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Climate is a problem of stock, and this changes everything for corporate climate strategies

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Abstract

In the business and management literature on sustainability, climate change is mainly approached as a problem of market and technological change. By introducing "greener" technologies, products and practices, the objective is to shift towards more sustainable models, progressively decreasing the CO2 intensity of economies through the diffusion of green innovations. While fully understandable from the perspective of innovation, social change and the diffusion of technologies, this vision of the ecological transition stands at odds with the physical bases of climate change: climate a is not a problem of "flow" but a problem of "stock" (the stock of accumulated amount of GHGs stored in the atmosphere). This impact paper explores the tension between a "stock" and a "flow" vision of climate, and examines its implications in terms of mitigation and adaptation. Overall, we suggest that climate change involves a structural "clash of temporalities" between ecosystems and socio-technical systems. By viewing climate as a problem of flow, managers misconceive the issue of climate and vastly underestimate the truly radical nature of the social and strategic transformations required. We make recommendations to align corporate practices with a stock vision of climate change, such as thinking in absolute and historic impacts (instead of relative impacts), replacing the concept of carbon neutrality with the concept of carbon budget, dealing with business vs. climate antagonisms, and increasing attention to the issue of adaptation and corporate preparedness to deal with unavoidable future climate risks.

Keywords: climate change, corporate strategy, carbon budget, mitigation, adaptation

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Introduction

In the business and management literature on sustainability, climate change is mainly approached through the processes of an institutional, market, technological and individual transformation. For an industrial company to become “green” or sustainable -whether in the automotive, energy or air travel market-, it is expected to reduce its emissions while remaining competitive under the current regulatory and market conditions. This should be achieved through new product development, low-carbon technologies, process improvement or new types of services. By introducing “greener” technologies, products and practices, the objective is to shift our societies towards sustainable lifestyles, progressively decreasing the CO2 intensity of economies through the diffusion of green innovations and sufficiency. This gradual perspective of transition is fully understandable from a managerial (micro level) or economic (macro level) point of view.

From a managerial perspective, it is impossible to change a company or sector overnight. Research in sustainability has explored the opportunities and challenges of such transformations. At the corporate level, real-life examples (Patagonia, Interface, etc.) as well as academic research suggest that sustainability can be a source of competitive advantage; however, such conditions are complex and demanding. For example, research on sustainable business models underline the complexity and specificity of such models (Lüdeke-Freund et al. 2024). Implementing sustainable business models requires time as well as unique managerial and institutional capabilities (Acquier, Carbone, et Ezvan 2024). Such transformations are particularly difficult for incumbent companies in established industries. For such companies, “sustainable” initiatives co-exist and compete internally with ‘business as usual’ practices which are not easy to replace (the example of electric vs. classic combustion engines in the automotive industry is one of many).

From a more macro-economic point of view, change also takes time. Within innovation studies, analytical frameworks such as the Multilevel Perspective of Sustainability Transitions (MLP) (Geels 2011) have been introduced in order to connect micro (corporate or local level) with more sectoral / macro consequences. MLP posits that transitions -as well as resistance to transition- result from complex interactions involving three analytical levels: niches (where sustainable technologies and innovations are introduced), socio-technical regimes (industrial sectors, regulations and industry policies, market and consumer preferences, which are often based on non-sustainable routines and trajectories) and a socio-technical landscape (higher order landscape elements, such as institutions, demographics, etc.). Again, studies involving such multilevel analysis show the complexity and time required to scale a sustainable regime, or shift from “non-sustainable” to a new and more sustainable technology, even in situations of disruptive technologies.

In this context marked by technological lock-ins or organizational inertia, companies are considered sustainable when they progressively reduce their impact, develop and diffuse green technologies, etc. From this perspective, the constraints weighing on the transition appear to be essentially economic, social and technological. A "successful" transition must be socially acceptable, desirable and non-punitive, but also conducive to economic competitiveness. This means gradually reducing and substituting renewable energies for fossil fuels, and gradually switching to clean technologies. Eventually, as available

innovations become cheaper and more efficient, society and companies will have substituted fossil fuels with "clean" energies. “Carbon neutrality” is seen as the culmination of this process, at which point the climate problem may be considered solved (after all, our impact would then be neutral, as the concept tends to suggest).

