am co-author. The latter builds on the work of chapter 5, sharing further useful background information for the reader regarding the Science Based Targets initiative, as well as highlighting the need for increased transparency in how corporate emissions targets are set. Sections **A.3**, **A.4**, **A.5** and **A.6** relate to the supplementary information provided in the articles constituting chapters 2, 3, 4 and 5, respectively.

A.1. Detailed presentation of the parties

A.1.1. TOOVALU, industrial partner and employer trough a CIFRE contract

TOOVALU SAS is a 30-person company based in Nantes, that provides support, training and software for organizations in the areas of corporate climate change mitigation and CSR. It is a French 'entreprise à mission' (purpose-driven company) and a benefit corporation (B-Corp), whose raison d'être is to "engage decision-makers in integrating climate change and, more broadly, sustainability issues into the heart of their organizations' strategy (Toovalu, 2023). Toovalu publishes the Toovalu Impact software to help companies calculate their carbon footprint and implement their Climate Change mitigation and corporate social responsibility (CSR) strategies. On the one hand, the software helps companies to carry out, monitor and manage their carbon footprint in order to define an organizational climate change mitigation strategy (OCCMS). On the other hand, the software has another web module focusing on CSR reporting, the definition of organizational extra-financial strategies and their monitoring. For

sub-state actors, these are the first steps to build and steer their sustainability strategy, to manage their contributions to the SDGs and to the objectives of the Paris Agreement.

In addition to its greenhouse gas (GHG) emission accounting activities through consultancy and software development, TOOVALU supports early-adopters in applying the Assessing low Carbon Transition (ACT) methodologies in partnership with the French Agency for Ecological Transition (ADEME) and the Carbon Disclosure Project (CDP). This methodology is focused on the assessment and the development of climate change strategies for companies to contribute to a well-below 2°C economy (ADEME & CDP, 2022). TOOVALU has been involved from the experimental phase in 2019, to current operational deployment. Through field experience and data collection, TOOVALU's projects have highlighted the willingness and difficulty of sub-state actors to build and operationalize low-carbon trajectories, as well as to quantify their contributions to global sustainability goals. Scientific barriers were identified in relation to the establishment of a science-based trajectory at the company level, such as a lack of harmonization between regulatory, scientific and operational aspects, or a lack of comprehensive method applicable by the private sector to define and drive decarbonization strategies and trajectories (TOOVALU, 2020). R&D being at the heart of the development of TOOVALU, this PhD research aims at contributing to further innovation of the software and bringing to the field a more scientific perspective with a robust methodology. Marie GABORIT, co-founder and CEO of Toovalu, is the corporate supervisor of the PhD.

A.1.2. Research Institute in Civil and Mechanical Engineering (GeM), Ecole Centrale de Nantes

Since 2021, Centrale Nantes has been a signatory to the Grenoble agreements, which propose common objectives for all higher education and research establishments committed to the socio-ecological transition (CTES, 2023). In addition, following several years of work, they adopted a sustainable development and corporate social responsibility action plan for the years

2021-2025, structured around 5 axes, 15 objectives and 38 actions (Centrale Nantes, 2023). One axis focuses on research, with the aim of aligning research themes with international and national sustainable development objectives, in particular actions to support the evolution of research themes or to develop research themes around the low carbon transition (Centrale Nantes, 2021a). In this light, the Research Institute in Civil and Mechanical Engineering (GeM) research unit at Centrale Nantes has taken a close interest in sustainability science (notably in sustainable industrial strategies, carbon accounting and CSR) with the "Cycle des hautes études pour le développement durable" (CHEDD) projects , the contributions to International Network on Risk Assessment and Climate Adaptation of Civil Engineering and Building Works (RI-ADAPTCLIM) (Collin & Farah, 2019), Competencies for CSR - COMP-RSE project (2014-2015) (Coëdel et al., 2015), and Carbon Neutrality educational project for engineering students (Auger et al., 2021; Centrale Nantes, 2021b). The interdisciplinary Thematic Research Unit (UTR) "Green engineering approaches" (INGVER) has recently been structured within GeM and this PhD falls into the scope of this UTR. Emmanuel Rozière, professor (civil engineering, sustainability, CSR) and director for Sustainable Development at Ecole Centrale de Nantes, is the PhD main supervisor. Benoit Hilloulin, professor (civil engineering, artificial intelligence, environmental engineering) is co-supervising this PhD.

A.1.3. Quantitative Sustainability Assessment (QSA), Denmark Technical University (DTU)

At DTU, QSA section is a research pioneer in terms of sustainability assessment models, conducting research notably on the integration of scientific sustainability models, e.g. planetary limits, into operational tools such as life cycle assessment; the aeronautics sector; or development policies (DTU, 2023). QSA develops, adapts and applies quantitative methods for the assessment of relative and absolute environmental sustainability of products, technologies and large-scale systems. The methodological work of the section focuses on three main areas which cover the disciplinary field of this PhD: Life cycle impact assessment (LCIA) Absolute

environmental sustainability assessment (AESA), macro-scale sustainability assessment including organizations level. Alexis Laurent, associate Professor in Quantitative Assessment and Interpretation of Environmental Sustainability, is co-supervising this PhD. He has a focus on methodological development and application of life cycle assessment (LCA) as well as life-cycle-based methods and solutions for quantifying environmental sustainability of large systems such as countries or organizations.

A.1.4. PhD candidate - Nicolas Desmoitier

I am an engineer with a double degree in general engineering from the École Centrale de Nantes and in environmental engineering from the Technical University of Denmark (DTU). Prior to this PhD, I worked for a year at the UNEP Copenhagen Climate Center (UNEPCCC, 2023) as research assistant in sustainability science, followed by a year at TOOVALU SAS as R&D lead. In parallel since 2019, I have been contract lecturer at Ecole Centrale de Nantes for the following courses: organizational low-carbon trajectories (annual 32h since 2020), environmental ethics for organizations (annual 32h since 2021), carbon neutrality project (annual 10h in 2020 and 2021), as well as contributor in lectures at Audencia business school (systemic impact assessment for organizations), Nantes university (GHG emission accounting and trajectories for organizations), and Denmark Technical University (Science-Based Targets and advanced GHG emission accounting).

In relation to the PhD, my activities at TOOVALU, covers consultancy in decarbonization strategies for organizations (ACT and SBTi methodologies, GHG emission accounting), professional trainer for customers (decarbonization practices for organizations, methods for low-carbon strategies definition) and some contributions in TOOVALU's R&D on the climate modules of the software (roadmap and priorities definition).

Driven by the desire to contribute to the ecological and social transition with a research-based approach connected to the field, I am convinced that the private sector and organizations

must be included in the academic contributions to initiate a credible low-carbon trajectory. This is crucial to make them accountable and contributors to the necessary systemic transformation to a safe and just state for the planet and human societies. Indeed, to reach the Sustainable Development Goals (SDGs) and limit global warming well below 2°C above pre-industrial levels, the action of the private sector and sub-state actors is essential: the ecological transition will be made with businesses. This is why I see TOOVALU, Centrale Nantes, DTU as the ideal partners for my research through the CIFRE program, as a way to decompartmentalize academia and organizations in terms of sustainability and climate action.

A.1.5. Monitoring committee (CSI)

The monitoring commitee (in French, 'Comité de suivi individuel' (CSI)) of doctoral school 'Sciences de l'Ingénierie et des Systèmes (SIS)' had two meetings, in the first and second years, bringing together the supervision team, the doctoral student and two external members. Yann Robiou Du Pont (Utrecht university) and Bertrand Huneau (Ecole Centrale de Nantes) are the members of the monitoring committee held in summers 2021 and 2022. Their respective research lies on the assessment of the fairness and ambition of climate pledges, national and subnational contributions to align with the Paris Agreement mitigation goals, and on materials engineering and materials science.

A.2. Comment as a co-author : increased transparency is needed for corporate science-based targets to be effective

This supplementary material is based on the comment entitled “Increased transparency is needed for corporate science-based targets to be effective”, published in Nature Climate Change in July 2023. My contribution as co-author was to review critically the article from a "corporate" and "inside" point of view. Having already provided support to companies in defining, submitting and validating their objectives with SBTi, this field knowledge had a strong added value for the co-authors. I took part in several calls with the co-authors as well as with the main author, carried out several proofreading, contributed to the writing, and realization of **Figure A.2**, which I then enlarged with the much larger sample of chapter 5 of this thesis (see section 8.6).

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Comment

Companies rarely disclose underlying calculations for their science-based emission reduction targets and the targets themselves lack important details. Increased transparency is necessary to assess the justice implications, whether aggregate emission reductions is sufficient, and hold companies accountable.

Science-based targets (SBTs) are an increasingly popular way for companies to commit to doing their part to meet the Paris temperature goal(Bjørn, Tilsted, et al., 2022; SBTi, 2022a). The Science Based Targets Initiative (SBTi), which has approved targets for more than 2,500 companies worldwide since 2015, is currently the de facto standard setter and approver for SBTs (Box 1 and **Figure A1**). This status has been reinforced by key stakeholders, including the United Nations, which highlighted SBTi´s target approval scheme as an example of integrity in corporate climate commitments (UN, 2022). While investors, industry associations, intergovernmental organizations, and other stakeholders increasingly encourage companies to voluntarily set SBTs, policymakers may soon require SBTs for some companies, as suggested by the Biden administration´s proposal to require SBTs for major federal contractors (The White House, 2022).

Targets approved by SBTi can differ considerably. For example, Daiseki Co., Ltd. (a solid waste manager) and Holcim Ltd. (a cement producer) were amongst the 262 companies whose SBTs were approved as 1.5°C-aligned by SBTi in the fourth quarter of 2022 (Box 1 and **Figure A.2** We can assume these companies followed the same SBTi guidance for calculating targets and, in turn, the SBTi evaluated their submitted targets against the same set of criteria. However, there is a large difference between the two companies' targeted reductions in combined scope 1 and 2 emissions (34% in absolute emissions and 25% per ton of cementitious material, respectively), the time frames (six years and twelve years, respectively) and the resulting annual reduction rates (5.7% in absolute emissions and 2.1% per ton of cementitious material,

respectively) (Fig. 1b). While there may be legitimate reasons for differences between SBTs, SBTi and companies rarely disclose the approach used to calculate individual targets (Bjørn et al., 2021). This makes it almost impossible to reproduce SBTs and to verify or refute SBTi's claim of a scientific basis. Moreover, SBTs lack planned trajectories for reducing greenhouse gas (GHG) emissions between the base year and target year and other important details.

The current lack of transparency threatens the effectiveness of SBTs in several ways: it inhibits societal deliberation about just climate futures; it increases the risk of insufficient aggregate emission reduction and consequent temperature overshoot; and it impedes holding companies accountable for acting on their targets. Here, we contextualize these potential negative outcomes of insufficient transparency. We then provide three specific recommendations for mitigating each transparency issue.

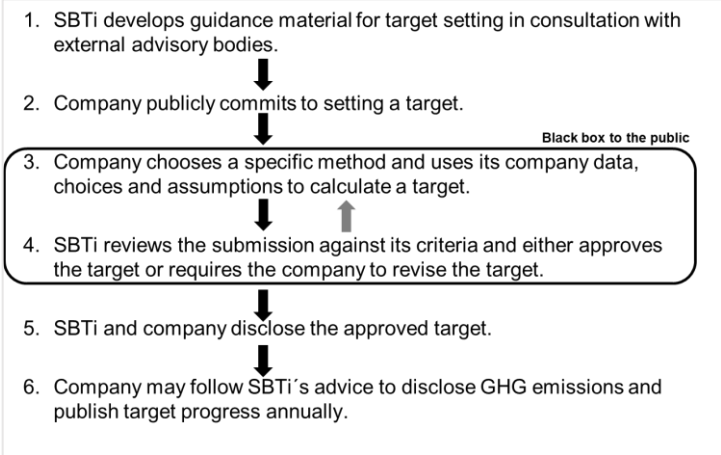

Figure A.1 : Flow chart of the target-setting process**.**

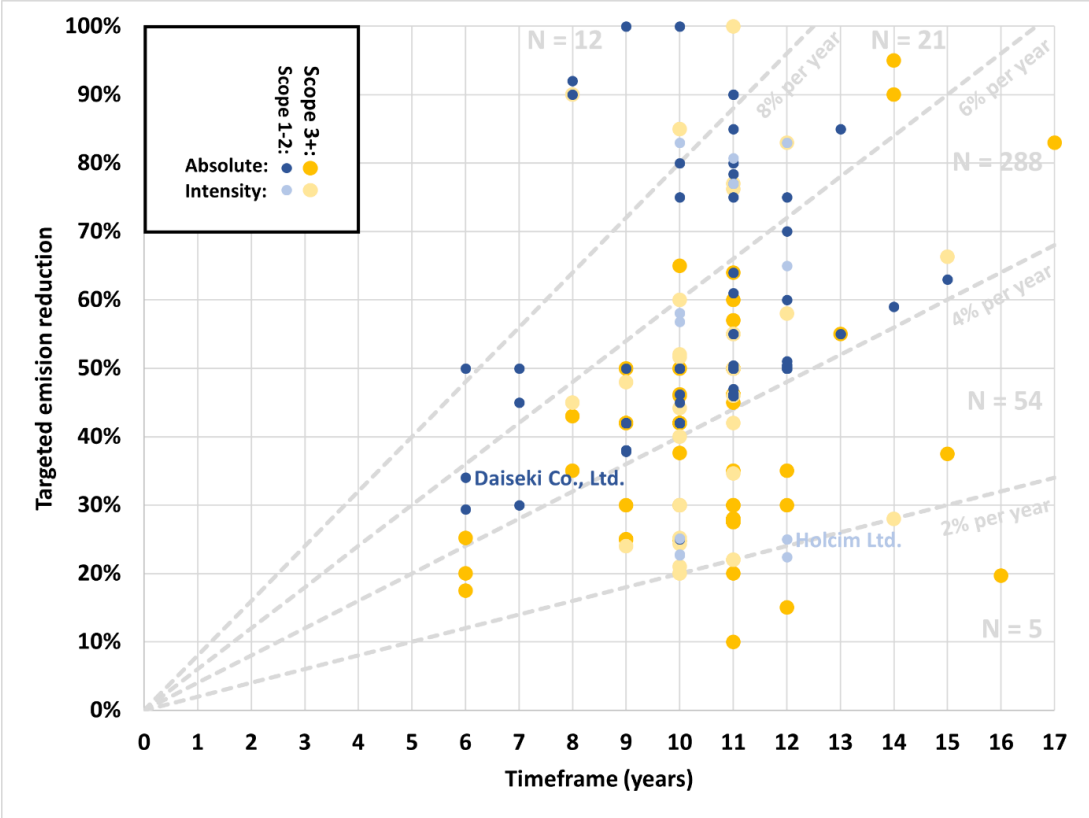

Figure A.2 : Timeframes and targeted emission reductions for the 380 SBTs set by 262 companies and approved by SBTi as 1.5°C-aligned in the fourth quarter of 2022.[24]

[24] "Scope 1-2" covers SBTs for scope 1 (N=8), scope 2 (N=3) and scope 1 and 2 combined (N=254). "Scope 3+" covers SBTs for scope 3 (N=100), scope 1 and 3 combined (N=5) and scope 1, 2 and 3 combined (N=10). The grey lines indicate corresponding annual percentage reductions in base year emissions for linear reduction pathways. The numbers written in grey indicate the number of targets falling within the zones demarcated by the grey lines.

Box 1: Basic description of SBTi and its target-setting guidelines and two examples of companies with approved targets

SBTi was established in 2015 as a partnership between CDP (formerly the Carbon Disclosure Project), the United Nations Global Compact, the World Resources Institute and the World Wildlife Fund. The SBTi is comprised of team members from these organizations and is advised by two advisory bodies made up of external experts from business, academia, government, non-profits and multilateral organizations. The SBTi states that "Targets are considered 'science-based' if they are in line with what the latest climate science deems necessary to meet the goals of the Paris Agreement – limiting global warming to well-below 2°C above pre-industrial levels and pursuing efforts to limit warming to 1.5°C." While SBTi initially allowed companies to set targets in line with 2°C and well-below 2°C warming, currently it only approves targets in line with 1.5°C warming. SBTi only gives temperature classifications to scope 1 and 2 emission targets (covering direct emissions and indirect emissions from purchased electricity, blue shades in Fig. 1b) and allows lower reduction rates for scope 3 emission targets(Bjørn, Tilsted, et al., 2022) (covering other indirect emissions, orange shades in Fig. 1b). SBTi allows companies to express targets as percentage reductions in absolute emissions (darker shades in Fig. 1b) or emission intensities (lighter shades in Fig. 1b), while targets not directly related to emission reductions (e.g., share of renewable electricity sourcing - not included in Fig. 1b) are in some cases also permitted. Since the development of SBTi´s net-zero standard(SBTi, 2021b), SBTs have also been referred to as "near-term targets", as they involve shorter timeframes than net-zero targets.

While sector-specific target-setting methods are emerging, SBTi generally advises companies to use either the Absolute contraction approach (ACA)(Bjørn et al., 2021), implying that all companies reduce absolute emissions by the same proportion, or the Sectoral decarbonization approach (SDA)(Krabbe et al., 2015), which assumes that some sectors will reduce emissions faster than others, based on differences in mitigation costs, while factoring in company-specific base year emission intensities and growth projections (SBTi, 2021a).

SBTi manages a database of approved targets, including for Daiseki Co., Ltd. and Holcim Ltd (highlighted in Fig. 1b):

"Daiseki Co., Ltd. commits to reduce absolute scope 1 and 2 GHG emissions 34% by FY2028 from a FY2022 base year. Daiseki Co., Ltd. also commits to increase annual sourcing of renewable electricity from 0% in FY2022 to 100% by FY2030. Daiseki Co., Ltd. further commits to reduce absolute scope 3 GHG emissions from purchased goods and services, capital goods, upstream transportation and distribution, waste generated in operations, and use of sold products 20% by FY2028 from a FY2022 base year."

"Holcim commits to reduce gross scope 1 and 2 GHG emissions 25% per ton of cementitious materials by 2030 from a 2018 base year.* Within this target, Holcim commits to reduce gross scope 1 GHG emissions 22.4% per ton of cementitious material and scope 2 GHG emissions 65% per ton of cementitious materials within the same timeframe.* Holcim commits to reduce gross scope 3 GHG emissions from purchased goods and services 25.1% per ton of purchased clinker and cement by 2030 from a 2020 base year. Holcim also commits to reduce scope 3 GHG emissions from fuel and energy related activities 20% per ton of purchased fuels by 2030 from a 2020 base year. Furthermore, Holcim commits to reduce scope 3 GHG emissions from upstream and downstream transport and distribution 24.3% per ton of materials transported within the same timeframe. *The target boundary includes land related emissions and removals from bioenergy feedstocks."

Underlying target-setting method

Several methods can be used to set an SBT (Box 1). However, companies and SBTi generally do not disclose underlying target-setting methods. Each SBT method involves a specific global emission scenario and one or more principles for allocating these future allowable emissions to companies(Bjørn et al., 2021). Global emission scenarios vary in their likelihood of staying below 1.5°C at the end of the century, and in their reliance on negative emission technologies for atmospheric carbon removal. Consequently, emission scenarios in the literature range considerably with respect to the extent of mid-century overshoot of the 1.5°C ceiling. While SBTi´s criteria for scenario selection include a limit on the amount of carbon removal, there remain substantial differences in the amount of carbon removal that is required for the range of scenarios used across SBT methods (Hadziosmanovic et al., n.d.; SBTi, 2019a). Emission allocation principles assign effort sharing between companies, thereby representing a central normative aspect of target-setting. Current SBT methods allocate effort narrowly based on emissions grandfathering, production growth, and production efficiency (Bjørn et al., 2021; Bjørn, Tilsted, et al., 2022) (Box 1).

The lack of method disclosure means that stakeholders have no way of knowing the assumptions and value judgements about climate futures and effort sharing embedded in SBTs. This, in turn, inhibits societal deliberation on acceptable levels of climate risks within the frames of the Paris Agreement as well as questions of justice in the transition to a low-carbon society. For example, discussions of fair and equitable allocations of global allowable emissions to companies are few and far between in the academic literature (Busch, Cho, et al., 2023; Rogelj et al., 2021; Ryberg et al., 2020).

The lack of method disclosure also means that it is unclear whether companies “cherry pick” methods to minimize their required emission reduction. Such an exploitation of SBTi´s rules

could lead to insufficient aggregate emission reductions even if all companies meet their approved targets (Bjørn et al., 2021).

