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Taking climate change seriously: time to credibly communicate on corporate climate performance

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Abstract. To address climate change, regulators have required companies to provide more information about their environmental impact such as their greenhouse gas emissions. However, reporting choices lacking comprehensiveness, corporate report users cannot assess how much companies contribute to limiting global warming. This research presents a new problematization of the multiple facets of this phenomenon and the subsequent communication requirements, drawn on the Luhmann's system theory. We position the issue successively in the scientific, political, and economic systems. Our analysis suggests that the economic system is unable to properly capture the messages from its environment and that it favors the outside-in perspective over the inside-out one, meaning that it focuses on the impact of its environment on itself and not the opposite. Therefore, any definition of corporate climate performance by the economic system will be limited because this system, like any other, is forced to understand its environment from its own perspective. We suggest that a new system, fully dedicated to sustainability, would be more appropriate to handle this concept and propose to consider corporate climate performance as an indicator reflecting how far a firm is from a targeted trajectory for keeping global warming below a threshold.

Keywords. System theory; Luhmann; global warming; climate performance; climate accounting; offsetting; carbon neutrality

1. Introduction

Earth is heating up: its average surface temperature increases. This phenomenon, called global warming, disturbs the physico-chemical balance of the Earth, which then naturally evolves towards a new state, possibly harmful for all current living beings, hence for human health and well-being. The effects of global warming are already reflected today by sea-level rise, ocean acidification, ice cap melting, shifts in flower/plant blooming, extreme weather events... In the first part of their sixth assessment report (2021), the scientists of the Intergovernmental Panel on Climate Change (IPCC) state that the increases in greenhouse gas (GHG) concentrations are “*unequivocally caused by human activities*” and that “*human influence has warmed the atmosphere, ocean and land*”. However, even if the causes of the problem are identified, the measures put in place to mitigate them are still very inadequate. The actual GHG reductions achieved in most economies are still below the rates needed to alleviate climate change. This raises questions about how to assess the company's commitment to limiting climate impacts (Aragon-Correa *et al.*, 2016; Dahlmann *et al.*, 2017).

Some gases present in the atmosphere trap the heat escaping from the Earth. This is the greenhouse effect. There exist many GHGs, both natural and human-made. The main anthropogenic GHGs are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and chlorofluorocarbons. Even though there are several anthropogenic GHG, most indicators refer to carbon because CO₂ is the most emitted and persistent GHG. We therefore talk about carbon footprint, carbon market, carbon neutrality...

A substantial part of the greenhouse effect is linked to the overexploitation of natural resources, particularly fossil fuels. The damage induced by extractive activities on the environment is a negative externality when it is borne physically and financially by civil society and the natural environment. This is because there is no translation of environmental consumption into the financial system. In such hermetic structure, fossil fuels as resources are currently underpriced because the GHG emissions resulting from their combustion has long been considered free. In such case, the financial markets learn to manage their own correction. A concrete example is Vale, the company responsible for two tailings dam collapses (both in Minas Gerais, Brazil). Although the company had adopted IAS 37, the International Accounting Standard related to provisions, contingent liabilities and contingent assets, there were no environmental provisions in the financial statements prior to the first accident (November 15, 2015, 19 deaths), and \$200

million before the second accident (January 25, 2019, 270 deaths) qualified as the worst human and environmental disaster in Brazil (Silva Rotta *et al.*, 2020). Provisions reduce the company's earnings and thereby the distributable dividend to shareholders, but there remains significant discretionary space in their valuation. In this case, the market perceived this amount as insufficient and Vale's market capitalization lost \$19 billion, in recognition of the externality price.

The emission of GHGs into the atmosphere is therefore an externality, but a very specific one since it is global. The release of a given amount of GHGs, regardless of the emitting country, affects the entire planet. The reduction in emissions is thus a global challenge and meeting it is expected to benefit everyone. However, as the causes of the problem are local and the consequences global, reducing emissions is a challenge that addresses issues of problematization, methodology and operationalization. The problem being still unsolved, we argue that the financial markets have demonstrated their inability to manage externalities through an efficient allocation of resources. Under these conditions, economists justify the intervention of public authorities and recommend the implementation of appropriate policies. Two economic instruments are usually considered: taxation with, for example, the carbon tax, or permit trading with the carbon market (Coase, 1960). Choices have so far favored the second option, but the efforts have clearly appeared insufficient to curb global warming. Because economy and climate change are interdependent — the industrial sector generates gas emissions that enhance global warming that ultimately affects economy even though the amplitude of this impact is still uncertain (Newell *et al.*, 2021) — authors (Persson and Rockström, 2011) recommend integrating industry in the definition of climate actions. Until recently, firms have focused solely on profit (Friedman, 1970), but they are gradually beginning to incorporate other concerns (Freeman, 1984), with global warming becoming a major one. Their involvement has become a corner stone likely to change marks.

Because the issue is multilevel, we propose an exploratory approach based upon the system theory developed by Luhmann (1997). His theory, which draws on a wide range of academic disciplines, aims at describing societies and explaining how they emerge and persist. This evolutionary theory differs from standard economic theory to which markets play a key role in structuring interindividual relations and from the Marxist view focused on the evolution of production modes. In the following sections, we first recap the main concepts of Luhmann's theory. Second, we consider global warming from different

perspectives rooted in the scientific, political, and economic systems. The coupling of systems, to which organizations also contribute, is ensured by communication media. The final section focuses on corporate climate performance as one tool, among others, for the aforementioned systems to properly communicate about their environment and identify actions to mitigate climate change.

2. Luhmann's system theory

The system theory due to Luhmann is rooted in the general system theory (Bertalanffy, 1968), which defines the system as a complex set of elements in dynamic interaction. It is noteworthy that Luhmann's theory departs from the classical Aristotelian conception according to which the whole is greater than the sum of its parts. It also contests the existence of a supra-system capable of driving the whole.

The following sections recap a few notions of the system theory (Holmström, 2007; Stichweh, 2011; Albert, 2016) before addressing the ecological views in a social perspective. For a more in-depth discussion, the interested reader can refer to Luhmann's ultimate book *"The Society of Society"* (1997), translated in English in 2012 and 2013.