While this vision of the ecological transition is understandable from an economic and managerial point of view, it stands at odds with the physical reality of climate change: climate a is a problem of stock (i.e. accumulated amount of GHGs stored in the atmosphere).

Climate change from the point of view of physics: a problem of stock

A major source of misunderstanding in the climate debate comes from a misrepresentation of the climate issue by managers: climate change and climate policies are often understood as a “flow” problem, whereas the physical reality of climate is one of “stock” (Sterman et Sweeney 2007; MacKenzie et Sahaie 2023).

From a physical perspective, climatologists are well aware that climate change is a problem of stock: the stock of greenhouse gases in the atmosphere (contributing to global warming) and also in the oceans (acidification). Because of the inertia of carbon in the atmosphere, burning fossil fuels and releasing them in the atmosphere will contribute to climate change over centuries. If we reduced these emissions - the opposite is happening on a planetary scale where emissions continue to grow (IEA 2024) -, the consequence would not be to reduce average temperatures... but to slow down the process of warming. This difference is fundamental.

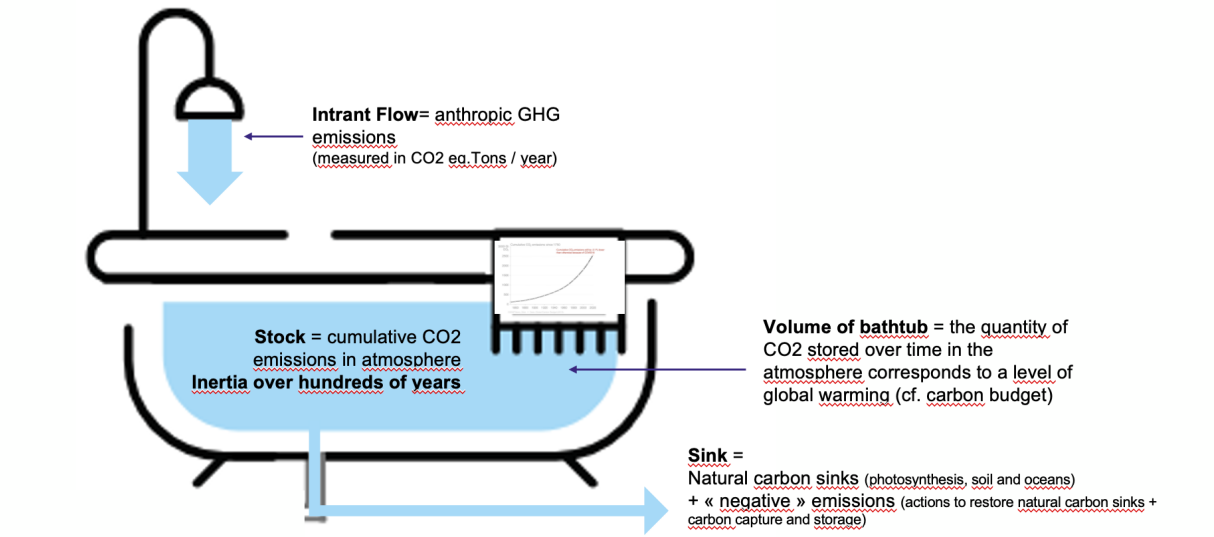

Figure 1 : Climate as a problem of stock: the metaphor of the tub

To illustrate the problem of climate as a stock, we can think of the atmosphere as a bathtub filled with CO2 (see figure 1). The tap -incoming flow- is made up of greenhouse gas emissions, largely linked to our use of fossil fuels -oil, coal, natural gas-. The bathtub fills up much faster than it empties. In fact, around half of our emissions are not evacuated through the drain which pours into the carbon sinks (photosynthesis, soils and oceans). It therefore adds to the stock, contributing to climate change for centuries to come. The filling level of our "atmospheric bathtub" is thus linked to the historical accumulation of emissions, which has a direct influence on the concentration of CO2 in the atmosphere (measured in ppm -particles per million-) - see figure 2.