We recommend that companies and SBTi systematically disclose the target-setting method and version underlying each approved SBT. Stakeholders can then access method documentation and related literature to understand embedded assumptions and value judgements.

Underlying company data and choices

Each target-setting method requires input from the company, including choices (e.g., base year, target year) and company data (e.g., base year GHG emissions, production projections) (Box 1)(Bjørn et al., 2021). Choices are also embedded in company data. For example, companies must select a GHG inventory boundary and emissions accounting approach when calculating base year emissions(Busch, Cho, et al., 2023) and a forecasting technique when projecting future production levels. Currently, SBTi only discloses some of these company inputs (see example SBTs in Box 1).

Company inputs can significantly impact committed and realized emission reductions. Incomplete documentation therefore impedes our ability to quantify the risk of insufficient aggregate mitigation based on the combined set of choices made by SBT-setting companies. For example, companies may follow location-based or market-based accounting to estimate scope 2 emissions, with the latter approach allowing companies to purchase renewable energy certificates and claim emissions reductions that are not actually realized (Bjørn, Lloyd, et al., 2022). As another example, the level of emissions allowed in the target year can be increased by selecting a base year with abnormally high emissions (NewClimate Institute, 2022). Also, estimating higher production growth when setting an absolute SBT than what is later achieved can lead to insufficient aggregate emission reductions.

The lack of attention to company inputs underpinning approved SBTs also hides unresolved questions around what accurate corporate emission accounting is(Brander & Bjørn, 2022; Busch,

Cho, et al., 2023). For example, some stakeholders find it unacceptable that current scope 2 accounting standards allow companies to claim emission attributes from power generators they are not physically supplied by(Robinson & Sullivan, 2022).

We recommend that companies and SBTi systematically and comprehensively disclose company data behind each approved target, the choices related to these data, and the justification for these choices.

Target specificity

SBTs typically cover multiple emissions scopes and a mix of GHGs aggregated and expressed in CO_2 equivalents (see examples in Box 1). In addition, SBTs provide no information on the emission trajectory companies plan to follow from base year to target year, which are typically separated by about 10 years (Fig. 1b).

The lack of specific emission trajectory projections makes it difficult to hold companies accountable for progressing towards their targets. Existing target-progress studies have analyzed whether companies are ahead or behind an assumed linear emission trajectory from base year to target year (Giesekam et al., 2021b; SBTi, 2022a). However, companies performing poorly by this measure can still claim (sometimes legitimately) that they will meet their target a decade down the line. Regardless, the lack of transparency associated with near-term targets, combined with the fact that many companies with SBTs do not disclose emissions annually or at all(SBTi, 2022a), make it difficult to hold companies accountable for delivering short-term actions.

The lack of target specificity also complicates understandings of the temperature implications of approved targets. When expressed in units of CO_2 equivalents, the resulting targets provide incomplete information about the climate response to the resulting emissions reductions. Studies have shown that similar CO_2 equivalent reduction pathways can lead to substantially different warming profiles, depending on whether short-lived GHGs or long-lived GHGs are

reduced (Sun et al., 2021), with CH_4 reduction mitigating the mid-century warming peak, while CO_2 reduction limits warming at the end-of century and beyond. Furthermore, for CO_2 and other long-lived gases, the temperature responds to cumulative emissions over time rather than emissions in a single year, so the pathways that companies follow towards their target years matter also for the resulting climate response(Hadziosmanovic et al., n.d.; Sun et al., 2021).

The lack of specificity for individual emission scopes by many SBTs (Fig. 1b) also complicates assessments of the combined mitigation outcomes of commitments at the company-, city- and national-levels(Bai et al., 2022; Kuramochi et al., 2020). This is especially the case for SBTs covering combined scope 1, 2, and 3 emissions owing to an unknown degree of overlap with the mitigation targets of cities and nations where companies with such targets reside, considering that scope 3 emissions of companies often occur far from their operations.

We suggest an increase in the granularity of SBTs along three dimensions. First, the planned emission trajectories from base year to target year should be clarified and companies should be required to make up for potential shortfalls in early years by increasing ambitions in later years, so as to achieve the same level of cumulative emissions as the originally targeted emission trajectory (Rekker et al., 2022). Second, in addition to formulating a target covering all GHGs, companies should present two sub-targets covering short-lived and long-lived GHGs, respectively (Allen et al., 2022). Third, SBTs should be specified for scope 1, 2 and 3, individually.

Outlook

We have shown here that there is a pervasive lack of transparency around SBTs, which threatens to undermine their effectiveness in contributing to societal climate mitigation goals. Increased transparency with respect to target-setting methods, company data and choices, and the specificity of the targets themselves, is needed. Many of our recommendations for increased transparency also apply to net-zero targets(T. Hale et al., 2022; Rogelj et al., 2021; SBTi,

2021b) and to science-based targets for other environmental problems other than climate change.

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A.3. Supplementary material for chapter 2

In this section, we present additional information to support the results and findings of the main manuscript. This includes the definition of the Social Foundation (SF), detailed methods for the social assessment. The published article Supplementary Information also cover a state of the art of social impact assessment frameworks, and further details on the illustrative case impact quantification, that fall outside the scope of this thesis. These can be found in (Desmoitier et al., 2023).

A.3.1. Defining social sustainability through the Social Foundation

A.3.1.1. Literature review

To map the current use of the Safe and Just Operating Space (SJOS) in the scientific sphere, a literature review was carried out for research articles, using the following search terms in Web of Science : *(TS=("donut economic*" OR "doughnut economic*" OR "social foundation" OR "just operating space" OR ("safe and just" NEAR/2 space))) AND TS=(thresholds Or indicators OR operational* OR metric* OR measure OR downscal* OR dimensions)*, restricting to research articles written in English between 2009/01/01 and 2022/30/11. The database search resulted in 49 journal articles that were screened and assessed for inclusion in the review, leaving 11 studies (see **Figure A.3**)

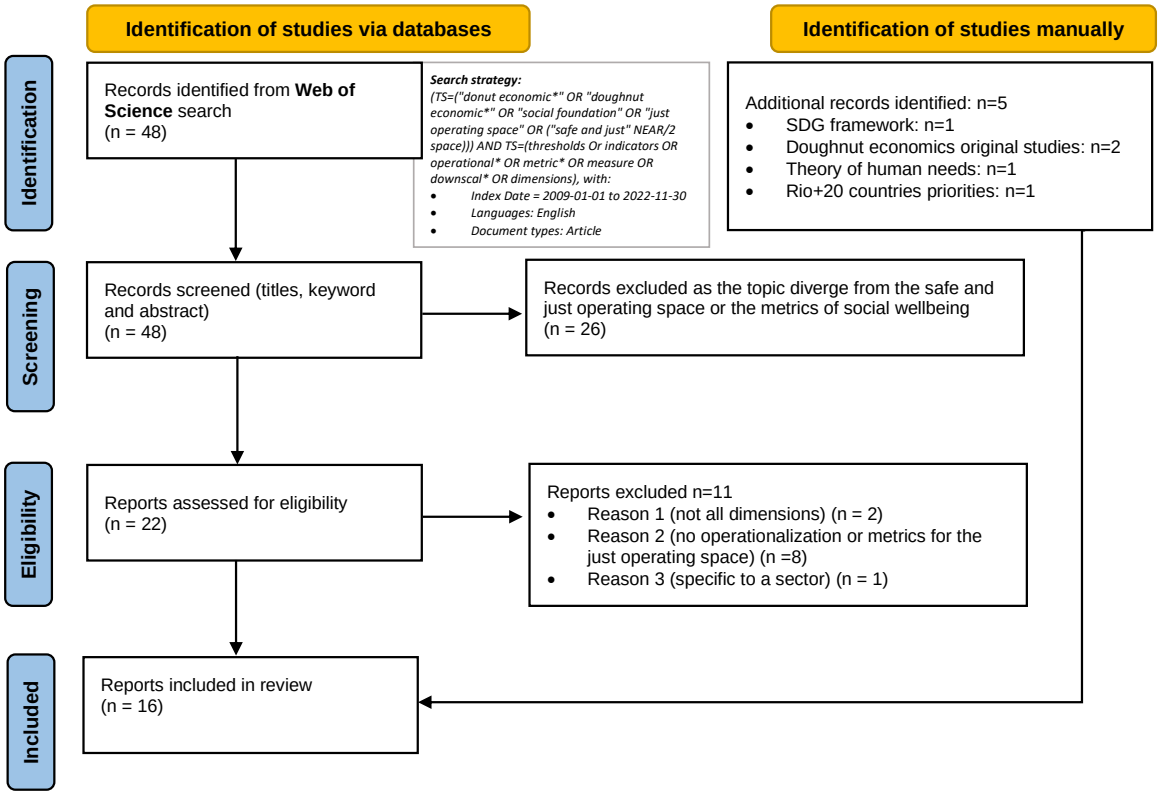

Figure A.3: Search strategy for the literature review on studies operationalizing the Safe and Just Operating Space

So far, studies have tried to operationalize the global SJOS for humanity to sub-levels (national or regional scales) to support and influence the decision-making process, notably because of its power as a communication tool (Dearing et al., 2014). Particularly, the SJOS was

downscaled at the national level to adjust to countries' priorities to define the 'national safe and just spaces' (Cole et al., 2014b). It was also used as a comparative tool to quantify the resource use associated with meeting basic human needs across 150 countries (D. W. O'Neill et al., 2018).

A.3.1.2. Definition of the dimensions

In its initial version, the Social Foundation (SF) consisted of 11 dimensions, defined in a top-down approach by countries' top priorities from the Rio+20 summit (Raworth, 2012). Since then, literature using the SJOS (e.g. Cole et al., 2014; Dearing et al., 2014; O'Neill et al., 2018; Raworth, 2017) reported differences or adaptations, depending on the end focus of the studies (e.g. drawing a national agenda based on people's priorities). The review of literature enabled to compare the dimensions representative of the SF across sources, showed in **Table A1**.

The social foundation of the SJOS (Raworth, 2012) relies on the fundamental concept of 'deprivation', approach pioneered by (Townsend, 1987). Deprivation focuses on ensuring to meet humans' needs for all. Thus, the focus on the 'Individual overall well-being' is kept in mind while selecting the dimensions. The final list is to be composed of 10 to 15 categories, deemed an appropriate number according to the screened literature. Selection of dimensions is supported by the SDGs framework as well as the theory of basic needs (Doyal & Gough, 1991). SDGs 12, 13, 14, 15 and 17 were not included as potential dimensions of the SF as they do not represent social issues or goals.

The dimensions *Income*, *Food*, *Health*, *Education*, *Sanitation*, *Energy* and Voice, the later referred as *Democratic rights*, seem consensual as all were found in the whole set of literature sources, although the literature uses various terms for describing the same dimensions. Therefore, they were included as such in the final list. The dimension *Work*, *Sanitation* and *Life satisfaction* were found to often be coupled with the dimensions *Income*, *Water* and *Health* respectively. As considered important according to the 'deprivation theory' and to meet humans' needs, such dimensions need to be represented. However, as dimensions are most often

merely represented by one indicator, it is chosen to make them self-standing dimensions. Specifically, *Income* is differentiated from *Work*, as it is formerly defined as a way to assess poverty, while the latter is one of the means to reduce poverty. So far, the SF is constituted of 10 dimensions.

The dimension *Housing* was added since considered a basic need and as a countries' priority at the Rio+20 Summit (Raworth, 2012), the latter choice supported by the SDGs framework (United Nations, 2018), focus of SDG 11. The dimensions *Social equity* and *Gender equality* could be cross-cutting with other dimensions and could be assessed within all dimensions (D. W. O'Neill et al., 2018; Raworth, 2017). Yet, it is difficult to do so with very few indicators, so they were both kept as self-standing dimensions. Social support, describing the ability of people to rely on relatives is included within the broader dimension *Networks*, referring to all types of networks, both material and immaterial. Lastly, *Peace and safety* is a less-consensual category in the literature. Yet, it is included in the theory of basic needs (Doyal & Gough, 1991). Moreover, promoting peaceful and inclusive societies and providing access to justice for all are key elements of SDG 16. Thus, it was decided to keep it as a self-standing dimension. Overall, the list is well aligned with the SDGs framework, as shown in **Table A.1**. Nine dimensions are directly linked with one unique SDG. Merely one is not really related to the set of social dimensions (SDG 9).

Table A.1: Cross-cutting of dimensions in the different sources of literature defining and operationalizing the SJOS.

Sustainable Development Goals (United Nations, 2018)	(Fanning et al., 2021; Hickel, 2018b) **based on** (D. W. O'Neill et al., 2018)	(Raworth, 2017)**.**	**(Cole et al., 2014))**	(Capmourteres et al., 2019; Dearing et al., 2014)**; based on Raworth, 2012)**	(Acosta, 2022)	(Roy et al., 2021)	(Y. Zhang et al., 2022)	(Luukkanen et al., 2021)	**Rio+20 priorities (source for Raworth, 2012)**	**Theory of basic needs** (Doyal & Gough, 1991)
1, No Poverty	Income	Income and work	Income and work	Income	Income		SDG 1		Income/Poverty	Economic security
2, Zero Hunger	Nutrition	Food	Food security	Food security	Food	Food	SDG 2	Sufficient Food	Food security	Nutritional food
3, Good Health and Well-being	Healthy life expectancy; Life satisfaction	Health	Healthcare	Health care	Health	Health	SDG 3 ; National Health Security	Healthy Life	Health care	Safe birth control; Appropriate healthcare
4, Quality Education	Education	Education	Education	Education	Education	Education	SDG 4	Education	Education	Basic education
5, Gender Equality		Gender equality		Gender equality	Gender equality	Gender equality	SDG 5	Gender equality	Gender equality	
6, Clean Water and Sanitation	Sanitation	Water and sanitation	Water access; Sanitation	Water and sanitation	Sanitation	Water and sanitation	SDG 6	Sufficient to Drink	Water and sanitation	Clean water
7, Affordable and Clean Energy	Access to energy	Energy	Electricity access	Energy	Energy	Energy	SDG 7		Access to energy	
8, Decent Work and Economic Growth	Employment		Jobs	Jobs		Employment	SDG 8	Employment	Jobs/decent work	Non-hazardous work environment
9, Industry, Innovation and Infrastructure	Social support	Networks		Social equity	Networks	Networks			Access to transport	
10, Reduced Inequality	Equality	Social equity		Resilience	Social equity		SDG 10	Income distribution	Social protection	Significant primary relationships
11, Sustainable Cities and Communities		Housing	Housing; Households goods		Housing		SDG 11		Adequate housing	Protective housing
12, Responsible Consumption and Production							SDG 12			
16, Peace and Justice Strong Institutions	Democratic quality	Political voice	Voice	Voice	Peace and justice; Political voice	Justice; Political voice		Human development index	Culture and indigenous rights; Voice and participation	Security in childhood; Non-hazardous living environment; Physical security

The final set of 15 dimensions constituting of the SF is presented in **Table A.2**.

Table A.2: Definition of the 15 dimensions constituting of the social foundation.

Dimension	Definition of the dimension
Food	End hunger, achieve food security and improved nutrition
Water	Ensure access to safe drinking water for all
Sanitation	Ensure clean and adequate sanitation for all
Housing	Ensuring adequate (safe and affordable) housing and upgrading slums
Health	Ensuring healthy lives for all
Income	Ending income poverty for all
Work	Promote full, productive employment and decent work for all
Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Energy	Ensure access to affordable, reliable, sustainable and modern energy for all
Safety and justice	Prevent all forms of violence and promote transparency and justice to ensure safety for all
Networks	Ensuring social inclusion (support and interaction) for all through all kind of networks
Gender equality	Achieve gender equality and empower all women and girls
Social equity	Reduce inequality within and among countries
Democratic rights	Protect fundamental freedoms for all (such as freedom of speech, association, information) and ensure transparent policy-making to enable inclusive social participation
Life satisfaction	Promoting well-being for all

A.3.1.3. Selecting social foundation indicators

Once the dimensions have been defined, the social foundation indicators were also reviewed to rationalise the process based on which they are selected for the shortlist of indicators (one per dimension). Ranking and ultimately selecting SF indicators entails assessing their quality based on defined characteristics to ensure that the chosen indicators are good indicators, i.e. as SMART as possible (Specific, Measurable, Achievable, Relevant, Time-Bound). Especially, having only one indicator to represent a full dimension, i.e. the best available proxy, requires meeting the highest standards in the defined characteristics. Accordingly, the selection process is based on 4 criteria of different importance, presented here

from the most to the least important: 1) Relevance, 2) Classification of the indicator in the UN Tiers, 3) Frequency, 4) Alignment with the SDGs.

Indicators are ranked based on their score in all successive 4 characteristics (from most to least important), using the following principle: the better the score of one indicator, the higher the rank. If two indicators happen to have the same score for one (or several) characteristic (from most to least important), the final rank is determined based on the score of the following characteristic. For example, if two indicators obtain the same score for the first and most important criteria, the indicator getting the highest score to the second scenario should rank higher. If both indicators get the same score, the process continues until the scores differ. The final list of ranked indicators can be found in **Table 2.1** of **Chapter 2**.

Criteria 1: Relevance

Relevance targets the question of "Does the indicator measure what really matters as opposed to what is easiest to measure?" (ICAT, 2019). Within this context, 'what matters' refers to the measure of a potential deprivation associated to ensuring humans' needs for all. In specific terms, relevance of indicators reflects two sub-aspects:

1. **Comprehensiveness**: Does the indicator entirely represent one dimension?
2. **Representativeness**: Does it directly measure the identified deprivation for the selected dimension?

To rank indicators according to their relevance, tiers are defined based on the answers to the sub-questions here above. Tier 1 (highest relevance): Both 'Yes'; Tier 2 (medium relevance): One 'Yes' and one 'No'; Tier 3 (lowest relevance): Both 'No'.

Criteria 2: UN tiers

Indicators within the SDGs framework are classified into 3 tiers based on their level of methodological development and data availability (IAEG-SDGs, 2018).

Tier 1: The indicator is conceptually clear, has an internationally established methodology and standards are available, and data is regularly produced by countries for

at least 50 per cent of countries and of the population in every region where the indicator is relevant.

Tier 2: The indicator is conceptually clear, has an internationally established methodology and standards are available, but data is not regularly produced by countries.

Tier 3: No internationally established methodology or standards are yet available for the indicator, but methodology/standards are being (or will be) developed or tested.

However, not all indicators are part of this classification. So, further information about all not-yet classified indicators was collected to be able to conclude on the tiers the indicators should relate to. Such information was found on common databases such as (IEA, 2017; WHO, n.d.; World Bank, n.d.-a). Ultimately, all indicators were associated to a specific tier.

Criteria 3: Frequency in the list

This criterion accounts for the number of times a specific indicator has been used across literature sources. This can be seen as a proxy for credibility and scientific consensus about this indicator.

Criteria 4: SDG alignment

This last criterion (of relatively low importance) consists in a final attempt to distinguish two equally ranked indicators. Assuming that two indicators were found to be equally ranked for one dimension, if one is in line with the corresponding SDG (only if stated in literature) and not the other one, the first one should be prevailing.

A.3.1.4. Defining absolute thresholds for the social foundation

In this part, social foundation indicators identified as proxies to represent the different dimensions are presented in more details in order to define their associated absolute thresholds. The tier-classification used to define thresholds is presented in this section.

Tier 1: *Food, Water, Sanitation, Housing, Income, Education, Energy, Safety and justice* and *Networks* dimensions

For these dimensions, indicators are scientifically sound and well defined, and used by many international institutions, particularly institutions of the United Nations. Dimensions are represented by indicators that directly measure a deprivation (or respectively an 'anti-deprivation'). Consequently, social absolute thresholds can be fairly easily and reliably defined as 0% as no one should suffer from any deprivation (or respectively 100 % if the indicator measures 'anti-deprivation'). Accordingly, 0% (or 100%) represent the absolute social thresholds for the 9 dimensions listed here above.

Food

Ending hunger and achieving food security is the focus of SDG 2. The human deprivation related to taking sustenance is represented by undernourishment, defined as follows: "Undernourishment is de-fined as the condition in which an individual's habitual food consumption is insufficient to provide the amount of dietary energy required to maintain a normal, active, healthy life." (Food and Agriculture Organisation of the United Nations (FAO), 2018). Undernourishment is reported by the FAO through the indicator Prevalence of Under-nourishment" (PoU), which is a "three-year average estimation of the percentage of individuals in the total population that are in a condition of undernourishment." Undernourishment is assessed in terms of minimum calorie intake, which varies according to gender, age and physical activity primarily and is referred as MDER (Minimum Daily Energy Requirements expressed in kcal/cap/day). MDER typically ranges between 2100 and 2900 kcal/day (D. W. O'Neill et al., 2018).