2.1. A few key concepts

Starting from the fundamental self-organization concept, Luhmann introduces notions such as order, disorder, environment, and complexity. A self-organizing system exists within an environment and in relation with it (Guy, 2018). It can control its own operations, but not those of its environment. Therefore, the system perceives itself and its environment as ordered and disordered, respectively. However, both are neither fully ordered nor disordered. Thanks to their capacity for self-organization, and by using their environment as a source of information, systems adapt and transform their internal disorder into order.

Luhmann tries to capture modern society complexity by introducing psychic, social, and biological systems. The psychic, social and biological systems are the centers of consciousness, communication, and life, respectively. Systems are autonomous but can be coupled via various mechanisms. Accordingly, the coupling between psychic and social systems relies on the existence of language (Stichweh, 2011). Communication is the elementary component of social systems; it also ensures their reproduction. However, it is created to disappear at once. Luhmann refers to the notion of event. An event lasts only an instant. Therefore, social systems must continually produce

events that connect to each other. Otherwise, they vanish.

The distinction between systems relates to the differentiation concept whose contribution is twofold. First, it makes it possible to assert system identity. Everything inside the system belongs to the system while everything outside belongs to its environment. Given this definition, each system is assigned its own environment. Differentiation is also a feature of the self-organization process as it replicates the system / environment distinction. The most encompassing social system, namely society, is composed of various sub-systems, including political, scientific, and economic. These develop using specific communication media. The political sub-system is based on power, the economic sub-system on money and the scientific sub-system on knowledge. Thanks to differentiation, systems split into sub-systems, each with its own function to handle a specific issue. The subdivisions follow one another as much as required, generating new functionalities. Each of the created sub-systems obeys its own logic. It captures the difference between the system to which it belongs and its environment, but from a perspective depending on its function. Shortly, social systems aim at reducing the complexity of their environment but doing so, they generate more internal complexity.

At the same time, the increasing complexity of systems is associated with their growing dependence on environmental complexity to which systems remain paradoxically insensitive (Valentinov, 2014). Systems are not able to understand and process all the outputs from their environment. They focus on one part only and ignore the rest. By developing sub-systems to deal with the selected outputs, they reduce the complexity of their environment and increase their own. Unfortunately, being selective, they may leave out important or critical outputs, and endanger themselves. They continue to evolve as long as their environment tolerates it. In the end, this evolution does not mean *"adaptation, but amplification of deviations"* (Luhmann, 1997, p. 133).

As systems have boundaries, they have their own operating mode. As a result, they are closed on themselves. However, they are also open because they constantly interact with their environment. Systems are therefore simultaneously closed and open, or autonomous and dependent. This contributes to the co-building of sense-making systems. In addition, because the systems are autonomous, there is no established hierarchy that gives one system precedence over the others. Therefore, none of them can have a global view on society, even though some experiment a larger volume of events.

2.2. Ecology from a social perspective

We next propose an analysis of the perception of ecological issues at the social system level. As noted above, Luhmann considers systems as both open and closed. Thus, social systems can adjust with the external complexity and develop their internal one. They also make themselves insensitive to their environment because of operational closure (Valentinov, 2014; 2017). Hence, systems can ignore the increasing complexity all around, and do not cope with it. Such *“precarious combination (...) underpins the ecological predicament of modern society. Evidently, it is rooted in the general destructive potential of structural couplings, which might lead systems to ignore crucial environmental conditions”* (Valentinov, 2014). This ultimately weakens sustainability of systems.

Risk gets growing attention in modern society. Although often understood as the result of technological progress, it is considered by Luhmann as a social construction derived from self-observation and questioning about future. From then on, risk extends to the entire society (Le Bouter, 2014). It can be associated with any social system, be it political, economic, legal, or other. Its probability of occurrence depends *a priori* on two factors: the increasing society complexity and the multiplication of decision possibilities. Luhmann distinguishes between risk and danger (Luhmann, 1993; Holmström, 2007). These two concepts refer to a potential loss, but do not have the same meaning. In the case of danger, the loss is incurred by the system because of an external cause, whereas in the case of risk, it is generated by an internal decision (Bolhom, 2012). It is known that the increase in knowledge generates an increase in technological risks, but it also makes people aware that more and more damages result from human decisions.

According to Alexander and Blum (2016), with the knowledge available in 1997 the latest, Luhmann does not blame either technology or capitalism for the ecological catastrophes in our society. Instead, such disasters are envisioned as an effect of functional differentiation and social system complexity. Within this framework, climate disruption results from an uncontrollable web of decisions rather than a manifest will. Finally, Luhmann is very pessimistic about society's ability to find solutions to environmental issues for various reasons. In particular, systems cannot communicate with the environment; they can only communicate about it. Also, the absence of a supra-system prevents the implementation of a unified system reaction.

3. Global warming from different perspectives

First, as the social system is closed, it cannot self-observe from outside. It is therefore necessary to select an observation point inside. Second, the social system comprises systems that only partially grasp their environment from a perspective depending on their function. Third, there is no social supra-system, meaning that there is no internal observation point providing a global view. To alleviate these shortcomings and address the problem of climate change in its multiple facets, we have chosen to place ourselves successively in the scientific, political, and economic systems, three sub-systems in the luhmannian social system. Our focus on these sub-systems builds on Alexander and Blum's (2016) identification of the significant role they played in the development of integrated corporate reporting initiatives and their steering ability, especially when coupled. It does not undermine the fact that many other sub-systems have a role to play in the development of the demand for sustainable corporate communication (Roth *et al.*, 2019), and amongst those, one finds the religious, law, and education sub-systems.

