

# *Climate change and financial risk*

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## **Table of contents**

1-	Introduction: the short history of climate change related risks for the financial sector ..	2
	The early days of climate change in finance .....	3
	An important issue for ‘responsible investors’ .....	4
	The acceleration .....	4
	Climate policy meets finance .....	7
2-	Climate change as a ‘new’ source of financial risk.....	7
	New types of financial risks .....	7
	Transition risks .....	9
	Physical risks .....	10
	Are those new types of risk priced by markets? .....	12
3-	The approaches to manage climate-related financial risks .....	16
	Materialisation channels of climate-related financial risks .....	17
	Climate scenario analysis .....	18
4-	Climate change risks and financial regulation .....	21
	Reporting and disclosure of climate-related risks .....	21
	Beyond reporting, an enhanced prudential framework .....	25
5-	Conclusion.....	27
	REFERENCES.....	30

*This paper is an introduction to climate change risk for the financial sector (banks and investors). We propose to cover how it emerged, what it means for financial institutions, what are the specific types of approaches to address it as well as current related developments in the industry, how regulation is approaching the question, and what are the next steps for academic research. The paper is aimed at financial professionals, researchers and policymakers in the area of banking and investment who seek to understand where this new field of research currently is and what evolutions are to expect. The paper's ambition is to provide the reader with a snapshot of the current state of the art and guidance on the relevant literature to go further.*

## ***1- Introduction: the short history of climate change related risks for the financial sector***

Since the creation of the Intergovernmental Panel on Climate Change (IPCC) in 1988,<sup>1</sup> the reality, extent and cause of climate change have been progressively understood and acknowledged by a broader part of the population, including economic decision makers. But while the scientific proofing of the anthropogenic origin of global warming gave rise to a gradual apprehension of the issue by policy makers and industry leaders around the world, the financial system has remained surprisingly long absent from this discussion. The situation has changed quickly: in the space of just a few years, finance has joined the forefront of the climate change economic debate, together with principal GHG<sup>2</sup> emitting

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<sup>1</sup> <https://www.ipcc.ch/about/history/>

<sup>2</sup> GHG: greenhouse gas

sectors such as fossil fuels. The following briefly unfolds the main steps of this short history, focusing on the risks that climate change is posing to the financial sector.<sup>3</sup>

### *The early days of climate change in finance*

For many years, climate change for the finance industry has been understood by market players and regulators as a totally exogenous perturbation that would be nothing more than a bunch of weather perturbations that already occur potentially everyday everywhere, and would eventually, if really things go bad in several decades, be addressed through their operational risk framework. The main feeling was indeed along the line of “Move along, nothing to see”, as climate change was not supposed to be a concern for the financial sector, if ever a reality, but rather a long-term issue for policy-makers. The first financial institutions that started in the early 2000s to work on climate change approached the question from their project finance activities, as part of their social and environmental risk appraisal,<sup>4</sup> which was more about risk from the project to the environment than risk from the environment to the project (a kind of climate change denial *per se*). One of the principal motivations was to respond to the growing pressure from environmental NGOs about the most polluting energy projects, in a concern to manage their reputational risk.

The next important step was the rise of carbon markets, in the wake of the Kyoto Protocol that lead in 2005 to the creation of the European Union Emissions Trading System (EU-ETS)<sup>5</sup> that distributes carbon quotas that companies can exchange for their compliance. Some

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<sup>3</sup> In the paper, we consider the “financial system” or the “financial sector” from the capital markets point of view, and voluntarily ignore the insurance sector, which needs to be addressed in a different way. Therefore we focus on banks and investors.

<sup>4</sup> The only risk management framework to treat those issues at that time was defined by the Equator Principles <https://equator-principles.com>

<sup>5</sup> EU-ETS is the first major carbon market framework, and largest to date, cf. [https://ec.europa.eu/clima/policies/ets\\_en](https://ec.europa.eu/clima/policies/ets_en).

financial institutions, especially corporate investment banks, saw in carbon markets a new business, which they developed closely to their energy trading desks. This contributed to increase the level of knowledge and understanding in banks about climate change and related mitigation policies. But the relative flop of carbon markets, with a carbon price that never really took off so far, lead most banks to close their carbon market activities in the early 2010s.

### *An important issue for ‘responsible investors’*

The development of socially responsible investment (SRI) in the early 2000s progressively put climate change on the agenda of investors, starting from charity funds, and joined by SRI-engaged pension funds and asset managers. The objective was twofold, driven by an ethical approach (the moral imperative to fight against climate change), and prominently a risk management perspective — that *a priori* should not have been limited to SRI —, considering climate change to be a future source of risk for financial returns, as well as the perception of upcoming risk from a policy-driven growing price of carbon. See e.g. Richardson (2009) for a detailed description of the rise of climate in SRI.

### *The acceleration*

In summary, until ~2010 climate change for banks was essentially limited to carbon markets and project finance, while the responsibility over GHG emissions was fully left to banks’ clients’ decisions. On the investor side, climate change started to be included to some of the most committed SRI narratives and strategies, having basically no concrete impact on investment decisions and composition of portfolios, due to the lack of ambition of climate policies after the landmark Kyoto Protocol. The question of risk from climate change was at that time more seriously approached by insurers and re-insurers, whose core business was

intuitively more directly concerned, on their liability side. NB: we treat in this paper only the asset side of the insurance industry.

