ENERGY AND CLIMATE SCENARIOS

Evaluation and guidance

Report by The Shift Project think tank for AFEP

November 2019

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1 Foreword

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A

Objectives of the study carried out by The Shift Project for AFEP

In July, the Task Force on Climate-related Financial Risk Disclosure (TCFD) published its final report for the G20. That report included eleven recommendations, including one on **energy and climate scenario analysis** covered in a 70-page appendix. In particular, the report stated: *"One of the Task Force's key recommended disclosures focuses on* ***the resilience of an organization's strategy, taking into consideration different climate-related scenarios, including a 2° Celsius or lower scenario****"*. Following the recommendations from the TCFD, an increasing number of investors, rating agencies and other stakeholders are starting to ask companies how they evaluate such resilience.

For many reasons – mainly linked to uncertainties over climate change and the timing – scenario analysis appears to be an appropriate way of evaluating the potential impacts of climate change or a "low-carbon" transition, particularly from a strategic viewpoint. This method could strongly influence the structure of strategic planning, climate risk analysis methodologies and reporting in the years to come.

However, the energy/climate scenario analysis approach, as recommended by the TCFD, is still new for companies building a climate strategy. In addition, companies do not always feel comfortable with disclosing the information concerning this procedure. For these reasons, they are seeking better understanding of the various questions and issues related to the use of energy/climate scenarios, for example:

- the scenarios to be used and the criteria used to analyse them according to the companies' business and location;
- the methods to apply when using these scenarios;
- the ways in which company stakeholders use the information that it discloses.

AFEP commissioned the think tank *The Shift Project* to conduct a study to provide French companies with insights on the issues related to energy and climate scenario analysis and to help them implement action plans compatible with the goals of the Paris Agreement. This study seeks to:

1. produce critical mapping of the main energy/climate scenarios publicly available;
2. conduct an analysis of the methodological choices made by company stakeholders (in particular, investors, rating agencies, financiers, regulators, etc.) when analysing information on these scenarios disclosed by companies;
3. formulate recommendations for companies on:
  a/ steps that companies can take to make use of the publicly available energy/climate scenarios or to devise their own scenarios;
  b/ how to steer these processes and disclose the related information outside the company.

Fifteen AFEP member companies – **Alstom, Axa, Bouygues, CGG, Generali France, LVMH, Michelin, Société Générale, Sodexo, Schneider Electric, Suez, Thales, Unibail-Rodamco-Westfield, Vallourec and Veolia** - joined up to initiate this study, which began in September 2018 and ended in June 2019.

B

Stakeholders involved

The results of this study are largely based on discussions between the *The Shift Project* team and numerous stakeholders involved in devising energy/climate scenarios or their use: companies themselves, modellers, scenario authors, forecasters, financial stakeholders (banks, rating agencies, investors) and regulators.

To deal with the full range of issues that arise from these complex questions and to analyse them objectively, our work was based on different types of discussion:

- **Four steering committee meetings** with representatives from the fifteen companies, supplemented by detailed interviews to better understand their questions on energy/climate scenarios and the available methodologies (see Appendix 1, Corporate members of the steering committee, p. 116);
- **Several meetings with other AFEP member companies** to identify best practises among the most advanced companies (see Appendix 1, Other AFEP member companies met, p. 117);

- **Discussions and meetings (based on company testimonies) with several stakeholders involved in scenario analysis:** scenario authors, modellers, foresight analysts, NGOs (see Appendix 1, Stakeholders in scenario analysis met, p. 117);
- **Discussions and meetings with financial stakeholders:** rating agencies, investors, banks (see Appendix 1, Financial stakeholders met, p. 118).

In addition, our analysis drew significantly on the relatively extensive literature available on the subject, listed in the appendices (See Bibliography, p. 122) to this report.

C

About this report

The conclusions in this report are presented under the sole responsibility of *The Shift Project.*

In addition to its complexity and scope, energy and climate scenario analysis is a fast-changing field. As such, ongoing monitoring of future developments, including good practises, will prove valuable for the economic operators and users of the information produced.

In this report, we have taken account of the fact that, while the impacts of climate change concern all areas of business, some will be affected directly and others indirectly.

D

About AFEP

AFEP stands for *Association française des entreprises privées* (French association of large companies). It was established in 1982 and its members are the largest French multinational companies. It is based in Paris and Brussels. Its objective is to help create a favourable environment for the development of sustainable economic activity, and to advocate its member companies' vision to the French authorities, European institutions and international organisations. AFEP has 113 member companies. They account for over 14% of French GDP, employ 2 million people directly and pay 19% of the compulsory contributions due by companies. Since the year 2000, the association has been vocal on climate, environment and energy issues. With regard to climate, in addition to its work on key pieces of legislation (most notably the EU ETS scheme, the energy efficiency and energy performance of buildings directives, and French legislation), it has also launched a number of initiatives backed by the large French corporations and the French authorities:

- Working with French companies and national authorities, it has created an innovative French supply for sustainable cities, with more than twenty demonstration projects, nationally and for export, aiming to reduce energy, climate and environmental impacts and to improve quality of life (called *démonstrateurs industriels de ville durable*, or DIVD);
- Design and implementation of voluntary corporate commitments involving the circular economy with a positive climate impact.

AFEP works on corporate climate reporting issues and on the capacity to engage in more advanced dialogue between investors, rating operators and companies. In this respect, the association called on *The Shift Project*, a think tank, to produce a study, published in 2018, to review how financial and extra-financial rating operators address the climate risk (Climate Risk Analysis: Stakeholders, Methodologies and Outlook). This study follows on from that work.

The Chairman of AFEP is Laurent Burelle, Chairman of Plastic Omnium.

E

About The Shift Project

The Shift Project is an officially recognised general-interest organisation founded in 2010 by Jean-Marc Jancovici (member of the French High Council for Climate). It is a think tank set up to inform and influence the debate on the energy and climate transition in France and Europe.

The Shift Project is now backed by several major French and European companies that want to make the energy transition a strategic priority and helps them identify relevant opportunities.

Since it was created, *The Shift Project* has developed twenty research projects, helped to establish two international events (Business and Climate Summit, World Efficiency), and organised 50 seminars, forums, workshops and conferences. It has had a significant influence on several major political decisions about the energy transition in France and within the European Union.

The Shift Project has a unique analytical approach based on the conviction that energy is an extremely important development factor and the risks arising from climate change, which are closely linked to the use of energy, have a particular systemic and transdisciplinary complexity.

The Shift Project was created in order to mobilise companies to engage not just with the risks but mainly with the long-term opportunities linked with climate change, in a French tradition of bounded optimisation in which it is essential to clearly prioritise the potential effectiveness of the various ways the issue can be addressed.

The Shift Project has completed a number of projects closely related to the subject of this study. Examples include:

- ***"Climate Risk Analysis: Stakeholders, Methodologies and Outlook",*** study published in 2018 and produced for AFEP, mentioned above;
- ***"Observatory 173 on Climate & Life Insurance",*** published annually and assessing the way climate risks are taken into account and managed by the life insurance sector in France in the context of article 173 of the LTECV;
- ***"Lean ICT: Towards digital sobriety",*** in liaison with the Caisse des Dépôts et Consignations and the French Development Agency (AFD), to establish a "digital ecological repository" describing the energy and environmental footprint of this sector, to draw up scenarios up to 2030 highlighting the key factors, and to put forward action plans.

The Shift Project is chaired by Jean-Marc Jancovici.

The study has also benefited from the support and expertise of Global Warning, a consultancy established by Michel Lepetit.

2 Summary and recommendations

Key messages

1. Both energy transition and climate change adaptation are unavoidable challenges to be tackled in the long run. They can occur in a chaotic and uncertain manner and will affect the environment in which corporates operate (operations and markets).

2. Stakeholders, in particular in the financial sector, are increasingly asking companies to provide information regarding their alignment with the Paris Agreement targets. These information however do not cover all the issues at stake and, as such, cannot substitute for a more in-depth analysis carried out by companies.

3. A scenario-based foresight analysis is to consider how an organisation might perform under possible but different futures, each of them described by a scenario. This is an appropriate tool for incorporating energy transition and climate-related issues (mitigation and adaptation) into a company's strategic planning and for understanding the related uncertainties.

4. Public energy-climate scenarios – on which the analyses carried out by companies and their stakeholders are or may be based – are not necessarily designed for this purpose. They come with certain limitations, particularly as regards the choice of input assumptions and the type of models used. Discussions with public scenario producers may help to overcome these difficulties.

5. Given the limitations of public scenarios, companies likely to be particularly affected by energy transition and climate change are recommended to conduct an operational foresight analysis based on in-house scenarios. Such scenarios are first based on a storyline describing the changes in the company's business environment.

6. Once a company has completed an in-house scenario-based foresight analysis, it may disclose information following the TCFD framework and the European Commission new guidelines on reporting climate-related information (that supplement the guidelines on non-financial reporting).

1 An unstable business environment

Over the years to come, the necessary energy transition and adaptation to climate change's consequences will play a major role in public and private organisations' decisions, and companies in particular.

The transformations required to meet the Paris Agreement targets are of such scale that they are an unprecedented challenge for economic players.

These transformations may be chaotic, with far-reaching technological, political, economic and social disruptions. To cope with the inevitable upheavals, companies need to develop an in-depth knowledge of how their own business model could be impacted by energy and climate change-related issues.

2 Incomplete approaches

To date, these financial stakeholders – among which rating agencies and investors – have rarely asked companies about their foresight analyses, instead favouring a "reporting" approach. When they do decide for long-term analysis, these actors readily adopt a normative sector-based approach (using "2°C pathways" for example, which are often incorrectly referred to as "2°C scenarios"). Rating agencies do not directly integrate scenario analysis into their credit rating methodology. Instead, they develop analytical services based on certain public energy-climate scenarios (e.g. those of the International Energy Agency).

For companies, complying to this kind of request from financial stakeholders can be justified by reporting requirements and the need for comparability with competitors on the market. Nonetheless, such approaches remain incomplete and are not a substitute for a comprehensive in-depth strategic assessment focused on the challenges of the ongoing energy revolution.

Main steps of the scenario planning process

ACTORS	MAIN STEPS	DELIVERABLES
EXCOM - Strategy dept.	1 Defining issues to be analysed	*Scope of analysis and questions to be answered*
Strategy dept. *Business units* *Risks dept. - Support dept.*	2 Identifying critical variables for the company	*Critical axes for building the scenarios framework*
Strategy dept.	3 Setting up the storylines	*Set of 3 to 4 different and exclusive storylines*
Strategy dept.	4 Quantifying the storylines	*Set of 3 to 4 quantified scenarios*
Strategy dept. *Business units* *Risks dept. - Support dept.*	5 Assessing the impacts on the company's operations and markets	*Impact assessment for each scenario*
EXCOM - Strategy dept.	6 Defining strategic options	*Action plan to be included in strategic planning*

3 Anticipate the future, support decision

The main goals of foresight scenario analysis are to develop different but possible views of the future (described by scenarios) and to assess their impacts on the robustness and the resilience of an organisation. This method has gained recognition for modelling access to resources for an organisation within an uncertain future (it has been used for example in wartime economy and reconstruction planning). Energy operators, including oil and gas companies, frequently use this method as well.

Applying scenario-based foresight analysis to energy transition and climate-related issues offers multiple valuable ways of helping companies' managers to identify business disruptions, manage uncertainties and finally build more robust strategies.

Yet the surveyed companies still claim to lack methods to conduct such foresight analyses and to assess energy transition and climate change impacts on their own activities and business model.

5 Tailored in-house scenarios

The advantage of in-house scenarios is to focus specifically on the issues affecting the company. They are primarily based on a storyline. However, they may also include quantitative elements that describe company specific factors (such as the "physical" determinants underpinning its activities and demand for its products and services).

Companies of different sizes and from various sectors have embarked on this approach, devoting a fair amount of resources to it. Design and use of in-house scenarios are also a source of motivation and guidance to all the company employees. Both executive management and business units play a decisive role in terms of raising the necessary awareness within organisations, initiating the process and developing in-house skills.

4 Inadequate public scenario offer

A scenario describes, for issues at stake, a possible future and the pathway that leads to it. Many stakeholders (international organisations, research centres, companies and NGOs) produce scenarios describing futures affected by the energy transition and climate change. So far, these scenarios have mainly been designed for public policies assessment or academic researches. As they stand, they have not been made to be used by companies.

For example, beyond data issue (availability and use), these scenarios often do not describe plausible disruptions (political, economic, societal) nor include a detailed "storyline" which grants meaning to the underlying assumptions.

Most scenario producers are aware of the difficulties that companies face. They are willing to work with them to build more accessible public energy-climate scenarios that meet their needs.

6 A communication under control

The purpose of conducting scenario-based foresight analyses is to meet an internal strategic need of the company, focused on its own challenges and environment. Whatever may be the approach, it will produce a number of deliverables for use by the company's executive management.

Some of the information contained in these deliverables is not intended to be disclosed, while some of it can be, depending on the company's requirements with regard to its stakeholders. For example, it is recommended to disclose a description of the scenario analysis process applied, a summary of the scenario narratives studied, as well as the main results concerning the business model resilience. By design, a foresight analysis enables a company to objectively study several futures – desirable or not – without committing the company to follow a specific pathway.

If energy-climate issues, erratic but unavoidable, are to be better understood and incorporated into decision-making processes, companies must implement rational and objective methods to analyse the future and build confidence both within and outside the company.
An essential step is to identify the determining factors which could be significantly affected by climate change and low carbon transition among all factors that shape company activities and markets. As a matter of priority, the scenarios used by the company should describe different evolution pathways for these determining factors, desirable or not.
Scenario-based foresight analysis is accessible to all companies. It requires however a significant commitment from the executive management and business units, with sharp-cut steering. This is essential for the challenge to be met.
The scenario analysis method is an effective way for companies to integrate energy transition and climate change-related issues in their strategy. It helps them establish key information on their business model evolution, particularly for investors and rating agencies.

The study formulates seven recommendations to help companies and their top management to commit their organisation to a process of strategic reflection, given the urgency of climate change and its systemic effects.

Recommendation n°1

Among the determining factors that shape the company's activities and its markets, identify those that could be significantly affected by climate change and the transition to a low-carbon economy.

Recommendation n°2

Implement regular foresight analysis based on multiple energy/climate scenarios that describe the possible processes for mitigating and adapting to climate change and low carbon transition.

Recommendation n°3

Devise in-house narratives that describe changes in the company's business environment in light of the energy/climate issues, but that do not simply extrapolate past trends.

Recommendation n°4

When quantitative data are applied in the scenario analysis, they should preferably describe the changes in the physical determinants that shape the company's activities and markets.

Recommendation n°5

Engage in a dialogue with the authors of public energy/climate scenarios to foster a diverse range of energy/climate scenarios better adapted to companies.
Encourage and take part in the creation of business consortia tasked with developing scenarios that match their requirements.

Recommendation n°6

Assign one or several members of the company's executive management to supervise the energy/climate scenario analysis process.
Set up a plan to ensure the main energy/climate issues are taken on board by the company's top managers and that they are all informed and able to contextualise them with regard to the company's specific challenges.

Recommendation n°7

After conducting scenario-based foresight analysis, draw up a summary version that may be disclosed (without revealing confidential strategic choices nor making commitments in annual reports that are not designed for that purpose).
In accordance with TCFD recommendations and the European Commission's new guidelines on climate reporting that supplement the guidelines on non-financial reporting, disclose:

- a description of the scenario analysis process implemented;
- a summary of the scenario narratives studied and their results describing the resilience of assets, the business model, and the predicted opportunities.

3 What exactly is meant by "energy/climate issues"?

The transformations required to mitigate and adapt to energy/climate issues are characterised by their **scope and uncertainty**. If they are not tackled head-on, these transformations will partially be endured and could occur in a chaotic manner with profound technological, political, diplomatic, economic and social disruption. They would threaten the **stability of the global socio-economic system**.

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A

Energy/climate issues: an uncertain future, risks with potentially high impact

1 Energy, the main key to the climate issue

The issues raised by climate change and its impact on society are more significant than ever before.

There is now a broad consensus as to the cause of these major impacts. Climate is being warmed to an alarming degree by the emission of increasing quantities of greenhouse gases and their higher concentration in the atmosphere.

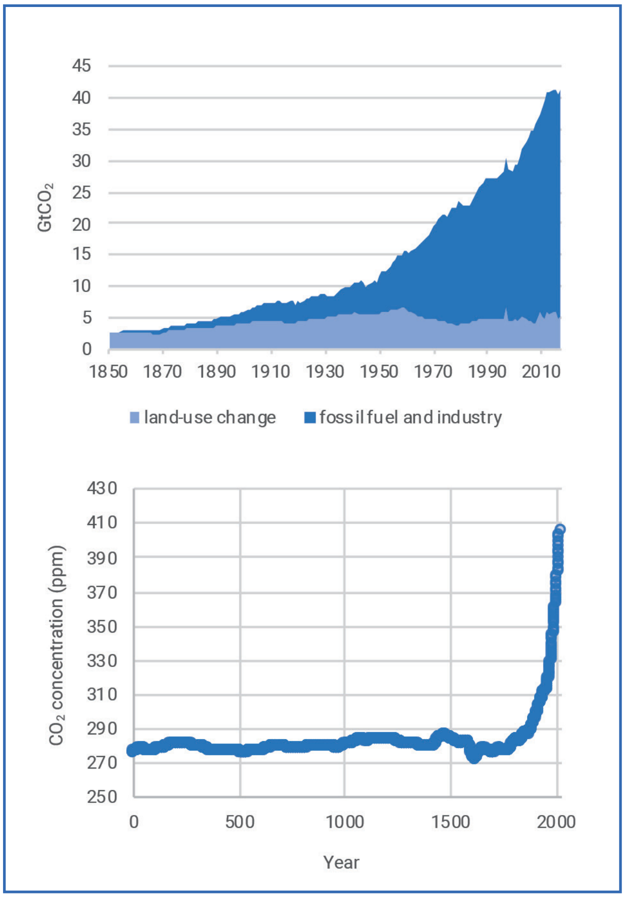
The consequences of this physical phenomenon have long been known: after Arrhenius's discoveries in the late 19th century, they created scientific fears in 1953[1], collective concerns in the late 1960s[2], and almost universal agreement since the Rio summit in 1992.