3.1. Scientific perspective

At the end of the 19th century, Arrhenius (1896) developed the first model to evaluate the effect of CO₂ concentration in the atmosphere on temperature. Later, measurement techniques became accurate enough to detect the continuous increase in this gas content (Keeling, 1960). Since then, the IPCC has built models to predict climate evolution using current scientific data and knowledge. It thus proposed four forward-looking scenarios, known as RCP for Representative Concentration Pathway (IPCC, 2014). These scenarios involve distinct assumptions about future GHG emissions: they are named accordingly RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. RCPs describe possible climate states given radiative forcing values that reflect the perturbations due to human activity. The greater the radiative forcing, the warmer the Earth-atmosphere system. RCP 2.6 is then associated with a forcing of 2.6 W/m² in 2100. For comparison, the average heat flux received by the Earth at ground level from the Sun is 340 W/m². This RCP 2.6 scenario is optimistic: it incorporates the benefits of GHG emission reduction policies and defines a system keeping global warming below 2°C relatively to pre-industrial period with a 67% probability. RCP 4.5 and 6.0 are intermediate scenarios aiming at stabilizing emissions. RCP 8.5 with high GHG emissions predicts a temperature increase in the range of 3.5 to 5.5°C. This extreme scenario is considered by some to be increasingly unlikely (Hausfather and Peters, 2020).

A quasi-linear relationship between cumulative CO₂ emissions and temperature has been evidenced (Matthews *et al.*, 2009). It permits to associate carbon budgets with RCPs. The pre-industrial era is considered as the starting point. If aiming at limiting the temperature increase to 1.5°C or 2°C, with a probability of 67%, the total carbon budgets are 2650 or 3400 Gt¹ of CO₂ (IPCC, 2018), respectively. As of January 1, 2018, human-induced emissions totaled 2230 Gt of CO₂. Therefore, the residual carbon budgets are 420 or 1170 Gt of CO₂ depending on the warming target. Recently, these budgets have been even revised downwards (The Constrain Project, 2020): as of January 1, 2020, they have been set to 235 or 985 Gt of CO₂.

Let us compare these budgets to the emissions that would be generated by burning the “1P” oil and gas reserves. Hydrocarbon resources represent the total quantities of hydrocarbons trapped in underground geological formations. They are split into reserves, contingent resources, and prospective resources. Reserves are the quantity of hydrocarbons deemed recoverable from known fields according to current technical and economic criteria. They are subdivided into three groups: proved or “1P” reserves with a commercialization probability greater than 90%, proved plus probable or “2P” reserves with a probability greater than 50% and proved plus probable plus possible or “3P” reserves with a probability greater than 10% (SPE, 2007). The CO₂ emissions that would result from the production and combustion of the “1P” reserves alone are of the order of 700 Gt for oil and 400 for gas (IEA, 2020). These volumes exceed the residual carbon budgets mentioned above, although coal was not even considered. In addition, the CO₂ emissions resulting from existing fossil fuel energy infrastructure (*e.g.*, coal and natural gas-fired power plants), if operated as historically, represent more than the remaining carbon budget if global warming has to be limited to 1.5°C (Tong *et al.*, 2019). This raises questions about the rationale and intrinsic value of the economic system. It also emphasizes conflicts between the economic and scientific systems.

3.2. Economic perspective

Before achieving his life-long work, Luhmann had observed the increasing volume of communication concentrated in the economic system. This was explained by the importance of reference to its medium, money. As money is central in decisions addressing climate change, a focus on the economic perspective is necessary. Today, the mainstream economic system follows a neoclassical model, based

on growth, and advocates this economic growth is driven by three factors: capital, labor, and technology (Solow, 1956). Sustainability concerns have been introduced more recently (Solow, 1993), in neoclassical economics, following two perspectives. Weak sustainability assumes that the various forms of capital (financial, social, and natural) are substitutable whereas its strong version considers they are not (Dietz and Neumayer, 2007). Nevertheless, in both approaches, natural capital is merely a set of inexhaustible environmental productive stock, and the concepts of resources and assets are mistakenly considered as equivalent (Missemer, 2018). Hence, the model tends to confine the economic system into its financial/productive rationality and to underestimate, if not ignore, the relation to its environment. With the raising awareness of new realities such as natural resources depletion or planet boundaries, natural capital is also currently understood, from a more ecological viewpoint, as a metaphor (Akerman, 2005) for expressing concerns about natural resources/entities for “their own sakes”. This perspective on natural capital is much more connected to ecological sciences and environmental ethics. It can be described as very strong or ecological strong sustainability (Turner, 1999). Also, the concept of natural resource is not only seen as a static entity but as a dynamic one, which includes the available stock of resources and the so-called regulating ecosystem services like climate or hydrological cycles (Berkes and Folke, 1992). This perspective on capital, in contrast to the neoclassical view, aligns with the notion of capital as a debt² (Richard and Rambaud, 2022) and not as assets, making natural capital the sum of ecological debts. This approach is echoed in several works (Gray and Bebbington, 2001) and structured in the Comprehensive Accounting in Respect of Ecology (CARE) accounting project (Rambaud and Richard, 2015; Rambaud and Chenet, 2021) (see section 4.4).

Carbon accounting, which emerges during the Earth Summit of Rio to fight global warming, offers another facet of the same issue. It has been developed to evaluate the GHG emissions of countries. In short, data characterizing company's activity (energy consumed, raw materials used, employee travel, *etc.*) over a reference period in a given country are collected and turned into emissions by applying conversion factors. This yields the carbon footprint that is the quantity of GHGs released in tons of CO₂ equivalent. Accountants have played an important role in the definition of “standards”. It follows that carbon accounting is similar to financial accounting (Lovell and MacKenzie,

¹ Gigatonne equals 10⁹ tons.

² Historically, capital refers to debts, not to assets: it originally meant the “capital” part of a (monetary) debt (Richard and Rambaud, 2022).