The mechanics of associating climate change and finance could have continued its slow catch on from then, but a combination of several events and initiatives lead up to a significant acceleration, especially in the build-up to the 2015 COP21<sup>6</sup> in Paris, which constitutes the cornerstone of our story. We propose here a selection of chronological events that had a substantial role in this:

- 2005: Several asset managers publish their financial portfolios' first carbon footprints
- 2007: European Investment Bank and World Bank issue the first "green bond"
- 2008-09: Launch of the first low-carbon stock indices
- 2011-12: Financial "carbon bubble" and "unburnable carbon" buzz
- 2012: China launches its Green Credit Guidelines
- 2013: NGOs launch their first large fossil fuels divestment campaigns
- 2013: First shareholder resolutions on carbon bubble and climate risk
- 2014: Launch of the UNEP Inquiry platform
- 2014: Investors pledges and high-level pre-COP21 policy push at the UN Climate Summit

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<sup>6</sup> COP21: 21st Conference of the Parties, in the frame of the United Nations Framework Convention on Climate Change (UNFCCC). Cf. <https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop>

- Oct 2014 - Sept 2015: Governor of Bank of England (BoE) and Financial Stability Board (FSB) Chairman Mark Carney comes out on climate risks for the financial system
- Aug 2015: France passes the Article 173 of the Energy Transition Act, on financial institutions' disclosure of climate risks
- Dec 2015: adoption of the Paris Agreement (esp. Art. 2.1(c) on finance flows) and launch of the Task force on Climate-related Financial Disclosures (TCFD) by the FSB
- Dec 2016: launch of the European High-Level Expert Group on Sustainable Finance (HLEG), which led to the publication of the EU Action Plan on Sustainable Finance
- 2017: introduction of a climate finance Bill by the California Senate
- Dec 2017: launch of the international Network of Central Banks and Supervisors for Greening the Financial System (NGFS)
- Mar 2018: publication of the EU Action Plan "Financing Sustainable Growth"

Among the multiple sources of information that detail each of the above (e.g. Dupré *et al.*, 2013; UN SG, 2015; Chenet *et al.*, 2017; Ducret and Scolan, 2017; ACPR, 2019), complementary insights about the chronology can be found among the 90+ reports published by the UNEP Inquiry platform between 2014 and 2019.<sup>7</sup>

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<sup>7</sup> See <http://unepinquiry.org>, and e.g. one of the last reports published by the programme: Zadek, S., Robins, N., 2018, "Making Waves - Aligning the financial system with sustainable development", UNEP Inquiry.

## *Climate policy meets finance*

Since the Paris Agreement (2015), ratified to date by 185 countries,<sup>8</sup> the objective of climate mitigation is clear: limiting global warming to “well below +2°C”. It requires to fully decarbonize the economy by the second half of the century, which means a fantastic energy and industrial revolution at global scale (e.g. Peake and Ekins, 2017). Financing such a radical transformation of the economy will require massive redirection of financial flows, for which public finance — traditionally at the core of climate finance — will clearly not be enough without substantial contribution of capital markets (e.g. Boissinot *et al.*, 2016; Louche *et al.*, 2019). This role of the financial system is now acknowledged by the Paris Agreement Article 2.1(c) that requires making “[...] *finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development*” (UNFCCC, 2015). This now constitutes the basic framework on which all financial institutions, private and public, work (e.g. BlackRock, 2016; Banque de France, 2017; Regelink *et al.*, 2017; Campiglio *et al.*, 2018; Carney, 2018; ING, 2018; Masson-Delmotte *et al.*, 2018; OECD, 2018; UNFCCC Standing Committee on Finance, 2018; Whitley *et al.*, 2018).

## *2- Climate change as a ‘new’ source of financial risk*

### *New types of financial risks*

The usual risk framework in finance, approaching risks through liquidity, interest rate, credit, market and operational risks, is currently not capturing risks coming from climate change.

First reason is that climate change, as explained in previous section, is a rather new topic for

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<sup>8</sup> <https://unfccc.int/process/the-paris-agreement/status-of-ratification>

financial institutions. Both in terms of knowledge and habit, risk managers and financial analysts are not well equipped to address climate-related risk. But what are those risks?

Since the publication of the TCFD report in 2017, the common understanding that prevails relies on splitting climate-related risk into two main categories: **physical risks and transition risks** (TCFD, 2017). This relates to the very nature of climate change, which needs to be quickly introduced.

Since the global recognition of the climate change problem in the 1980s, its anthropogenic root has been acknowledged and proven (IPCC, 2014). Climate change has therefore two aspects: the geophysical mechanisms that produce global warming and its impacts, and the socioeconomic processes at their origin. This corresponds to the dichotomy between the effects of climate change and its causes. Thus, fighting against climate change — the mitigation objective<sup>9</sup> — imposes to curve down greenhouse gas emissions (GHG) from human activity, and reach a level of emissions that is compatible with the maximum global warming level that is sustainable. This level, as inscribed in the Paris Agreement (United Nations, 2015), has been set in the objective to “*Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels*”. Reaching such a goal requires not only to develop low-carbon industrial and lifestyle alternatives, but to fully decarbonize our economies worldwide, i.e. reach a global “net-zero carbon” economy (e.g. Masson-Delmotte *et al.*, 2018; Millar *et al.*, 2018). As explained above, this challenge represents nothing but an industrial, energy, and economic revolution, as our economies and infrastructures still rely

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<sup>9</sup> The fight against climate change is usually split in two main streams: mitigation of the effects (decreasing GHG emissions) and adaptation to the residual effects (e.g. via an evolution of infrastructures).



deeply on fossil fuels and global emissions continue to grow (IEA, 2019).<sup>10</sup> Indeed, a net-zero GHG world would first rely on an energy system that, at global scale, does not produce a single kg of GHG, or that is able to capture and store forever the residual GHG emissions. In 2018, renewables all together (including hydropower) accounted for almost 25% of the global power output, with only 7% of the electricity generation coming from solar PV and wind (IEA, 2019). Besides energy, which represents about three quarters of the GHG global emissions, agriculture, land-use change, forestry, industrial processes and waste are also majors sectors and industrial activities that need to be fully decarbonized between 2050 and 2070 to reach climate objectives.