From a rights-based approach, i.e. based on the deprivation concept, 0 % of the population should remain in a state of undernourishment. Therefore, the absolute threshold as regards to the objective of no 'food deprivation' for the indicator "Fraction of the population being undernourished, based on the adequate daily calorie intake depending on age or gender" is set at 0%.

Water

Ensuring access to safe drinking water for all is one of the focuses of SDG 6. The indicator used is "Fraction of population using safely managed drinking water services (%)". Safe water is provided by "improved sources", including piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water. Besides, safely managed drinking water sources should meet 3 criteria: i) it should be accessible on premises, ii) water should be available when needed, and iii) the water supplied should be free from contamination (WHO/UNICEF, 2017b). It corresponds to the most stringent level of service (safely managed, basic, limited, unimproved, surface water).

From a rights-based approach, 100 % of the population should be granted access to safe drinking water. Therefore, the absolute threshold as regards to the objective of no 'safe water deprivation' is set at 0% of the population.

Sanitation

Ensuring access to safely managed sanitation services for all is one of the focuses of SDG 6. The indicator used is "Fraction of population with access to improved sanitation (%)". Improved sanitation facilities are designed to hygienically separate excreta from human contact. Such facilities include flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets or pit latrines with slabs. Access to improved sanitation includes 3 levels of service (depending on whether sanitation facilities are shared between households or not): limited, basic and safely managed. (WHO/UNICEF, 2017b).

From a rights-based approach, 100 % of the population should be granted access to improved sanitation. Therefore, the absolute threshold as regards to the objective of no 'decent sanitation deprivation' is set at 0% of the population.

Housing

Ensuring access for all to adequate, safe and affordable housing covered by SDG 11. The indicator used here is "Proportion of urban population living in slums, informal settlements or inadequate housing (%)" and focuses on the adequacy of habitats (United Nations, n.d.-a). Such inadequate housing, slums especially, are reported to be lacking in at least one of the following four characteristics: access to improved drinking water, access to improved sanitation, no overcrowding, dwellings made of durable material (Raworth, 2017).

From a rights-based approach, 0 % of the population should be living in inadequate housing. Therefore, the absolute threshold as regards to the objective of no 'inadequate housing deprivation' is set at 0% of the population.

Income

Eradicating income poverty is one aspect of ending poverty in the world and it is focused on by SDG 1. The indicator used here is "Fraction of population living below the national poverty line (%)", which represents a relative measure of poverty. National poverty lines are often taken as "half the median household income of the total population" (OECD, 2014), yet some countries adopt different specific methods. In other words, this indicator measures the fraction of population whose average household income is inferior to half the median household income of the total population. Poverty data is provided by administrative unit level 1 institutions (highest sub-national unit level, including e.g. 'state', 'governorate', 'province' (World Bank, n.d.-a).

From a rights-based approach, 0 % of the population should be living in a state of poverty. Therefore, the absolute threshold as regards to the objective of no 'income poverty' is set at 0% of the population.

Education

Ensuring inclusive, equitable and quality education is the focus of SDG 4. The indicator used here is "Children aged 12-15 out of school (%)".

From a rights-based approach, 100 % of the population should be granted access to primary and secondary education. Therefore, the absolute threshold as regards to the objective of no 'education deprivation' is set at 0% of the population.

Energy

Ensuring access to energy for all is the focus of SDG 7. The indicator used here is "Fraction of population with access to electricity (%)". Access to electricity is measured in terms of household possessing a direct electricity supply, which is provided with a minimum of 250 and 500kWh/yr respectively for rural and urban areas (Raworth, 2017).

From a rights-based approach, 100 % of the population should be granted access to electricity. Therefore, the absolute threshold as regards to the objective of no 'energy deprivation' is set at 0% of the population.

Safety and Justice

Preventing all forms of violence, promoting transparency and justice to ensure safety for all is the focus of SDG 16. The indicator used here is "Number of victims of intentional homicide per 100,000 people". Intentional homicide refers to unlawful death purposefully inflicted on a person by someone. However, killings in periods of war or conflicts are not included (Raworth, 2017).

From a rights-based approach, 0 % of the population should be a victim of intentional homicide. There-fore, the absolute threshold as regards to the objective of no 'safety and justice deprivation' is set at 0 homicide (per 100,000 people).

Networks

Ensuring social inclusion (support and interaction) for all through all kind of networks correspond to targets 1.5 and 9.c within the SDG framework. The indicator used here is

"National average of binary responses to the question: If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?" and the answer is binary (yes or no). This indicator is monitored by the Gallup World Poll and is part of the World Happiness Report (Helliwell et al., 2019b).

From a rights-based approach, 100 % of the population should be included in social networks. Therefore, the absolute threshold as regards to the objective of no 'social inclusion deprivation' is set at 0% of the population.

Tier 2: *Work, Gender equality,* and *Life satisfaction* dimensions

This type refers to dimensions for which there is no inherently absolute threshold defined in the indicator, since they do not directly measure deprivation. However, social and scientific studies are numerous enough to represent sound literature to rely on when defining the threshold.

Work

Promoting full and productive employment for all, as part of the focus of SDG 8, is one of the key-stones to reduce income poverty, entailing insecurity and instability (Raworth, 2017). The indicator used for this dimension is the unemployment rate, which is defined as "the number of unemployed people as a percentage of the labour force, where the latter consists of the unemployed plus those in paid or self-employment. Unemployed people are those who report that they are without work, that they are available for work and that they have taken active steps to find work in the last four weeks", according to OECD (OECD, 2019).

Despite misconceptions, an unemployment rate of 0 % is not the target to aim for. Indeed, frictional unemployment, which allows workers to transition between jobs, is inevitable and even desirable for a well-functioning economy. As opposed to it, structural and cyclical types of unemployment reflect a mismatch between jobs and employees' skills or a fall in the aggregate demand for goods and services (Goodwin et al., 2015). The objective is then to reach

'full-employment', term that can be economically defined in many ways. The adopted definition here is to relate the optimal unemployment rate to the average Non-Accelerating Inflation Rate of Unemployment (NAIRU). Full-employment is reached when the unemployment rate is below the NAIRU (Zagorsky, n.d.). It is currently set at 4.6% by the U.S. Congressional Budget Office (CBO), but it can vary between 4.5 and 6 % (U.S. Congressional Budget Office, 2019).

Consequently, the absolute threshold for the "Work" dimension is set as roughly equal to 5 %.

Gender equality

Seeking gender equality and empowering women is the focus of SDG 5. The indicator used here is "Share of women in national parliaments". For this indicator, parity is sought, as indicated in the Global Gender Gap Report (World Economic Forum, 2017).

For this indicator, the absolute threshold is set equal to 50 %, meaning that full deprivation (resp. zero deprivation) is reached when women hold 0 % of seats (resp. 50 % of seats) in the national parliament.

Life Satisfaction

Ensuring life satisfaction and well-being for all is a part of the focus of SDG 3. To measure it, the Cantril Self-Anchoring Scale (Cantril, 1965), developed by pioneering social researcher Dr. Cantril, is used. It is defined as follows: "Please imagine a ladder with steps numbered from zero at the bottom to 10 at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time? (ladder-present) On which step do you think you will stand about five years from now? (ladder-future)". Accordingly, the score given as an answer ranges from 0 to 10. Analysing data from hundreds of thousands of respondents to the Gallup World Poll in more than 150 different countries lead to the definition of three meaningful categories, according to Gallup (Gallup, 2019):

i. Suffering (0-4): well-being that is at high risk. These respondents have poor ratings of their current life situation (4 and below) and negative views of the next five years (4 and below). They are more likely to report lacking the basics of food and shelter, more likely to have physical pain, a lot of stress, worry, sadness, and anger. They have less access to health insurance and care, and more than double the disease burden, in comparison to 'thriving' respondents.

ii. Struggling (4-7, both excluded): well-being that is moderate or inconsistent. These respondents have moderate views of their present life situation or moderate or negative views of their future. They are either struggling in the present or expect to struggle in the future. They report more daily stress and worry about money than the 'thriving' respondents, and more than double the amount of sick days. They are more likely to smoke and are less likely to eat healthy.

iii. Thriving (7-10): well-being that is strong, consistent, and progressing. These respondents have positive views of their present life situation and have positive views of the next five years. The report significantly fewer health problems, fewer sick days, less worry, stress, sadness, anger, and more happiness, enjoyment, interest, and respect.

Other approaches exist in order to measure subjective well-being and life satisfaction. Another widely resorted to approach is the World Value Survey (Ortiz-Ospina & Roser, 2013), that also provides cross-country data (including around 100 countries) on self-reported life satisfaction. The question being answered is: "Taking all things together, would you say you are (i) Very happy, (ii) Rather happy, (iii) Not very happy or (iv) Not at all happy". Even though the scores between the two approaches seem to correlate well, a bias seems to be consistently found in the results of the Cantril ladder, results being lower of 0.5 point on average compared to other questions used to measure well-being (D. W. O'Neill et al., 2018).

A score of 7 (lower bound of the 'Thriving' category) seems to be an appropriate and reliable threshold to be reached to ensure that one is fulfilled with his/her life (D. W. O'Neill et al., 2018). To take into account the lower score given to the Cantril ladder of 0.5 point compared to other methods, the minimum value is set to 6.5. This score corresponds to the answer of the first question of the Cantril Self-Anchoring Scale (ladder-present).

Tier 3: *Health, Social equity,* and *Democratic rights* dimensions.

Lastly, the third tier refers to dimensions, for which defining thresholds can be disputable and involves making 'strong' decisions. Ethical, social and cultural perspectives are involved when it comes to answering the question of 'what is good enough?'. Besides, little literature is available to support such choices. Both reasons make the definition of a threshold difficult and largely uncertain.

To set thresholds for the dimensions *Health*, *Social equity* and *Democratic rights*, the Human Development Index (HDI) developed by the United Nations Development Programme (UNDP), (UNDP, 2018b) was used as suggested by Raworth (Raworth, 2017). Most countries in the world are classified into the following categories: 'Very high', 'High', 'Medium' or 'Low' human development, depending on the extent of their human development based on several criteria such as Long and healthy life, Knowledge and Decent standard of living (UNDP, 2018b). The threshold is defined as the median of a certain group of countries, the latter differing from dimension to dimension. The choice of the targeted group to set the threshold is made based on literature (Raworth, 2017) and benchmarked based on global performance.

Health

Ensuring healthy lives is part of the focus of SDG 3. The indicator used to represent the dimension *Health* is Life Expectancy at Birth (years). The definition is: "The number of years a newborn infant could expect to live if prevailing patterns of age-specific mortality rates at the time of birth stay the same throughout the infant's life." (UNDP, n.d.) No international

benchmark has been defined yet to set a minimum life expectancy. Raworth (2017) suggests using the HDI and uses 70 years as a threshold since it is "an outcome typically achieved by countries classified under medium human development according to UNDP's HDI" (Raworth, 2017). In other words, *Health* is a dimension for which most countries 'perform' relatively well.

As life expectancy keeps increasing in many countries, it is expected that most countries will reach this threshold of 70 years in the coming years (WHO, 2018). That is why it is found relevant to set a higher threshold, corresponding to the median life expectancy at birth of countries classified under "High" hu-man development, equals to 74.9 years (UNDP, n.d. data from 2017). The threshold is accordingly set to 75 years. Being under that threshold reveals overall worse health conditions than average (high infant mortality, limited access to essential cares etc), hence measurement of health deprivation.

Social equity

Reducing inequality within and among countries is the focus of SDG 10, which is often measured in terms of income inequality. The Palma ratio is used and is defined as "a measure of income or consumption concentration based and calculated as the Gross National Income capture of the richest 10% divided by that of the poorest 40 %" (Cobham et al., 2016). This indicator is easy to understand for policy-makers and is a policy-relevant measure of inequality (Cobham et al., 2013). Indeed, it focuses on capturing relative changes at the extremes of the income distribution, since "changes in income or consumption inequality are (almost) exclusively due to changes in the share of the richest 10 % and poorest 40 % because the 'middle' group between the richest and poorest tend to capture approximately 50 % of gross national income." (Cobham et al., 2016).

Setting an absolute threshold for the Palma ratio, i.e. questioning it 'being normal or not' inevitably involves making a normative choice. A benchmark was set at a Palma ratio of 2 by Raworth (Raworth, 2017), which occurs when the richest 10 % earn twice the annual income of the poorest 40 %. No clear rationale supports this choice. Instead, the threshold was set as

the median of the Palma ratio scores for countries classified under the group 'Very high' human development. This group was chosen since 'High' and 'Medium' human development groups showed high income inequalities. The calculated numeric value for this threshold is 1.2 (Kaufmann & Kraay, n.d. data representative of years 2010-2017).

Democratic rights

The dimension *Democratic rights* aims at safeguarding fundamental freedoms while ensuring transparent policy-making to enable inclusive social participation. This dimension is related to one of the focus of SDG 16. The indicator used to represent this dimension is the Voice and Accountability index, the latter indicator being part of the six indicators used in the World-wide Governance Indicators (WGI) project (Kaufmann et al., 2010). The Voice and Accountability index captures "perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media." Estimates give the countries' scores in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5 (Kaufmann & Kraay, n.d.).

It is difficult to benchmark an absolute threshold for this indicator, as it involves a normative choice. As an example, O'Neill (D. W. O'Neill et al., 2018) takes 0.8 as a threshold, because of it being the score for Great-Britain and the United-States (that are "two democratic systems that are by no means the highest performing but are nonetheless well-knowns in terms of their strengths and weaknesses"). This approach is deemed too arbitrary, so the threshold is set based on the HDI. The threshold for this indicator was defined as the median of the Voice and Accountability scores for countries classified under the group 'Very high' human development. This group was chosen since countries overall do not perform very well as regards democratic rights, the current state being away from the ideal state of 2.5 (normal distribution between -2.5 and 2.5, centred on 0). The calculated numeric value for this threshold is 1.0 (Kaufmann & Kraay, n.d. data from year 2017).

A.3.2. Social impact assessment:

A.3.2.1. Significance assessment

After social impacts have been identified, these must be quantified to facilitate a comparison with the baseline scenario. However, as standardized methods for quantification of social impacts and databases on impact of different process are lacking, each social impact has to be quantified and assessed specifically. Thus, to increase efficiency of the assessment and only focus on the important social impacts, we follow the recommendations in the *ICAT Sustainable Development Guidance* (ICAT, 2019), and carry out a significance assessment to identify the significant impacts.

The methodology adopted here to assess the significance of impacts is adapted from (Terrapon-Pfaff et al., 2017)). Assessing significance is based on 4 criteria, namely Likelihood, Intensity, Geographic extent, Duration, further detailed in **Table A.3**.

A set of experts is selected and each expert evaluates all the identified impacts against the four criteria on a five-point scale (from 1 to 5) which is then aggregated to an overall significance score based on **Eq. S1** (Terrapon-Pfaff et al., 2017) as can be seen in **Table A.4**.

$$S_i = L_i * (In_i + G_i + D_{i)} \qquad \textbf{Eq. S1}$$

Where S_i is significance, L_i likelihood, In_i intensity, G_i geographic extent and D_i duration of impact *i.* The impact specific significance scores from the different experts are averaged to obtain the final significance score for the specific impact. The final significance scores are, hereafter, ranked and classified as being either ’very low’, ‘low’, ‘moderate’, ‘high’ or ’very high’ (see

Table A.3: Definition of significance criteria

Criteria	Scale	Definition
Intensity	None	No impact on individual well-being
	Low	Low impact on individual well-being
	Medium	Moderate impact on individual well-being
	High	High impact on individual well-being
	Very high	Very high impact on individual well-being
Geographic extent	Punctual	Communitie(s) around the geothermal energy power plant
	Urban	Citie(s) around the geothermal energy power plant
	District	District(s) around the geothermal energy power plant
	Regional	Region(s) around the geothermal energy power plant
	National	Uganda
Duration	Momentary	Less than one year
	Short-term	1 to 5 years
	Medium-term	5 to 10 years, less than the project lifespan
	Long-term	10 to 20 years, order of magnitude of the lifespan of the project
	Irreversible	Permanent
Likelihood	None	Impact will not occur
	Unlikely	Impact is unlikely to occur
	Likely	Impact is likely to occur
	Most likely	Impact is most likely to occur
	Definite	Impact will definitely occur
Confidence level	High	Very confident in the accuracy of the rating
	Medium	Confident in the accuracy of the rating
	Low	Not confident in the accuracy of the rating

Table A.4: Scoring for each significance criteria based on different confidence levels.

Intensity	***Confidence level***		
	High	***Medium***	***Low***
None	*0*	*2*	*2*
Low	*2*	*1.5*	*1*
Medium	*3*	*2.5*	*2*
High	*4*	*3.5*	*3*
Geographic extent	***Confidence level***		
	High	***Medium***	***Low***
Punctual	*1*	*0.5*	*0.5*
Urban	*2*	*1.5*	*1*
District	*3*	*2.5*	*2*
Regional	*4*	*3.5*	*3*
National	*5*	*4.5*	*4*
Duration	***Confidence level***		
	High	***Medium***	***Low***
Momentary	*1*	*0.5*	*0.5*
Short-term	*2*	*1.5*	*1*
Medium-term	*3*	*2.5*	*2*
Long-term	*4*	*3.5*	*3*

Irreversible	*5*	*4.5*	*4*
Likelihood	***Confidence level***		
	High	***Medium***	***Low***
None	*0*	*1*	*1*
Unlikely	*2*	*1.5*	*1*
Likely	*3*	*2.5*	*2*
Most likely	*4*	*3.5*	*3*
Definite	*5*	*4.5*	*4*

Aggregated significance

It is plausible that numerous impacts with 'very low' or 'low', but which all affect one specific SF dimension altogether have a significant impact. To avoid overlooking such case, significance scores are also aggregated per dimension and converted into an aggregated significance level per dimension. Here, dimensions with a 'moderate' or higher level of aggregated significance should also be included as part of the impact quantification step and are referred to as 'relevant dimensions'.

To identify relevant dimension of the SF to quantify, all impacts within this dimension are classified per 'direction', with impacts being either positive or negative. At the dimension level, the quantification needs to be done for the significant direction(s), i.e. positive and/or negative. If both positive and negative impacts of a dimension are significant, they need to be quantified separately, potentially entailing building different social impact pathways for both directions. The final overall impact within this dimension represents the aggregation of all negative and positive impacts. The aggregated significance score (S) of the overall impact for one given dimension D with n identified impacts and one given sign S (positive or negative) is given in **Eq. S2**:

$$S2\ (D,S) = \sum_{i=1}^{n} S1\ (Ii) \qquad \textbf{Eq. S2}$$

with Ii being the impact i of the social dimension D and of sign S, S1 its significance score and S2 the aggregated significance score of the impacts of sign S on the relevant dimension D.

Table A.5: Significance levels and scores for individual impacts and dimensions

Significance	Scores for individual significance	Score for aggregated significance
Very high	61-75	>213
High	46-60	160-212
Moderate	31-45	107-159
Low	16-30	54-106
Very low	0-15	0-53

A new scale of significance levels is defined for the aggregated significance. As for the significance levels of a single impact, aggregated significance levels for relevant dimensions consist of 5 intervals from 'very low' to 'very high' significance. The interval size is defined by the interval size for the significance levels of a single impact (i.e. 15) multiplied by the average number of impact per dimension (N/15, with N being the number of identified impacts), hence an interval size equal to N (50 for the illustrative case in Uganda). All dimensions with a 'moderate' or higher level of aggregated significance are classified as relevant dimensions in which quantification has to be performed.

A.3.2.2. Impacts quantification

The objective of this section is to draw 'social impact pathways' to quantify both significant impacts and overall impact on relevant dimensions. The term 'social impact pathway' represents a range of causal relationship between indicators until the associated social foundation. Quantifying social impact pathways requires establishment and quantification of causal links between the policy outcomes, the significant impact(s) of the dimension and the associated social foundation indicator. It is recommended to consult a panel of experts to develop the social impact pathways, similarly to the significance assessment step. Specifically for the quantification of causal links, the recommended approach is to rely on mechanistic models which express the change in one indicator as a result of a change in another indicator

located earlier in the impact pathway. In cases where development of mechanistic models is not possible, other approaches are needed. It is recommended to use statistical correlations to express the relationship between different indicators on the social impact pathway and between different SF dimensions. A set of validation conditions were defined in order to judge if the correlation between e.g. two indicators, was sufficiently strong. It is important to be aware that correlation does not imply causality (Marken & Horth, 2011), thus correlations must be critically evaluated.