Between 1876 and 2017, almost 2,220 $GtCO_2$ have been emitted into the atmosphere (out of a total 3,000 $GtCO_2$, corresponding to the budget that would make it possible to limit global warming to 2°C; see Part 3.A.3, p. 19), leading to warming of 1°C above pre-industrial levels[3]. If the current rate of temperature increase continues, global warming will reach 1.5°C by 2040[4].

CO_2 emissions, which amounted to almost 42 billion metric tonnes of CO_2 in 2017[5] (excluding other gases in the Kyoto protocol[6]) can be split into three categories:

1. **energy emissions** (i.e. heat generation through combustion) make up the largest category and account for nearly 35 $GtCO_2$/year;
2. **non-energy industrial emissions,** i.e. emissions related to industrial processes (e.g.: cement production[7], heavy chemistry, etc.), accounting for 2-3 $GtCO_2$/year[8];
3. **emissions associated with land use,** which account for almost 5 $GtCO_2$/year[9].

Figure 1: Change in atmospheric CO_2 emissions from 1850 to the present day, by source (left) and change in CO_2 concentration in the atmosphere from the start of the modern era to 2019 (right).



Source: Global Carbon Budget and Scripps CO_2 Program

1 - "Energy in the future" by Palmer Cosslett Putnam, consultant to the United States Atomic Energy Commission, 1953.
2 - "The Historical Roots of Our Ecologic Crisis" by Lynn White, Jr. – Science, 1967.
3 - See Chapter 2 of the "Special Report on Global Warming of 1.5°C", IPCC (2018), figure 2.3, p. 105.
4 - Ibid.

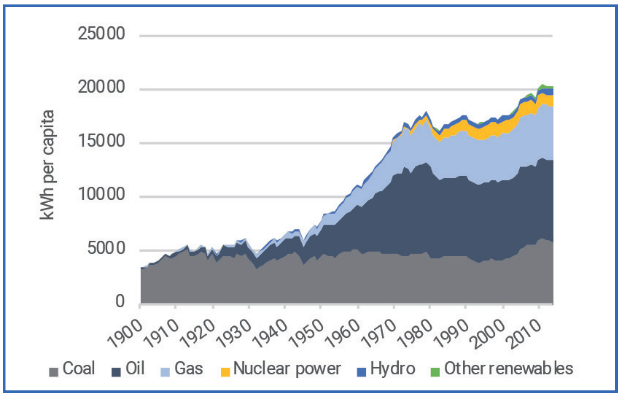
5 - Ibid. p. 107.
6 - The six gases in the Kyoto protocol are: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6.
7 - The calcination of limestone, which is part of the clinker (the main component of cement) manufacturing process, turns the limestone (calcium carbonate or $CaCO_3$) into lime (CaO). It results in the formation of CO_2. Annual non-energy CO_2 emissions linked to cement production stood at 1.4 $GtCO_2$ in 2010. See the Fifth IPCC Assessment Report, Chapter 10, p. 749.
8 - Annual CO_2 emissions linked to industrial (non-energy) processes came to 2.6 $GtCO_2$ in 2010. See the Fifth IPCC Assessment Report, Chapter 10, p. 749.
9 - There is some uncertainty over the measurement of CO_2 emissions associated with agriculture or land use, which are thought to amount to 5 $GtCO_2$/year +/- 2.5. See «Global Carbon Budget 2018», Quéré et al. (2018).

Energy has been and still is an essential factor in the development of societies. Energy can be defined as the physical quantity that measures the “change of state of a system”. In other words, when a system is transformed, energy is consumed. The quantity of energy mobilised characterises the degree of transformation. This holds true for changes of temperature, shape, speed or chemical composition.

As a first approximation, a human society can be seen as a system that extracts, transforms, works and transports mineral or biological resources drawn from the environment, in order to produce goods and services individuals consume to meet their needs.

As a result, the discovery of energy followed by the growing use of primary energy[10] – especially via “transformers” that turn it into mechanical energy (steam engine, internal combustion engine, turbines, etc.) – and the increase in all the physical flows that underpin production activities, vastly contributed to the rise in labour productivity and the economic, social and demographic growth of human societies.

Figure 2: World primary energy consumption per capita in the world from 1900 to 2015 (excluding wood).



Source: TSP data portal and UN statistics division

This growth accelerated across the world in the 19th century with the discovery and widespread use of fossil fuels in all sectors of the economy, from agriculture to industry and transport. Over 2016, for example, nearly 13,760 Mtoe of primary energy was consumed across the globe, 32% of which was oil, 22% gas and 27% coal[11].

For almost 200 years, our societies have scaled their development on the basis of unprecedented energy abundance. Energy production, industrial activity (metallurgy, cement works and the chemical industry in particular), land development, trade and the shortening of distances and times, the rise in agricultural yields, along with social progress (material comfort, better sanitation, education, security, mass tourism and so on), and more recently digital technology[12] have all been made possible by this plentiful energy supply.

For this reason, the climate issue is particularly difficult and complex. It is closely linked to the use of fossil fuels which have, until now, enabled modern economies to function and grow.

Note: From here on, we will use the expression “energy/climate issues” to cover this aspect.

2 Transition risks and physical risks

For the economic system and its various operators, the energy/climate issues are embodied in two types of risks[13].

“Transition” risks cover all risks associated with the *profound restructuring of the economic system* brought about by the evolution of the energy mix, itself made necessary by the reduction of CO_2 emissions into the atmosphere. The transition to a low-carbon economy implies a far-reaching transformation of the energy **generation** and **consumption** system (today, industrial facilities and lifestyles are still based on hydrocarbon use). This transformation will affect most physical flows (of energy, raw materials and goods). It will directly or indirectly concern every sector of the economy.

“Physical” risks are linked to the *physical consequences* of climate change, such as the increased frequency and intensity of extreme climate events, rising sea levels, certain public health issues and changes to river flows. These phenomena could significantly disrupt the economic system, especially production activities and supply chains.

10 - Primary energy is a form of energy available in nature before any transformation.
11 - See IEA statistics. The energy mixes of the world’s major economies consist primarily of hydrocarbons (74% in the European Union, 81% in OECD countries, 88% in China, 92% in India and 86% in the United States in 2015).
12 - The so-called “dematerialised” economy is also a huge consumer of transformed resources, and it can only exist in an energy-hungry world. See the “Lean ICT: Towards digital sobriety” report, The Shift Project (Oct. 2018).
13 - Most notably, see the now-famous speech given by Mark Carney at Lloyds in September 2015.

The recent negotiations over the opening of new maritime shipping routes in the Arctic Ocean[14] and the low level of the Rhine in autumn 2018[15] are just two examples of the risks (or opportunities) involving the flow of commodities and merchandise.

The materiality of this risk is the subject of a growing number of studies by international scientific and political organisations, and by areas of business such as insurance and certain industries. They look at the likely impacts and at the adaptation and resilience of organisations and institutions (states, companies, etc.).

These risks are different from other kinds of risks for the following reasons:

- their unprecedented nature and hence the impossibility of using historical values to predict and prepare for them, or to validate any model (back-testing);
- their extent and their global, irreversible nature (in one way or another, these risks will affect all areas of the economy and particularly the financial sector);
- the uncertainty over when they will occur, how far they will reach and what form they will take;
- the (partial) dependency of their extent on the actions decided on as of now.

3 Carbon budget

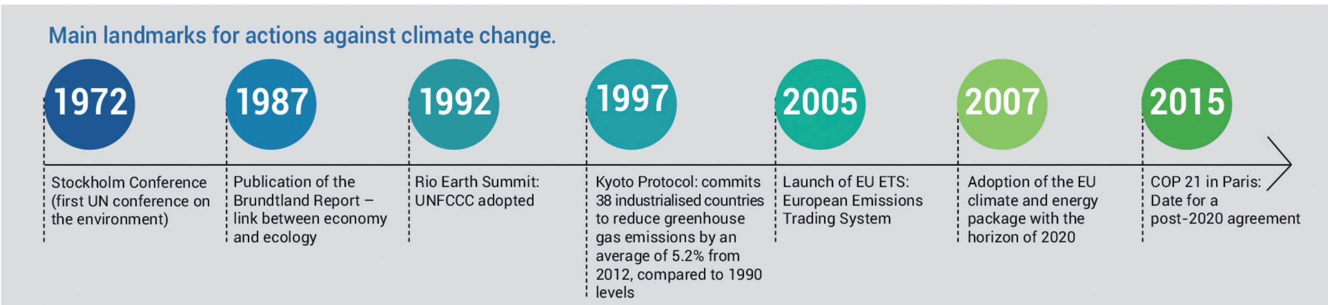
Gradual mobilisation, stemming from the desire to mitigate and manage the climate risk, resulted in the signature of the Paris Agreement in December 2015. Signatory countries pledged to take action to keep the global average temperature rise below 2°C and to pursue efforts to limit the temperature increase to 1.5°C.

The goal of limiting global warming to well below 2°C above pre-industrial levels has gradually gained momentum in international discussions.

Because GHG concentrations in the atmosphere are strongly linked to the rise in average temperature, putting such a cap on warming implicitly means setting a **"carbon budget"**. This is the total quantity of GHG that may be emitted to maintain their concentration in the atmosphere within a certain threshold consistent with the targeted limit on warming.

In the "Special Report on Global Warming of 1.5ºC" (SR15) published in 2018, IPCC experts considered that, in 2018, the CO_2 budget that would make it possible to limit global warming to **below 2°C, with 66% probability**, is **1,170 $GtCO_2$**[16] (1,500 $GtCO_2$ with 50% probability). The CO_2 budget that would make it possible to hold global warming **below 1.5°C, with 66% probability**, is **420 $GtCO_2$** (580 $GtCO_2$ with 50% probability).

Figure 3: Main events in the fight against climate change



14 - "Estimation de l'impact des nouvelles routes polaires sur la géographie du commerce mondial" [Estimation of the impact of new polar routes on the geography of world trade], CEPII (Oct. 2018).

15 - "The levels of the Rhine are becoming 'critical' for navigation and industry". L'Alsace newspaper (31 Oct 2018). Poor navigability of the Rhine could partially explain the economic slowdown in Germany. See "Europe's mightiest river is drying up, most likely causing a recession in Germany. Yes, really". Business Insider France (22 Jan 2019).

16 - See Chapter 2 (Table 2.2) of the "Special Report on Global Warming of 1.5ºC", IPCC (2018). This budget covers only energy and non-energy CO_2 emissions but its calculation takes emissions of other GHG into account (most notably methane and nitrous oxide). See Section 2.2.2.2. p. 106. The authors underline that there are still many uncertainties about its value (amounting to several hundreds of $GtCO_2$).

B

The low-carbon transition could be disorderly and uncertain

Tackling climate change means tackling the "*tragedy of the horizon*[17]". The materiality of the energy and climate risks is not yet felt acutely enough among economic operators, who find themselves faced with the prisoner's dilemma[18]. Hence, they are not yet taking action to encourage more drastic or radical policies on the reduction of GHG emissions (to compensate for lost time).

A reduction in the consumption of hydrocarbons implies major transformations (energy use, productive system, regional development, etc.). The current economic system was scaled on the basis of an abundant supply of hydrocarbons. This de facto leads to an array of "organisational dependencies" and it could take considerable time, resources and commitment from the public authorities to overcome them. Globally, these dependencies could delay action and trigger significant social reactions.

The dynamics of climate change are complex and modelling still involves considerable uncertainties. While the breadth of work completed by IPCC researchers means we can estimate how climate change may affect natural and human ecosystems (working groups 1 and 2), these estimates are subject to uncertainty (especially when it comes to the location, extent or frequency of these changes), which makes forecasting the physical displays of climate change a complex challenge[19] (Hallegate, 2008).

The consequences of these displays (and their reach), especially in socio-economic terms, are equally hard to predict. The sudden bankruptcy of PG&E after the Californian wildfires of 2017-18 is just one example[20].

The commercial and geopolitical environment is undergoing huge change. The context of a price war affecting international trade[21] (which was unimaginable three years ago despite the difficulties affecting the WTO), Brexit and the direction that foreign policy is taking in several countries (much less "multilateral") are all factors that could obstruct international cooperation on climate issues and create even greater uncertainty. The potential introduction of carbon taxes at borders[22], plus the difficulties encountered by governments looking to introduce a rising carbon-price signal (particularly in France with the government's decision not to pursue the increase in the carbon tax) seem to suggest that States are increasingly making use of regulatory instruments that may be introduced abruptly and/or without coordination with their partners[23].

17 - This expression refers to the gap between the perceived horizon for the occurrence of climate risks and the horizons binding organisations and financial organisations in particular. It was discussed by Mark Carney, Governor of the Bank of England, in his speech at Lloyd's of London in 2015.
18 - As long as the cost of externalities remains low, an actor may incur a "competitive disadvantage" by being "too virtuous too soon", compared to their competitors.
19 - In the assessment reports published by the IPCC, the authors include terms such as "medium evidence" or "high confidence" in their conclusions. See, for example, "Special Report on Global Warming of 1.5°C" (2018).

20 - PG&E Corp, owner of the biggest electricity company in the United States in terms of customer numbers, filed for bankruptcy in January 2019, due to the financial challenges associated with the wildfires in 2017 and 2018. The PG&E stock was deemed "investable" by financial rating agencies until November 2018, after which the company's credit rating rapidly deteriorated until it filed for bankruptcy. See for example Moody's website: https://www.moodys.com/credit-ratings/PGE-Corporation-credit-rating-600022576.
21 - See "International Trade Under Attack: What Strategy for Europe?", French Council of Economic Analysis (2018).
22 - See "Initiative for Europe – Emmanuel Macron's speech advocating a sovereign, united and democratic Europe". (September 2017). Also The Economist – How to design carbon taxes – 18 Aug 2018.
23 - See also "The material scenario of potential carbon border taxes", Beyond Ratings (July 2019): "To put it simply, the development of carbon border tariffs is a scenario to consider in the fundamental analysis of sovereign and corporate assets. It is, of course, uncertain (as illustrated for example by the recent trade deal between the EU and Mercosur), but it deserves attention as its impacts could be significant for investors. If climate issues are more integrated in trade in the future, there will unavoidably be losers and winners. Such changes could be more or less progressive or non-linear, strong or moderate, but they would be meaningful".

4 Companies' value chains will be affected by these energy/climate issues

The activities of most companies and the markets on which they operate depend on **physical determinants** (e.g.: quantity of energy consumed, raw material flows, vehicle fleets, surface areas built or renovated, etc.), which will be affected by climate change and the transition to a low-carbon economy. Some sectors will be more affected than others.

A. Physical determinants of the company's activity 23

B. Identify the physical determinants 24

A

Physical determinants of the company's activity

Companies' value chains and activities depend on physical determinants.

A company's value creation process generally involves the following stages:

1. Procurement of raw materials and goods for processing (supply chain);
2. Processing of these inputs using labour and production facilities that consume energy and raw materials (production activity);
3. Distribution of the processed products (distribution chain) to an end market, to serve demand.

These activities aim at transporting materials, heating, processing and so on, all to varying degrees, and they inevitably involve "physical determinants[24]" such as available labour, the amount of final energy consumed, the quantity of raw materials (or intermediate processed goods), the availability and capacity of machines or infrastructure and transport flows bringing or delivering goods and materials that the company buys or sells.

The structure of the markets on which the company sells goods and services and of the markets from which it buys supplies, is also to some extent based on physical determinants that affect their size and dynamics[25]. For example, air passenger flows could affect demand for products marketed by a sub-contractor working for an aircraft builder.

The nature of these determinants is highly variable and depends on the company, the type of activity, the geographic location and the markets in which it operates. They share the fact they are all part of the "physical reality of the world". In other words, these determinants are bound by certain limits. For example, the production of digital devices (telephones, computers, etc.) requires rare metals, the availability of which is naturally limited. The scale of rare metal flows directly conditions the production of digital devices.

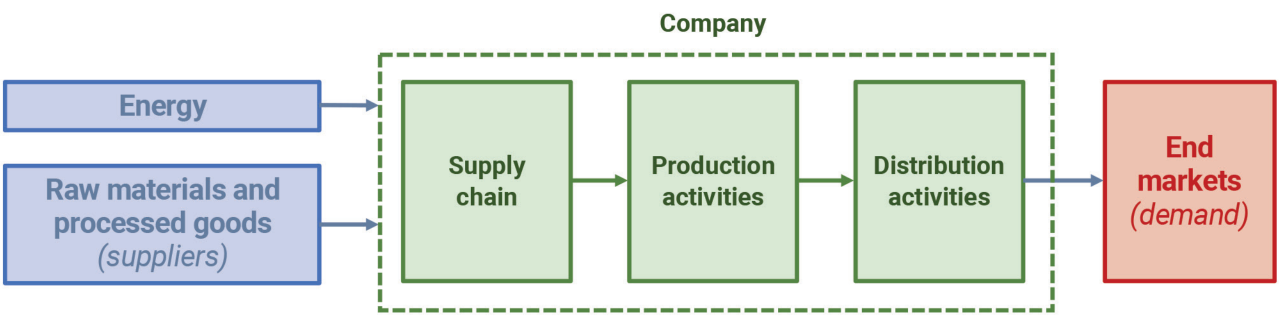
Physical determinants will be structurally affected by the low-carbon transition and climate change.

The transition to a low-carbon economy and adapting to climate change means **large-scale transformations of the energy production and consumption system** (most notably industrial facilities and lifestyles, which are currently scaled for hydrocarbon use).

These transformations are subject to many uncertainties and interdependencies, the gathering pace of change in certain areas (e.g.: digital technologies, social media, etc.), greater inertias in other fields (e.g.: demography), and the potential disruptions ahead (e.g.: in technology, politics, geopolitics, regulations, taxation, society, finance, etc.).