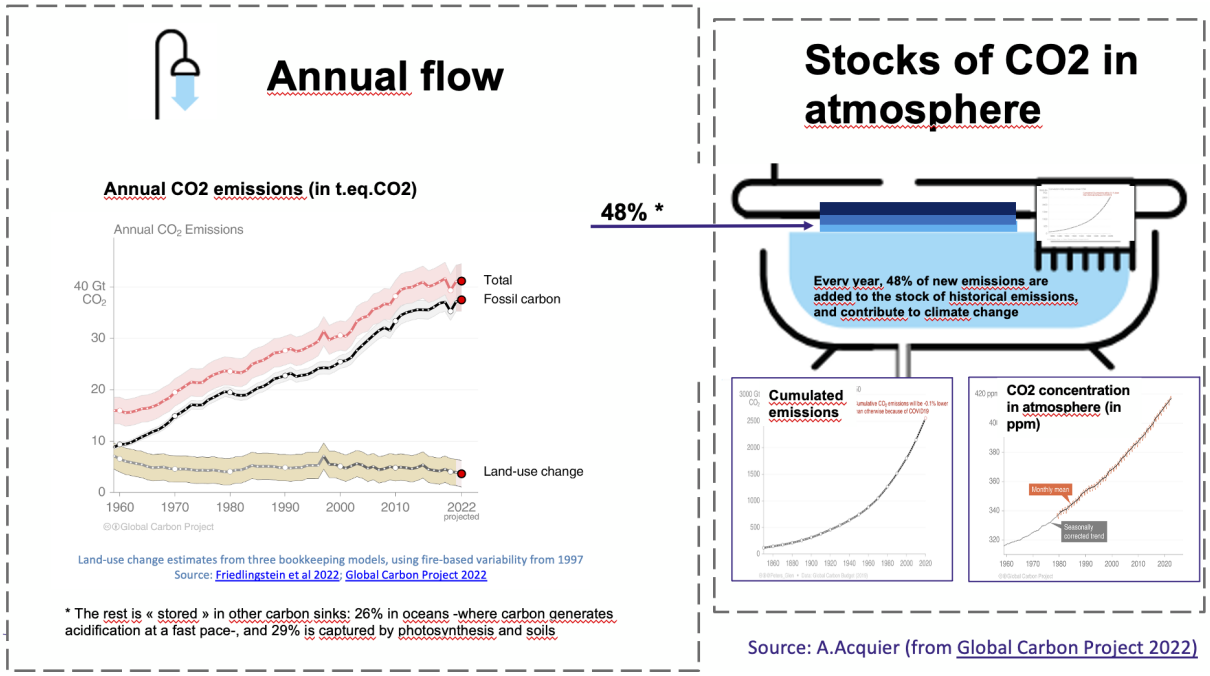

Figure 2: Articulating *flows* and *stocks* of CO2 emissions

The total volume of the bathtub (its "overflow threshold") corresponds to a certain threshold of global warming. Closely related is the concept of carbon budget, which measures the total volume of greenhouse gases that humanity can still emit in a given period of time before crossing certain warming thresholds. According to IPCC, at the current rate of filling the bathtub, it will overflow in approximately 5 years if the threshold is calibrated for 1.5 degrees of warming (with a 66% chance), and 15 to 20 years if the threshold is set at 2 degrees (with a 66% chance) (IPCC 2022).