2011). This has led to the creation of the GreenHouse Gas Protocol (GHGP) or the Carbon Disclosure Project (CDP), which define the carbon information required and how it should be disclosed in non-financial or extra-financial reports. However, there is still no universally accepted standard for defining the information to be disseminated. Also, the identification of the perimeter to be considered for the firm's activity remains controversial. Three scopes are distinguished, but not equally treated depending on the standards. Scope 1 refers to direct emissions linked to the company's production process. Scope 2 corresponds to indirect emissions, which include the emissions due the production of the energy necessary for the company's operations. Scope 3 is associated with all other indirect emissions generated by the company. Although reported separately, all these emissions equally contribute to global warming. With the developments of such initiatives, GHG emissions have become the fundamental building blocks for a language shared by scientific, economic, but also political systems, making carbon accounting a coupling mechanism in Luhmann's terminology. Nevertheless, the way the economic system uses this tool highlights some of its weaknesses. The dominant perception is that carbon accounting is a purely technical instrument to assess the short-term GHG risks, and opportunities faced by companies and to satisfy shareholders' demands for maximum profitability (Le Breton, 2017). This is because, by construction, it misjudges the coupling of the economic system with its environment. Thereby, it experiences the same pitfalls as that identified by Alexander and Blum (2016) when analyzing another initiative, the International Integrated Reporting Council. Referring to Luhmann (1989), these authors noted that organizations prioritize communication within their own network. Moreover, *"organization is a societal medium for temporary forms (of social systems)"*, whereas *"operationally closed systems cannot reach the environment with their own operations. It cannot adapt to the environment through cognition. It can operate only within the system, not partly inside, partly outside"* (Luhmann, 1997, p.74 and 77).

In this context, an accounting approach addressing "outside-in" and "inside-out" issues, such as the Richard's proposal (2012), offers a possible and promising way forward. The "outside-in" approach uses ecological information to assess the risks and opportunities that the ecosystem represents for the firm. This view prevails for neoclassical economists, as aforementioned. The "inside-out" logic exploits the same information, but to assess the company's impacts on the ecosystem. Those impacts are usually neglected if not ignored by the neoclassical model because they generally entail no direct costs for

economic agents. The focus again is on the sustainability of the business, not on the sustainability of the system as a whole. The two conceptions differ in their relation to the notion of capital (Richard, 2012). Although managers often equate "outside-in" accounting with ecological or environmental accounting, it is financial accounting. The form of carbon accounting as developed by GHGP or CDP is an example of such "outside-in" impact. It reports the GHGs released into the atmosphere, but those ones, while quantifying the company's output on its environment, do not allow a direct estimate of its impact on climate. This information is mainly intended for shareholders so that they can assess how exposed the company is, for example, to a tightening of environmental policies. Said differently, "outside-in" accounting aims at preserving financial capital and maintain the business sustainability. To the contrary, "inside-out" accounting focuses on the impact of the firm on its environment and measures the resulting degradation of non-financial capitals, including natural capital. The example of a cooperative practicing organic agriculture is developed by Lamberton (2000). It illustrates the search for economic development in line with environmental and social objectives and highlights the difficulties encountered, including competition with other organizations that favor short-term cost reduction opportunities over long-term sustainability objectives.

As introduced above, usual shareholders aim at maximizing profit and approaches global warming as a source of risks, and symmetrically opportunities, but not as an environmental constraint. They typically envision two types of risks: carbon risk and climate risk. Generally, carbon risk refers to the negative impact on an asset of the unexpected changes in the prices of the carbon emitted and of carbon-based energy (e.g., Busch and Hoffmann, 2007). On the other hand, climate risks refer to the material consequences of global warming. For instance, it can be the flooding of a firm's buildings. The notion of risk, as understood here, can be misleading because it underpins an "outside-in" idea. Coming back to Luhmann's theory, risk is associated with the consequences of a decision that is internal to the system, whereas danger reflects a negative effect generated by something external to the system. In this sense, risk reflects an "inside-out" vision and danger an "outside-in" vision. Thus, carbon and climate risks as defined above should be considered as "outside-in" dangers, not risks. Climate risks exist, but according to the "inside-out" view, they correspond to the consequences of the GHGs emitted by firms: extreme weather events, sea level rise, deterioration of crop yields... Shortly, investors focus on dangers, not risks and in doing so, they remain unaware of the true "inside-out" risks, such as climate

risks. Therefore, they do not attempt to mitigate any climate risk, which means that they are increasingly subject to climate dangers as risks and dangers are interdependent.

Consideration of both "inside-out" and "outside-in" rationales calls for a new economic posture towards natural capital, in line with a very strong approach to sustainability. Capital is historically a matter addressed in corporate reporting. Whether it is named accounting reporting or financial reporting, corporate accounting information systems have since their inception focused on the outside-in view and ignored planetary limits. This is with no surprise as for centuries, the planet limits remained out of reach. At the same time, the blindness of the closed-form tools and theoretical apparatus adopted by corporations, as quasi-social systems, have led to over-exploitation of resources and permitted the invisibility of the phenomenon (Roth and Valentinov, 2020). Today, with raising awareness and with the emergence of a new kind of reporting, namely sustainability reporting, the issue of how to communicate about inside-out phenomena has entered the social debate. Solutions encompassing both "inside-out" and "outside-in" views fall under the new designation of double materiality, *i.e.*, they address material issue to the company and material issues to the society and the environment. The importance of double materiality has already been perceived and adopted by the European Commission (2019) but rejected by the International Sustainability Standards Board (ISSB) that was created by decision of the International Financial Reporting Standards (IFRS) Foundation.

3.3. Political perspective

Alexander and Blum (2016) suggested that in the absence of citizen coordination, of effective market allocation and of efficiency of ecological protests, only a political steering could resolve a multi-level issue such as climate change. Moreover, one very special feature of climate change is related to the involved time and space scales, that need to be safeguarded from pressures likely to narrow those down. Indeed, the current implementation of solutions will bear fruit in the long run. Politicians are not spared from such pressures. Those can be identified at two levels. At institutional and individual levels, a government, elected for a few years, is unlikely to commit to a voluntary and ambitious GHG emission reduction policy. It would bear the consent of efforts without benefiting from their positive effects that would become observable much later, and more likely after their electoral term. Of course, many governments have adopted a net zero target for mid-century. However, setting a target well beyond one's electoral

mandate does not mean that the necessary efforts to achieve it are going to be made by the current government. At a national level, a state cannot approve difficult and costly economic policy transformations that will hamper the competitiveness of national actors, if not ensured to be followed by other countries. These drawbacks — asymmetric temporalities, and lack of coordination — are two forms of asynchronicities that make an upper-level international policymaking essential.