### *Transition risks*

Despite the science being clear about it for some time now, the IPCC having been created three decades ago, the complete decarbonization challenge is somehow only starting to reach significantly the policy space now, and very few companies are yet embracing it. In the face of the unprecedented transformation challenge described above, this transition to a global net-zero carbon economy will undoubtedly have significant consequences on economic agents, generating winners (typically those industries that can provide the economy with alternatives to carbon-intensive technologies) and losers (in particular sectors relying on fossil fuels, starting with coal). Those consequences will very probably impact the risk and profitability of financial assets. If such a transition can be seen as generating both

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<sup>10</sup> The International Energy Agency (IEA) in its 2018 Global Energy & CO<sub>2</sub> Status Report, reports that “energy demand worldwide grew by 2.3% in 2018, its fastest pace this decade, thanks to a strong global economy and higher demand for heating and cooling. Natural gas emerged as the fuel of choice, posting the biggest gains and accounting for 45% of the rise in energy consumption. Solar and wind generation grew at double-digit pace, with solar alone increasing by 31%. Still, that was not fast enough to meet higher electricity demand around the world that also drove up coal use. **As a result, global energy-related CO<sub>2</sub> emissions rose by 1.7% to 33 Gigatonnes (Gt) with coal use in power generation alone surpassing 10 Gt and accounting for a third of total emissions.**”

risks and opportunities (e.g. Stern, 2008), the more delayed and abrupt the transition will be, the harder those consequences of sudden adjustment from economic agents will be, and accordingly on financial assets, potentially leading to the quick stranding of carbon-intensive assets, and related propagation to a systemic financial instability (e.g. Carney, 2015; Gros *et al.*, 2016). This constitutes the “**transition risks**” to the financial system, i.e. the financial risks coming from the energy and industrial transition in the context of climate change mitigation. These transition risks can actually come from different direct and indirect sources, usually classified into policy and legal risks,<sup>11</sup> technology risks, market risks, and reputational risks (TCFD, 2017).

### *Physical risks*

The other side of the coin consists in the financial risks related to the physical impacts of climate change themselves. As mentioned above, global warming is a result of increasing GHG concentrations in the atmosphere. Those concentrations already exceed the safety thresholds, and because of the physical inertia of the climate system warming response, global temperatures will continue to grow even if emissions were stopped now.

Consequently, the impacts of physical climate change are delayed in the future, and even if the first effects of climate change are already present and documented, they represent only a meagre precursor of the most damaging consequences that are to materialize later, typically in a few decades, which is considered by most economic decision makers as ‘the long term’. For financial decision makers, reputed short-sighted, this is relatively even further away in time. If the initial effect of climate change is temperature rise, the indirect

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<sup>11</sup> NB: while the TCFD includes liability and litigation risks in the transition risk category, some alternative classifications propose it as distinct category, being potentially triggered directly by physical impacts of climate change as much as they can from transition impacts.

impacts are much more diverse. First, the warming effect from climate change is global, but with very high geographical and temporal heterogeneities. Then, it is the indirect consequences of this warming that will impact the most our societies: through modifications of the climate regimes (e.g. heatwaves, droughts, floods, extreme events) and their related impacts (e.g. on fires frequency, sea level, crop yield, fresh water availability). These physical risks from climate change are either categorized as ‘acute’, i.e. point-in-time risks generated by events (e.g. cyclone, flood) or ‘chronic’, i.e. resulting from evolving climate conditions (e.g. heatwaves, sea level rise). Physical risks affect the operations of organisations, potentially damaging their assets, or affecting their supply chains or conditions of work, as well as the demand side from clients and citizens. As such, physical risks can have financial implications for those organisations, which may propagate to their valuations or risk profiles via impacts on their income, cash flow, or balance sheet (cf. Figure 1).