Consequences of viewing climate as a problem of stock

The consequences of viewing climate change as a problem of stock are manifold. First, **reducing emissions does not in any way guarantee that climate change will be stopped or reverted**, **but only** - and that's already a long way off - **that the extent and speed of warming will be limited**. Indeed, slowing down the rate at which the bathtub fills up by turning off the tap is not enough to lower its level. This means that future climate change (and climate crisis) are already locked in by the inertia of our organizational, social, and economic systems. Said differently, it is virtually certain that the atmosphere will continue to warm up in the coming years and decades. This will bring new threats as each additional tenth of degree amplifies the risks. Climate change brings us into a new era of “locked-in future damages” which should compel us to radically rethink our relationship to risk and certainty.

Second, “stabilizing the climate” would require to reach **carbon neutrality** at a global level, i.e. a situation - largely hypothetical today – in which human removals of greenhouse gases compensate for human emissions. Therefore, **carbon neutrality will not reduce average temperatures, but only stabilize them** after a phase of anthropogenic warming: the moment of reaching carbon neutrality marks a point of arrival, and stabilization for the bathtub level, in which the inflows (emissions) would be equivalent to the outflows

(capture and sequestration devices). To reduce the climate, we would have to go beyond carbon neutrality, with *negative net emissions*.

Third, until this fictive scenario of carbon neutrality becomes real, **climate change is an *irreversible* process.** As climatologist and IPCC author Christophe Cassou points out, *"we are embarking on a one-way journey with no return, into uncharted territory"*. As long as human activities continue to emit more greenhouse gases into the atmosphere than they remove, global warming will continue. Extreme heat and precipitation records will fall regularly in the years to come. In this context, the very notion of "norm" tends to disappear: each year defines a new ***moving baseline***, shifting as new extremes are crossed. This journey leads us to "uncharted territory" because *homo sapiens*, our species, has never breathed such a carbon-rich atmosphere in its 300,000-year existence.

Fourth, **reducing our emissions will not be enough** to reduce temperatures, but it **is nonetheless essential**. Indeed, each additional tenth of a degree increases the number and scale of climate risks and disasters. As we fill the bathtub, our vulnerability increases and adaptation becomes more difficult and costly, until it becomes impossible beyond certain thresholds. The year 2023 has been marked by a multiplication of climate catastrophes around the world, from fires in Canada (where the equivalent of the surface area of Greece burned in 6 months) to floods that have claimed thousands of lives in Libya. The acceleration of these disasters and the scale of our vulnerability should give us cause for alarm, given that the climate has so far warmed by "only" 1.2 to 1.3 degrees since the pre-industrial era.

We can summarize the situation by drawing an analogy between the sustainability transition and a diet. When it comes to carbon, we are currently in a situation of obesity with significant morbidity risks. For this reason, the doctor (i.e. climate scientists and policy makers) prescribe a very drastic diet (i.e. reducing our consumption of fossil energy), but *without the perspective of losing weight* (as this is virtually impossible in the short- and mid-term) but only *to limit weight* gain under bearable proportions to avoid life-threatening risks (tipping points). At the same time, our body (the economy) would require additional calories (energy and materials) to cope with the inevitable health risks that will inevitably appear as we gain weight (investment in adaptation). Admittedly, such a diet doesn't look very appealing.

Flow, stock and the clash of temporalities and realities

This unappealing character suggests a fundamental tension between existing processes of economic and social greening (which are gradual by nature) and the accumulative nature of climate change. We are confronted with a structural "clash of logics and temporalities" between ecosystems and socio-technical systems.

By viewing climate as a problem of flow, managers misconceive the issue of climate and vastly underestimate the radical nature of the social and strategic transformations implied by the battle against climate change. Several academics cast doubts on the very possibility for our societies to transition towards green sources of energy. Based on an historical and statistical analysis of the evolution of energy technical systems and material consumption, Jean-Baptiste Fressoz questions the very possibility of an "energy transition" (Fressoz 2024). On the contrary, historical data on energy consumption suggests a process of accumulation -not substitution- of energy sources (see also figure 3), leading to a constant rise in total energy consumption (see also York et Bell 2019). And studies exploring the possibility of decoupling economic growth from carbon emissions reveal an

inconvenient truth: nowhere -not even in high-income countries- is decoupling happening fast enough to comply with low-carbon trajectories (Vogel et Hickel 2023).