For those reasons, and although the scientific system has been able to identify the physical principles governing greenhouse effects for more than a century, addressing this issue at the Earth scale is more recent. A movement towards actions was ignited thanks to the confluence of various events, including the creation of the United Nations. Since the end of the Cold War, the objective of this organization has been to encourage international cooperation. In 1961, it recommended the World Meteorological Organization (WMO) and the International Council for Science to work together to better understand climate phenomena. In 1979, the WMO organized a world climate conference that triggered public awareness of global warming. Next, a series of reports and conferences led to the creation of the IPCC in 1988. Based on the first results obtained by this group of experts, the United Nations General Assembly created in 1990 a committee in charge of negotiating the United Nations Framework Convention on Climate Change (UNFCCC). Its purpose was to stabilize "*greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*". This illustrates the notion of politic steering (Alexander and Blum, 2016).

The Kyoto Protocol, adopted in 1997 by 37 countries, operationalized the UNFCCC. It was the first treaty defining GHG abatement targets and coupling the political and legal systems: the industrialized countries committed to reducing their emissions by at least 5% compared to 1990 over the period 2008-2012. Despite significant results, the Kyoto Protocol underperformed. At the time of signing, the participants represented more than 65% of global GHG emissions. Unfortunately, in 2012, this percentage had dropped to less than 15. The Kyoto Protocol has nevertheless allowed for progress, particularly by inspiring the mechanisms behind the carbon markets.

In 2009, the Copenhagen Accord was presented during the Conference of the Parties 15 (COP15) by a few countries. Rejected by the majority, it has no legal value. However, it marked a step forward because it introduced the need to limit global warming to 2°C: "*To achieve the ultimate objective of the Convention to*

stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change" (UNFCCC, 2010).

Afterwards, the Paris Agreement was signed by 195 of the 197-member countries of the United Nations at COP21 in 2015. This treaty sets the upper limit of the average temperature rise to "well below 2°C" and calls for "further action" to keep it below 1.5°C by 2100. Reaching this ambitious goal calls for a "balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of the century." The Paris Agreement was probably widely adopted because it is not very binding. Unlike the Kyoto Protocol, it allows countries to fix their own GHG emission reduction targets. Governments must then review and submit their contribution intentions every five years. There is no penalty for noncompliance, but the review and reporting processes are mandatory. Interestingly, the Paris Agreement aligns on the Luhmannian approach to social system when it recognizes communication as a key strength. The communication events that the Agreement mechanically generates is expected to mobilize social pressure, increase social awareness and alignments across the scientific, the political and the economic system.

4. Discussion: towards a corporate communication addressing carbon budget and temperature trajectories?

The debate over what information companies should disclose in their corporate reporting to determine the link between their activities and global warming has been heating up in recent years. For instance, the trustees of the IFRS Foundation issued a consultation paper in 2020 to determine whether there is a need to develop global sustainability standards, with a particular focus on climate issues. In the end, "*the majority (72%) of academic submissions were opposed to the IFRS Foundation Trustees' proposals on key issues. This dissenting majority collectively have substantial research records in sustainability reporting and its outcomes. Those supportive were significantly less likely to reference research or state their credentials and, despite being supportive, nevertheless raised concerns with the proposals"* (Adams and Mueller, 2022). This illustrates the challenges of this type of reporting and the dangers of an unscientific, purely financial approach.

To date, a variety of parameters, including GHG emissions, can be given in non-financial reports to help investors assess risks likely to affect company value. Are they relevant? Put another way, how to define corporate climate performance to credibly report on global warming? The following sections discuss the meaning of commonly used indicators, and then address the notions of climate trajectory, carbon neutrality and carbon offsetting. They end up with the CARE model, an integrated accounting framework appropriate to meet these challenges.

4.1. Commonly used climate indicators and their limitations

Organizations provide their GHG emissions from scopes 1 and 2, sometimes 3 in their non-financial reports. As mentioned above, the economic system favors the outside-in perspective over the inside-out one. Because of this bias, it ignores climate risks and focuses on climate and carbon dangers that are of primary concern to the investor, with risks and dangers understood in the Luhmann sense. Scope 1 and 2 emissions are useful for assessing carbon dangers, while scope 3 emissions are necessary for evaluating climate risks. Without this last input, the implementation of measures to limit climate risks is futile. Let us consider the data given by two oil and gas companies, Shell and Total, that disclose their scope 1, 2 and also 3 emissions. Over the last few years, their scope 3 emissions are much larger than those of scopes 1 and 2, those of scope 1 tend to decrease while those of scope 2 remain roughly unchanged. Beyond these conclusions, such data do not indicate how well both companies meet the objectives of the Paris Agreement. Moreover, the methodologies used to estimate emissions vary. Shell applies the approaches developed by the IPCC and the GHGP, whereas Total relies on the International Petroleum Industry Environmental Conservation Association's guide. The lack of an international standard penalizes comparison. Non-financial reporting also provides carbon intensity, which is the ratio of GHG emissions to the amount of energy produced. In 2020, Total announced its intention to reduce the average carbon intensity of energy products used worldwide by its customers by at least 60% by 2050. However, lower intensity can mean more GHG emissions when combined with more energy produced. In short, one can put less carbon per produced unit but more cumulated carbon if activity increases. Clearly, information on GHG emissions is not sufficient on its own to figure out the efforts of companies to limit climate change.