These transformations are of different natures (e.g.: demographic, societal, economic and commercial, political, environmental, diplomatic, technical, etc.) and **will significantly affect all the physical determinants**

Figure 4: Simplified diagram of a company's value chain



24 - A physical determinant is a dimension that can be measured in physical units (weight, volume, flow rate, etc.) and not in euros or dollars. The cost of a product or service is not a physical determinant, but the quantity of products sold is.

25 - Examples of physical determinantes are: the size of a population, the number of consumers, the infrastructure capacity, the passenger and freight flows, the surface area of buildings, the final energy flows, the raw material flows and the processed goods/material flows.

mentioned above for a very simple reason: **most of these flows depend on energy use**. Changing the energy system also means changing the physical determinants.

For example, as pressure on the use of hydrocarbons evolves, we could see changes to the structure of transport flows (shorter journeys, a shift to zero-carbon modes of transport or public transport, etc.). Actions designed to limit CO_2 emissions (regulatory and fiscal measures, market instruments) will affect the availability of certain "carbon-based" materials (such as cement, steel, glass, plastic, chemicals, etc.), which are often difficult to substitute and on which certain areas of the economy depend.

As such, companies need to identify how dependent their activities and their markets are on these transformations.

B

Identify the physical determinants

Companies can ascertain how dependent their activities and markets are on the transformations triggered by climate change and the low-carbon transition.

Supply and distribution chains and production activities largely depend on **the availability of raw materials and the smooth running of production facilities**. A **carbon assessment**[26] can be conducted to identify the variables that affect these activities.

Examples of the vulnerabilities of a company's activities to the "transition challenges"
Availability of raw materials with high carbon or embodied energy content, or materials at risk of depletion.
Availability of a fuel or material that cannot be easily replaced in the production process.
The company's dependency on "exposed" suppliers.
Procurement or distribution logistics' dependency on fossil fuels.

Examples of the vulnerabilities of a company's activities related to the physical impact of climate change
Breakdown in supply from an affected supplier.
Sensitivity of the company's operations to heatwaves.
Sensitivity of the company's operations to drought (especially use of water-cooling systems).
Sensitivity of the company's operations to the navigability of the main waterways (depth).
Sensitivity of the company's operations to an increase in precipitations and flooding.
Sensitivity of the company's operations to extreme weather events.
Sensitivity of the company's operations to rising sea levels.

Dependency of the demand for products and services sold by the company requires a more in-depth analysis. A company has a portfolio of products and services to satisfy demand on one or several markets.

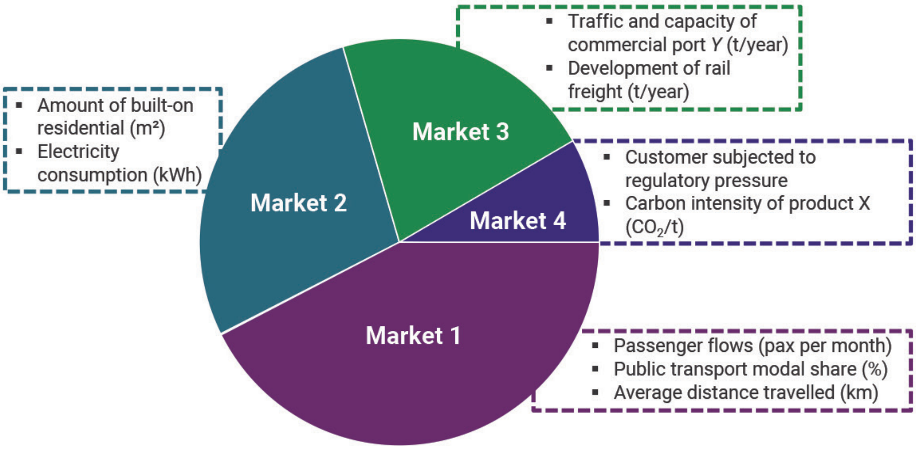
The first stage is to break down demand for each product and service marketed by the company according to the different end markets (sectors and geography). This analysis is fairly common and is already done by certain departments in the company.

The second stage is, for each market, to identify and make an initial estimate of the main physical determinants underlying each of the products and services sold by the company.

Finally, the third stage involves looking at these determinants and identifying those that could change considerably in the future, given the pressures from energy/climate issues. This is the case, for example, of carbon-related physical determinants (e.g.: the volume of sea freight) and those exposed to the physical impacts of climate change (e.g.: the volume of river freight).

26 - The low water levels of the Rhine had a considerable impact on the revenues of BASF: "In the second half of the year, low water levels on the Rhine River posed a particular challenge for us. At the Ludwigshafen site, at times we were unable to receive any deliveries of raw materials via inland waterways. Consequently, we were forced to reduce capacity utilization at our plants. This alone reduced our earnings by around €250 million". BASF Report 2018, p. 8.

Figure 5: Example of how demand for a company's products can be broken down according to markets, and examples of physical determinants.



Several companies have adopted this kind of approach in the past, although unrelated to energy/climate issues, with for example Hermès in the early 20th century[27]. The company specialised at that time in the design and manufacture of equestrian items (mostly leather saddles and silks), but on its directors' (Adolphe et Emile-Maurice Hermès) initiative, gradually repositioned to produce luggage (mainly leather), a move largely due to changes in physical determinants:

- The large-scale shift away from equestrian transport as the motor car rapidly gained ground, with a gradual fall in demand for riding equipment;
- The growth of mass transport and the very steep rise in the number of people travelling.

Some business sectors could be more vulnerable than others.

While the entire economy will be affected, some areas of business will be more exposed than others to the energy/climate issues. The TCFD identifies five exposed sectors (see Part 9.A.1, p. 95). These sectors are those in which the activities and markets could be the most affected.

The financial rating agencies are also adopting a sector-based approach to the energy/climate issues (see Part 10.C.1, p. 110).

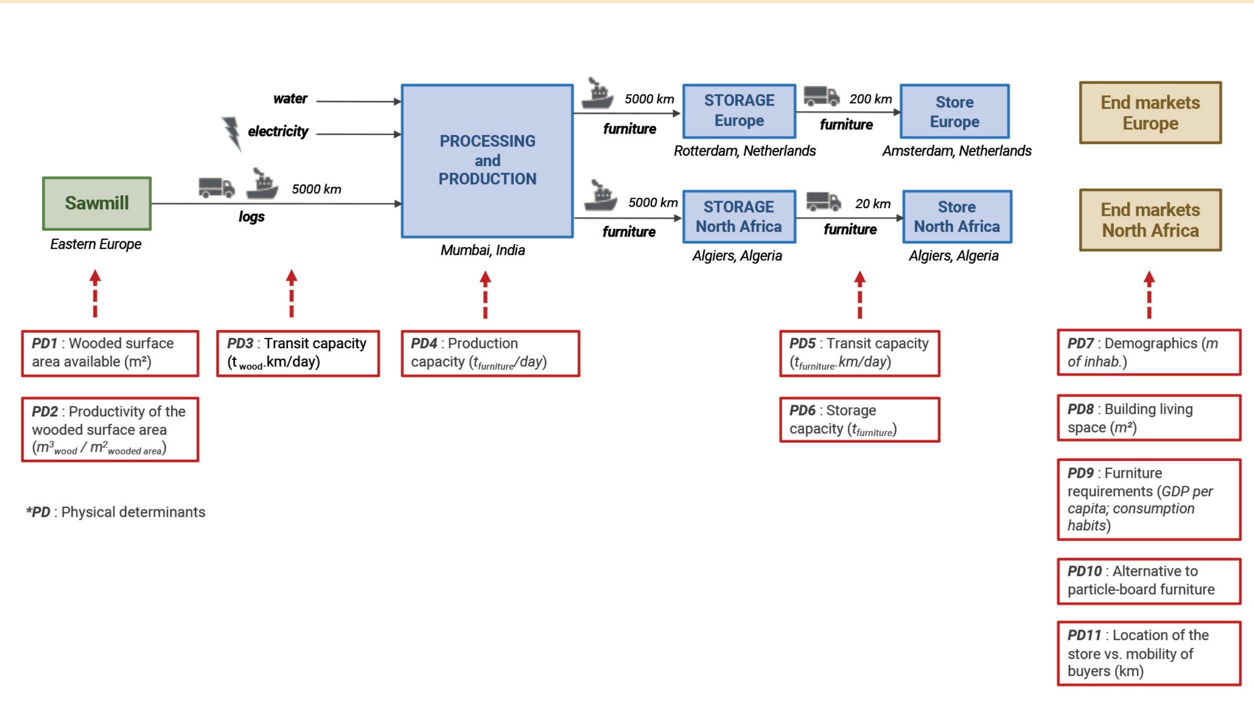
27 - See *"Hermès: les secrets d'un géant du luxe", entreprendre.fr (2014).*

Box 1: Ascertaining how dependent a company's activities are on the transformations brought about by the energy/climate issues (example)

Take *company λ*, specialised in the manufacture and distribution of particle-board furniture (kitchen, office, etc.). This company operates on two main markets: Europe and North Africa. It procures logs from Eastern Europe, and processes them at a production site in the region of Mumbai in India. It then ships them to two warehouses in Amsterdam and Algiers. Apart from wood, the production process mainly requires electricity and water.

The determinants of *Company λ*'s activities and its demand (see red boxes above) may be affected by energy/climate issues. For example, the wooded surface area available (VC1) may be affected by forest fires associated with more intense and frequent periods of drought. The need for furniture may be affected by changes in lifestyles (consumerist or otherwise) in the regions or outlets where the company operates, or the location of sales outlets (links to public transport networks, for example). Finally, given the considerable distances covered by the company's various products and the means of transport used (carbon-based), the introduction of restrictive regulations on the carbon content of goods sold could affect flows.

Figure 6: Simplified breakdown of Company λ's value chain and the main determinants of its activities.



5 Scenario-based foresight analysis

Scenario-based **foresight analysis** is a **method used** by several stakeholders. It implies **measuring an organisation against several different futures**. When applied to the energy/climate issues, it can be used to evaluate the related risks and opportunities. This method informs the strategic thinking of a company faced with the uncertainty of the far-reaching social and economic changes brought about by the energy/climate issues, and the prospect of a non-linear future and potential disruption.
It is vital that the company's leaders and operational management are committed if the implementation of energy and climate scenario analysis is to be a success.

A. What does scenario-based foresight analysis involve? 29

1. Foresight: a way of anticipating and taking action 29

2. What is a scenario? 31

B. An effective way of addressing energy/climate issues 33

C. Suggested scenario-based foresight analysis process 34

D. Backing of the company's top management is the key success factor 36

When building their strategic plan, companies most often strive to predict trends, but this approach does not give full consideration to the energy/climate issues they may have to face.

Most companies form a strategic plan to structure their activities and future investments over the medium term (the time frame considered varies from one sector to another, but rarely goes beyond an average five years).

Most of the time, the development of this plan is part of an analytical process that involves **anticipating changes to the company's financial results** (sales revenue, net revenue, EBITDA, cash flow, return on equity, funding requirements, etc.) based on changes in key parameters in the company's business model (demand, price of inputs required for the company's activity, sales price of goods/services marketed, taxation, macro-economic variables, etc.).

Changes to these key parameters are usually estimated using a set of relatively heterogeneous data (market surveys, research by specialist consultants, forecasts from economic and financial institutions) that are not always consistent with one another.

The economic and financial system will be disrupted by the energy/climate issues, which cannot be fully gauged using this approach (disparate, inconsistent data), so the system's vulnerabilities could be brought to the fore.

To attenuate these vulnerabilities, many companies have incorporated the carbon price[28] to calculate the profitability of their investments or changes in their margins but, as such, do not cover the full extent of the energy/climate issues.

The introduction of a **carbon price** by companies is a positive move in many ways and a real step forward. However, as an approach, it **takes into consideration only some of the many far-reaching transformations of the socio-economic systems.**

Changes to lifestyles, behaviour and the related impact on the demand for the company's products and services, changes in transport modes and the associated costs, the redefinition of world trade rules, the reorganisation of the production system and the impact of more frequent extreme weather events are all factors that an internal carbon price alone cannot incorporate.

Executive managers need in-depth understanding of how their corporate environment will evolve in response to the energy/climate issues over a given time horizon so that, as of now, they can make strategic decisions to ensure the company's continued viability.

28 - The carbon price is sometimes indexed on the price applied by certain governments or follows the (upward) trend deemed compatible with the Paris Agreement.

A

What does scenario-based foresight analysis involve?

1 Foresight: a way of anticipating and taking action

Foresight analysis is a set of methods designed to feed into an organisation's strategic thinking when the future is very uncertain and marked by changeable, complex or interdependent challenges.

Primarily, these methods can be applied to **anticipate** the evolution of these challenges and, within an organisation, contribute to the development of **adaptation (or transformation) strategies** to foresee risks and seize all opportunities, regardless of their outcome.

This corpus of methods has been developed progressively in line with its use by an array of very different stakeholders, such as the armed forces and central administrations in certain countries, and businesses.

The methods emerged immediately after World War II in government structures (mainly military) in light of the new geopolitical balance and the related security issues (development and proliferation of weapons of mass destruction).

They gradually spread to civil and economic administrations. In France, for example, the DATAR (inter-ministerial delegation for regional development and attractiveness) introduced forward-looking analysis in the early 1970s[29].

Companies – starting with oil businesses – began to adopt these methods at around the same time, against a background of international tension, especially on the oil markets. The remarkable work of Frenchman Pierre Wack[30], head of the newly created planning department Royal Dutch Shell, paved the way for the implementation of scenario-based foresight analysis in businesses (Mietzner and Reger, 2005).

Forward-looking analysis methods for businesses have since been significantly enhanced and updated, giving rise to several schools of thought and approaches (Bishop, Hines and Collins, 2007). In France, there is a strong culture of foresight, developed on the impetus of the *Commissariat Général au Plan*, now known as *France Stratégie*. Also worthy of note is the work of Michel Godet (professor at the *Conservatoire national des arts et métiers*, holder of the Chair of Strategic Foresight), the centre for foresight thinking and studies *Futuribles*[31] (founded by Bertrand de Jouvenel) and its journal, and the Centre for Strategic and Prospective Studies (CEPS) and its review *Prospective Stratégique*[32].

There are many foresight practises, meeting different requirements.

Depending on the organisation's specifics (culture, history, size, activities, etc.), the type of approach it wishes to take (decision-making aid, strategic orientation, change management, etc.) and the resources at its disposal, the foresight method and the implemented process may be very different (i.e. rolled out at different strategic levels, different scope of mobilisation, requiring use of formal or informal mechanisms, time involved, etc.). Four types of foresight approach can be identified, depending on whether they lead directly or indirectly to strategic decisions or mobilise a large number of participants (Bootz and Monti, 2008):

- *decision-making support:* involving a low level of mobilisation and having an indirect impact on strategy;
- *strategic orientation:* having a direct impact on strategy and involving a limited number of participants;
- *mobilisation:* requiring a high level of mobilisation and having an indirect impact on strategy;
- *change management:* requiring strong mobilisation and with a direct impact on strategy.

Scenario-based foresight analysis (or the scenario method) generally involves all of these procedures. Depending on the selected approach, different scenarios will be studied.

Box 2: Proposed definition of scenario-based foresight analysis

Scenario analysis is a method of foresight which, by its very nature, means looking at possible futures and tracing the logical chain of events that might lead to those futures, in order to better inform future action (Godet, 2011):

1. Measuring the company's present activities against several different possible futures, described in scenarios and characterised by the issues under study;

2. Identifying the risks and opportunities that could affect the company's business model in each of these futures and **assessing the resilience of that business model** (i.e. the company's capacity to withstand the disruption brought about by the issues examined and to adapt to changes or uncertainties in its business environment);

3. Identifying the options for action to seize opportunities and counter risks, **and using the results as input in the company's specific "strategic" thought process.**

This method is similar to that recommended by the TCFD in its final report[33] with regard to companies' analysis of energy/climate issues.

Finally, there are several ways of looking at the future, and scenario-based foresight analysis should not be confused with them.

This is clearly indicated in the TCFD's Technical Supplement:

- *Scenario-based foresight analysis is not a forecast* (of what will happen to the company). Producing a forecast means **predicting the most likely future** analysing historical data and trends. It is an **estimate of the future stated with a level of confidence.**
- *Scenario-based foresight analysis is not a sensitivity analysis,* which is more about assessing the impact of the

29 - See "Scénario de l'inacceptable. Une image de la France en l'an 2000" [A scenario of the unacceptable, an image of France in the year 2000], DATAR, La Documentation française, 1971.
30 - Most notably, this work helped Shell anticipate the consequences of the 1973 oil crisis (fivefold rise in oil prices) and to adapt more rapidly than its competitors. See Mietzner and Reger (2005).
31 - See the Futuribles website.
32 - See http://www.ceps-oing.org/prospective-strat%C3%A9gique.

33 - "The purpose of scenario analysis is to consider and better understand how a business might perform under different future states (i.e. its resiliency/robustness). In this context, resiliency/robustness refers to the ability of an organization's business or investment strategy to tolerate disruptions or adapt to changes or uncertainties in the business environment that might affect the organization's performance and to remain effective under most situations and conditions". TCFD final report (2017).

variation of a specific variable on the results of a modelling exercise, for example.

- *Scenario-based foresight analysis is not a stress test.* This type of analysis, conducted by financial regulators, evaluates the consequences of unfavourable market scenarios or severe, sudden shocks on the stability of the financial system, and in particular the solvency of financial stakeholders (banks, insurance companies, etc.). We sometimes talk about the climate stress test.

2 What is a scenario?

Scenarios play a key role in most forward-looking analysis methods.

A *scenario* is a description of a possible future and the course of events taking us forward to it, from the original situation (Godet, 2011). This description includes various qualitative and quantitative elements that develop over time in a coherent manner in a *narrative* (Mietzner and Reger, 2005).

A scenario is not an exhaustive description of a possible future. Instead it covers a certain scope (theme, geographic, time, etc.) and, as such, **a scenario describes the main elements that characterise the issues examined** and the key factors that drive their development[34].