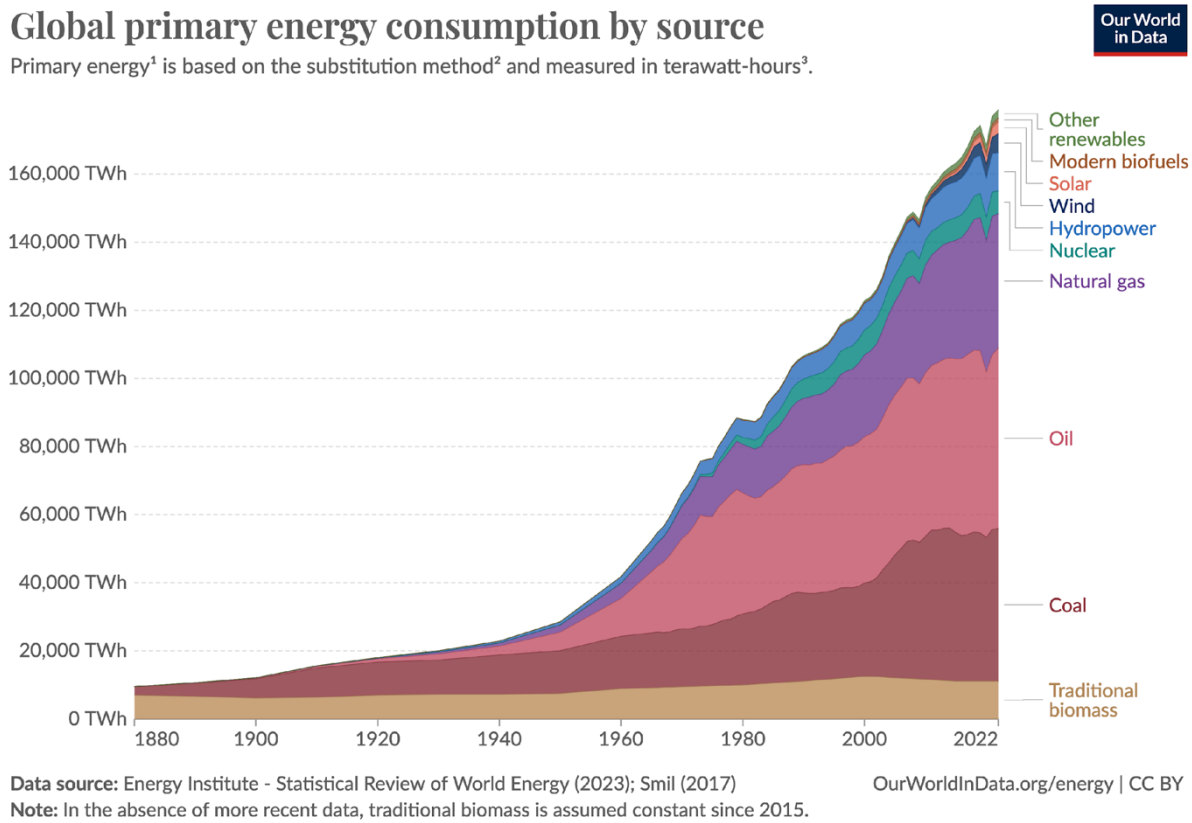

Figure 3: Growth of global primary energy use by source, 1880-2022

Managerial and policy recommendations

Various recommendations can be made to realign economics and management with the physical reality of climate change. The issue, overall, is to develop more accurate managerial perceptions of the climate issue and better integrate it with the accumulative nature of climate change. A few simple rules and principles of action could help managers to develop more robust and relevant climate strategies:

1. *Thinking in absolute volumes instead of relative decrease and efficiency improvements*

In order to make climate objectives compatible with business growth objectives, many companies are tempted to set corporate targets on efficiency improvement. Even standard setters, such as the Science-Based Targets Initiative (SBTi), allow high-growth companies to take commitments based on efficiency improvements. However, such approaches can be deceptive: for example, an automotive manufacturer communicating on fuel efficiency improvement per vehicle may fail to account for volume effect related to growth in sales volumes, also known as rebound effects (Greening, Greene, et Difiglio 2000). If they want to account for their actual impact on climate change, companies

should communicate on absolute volumes of CO2 decrease across all scopes of its activity, instead of just focusing on relative impacts.