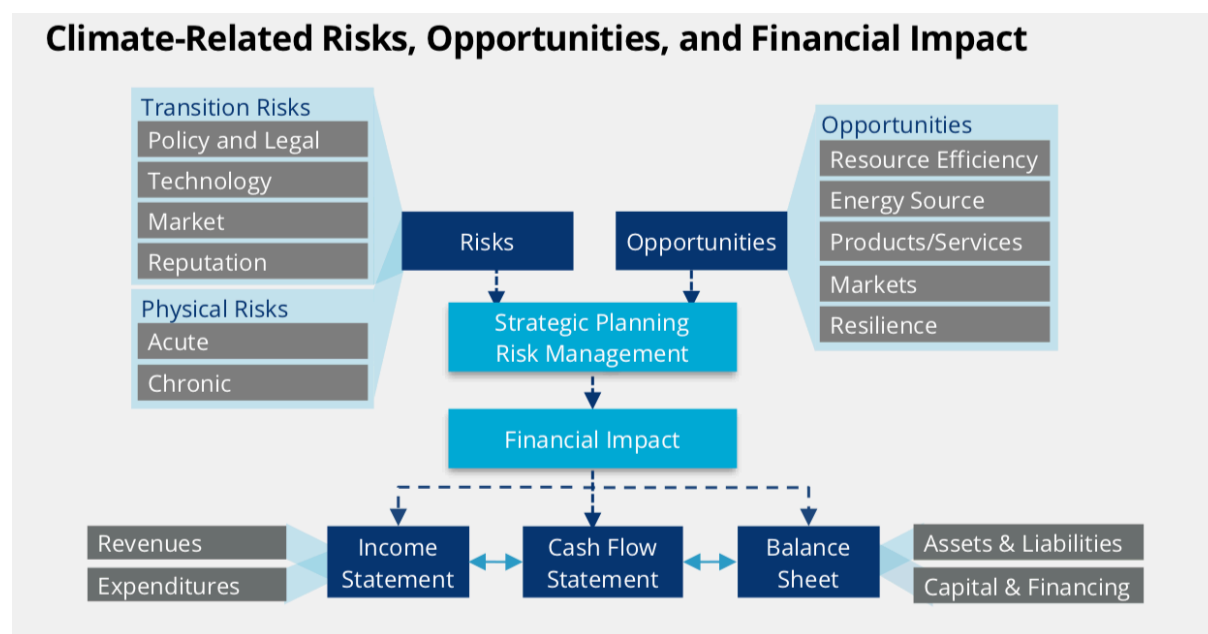


Figure 1: Climate-related risks, opportunities, and financial impact (source: TCFD, 2017)

### *Are those new types of risk priced by markets?*

Of course, risks coming from climate change, both physical and transition risks, are not completely new, and have somehow affected financial assets in the past. As such, climate-related risks should be captured by usual risk management frameworks, and would therefore not need specific attention compared to other types of risk. But there are several reasons why those risks parameters are probably not currently captured, i.e. not priced or mispriced, by financial markets, tending to turn down the pricing efficiency of markets (Thomä and Chenet, 2017). If so, this mispricing and subsequent misallocation justify the current specific attention devoted to climate-related risks in the financial sector, and the development of ad hoc approaches to manage them, both inside the market via dedicated tools and from a regulatory perspective via policies to fix market failures. The different causes of potential mispricing are explained below, following Thomä and Chenet (2017).

#### *Unprecedented phenomena*

First, the climate change we are experiencing is an unprecedented phenomenon at the scale of our modern economies, both in terms of scale and speed. Therefore, no record nor experience exist on how our economic and financial systems may react to those changes, whether shocks or trends. Consequently, no historical nor statistical data are available to feed the usual risk analyses that are performed on financial markets, typically based on ergodic models and sensitivities of financial assets to historical shocks (e.g. Beckert and Bronk, 2018). More broadly speaking, future will not be a replication of the past, and the understanding of past events and crises will be of little use to undertake classical risk management approaches for climate change risks.

### **Radical uncertainty**

The second reason lies in the definition of risk, in relation to the previous item. Since Knight (1921) and Keynes (1936), the distinction of risk and uncertainty in economics has been clarified relatively to the capacity to assess probabilities to possible events. Climate-related risks and in particular transition risks involve many situations of radical uncertainty, as opposed to so-called ‘Knightian risks’, which are computable. Indeed, the possible realisations and outcomes of the transition entangle both complexity (because of the intricate interaction of non-deterministic phenomena related to policy decision, industrial reaction, technological innovation, and legal, social, and consumer response) and multiplicity (because of the quasi-infinite combinations of those local and global scale evolutions throughout the century) that make those risks unmeasurable, unquantifiable, uninsurable and only characterizable in terms of qualitative possibility or plausibility (see also King, 2017; Boyer, 2018).

### **Non-normal probability distributions**

The third item relates to modelling approaches to risk and pricing, mostly relying on modern portfolio theory (e.g. Markowitz, 1952; Tobin, 1958; Sharpe, 1964; Fama, 1970) derived from early works from Bachelier (1900), which largely structures a simplified vision of risk where normal distributions are the rule (e.g. Walter, 2000; Thomä and Chenet, 2017). But climate-related risks are poorly fitting into normal distributions, with significant kurtoses and skews (e.g. Anda *et al.*, 2009; Calel *et al.*, 2015; DG Treasury, 2017), where ‘black swans’ are the norm (e.g. Taleb, 2007; Weitzman, 2012; Naqvi *et al.*, 2017). Indeed, climate-related risks involve probability distributions that come with ‘fat tails’, i.e. higher probabilities for extreme risks compared to the usual normal distributions (e.g. Halsnaes *et al.*, 2007; Hjort, 2016).

### **Bounded rationality**

The fourth reason why climate-related risks may be mispriced is related to a fundamental limitation of markets, coined by Hebert Simon (Simon, 1957; Thomä and Chenet, 2017) as ‘bounded rationality’, where market players in the face of complexity may need to construct a simplified model of the real world in order to deal with it. But behaving rationally to this simplified model does not guarantee an optimal reaction to the real world. If such simplifications are perhaps satisfying at limited scale, the generalisation of such approaches may lead to a collective misread of the reality, especially if associated to the herding behaviour present on markets that impedes single investors to ‘swim against the current’, thanks to the adage that it is better to be wrong in a group (e.g. Keynes, 1936; Christophers, 2017; Thomä and Chenet, 2017 and references therein). Therefore, despite climate change and related risks are now acknowledged by most financial institutions and financial system governance frameworks (e.g. Farid *et al.*, 2016; Banque de France, 2017; Pereira da Silva, 2017; EC, 2018; EIOPA, 2018; IMF, 2018; NGFS, 2018), the usual behavioural functioning of markets appears to preclude an optimal response to climate change and the real turnaround in terms of asset allocation has still not taken place (Christophers, 2019).