Significant impact quantification: impact pathway based on the DPSIR framework

The DPSIR framework supports the mapping of the interactions and dynamics of a social-ecological system through causal chains, and is relevant to use in the context of this study due to its policy orientation (Binder et al., 2013). In the context of policy, the 'DPSI' could be seen as the baseline scenario and the Response (R) as the policy (J. Zhang & Fujiwara, 2009), as illustrated in **Figure A.4**. There are several types of responses, corresponding to different policies or different focuses of policies. For example, policies aiming at restructuring social systems or controlling generation are response to drivers, policies enforcing laws and regulations are responses to pressures. The DPSIR facilitates the process to understand the behaviour of the system and to draw causal links. It is recommended to use the DPSIR framework at the system and policy levels first to have an understanding of the system, and then to add specific impacts. Details on processes and causal links are driven by the specific problem domain under consideration (Binder et al., 2013), hence more details on methods can be found in the following section for the definition of impact pathway in the case of the illustrative example of the Geothermal Energy Development Policy in Uganda.

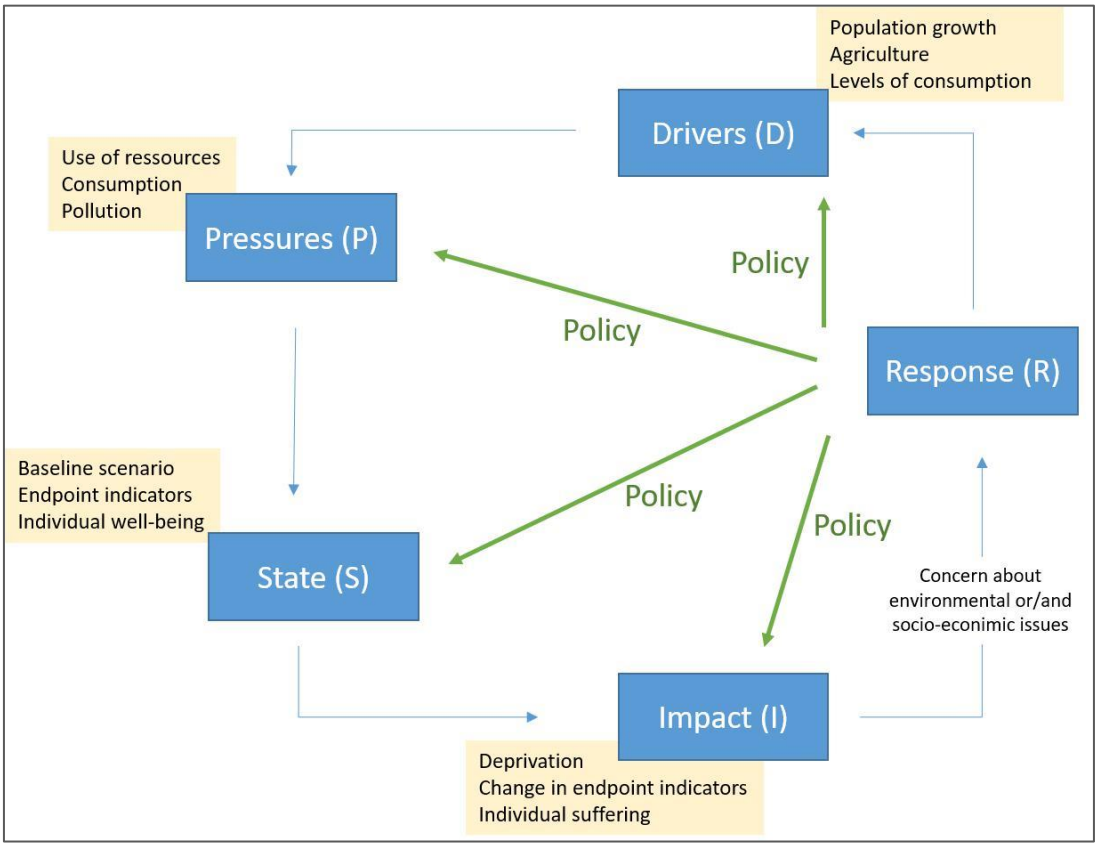

Figure A.4: The DPSIR framework adapted to the context of policies

Impacts at the dimension level with the use of correlations

Using correlations comes back to quantifying how much the change of a social foundation indicator of a dimension influences the change of the social foundation indicator in another dimension, based on empirical data for the current situation. As a proxy for the current year, it is recommended to use the most recent year in which data is available for both indicators.

Five validation conditions were defined. It is important to note that these proposed conditions are defined as necessary to validate the correlation, but do not claim to be necessarily sufficient, hence a critical evaluation of all correlations is recommended.

1. An impact exists within the 'reference dimension' of the correlation and it had been possible to quantify the impact in the metrics of the indicator representative of this dimension.

2. The impact in the assessed dimension calculated with the correlation is going in the same direction (i.e. positive or negative impact) (see Section S3.1) as the overall impact in the assessed dimension level, assessed in the significance assessment step.
3. An apparent correlation can be observed when plotted.
4. Coefficient of determination (r^2) > 0.5.
5. The correlation coefficient is statistically significant, i.e. p-value < 0.05.

A.3.3. Normalization of results

Normalization is carried out to put the results into perspective, with respect to the absolute thresholds set for the dimensions of the SF. Normalisation principles depend on the nature of the threshold, which is necessarily a critical value. The value can either be an acceptable maximum not to be exceeded or an acceptable minimum, not to fall below. For Tier 1 dimensions of the SF (defined in Section **SA.3.1.4**), these acceptable extrema are simply the theoretical extremum of the indicators (0 or 100%). For Tier 2 and Tier 3 dimensions, the indicators' theoretical extremum can be different from these critical values. The latter are defined based on empirical extremum. The normalisation step is performed according to **Eq. S7**.

$$|S| = \begin{cases} \frac{S - min_{acc}}{T - min_{acc}} & if\ the\ threshold\ is\ a\ maximum \\ \frac{max_{acc} - S}{max_{acc} - T} & if\ the\ threshold\ is\ a\ minimum \end{cases} \qquad \textbf{Eq. S7}$$

with S being the social (resp. environmental) score for a given state (e.g. baseline or policy scenario) and a given indicator (resp. control variable), |S| the normalised score associated to S, T the threshold set for the chosen indicator (resp. for the given control variable), minacc the minimum acceptable value of the indicator and maxacc its maximum acceptable value. 0 represents a full deprivation state and 1 represents the social foundation of the SJOS (zero-deprivation state).

A.4. Supplementary material for chapter 3

This document presents supporting information regarding the performance of the 25 retrieved methods that may contribute to the definition of an organizational climate change mitigation strategy (OCCMS). First, **Table A.6** and **Table A.7** provide values relating to sub-criteria fulfilment according to various parameters. Then, **Figure A.5** highlights the number of sub-criteria met for each method and **Figure A.6** show how each sub-criterion are fulfilled, showing differences between them.

Subsequently, **Section A.4.2** provides the detailed evaluation of each method.

A.4.1. Supplementary analysis of the evaluation of the 25 retrieved methods

Table A.6*: Evaluation of 25 methods according to the 5 criteria and 15 sub-criteria*

	Multi-level applicability			Scope			Scientific robustness			Accessibility and adoption			Stakeholders' involvement			Targeted user		Categorization according to OCCMS steps								
	Adaptability to all sectors	Applicability to all sectors	Adaptability to all sizes and types	Climate-associated risks and opportunities	Consideration of the initial organizational climate context	Inclusion of all organisation activities	Uncertainty assessment	Consideration of other sustainability parameters	Scientific review of the method	Accessibility of the method	Usage by organizations	Existing public case studies	Involvement of multiple stakeholders in the processes	Support for organizations	Alignment with recognized authorities and policies	Financial	All organizations	Goal & Scope definition	GHG emission accounting	Current situation analysis	Climate mitigation targets	Action plan definition & deployment	Monitoring of progress, reporting and verification	Number of level 2 (green)	Number of level 1 (orange)	Number of level 0 (red)
SBTi short term																								80%	7%	13%
BC																								73%	20%	7%
ACT-A																								67%	27%	7%
ACT-S																								67%	13%	20%
GHGP																								80%	13%	7%
CDP-Q																								67%	13%	20%
SBTi NZS																								67%	13%	20%
TCFD																								60%	27%	13%
ISO 14064																								60%	20%	20%
BIA																								67%	20%	13%
NZI																								53%	33%	13%
Q-GES																								53%	33%	13%
GRI 305																								53%	13%	33%
SM GES																								33%	20%	47%
ACCR																								0%	40%	60%
CBI																								73%	0%	27%
CA100+																								67%	0%	33%
GFANZ																								60%	13%	27%
SOC																								47%	20%	33%
TPI																								47%	13%	40%
PAII																								47%	13%	40%
ICAPs																								40%	20%	40%
CSLN																								27%	27%	47%
OMPCCM																								27%	13%	60%
ICMA																								27%	27%	47%

Table A.7*: Analysis of sub-criteria fulfilment according to targeted user or step in climate strategy*

		V_1	V_2	V_3	S_1	S_2	S_3	R_1	R_2	R_3	T_1	T_2	T_3	I_1	I_2	I_3
		Adaptability to all sectors	**Applicability to all sectors**	**Adaptability to all size and types**	**Climate-associated risks and**	**Consideration and implementati**	**Consideration of the initial situation**	**Uncertainty assessment**	**Consideration of other sustainability**	**Scientific review of the method**	**Accessibility of the method**	**Usage by organizations**	**Existing public case studies**	**Involvement of multiple stakeholders**	**Support for reorganizations**	**Alignment with recognized**
	Total score	19	17,5	21	15	17,5	14,5	7	4,5	19	21	20,5	14	15,5	9,5	20
	% total	76%	70%	84%	60%	70%	58%	28%	18%	76%	84%	82%	56%	62%	38%	80%
	Score of financial organizations	8,5	3,5	7	7,5	6,5	4	1	0,5	7,5	9,5	7	5	4	2,5	6
	% financial	85%	35%	70%	75%	65%	40%	10%	5%	75%	95%	70%	50%	40%	25%	60%
	Score of non-financial organizations	10,5	14	14	7,5	11	10,5	6	4	11,5	11,5	13,5	9	11,5	7	14
	% non financier	70%	93%	93%	50%	73%	70%	40%	27%	77%	77%	90%	60%	77%	47%	93%
All steps and methods	Median	1,00	1,00	1,00	1,00	1,00	0,50	0,00	0,00	1,00	1,00	1,00	1,00	0,50	0,00	1,00
	Average	0,76	0,7	0,84	0,6	0,7	0,58	0,28	0,18	0,76	0,84	0,82	0,56	0,62	0,38	0,8
Goal and scope definition	Median	1	1	1	1	1	1	0,5	0	0,5	1	1	0,5	0,5	0	1
	Average	0,69	0,77	1,00	0,69	0,69	0,69	0,46	0,15	0,73	0,85	0,92	0,50	0,65	0,38	0,96
GHG emission accounting	Median	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,00	1,00	1,00	1,00	1,00	0,50	0,50	1,00
	Average	0,83	1,00	1,00	0,83	0,83	0,83	1,00	0,00	1,00	0,83	1,00	0,67	0,67	0,50	1,00
Strategic analysis of the current situation	Median	1	1	1	1	1	0,5	0	0	1	1	1	1	0,5	1	1
	Average	0,94	0,89	0,89	1,00	0,94	0,50	0,28	0,22	0,83	0,83	1,00	0,67	0,50	0,61	0,94
Climate change mitigation targets definition	Median	1,00	1,00	1,00	1,00	1,00	0,50	0,00	0,00	1,00	1,00	1,00	0,50	0,50	0,00	1,00
	Average	0,80	0,57	0,73	0,60	0,70	0,60	0,27	0,07	0,73	0,87	0,77	0,50	0,57	0,37	0,73
Action plan definition and deployment	Median	1,00	0,00	1,00	1,00	0,50	0,50	0,00	0,00	0,50	1,00	1,00	0,00	1,00	0,00	0,50
	Average	0,78	0,44	0,89	0,67	0,61	0,61	0,11	0,06	0,56	0,83	0,67	0,33	0,61	0,22	0,61
Monitoring of progress	Median	1	1	1	0,75	0,75	0	0	1	1	1	1	1	0,75	0,25	1
	Average	0,75	1,00	0,75	0,63	0,63	0,25	0,00	0,75	1,00	0,88	1,00	0,88	0,63	0,38	0,88

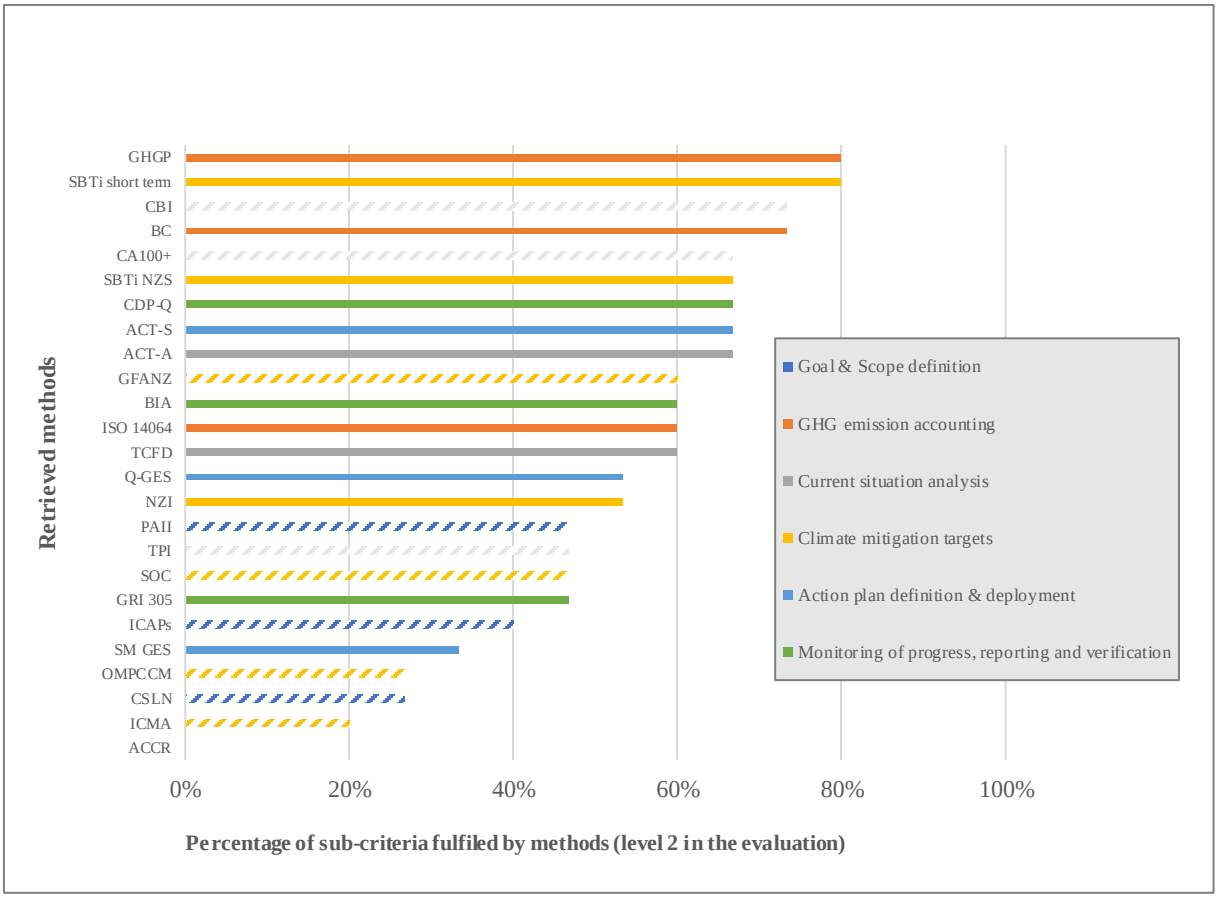

Figure A.5*: Share of sub-criteria fulfilled for each OCCMS method*
Note: the dotted bars correspond to methods targeting financial organizations

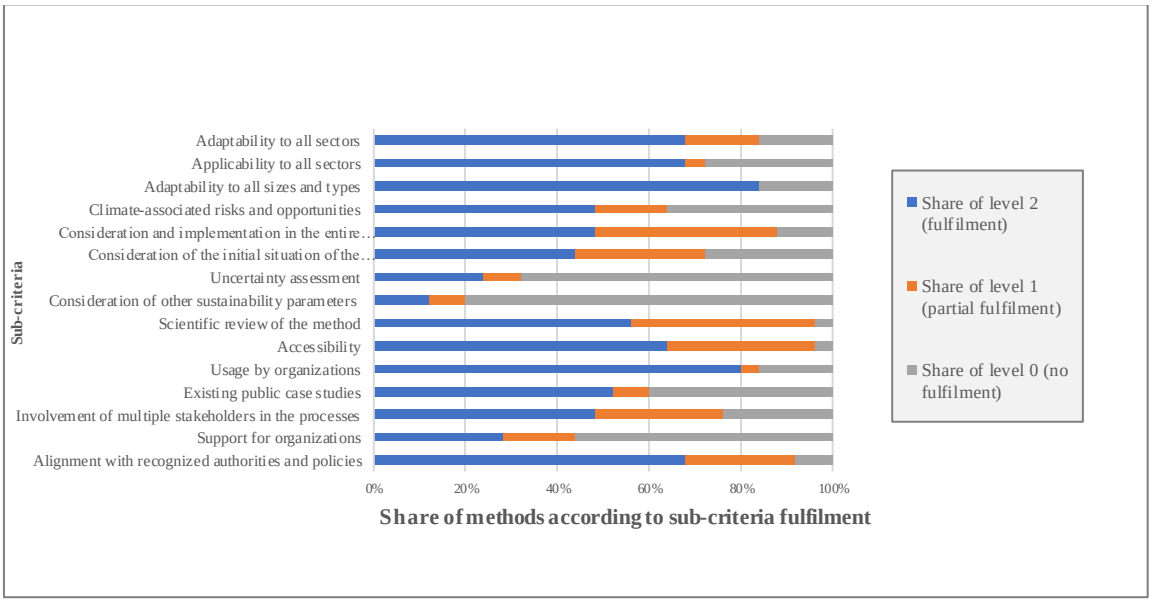

Figure A.6: *Performance in fulfilling sub-criteria, for all OCCMS methods*

A.4.2. Detailed evaluation of the methods

This section presents the evaluation of the 25 retrieved methods based on the 15 developed sub-criteria. The following sub-sections are dedicated to all the methods. The color code reads as follows: a sub-criterion in red in the explanations column corresponds to a method that does not meet this sub-criterion. Orange indicates partial fulfilment of the sub-criterion. Green is used when the sub-criterion is met.

Evaluation of '2021 Climate plan voting guidelines' (ACCR, n.d.)