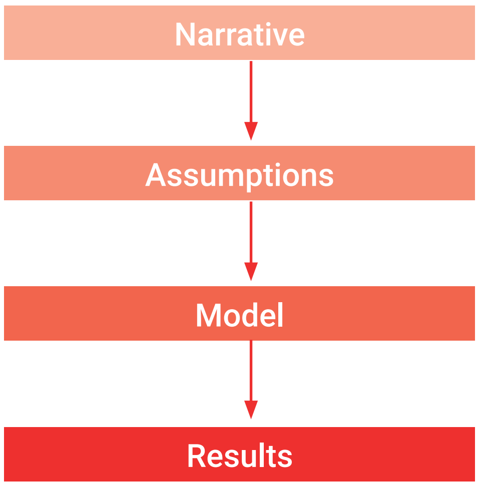
Broadly speaking, a scenario comprises four main parts:

The **narrative** of the scenario is a written *qualitative description* of the future. This description is generally structured around determinants of various types (political, economic, social, behavioural, environmental, geopolitical, technological and so on), which are specific to the system being examined and to its environment and which will evolve in the future. The narrative is the scenario's "storyline". It is the framework that gives the quantitative assumptions meaning.

The (input) assumptions are *quantitative variables*, the evolution and value of which are defined and known beforehand. In certain scenarios, population growth is generally an assumption. These assumptions are only meaningful in the context of the narrative.

The model is a mathematical or logical construction designed to use the input assumptions and a governing process to provide a representation of how a real system works (the climate, a country's economy, etc.) and how it will evolve over time. The models come with varying levels of complexity and sophistication.

The scenario results are the quantitative data obtained by the model's "processing" of the input assumptions. These results thus depend on the input assumptions and the model's characteristics. They are interpreted to provide an ending to the scenario's storyline.



A scenario is not necessarily suited to precise calculations, as practised in other fields (e.g. physics). **At the very least, a scenario will comprise a narrative** (see Chapter 6, p. 38). Depending on the type of requirement and the use that is made of the scenario, quantitative elements (input assumptions, model and results) can be added to the narrative.

The literature tends to agree on the main characteristics of a scenario (Mietzner and Reger, 2005). The TCFD recalls these characteristics in its final report:

1. **Plausible:** the events described in the scenario should be possible and credible;
2. **Distinctive:** each scenario should be based on a distinct and clearly differentiated set of determinants;
3. **Consistent:** interaction between the qualitative and quantitative elements described in the scenario should

34 - See the Technical Supplement to the final report of the TCFD, "Scenarios are not intended to represent a full description of the future, but rather to highlight central elements of a possible future and to draw attention to the key factors that will drive future developments. It is important to remember that scenarios are hypothetical constructs".

obey strong logic. If the reversal of past trends is predicted, a logical explanation of such a reversal should be provided;

4. **Relevant** (to the issues examined): the specific issues at stake should be key to the scenario;

5. **Challenging:** the scenarios should challenge the prevailing visions of the future and the *status quo*.

Several specialists add a final characteristic: **transparency**. This primarily concerns the methods applied, the assumptions made, the reasons behind their choice, the results and the conclusion of the scenarios (Godet, 2011).

There are many scenario-building approaches, which may be either:

- **normative or backcasting**: it starts by defining a desirable future (defining all or part of the end state of the scenario), then working backwards to define the path that would lead to that future. This may be done, for example, to analyse the feasibility of the path and the conditions required to attain that future; or
- **exploratory:** it starts with the present situation and describes a logical chain of events that would lead to a possible future, whether desirable or not. For example, "business-as-usual" scenarios are mainly exploratory and describe the continuation of historical trends.

A scenario rarely exists alone. It is part of a family of scenarios, where it fulfils a function.

A family of scenarios is the group of scenarios underpinning an organisation's scenario-based foresight analysis. The structure of this family and the scenarios that it comprises depend on the objective and expected outcomes of the analysis.

Within a family of scenarios, we usually define a *baseline scenario*, to which all the other scenarios in the family are compared, for example to measure the impacts of a specific event or action described in one of them (see Box 21: Scenario analysis process deployed by the company South32, p. 101). This is usually a business-as-usual scenario, or a scenario in which there are only limited changes to the original situation. In this respect, baseline scenarios do not comply with the "challenging" criterion listed above (but will still comply with the others[35]).

The other scenarios in a family are referred to as alternative (to the baseline scenario). These scenarios are usually retrospective, i.e. they describe a possible and desirable future (and the path that leads to it) that is different to the baseline scenario, with reference to the issues examined.

Box 3: Energy/climate scenarios and 2°C scenarios

Energy/climate scenarios are scenarios that focus on the issues linked with climate change mitigation (or transition issues) and/or the challenges associated with adapting to the consequences of this change.

When a scenario only deals with mitigation issues, we refer to them as **"transition energy/climate scenarios"** or simply **"transition scenarios"**. They describe a gradual transformation and reorganisation of the world socio-economic system (and its stakeholders) leading to the gradual capping of annual GHG emissions.

The scenarios usually referred to as **"2°C scenarios"** (especially the public 2°C scenarios, see Chapter 8, p. 54) are transition scenarios where the total CO_2 emissions over a given period are compatible with the carbon budget set for the same period (see Part 3.A.3, p. 19). A **"2°C trajectory"** is often equated with the projection over time of world GHG emissions in a 2°C scenario.

The 2°C scenarios usually combine a **normative approach,** in the sense that a setpoint temperature (or CO_2 emissions, etc.) is defined, with an **exploratory approach,** given that the future characteristics of the other components of the scenario are not predefined.

35 - We can thus raise questions about the consistency (criteria 3) of some public energy/climate scenarios (most of which are baseline scenarios, such as the IEA's WEO Current Policies Scenario (CPS)), which forecast a considerable increase in CO_2 emissions but do not include the physical consequences of global warming on the economic system.

B

An effective way of addressing energy/climate issues

Scenario-based foresight analysis helps decision-makers gauge the profound transformation of the corporate environment brought about by energy/climate issues.

The changes triggered by the energy/climate issues will be deep-seated and could disrupt the economic, geopolitical and financial system. However, they remain uncertain. Projecting the company into several possible futures shaped by these issues is a way for decision-makers to address this uncertainty and convert it to a range of strategic options (Wack, 1985).

The advantage of this method does not therefore lie in the accurate description of the future (which we are not striving to forecast), but in making better decisions based on the different possible futures (Mietzner and Reger, 2005).

The scenarios give a consistent, plausible and challenging description of several future changes in the corporate environment, related to energy/climate issues (commercial environment, economic, social or political context, geopolitics, etc.). As they analyse these scenarios, decision-makers are able to weigh up the strengths and vulnerabilities of their company's business model in these future environments, to identify potential disruption and the signals characterising it and, in the most objective manner possible, make the strategic decisions – as of now – required to ensure the company can continue to operate.

Scenario-based foresight analysis is a powerful way of mobilising management and staff to adapt the company to the energy/climate challenges.

Changes to the corporate environment triggered by energy/climate issues could urge business leaders to transform some of the company's activities and/or opt for some degree of repositioning.

Scenario-based foresight analysis not only broadens executive managers' strategic view, it can also be a good opportunity to help company staff understand the phenomenon and identify relevant solutions for the company. Looking forward to and reflecting on the future can be a stimulating exercise, allowing the development of a common vocabulary to address energy/climate issues and helping everyone to embrace the challenges.

Several specialists point out that one of the main benefits of forward-looking analysis lies less in the ensuing report than in what happened in the minds of the people involved in the thought process (Godet, 2011).

While there is growing awareness of the energy/climate issues and while the future of certain highly exposed business sectors may seem compromised, conducting scenario-based foresight analysis projects the company into the long term and confronts it with the challenges of its time, thus making its future meaningful and highlighting the opportunities it has to remain efficient in the future (see Box 6, p. 46).

Conducting scenario-based foresight analysis to address the energy/climate issues is relevant for all companies.

As previously indicated, most areas of business (some more than others) and world regions will be affected by the changes brought about by these challenges.

Depending on the problem raised and the company's resources, the exercise will vary in complexity and depth. The TCFD considers several levels of analysis[36] :

> *« The Task Force recognizes that, for many organizations, scenario analysis is or would be a largely qualitative exercise. However, organizations with more significant exposure to transition risk and/or physical risk should undertake more rigorous qualitative and, if relevant, quantitative scenario analysis with respect to key drivers and trends that affect their operations. »*

The following sections of the report set out the methodological components that a company can apply to conduct a scenario-based foresight analysis. Finally, there are many organisations able to assist companies in their forward-looking analysis, especially when it comes to methodology.

36 - See "Final report: Recommendations of the Task Force on Climate-related Financial Disclosures", TCFD (2017).

C

Suggested scenario-based foresight analysis process

While there are several variations, most of the scenario analysis methodologies are similar in construction (Mietzner & Reger, 2005).

By nature, this method is based on scenarios (stages 3 and 4) that each describe a different future marked by profound changes to the corporate environment. Several stakeholders[37] are involved throughout the process and produce a number of deliverables.

Prior to the process, it is necessary to define the goal of the analysis (impact on strategy and number of participants in the exercise) and to secure the support of the company's management.

The first stage is then *to define the problem to be analysed, to mark the boundaries of the analysis (time, geography, etc.) and to formulate one or several questions to be answered by the analysis.*

For energy/climate issues, these questions should:

- include aspects concerning the energy transition and "physical" aspects related to climate change;
- establish a long-term horizon, not only given the nature of the issues at stake but also to "unleash" thinking.

Examples of these questions include:

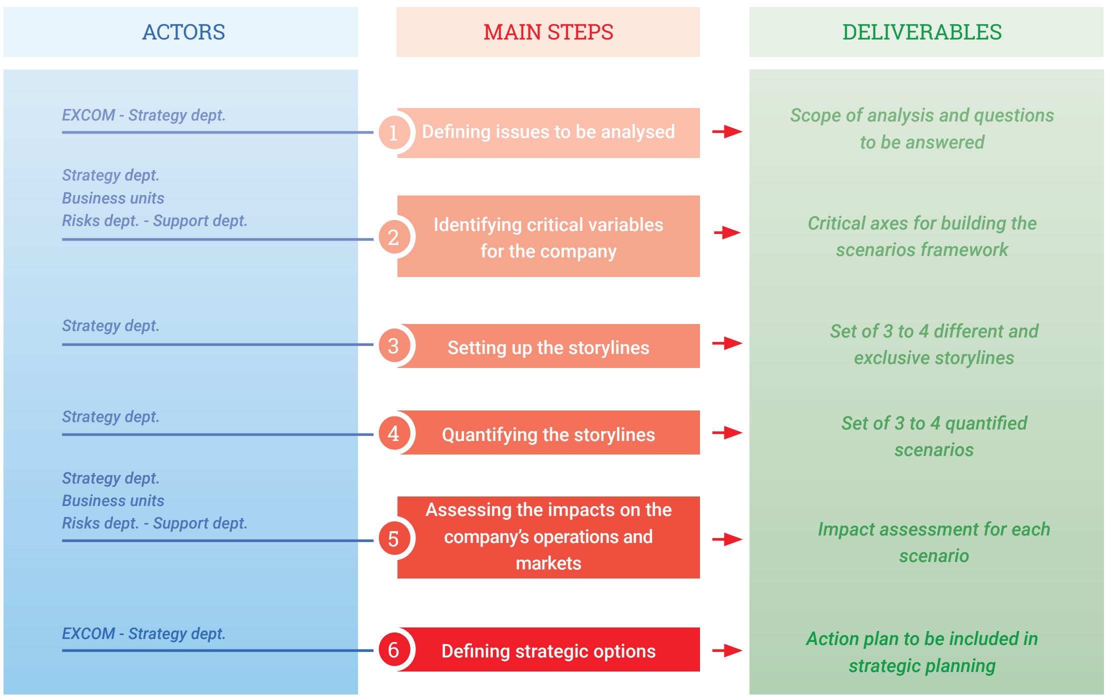
- *"What are the opportunities for diversifying my company's activities if the markets change in response to a significant fall in CO_2 emissions?"*
- *"Are my company's business model and assets vulnerable to major changes to the climate?"*

This stage involves the strategy division and possibly the executive committee.

The second stage is *to identify the company's "critical variables"* within the framework established in stage one.

A *critical variable* is a parameter that characterises the corporate environment and which, if changed – under the effects of the issues being examined – could affect its value chain (e.g.: market structure, demand for goods and services sold, raw materials and components, distribution

Figure 7: Simplified diagram of the scenario analysis process (adapted from Mietzner & Reger, 2005)



37 - The term "support functions" refers to the sustainable development department, the purchasing department, marketing and communications, and the like.

chain of the goods and services sold). There are several types of variable (e.g.: social, political, economic, financial, technical, environmental, etc.) and they may concern the company itself (in particular its structure, systems, management, etc.) or its external environment.

When applied to energy/climate issues, these critical variables describe transformations in the corporate environment marked by the low-carbon transition or climate change, or both.

There are several methods for determining a company's critical variables[38]. Whichever method is selected, it should assess how dependent the company's activities are on its physical determinants (see Chapter 4, p. 22).

During this stage, we also identify the main stakeholders in the corporate environment (competitors, customers, regulators, etc.), their strategies and the resources at their disposal to attain their objectives.

This stage involves the strategy division, the operational divisions (to ground the analysis in the reality of the company's operations) and some support divisions (e.g.: sustainable development).

The third stage is *to construct several narratives* around the critical variables identified.

These narratives describe the evolution of different sets of critical variables defining the transformations that will affect the company's activities. It is a structured, written text (see Chapter 6, p. 38). In practise, there are rarely more than four narratives.

This stage mainly involves the strategy division. It may take on board input from an array of internal (company research and expertise) and external (experts, IPCC publications, national plans and NDCs, specialist scenarios) sources.

The fourth stage is *to quantify certain elements in the narratives* produced in stage 3.

This provides additional input for the impact analysis (stage 5), most notably to evaluate the economic impacts the scenarios would have on the company's activities (see Chapter 7, p. 48) by quantifying certain key physical determinants.

This stage mainly involves the strategy division.

The fifth stage involves *projecting the company into the futures described* (in stages 3 and 4) to assess the impacts on its activities.

This stage involves the strategy division, the operational divisions (to ground the analysis in the reality of the company's operations) and some support divisions (e.g.: sustainable development). The participants are put before the different possible futures and their thoughts collected. At the end of this stage, the participants have an idea of how the company's activities could be affected.

The sixth and final stage is *to define an action plan*, i.e. putting thought into action. This is a task for the executive committee, with support from the strategy division.

The scenarios are devised in stages 3 and 4.

When studying energy/climate issues, these stages can be completed in-house (following the process described above, for example) or outsourced. If the people leading the analysis prefer to outsource scenario development, they have two options:

- **Use publicly available scenarios, produced for another study by an external organisation** (see Chapter 8, p. 54): in this case, the analysis leaders subscribing to these narratives have no control over the input assumptions or the results of the scenarios used.
- **Use the services of organisations specialised in constructing scenarios on the basis of narratives and input assumptions predefined in-house by the company (stage 2):** these organisations have usually developed a model to represent the complex interactions between the variables in a scenario, especially in quantitative terms. In this case, the analysis leaders define the framework of the modelling exercise (i.e. they provide a narrative and input assumptions for the modelling team) and remain partially in control of the results (see Part 8.B.1.d Modelling issues, p. 63).

38 - See, for example, the structural analysis or the MICMAC method (Godet, 2011).

D

Backing of the company's top management is the key success factor

One of the main keys to success for the forward-looking analysis of energy/climate issues is strong commitment from the executive management.

Although the practise of scenario-based foresight analysis is long-established, having been applied by certain companies for several decades, its implementation has become rarer since the late 1990s and it has gradually disappeared from corporate cultures. Several of them say that the financialisation of the economy and short-term profitability requirements (e.g.: the publication of quarterly performance reports) have gradually diminished the need to look to the long term. Companies' strategic plans rarely go beyond five years.

The nature of the energy/climate issues means forward-looking analysis is a good way of assessing risks and opportunities, yet its application is not necessarily self-evident (see *The Tragedy of Horizons*, Part 3.A, p. 17).

For this reason, strong commitment from companies and their executive committees – the governance body that shapes the company's strategy and which, more than any other, may reflect on a long-term projection – is vital in incorporating energy/climate issues into the company's strategy and in actively supporting the steps taken to do so in an objective manner, most notably through scenario-based foresight analysis.

In most companies that have introduced this type of analysis, the top management and executive committees have played a crucial role, mainly by providing the initial impetus and supporting the process.

Box 4: The crucial involvement of Air Liquide top management

Air Liquide creative oxygen

Air Liquide is an industrial group operating worldwide (Europe, America, Africa, Asia, etc.) on several markets (Industry, Healthcare, Electronics, etc.). Its activities are mainly generation and supply of industrial and medical gases. Long term investments (more than 15 years) are required to meet the growing demand and the strong trend for outsourcing.

Air Liquide has conducted a climate and energy scenario analysis (see box 8 p. 52). This analysis is part of a broader work clustered by a "Climate Task Force". This is the result of a strong impulse from the top management, especially in the first place from Benoît Potier, CEO of Air Liquide, who has been very much involved from the beginning, and the high expectations of the company's stakeholders (employees, clients, investors, etc.). The main departments of the group (business lines, finance, engineering, R&D, etc.) took part under the supervision of a steering committee including three members of the Executive Committee in charge of Strategy, Innovation and Development.

On its launch, the Task Force was assigned to come up with some tangible, intelligible climate objectives, applicable by all and operable in the field. This was a key factor in the success of Air Liquide's climate action. *"Mission accomplished! I can see it every day, when out in the field or when called on by the operational divisions with regard to investment decisions"*, says David Meneses, Group VP Sustainability.

Strong governance and close involvement of the operational divisions is also a key to success for the scenario-based foresight analysis process.

Scenario-based foresight analysis mobilises several stakeholders and a wide range of skills that have to be coordinated and managed throughout the different stages of the process.