### **Discrepancy in time horizons**

The last point we emphasise here is undoubtedly the most fundamental one: time horizons discrepancy (e.g. Carney, 2015).<sup>12</sup> As mentioned above, while climate change already started to become tangible and acknowledged globally by most citizens and decision makers,<sup>13</sup> the

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<sup>12</sup> This speech from Mark Carney (Governor of the Bank of England and Chairman of the Financial Stability Board), “Breaking the Tragedy of the Horizon - climate change and financial stability”, on 29 Sept. 2015, constitutes a landmark for both the financial industry, the policy-makers and the academia. It was the first time that a ‘mainstream’ finance leader made such a ‘coming out’ on climate. The speech focuses on climate-related risks for the financial sector, and the potential financial instability (systemic risk) resulting from related time horizon mismatch.

<sup>13</sup> For instance, recently the bankruptcy of PG&E — California’s largest utility and one of the United States’ largest investor-owned electric utilities — is considered as an indirect impact of climate change. Cf. “*Pacific Gas*

most significant impacts will only happen in several decades. Transition risks may materialise earlier, as climate change and energy policies, low-carbon technology developments or changes of consumer patterns — expected to mitigate climate change before its main impacts — can become significant any time from now on. Nevertheless, the current very slow decarbonisation progress (e.g. IEA, 2019) and geopolitical context not in favour of international cooperation, make most observers fear a “too late, too sudden” energy transition (Gros *et al.*, 2016) that would probably not occur significantly before several years still. Such risk materialisation time horizons are long when compared to the usual horizons in finance. Investment portfolios display a typical turnover of about 1-2 years (Bernhardt *et al.*, 2017), and financial analysis is generally limited to 3-5 years (Dupré and Chenet, 2012; Naqvi *et al.*, 2017) while most portfolio managers’ incentives are on an annual basis (Thomä *et al.*, 2015). Even so-called long-term investors (e.g. pension and retirement funds) have artificially shortened time horizons: while on the liability side they are indeed responsible of their clients’ pensions over several decades, most often the management of the funds is entrusted to external investment managers whose mandates do not exceed 3 to 5 years. And very often, at the employee level, portfolio managers in those asset management companies are benchmarked on their short-term (weekly or quarterly) performance (Naqvi *et al.*, 2017). Credit institutions are usually exposed to slightly longer time horizons, having an average 3-5-year loan horizon (Thomä *et al.*, 2015; Cortina-Lorente *et al.*, 2016; Paligorova and Santos, 2017). In the bond universe, durations are longer and sometime can reach several decades, up to 50 years (e.g. EIB, 2004). But the vast majority of financial

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and Electric is a company that was just bankrupted by climate change. It won't be the last.”, Washington Post, Jan.30 2019, <https://www.washingtonpost.com/news/monkey-cage/wp/2019/01/30/pacific-gas-and-electric-is-a-company-that-was-just-bankrupted-by-climate-change-it-wont-be-the-last/>.

assets and related market operations is still short term (Haldane and Davies, 2011; Wehinger, 2011; Davies *et al.*, 2014; Cremers *et al.*, 2017; Kay, 2017).

### *Climate change inefficiently priced by markets*

In summary, for all the different reasons stated above, the dominant assumption at the base of the functioning of the financial markets since the 1970s, the efficient market hypothesis (EMH),<sup>14</sup> seems to be undermined when it comes to climate, and it is very plausible that climate-related risks are mispriced (Thomä and Chenet, 2017).<sup>15</sup> Consequently, financial decisions (i.e. buying or selling a financial asset) based on traditional risk pricing would be misinformed. This poses a dual problem: financial institutions cannot do their part to orient markets in the right direction to fight climate change (in other words, they cannot allocate capital optimally to the decarbonisation of the economy), and they are potentially overexposed to risk, opening the way to systemic instability (Battiston *et al.*, 2017; Campiglio *et al.*, 2018; Dafermos *et al.*, 2018; NGFS, 2018).

## ***3- The approaches to manage climate-related financial risks***

As we have seen in the first section, climate change risks for the financial sector were first approached as a reputational risk, and limited to specific business lines such as carbon finance and fossil fuel project finance. But the section 2- illustrated that the risks from climate change, whether physical or from the mitigation efforts (transition risks), may become material throughout financial institutions' activities. In other words, dealing with climate change for a bank or an investment company is not limited anymore to improving

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<sup>14</sup> The efficient market hypothesis (EMH) stipulates that on a market where all the relevant information is available to market participants, the market price of a traded security equals its 'fundamental value' (Fama, 1970).

<sup>15</sup> The report published in April 2019 by BlackRock, "Getting physical – Scenario analysis for assessing climate-related risks" (Schulten *et al.*, 2019), emphasises that physical climate risks demonstrate to be mispriced.



light bulbs efficiency in their own premises, nor to managing communication issues from a public affairs perspective. It is now a concrete matter for the core finance business, both in terms of risk and opportunity. For the sake of this paper, we will focus in the following on risk and risk management. Investment opportunities are for instance developed in (e.g. Guyatt and Chatterjee, 2018 and references therein).

### *Materialisation channels of climate-related financial risks*

The first step to manage climate-related financial risks is to understand where they come from. In the following we will leave aside the risks that can affect a financial institution (FI)<sup>16</sup> directly, in the same way that any other company or organisation can be affected, which are supposed to enter the operational risk management framework of the FI. Thus, we will focus on those risks that may impact the business activities, i.e. affecting financial assets.