Category	Criteria	Explanations
Multi-level applicability		
	Adaptability to all sectors	Any sectoral adaptability
	Applicability to all sectors	No information
	Adaptability to all sizes and types	No information
Scope		
	Climate-associated risks and opportunities	No specific consideration
	Consideration of the initial organizational climate context	"Absolute emissions reduction targets on a clearly defined set of emissions including scope 1, 2 and 3, that represent at a minimum 95% of total emissions" Consideration of short-term targets, but not previous targets or trajectory. No consideration of the operational contexte
	Inclusion of all organisation activities	"Clearly defined set of emissions including scope 1, 2 and 3, that represent at a minimum 95% of total emissions (inclusive of scope 1, 2 and 3)" Executive remuneration incorporates performance linked to short-term and medium-term absolute emissions reduction targets
Scientific robustness		
	Uncertainty assessment	Any uncertainty of answers
	Consideration of other sustainability parameters	Only carbon indicators
	Scientific review of the method	No review found
Accessibility and adoption		
	Accessibility of the method	Informations on public case studies are available on their website, no information on rationale and hypothesis
	Usage by organizations	8 companies, on the last update

	Existing public case studies	Two public case studies, available on their website
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	No involvement of external partners
	Support for organizations	No specific support for companies from the methodology
	Alignment with recognized authorities and policies	"The company demonstrates that the trajectory of its short-term and medium-term targets is aligned with the Paris Agreement goal of limiting global temperature increase to 1.5°C with low or no overshoot". Australasian Centre for Corporate Responsibility is behind the tool development

Evaluation of 'ACT-A methodology, version 1.1' (ACT Initiative, n.d.-a)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	Specific ACT methodologies exist, to be adaptable, and a generic version is available for organisations not represented by sectoral methodologies
	Applicability to all sectors	All organisations can use the generic version "The present ACT Generic methodology refers to all sectors not covered by other ACT methodologies (existing or future)"
	Adaptability to all sizes and types	All organisations can use the generic version
Scope		
	Climate-associated risks and opportunities	On module 5.3, the transition plan should consider transition risks (physical, financial, social)
	Consideration of the initial organizational climate context	By taking into account suppliers and clients engagement, sectoral pathways and comparisons with different actors in the same sectors, we can consider that ACT-A considers the operational context
	Inclusion of all organisation activities	Only assess the strategy, but doesn't develop a new one. "a low-carbon transition will lead to a transformation of the company's activities and assets as well as the entire value chain, from upstream activities to downstream activities. By taking into account suppliers and clients engagement, sectoral pathways and comparisons with different actors in the same sectors, we can consider that ACT-A considers the operational context
Scientific robustness		
	Uncertainty assessment	Never take into account uncertainty in calculations
	Consideration of other sustainability parameters	Other environmental indicators than just carbon performance, but not based on planet boundaries or impact categories
	Scientific review of the method	Mentions in research paper, scientific committee (within co-founders) but no academic peer-review

Accessibility and adoption		
	Accessibility of the method	An assessment summary is available on ACT website
	Usage by organizations	More than 10 on the ACT initiative website
	Existing public case studies	More than 5 on the ACT initiative website
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Client and partners engagement involve external partners
	Support for organizations	Database of trained external expert on ACT initiative website
	Alignment with recognized authorities and policies	Linked to Paris Agreement targets. Technical assistance from recognized organisations, and founding by CDP and ADEME which are recognised authority

Evaluation of 'ACT-S methodology' (ACT Initiative, n.d.-b)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	"The application of the methodology will […] adapt according to the sector"
	Applicability to all sectors	"ACT-S provides a unique cross-sectoral methodology for all companies, irrespective of their sector of activity and size."
	Adaptability to all sizes and types	**"**ACT-S provides a unique cross-sectoral methodology for all companies, irrespective of their sector of activity and size."
Scope		
	Climate-associated risks and opportunities	Methodology defined itself as "identifying changes that will impact the Company in the context of the transition, in terms of regulation, markets, resources and performance standards, and then taking these changes into account in the design of the strategy." Which is a consideration of transition risks.
	Consideration of the initial organizational climate context	"The results of the Company's carbon performance and strategic analyses carried out through actions 2A to 2C should also feed the training module with contextual/specific information". Step 2C "strategic analysis" is based on current strategy.
	Inclusion of all organisation activities	Actors involved in the step 5b implementation are "all employees + stakeholders", we can then consider that it takes into account the entire organisation
Scientific robustness		
	Uncertainty assessment	ACT-S never take into account uncertainty

	Consideration of other sustainability parameters	Other environmental indicators than carbon performance are not mentioned in ACT-S methodology, nor potential burden shifting between impact categories "The specificity of a climate action plan is that some relevant monitoring indicators will be related to carbon performance, the degree of Stakeholder engagement on climate issues or transformative aspects related to decarbonization (management, business models, research & development, etc.)"
	Scientific review of the method	Mentions in research paper, scientific committee (within co-founders) but no academic peer-review
Accessibility and adoption		
	Accessibility of the method	There is not any existing case study and tools associated with the method are not publicly available
	Usage by organizations	More than 10
	Existing public case studies	Zero existing case study
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	All stakeholders are, in every step, encourage to participate and to help the Company in its trajectory definition
	Support for organizations	"The Company may also decide to benefit from the support of a specialized consultant, who will be the Company's advisor throughout the ACT-S project", and a database is existing on the ACT initiative website
	Alignment with recognized authorities and policies	**"**The Company's ambition is to be an active contributor to the low-carbon transition. This includes contributing to climate change mitigation at a level that is in line with the objectives of the 2015 Paris Agreement, or with the future global political agreement(s) that may replace the Paris Agreement in the coming years." Technical assistance from recognized organisations, and founding by CDP and ADEME which are recognised authority

Evaluation of 'Bilan Carbone v8' (ABC (Association Bilan Carbone), 2017)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	No specific factors or differences in concordance with the organisation sector, but some guidelines exist to provide sectoral recommandations
	Applicability to all sectors	Methodology applicable to absolutely every organisation, with no exclusion
	Adaptability to all sizes and types	Any limitation of size for organisations that use Bilan Carbone methodology " Organization: a company, corporation, firm, enterprise, authority, institution or any part or combination thereof, incorporated or otherwise constituted under private or public law, which has its own administrative and functional structure"
Scope		
	Climate-associated risks and opportunities	Methodology step 3.6.3 is « Transition risks and opportunities", with a developed model on how to calculate these risks

	Consideration of the initial organizational climate context	Step 2.3 is the operational scope of the study. During the mid-term feedback phase, a "reminder of ongoing actions within the organisation and the organisation's strategy towards the energy-climate transition (if any)" is made, **but the actions are based on the GHG emissions profile only**
	Inclusion of all organisation activities	Only general suggestions on how to implement actions into their strategy. During the choice of the study scope, "By default, the organisational scope "operational control" (emissions from operated installations are taken into account) should be used. Any other choice must be justified."
Scientific robustness		
	Uncertainty assessment	The methodology defines its calculations as "a "quantification by estimation" because there is an uncertainty associated with the activity data and the emission factors." Uncertainty of every data is specified.
	Consideration of other sustainability parameters	Every action or product is translated into a unique indicator, carbon footprint in kgCO2e
	Scientific review of the method	Mentions in research paper, scientific committee (within co-founders) and peer-review
Accessibility and adoption		
	Accessibility of the method	Results of each step are visible
	Usage by organizations	More than 2000 organisations
	Existing public case studies	More than 2000 public case studies existing, on Bilan GES platform
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Each stakeholder has the possibility to understand the methodology, but a minimum of knowledge and explanation is necessary to fully understand these data (especially carbon footprint knowledge)
	Support for organizations	Possibility, and an accessible database on ABC website
	Alignment with recognized authorities and policies	Current policy targets are based on GHG emissions accounting, as this tool. ADEME is recognized as an international expert institution on environmental and climate sciences

Evaluation of 'B-Impact Assessment v7' (B Lab, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	Available for every organisation
	Applicability to all sectors	They define the first step with the sentence: "Your company will receive questions that are tailored to your company's size, sector, and geography"
	Adaptability to all sizes and types	They define the first step with the sentence: "Your company will receive questions that are tailored to your company's size, sector, and geography"

Scope		
	Climate-associated risks and opportunities	Risks are not taken into account
	Consideration of the initial organizational climate context	The Assessment comprehensively covers the impact of a business on all of its stakeholders, including its workers, suppliers, community, and the environment. The Assessment also captures best practices regarding mission, measurement, and governance.
	Inclusion of all organisation activities	Yes, it touch every department as follows : "Marketing/Communications Director, Technology Dept, Quality Assurance, Designers, Board Members, etc » The last, heavily weighted, portion of the Assessment identifies the company's specific "Impact Business Models," which include the targeted, formal focus on a benefiting a particular stakeholder through products and services or internal practices.
Scientific robustness		
	Uncertainty assessment	Uncertainty of data is not taken into account at all
	Consideration of other sustainability parameters	Different categories (environment, waste, energy, water, etc.) with the assessment on what they do, their actions, and not an environmental indicator
	Scientific review of the method	Mentions in research paper, scientific committee (within co-founders) and peer-review
Accessibility and adoption		
	Accessibility of the method	Full reports available on the B-Lab website
	Usage by organizations	20 available case studies Case Studies | B Impact Assessment
	Existing public case studies	More than 15000 Source : Case Studies | B Impact Assessment
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Need for organisations to answer suppliers' questions, thus it's a possibility to involve them in the process, but these informations can be found without their help
	Support for organizations	Q&As section is existing, but external trained experts are not existing on the website
	Alignment with recognized authorities and policies	Doesn't consider current policy targets, because it doesn't give a GHG emission reduction target Supported by an external council, but not a recognised authority "The standards are created and revised by the Standards Advisory Council (SAC), a group of independent experts in business and academia."

Evaluation of ' CA100+ initiative and Net-Zero Company Benchmar v1.2: October 2022'
(Climate Action 100+, n.d.)

Category	Criteria	Explanations
Multi-level applicability		

	Adaptability to all sectors	"Provide enhanced corporate disclosure in line with the final recommendations of the Task Force on Climate related Financial Disclosures (TCFD) and sector-specific Global Investor Coalition on Climate Change (GIC) Investor Expectations on Climate Change guidelines"
	Applicability to all sectors	Companies already in the action are from different sectors, representing almost every sectors
	Adaptability to all sizes and types	Especially for the "world's largest corporate greenhouse gas emitters"
Scope		
	Climate-associated risks and opportunities	In the "Just transition" indicator
	Consideration of the initial organizational climate context	"If the company has set a scope 3 GHG emissions target, it covers the most relevant scope 3 emissions categories for the company's sector (for applicable sectors)" Consideration of short-term targets (2025) targets in the assessment« 8.1 : The company's board has clear oversight of climate change."
	Inclusion of all organisation activities	No requirement on the scope of applicability
Scientific robustness		
	Uncertainty assessment	No uncertainty of answers taken into account
	Consideration of other sustainability parameters	Only carbon indicators
	Scientific review of the method	Mention in research paper (analysis) + technical advisory group
Accessibility and adoption		
	Accessibility of the method	Indicators and answers are public
	Usage by organizations	More than 150 companies
	Existing public case studies	More than 150 public case studies
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	No involvement of external partners
	Support for organizations	The investor network is existing on the CA100+ website
	Alignment with recognized authorities and policies	"An important component of company commitments on climate change is the formation of comprehensive business strategies that fully align with the goals of the Paris Agreement". CA100+ initiative is supported by 5 recognised authorities (IIGCC, PRI, IGCC, CERES, AIGOCC)

Evaluation of 'Climate Bonds Standard Version 3.0' (Climate Bonds Initiative, n.d.)

Category	Criteria	Explanations
Multi-level applicability		
	Adaptability to all sectors	"Sector criterion for determining the low-carbon and climate resilient credentials of projects and assets"
	Applicability to all sectors	"Climate Bonds seeks to mobilise investors, industry and government"
	Adaptability to all sizes and types	"Climate Bonds seeks to mobilise investors, industry and government"
Scope		
	Climate-associated risks and opportunities	"related eligibility criteria, including, if applicable, exclusion criteria or any other process, applied to identify and manage potentially material environmental, social or governance risks associated with the Nominated Projects & Assets."
	Consideration of the initial organizational climate context	Market value is defined by the market, and thus the operational context". How the climate-related objectives of the Bond are positioned within the context of the Issuer's overarching objectives, strategy, policy and/or processes relating to environmental sustainability"
	Inclusion of all organisation activities	No specific recommendations on scope of implementation or consideration in the entire organization
Scientific robustness		
	Uncertainty assessment	Never considered
	Consideration of other sustainability parameters	Any obligation "Impact metrics and indicators can include but are not limited to: greenhouse gas emissions reduced/avoided, number of households provided with access to clean power, decrease in water use, reduction in number of cars required."
	Scientific review of the method	Mention in research paper (analysis) + technical advisory group
Accessibility and adoption		
	Accessibility of the method	Report are completely available on CBI website
	Usage by organizations	More than 100
	Existing public case studies	454 existing public cases
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	No involvement of external partners
	Support for organizations	Database of verifiers is available on CBI website

	Alignment with recognized authorities and policies	**"**A Scientific Framework underpins the definitions of which projects and assets are consistent with achieving the goals of the Paris Climate Agreement". Climate Bonds Initiative is founded by recognised authority (e.g. EIT Climate-KIC)

Evaluation of ' CDP Climate Change 2022 Questionnaire' (CDP, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	Adaptable to almost every sector, and a "all other sectors" category
	Applicability to all sectors	Applicable to all professional sectors
	Adaptability to all sizes and types	Adaptable to all company, not depending on their size
Scope		
	Climate-associated risks and opportunities	"(C2.1b) How does your organization define substantive financial or strategic impact on your business?"
	Consideration of the initial organizational climate context	Consideration, but optional and not score "(C-FI) Use this field to provide any additional information or context that you feel is relevant to your organization's response. Please note that this field is optional and is not scored." Part C3 is focused on business strategy
	Inclusion of all organisation activities	No new decarbonisation strategy developed. No information on the questionnaire scope
Scientific robustness		
	Uncertainty assessment	Uncertainty of answers is never considered
	Consideration of other sustainability parameters	Biodiversity, land management impacts, energy usage, and other climate-related metrics are used
	Scientific review of the method	Mention in research paper (analysis) + technical advisory group
Accessibility and adoption		
	Accessibility of the method	Guidance and questionnaires publicly available. For the answers of participating companies, there is only scores, and not all answers "Public responses from companies are available on the website. Scores are now available to companies on their corporate dashboards. Public scores are also available on the website."
	Usage by organizations	200 in 2021
	Existing public case studies	More than 10

Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Partners data and engagement are taken into account
	Support for organizations	No trained expert for the questionnaire
	Alignment with recognized authorities and policies	Aligned with European targets: "Accountability is needed to raise the bar to align with halving emissions, shifting towards nature positivity by 2030 and achieving net-zero emissions and full nature recovery by 2050." CDP is a recognised authority

Evaluation of 'Taking the Carbon Out of Credit: An integrated approach to removing climate emissions from lending, July 2020' (Climate Safe Lending Network, n.d.)

Category	Criteria	Explanations
Multi-level applicability		
	Adaptability to all sectors	A specific part of the CSLS Toolkit is "Creating sector decarbonization plans"
	Applicability to all sectors	Method specifically applicable to financial sector
	Adaptability to all sizes and types	"Every lending institution is different in terms of its geography, sector-focus, business model, and client base."
Scope		
	Climate-associated risks and opportunities	In the "Disclosing climate-related risks" part
	Consideration of the initial organizational climate context	Not specifically taking into account the operational context. "Learning & Strategy Adjustments" part, with a comparison of the current strategy and the goal
	Inclusion of all organisation activities	"Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks." "Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks."
Scientific robustness		
	Uncertainty assessment	"Financial institutions need to act on the basis of scientific understanding despite some levels of uncertainty attaching to data or methodologies.". Uncertainty are considered but not taken into account.
	Consideration of other sustainability parameters	Only carbon indicator as environmental indicators
	Scientific review of the method	Mention in research paper (analysis) + technical advisory group
Accessibility and adoption		
	Accessibility of the method	All the methodology is available on their website, but no case study nor business cases or participating companies
	Usage by organizations	No information

	Existing public case studies	No existing public case study
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Involvement of clients in the process
	Support for organizations	No specific support for companies
	Alignment with recognized authorities and policies	Climate Safe Lending Network is behind the tool development (no other stakeholder). No mention in official text.

Evaluation of 'GFANZ for Net Zero' (Glasgow Financial Alliance for Net Zero, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	« Sectoral pathways » part is existing
	Applicability to all sectors	Framework specialized for financial sector ("bank, insurer, investment consultant, or other financial services provider")
	Adaptability to all sizes and types	Organizations in the GFANZ group have different sizes
Scope		
	Climate-associated risks and opportunities	Risk management disclosure is encouraged
	Consideration of the initial organizational climate context	No consideration of the operational context of the organisation in the sector. No consideration of the current strategy of the organisation
	Inclusion of all organisation activities	"The guidelines cover all emission scopes"
Scientific robustness		
	Uncertainty assessment	Use corridor to define uncertainty of pathways "A helpful conception of the credible range of values between different pathways is as a corridor"
	Consideration of other sustainability parameters	" Some pathways define net zero as net zero for CO_2, whereas others consider net zero to mean net zero for all greenhouse gases" Only carbon indicator
	Scientific review of the method	Mention in research paper (analysis) + technical advisory group
Accessibility and adoption		

	Accessibility of the method	All informations are available for each public case study
	Usage by organizations	More than 450 members
	Existing public case studies	17 case studies are available on their website
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Noticed in best practices, but that's all "Describe current and future engagement with customers, clients, and suppliers"
	Support for organizations	No specific support
	Alignment with recognized authorities and policies	GFANZ aims "to achieve the goals of the 2015 Paris Agreement" UN's Race to Zero and the COP26 Presidency are behind the tool, and can be considered as recognised authority

Evaluation of 'GHG Protocol revised version' (GHG Protocol, 2004)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	"Industry Sectors and Scopes" Annex gives recommendations for each sector
	Applicability to all sectors	This methodology is possible to use for all professional sectors "This standard is written primarily from the perspective of a business developing a GHG inventory"
	Adaptability to all sizes and types	This methodology is possible to use without any size necessity "This standard is written primarily from the perspective of a business developing a GHG inventory"
Scope		
	Climate-associated risks and opportunities	As a result, companies must be able to understand and manage their GHG risks if they are to ensure long-term success in a competitive business environment, and to be prepared for future national or regional climate policies. A well-designed and maintained corporate GHG inventory can serve several business goals, including: • Managing GHG risks and identifying reduction opportunities • Public reporting and participation in voluntary GHG programs • Participating in mandatory reporting programs • Participating in GHG markets • Recognition for early voluntary action.
	Consideration of the initial organizational climate context	Type of business and geography boundaries are taken into account on the GHG target step, not more (competitors, etc.) "It is important to recognize that the inherent diversity of businesses and the circumstances of individual companies can result in misleading indicators. Apparently minor differences in process, product, or location can be significant

		in terms of environmental effect. Therefore, it is necessary to know the business context in order to be able to design and interpret ratio indicators correctly."
	Inclusion of all organisation activities	As for consideration of the entire organization criteria, boundaries must be the more precise possible, and then taking into account the entire organisation Organisational and operational boundaries must be the more precise possible "For effective and innovative GHG management, setting operational boundaries that are comprehensive with respect to direct and indirect emissions will help a company better manage the full spectrum of GHG risks and opportunities that exist along its value chain."
Scientific robustness		
	Uncertainty assessment	"Uncertainty in data inputs and calculation methodologies used to quantify GHG emissions."
	Consideration of other sustainability parameters	Only a carbon indicator of GHG emissions
	Scientific review of the method	Mention in research paper (analysis) + technical advisory group
Accessibility and adoption		
	Accessibility of the method	Methodology and calculation tools are available on the GHG Protocol website Recommendations from the GHG Protocol are "Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used."
	Usage by organizations	More than 10 examples
	Existing public case studies	No existing case study on the GHG Protocol website but many business cases available online
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	External partners help is possible, but not encouraged, especially on gathering precise data and minimizing data uncertainty
	Support for organizations	Possibility to be helped by trained external expert, but no database on the GHG Protocol website
	Alignment with recognized authorities and policies	Not especially based on current policy targets but often mentioned as a reference for GHG emissions inventory. WRI and WBCSD developed the project, and are recognised authority

Evaluation of 'Methodology : GRI 305 Emissions' (GRI, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	No sectoral adaptability

	Applicability to all sectors	Applicable to all organisations
	Adaptability to all sizes and types	Applicable to all organisations
Scope		
	Climate-associated risks and opportunities	On the 305-3 guidance, climate change related risks are recommended to be taken into account, but any obligation
	Consideration of the initial organizational climate context	Not taken into account
	Inclusion of all organisation activities	Nospecific recommendation about the organisational scope
Scientific robustness		
	Uncertainty assessment	No uncertainty in the methodology
	Consideration of other sustainability parameters	2 planetary boundaries taken into account (climate change and stratospheric ozone depletion) in the reporting
	Scientific review of the method	Mention in research paper (analysis) + technical advisory group
Accessibility and adoption		
	Accessibility of the method	Accessibility for everyone to standards. Existing case studies and guidelines
	Usage by organizations	More than 10
	Existing public case studies	No existing public case study on the website
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	In the scope 3 GHG emissions accounting
	Support for organizations	No support for companies
	Alignment with recognized authorities and policies	No link with current policy targets. Global Sustainability Standards Board is behind the tool development, and is a recognised authority

Evaluation of 'ICAPs Expectation Ladder, May 2021 version' (Investor Climate Action Plans, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		

	Adaptability to all sectors	Kind of, in Bilateral engagement Tier 1 "Ensure that most of the companies in the portfolio meet 1.5ºC-aligned (external) sectorspecific benchmarks, taxonomies, or thresholds" but not much more
	Applicability to all sectors	"The Expectations Ladder is inclusive and meant for all investors wherever they are on their climate change journey."
	Adaptability to all sizes and types	"The Expectations Ladder is inclusive and meant for all investors wherever they are on their climate change journey."
Scope		
	Climate-associated risks and opportunities	Taken into account in the risk management part
	Consideration of the initial organizational climate context	No consideration of the operational context, but somehow of the current strategy as the goal of the methodology is "Assessing their current approach to managing climate change risk and opportunity"
	Inclusion of all organisation activities	No obligation
Scientific robustness		
	Uncertainty assessment	Uncertainty of answers is not considered
	Consideration of other sustainability parameters	Only GHG emissions as environmental indicators
	Scientific review of the method	Mention in research paper but no analysis or peer-review available
Accessibility and adoption		
	Accessibility of the method	Guidances and expectation ladder are available on the IPAC website
	Usage by organizations	More than 10
	Existing public case studies	10 case studies
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	No specific involvement
	Support for organizations	No specific support from IPAC
	Alignment with recognized authorities and policies	Mention alignment with Paris Agreement; UNEP and CDP are behind the tool development

Methodology : Green Bonds Principle 2021 (ICMA, n.d.)