The leader of this kind of process will have a direct influence on its successful completion. The authority, expertise and experience (and knowledge of the company's organisation in particular) needed to build support from staff and the company's management are decisive qualities for the role.

Proper coordination of the forward-looking analysis with the company's existing processes (risk management, sustainable development, strategy) is also crucial.

Finally, involving the business units, which are vital to the company's added value creation, is a way of ensuring "grassroots" input and experience for the analysis and of grounding the results in the reality of the company's operations.

These observations are shared by most companies that have introduced scenario-based foresight analysis (see the statements from Michelin and Axens, Box 5 and Box 6, respectively p. 45 and p. 46).

In its final report, the TCFD cites governance as the first stage in its recommended analysis process:

> *"Ensure governance is in place: Integrate scenario analysis into strategic planning and/or enterprise risk management processes. Assign oversight to relevant board committees/sub-committees. Identify which internal (and external) stakeholders to involve and how".*

To be efficient, scenario-based foresight analysis of energy/climate issues must benefit from adequate resources.

The time and resources required to conduct forward-looking analysis depend on the objective and scope. These parameters also vary according to the expertise available in-house and the company's organisation (whether there is a foresight department or not, processes in place, etc.).

Generally speaking, the identification of critical variables (stage 2) and impact assessment (stage 5) mobilise more resources than the other phases.

Devising the scenarios – at least qualitative ones – does not appear to be the most time-consuming or resource-intensive phase, but this depends on the level of scenario sophistication.

Energy/climate issues cover complex phenomena. Ensuring they are shared by the top management before the launch of the forward-looking analysis, will make it easier to complete and more effective overall.

6 The "narrative" is the starting point for the scenario analysis.

Scenario-based foresight analysis starts with a critical review of the **qualitative elements** (the "narrative" of the scenario) which structure the collective thinking and make it easier for the company's staff to take the issues on board.

A. Why is the narrative important in the scenarios used by companies? 39

B. The main determinants to be considered in an energy/climate scenario . . 40

C. Suggested narrative development process. 43

A

Why is the narrative important in the scenarios used by companies?

The scenario narrative is a *qualitative written description* of the future. This description is generally structured around determinants of various types (political, economic, social, behavioural, environmental, technological and so on), which are specific to the system being examined and to its environment and which will evolve in the future. The narrative is the scenario's "storyline".

Narratives can cover a very broad spectrum of possible futures and are only limited by the dual requirement of overall consistency and plausibility.

To encourage reflection and questions about projected future trends, scenarios should remain plausible and consistent as they describe an original future marked by the issues under examination. In this respect, when building scenarios, we should not draw exclusively on "mathematical" modelling, which is naturally limited by the model itself.

Because narratives tell the story of the future without any quantified content (which can sometimes be limiting), they provide various degrees of freedom to explore and identify possibilities. Although they are bound by the problem under study and structured around the company's critical variables, they are the outcome of collective reflection, with plenty of room for imagination.

Indeed, many of the elements that shape the future are not quantifiable, but can be taken into account in qualitative terms in narratives (e.g.: political stability, the chosen governance methods, etc.).

These elements are especially important when studying energy/climate issues. Although only very marginal consideration is given to the consequences of climate change on the economic system in the public scenarios (see Part 8.B.3.e, p. 86), mainly because these consequences cannot be accurately modelled, in a narrative it is quite possible to describe a corporate environment affected by these phenomena.

The narratives are "tailored" for company scenarios.

Scenario-building follows certain rules (see Part 6.C, p. 43). By its very nature, the process is structured around changes in the company's specific critical variables, with the issues under examination providing the context. Elements from external analyses may provide input when drafting the narrative, but the narrative will tell the story of the company's future and environment.

This aspect is key to ensure the issues are shared by the top management and staff. It is also important to secure the company's "independence" when it comes to selecting the assumptions that will structure the futures it will examine.

The narrative provides a context of relevance for all the input assumptions and quantitative projections used to describe the future.

Each input assumption forms part of a more or less explicit frame of reference, which is used to measure its plausibility and its relevance. The more implicit and ill-defined this frame of reference, the harder it is for the scenario user to endorse the results derived from the assumptions. For example, how can we measure the plausibility of an assumed establishment of a global carbon price if we do not know the geopolitical factors that would enable countries to work together to make this happen?

The narrative is thus the frame of reference that describes the system studied and/or its environment; it ensures consistency between the assumptions in a scenario, while making sure they are plausible and relevant.

B

The main determinants to be considered in an energy/climate scenario

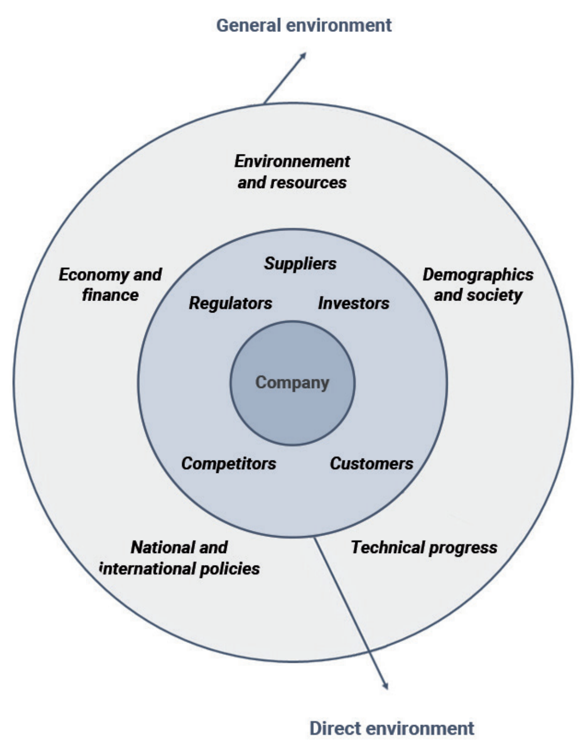
The environment-related determinants describe the immediate and general environment in which an organisation or company operates.

The general environment-related determinants set out below are grouped into five categories and are inspired by the grid put forward[39] to develop the *Shared Socio-economic Pathways (SSPs)* analysed by the IPCC (see Box 15: The Shared Socio-economic Pathways (SSPs), p. 69).

They cover the aspects that could affect the evolution of a company's critical variables and which could be integrated when developing the narrative for an energy/climate scenario in-house. These aspects can also be considered when assessing the narrative of a public energy/climate scenario.

The main factors influenced by the evolution of these determinants are also set out.

Figure 8: Main determinants of a company's direct and general environment



39 - See "The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century", O'Neill et al., Global Environmental Change, Volume 42, 2017.

Category 1: **social and demographic determinants,** which describe the context of population change and social behaviour.

Determinants	Scope of influence
Demographic and human development determinants can be characterised by: • The extent and characteristics of the urbanisation process (controlled or otherwise, sustainable or not)	• Volume and structure of demand (for raw materials, goods and services) • Volume of flows of people, raw materials, goods and services in circulation
• The development and accessibility of education and health services and facilities, and access to vital resources (water and food) • The extent and nature of population movements (particularly related to climate change)	• Artificial development of land (urbanisation and crops) • National and international political stability
Social determinants can be characterised by: • Social cohesion in countries • Citizens' level of commitment and participation in public life • Tolerance to change in lifestyle and acceptability of new constraints	• Change in citizens' behaviour (activism, judicialisation) • Volume of flows of people, raw materials, goods and services in circulation • Deployment and implementation of public policies

Category 2: **domestic and international policy determinants.** These elements of the narrative describe the political, diplomatic and geopolitical context in which national and international public action is rolled out.

Determinants	Scope of influence
International policy determinants can be characterised by: • The scope, object and effectiveness of international cooperation and international agreements (WTO, ECT, etc.) • The shift in the epicentre of power from one region to another • The extent of power rivalries or the evolution of political instability in certain key regions (conflicts, etc.)	• Volume of flows of people, raw materials, goods and services in circulation • Deployment and implementation of international actions (especially action to adapt to and mitigate climate change) • National and international political stability, roll-out of carbon taxes at borders • Primary energy consumption mix • Management of externalities linked to the energy/climate issues
Domestic policy determinants can be characterised by: • The level of mobilisation of stakeholders (public authorities, civil society, companies and markets), especially as concerns the energy transition • The nature and scope of the public mechanisms implemented (regulatory or tax measures, etc.) • The type of governance introduced by the various public players (centralised or decentralised, vertical or horizontal, etc.)	• Deployment and implementation of public actions (especially action to adapt to and mitigate climate change, acceptability of a carbon price) • Primary energy consumption mix • Volume of flows of people, raw materials, goods and services in circulation • Management of externalities linked to the energy/climate issues

Category 3: macro-economic and consumption determinants. These elements of the narrative describe the context in which the economic system operates.

Determinants	Scope of influence
Macro-economic determinants can be characterised by: • The level of public and private stakeholders’ debt • The nature and level of economic growth in different parts of the world, productivity trends • Structuring of the world economy (service economy, industrial production, etc.) in the different regions • Stability of the financial system and how investments are allocated • The nature and extent of inequalities within and between countries	• Volume of flows of people, raw materials, goods and services in circulation • Volume and structure of demand (for raw materials, goods and services) • Deployment and implementation of action to adapt to and mitigate climate change • National and international political stability • Interest rate levels (“Lower for longer” scenario shifting towards “Lower forever” scenarios) and changes to monetary policies
Consumption determinants can be characterised by: • The degree of connection and trade between markets (protectionism and globalisation) • Change in consumer behaviour (material consumption standards, type of diet, etc.) in different parts of the world • The weight and structure of the different markets (e.g. shift towards Asia, development of the circular economy, digital boom) • Raw material (energy included) price levels and costs (capital and operation) of the various technologies which have a high impact on energy demand and the composition of the energy mix • Acceptability of a resurgence in inflation • Control over the rebound effect	• Volume and structure of demand (for raw materials, goods and services) • Volume of flows of people, raw materials, goods and services in circulation • Artificial development of land (urbanisation and crops) • Deployment and implementation of action to adapt to and mitigate climate change • Improved energy efficiency of the economic system • Reduction in the economic system’s carbon intensity

Category 4: technical determinants. These elements of the narrative describe the context in which technologies are developed and deployed, and how they help solve global issues, especially climate issues (technology optimism or pessimism).

Determinants	Scope of influence
Technical determinants can be characterised by: • The extent of research efforts, their orientation (e.g. split between carbon efficiency and other areas of research) and their effectiveness (scientific progress) • The speed with which technology is made available (speed from development to commercial maturity) • The ease with which technologies are dispersed and the consensus on the scientific solution	• Large-scale deployment of technologies, especially low-carbon solutions (transport, industry, construction, power generation) and artificial compensation techniques (CCS) • Improved energy efficiency of the economic system • Reduction in the economic system's carbon intensity

Category 5: environmental determinants. These elements of the narrative describe the context in which resources are taken from the environment and the related externalities.

Determinants	Scope of influence
Environmental determinants can be characterised by: • The scope and nature of abstraction from the environment (extraction of raw materials, breeding, land occupation, pressures on biodiversity) • The scope and nature of the related externalities (changes to biodiversity, climate change, pollution, deforestation)	• Artificial development of land (urbanisation and crops) • Availability of certain resources (energies, materials and production capacities) • Local, national and international political stability, judicialisation and activism • Deployment and implementation of measures to adapt to and mitigate climate change

C

Suggested narrative development process

Once the company's critical variables with regard to the energy/climate issues have been identified, the narrative for the scenario can be developed.

The suggested process that follows is based on the processes implemented within certain companies and aims to highlight the main stages in narrative development. Other processes are available and may also be used.

Stage 1: for each of the main critical variables, identify the environment-related determinants that could affect their evolution within the context of the energy/climate issues.

The evolution of a company's critical variables can be influenced to varying degrees by one or several environment-related determinants. The first step is therefore to identify the most influential determinants for each critical variable.

For example, if one of the company's critical variables is the number of people using the train to travel, the evolution of that variable can be influenced by several determinants such as a change in consumer behaviour, the roll-out of mitigation or adaptation policies by the public authorities (for example, a regulatory or fiscal measure affecting means of transport, or the building of rail infrastructure) and population trends.

Stage 2: select sets of environment-related determinants that have a significant effect on the critical variables

It is possible to take the combination of “critical variables/ environment-related determinants” and identify the determinants that most significantly affect the evolution of the largest number of critical variables.

Here the goal is to select, from among all the possible combinations of identified determinants, the three or four sets that have the greatest impact on the evolution of the main critical variables[40]. Some of them may be eliminated, depending on criteria such as their exclusivity, their relevance to the issues under examination, their internal consistency and their plausibility.

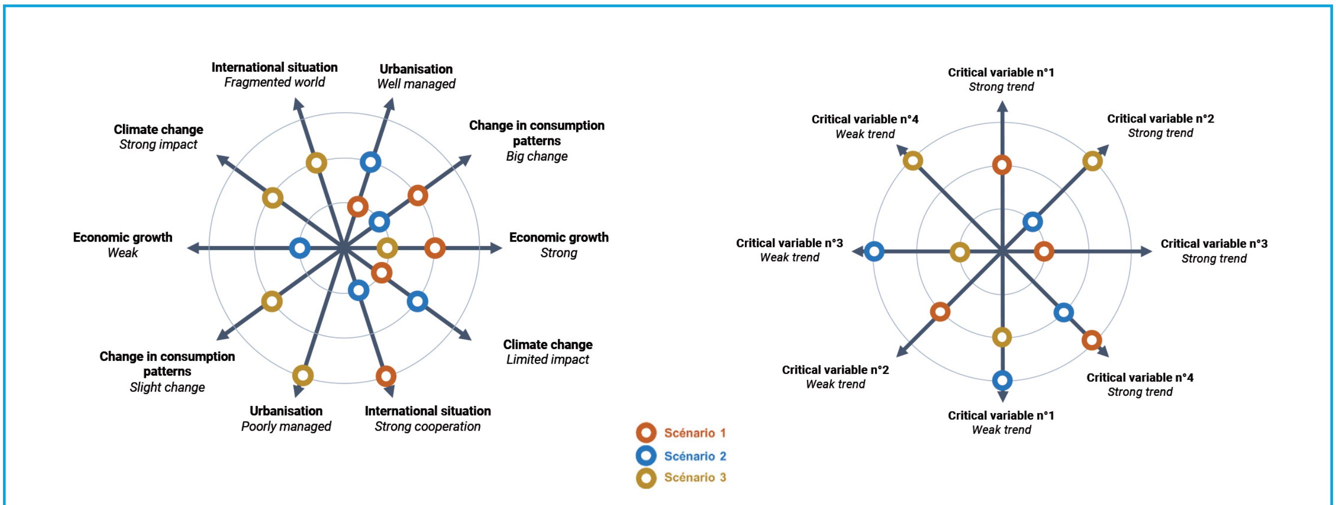
At the end of this stage, the identified sets of determinants each describe a different corporate environment marked by the energy/climate issues and affecting the evolution of the company’s main critical variables in a consistent and plausible manner.

Stage 3: draft the narrative describing the evolution of the environment-related determinants

Here the aim is to write the narrative that describes each set of determinants and how the company’s main critical variables evolve.

The text may be organised by determinant set, by critical variable or use a different structure.

Figure 9: Illustration of narrative structure taking into account five environment-related determinants (left) and their impact on four critical variables for the company (right)



40 - When selecting sets, we can refer to the morphological analysis methods used to systematically explore possible futures using all the potential combinations. See Godet (2011).

Box 5: Foresight analysis is central in the developing of Michelin strategy

The world's second largest tyre manufacturer, Michelin, has long opted to promote sustainable mobility as a means of setting itself apart from the competition. It is active in all areas of mobility, a crucial aspect of climate and pollution issues. For several years now, the Michelin group has had a foresight unit, operating within its strategy division.

This unit comprises a team of experienced staff members from the Group's business units. Their ongoing task is to identify and formulate the main trends that structure and will continue to structure the markets on which Michelin operates. More than 50 trends, organised according to "key drivers", have thus been listed. The foresight unit works closely with the Group's business units.

The complexity and global nature of the energy/climate issues has prompted Michelin to organise its long-term strategic thinking on these issues (with a horizon of 2035) around the analysis of three mainly qualitative scenarios (i.e. narratives) developed in-house by the foresight unit.

The scenario-building process spans three phases.

1. **Identifying the variables that will remain constant** from one scenario to another (this is most notably the case of demographics, considered a "foregone conclusion" within the study's time frame), **and certain "aspirations"** for which the scenarios modify the achievement potential, which is then indicated in the narrative. These aspirations may be technological (IoT, cybersecurity, etc.) or societal (communitarianism aspirations, social media influence, etc.).

2. **Identifying seven critical areas** – such as the level of economic growth (high or low), the degree of global warming (limited or high), consumption patterns (sustainable or otherwise) and the degree of globalisation (high or low) – that may shape how the main worldwide trends evolve.

3. **Establishing three sets of positions in these seven areas,** which will provide the framework for the scenarios and describe three different possible futures.

4. **Drafting the narratives,** developed using the elements acquired during the unit's foresight work with special focus on the Group's corporate environment (mobility).

This process is inspired by existing foresight practises, widely documented in the literature.

These qualitative scenarios are then submitted to a group of managers and experts from the business units. They provide the basis for discussion aimed at measuring the group's activities against each of these scenarios to assess the impacts and draw up a strategy. The scenarios are updated annually by the foresight unit in light of various internal and external interactions.

Each scenario contains "desirable" and "non-desirable" elements and none of them represent "dogmatic" visions of the world. Apart from having strategic benefits, they can be used to spark ideas, create a shared vocabulary and structure discussions, all with the aim of getting the Group's different business units to take the energy/climate issues into consideration. When the substance and format of the scenarios are of high quality, it is much easier to use them in working groups made up of different profiles.

This work is conducted under the impetus of the general management but is not done from "scratch". It makes significant use of the work done upstream by the foresight unit.

At this stage, the analysis results are not necessarily taken into consideration in the company's strategic plan. They serve as a basis when testing interaction between foresight and business units, which is optional but increasingly sought by participants.