A further component is the target. Why did international fora limit global warming to 2°C? Why

did the Copenhagen Accord, and then the Paris Agreement, set the limit at 2°C? The Copenhagen Accord favored this threshold to avoid "*dangerous anthropogenic interference with the climate system*" that would occur for larger temperature rises. However, harmful effects are expected even below 2°C. Defining a temperature threshold emphasizes how meaningful the notion of critical natural capital is. According to Ekins (2003), this critical capital includes the set of environmental resources and services, which provide life-support functions essential to human well-being, and "*for which there is no substitute type of capital, natural or human-made*". The emission of too much GHG will cause a substantial change in the environment, making it potentially hostile to living species. The well-being, even the survival, of future generations then depends on the respect of certain natural thresholds. Put differently, we suggest that the concept of strong sustainability (Dietz and Neumayer, 2007) should also drive the definition of climate performance. At this point, the challenge consists in identifying the critical thresholds and their values. Have we already passed them? Do current physical and chemical conditions allow climate change to be self-sustaining? Are there feedback loops that could significantly slow down global warming? These questions remain unanswered. Considering the temperature target is set, the notion of carbon budget then takes on its full meaning. As a reminder, this budget corresponds to the "*estimated cumulative net global anthropogenic CO₂ emissions from the pre-industrial period to the time that anthropogenic CO₂ emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions*" (IPCC, 2018). The RCPs developed by the IPCC help determine a budget for a given temperature increase, hence for a maximum warming of 2°C. However, the relationship between zero GHG emissions target and temperature targets is not straightforward. It may be more appropriate to refer to the goal of zero CO₂ emissions, rather than GHGs, to comply with the Paris temperature objectives (Tanaka and O'Neill, 2018).

The link between derivatives and integrals is the same as between flows and stocks. In this sense, annual GHG emissions correspond to flows, and carbon budgets to stocks. To evaluate the alignment of companies with the objectives of the Paris Agreement, a first approximation consists in checking that the cumulated GHG flows do not exceed the still available carbon stock (IPCC, 2018). Therefore, both flows and stocks must be considered for quantifying climate performance. The time scale of global warming is another concern. Because of its significant duration compared to human scale, it is hardly perceived. This

recalls the boiling frog syndrome. Suddenly put into boiling water, the frog hops right out to save itself from death. In water slowly boiled, it does not feel the deterioration of its ambient conditions and it is ultimately boiled alive. In both cases, the quantity of heat is the same, but not heat flux. Bateson (1979) wondered whether human beings, who are progressively destroying the Earth and its resources, are not finally behaving like the frog. This pleads in favor of incorporating long-term views in the evaluation of climate performance.

Finally, the impacts of human-made GHG emissions are felt at the Earth scale. Therefore, carbon budgets are estimated at this same scale given the current scientific knowledge. Bringing budgets back to the firm requires downscaling methodologies. This calls for transferring a global budget to countries, then to industrial sectors and finally to organizations. Defining a suitable distribution rule is the key. In the case of the European carbon market, member states define carbon credit allocation principles and propose national allocation plans subject to approval by the European Commission (Bayer and Aklin, 2020). For instance, the French allocation plan attributes a maximum number of carbon credits per targeted sector depending on its reduction potential and growth forecasts. This number of credits is then redistributed to the firms in this sector according to their past emissions. Another example is given by the science-based targets initiative, launched in 2015 by the World Wildlife Fund, the World Resources Institute, and the CDP. It proposed treating the carbon budget and GDP in parallel, which may be appropriate as long as both are correlated. The carbon credits assigned to a company then depend on its gross profit relative to the sum of the gross profits of all companies. Overall, the determination of a distribution rule accepted by all parties must account for multiple perspectives: historical responsibility of nations, number of inhabitants, economic growth and potential...

4.2. Temperature trajectory

The above discussion highlights the need to revisit the assessment of corporate climate performance and to strengthen the coupling between the scientific, economic, and political systems by defining a medium able to properly capture the impact of company's activities on global warming.

Various methodologies have been developed to quantify the emissions associated to asset portfolios and to evaluate their resulting climate performances (Raynaud *et al.*, 2020). The 2° Investing Initiative think tank introduced the concept of portfolio alignment to go beyond the limitations of conventional carbon

footprint analysis (Thomä *et al.*, 2015). The idea consists in measuring the portfolio alignment with the objectives of the Paris Agreement. Thus, the portfolio is said to be consistent with a temperature trajectory such as a 2°C, or whatever, trajectory. This methodology calls for a common parameter, that is the carbon budget, to connect temperature trajectories to technology trajectories. The RCPs built by the IPCC provide the necessary temperature trajectories that can be translated in terms of carbon budget. On the other hand, several organizations, including the IPCC, the IEA and BP, developed technology scenarios. Those ones correspond to technology, energy, and infrastructure packages consistent with the carbon budgets of the RCPs. The differences between the scenarios result from the weighting of the means deployed that include energy sources and technologies for reducing, capturing, and storing GHG emissions. Referring to technology scenarios instead of RCPs reverses the paradigm since GHG emissions are no longer considered as an output, but as an input.

The 2° Investing Initiative approach makes it possible to shift, at least partially, the concept of climate performance from theory to practice. In the case of energy, the mix characterizing a specified asset portfolio is used to determine a technology scenario: the portfolio is translated into technology segments with barrels of oil, m³ of gas, GWh of nuclear, wind or solar power... In addition, data providers give the required information to determine the asset evolution over the next 5 to 10 years. Then, if the composition of the portfolio remains unchanged over time, its technology projection can be compared with the first few years of a target trajectory to evaluate its alignment. Such a method permits to monitor the evolution of a portfolio compared to a temperature trajectory and to predict potential departures.

However, the mechanism still has weaknesses. The comparison of trajectories over short periods of time makes it difficult to identify departure points. Also, the technology scenarios provided by the IEA are based upon hypotheses that reflect the agency's perception. They assume an average annual growth rate of 3.4% between 2017 and 2040 and mainly mobilize the following low-carbon solutions: nuclear and renewables energies, energy efficiency, carbon capture, utilization, and storage (CCUS), and reduction of methane emissions in the oil and gas sector. Because the model is situated at the aggregate level, no specific actions are envisioned to account for changes in individual behaviors. Considering additional alternative scenarios is necessary for deeper analyses. Last, the forecasts about the technology evolutions of firms are subject to

uncertainties. Besides, similar methodologies have been developed by various groups: they yield different results because they rely on different assumptions. For example, the analysis of the alignment of the Euronext Low Carbon 100 Europe index with 11 existing methodologies yields trajectories corresponding to average warming ranging from 1.5 to 3.5°C (Raynaud *et al.*, 2020). Larger dissimilarities can be even pointed out for individual firms.