2. *Considering historic, cumulated emissions instead of "spot" emissions*

Existing corporate and government commitments towards "net zero" emissions reflect the inability of current thinking to think in historical cumulated emissions. By focusing on flows and the point of arrival (for example 2050 as the target year to reach net zero), climate neutrality claims neglect the stocks of cumulated emissions and the corresponding decarbonization trajectory. Yet it's not just the date of achievement of hypothetical carbon neutrality that counts: the trajectory is just as important. As the two carbon-neutrality trajectories in figure 4 indicate, achieving carbon neutrality in 2050 will be far "CO2 heavier" if emissions continue to rise until 2040, only to fall sharply in the final years (scenario 1), than if they decline steadily over time (scenario 2). While the two trajectories lead to carbon neutrality in 2050, they differ considerably in terms of warming trajectories: trajectory 1 emits three times more CO2 than trajectory 2 (see figure 4).

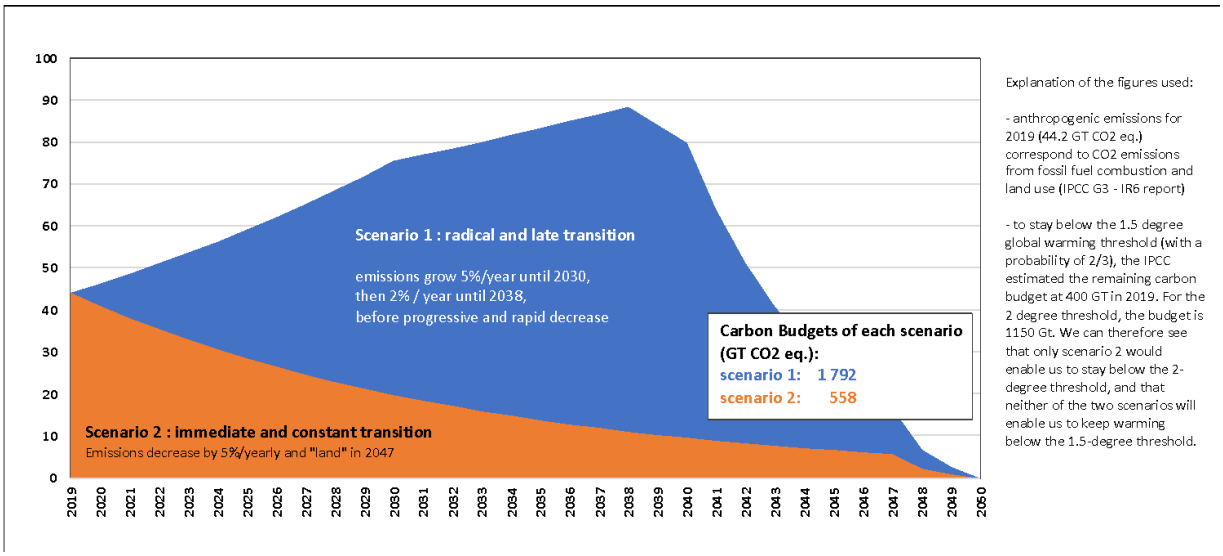

Figure 4: Two scenarios of carbon neutrality with varying yearly emissions (emissions GT CO2 eq./year)

For this reason, we need to systematically question claims around "carbon neutrality" or "net zero targets", which have a number of weaknesses, starting with their distant nature in time (who can project to 2050?) and the failure to take into account the trajectories leading to neutrality. In this respect, the **notion of carbon budget has many advantages over that of carbon neutrality**: beyond the point of arrival (carbon neutrality), it takes into account the reduction trajectory leading to it.