Box 6: Foresight analysis is not limited to large companies

Axens is a non-listed French energy company operating on the refinery, petrochemical, gas, renewable energy and water treatment markets. Its business focuses on the design of technologies (licensor), products (catalysts and adsorbents), furnaces and related services (technical support, consulting, training, digital applications). Axens is an international business with almost 2,000 employees.

For several years now, Axens has undertaken work to adjust its offering in light of the sustainable development and low-carbon transition challenges. This approach comes in response to the uncertainty and scope of the transformations to come, which could affect the company’s markets. More recently, Axens has readjusted its approach to incorporate forward-looking analysis based on qualitative scenarios.

This foresight work is done jointly with staff from IFP Energies Nouvelles (IFPEN, sole shareholder of Axens). On Axens’ side, the project is headed by the marketing department and more specifically by the strategic marketing team. Over the longer term, the process aims to diversify the company’s activities in response to future changes linked to the energy transition and sustainable development. The project is backed by the general management and comprises four stages:

1. **Building the scenarios on which the analysis will be founded.** First, a tight-knit group of employees was trained in the technical aspects of forward-looking analysis. That group then identified the company’s main critical variables, the evolution of which could impact its activities. Several different scenarios (narratives) were then developed and written up, drawing on a combination of trends affecting these variables. A group of staff representing the company’s business lines was then included and three scenarios were selected for use in the next phase.
2. **Within these scenarios, identifying the impacts and opportunities for the company.** The entire project team took part in brainstorming sessions aimed at pinpointing opportunities for the company in these three possible futures, which were designed to be inspiring. The conditions required to “unleash” participants’ debate were created and a vast array of ideas emerged. The ideas were sorted, ranked, then summarised as opportunities and some were retained by the managing bodies for the next phase.
3. **Developing the opportunities.** At this stage, the project team was expanded to include other staff members. The aim was to start to explore avenues for diversification within the scope of the selected opportunities.
4. **Building the related action plan.** This stage is currently underway. It is based on an analysis of the solutions put forward in the preceding stage. The aim is to define an action plan with short-, medium- and long-term actions to meet the project goal of diversification.

This is the first time that Axens’ staff have completed a scenario-based foresight analysis process. Several factors facilitated the task. First, there was strong methodological support from IFPEN’s economics and intelligence division, which has sound experience in this type of analysis. This helped establish a robust framework for an exercise which can often veer from its initial objective. Then, the selected time frame – far enough ahead but close enough to the present – helped unleash ideas and proposals from team members. Meanwhile, the inclusion of a representative sample of the company’s staff, especially from the business units, helped keep the task grounded in reality. Last but not least, support from the top and operational management was decisive.

The project leaders have also noted that in a context of increasing awareness of environmental issues, this scenario-based foresight analysis has brought benefits beyond the strategic aspect. It is, in fact, an excellent way of mobilising the company’s staff.

7 Scenario analysis with a quantitative approach

Quantitative elements are used primarily in the forward-looking analysis to assess the impact that the various scenarios have on the company's business. In this type of evaluation, financial and economic variables should not be introduced too early in the process or they may interfere with the clarity of the results or give a poor representation of the "physical" reality.

A. Evaluating financial impacts 49

B. The "financial" approach and the "material" approach. 49

A

Evaluating financial impacts

In the context of scenario analysis, a *quantitative approach* means taking a quantitative measurement of the impact on the company of changes to its corporate environment brought about by the issues at stake, described in a scenario.

Most often, the quantitative approach aims to assess the financial impact resulting from these changes. This is particularly the case when a company conducts a scenario analysis of energy/climate issues. In its final report, the TCFD states:

> *"Scenario analysis can help organizations frame and assess the potential range of plausible business, strategic,* ***and financial impacts from climate change*** *and the associated management actions that may need to be considered in strategic and* ***financial plans***[41]*"*.

It is also recommended that certain companies disclose this type of information for the markets:

> *"Organizations with more significant exposure to climate-related issues should consider disclosing key aspects of their scenario analysis, such as [...]* ***potential material financial implications for the organization's operating results and/or financial position***[42]*"*.

While use of a quantitative approach in scenario analysis is not essential and depends mainly on the objectives of the analysis, this kind of approach is usually presented as a guarantee of more robust results. The TCFD states:

> *"Organizations that are* ***likely to be significantly impacted*** *by climate-related transition and/or physical risks* ***should consider some level of quantitative scenario analysis****"*.

When it comes to energy/climate issues, the quantitative approach is based on use of transition energy/climate scenarios – developed in-house or devised by agents from outside the company – where the projections are quantified (see Part 5.C, p. 34).

B

The "financial" approach and the "material" approach

The financial approach, which is mainly based on prices (of raw materials, products, wages, etc.), does not faithfully reflect transformations occurring in the corporate environment, especially in a "disorderly" scenario.

The financial approach to scenario analysis is in some ways similar to the analytical procedure underpinning the development of strategic plans mentioned at the start of Chapter 5. Using the quantified data described in the scenario (demand, commodity or carbon prices, the cost of certain technologies, the discount rate, etc.) or from other sources (Platts, Bloomberg, etc.), the company calculates the key parameters in its business model (demand, input costs, sales price of the products/services marketed, taxation, etc.) and, using a financial model, works out the trend for some of its financial results (sales revenue, EBITDA, net revenue, return on equity, funding requirement, etc.)[43].

This type of approach can be used to estimate the company's profitability in a scenario within a given time frame.

However, the financial approach comes with a number of pitfalls. For example, it can be difficult to pinpoint the determinants of the financial indicators used, so the latter can be subject to discussion (what is the right discount rate? is the price for this or that commodity plausible?). As a result, the results may not be appropriate or may even be challenged.

41 - See Figure 7 "Reasons to Consider Using Scenario Analysis for Climate Change", p. 26, final report of the TCFD (2017).
42 - See Figure 8 "Disclosure Considerations for Non-Financial Organizations", p. 28, final report of the TCFD (2017).

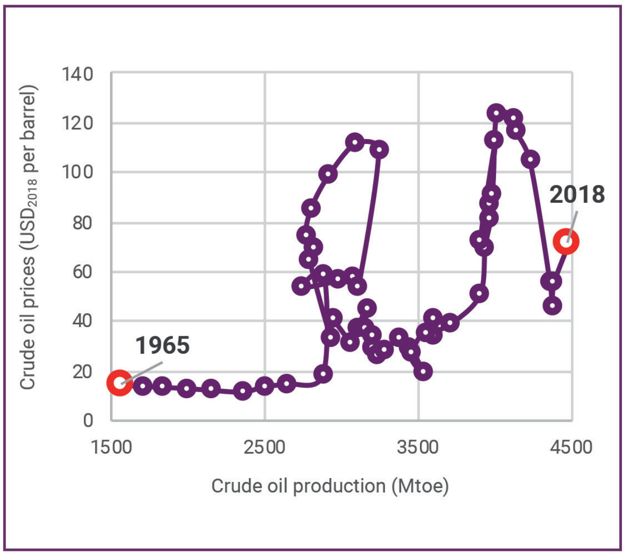
43 - A quite detailed list of financial parameters, the evolution of which may be analysed, is provided in the Technical Supplement to the final report of the TCFD. See Figure 3 "Key considerations: parameters, assumptions, analytical choices, and impacts".

Furthermore, the financial indicators used (mainly prices) only partially reflect reality[44] and do not provide the company's management with a tangible view of the impacts of changes to the corporate environment brought about by pressures from the energy/climate issues.

The financial parameters (mainly prices) described in some of the energy/climate scenarios a company might use are the outcome of modelling exercises, which have their limits.

This aspect, referred to in Part 8.B.3.d, is linked to the very nature of the models underpinning certain energy/climate scenarios.

Figure 10: Crude oil production (supply) according to price (in constant dollars) between 1965 and 2018.



There is no linearity between the oil price and the available volume. From 1965 to 1973, the quantity of oil consumed doubled with a constantly falling price, moderately until 1971. From 1973 to 1986, the volume consumed remained pretty much unchanged with a very variable price, then from 1986 to 2000, we returned to a relatively stable price but volumes increased significantly. Finally, from 2000 to 2018, the volume remained almost constant while the price again varied considerably.

Source: BP Statistical Review 2018

In most of them, the prices of certain commodities, especially energy (fossil fuels, electricity, etc.), are determined by balanced supply and demand when modelled. However, the formation of these prices on highly financialised markets, especially where oil is concerned, does not follow this kind of law[45]. There are also many financial, geological and geopolitical factors at play but they are barely taken into account[46].

Although these models are used to develop transition scenarios projecting a continued, simultaneous imbalance in the supply and demand for certain products and services, we may question for these reasons the meaning of the various price signals used.

By first quantifying the change (in volume) in demand for the company's products and services (using the physical determinants that underpin this demand), more faithful integration of the energy/climate issues becomes possible.

Before affecting prices and other economic and financial indicators, the transformations linked to the energy/climate issues will first affect the evolution of physical determinants, which do not obey any "economic" law. However, the company's activities and demand for the products and services it sells depend on these determinants (see Chapter 4, p. 22).

A "material" quantitative or bottom-up approach is then possible. This means quantifying the (consistent) evolution of the physical determinants in a scenario and, after studying the relationships of dependency, deducing the consequences on the **volume** of demand for the company's products and services and on its activities.

On this basis, an estimate of the financial impacts can be made, providing a more faithful reflection of the consequences of the energy/climate issues.

This approach is easy to understand and rooted in "reality", and offers the company's management a very tangible view of the way its business lines and activities will be affected by the energy/climate issues. It also helps overcome the pitfalls of a financial approach (see above).

44 - For example, the assumption according to which prices indicate scarcity is debatable, especially for the main commodities like energy, since their price formation is financialised. See "Prix mondiaux futurs des ressources épuisables" [Future world prices of finite resources], Nicolas Bouleau (2013).

45 - There is no clear link between the volume of oil consumed and barrel prices. See Box 11: Coupling of GDP and oil.
46 - "International prices for coal, natural gas and oil in the WEM reflect the price levels that would be needed to stimulate sufficient investment in supply to meet projected demand". See World Energy Model, IEA (2018).

Box 7: The analysis of essential physical factors for South32

South32 is an Australian mining company formed in 2015 following the demerger by BHP Billiton of some of its mining activities. South32 mainly produces metals (aluminium, manganese, silver, zinc, lead and nickel) and coal (coke and thermal). The company achieves a net result of almost USD 500 million. Its activities are located in South Africa and Western Australia.

In 2018, South32 published a "climate" report[47] in which the company described its scenario analysis process. A detailed description of this process is set out in Part 8.D.2 (p. 91).

South32 reflects on the use of a financial approach to assess the impacts of changes in the corporate environment, observing:

> *"When comparing outcomes between the base case and the Global Cooperation scenario drivers, we found that comparisons of net present value or earnings forecasts **did not provide us with meaningful insights on broader portfolio resilience**. This was largely due to the variability of other underlying factors (particularly commodity price forecasts) **overshadowing the impacts of the climate scenario related inputs**".*

To overcome this flaw, South32 measured changes in demand for its products (in volume) for each of its production sites:

"We instead took the decision to use a fit-for-purpose resilience metric (Figure 4), which **focused on the demand for each commodity from each operation in our portfolio**. Resilience was determined by a **quantitative assessment** of whether the supply and demand balance increased or decreased (ten per cent either way) or materially increased or decreased (20 per cent either way), relative to our base case forecasts out to 2040".

47 - See "Our approach to climate change 2018", South32 (2018).

Box 8: The quantitative approach used by Air Liquide

Air Liquide creative oxygen

Several years ago, the Group committed to tackle global warming and stepped up its pledge in 2015. Complying with the target set in the Paris Agreement means applying a physical limit (limiting GHG emissions), which triggers a series of changes along all the value chains. Air Liquide's climate approach focuses on understanding how these changes could affect its activities, not only through the constraints affecting its own operations but also with the impacts on the downstream markets served by the company, as well as new markets where the Group could contribute to the low-carbon transition.

These developments prompted the company to conduct a scenario analysis of energy/climate issues, and in November 2018 it published the Group's first climate goals.

The scenario approach

The first stage in this process was to measure how the markets on which the Group operates could be transformed by the low-carbon transition, in other words how demand for its products and services and its sales packages could be affected.

For example, on the steel market, the need to reduce CO_2 emissions will force the main stakeholders to reduce use of coal. This could affect oxygen requirements but at the same time generate new requirements, such as use of hydrogen in the process to reduce iron ore into steel.

Several different energy/climate scenarios were then selected. Each gave a quantitative description of the changes in the previously identified physical determinants.

Using these scenarios, it was then possible to project changes in demand for the solutions on offer from the Group, according to their different markets.

The Group started with the available scenarios, which were adapted to make certain assumptions (macro-economic, e.g. GDP growth, or technological, e.g. improved energy efficiency, CCS, etc.) more realistic and, overall, less optimistic as it deemed appropriate.

The results obtained feed into a process of strategic thinking primarily focused on allocating the Group's investment efforts on certain promising markets such as hydrogen energy and renewable natural gas.

8 The public energy/climate scenarios: inventory and limits

The public energy-climate scenarios include limits which, if not well known or understood, hinder their interpretation.
There is a wide range of public energy/climate scenarios, **but**
1. they were **not designed for companies**;
2. they come with **certain limits** related to the input assumptions selected by the scenario author and to the models used. Most companies are unfamiliar with these limits, which could jeopardise their use of these scenarios.

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A

Overview of the climate scenarios

The IPCC's work dealing with the "physical" consequences of climate change are based on the definition of greenhouse gas concentration and emission trajectories, known as the "Representative Concentration Pathways" (RCPs).

The RCPs are a consistent set of projections of changes in radiative forcing[48] and are used as **input data** to model the development of the climate system (IPCC Working Group 1, see Box 17: 1.5°C scenarios from the IPCC "Special Report on Global Warming of 1.5°C" (**SR-1.5, 2018**), p. 71).

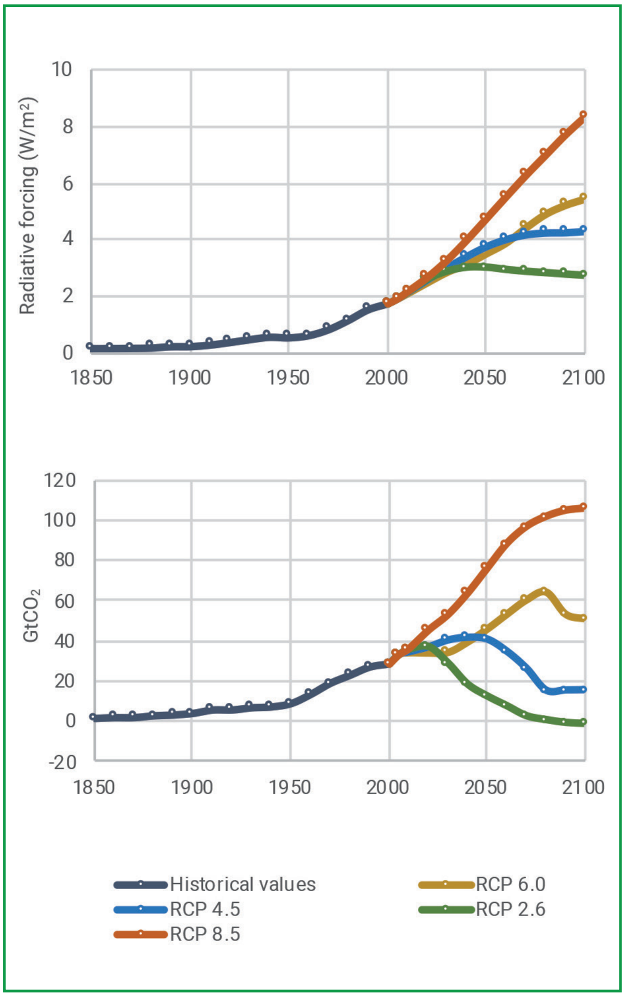
Four GHG concentration scenarios, indicating a level of "radiative forcing", have been selected:

- **A RCP 2.6[49] pathway**, where radiative forcing rapidly reaches a peak then gradually declines to 2.6 W/m² in 2100, which means warming of 0.9-2.3°C. This pathway assumes there will be rapid reduction in GHG emissions.
- **Two pathways (RCP 4.5 and RCP 6.0)** see GHG emissions stabilise by 2100: in RCP 4.5, radiative forcing stabilises at 4.5 W/m² (1.7-3.2°C) by 2100, while in RCP 6.0, radiative forcing continues to rise to reach 6.0 W/m² in 2100 (2-3.7°C).
- **One pathway (RCP 8.5)**, where GHG emissions are very high, leading to a non-stabilised growing rise in radiative forcing, reaching 8.5 W/m² by 2100 (3.2–5.4°C).

The RCPs are not scenarios in the sense that they do not constitute a full set of socio-economic and climate projections and do not include a narrative or the accompanying assumptions.

The RCPs themselves are not linked to a socio-economic scenario: each RCP is compatible with an array of socio-economic scenarios because several different socio-economic scenarios can give rise to a concentration of GHGs in the atmosphere and to similar radiative forcing. What is more, the RCPs with the lowest radiative forcing (RCP 4.5 and RCP 2.6) do not derive from those with the highest radiative forcing (RCP 8.5, or even RCP 6.0). The differences between each RCP cannot therefore be interpreted as the result of a climate policy or trends in socio-economic variables.

Figure 11: Radiative forcing pathway (high) and CO_2 emissions pathway (low) described in the four RCPs.



Source: RCP database v2.0.

The results of the climate system modelling work can be used to evaluate changes in certain parameters such as temperature, rainfall, hydrometry and the rise in sea levels. These results also provide input for IPCC Working Group 2, which assesses the vulnerabilities and impacts of these changes on ecosystems and human communities.

48 - The radiation balance marks the difference between solar radiation received and infra-red radiation emitted by the planet. It is calculated at the top of the troposphere (10-16 km altitude). Under the effect of the drivers of climate change, such as GHG concentration, the balance is altered: we call this radiative forcing. This physical parameter is measured in W/m².
49 - The RCPs are named according to their level of radiative forcing in 2100. RCP 2.6 describes projected radiative forcing of 2.6 W/m² in 2100.