We then propose to stick to the concept of alignment with a trajectory. For a given company, and considering the three emission scopes, there are three relevant components: the initial trajectory that is the company's trajectory defined by the previous three to five years; the target trajectory that aims to keep global warming below a specified level; and the position achieved for the year under consideration. Climate performance can be viewed as the difference between the current position and the target trajectory relative to the difference between the initial and target trajectories. In other words, it reflects how close or far the firm is from the target trajectory. Such a definition removes at least some of the drawbacks outlined in the previous section. First, it is more informative than GHG emissions alone. It better captures company's efforts to align with a global warming target. Second, the chosen objective can be translated into a carbon budget, which refers to the strong sustainability paradigm. Third, both flows and stocks are considered: flows are given by the trajectory, stocks by its integral. Last, the definition of a trajectory helps to project oneself into the future. This could improve the coupling between scientific, social, and economic systems although there many questions remain.

4.3. Carbon neutrality and offsetting

Let us now consider a company claiming to follow a trajectory consistent with the 1.5°C global warming target. This trajectory reaches carbon neutrality by 2050. Is this statement sufficient to guarantee the company's effective contribution to constrain global warming?

The Paris Agreement is the first international treaty to mention carbon neutrality. This notion underlies the search for a balance that is achieved when human-made GHG emissions are offset either by lessening emissions in the atmosphere or by stimulating sequestration in carbon sinks. Those ones are natural or human-made reservoirs that accumulate carbon. They include forests, soils, underground geological storage... Their influence can be amplified, for instance by increasing forest surface areas, by modifying agricultural practices to promote carbon absorption in soils or by creating and operating geological storage

sites. This is the basis for carbon offsetting. It permits an organization to neutralize its incompressible emissions by financing projects that avoid GHG emissions. In practice, carbon offsetting is used to compensate any kind of GHG emissions, not only the incompressible ones. This principle, although valuable, has negative counterparts (Allen *et al.*, 2021). It can be compared to the indulgence trade of the Middle Ages, which allowed rich people to buy remission for the punishment of sins. Shortly, a company that finances offsetting projects is cleared of its own emissions. This does not motivate any change in its activity or production processes since offsetting is usually less expensive. Offsetting generates a geographical, but also temporal shift: the emissions are made here and now, the counterpart there and later. A company can release a certain amount of GHGs into the atmosphere while offsetting them by creating a tree plantation. As trees grow slowly, carbon storage is not effective when the offset option is activated. In addition, there is no guarantee that the planted trees will survive, as they can suffer from fire, drought, disease, *etc.*

This questions the relevance of the offsetting concept in its current format. Cames *et al.* (2016) analyzed the results of the Clean Development Mechanism established by the Kyoto Protocol. This mechanism allows industrialized countries to get the carbon credits generated by offsetting projects operated in developing countries. Out of 5655 financed projects, 85% had a low probability of achieving the promised emissions reductions while only 2% met their targets. The activation of offsetting options underlines the need to properly account for inside-out effects, whether directly or indirectly related to company's activities, and to assess the associated uncertainties. This also calls for defining the CO₂ scope considered by the interested parties. Consistency requires that GHG emissions be offset by emission reductions in the same scope.

Finally, organizations variously perceive carbon neutrality. Shell's and Total's announcements of "net zero" by 2050 do not have exactly the same meaning. Shell has committed to achieving carbon neutrality for its upstream operations by 2050, based on scope 1 and 2 emissions. Total is targeting the same goal for its worldwide operations. It has also announced that it will be carbon neutral in Europe for all its production and use of products sold to its customers in 2050 or earlier, which includes the three scopes. Moreover, some companies favor emission reduction while others prefer carbon credit purchase. Because of carbon offsetting, some can even claim to be carbon neutral while their actual emissions are increasing.

Another weakness is the possibly unlimited use of carbon credits: private markets are not bound by the supplementarity clause of the Kyoto Protocol that only permits a reasonable use of carbon credits on top of reduction actions. It is therefore essential that companies base their announced objectives on a shared definition. The implementation of carbon neutrality must be fully transparent, whether in terms of emission reduction or offsetting.

4.4. An integrated accounting framework: the CARE model

This discussion leads to the question of an appropriate framework for structuring accounting information, connecting financial and non-financial data (in an integrated way), taking full account of the above debate, and countering the ISSB's detrimental approach on climate change. A multi-stakeholder community³, federated today by the chair "Ecological Accounting", started a research project⁴ ten years ago to address this challenge with a dedicated program: the CARE model (Rambaud and Richard, 2015; Rambaud and Feger, 2020; Rambaud and Chenet, 2021).

Unlike neoclassical economics and (fair) value accounting, the model takes the notion of "capital" for what it is historically: a debt and not a set of assets (Richard and Rambaud, 2022). Moreover, environmental corporate accounting models grounded in a neoclassical approach with "value" created by nature and humans (including ecosystem services) are potentially incompatible with science-based and collectively accepted ecological conservation issues. They therefore depart from ecological strong sustainability.

CARE is different. It provides an operational accounting conceptual framework, which scientifically explores the convergence between historical cost accounting and ecological conservation issues. CARE originally extends the definition of financial capital as advance/debt to non-financial issues, such as human capital and natural capital. Following this model, and in line with a very strong sustainability approach, a natural (human) "capital" is a natural entity -like climate- (a human being), that is used, and consumed by the organization while operating its business model. The entity's existence does not depend on the organization's activity (including its productivity), but its preservation is considered necessary. A capital is therefore a "capital" or "paramount" entity. CARE generalizes the extension of the monitoring of the uses and consumptions of these capitals, in the organization's operating process. It sets the obligation

³ <https://www.cerces.org/>

⁴ <https://www.chaire-comptabilite-ecologique.fr/?lang=fr>

of their “reimbursement” in the long term, as a means of preservation. Therefore, it leads to the implementation of biophysical accounting systems and management dashboards adapted to these capitals, the separation between operating and preservation activities in the business models, and the valuation of these capitals on the basis of their *budgeted preservation costs*.