Once materialised, both physical and transition risk sources have quite similar propagation patterns that can lead to financial risk. We take here the example of an industrial company 'A', but a household, an infrastructure project, a municipality, a state or any other type of economic entity being the underlying or the counterpart of a financial security would follow the same mechanics. First the conditions of operation of 'A' are changed, either because of a new law (e.g. a carbon tax is put in place), a new technology available (e.g. a cheap energy storage device is available on the market), a new climate regime (e.g. regularly warmer summers), a new client/consumer demand (e.g. local food products) or else. Under these new conditions, 'A' can be affected directly through its own operations but also indirectly, via its supply chain or its competitors' own operations. These changes may then have a long-lasting impact on its expenditures (e.g. higher energy costs) and revenues (e.g. decline

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<sup>16</sup> 'FI' will stand for 'financial institution' throughout the rest of the paper.

in productivity),<sup>17</sup> which modifies 'A's financial performance and risk profile. Both 'A's access to capital and market value can thus be affected. From the FI's perspective, climate change can hence lead to modify credit risk, market risk and liquidity risk.

The propagation chain is quite simple in the case of an isolated risk factor materialisation and if 'A' is a simple company owning only one single physical asset producing a single unchanging product, but it becomes more complex if 'A' is a multinational diversified company present in 100 countries and producing various families of merchandises and services, exposed to a broad set of physical and transition factors together. Moreover, each of the single transmission mechanics involved correspond to complex and agent-specific processes that are not simple — if possible — to model. For this reason, the assessment of climate-related financial risk needs to rely on different approaches, depending on whether it is expected to inform an individual asset or broader risk management at portfolio, FI, or financial system-wide levels.

### *Climate scenario analysis*

For the reasons highlighted in section 2-, the multiplicity of future realisations of climate change and related contextual anticipations and reactions from all the economic agents participating or influencing the market prevent any deterministic forecast of what will happen, beyond a few days horizon. Alternatively, a relative consensus emerged on the necessity to use scenario analysis as central approach to risk assessment (e.g. Batten *et al.*, 2016; DG Treasury, 2017; Regelink *et al.*, 2017; TCFD, 2017; Knight and Ganguly, 2018; NGFS, 2018). Indeed, instead of analysing the possible risk materialisation under a specific

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<sup>17</sup> We do not address here the case of insured losses, which transfer the risk to the insurance sector, but should not be significant to the entity in question from a single-event perspective.

expected future, scenario analysis proposes a ‘what-if’ analysis under a specific possible future, that can be reiterated for as many different assumptions as wanted. This avoids attributing scenarios a probability of occurrence — which in the case of climate change appears to be impossible (cf. section 2-) — and rushing into the ‘most probable’ one to undertake a single risk assessment. On the contrary, the logic of scenario analysis lies in the comparison of different possible futures, typically testing at least 2 options such as a baseline and an *a priori* adverse scenarios. This corresponds to the same rationale than regulatory stress-tests carried out by central banks and banking authorities (e.g. Chenet *et al.*, 2015).

One of the difficulties of such exercise comes from the long-time horizon at stake. While regulatory stress tests are performed on the basis of rather short time horizons (typically of 1-2 years maximum and often less than 1 year), in order to test the current resilience of banking institutions under possible shocks that can happen overnight to the economy, providing a snapshot of the present situation, climate stress tests and related scenario analysis have to cope with much longer horizons (say up to 30 years or more), to cope with the materialisation of climate risks. The extent to which the current portfolio composition or balance sheet of a financial institution is relevant to be tested with such a time horizon, which corresponds to a static assumption, is debated (e.g. DG Treasury, 2017). This explains why most of current climate stress testing exercises at portfolio or balance sheet levels focus on relatively short term, i.e. using scenarios or events which occurrence seem plausible in the 1-5-year interval (e.g. Regelink *et al.*, 2017; Thomä and Dupré, 2017; Vermeulen *et al.*, 2018; Battiston and Monasterolo, 2019; Ralite and Thomä, 2019). Nevertheless, even with their current limitations, such scenario analysis exercises are useful to explore the exposure

of a FI to specific risk materialisation, and to map and better understand the variety and transmission of risks depending on different assumptions of the future.

Usually, banks use scenarios that project specific economic and financial parameters in the future both at macro and sectoral levels, such as GDP, inflation, exchange rates, commodity prices, etc., because those parameters easily fit with the different types of models used throughout the bank and are well-known to most operators. But the difficulty for climate change is to translate the factors of transition risks (climate policies, technology evolutions, consumer preferences, etc.) and physical risks (variations in temperatures and rainfalls, extreme events intensity and frequency, etc.) into those macro/micro economic and financial variables, to be able to simply plug them in usual stress testing tools. Indeed, the relationships between climate-related variables and the economic and financial variables necessary to stress test the portfolios and balance sheets of FIs are not clearly determined so far, mostly because they are complex and unprecedented. Nevertheless, at this stage it is possible to build on different existing literature or to run specific models in order to collect some estimates on macroeconomic effects, sectoral effects, impacts on share prices, or impact on corporate/sovereign rating (Battiston and Monasterolo, 2019; Ralite and Thomä, 2019).

Such climate scenario analysis can be undertaken at different levels to challenge financial institutions' resilience, strategy, profitability or capital adequacy. Bottom-up analysis, financial asset per financial asset (typically at company level), is relevant from a financial analyst perspective, to inform investment decision, but is not compatible at the moment with a broader exercise at portfolio, financial institution or system levels, because such an aggregation of granular information and potential combinations effects are not fully

mastered. At sector level, climate scenario analysis can inform both banks and investors on their strategies and exposure, as well as supervisors from a macroprudential perspective. In order to simplify the exercise, alternative approaches consisting in stressing just one parameter of the scenario (e.g. carbon price) may also be useful as a first stage sensitivity test (Regelink *et al.*, 2017; Bank of England, 2018; DNB, 2018; Vermeulen *et al.*, 2018; ACPR, 2019a).