B

Overview of the public energy/ climate transition scenarios

The "public" energy/climate scenarios are publicly available (free-of-charge or to purchase) scenarios that project future changes in energy flows, GHG emissions and certain socio-economic variables. They are transition scenarios. They are produced by different types of stakeholders.

This sort of scenario could be used by companies in their strategic thinking, at least according to the TCFD in its final report and the appended Technical Supplement[50].

However, these scenarios can be very different in nature and were designed to meet requirements that may well differ from those of a company seeking to use them. Before embarking on an analysis, it is therefore necessary to decipher the publicly available energy/climate scenarios.

1 How to read a public energy/climate scenario

A public energy/climate scenario is rarely published alone. Instead, there are often one or several other scenarios comprising a "family", which more often than not includes a baseline scenario to which the others are compared.

A family of scenarios is usually put together as part of a particular study of energy/climate issues. This kind of study aims to meet a specific requirement, such as informing a public decision by assessing the impact of policies implemented or likely to be implemented (see Part 5.A.2 "What is a scenario?", p. 31).

The scenario user must bear the following point in mind: these studies and the scenarios they apply were produced in response to one or several issues that they seek to address. This conditions the way in which the scenarios are developed, their time horizon and geographic or sectoral scope, the assumptions made, the results obtained and the data published or presented.

> **Interpretation aid**
>
> Users of a scenario should identify the family to which it belongs (including the baseline scenario), the study in which it is included and the question that this study seeks to answer.
> Users should also identify the elements that are common to scenarios in the same family (especially input hypotheses and narratives).

a — Scenario narrative

As previously indicated, the scenario narrative is key as it defines the context in which the quantitative assumptions and results become meaningful and coherent. For example, if the introduction of a world CO_2 price is to be credible, it has to be substantiated in the narrative by the description of a political and economic context that would favour such a measure.

Public energy/climate scenarios are environmental scenarios (i.e. they do not integrate the company's particularities). Their narrative should cover demographic, social, political, economic, technological and environmental determinants (see Part 6.B, p. 40).

The narratives must be explicit and clearly set out. They should also address climate change adaptation and mitigation concerns.

> **Interpretation aid**
>
> Scenario users should question the following aspects of the scenario:
> - Is the narrative explicit or implicit? Is it clearly set out?
> - Does the narrative explicitly set out the five determining determinants (demographic, social, political, economic, technological and environmental)?

50 - See the Technical Supplement to the TCFD final report (2017): "These publicly available scenarios can help inform development of an organization's own scenarios or they can be used directly as a framework for strategic planning discussions".

- Does the trajectory described by the narrative follow a long-term trend or mark a breakthrough?
- Are the impacts of climate change mentioned in the narrative?

b —— Interpretation based on the Kaya Identity

Public energy/climate scenarios involve a large number of physical and socio-economic variables that are either determined at the outset (assumptions) or calculated (results). Some of these variables can be seen as key drivers in the evolution of CO_2 emissions (IPCC, 2014[51]) and warrant the special attention of scenario users. This is in particular the case for population size, the amount of energy produced, economic growth and the CO_2 content of the energy produced.

The contribution from these variables can be represented by the **Kaya Identity** (Kaya, 1990), which is generally expressed as:

$$CO_2 = Pop \times \frac{GDP}{Pop} \times \frac{E}{GDP} \times \frac{CO_2}{E}$$

Or:

$$\Delta CO_2 = \Delta Pop + \Delta\left(\frac{GDP}{Pop}\right) + \Delta\left(\frac{E}{GDP}\right) + \Delta\left(\frac{CO_2}{E}\right)$$

Where:

CO_2	global CO_2 emissions (energy and industry sources)
Pop	global population
GDP	world GDP
E	primary energy consumption
$\frac{GDP}{Pop}$	GDP per capita
$\frac{E}{GDP}$	energy intensity of GDP
$\frac{CO_2}{E}$	carbon footprint of energy

Box 9: Energy intensity and carbon intensity

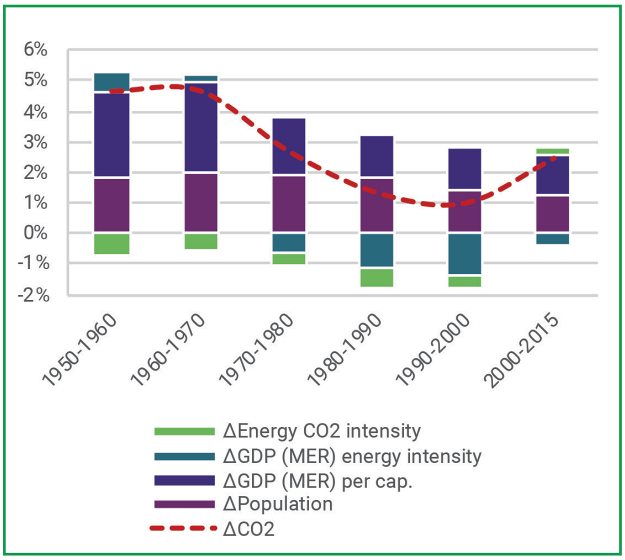
The energy intensity of a country's (or group of countries') GDP refers to the ratio between the amount of energy (primary or final) consumed[52] by that country and its gross domestic product. It is thus the amount of energy required to produce one unit of GDP and defines the energy efficiency of an economy.

The carbon footprint of energy (primary or final) refers to the ratio between the amount of CO_2 emitted by the economic system (energy use and industrial processes) and the amount of primary energy consumed. It is thus the amount of CO_2 emitted per unit of energy consumed.

Any action taken to limit CO_2 emissions modifies the factors in the Kaya Identity to different degrees

First observation: at a global level, the factors in the Kaya Identity evolve at a relatively low rate, despite the profound changes that have occurred since the late 1970s (oil crises, the collapse of the Soviet Union, etc.). Most significantly, this points to the inertia of the economic system.

Figure 12: Average annual variation of the main factors in the Kaya Identity between 1950 and 2015, at global level.



Sources: for the population, UN DESA World Population Prospects 2019; for GDP (expressed in MER[53]) from 1950 to 1980, Maddison project, from 1981 to 2017, IMF World Economic Outlook 2018; for primary energy production, from 1950 to 1965, Etemad & Luciani, from 1966 to 2017, BP Statistical Review 2018; for CO_2 emissions (excluding LULUCF), Global Carbon Budget.

51 - See "Box 5.1: IPAT and Kaya decomposition methods", AR5 Chap. 5, IPCC (2014).

52 - When we look at things at global level, we can consider that the amount of primary energy produced and the amount of primary energy consumed are equal, apart from (generally marginal) inventory changes.
53 - Market Exchange Rate (MER).

Since 1980, at global level, **population growth** (+1.5%/year between 1980 and 2015) **and GDP per capita growth** (+1.9%/year between 1980 and 2015) **have been the two main contributors to CO_2 emissions**. This contribution has been partially **offset** (the growth rate of CO_2 emissions remains positive) by an **improvement in the energy intensity of GDP** (down 1.3%/year from 1980 to 2015) and a **reduction in the carbon footprint of energy** (down 0.2%/year from 1980 to 2015).

Second observation : significantly reducing CO_2 emissions while upholding the growth of one factor necessarily implies very significant efforts to reduce the other factors.

Demographic dynamics are structurally very inertial. In addition, coercive demographic policies trigger much debate and, from a political viewpoint, appear very difficult to implement in the short term. There are therefore some very demanding conditions when it comes to restricting demographic growth or reducing the population.

GDP per capita is a variable that has always tended to grow and is one of the key indicators of an economy's health. Among other things, it establishes the number of machines (consumers of energy) in operation. While it does not provide an indication of future trends (particularly over the medium and long term), any fall in this variable has socio-economic consequences that are perceived as politically unacceptable.

If these two factors are to continue to rise, the other two factors must see a significant reduction: the energy intensity of GDP and the carbon footprint of energy.

The reduction in the energy intensity of GDP (i.e. energy efficiency), which is often applied to limit CO_2 emissions, has evolved slowly since the 1970s (it decreased by only 35% between 1980 and 2015).

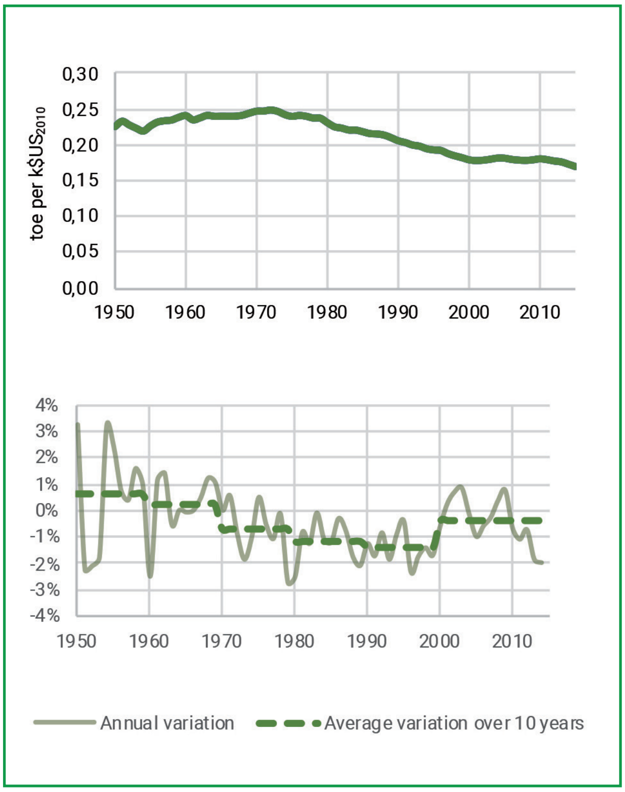
This phenomenon can be linked to three main trends that more or less offset one another:

1. The modernisation (mechanisation, then automation, computerisation and robotisation) of the economic system, which basically means replacing human labour with machines that require energy to operate. This trend leads to significant productivity gains but also drives energy consumption upwards.

2. Technological progress helps improve the energy efficiency of machines (we talk about "technical" energy efficiency) which, for equivalent production levels, consume less energy over time, driving energy consumption downwards.

3. The "organisational" improvement of the economic system, which means improving the movement of individuals, goods and services within an organisation or territory; this also reduces energy consumption for the same level of production.

Figure 13: Trend for the energy intensity of GDP (left) and annual variation in the energy intensity of GDP (right) between 1950 and 2015, at global level.



Source: The Shift Project calculation (for GDP expressed in MER from 1950 to 1980, Maddison project, from 1981 to 2017, IMF; for primary energy production, from 1950 to 1965, Etemad & Luciani, from 1966 to 2017, BP Statistical Review 2018).

Historically, the latter two trends have prevailed over the former, but at a very stable pace since 1980. **This reflects the very strong relationship[54] between GDP and energy use**.

Future trends in the energy intensity of GDP are therefore crucial in energy/climate scenarios. The question is: *"will it be possible to significantly and sustainably reduce the energy intensity of GDP, well beyond the trend observed over the last 50 years?"*

There are no clear-cut answers to this question. In recent history, periods during which the world economic system has experienced real constraints on energy use have been

54 - This relationship is said to exist when a series of successive years represented by the GDP/oil production pair lie on a straight line.

rare and short-lived[55]. Primary energy production increased by on average 3.5%/year between 1950 and 2000 and has risen by 2%/year since 2000.

In addition, any improvement in energy efficiency can be at least partially offset by a "*rebound effect*" (see Box 10: The rebound effect, p. 59).

Box 10: The rebound effect

The rebound effect is an economic phenomenon describing the consequences of investing the (financial or other) gains achieved by the improved "efficiency" (energy or another resource) of the use of a good or service.

When applied to energy, the rebound effect defines the additional energy consumption generated when reinvesting energy efficiency gains in certain uses. This additional consumption can partially or even totally offset the expected energy savings.

For example, when a homeowner carries out thermal renovations to their home, they see an economic benefit (the cost of saved energy). That gain may be partially or totally reinvested in the same use (= the direct rebound effect) or in other potentially energy-consuming uses (= an indirect rebound effect), thus offsetting the savings expected from such an improvement

It is generally expressed as follows:

$$\text{Rebound effect} = \frac{\text{expected energy gains} - \text{actual energy gains}}{\text{expected energy gains}}$$

In OECD countries, the direct rebound effect of passenger car transport and domestic heating is estimated at between 10% and 30% of the savings achieved (ADEME, 2010).

The rebound effect is real but remains a complex and difficult phenomenon to quantify. It could be more significant in emerging countries.

We are not here to assess the credibility of a rapid, significant, lasting and probably desirable decoupling of GDP and energy as part of efforts to keep the temperature below the 2°C threshold, but it is worth pointing out the limits of an overly simplified or "painless" decoupling.

In other words, **reducing the energy intensity of GDP even further in the future, all other things being equal, implies huge efforts** from all stakeholders, an ambitious and profound transformation of the system that produces energy, goods and services, and a relatively favourable political context (stability and social acceptance).

A scenario projecting a rapid and significant decoupling of GDP and energy should thus set out the very specific conditions required to achieve this (i.e. the political, social, economic, industrial and technical reasons that explain the fall in the energy intensity of GDP) in its narrative, and particularly:

1. the reasons that make this improved efficiency physically realistic or possible;
2. the measures encouraging "technical" energy efficiency for all stakeholders and the measures limiting the rebound effect;
3. the potential energy-saving measures for the main stakeholders (individuals, public and private organisations) in the main energy-consuming sectors (industry, transport, construction) and regional redevelopment;
4. the regulatory, fiscal and political measures leading to transformations of the economic system (particularly production facilities) linked to the decoupling of GDP and energy;
5. the social and behavioural changes that make the decoupling of GDP and energy acceptable.

In particular, these aspects should be described in the main primary energy-consuming countries.

A reduction in the carbon intensity of energy, which implies a reduction in the share of fossil energies in the primary energy mix, is a powerful lever for cutting CO_2 emissions.

A significant reduction in the carbon intensity of energy is technically possible but also requires huge efforts, given how dependent the economic system is on fossil fuels, especially for electricity generation (coal and gas), transport, industry and construction (oil and coal).

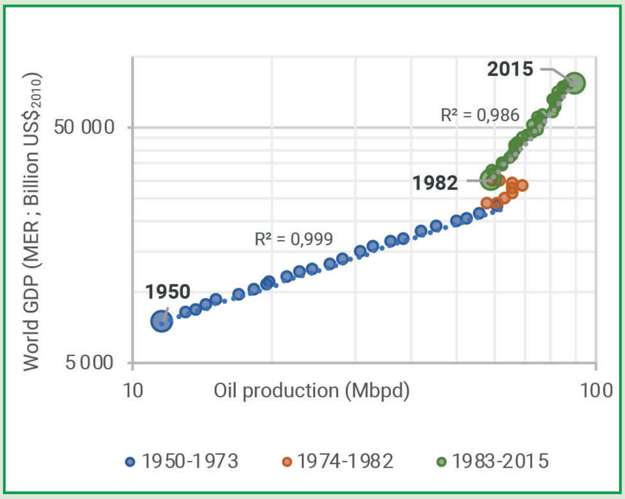
55 - For example, the periods from 1979-1982 and from 2007-2009.

Box 11: Coupling of GDP and oil

Historical data series highlight the very strong link between crude oil availability[56] (in volume) and the economy growth during the post-WW2 period. After the two oil shocks of the 1970s, this relationship became more complex, but it is a coupling that remains strong today.

The relationship between GDP and oil, observed up to now, and the modelling of future trends, especially in a context of decarbonisation of the economy, is an issue for the consistency of transition scenarios and their analysis[57].

Figure 14: Trend for GDP according to crude oil production between 1950 and 2017.



Source: "Méthodologie d'analyse des scénarios utilisés pour l'évaluation des risques liés au climat par une approche paradigmatique PIB-Pétrole" [Methodology for scenario analysis to assess climate risk using a GDP/oil paradigm approach], Lepetit (2018).

The coupling of GDP and oil can be broken down into three clear phases:

1. **The post-war boom (1950-1973):** during this period, there was an extraordinary correlation between GDP and crude oil consumption. In this "golden age", world GDP grew rapidly – by an average of almost 5% pa – and world crude oil production grew at the very high rate of 7.6% pa.
2. **The 1970s crisis (1973-1982):** during this period, there was a break in the coupling of GDP with crude oil consumption, which came up against physical limitations. This period was marked by the 1973 and 1979 oil shocks that led to a very sharp increase in oil prices[58]. This unprecedented "price signal" led to multiple, systemic changes in political, institutional, economic and social organisations, resulting in world economic growth turmoil. In most oil-importing countries, the resource became the focus of projects to control energy consumption and find replacement energy sources (especially for electricity generation and domestic heating). The level of CaPex devoted to searching for new oil resources also grew considerably.
3. **The post-oil shock period (1982-2016):** this period saw renewed stability in the relationship between economic growth and oil consumption. The correlation between GDP growth and crude oil consumption remained very high but the average values of the macro-economic parameters changed. Global crude oil consumption now only grows by 1.2% a year (i.e. 6 times slower than in the 1970s) and world GDP has grown by "only" 3.2% a year since 1982. Crude oil consumption is now more efficient (energy savings, alternative energy sources), but world economic growth has still been affected.