Category	Criteria	Explanations
Multi-level applicability		
	Adaptability to all sectors	Adaptability to different sectors (Buildings, energy, transport, agriculture)
	Applicability to all sectors	Applicable specifically to financial sector
	Adaptability to all sizes and types	Not adaptable to companies, but to bonds or projects
Scope		
	Climate-associated risks and opportunities	"Complementary information on processes by which the issuer identifies and manages perceived social and environmental risks associated with the relevant project(s)."
	Consideration of the initial organizational climate context	No specific consideration of operational context or the current strategy
	Inclusion of all organisation activities	Scope of bonds is not taken into account
Scientific robustness		
	Uncertainty assessment	Uncertainty is never considered
	Consideration of other sustainability parameters	Multiple environmental indicators, but with a specific focus on climate change
	Scientific review of the method	Mention in research paper but no analysis or peer-review available
Accessibility and adoption		
	Accessibility of the method	All documents are accessible on their website
	Usage by organizations	No specific information
	Existing public case studies	No existing public case study
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Direct involvement of issuers in the process
	Support for organizations	Only a helpdesk for questions and issues
	Alignment with recognized authorities and policies	Aligned with Paris Agreement ICMA is behind the tool development

Evaluation of 'ISO 14064-1:2018' (ISO, n.d.)

Category	Criteria	Explanations
Multi-level applicability		
	Adaptability to all sectors	Annex B provides specific/sectoral guidance on GHG emission quantification
	Applicability to all sectors	"The concept of organization includes, but is not limited to, sole-trader, company, corporation, firm, enterprise, authority, partnership, association, charity or institution, or part or combination thereof, whether incorporated or not, public or private."
	Adaptability to all sizes and types	"The concept of organization includes, but is not limited to, sole-trader, company, corporation, firm, enterprise, authority, partnership, association, charity or institution, or part or combination thereof, whether incorporated or not, public or private."
Scope		
	Climate-associated risks and opportunities	Transition risks are taken into account in the evaluation of emissions significance, but guidances are in ISO 13065
	Consideration of the initial organizational climate context	In the targets guidances, the international, national and sectorial contexts are considered, but not the specific context of the organisation. In the part 9.2 Planning the GHG report, a documentation on the organization's GHG strategies is needed, but it's not taken into account in the target guidances
	Inclusion of all organisation activities	"The organization accounts for all GHG emissions and/or removals from facilities over which it has financial or operational control."
Scientific robustness		
	Uncertainty assessment	Part "8.3 Assessing uncertainty" is focused on that goal
	Consideration of other sustainability parameters	Only GHG emissions indicators
	Scientific review of the method	Mention in research paper and technical advisory
Accessibility and adoption		
	Accessibility of the method	ISO documents are not available publicly but some synthetic documentation exist
	Usage by organizations	More than 10
	Existing public case studies	No existing public case study on ISO website
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Involvement needed for the indirect GHG emissions quantification
	Support for organizations	No specific support for companies
	Alignment with recognized authorities and policies	ISO is a recognised authority

Evaluation of 'Net Zero Initiative, version intiale 2020-2021' (Carbone 4, n.d.)

Category	Criteria	Explanations
Multi-level applicability		
	Adaptability to all sectors	Sectoral adaptability not already developed, but it's the major workstream for 2022 "NZI would like to carry out methodological developments specific to each economic sector in order to be able to formulate more precise and operational recommendations for the actors of a sector that can contribute to the reduction of emissions in other sectors"
	Applicability to all sectors	NZI referential is applicable to every organisation "The main objective of the Net Zero Initiative is to provide to organisations a vision of things that will enable them to optimise their climate action, thanks to a coherent and harmonious climate action instrument"
	Adaptability to all sizes and types	NZI referential is applicable to every organisation "The main objective of the Net Zero Initiative is to provide to organisations a vision of things that will enable them to optimise their climate action, thanks to a coherent and harmonious climate action instrument"
Scope		
	Climate-associated risks and opportunities	This framework addresses the notion of different transition risks, but without ever providing methodological keys to address these issues
	Consideration of the initial organizational climate context	It is taken into consideration in different pillars.
	Inclusion of all organisation activities	Value chain, and even outside the value chain, is taken into account in the three pillars
Scientific robustness		
	Uncertainty assessment	This depends on the methodologies to which NZI refers
	Consideration of other sustainability parameters	Only carbon indicators
	Scientific review of the method	No mention in research papers, but scientific advisory
Accessibility and adoption		
	Accessibility of the method	Accessibility, via its own website, of the entire report
	Usage by organizations	More than 10
	Existing public case studies	None
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	External partners help is possible, but it depends on the methodology chosen in the NZI framework (it's not always encouraged)

	Support for organizations	Trained external expert for NZI doesn't exist, even if trained external expert exist for the different methodologies included in the framework (ACT, BC, etc.)
	Alignment with recognized authorities and policies	NZI use methodologies that are relevant with current policy targets. NZI is supported by ADEME and French minister of ecological transition, and co-created with numerous recognized international institution such as UNFCCC, WRI or NewClimate Institute

Evaluation of 'Oxford Martin Principles for Climate-Conscious Investment' (Oxford Martin School, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	No sectoral adaptability
	Applicability to all sectors	Targeting financial actors
	Adaptability to all sizes and types	No information
Scope		
	Climate-associated risks and opportunities	Any consideration of transition risk are taken into account
	Consideration of the initial organizational climate context	Principles depends on current market and available ecological products and services. Principles depends on current strategy of organisations
	Inclusion of all organisation activities	Reputational impact is not taken into account
Scientific robustness		
	Uncertainty assessment	Uncertainty is never taken into account
	Consideration of other sustainability parameters	Only indicators linked to global warming
	Scientific review of the method	Is research oriented, and base on a publication in Nature Climate Change
Accessibility and adoption		
	Accessibility of the method	Accessibility to the paper available on the OMPCCi website
	Usage by organizations	No information
	Existing public case studies	No existing public case study
Stakeholders' involvement		

	Involvement of multiple stakeholders in the processes	"If a company has a plan for a progressive transition to net-zero emissions, investors should be able to monitor their progress to ensure it is consistent with minimising risks to future climate and risks to future asset owners, consumers and taxpayers."
	Support for organizations	No specific support on their website
	Alignment with recognized authorities and policies	Mention alignment with the Paris Agreement, University of Oxford behind the method development, recognized authority

Evaluation of 'Implementation guide, Net Zero Investment Framework 1.5 °C' (IIGCC, 2021)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	Sectoral pathways are available
	Applicability to all sectors	Especially for investors
	Adaptability to all sizes and types	Available for all financial organizations, no matter their size
Scope		
	Climate-associated risks and opportunities	"The company provides disclosures on risks associated with the transition"
	Consideration of the initial organizational climate context	Part "Asset alignment and climate solutions assessment criteria" consider the operational context. Current strategy is taken into account in part 7 "Current alignment of building carbon emissions and energy use in line with regional/building type net zero pathway"
	Inclusion of all organisation activities	No specific requirement on that implementation. "The board or investment committee commits to the goal of achieving net zero portfolio emissions by 2050, or sooner"
Scientific robustness		
	Uncertainty assessment	Uncertainty is never considered
	Consideration of other sustainability parameters	Only GHG emissions indicators
	Scientific review of the method	Mention in research papers, but no peer-review of the framework
Accessibility and adoption		
	Accessibility of the method	Methodology is accessible on their website
	Usage by organizations	More than 780 stakeholders
	Existing public case studies	No existing public case studies

Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	"Definitions, methodologies and strategies should allow clients, beneficiaries and other stakeholders to assess whether investors and assets are aligned with the goals of the Paris Agreement."
	Support for organizations	No specific support
	Alignment with recognized authorities and policies	IIGCC created the project

Evaluation of 'QuantiGES v3' (ADEME, 2022)

Category	Criteria	Explanations
Multi-level applicability		
	Adaptability to all sectors	In step 1, you can "Indicate the main sector of activity concerned by the action", but this remains optional
	Applicability to all sectors	"This method is intended for all organisations, whether or not they are affected by the regulations, that are implementing GHG emission reduction actions and wish to quantify their GHG impact."
	Adaptability to all sizes and types	"This method is intended for all organisations, whether or not they are affected by the regulations, that are implementing GHG emission reduction actions and wish to quantify their GHG impact."
Scope		
	Climate-associated risks and opportunities	Transition risks are not taken into account
	Consideration of the initial organizational climate context	The company operational context is taken into consideration to define the actions or the reference scenario. No consideration of current strategy
	Inclusion of all organisation activities	A reliability grade is given in function of the chosen scope, but it's not an obligation. Not specifically, it depends on the action and is therefore not an obligation
Scientific robustness		
	Uncertainty assessment	Uncertainty is considered in the reliability grade
	Consideration of other sustainability parameters	Only GHG emissions indicators
	Scientific review of the method	No mention in research papers, technical advisory
Accessibility and adoption		
	Accessibility of the method	Methodology is publicly available on the internet Available example sheets with every step detailed
	Usage by organizations	More than 35

	Existing public case studies	More than 10 example sheets
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	"The project leader may have to mobilise internal (human resources, logistics, purchasing, etc.) and external logistics, purchasing, etc.) and external (suppliers, transporters, customers etc.) to the organisation, in addition to the owner of this quantification project. In this case, it is a matter of identifying these people, these people must be identified at this stage."
	Support for organizations	No support given by ADEME but a training
	Alignment with recognized authorities and policies	ADEME is behind the tool development, and is considered as a recognised authority

Evaluation of 'SBTi Net-Zero Standard Corporate Manual, version 1.1' (Science Based Targets Initiative (SBTi), n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	"Some sectors have specific guidances"
	Applicability to all sectors	Applicable to all organizations
	Adaptability to all sizes and types	Applicable to all organizations
Scope		
	Climate-associated risks and opportunities	No transition risks consideration
	Consideration of the initial organizational climate context	Consideration of sector and subsidiaries, but no other indicators. **"**Ensure the target boundary is aligned with the GHG Inventory boundary"
	Inclusion of all organisation activities	"Long-term SBTs must cover at least 95% of company-wide scope 1 and 2 emissions and 95% of scope 3 emissions." Companies must develop a complete scope 3 inventory"
Scientific robustness		
	Uncertainty assessment	Uncertainty never taken into account
	Consideration of other sustainability parameters	Only a single indicator
	Scientific review of the method	Mention in research papers, technical advisory group, public consultations
Accessibility and adoption		
	Accessibility of the method	Accessibility of methodology on SBTi website. Companies taking action share their targets but not their hypothesis and rationale.

	Usage by organizations	More than 2000 companies
	Existing public case studies	More than 2000 existing public case studies
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	"Companies must set one or more emission reduction targets and/or supplier or customer engagement targets that collectively cover(s) at least two-thirds (67%) of total scope 3 emissions considering the minimum boundary of each category in conformance with the GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard."
	Support for organizations	Help to validate and certificate the output, and documentations available
	Alignment with recognized authorities and policies	CDP, UNGC, WRI and WWF are recognised authorities behind the tool

Evaluation of 'SBTi short-term (5 to 10 years), SBTi Corporate Manual' (SBTi, 2019c)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	Main objective of the approach, to be sectoral adaptable
	Applicability to all sectors	All professional sector, with a "non-included sectors" category
	Adaptability to all sizes and types	Available for all organisations, independent of their size
Scope		
	Climate-associated risks and opportunities	Never take into account transition risks
	Consideration of the initial organizational climate context	Take into account activity level. Take into account predicted level in 2030 and 2050
	Inclusion of all organisation activities	Scope 3 is mandatory
Scientific robustness		
	Uncertainty assessment	"This inherent uncertainty and the evolution of scientific knowledge in the climate fi eld requires a periodic revision of the method as well as regular updates in the emissions reduction targets by companies to reflect realistic forecasts." Take into account uncertainty in methodology revision
	Consideration of other sustainability parameters	Only carbon indicators
	Scientific review of the method	Mention in research papers, technical advisory group, public consultations
Accessibility and adoption		

	Accessibility of the method	Accessibility of methodology on SBTi website. Companies taking action share their targets but not their hypothesis and rationale.
	Usage by organizations	More than 10
	Existing public case studies	More than 2000 existing public case studies
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Companies must set one or more emission reduction targets and/or supplier or customer engagement targets that collectively cover(s) at least two-thirds (67%) of total scope 3 emissions considering the minimum boundary of each category in conformance with the GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard."
	Support for organizations	Help to validate and certificate the output, and documentations available
	Alignment with recognized authorities and policies	CDP, UNGC, WRI and WWF are recognised authorities behind the tool

Evaluation of 'SM-GES v2, 05/01/2015' (Association Bilan Carbone (ABC), n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	No sectoral adaptability
	Applicability to all sectors	"Applicable to all organisms"
	Adaptability to all sizes and types	"Applicable to all organisms"
Scope		
	Climate-associated risks and opportunities	Never take into account transition risk
	Consideration of the initial organizational climate context	Not specifically. Not the first year, focused on the GHG emission accounting, but necessary then, each 3 years and even each year optionally
	Inclusion of all organisation activities	"This policy should be communicated to all internal stakeholders" "Management at the highest level must appoint one or more representatives from within its ranks to ensure the proper functioning of the SM-GES" Same as BC, the entire organization must be taken, and a justification must be given if it's not the case
Scientific robustness		
	Uncertainty assessment	Uncertainty never taken into account
	Consideration of other sustainability parameters	Just carbon footprint as environmental indicator
	Scientific review of the method	No mention in research papers, technical advisory
Accessibility and adoption		

	Accessibility of the method	Methodology documentation not accessible publicly but is available upon connexion
	Usage by organizations	No information about that indicator
	Existing public case studies	No existing public case study
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	Necessity to communicate with them about results, targets, initial GHG emission accounting, and action plan
	Support for organizations	No external trained experts available
	Alignment with recognized authorities and policies	ABC is a french recognised authority, and ADEME is supporting the project

Evaluation of ' Say On Climate - Guide for companies' (Say on climate, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	"Minimum emission reductions by sector" slide in the plan presentation
	Applicability to all sectors	Applicable to every company
	Adaptability to all sizes and types	Applicable to every company
Scope		
	Climate-associated risks and opportunities	No consideration
	Consideration of the initial organizational climate context	"Annual emission reduction rates were estimated using Compound Annual Growth Rate (CAGR) calculations. This provided an estimation of the average annualised percentage reduction required for emissions to decrease as required from the baseline year to 2030. "No consideration of the current strategy
	Inclusion of all organisation activities	**"**Scope 1, 2 and 3 emissions coverage is essential for disclosure, targets and plan"
Scientific robustness		
	Uncertainty assessment	Not taken into account
	Consideration of other sustainability parameters	Only carbon indcators for environmental assessment
	Scientific review of the method	Mentions in research papers, but no technical committee with external scientific presented on the website

Accessibility and adoption		
	Accessibility of the method	All the guidelines are available publicly. All climate action plans are available on the SOC website
	Usage by organizations	23 companies
	Existing public case studies	23 public case studies
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	No specific involvement of partners needed
	Support for organizations	No specific support given for companies
	Alignment with recognized authorities and policies	CDP is supporting this initiative. No specific mention in official text.

Evaluation of 'TCFD recommendations' (TCFD, 2015)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	A supplemental guidance is available for financial and non-financial groups, covering approximatively every professional sector
	Applicability to all sectors	On of the key features of recommendation is "Adoptable by all organizations"
	Adaptability to all sizes and types	On of the key features of recommendation is "Adoptable by all organizations"
Scope		
	Climate-associated risks and opportunities	In its Climate-related risk part, take into account transition risks in 4 sections: Policy and legal, technology, market and reputation
	Consideration of the initial organizational climate context	In its opportunity assessment, TCFD recommendations take into account how the market is currently and in the future. Recommendation of strategy is defined as "Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy and financial planning where such information is material."
	Inclusion of all organisation activities	We can consider that the entire organisation is taken into account, because to be considered as effective, a disclosure should be complete and should represent relevant information, but it's not enough precise as a recommendation
Scientific robustness		
	Uncertainty assessment	Uncertainty is cited, but never quantified numerically
	Consideration of other sustainability parameters	At least one (Recommendation b of Metrics & Targets), maybe more (Recommendation c of Metrics & Targets) but it depends on metrics chosen by the organisation, it can be just GHG emissions

	Scientific review of the method	Mentions in research papers, and technical committee with external scientific experts
Accessibility and adoption		
	Accessibility of the method	Methodology and updates are publicly available on the TCD website. A key features of these recommendation is "Disclosure under the strategy and metrics and targets recommendations in financial filings is subject to a materiality assessment, although all organizations are encouraged to disclose publicly if practicable"
	Usage by organizations	More than 2600 globally
	Existing public case studies	No specific case study available
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	TFCD recommendations are created for external partners to have a general view of climate impact of the organisations, thus they are not involved in the process
	Support for organizations	No external trainers
	Alignment with recognized authorities and policies	With 2021 updates, the TFCD recommendations are aligned with a 2-degres scenario, and is often taken as a reference. TCFD is supported and founded by recognised authority or person, and is considered as a recognised authority

Evaluation of 'TPI Sectoral Decarbonisation Pathways ; TPI's methodology report: Management Quality and Carbon Performance version 4.0' (Transition Pathway Initiative, n.d.)

Category	**Criteria**	**Explanations**
Multi-level applicability		
	Adaptability to all sectors	Sectoral decarbonisation pathways exist
	Applicability to all sectors	Especially for investors and investor networks
	Adaptability to all sizes and types	Adaptable to every company size
Scope		
	Climate-associated risks and opportunities	Question 2, 11 and 16 of Management Quality Assessment
	Consideration of the initial organizational climate context	Sector is taken into account when pathway is calculated. "Indicators should link to, or build on, existing initiatives and disclosure frameworks as far as possible"
	Inclusion of all organisation activities	"TPI benchmarks cover the majority of lifecycle emissions in each sector" Indicators should be pitched at a high level of aggregation and apply to the corporation as a whole"
Scientific robustness		
	Uncertainty assessment	Never considered

	Consideration of other sustainability parameters	Only GHG emissions indicators (or management indictors but without any consideration of planetary boundaries)
	Scientific review of the method	Mentions in research papers, but no technical committee with external scientific presented on the website
Accessibility and adoption		
	Accessibility of the method	Methodology accessible publicly on the TPI website
	Usage by organizations	More than 450
	Existing public case studies	No existing public case studies
Stakeholders' involvement		
	Involvement of multiple stakeholders in the processes	No involvement necessary from external partners
	Support for organizations	No specific support from TPI
	Alignment with recognized authorities and policies	LSE and FTSE Russel are behind the tool development, no mention in official texts

A.5. Supplementary material for chapter 4

A.5.1. Supplementary information on ACT-S methodology

A.5.1.1. In-depth presentation of ACT initiative and the ACT-S methodology

The Assessing low-Carbon Transition initiative (ACT) is a joint voluntary initiative of the UNFCCC secretariat Global Climate Agenda, developed from 2016 by the French Agency for Ecological Transition (ADEME) and CDP with the objective of fostering climate action by organizations around the world.

The objective of ACT is to provide guidance and support for organizations to assess, prepare, structure and implement their climate change mitigation strategies (ADEME & CDP, 2022). It provides a cross-sectoral methodology for all organizations, irrespective of their sector of activity, size or position in the value chain. The principles of the methodology are clear-sightedness (informed analysis of the current situation), ambition (in line with the objectives of the Paris Agreement), feasibility (compatible with current resources, practices and mission), consistency (with other aspects of the organization's strategy), profitability (contribution to the organization's overall profitability).