Table 1: Accounting for climate – CARE methodology. X t CO₂-eq: emissions beyond a carbon budget; Y \$: budgeted costs of climate preservation activities; Z \$: Actual costs (Z \$ ≤ Y \$) spent for climate preservation activities (it may remain a debt, financially assessed to Y-Z \$). 1) Climate preservation activities are classified according to the nature of these activities: purchase of machines or other fixed assets, service delivery, etc. 2) Climate preservation activities are classified according to the function of these activities, *i.e.*, the impact on the possibility to extinguish the climate debt: capture or storage of carbon emissions.

Operating ^a liability: Climate debt Operating asset: GHG warehousing Biophysical climate accounting	X t CO ₂ -eq	X t CO ₂ -eq
Operating liability: Climate debt Operating asset: GHG warehousing Financial translation accounting of this recording	Y \$	Y \$
Operating asset: Cash Preservation expense: Climate preservation activities (1) Actual expenditures of preservation (nature of expenditures)	Z \$	Z \$
Preservation revenue ^b : Climate preservation activities (2) Operating liability: Climate debt Actual expenditures of preservation and impact on debt	Z \$	Z \$

^a Operating activities/accounts are separated from preservation activities/accounts.

^b For CARE, first, costs are incurred (preservation expenses) and second, these are also forms of societal value creation (preservation revenues), as an opportunity for climate debt extinguishment.

Concretely, with respect to climate issues, the CARE balance sheet recognizes⁵ a liability, that is a biophysical climate debt, corresponding to the carbon emissions exceeding the “carbon budget”. The amount is also recorded as an asset, named “GHG warehousing”. Then, this debt is translated into a financial value, equal to the sum of all the (non-discounted) costs of the activities that will be dedicated to carbon capture or carbon storage, in the aim to extinguish this biophysical climate debt. Finally,

CARE’s profit and loss account recognizes the actual costs spent to (partially) settle this debt.

Table 1 shows the recordings recommended by the CARE model (Rambaud and Chenet, 2021). It illustrates the requirement for full alignment of accounting with scientific questions on carbon budgets, which are taken as a basis for defining the so called “capital-climate” (Rambaud and Chenet, 2021) and neutrality trajectories. CARE highlights how entities present in the social system borrow elements from their environment through their exploitation process. In the Luhmannian framework, the idea is transposed as that of all forms of organizations evolving in the social system borrow features such as mineral, atmospheric resources, but also human resources such as labor forces or intellectual abilities, from the social systems’ environment.

Consequently, the CARE conceptual framework re-problematizes and re-operationalizes the approach to climate change (Rambaud and Chenet, 2021). While the usual practice is to approach the issue first at the meso-level by focusing on corporate GHG emissions, and then moving to the macro-level with global warming (inside-out), CARE reverses the perspective, moving from the environmental macro to the organizational meso-level (outside-in). The relation is made visible through the concept of climate as a “natural capital/debt” to be preserved. Thus, CARE conceptually refers to double materiality, rejecting the pre-eminence of “financial capital” as the driver of ecological redirection. It yields a framework for moving towards better structuring of integrated accounting information on climate issues.

5. Conclusions

Luhmann's theory provides an appropriate framework for describing the complex interactions among political, scientific, and economic functional systems as they attempt to manage global warming. These systems do not share the same understanding of sustainability, partly because they do not consider the same time scale. As they are unable to process all the data from their environment, they focus on part of it only and develop functionalities on this basis. Specialization leads them to ignore data potentially important to perceive what sustainability is. Consequently, they may approach this concept incorrectly. The economic system can give its own definition of corporate climate performance, but this is biased because based on a perspective depending on its function. We also noted that this system favors an outside-in perspective, and that carbon accounting focuses more on assessing carbon danger than true climate risks, danger and risk being defined following

⁵ CARE is based on double entry bookkeeping.

Luhmann. As stated above, Luhmann's theory does not include a supra-system, and it seems that like the economic system, all existing systems are already too specialized to properly account for sustainability. These conditions argue for the emergence of a new system entirely dedicated to sustainability, just as the political, economic and scientific systems deal with politics, economics and science, respectively. Being new, this system should be able to process the data from its environment that are relevant to sustainability. It would then be able to properly define corporate climate performance and develop appropriate functionalities. As a first step, we propose to build the notion of climate performance on the idea of alignment with a trajectory and we suggest then a way to connect this approach of climate performance with corporate accounting through a dedicated model, the CARE model. For a given company, and with the three emission scopes, we look at the initial trajectory that is the company's trajectory defined by the previous three to five years; the target trajectory that aims to keep global warming below some threshold; and the position achieved for the year considered. Corporate climate performance reflects how close or far the firm is from the target trajectory. While the concept of a trajectory is debatable, if only because of its non-unique nature, it has some advantages over using GHG emissions alone. First, a trajectory-based definition captures companies' efforts over a broad period of time. Second, a global warming target corresponds to a carbon budget, a critical value not to be exceeded under the strong sustainability paradigm. Third, a trajectory-based definition integrates the concepts of flow and stock. Finally, it is a necessary step to project into the future. Carbon neutrality as introduced by the Paris Agreement means that the carbon emitted can be balanced or offset by the carbon adsorbed in carbon sinks. Putting this concept into practice requires a shared definition and transparency. It is essential to know what companies are emitting today, what they are doing to offset their current emissions, and when the offsetting is effective. Offsetting is not a neutral choice. It postpones a problem instead of facing it. Activating this option should be done with great care as it can lead to harmful consequences.

With the creation of the ISSB and the mission of the European Financial Reporting Advisory Group about the development of European sustainability reporting standards, climate reporting has never been so debated. As this paper shows, the balance between outside-in and inside-out perspectives is critical, and we hope to raise awareness among standard-setters. We encourage the ISSB to give due consideration to the impacts to the environment.

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