3. *Build a two-legged corporate climate strategy dealing with mitigation and adaptation*

Relatedly, the focus on "carbon neutrality" tends to put all light and efforts on the issue of mitigation, i.e. strategies to reduce greenhouse gas sources and emissions. By contrast, it tends to detract the attention away from the damage caused by each greenhouse gas emission trajectory. This reflects a key problem in current climate strategies, which are too much focused on climate mitigation (i.e. strategies to reduce GHG emissions), and tend to neglect the issue of adaptation (i.e. the process of adjusting to actual and expected climate change, its effects and unavoidable consequences).

This is all the more important as all climate emission scenarios (including the most optimistic ones) will create irreversible change in living conditions. Current and future climate change will generate new risks and disrupt the way we live, travel, live, feed, care, produce, educate and so on. All this should force us, in addition to mitigation strategies, to think about the transformation of our societies, ecosystems and common goods - such as water, air and biodiversity - and to act to reduce our vulnerabilities in the face of inevitable climatic damage. Adaptation will require economic investments from public and private actors, which should be at the core of the discussions in climate strategies. One of the major challenges -both at the managerial and more political level- is to consider these issues within a framework of equity and social justice.

4. Identify business vs. climate antagonisms

In this context, most companies will face business & climate antagonisms (Peyretou 2023) based either on a) structural contradictions between their business vs. climate objectives (ex: volume-based business models), or b) particular vulnerabilities of their operations or supply chain on the front of adaptation.

Businesses should start with clarifying business vs. climate antagonisms, and explore how to deal with them: Should companies consider stopping some activities which appear incompatible with a low-carbon society, shifting business models towards service-based models, and/or engaging in strategic diversification? Which efforts should they engage to map the inevitable future climate risks and engage investments towards adaptation?

5. Reconsider the semantics of climate change

Lastly, we should choose the words and concepts with care, and reconsider the semantics of climate change. In particular, the previous analysis suggest that terms such as *"the climate crisis"*, *"transition"* or *"carbon neutrality"* convey an erroneous imaginary in which climate change is seen as a temporary, episodic problem that can be resolved by a low-carbon transition. This is false: global warming is chronic and structural. We have entered a new climate regime that represents an irreversible transformation of the Earth system. There is a need to rebuilt concepts which better reflect the irreversible nature of climate change. As well, we need to reconceptualize the concept of risk to reflect how certainty reshapes the relationship between risk, certainty and uncertainty in new unexpected ways.

Conclusion

"When the bathtub overflows, before mopping and repairing the drain, it is recommended to turn off the tap". (popular wisdom)

Over the past years, various calls have been made to take stock of the multidisciplinary, interconnected and systemic nature of sustainability (Baudoin et al. 2023), involving major disciplinary shifts for management (Acquier, Mayer, et Valiorgue 2024). Next to the necessary inputs of social sciences (sociology, public policy and philosophy), this paper is a call to better integrate inputs from physical and natural sciences, which are critically important to build coherence between sustainability management models and the natural and physical dimensions of sustainability (Whiteman, Walker, et Perego 2013; Schad et Bansal 2018).

Focusing on the case of climate change, this paper has shown how sustainability management appears partly disconnected from the physical and natural realities of sustainability. By viewing the issue of climate as a problem of flow, managers (as well as many political and economic decision makers) misconceive the issue of climate from a physical point of view, and vastly underestimate the radical nature of the social and strategic transformations required to address climate change. Realigning business thinking and education with sustainability is an important challenge. A first step is to boost the literacy of managers, policy makers and academics on a) the physical and natural foundations of sustainability and b) bring them to reflect on how management tools or public policy frameworks build on relevant or false hypotheses related to the natural constraints of the phenomenon we are trying to manage. Clearly, addressing the sustainability challenge calls for a deep and courageous reimagination of business schools research and curricula.

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