The methodology framework was designed using: i) the continuous improvement approach adapted to the context of the strategic cycle (Deming wheel, Plan-Do-Check-Action (PDCA)) (Deming, 1994), ii) the classification of the TCFD recommendations, iii) existing best practice in the development of standards namely the work done by the Global Initiative for Sustainability Ratings (GISR), ISEAL alliance credibility principles, ISO development principles, ISO 14080 of the ISO 14080 Standard - Guidance with framework and principles for methodologies on climate actions.

Practical resources and full methodologies are available on the website of ACT initiative (ADEME & CDP, 2022) and the full initial version of the ACT-S methodology as well (Marcus et al., 2021).

A.5.1.2. Further details on ACT-S steps

Table A.8: *description of ACT-S 5-step process with associated actions and strategic levels*

Step	Suggested duration	Action	Strategic level	Action description
1. Current situation	1 week to a month	1A. Company profile	Strategy	Identify the applicable ACT-S criteria
		1B. Maturity of decarbonization strategy	Strategy	Initial diagnosis
2. Issues and challenges	1 to 3 months	2A. Carbon performance metrics	Metrics and targets	Identify the applicable carbon performance metrics and associated benchmark pathways
		2B. Carbon performance assessment	Metrics and targets	Assess the Company's carbon performance and position with respect to existing targets
		2C. Strategic analysis	Strategy	Analysis of the Company's strengths, weaknesses, opportunities and threats in the context of the low-carbon transition
		2D. Board training	Governance	Train the Company's decision-making individuals on climate-related stakes in relation to the Company's strategy
3. Vision	2 weeks to 1.5 months	3A. Long-term vision	Strategy	Develop a vision of the Company in a low-carbon world
		3B. Transition roadmap	Strategy	Roadmap by steps from today to the low-carbon vision
		3C. Board engagement	Governance	Formal endorsement of the vision and roadmap
4. New strategy	1 to 3 months	4A. Carbon performance targets	Metrics and targets	Setting of new carbon performance targets
		4B. Strategic plan	Strategy	Design of the new strategic plan
		4C. Board commitment	Governance	Formal commitment to the targets and strategic plan
5. Action plan	4 months to 1 year until action plan launch	5A. Definition	LCT management	Identification of potential concrete actions that will allow implementation of the strategic plan and selection of the most relevant set of actions for implementation
		5B. Implementation	LCT management	Implementation of selected actions
		5C. Monitoring	LCT management	Monitoring and steering of action plan implementation

The step of current situation aims at describing the initial maturity of the OCCMS, to identify strength and priorities. First, relevant criteria and questions are identified based on the sector of activity and the GHG emission profile of the organization, to give relative importance to certain aspect of the initial assessment. Then a diagnosis is conducted with a set of 60 guiding questions, organized in three types: i) performance questions related to performance and indicators, ii) process questions addressing actions which should be carried out throughout the climate change mitigation strategy definition and iii) narrative questions, to describe the aspects that address the transformation of the organization. For each question, the answer is classified

on a 5-level maturity scale (Basic, Standard, Advanced, Next practice, Low-carbon aligned), to understand where an organization stands compared to the maturity level that is necessary for the low-carbon transition. The diagnosis explores all nine ACT modules, which cover core business performance, business models, value chain and policy engagement, and carbon performance.

The goal of step 2, issues and challenges is to inform the board of the organization on its maturity and on strategic and performance analysis, to improve its ability to assess and manage carbon performance. For that end, a climate-related risk and opportunity assessment is conducted to identify major climate-related challenges, through a Strength-Weakness-Opportunities-Threats (SWOT)-inspired analysis combined with the categorization of the Task Force on Climate-related Financial Disclosures (TCFD), covering regulatory, reputational, technological and market-related risks and opportunities. For each identified risks and opportunities, the likelihood and the magnitude of impact on the organization are assessed by the organization based on two semi-quantitative 5-ladder scales (see **Table A.9** for details). In addition, quantitative climate performance indicators are defined and compared with relevant benchmarks to evaluate the organization performance and compose a strategic climate-related dashboard to monitor progress.

Step 3, vision, is building a new narrative on the OCCMS and the role and place of the organization in a decarbonized world. It is based on the transformation of the organization's business model and activities, to capture what it would look like in a low-carbon economy. Once this destination is defined, intermediate milestones are defined. The board is involved in these actions and formally endorse the defined vision. There are no specific guidelines in this step, other than delivering the narrative. This is notably due to the specificity of each organization, governance and working culture.

In the step 4, new strategy, the organization commit to a detailed strategic plan including quantitative performance targets and strategic axis through the board. On one hand, quantitative climate change mitigation targets are defined, with intermediate targets, on different perimeters. The most common approach is to distinguish direct emissions targets (Scope 1 and Scope 2) and indirect emissions targets (Scope 3), to acknowledge differentiated responsibilities in mitigating emissions. The recommendation for this step is to align with the widely adopted methodology of the Science-Based Targets Initiative (SBTi). On the other hand, a qualitive strategic roadmap is also defined, potentially covering the nine ACT modules and aligning with the priorities identified in step 1 and 2 as well as with the orientation given in step 3. Several strategic pillars are defined, that will allow to categorize the actions and structure the OCCMS.

In the final step of action plan, the strategic plan of step 4 is converted into an operational action plan linked to previously defined pillars. All the actions that may contribute to the implementation of the strategic plan and ensure consistency with the climate mitigation trajectory, are identified by a transverse team. Then prioritization and selection is done to efficiently and effectively implement the strategy in operational terms. For each action, operational elements (e.g., description, monitoring indicators, resources, person in charge) and climate-related elements (e.g., GHG emission target, reduction type, intensity unit) are required for monitoring and reporting. Each selected action is then assessed through the Specific-Measurable-Achievable-Realistic-Time based (SMART) criteria, as well as through climate-related criteria (climate impact, acceptable, transformative, engaging).

A.5.1.3. Guiding questions

Table A.9: Guiding questions to be produced by the company in the current situation analysis step

Company profile description		Are the Scope 1+2 emissions of the company that are due to its building portfolio and/or its transport fleet significant?
		Do the transport services subcontracted by the company potentially represent a significant share of the company GHG freight-related emissions?
		Does the company operate some upstream carbon-intensive activities/sectors?
		What is the extent of climate challenges related to Scope 1+2 emissions ?
		Does the company operate in a sector in which the R&D levers are important for the transition ?
		What is the extent of climate challenges related to Scope 3 emissions ?
		What is the extent of climate challenges related to upstream emissions ?
		What is the extent of climate challenges related to downstream emissions ?
Initial situation analysis	**Progress question**	Have I carried out a GHG inventory?
		Have I identified the metrics that is/are relevant to assess my company carbon performance?
		Have I identified the benchmark pathway(s) that is/are relevant to assess my company carbon performance?
		Have I conducted a strategic analysis that considers the context of CC & LCT?
		Does my strategic process include carrying out a strategic analysis that systematically considers the context of CC & LCT?
		Has my Company developed a vision of the company in a low-carbon world?
		Was my Board involved into the design of the low-carbon strategy?
		Is my low-carbon strategy effectively integrated into my overall business strategy?
		Have I identified all potential actions which could contribute to my decarbonization strategy?
		Have I evaluated whether the action plan implementation should allow achieving my strategic goals?
	Targets	Do I have upstream emissions reduction targets that are aligned with my company's benchmark pathway?
		Do I have downstream emissions reduction targets that are aligned with my company's benchmark pathway?
		Are my existing carbon performance targets covering the long term as well as intermediate milestones?
		Am I on the way to achieve all past and current performance targets?
		Have I set upstream emissions reduction targets that are aligned with my company's benchmark pathway?
		Have I set downstream emissions reduction targets that are aligned with my company's benchmark pathway?
		Are my new carbon performance targets covering the long term as well as intermediate milestones?
	Material	What is the share of my CAPEX that is dedicated to low-carbon investments?
		Does my strategy include increasing the share of my CAPEX dedicared to low-carbon investments?
		Am I taking actions to increase the share of my CAPEX dedicated to low-carbon investments?
	Intangible	What is the share of my R&D investments that is dedicated to climate change mitigation technologies compared to the total R&D costs/investments?
		Does my strategy include increasing my R&D investments into climate change mitigation technologies?
		Am I taking actions to increase my R&D investments into climate change mitigation technologies?

		What is the share of patents in climate change mitigation technologies compared to the total patent activity?
		Does my strategy include increasing the share of my patenting activity dedicated to low-carbon and mitigation solutions?
		Am I taking actions to increase the share of my patenting activity dedicated to low-carbon and mitigation solutions?
	Sold product performance	Does my strategy include ecodesign of my products with the objective of improving their carbon performances?
		Am I carrying out interventions on my products to improve their carbon performances?
		Is the recent past trend of my products carbon performance aligned with the trend of my company's benchmark pathway?
		Does my strategy include ecodesign of my products with the objective of improving their carbon performances?
		Am I carrying out interventions on my products to improve their carbon performances?
		What is the share of low-carbon products in my product portfolio?
		Does my strategy include maximizing the share of low-carbon products in my products portfolio?
		Am I taking actions on my products portfolio to increase the share of low-carbon products?
	Management	What function/entity internally has highest oversight of climate change issues?
		Is the function/entity which internally has highest oversight of climate change issues fully aware of the climate change challenge and potential consequences on the business and operations?
		Does my company have a plan on how to transition the company to a model, strategy and activity compatible with a low-carbon economy?
		Are the managers of the company incentivized on carbon action and performance?
		Does my strategy include using climate change scenario testing to feed the analysis?
		Am I carrying out scenario testing in order to inform my strategy on climate-related risks and opportunities?
	Suppli	Does my strategy include engaging the suppliers to reduce their GHG emissions?
		Am I carrying out concrete actions to engage the suppliers to reduce their GHG emissions?
	Custo	Does my strategy include engaging the clients to reduce their GHG emissions?
		Am I carrying out concrete actions to engage the clients to reduce their GHG emissions?
	Public engagement	Does my strategy include having a policy on engagement with trade associations related to their climate activities or positions?
		Am I supporting any trade associations that have climate-negative activities or positions?
		Does my strategy include systematic positions on significant climate policies?
		Does my strategy include collaborating with local public authorities for the implementation of low-carbon solutions?
		Am I effectively collaborating with local public authorities for the implementation of low-carbon solutions?
	Business model	Does my strategy include progressing towards a fully decarbonized business ?
		Am I carrying out concrete actions to progress towards a fully decarbonized business ?
		Does my strategy include developing business models that contribute to the low-carbon economy?
		Am I effectively developing business models that contribute to the low-carbon economy?
		What is the share of my clients that may be considered low-carbon?
		Does my strategy include increasing the share of my clients that may be considered low-carbon?
		Am I taking actions to increase the share of my clients that may be considered low-carbon?

A.5.2. Supplementary method

A.5.2.1. Definitions of strategy and OCCMS

There is no consensual definition of the concept of strategy, with more than 250 definitions of 'strategy' that can be categorized in different approaches (planning, fit, emergent positioning, resource-based and stakeholders) (Simeone, 2020). A contemporary definition is proposed in Oxford University press, as being about "maintaining a balance between ends, ways, and means; about identifying objectives; and about the resources and methods available for meeting such objectives" (Freedman, 2013). Organization or non-state actor refer to a group of people who work together in an organized way for a shared purpose (Cambridge dictionary). Non-state actors include organizations and individuals that are not affiliated with, directed by, or funded through the government. It can relate to NGOs, associations, corporations. Starting from the definitions of sustainability and strategy, we define an organizational climate change mitigation strategy (OCCMS) as a time-bound set of means and ends an organization makes use of to achieve goals that are intended to mitigate the impacts of climate change in its value chain. OCCMS are also commonly called climate transition plans, climate strategies, low-carbon strategies, which typically constitute a crucial component of broader transition initiatives encompassing climate change adaptation and other environmental impact mitigation. While some scholars tried to build theoretical frameworks for corporate sustainability (Molin et al., 2022; Sanchez-Planelles et al., 2021), no academic research has been directed to a comprehensive OCCMS framework, specifically addressing climate change from corporate levels.

A.5.2.2. Step 3 : description of the vision workshop

This vision-formulation stage was facilitated by a full day dedicated to foresight and understanding the different projection scenarios towards 2050 (based on IPCC, ADEME, the Shift Project scenarios), to enable participants to see the potential implications of a carbon-neutral world in 2050.

With the help of Virginie Raisson-Victor, geopolitologist and President of the "GIEC Pays de la Loire", we i) Identified the parameters relevant to companies (e.g. energy, mobility,

resources, work organization) ii) Described the trends for each of these parameters. Companies were thus able to take note of all these trend factors, which are key indicator points for the evolution of society. These are linked to strong uncertainties, but which, taken together, become strong markers of a low-carbon society. iii) Gathered the participants in groups, to project themselves into 2050, and to relate what has happened over the last 30 years, in order to draw up desirable visions of a low-carbon world in 2050. To animate these workshops, we added "random factor cards" which, for example a pandemic or a war, often change the current situation, and can lead to unexpected scenarios. iv) Let each company work on their projection in the defined scenarios, to bring out a possible low-carbon vision.

This day was perceived by participants as a strong lever for transformation, which then enabled them to formulate concrete risks and, after further work within the company, a vision of the company in a low-carbon world.

A.5.2.3. Climate-related risk library

POLICY AND LEGAL TRANSITION RISKS	Financial risk linked to the introduction of a carbon tax / green taxonomy / quotas - increase depending on the sector of activity, or future tax that does not exist today.
	Risks associated with the ELAN law (evolution of housing, development and digital) / tertiary sector decree: 40% reduction in energy consumption in the tertiary sector by 2030 (end of gas boilers, sobriety, etc.) -> Penalties and fines
	End of internal combustion engines for new vehicles, traffic restrictions (cities, zero-emission zones, last mile, etc.), alternative vehicles that are not currently accessible.
	Building and property regulations (RE2020, BEPOS, etc.): energy performance and self-generation
	Border regulations: European tax (carbon cost of transport and/or production). Potentially banned or inaccessible products, impact on suppliers
	Regulations: evolution and obligation of the various reporting systems (simplified GHG balance for companies with more than 50 employees who received aid during the COVID, more ambitious GHG balance, reporting applicable without threshold conditions, etc.).
	GES regulations on financial products (consumer loans, savings, investments)
	More generally, regulatory risk in the specific business sector
	EU pressure on agriculture, Europe's most emissive sector.
	Rising energy prices
	Impact on team skills and professions, risk of bad decisions
	Requirements, customer capabilities & resistance to change: Difficulty enforcing regulatory and climate-compatible practices on our customers (vegetarian, less meat, transport...)
	100% circular economy mandatory in our projects and/or fine control on projects
	Increasing demands on waste collection, plastic removal
TECHNOLOGICAL TRANSITION RISKS	Digitization, digital transition
	Cyberattacks, new security methods (blockchain, etc.)
	Risks of increased environmental impact & consumption of resources (energy, water, rare metals, etc.) linked to the development of digital technology and the evolution of our businesses + dependence on some of these rare resources (scarcity and rising prices).
	Sobriété numérique, optimizing energy use
	Financial difficulties for the "necessary" technological transition (devaluation of energy-intensive assets, unamortized technological investments and increasing costs of renovations) Reliability of companies and innovative materials, market availability, measures dependent on political will
	Limited mastery of certain technologies for transition
	Strong impact of low-carbon transition on travel. Need for transition to ensure consulting and research activities: travel.
	Dependence on third parties for the climate impact of digital technology
	Lack of leverage on changes in healthcare professions
	Large-scale IOT development in single-family homes
	Development of new technologies (easier-to-install panels, carbon capture, etc.)
MARKET TRANSITION RISKS	Energy costs
	Shortage of components and raw materials (scarcity or geopolitical tensions/privileges)
	Insufficient involvement and availability of stakeholders in transformations (poor supplier practices, etc.), maturity required (customers, beneficiaries, etc.).
	Acceptability of any additional costs, due to the expected rise in the price of CO2 and other greenhouse gases
	Specific consulting: Evolution in the need for consulting to integrate these issues, carbon accounting etc...
	Risk linked to the evolution of supply and demand: the 'cultural time' between the company and the market is different. Be ahead of the game and stop accelerating as fast as the market or competitors. Change or a more corresponding offer. Rapid customer demand for low-carbon products
	Reduced meat consumption (climate and health risks) in Europe, leading to a loss of income for farmers / inability to invest or even a reduction in the number of farmers
	Disruptive competitive offer or new competitors on low-carbon offers, local products, low tech (easier to maintain and less costly)
	Questioning of certain customer markets (impacting regulations, relocation) E.g.: Devaluation of climatic financial assets, loss of customers or certain long-term businesses.
	Direct impact of climate change (products not designed to last in high temperatures)
	Specific: Breaking the housing access model

	Specific: Falling gold price
	Specific: High-tech products for high productivity, connected to control your farm/operations
	Specific: Increased demand for care, new diseases….
REPUTATIONAL TRANSITION RISKS	Difficulty finding financing/access to public aid/opportunities, signing or renewing contracts, potential reorientation of investments from fossil fuels to sustainable funds
	Loss of attractiveness/recruitment difficulties/turn-over due to a company's lack of commitment to climate protection
	Loss of consumer consideration for products that are no longer in line with the demand for low-carbon products = adaptation to customer demand. Loss of appeal
	External communications, bad reputation/image pointing to inefficiency on environmental/social/societal aspects (*waste generated, targets not met, unethical investments, fossil fuel customers, transition too slow…*),
	Market maturity: failure to convert our customers to a "blue ocean" offer (including a climate-friendly dimension) in a short space of time: risk of losing customers, potential loss of appeal because "considered too expensive". *e.g.: ability to get customers to accept price changes, changes to menus, delivery times, changes to offers and products… linked to the climate.*
	Beware of the social risk (e.g. a smaller office may mean less comfort for employees).
	Cognitive dissonance between vision and actions, lack of coherence (investment actions vs. communication plan)
ACUTE PHYSICAL RISKS	Extreme and frequent meteorological crises that would paralyze production (= loss of revenue, disruption of customer flows): *heat wave that prevents work in factories for several days, low humidity over long periods disrupting our processes, etc.*
	Impact of natural disasters on infrastructures/buildings/business: floods or storms, which would force us to rethink our construction plans and position our buildings in critical areas?
	Rising cost of insurance (increased risk of extreme events and long-term climate change)
	Loss of revenue for our users/customers due to lower productivity (linked to other risks)
	Supply risk & rising raw material prices
	Increased absenteeism
	Rising energy costs
	Health crisis immobilizing teams/production (e.g. pandemic)
	Changes in food safety
CHRONIC PHYSICAL RISKS	Increased impact on the environmental health of populations, epidemic risk
	Loss of productivity due to extreme heat: - Lack of water leading to reduced productivity and profitability - Uncomfortable or impossible to work - Loss of biodiversity (fauna & flora)
	Specific: Increased heat has a direct impact on datacenter cooling, and therefore on energy consumption. Natural cooling will be used less. Particularly on successive hot days, which also cause thermal discomfort for employees in non-air-conditioned buildings.
	Specific: Impact of global warming on the growth/survival of purchased wood species
	Major rise in insurance costs for buildings and activities due to repeated climatic disasters
	Rising sea levels threaten activities in certain areas
	Will the costs generated by solidarity enable us to address new social and societal issues, such as the potential loss of access to healthcare?
	Rationing of resources no longer corresponding to business needs
	Falling birth rate and sharply declining growth, which would reduce local authorities' urban planning projects.
	Reduced recruitment radius (attractiveness/availability) with higher energy prices
	Direct impacts of climate change: Risk of loss of service due to bad weather/fire … (absenteeism, power cuts, etc.) or damage to assets

A.6. Supplementary material for chapter 5

A.6.1. Supplementary analysis of all SBTi absolute targets

A.6.1.1. Trends in selecting base years for all absolute targets with base year from 2015

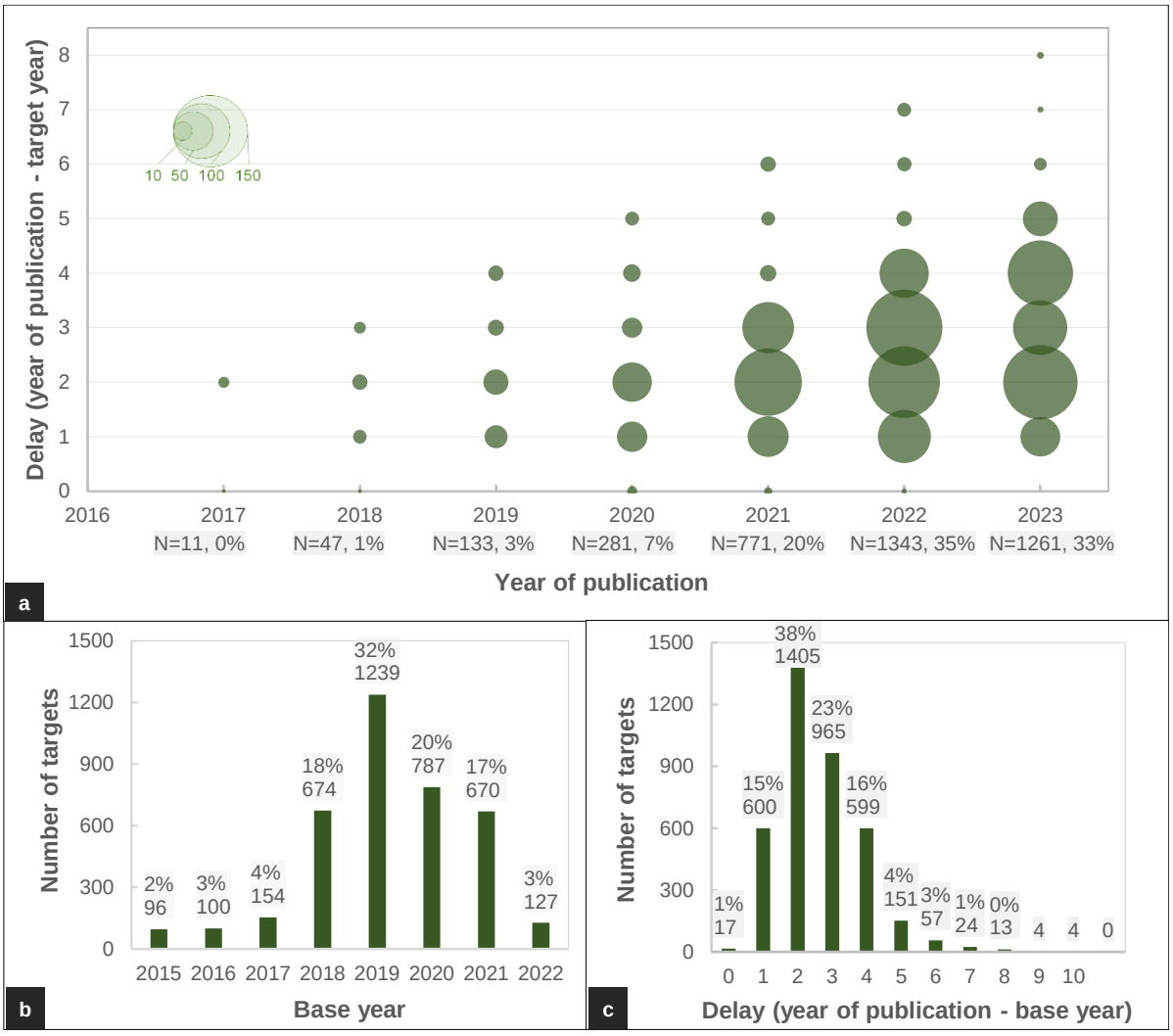

Figure A.7: analysis of trends in selecting the base year for all absolute targets in SBTi target dashboard (N=3847)[25].