#### *4- Climate change risks and financial regulation*

We have seen in the first section that on the road to mobilisation of the financial sector for climate, several initiatives came from regulation. Since about 2015, several policy frameworks, involving both voluntary and compulsory provisions, created a real emulation. Providing for an exhaustive analysis of the current policy developments on climate-related financial risks is far beyond the scope of the paper, but it is important to understand the role of policy and regulation on the topic to grasp the present stand of the field and its fast evolution. Therefore, in the following we propose an overview of the key frameworks in place and under development.

##### *Reporting and disclosure of climate-related risks*

The principal stream of policy and regulation targeting climate-related risks deals with disclosure and reporting. Referring to our chronology above, this emerged essentially in the lead-up stage of the landmark COP21. The two main elements are the Article 173 of the French Energy Transition Act and Mark Carney's speech on the 'tragedy of the horizon'.

### *The Article 173 of the French Energy Transition Act*

On the road to the COP21 hosted in Paris, France passed in August 2015 its Energy Transition for Green Growth (ETGG) Act (often summarized Energy Transition Act). The Article 173 of the law requires new specific reporting on climate change, from both non-financial companies and financial institutions themselves (French Republic, 2015). Being a law, requirements are mandatory, but based on the “comply or explain” principle, letting institutions report with much flexibility on the tools and approaches they apply. Art. 173’s provision for institutional investors was internationally acknowledged to be a landmark and opened the way to similar discussions in many other jurisdictions (e.g. CS, 2018; EC, 2018; UKP, 2018). While the initial amendment proposal to the Bill of Law from September 2014 was only covering “carbon footprint of institutional investors’ funds”, the final text includes provisions at three different levels, significantly addressing the risk dimension but without constituting any constraint for FIs to fight against climate change beyond disclosing what they do:

- Corporate reporting requirements for listed companies, including banks:

Financial risks related to the effects of climate change and the measures adopted to reduce them, including the consequences on climate of the company’s activities and of the use of goods and services it produces (i.e. indirect GHG footprint).

- Climate risks assessment and reporting requirements for banks and credit institutions:

Risk of excessive leverage and the risks evidenced in the frame of the regularly implemented stress tests, to be disclosed in the mandatory annual risk report.

- Disclosure requirements for institutional investors:
  - Information on how their investment decision-making process takes environmental, social and governance (ESG) criteria into consideration, and the means implemented to contribute to the energy and ecological transition.
  - Their exposure to climate-related risks.
  - GHG emissions associated with assets owned.
  - Their contribution to the international and French climate goals.

Details of the provisions can be found in e.g. 2°ii (2015), FIR (2016) and Mason et al. (2016).

Since the first year of implementation (financial year 2016), several reviews were published that analyse the progress — if not the compliance — of financial institutions in this new reporting exercise, which state a strong heterogeneity in the types and depths of reporting as well as a broad diversity in the methodologies and approaches followed by FIs (e.g. TSP, 2017; WWF, 2017; Evain *et al.*, 2018; Redon *et al.*, 2018; ACPR, 2019a, 2019b). While the provisions of the law themselves were ambitious and outstanding, the implementation seems to many observers unsatisfactory and has not produced the expected changes in reporting practices that, for most of them, only aim to ‘tick the box’ rather than disclosing their strategies and risk exposures, as was expected by the regulator. It is worthwhile to notice that the climate stress-testing provision for banks has been unevenly interpreted by stakeholders, and as of today no French bank has undertaken, or disclosed, any proper climate-stress test (ACPR, 2019a), while some supervisors recently started developing their own approaches, in particular De Nederlandsche Bank (DNB) (Regelink *et al.*, 2017;

Vermeulen *et al.*, 2018), and Bank of England and Banque de France (upcoming publications).

The French Government is committed by the law to publish a review of the implementation of Art.173 after 2 years, which is expected to provide the key features to be improved through a potential modification of the Decree implementing the law. And especially, it will be the occasion for the government and other observers to promote what they consider being the main approaches, methodologies and tools to address the different provisions, which will provide the market with important signal on how to address climate-related risks.

#### *Mark Carney's speech on the 'Tragedy of the horizon'*

In September 2015, about 2 months ahead the COP21 gathering in Paris, to which all eyes were turned, Mark Carney, Governor of the Bank of England (BoE) and at that time Chairman of the Financial Stability Board (FSB) made a seminal speech at Lloyd's of London on "Breaking the tragedy of the horizon" that, certainly for the first time at this level, clearly acknowledged the role of the financial system in the fight against climate change and, noteworthy, its exposure to climate-related risks (Carney, 2015). In particular, emphasizing the discrepancy in time horizons between the probable occurrence of risk and the current time horizon of financial sector's decisions, Carney focused on the systemic feature of climate-related risks and their potential threat to financial stability. In the wake of the French Article 173, this speech, which had matured through a series of previous public statements on climate-related risks (Carney, 2014a, 2014b; The Guardian, 2014) opened a new track for both finance-related climate policies and climate-related finance policies. In particular, being both at the head of the BoE and the FSB, Carney clearly pointed to the role of self-regulation via risk disclosure, versus any tweak of prudential regulation to adjust



banks and insurers' capital regime in order to accelerate the financing of a low carbon economy. Indeed, this idea was soon after transformed by the FSB into an industry-led working group in charge of setting the basis for a voluntary standard for disclosure of climate-related risks: The Task force on Climate-related Financial Disclosures (TCFD). Launched officially during the COP21 in December 2015, the TCFD published its final recommendation report in 2017, and became the principal framework promoting climate-related financial disclosure, on the basis of scenario analysis. Those recommendations actually focus on both financial and non-financial companies, for the former to take financial decisions based on the reporting from the latter. But as of today, this interesting initiative still suffers from two caveats. Being a purely voluntary framework, it amplified the idea that regulation is not needed and that market players can manage risk by themselves, which so far did not trigger any significant transformation in risk management practices of FIs. Moreover, falling short of precise technical guidelines such as specific scenarios with quantified parameters, companies — especially financial institutions — do not really know so far how to operate climate and transition scenario analysis. As a consequence, FIs still have a long way to go on the analysis of their climate-related financial risks.