[25] 43 targets have been removed as their base year was prior to 2015, i.e. not compliant with SBTi criteria. Figure A.7.a: delay between year of publication and base year, as a function of year of publication. The grey box below the x-axis indicates the number of validated targets for each year, and their relative share within the sample, and

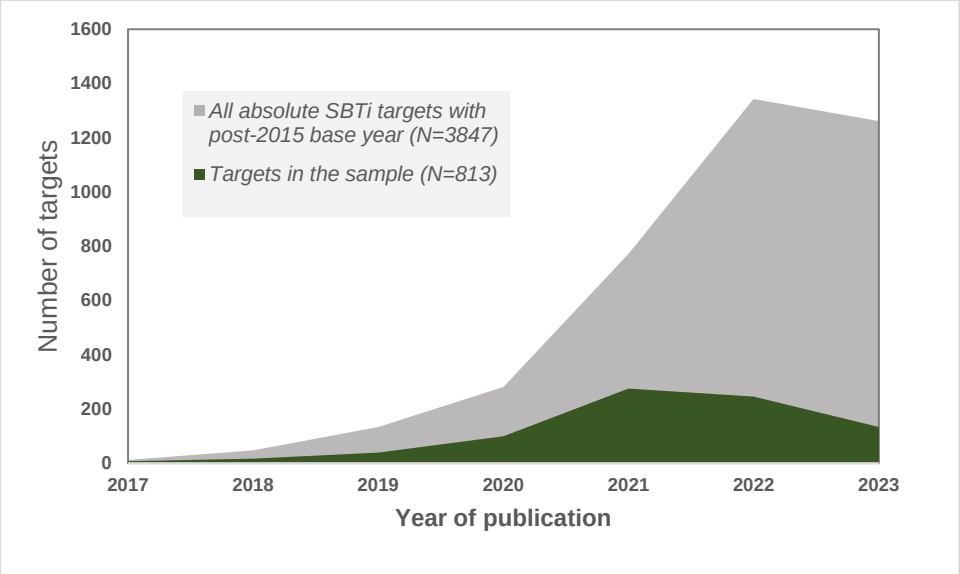

Figure A.8: number of SBTi-approved targets published by year from 2017 to 2023, as of 30/06/23, both for the sample of this study and for all absolute reduction targets with a post-2015 base year.

the 2023 point corresponds to the situation at mid-year (as of 06/30/23). Figure A.7.b: distribution of base year for the 772 targets of the dataset. Figure A.7.c: analysis of trends in selecting base year with the delay of publication.

A.6.1.2. Targeted reduction as a function of timeframe

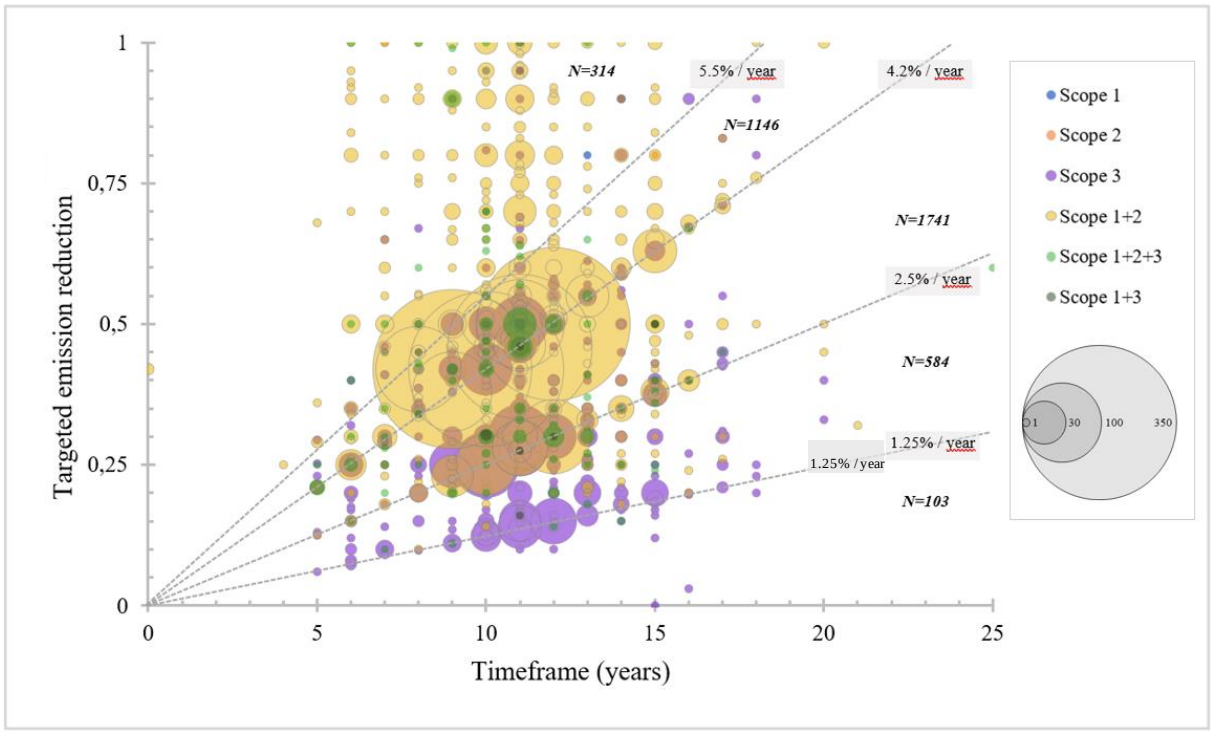

Figure A.9: Timeframes and targeted emission reductions for validated SBTi emission reduction targets (N=3847).

The chart covers the 3888 SBTs set by 2917 companies and approved by the SBTi. The dashed lines indicate corresponding annual percentage reductions in base-year emissions. The numbers indicate the number of targets falling within the zones demarcated by the dashed lines.

Trends following the three SBTi Absolute Contraction Approach (ACA) methods, i.e.

- Absolute reduction for 1.5°C or 4.2% per year for Scope 1(yellow dashed line). This trajectory is the only ACA method accepted by SBTi for Scope 1 and 2 since the last update of the SBTi criteria (SBTi criteria, April 2023)c
- Absolute reduction for the well-below 2°C (WB2C) SBTi scenario (orange dashed line)
- Absolute reduction for the 2°C scenario (red dashed line).

Nevertheless, there are still emission reduction targets outside these three absolute SBTi methods. This could be explained by sectoral guidelines for certain organizations (e.g., as per SDA method), or by higher ambitions that the minimum ambition required by SBTi.

A.6.2. Supplementary analysis of the dataset

A.6.2.1. Completeness of the dataset and availability of data

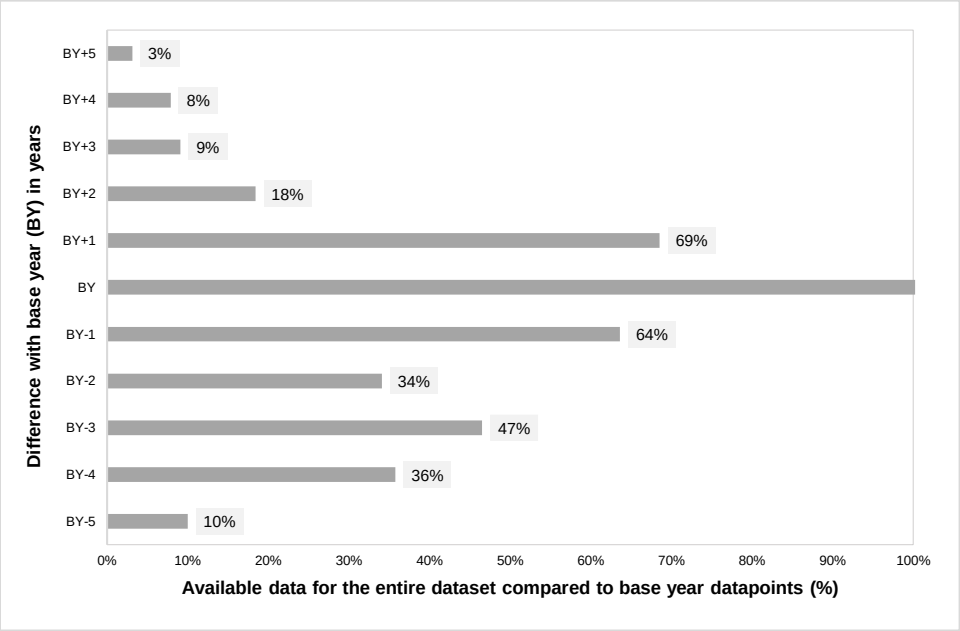

Figure A.10: data availability for years before and after the base year

A.6.2.2. Analysis of targets by sector and sample representativeness

Figure A.11: analysis of approved targets, by sector, by Scope over time and by world region, for the sample of targets of this study (N=814).

A.6.2.3. Repartition of target year

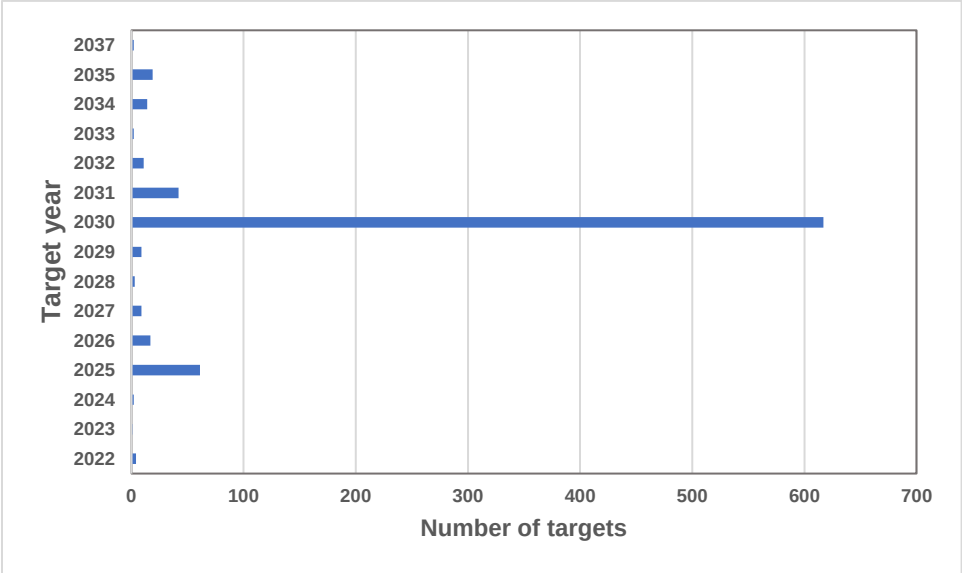

Figure A.12: Analysis of the trends in defining the target year, considering number of targets and base year.

A.6.2.4. Treatment of outliers

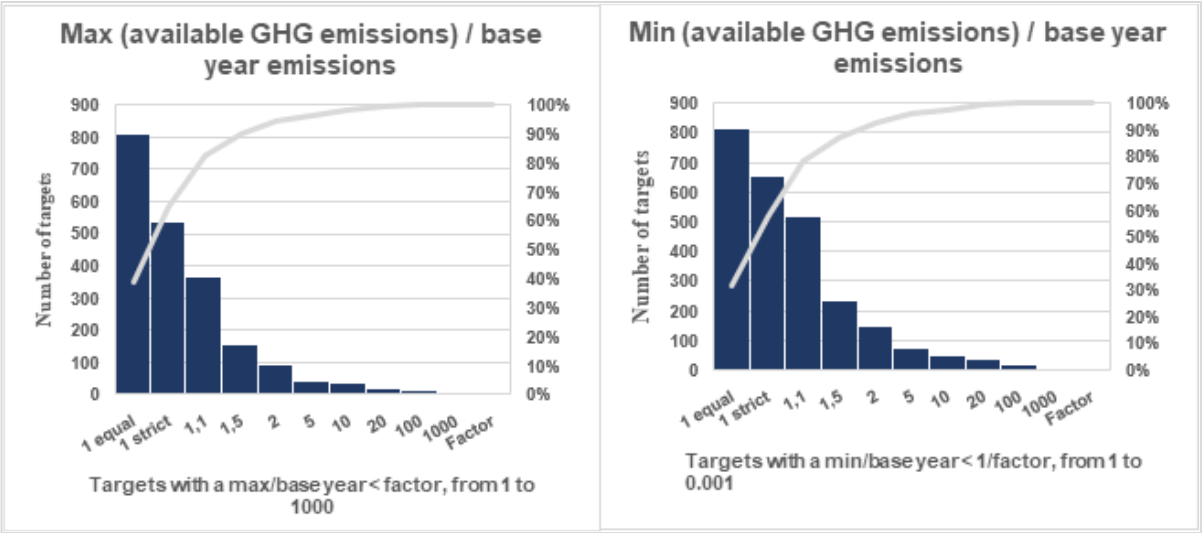

Figure A.13: Analysis of variation in normalized emissions for the sample of 813 absolute reduction targets. Left figure focus on maximum value for each company that set a SBT and have available reporting GHG emissions within CDP reporting from 2015 to 2021; Right figure focus on the minimum value, and factor 1/factor.

Titre : Décliner les cadres de soutenabilité globaux en méthodes opérationnelles à différentes échelles : vers des stratégies ambitieuses et justes des organisations pour atténuer le changement climatique

Mots clés : évaluation de la soutenabilité ; science-based targets ; limites planétaires ; soutenabilité des organisations ; atténuation du changement climatique ; sciences de l'environnement

Résumé : Combiner le cadre des limites planétaires avec un socle social représentant les besoins humains façonne un modèle de soutenabilité « absolue », soit un espace « sûr et juste » alliant justice sociale et enjeux environnementaux. Cette thèse par articles, réalisée dans le cadre d'une convention CIFRE, s'intéresse à la déclinaison des cadres de soutenabilité absolue à des sous-échelles. En partant du niveau mondial, elle se centre progressivement sur les stratégies d'atténuation du changement climatique à l'échelle des organisations, dans une approche de recherche-intervention. La partie introductive porte sur les principes éthiques sous-jacents au partage des limites planétaires et du budget mondial d'émissions de gaz à effet de serre. Dans ce prisme, elle montre le manque de méthodes fondées sur les besoins humains. Le premier article en développe une au niveau national, pour évaluer les impacts sociaux d'une action ou d'une politique dans le cadre de la « théorie du doughnut ». Ensuite, les travaux se concentrent au niveau organisationnel en interrogeant la réalité des contributions ambitieuses et justes des organisations aux objectifs des Accord de Paris. Le deuxième article constitue ainsi une revue des méthodes opérationnelles à disposition des organisations pour définir des stratégies d'atténuation du changement climatique. Cette revue souligne notamment un besoin de standards méthodologiques scientifiques intégrant et dépassant les notions de comptabilité carbone et d'objectifs de réduction d'émissions pour les organisations. Ces notions sont nécessaires mais non suffisantes et doivent en effet s'inscrire dans des stratégies d'atténuation du changement climatique plus globales. Le troisième article contribue à répondre à ce besoin à travers une étude multi-cas portant sur la définition de telles stratégies. La revue théorique et l'approche de terrain montrent toutes deux la nécessité d'une transparence accrue dans la manière dont les quotas d'émissions sont alloués aux organisations. De manière quantitative, le quatrième article illustre ainsi les risques de dépassement du budget carbone mondial en analysant la sensibilité de certains paramètres dans les méthodes de référence « Science-Based Targets ». Dans son ensemble, cette thèse contribue à relier les cadres de soutenabilité « absolue » définis au niveau mondial et les stratégies des organisations. Cette contribution vise à soutenir la construction de stratégies d'atténuation du changement climatique, à la fois robustes, ambitieuses et justes, sur des bases scientifiques.

Title: Bridging sustainability scales, from global frameworks to operational methods for sub-level actors: focus on climate change mitigation strategies for organizations

Keywords: absolute sustainability assessment; science-based targets; planetary boundaries; corporate sustainability strategies; climate change mitigation; environmental science

Abstract: The integration of Earth biogeophysical limits, as for example proposed by the Planetary Boundaries framework, with a need-based social foundation shapes a framework for "absolute" sustainability, i.e. defining a "safe and just" space uniting social justice and environmental issues. This article-based thesis, carried out under a CIFRE agreement, investigates the application of absolute sustainability frameworks to sub-global scales. Starting from the global level, it progressively focuses on climate change mitigation strategies at the scale of organizations. The introductory section examines the ethical principles underlying the allocation or sharing of the planetary limits and, in particular, the global greenhouse gas emission budget. From that perspective, it shows the lack of sharing principles based on human needs. One such method is developed at national level in the first article, by developing an approach to assess the social impacts of an action or policy within the framework of the "doughnut theory". The work further investigates on questioning the fair contributions of organizations to the objectives of the Paris Agreement. In a second article, a critical review of the operational methods available to organizations for defining climate change mitigation strategies is performed. It highlights the need for scientific methodological standards that go beyond carbon accounting and emissions target setting for organizations. These two elements are necessary but not sufficient, and need to be embedded in comprehensive climate change mitigation strategies. A third article tackle that need throughout a multi-case study of the definition of such strategies. Both the theoretical review and the field approach demonstrate the need for greater transparency in the way global emission allowances are allocated to organizations. The fourth article illustrates the risks of exceeding the global carbon budget through an analysis of the sensitivity of specific parameters, in particular the definition of the base year, when setting targets within the widely adopted "Science-Based Targets" method. Its results call for corrective actions in the use of the method by organisations. Overall, through its four papers, this thesis contributes to bridging the gap between "absolute" sustainability frameworks defined at global level and organizational strategies. This contribution brings us one step closer to the development of robust, ambitious and fair climate change mitigation strategies.