### *Beyond reporting, an enhanced prudential framework*

#### *The European Commission Sustainable Finance Action Plan*

Since the 2015 initial boost, the most significant regulatory initiative in terms of climate-related financial risks came from the European Commission (EC). In December 2016, in the frame of its Capital Markets Union reforms, the EC established a High-Level Expert Group on Sustainable Finance (HLEG). The HLEG's mandate was to provide advice to the EC on how to

mobilise the European financial sector on several issues including climate- and environment-related risks (HLEG, 2018):

- Steer the flow of public and private capital towards sustainable investments,
- Identify the steps that financial institutions and supervisors should take to protect the stability of the financial system from risks related to the environment,
- Deploy these policies on a pan-European scale.

Quickly after the publication of the HLEG's recommendations in January 2018, the EC adopted in March 2018 its action plan on sustainable finance, followed by a package of first measures adopted in May 2018. The action plan consists of 10 actions organized under three main objectives, aiming to i) Reorient capital flows towards sustainable investment; ii) Mainstream sustainability into risk management and iii) Foster transparency and long-termism in financial and economic activity (EC, 2018). While having officially a broader scope than purely climate change (i.e. sustainability), we see here again the tryptic climate objective, climate-related financial risk, and disclosure. Indeed, the perimeter of the EC action plan is very large and ambitious, spanning from the creation of an EU taxonomy for sustainable economic activities (EC TEG, 2018) to the development of standards and labels for green financial products, the clarification of institutional investors and asset managers' duties, the strengthening of sustainability disclosure and accounting, or the attenuating of short-termism in capital markets. Concerning risk per se, a specific action looks at incorporating sustainability in prudential requirements. With this action, the EC opens the core — and controversial — issue of how mobilizing central regulation for climate change and sustainability, by exploring the feasibility of including risks associated with climate and

other environmental factors in institutions' risk management policies, and the potential calibration of capital requirements of banks. The aim would be to take into account such factors, when relevant, to safeguard the coherence and effectiveness of the prudential framework and financial stability (e.g. Thomä and Hilke, 2018). The Action Plan opens the way to provisions such as a "green supporting factor" or/and a symmetric "brown penalizing factor", which would operate in a similar way by either respectively decreasing or increasing capital requirements for holdings related to activities that should be invested in priority for the transition or respectively not be invested in anymore for the sake of climate stabilisation. While a "brown penalizing factor" was initially mainly backed by environmental NGOs, it recently received the support of some supervisors (e.g. ACPR, 2019a), whereas its green counterpart has been publicly supported by some banks (e.g. FBF, 2018) and by EC Vice-President Dombrovskis himself (EC, 2017).

## *5- Conclusion*

This paper was an attempt to demonstrate how climate-change related financial risks quickly emerged from a new topic limited to marginal activities in financial institutions, to a mainstream issue for the whole financial sector. As any new emerging subject, it experiences a booming phase with new reports and publications every week, both on the practice, policy-making and research space. At the time of writing these last words, two new reports have just been published from some European supervisors, and two others are announced for next week. It is therefore very much a work in progress, and therefore a very challenging objective to describe here a stabilised state of the art. Nevertheless, through these pages we were able to identify a set of clear elements that will structure the next years and more of practice and research for the financial sector. First, the risks related to climate change are

now attached to the core of the financial system, treated by regulators and supervisors, climate policy makers, tools and data providers, researchers, NGOs, and of course financial institutions themselves. Second, while having just reached such a significant importance, we are just at an early stage of both the understanding of the risk nature itself in all its complexity, and of the development of the related approaches to manage it. Third, the differentiation of physical and transition risk is robust, but both make sense to be addressed through scenario analysis and stress tests, which allow to explore various future states of the world in order to test the possible impact of some risk parameters materialisation. Fourth, such exploratory methods and open-mindedness are necessary to cope with the unprecedented features of climate change for the financial sector, as opposed to traditional financial risk management approaches rooted in statistical, deterministic and ergodic approaches. Fifth, those characteristics make climate-related financial risks possibly mispriced by markets, which implies a potential misallocation of financial capital in relation to the real risks from climate change and the transition to a net-zero carbon economy, as well as a potential over-exposure of the financial system to those risks, bearing the possibility to trigger systemic instability. Seventh, financial regulators and supervisors are moving forward to fix market failures coming primarily from discrepant time horizons, first by resorting to voluntary disclosure and self-regulated reporting, and gradually using more mandatory regulations that may attain soon prudential frameworks. Finally, this paper needs to be seen as a modest introduction to a broad and dynamic new topic that will undoubtedly continue to evolve at a fast pace in the near future, as long as climate change continues to constitute a dramatic threat to our societies and our economies. Unfortunately, climate change is not the sole global environmental threat and challenge to the financial system that should be taken into account as a major source of risk, but compared to other natural

calamities such as biodiversity loss, water and air pollution, natural resources scarcity, and their various consequences to human health and welfare, climate change is probably the best understood and most closely linked to financial sector activities. A modest contribution on an indispensable issue to start with.

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