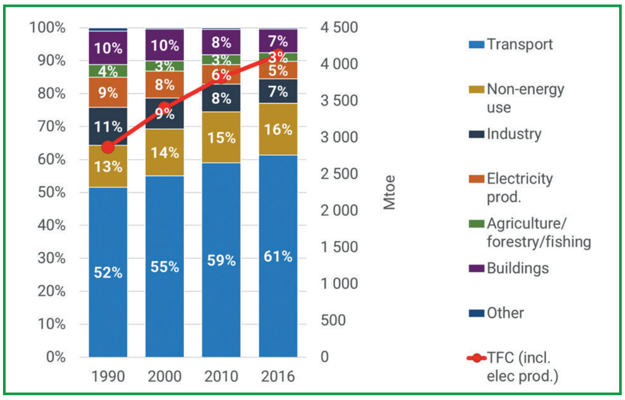
56 - Consumption of crude oil and its production on a global level are comparable, notwithstanding the albeit relatively low variations in inventories. For a country-level analysis, this is no longer true

57 - The summary below is based on the note "Méthodologie d'analyse des scénarios utilisés pour l'évaluation des risques liés au climat par une approche paradigmatique PIB-Pétrole" [Methodology for scenario analysis to assess climate risk using a GDP/oil paradigm approach], published by Michel Lepetit (2018) and the note "Questioning the scenarios of the International Energy Agency (IEA)", published by The Shift Project (2017).

58 - In constant dollars, oil prices increased fivefold between 1970 and 1974, then doubled between 1978 and 1980. In current dollar terms, over ten years, these crises resulted in a twenty-fold increase in barrel prices.

Although oil use has changed considerably since the 1970s crisis (the share of oil in electricity generation dropped from 21% in 1973 to 9% in 1985, then fell to 3% in 2015[59]), the world economic system, with 4,000 Mtoe (million tonnes oil equivalent) consumed in 2016, remains highly dependent on oil product availability.

Figure 15: World use of oil products per sector (as % on the left axis) and world consumption of oil productions (in Mtoe on the right axis).



Source : IEA website statistics

This consumption is mainly attributed to the **transport sector (passengers and goods) and non-energy uses (petrochemicals)**. We have not seen any reversal of this trend at present, as shown in the graph above, in spite of strong variations – often upwards – in oil product prices (for example, from 2010 to 2014 when oil prices reached $100/bbl).

At the global level, in both the short and the long term[60], the price elasticity of demand for oil[61] observed since the 1980s **has remained very low** (around -0.1[62]). In other words, even if the oil price rises, the impact on demand is relatively marginal.

All of these factors demonstrate the challenge of switching away from oil to another source of energy. Given its various characteristics (energy density, liquid state easy to store and transport, etc.), oil could be seen as the most advantageous and most "practical" of all primary energies.

It is not a matter here of evaluating the possibility or impossibility of limiting oil use very significantly – an unavoidable task if we are to maintain temperatures within the 2°C threshold – nor of measuring the potential of the existing alternative solutions (e.g. electric cars). Moving away from our reliance on oil implies **profound changes to the production system** (e.g. the availability of mineral resources to develop other energy sources, such as the creation of a fleet of electric cars[63]) and **infrastructure** (most notably for power generation), especially in emerging countries.

In other words, a scenario that projects a limit on oil consumption **should model** these aspects and indicate **the resources required** and potentially **the related socio-economic externalities** (like those observed during the 1970s oil crisis, for example).

Interpretation aid

A relevant way of gauging the nature of the transition described in the scenarios, the levers applied and potential shifts in trends is to analyse changes to the determining factors in the Kaya Identity described in the global energy/climate scenarios, compared to the historic values observed.
The scenario user should place a special focus on the qualitative and quantitative description of the causes of the fall in the energy intensity of GDP (especially accounting for the rebound effect) and the fall in the carbon intensity of energy.

c — Other issues to be taken into account

The scale of the roll-out of carbon capture and artificial storage (CCS) technologies may lead to an underestimation or delay in efforts to reduce CO_2 emissions. The carbon budget mentioned above (see Part 3.A.3, p. 19) sets a time frame for the transition to a low-carbon economy. The later the actions designed to significantly reduce CO_2 emissions

59 - World Bank data (Electricity production from oil sources (% of total)).
60 - Variation in demand and the corresponding variation in price: price elasticity of demand = (Δ Demand)/(Δ price). This value is usually negative (a price increase usually leads to a fall in demand). The lower it is (i.e. a price rise has little or no effect on falling demand), the greater the dependency on the product in question, reflecting the lack of any replacement product. Price elasticity of demand varies according to the geographic area, sector and time frame in question.
61 - Demand tends to be more "inelastic" in the short term: replacements are not necessarily available and consumers need time to adapt their consumption habits.
62 - See, for example:
-"Oil Price Elasticities and Oil Price Fluctuations", International Finance Discussion Papers 1173, Board of Governors of the Federal Reserve System (2016): Table A.3 - Oil Elasticities across Studies: Literature Search.
-"Using Meta-Analysis to Estimate World Oil Demand Elasticity", Uria-Martinez et al. (2018).
-"World Oil Demand in the short and long run: a cross-country panel analysis", Bank of England and City University.

63 - The article "Pourquoi parle-t-on de « criticité » des matériaux ?" [What do we mean by material "criticality"?] is worth reading, along with the analysis "Quelle criticité du lithium dans un contexte d'électrification du parc automobile mondial ?" [The criticality of lithium in a global context of automobile electrification?] published by IFPEN and IRIS.

are introduced, the greater the scope and intensity of these actions will need to be; they may then turn out to be unfeasible within an "organised" context.

Carbon capture and storage technologies[64] could serve as an additional instrument in attempts to reduce CO_2 emissions by artificially increasing the available carbon budget. Nonetheless, use of these technologies, which are still under development[65], on a large scale in the short term remains a technological, economic and political challenge.

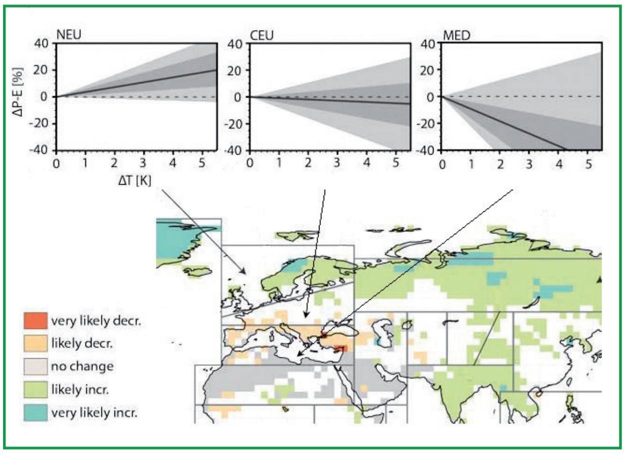
The availability of transition materials (land and rare metals) could be disrupted. Other than fossil fuels, other resources such as rare earths and metals are available in limited quantities (i.e. their stock will not be renewed within humanity's timescale). Several of these resources (e.g. copper in the event of widespread electrification) could play a key role in the low-carbon transition. However, the availability of these resources cannot be taken for granted. Apart from issues over the sustainability of potentially growing demand (Elshkaki, 2016), the known reserves of certain transition materials are today controlled and produced by a limited number of countries, who will likely see their market powers reinforced in the years to come (Hache, 2019). Finally, as is the case for all stock resources, the quantity of energy required to extract and produce one tonne of these materials increases as production goes on, mainly due to a fall in their mineral content[66].

In addition to the mitigation issues widely described in the public energy/climate scenarios, users should also be alert to the challenges of adapting to climate change. The "physical" consequences of climate change (rise in the frequency and intensity of extreme climate events) are subject to ongoing scientific research and are now well documented in the IPCC's various publications.

These physical consequences are now perceptible and could intensify in the years to come. **It is therefore vital that they are taken into account in public energy/climate scenarios.** It is also worth pointing out that even if the 2°C threshold is respected, significant impacts could disrupt the economic system[67].

The IPCC "Special Report on Global Warming of 1.5°C" points out that, among other impacts of climate change, the Mediterranean rim could suffer more intense and longer-lasting periods of drought for a 2°C rise in temperature.

Figure 16: Summary of the likelihood of increases/decreases in precipitation minus evapotranspiration CMIP5 simulations



The graph above shows the trend for the balance between precipitation and evaporation in three geographic regions, including the Mediterranean rim ("MED" graph top right), according to the rise in temperature (x axis). Hence, if the precipitation/evaporation balance falls, drier conditions increase proportionally. We can see that for 1°C warming, dry conditions increase by 10%, for 2°C, they increase by 20%, and for 4°C by 40%.

Source: IPCC "Special Report on Global Warming of 1.5 ºC" (2018).

It is important to maintain geographic and sectoral consistency between the scope of the scenario and the rest of the world (i.e. the stocks and flows loop).

Some scenarios focus on one country or business sector, yet these geographical areas or sectors inevitably interact with the rest of the world (which remains a closed system).

64 - The process involves capturing the CO_2 emitted by various chemical processes and transporting it to a storage site. The efficiency of the procedure depends mainly on the concentration of CO_2 emissions at their source. The storage sites may be geological formations or depleted oil fields (such as those in the North Sea). The captured CO_2 may come from the combustion of hydrocarbons (power generation, heavy industry) or industrial processes (cement production, heavy chemistry). When the captured CO_2 comes from the combustion of bio-energy (biofuel, biogas, etc.), we call this BECCS (Bio-Energy with Carbon Capture and Storage).

65 - The IEA estimates that 30 $MtCO_2$ are currently captured and stored, i.e. less than one thousandth of world CO_2 emissions in 2017. See https://www.iea.org/topics/carbon-capture-and-storage/.

66 - See, for example: "L'épuisement des métaux et minéraux : faut-il s'inquiéter ?" [The depletion of metals and minerals: should we be worried?], ADEME (2017) and "Les mines de cuivre vont continuer de décevoir" [Copper mines will continue to disappoint], L'usine nouvelle (22 Aug 2012).

67 - Because of persistent drought in 2018, the level of the Rhine fell so low that the river became impassable to ships. Bloomberg reports that this situation affected the business of BASF, one of the world leaders in the chemical industry, and of steel company Thyssenkrupp, See "Rhine River Could Run Too Low Again for Shipping in Germany ", Bloomberg (2019).

Interpretation aid

The scenario user should identify:

- whether the roll-out of carbon capture and storage technologies is envisaged: if so, they should measure the pace and scope of this roll-out;
- whether the physical impacts of climate change are taken into account in the projections; if they are not, they should determine whether the scenario author explains why these impacts are not taken into account and assess the relevance of that reasoning;
- whether the availability of transition materials is mentioned and taken into account by the scenario author;
- whether the scenario author has included the external system (rest of the world) in the loop, if using a sector-based scenario or one restricted to a specific geographic region.

d — Modelling issues

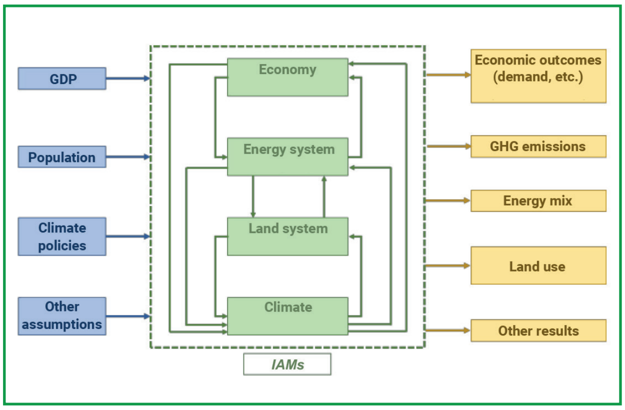
Note: The following is a summary of the analytical note on the challenges of modelling, produced by The Shift Project in liaison with IFPEN[68].

The public energy/climate scenarios give a quantitative description of the complex and interdependent interactions between the economic, energy and climate systems. To this end, they each make use of models.

A model is a mathematical construction that uses input assumptions and a governing process to provide a representation of how a real system works (the climate, a country's economy, etc.) and how it will evolve over time, in order to help users organise, in a logical and consistent manner, their process of reflection on the behaviour of such a system.

By nature, the representation put forward by the modeller remains simplified. It depends on the objective of the modelling exercise and is inevitably based on debatable choices regardless of the real system being studied, and in spite of the millions of equations and variables. The results of the exercise should always be analysed with these points in mind.

Figure 17: Simplified representation of the structure of an integrated assessment model (IAM)



When a model is used, it is important to differentiate between the role of the scenario author and that of the modeller (who may be the same person). The scenario author is the modeller's "client" and remains responsible for the choice of model and the choice of input assumptions that illustrate the scenario narrative. The modeller is responsible for the model's structure and the setting of certain parameters inherent to the model.

Box 12: The model's variables

Among the variables included in the model, we usually distinguish between exogenous and endogenous variables.

- **Exogenous variables** are not calculated by the model. They are input data from external sources[69]. They are considered independent of changes to other variables in the model. Their value is not necessarily constant and may evolve. However, this evolution must be entered by the model user. In the models evaluated in this note, GDP and technology costs are generally exogenous variables. We refer to them as the **input assumptions**.
- **Endogenous variables** are calculated by the model through the solving of the system of equations and changes in other endogenous or exogenous variables. These variables are, by nature, the results of the model as sought by the user. In the models studied in this note, the quantity of energy produced or consumed, and the share of each energy source in the energy mix are generally endogenous variables.

68 - *See "Note d'analyse sur les enjeux de modélisation" [Analytical Note on the Challenges of Modelling], The Shift Project (2019).*

69 - *They may be the results from another model, data from benchmark institutions like the World Bank, the International Energy Agency, and so on, or expert opinion.*

Given the complexity of the energy/climate issues, the models used to describe these systems are increasingly sophisticated, which makes it especially difficult for the uninitiated to really understand how they work. However, the results produced by a model very much depend on its structure and the modeller's choices.

Interpretation aid

Models are complex tools, which are difficult for the untrained user to understand.[70] There is no guide to interpreting these models currently available. Wherever possible, however, the user may distinguish between endogenous variables and exogenous variables to identify what can be attributed to the scenario author or to the modeller.

2 Scenarios studied, selection criteria, authors

Over the years, a wide variety of public energy/climate scenarios have been produced by a broad range of stakeholders. Although some of them can be used by companies, they can be subject to critical analysis using the "interpretation aids" set out above.

a —— Who devises the public energy-climate scenarios?

We can identify several types of public energy/climate scenario author.

The international institutions such as the *International Energy Agency* (IEA), the *World Energy Council* (WEC) and the *International Renewable Energies Agency* (IRENA). These organisations bring together member countries and defend those countries' interests compliant with their mandate. Some of them, particularly the IEA, have been producing energy scenarios for several decades and have gradually incorporated energy/climate issues into their scenarios. They generally benefit from substantial resources (funding from member countries) and recognised expertise, enabling them to conduct sophisticated modelling work in-house. These stakeholders sometimes also use external models.

Research facilities with their own modelling laboratories, such as the *Potsdam Institute for Climate Impact Research* (PIK) or the *International Institute for Applied Systems Analysis* (IIASA). These organisations have usually developed their own model used for research or commercial purposes. Because of their scientific character and the modelling expertise at their disposal, they take part in research projects focusing on energy/climate issues. Some of these stakeholders devise energy/climate scenarios within the framework of IPCC work and are part of the *Integrated Assessment Modelling Consortium*[71] (IAMC). These organisations are usually funded by contributions from different types of organisation (research bodies, foundations and public authorities), grants or their commercial activity.

Non-governmental organisations, such as the *Institute for Sustainable Development and International Relations* (which goes by its French acronym, IDDRI) and *Greenpeace*. Scenario production is not their main activity, so when they publish scenarios it is usually in conjunction with research facilities as part of a specific project. Their role is limited to defining the input assumptions for the external model being used.

Certain companies, such as the big energy firms (Shell, Equinor and BP). These businesses devise scenarios as part of their strategic reflection processes or to communicate on their vision of the energy/climate issues. Some have developed an – often partial (i.e. it only models part of the energy and climate system) – in-house model. Others use an external model. The scenarios produced by these companies are not always disclosed. This analysis will focus on the scenarios that these companies have chosen to disclose.

70 - See "Note d'analyse sur les enjeux de modélisation" [Analytical Note on the Challenges of Modelling], The Shift Project (2019).

71 - The IAMC is a consortium of scientific research organisations founded in 2007 in response to a call from the IPPC. Its role is to lead the work of the modelling community in the development of new energy/climate scenarios. The IAMC currently counts over 10 research centres. See http://www.globalchange.umd.edu/iamc/about/ and https://www.iamcdocumentation.eu/index.php/IAMC_wiki.

Figure 18: List of authors of the scenarios analysed in this study, by category

Acronyme	Désignation complète	Catégorie	Pays
IEA	International Energy Agency	International institution	International
IRENA	International Renewable Energy Agency	International institution	International
WEC	World Energy Council	International institution	International
PBL	Netherlands environmental assessment agency	Research centre	Netherlands
IIASA	International Institute for Applied Systems Analysis	Research centre	International
NIES	Japan National Institute for Environmental Studies	Research centre	Japan
PNNL	Pacific Northwest National Laboratory	Research centre	United States
PIK	Potsdam Institute for climate impact research	Research centre	Germany
Greenpeace	N/A	NGO	International
Shell	N/A	Company	Netherlands
Equinor	N/A	Company	Norway
BP	N/A	Company	United Kingdom

Box 13: The International Energy Agency (IEA)

The International Energy Agency (IEA) is an international organisation set up within the OECD in November 1974

Today, the IEA has 31 members[72] – all signatories of the Paris Agreement – who are also members of the Organisation for Economic Cooperation and Development (OECD). It is based in Paris.

History

The IEA was founded in the wake of the 1973 oil shock to improve oil-importing countries' resilience in the event of potential disruption to supply by supervising and coordinating the management of strategic oil reserves. In other words, the original mandate of the IEA was to secure hydrocarbon supplies for the main consuming countries.

In this respect, the IEA was formed as a counterpart to the Organization of the Petroleum Exporting Countries (OPEC), whose action at the time largely contributed to the two oil crises.

Since then, the IEA's activities have broadened considerably to include the full spectrum of energy issues – although security of supply remains one of its key priorities – to *"ensure reliable, affordable and clean energy[73]"*.

To keep pace with global trends and the appearance of new energy consumer profiles, the IEA is gradually opening up to emerging powers. A category of "associate members[74]" has thus been formed to improve the organisation's representativeness, primarily by recognising the growing role of China and India in world leadership.

Objectives

Today, the IEA's action focuses on four areas:

1. **the security of energy supplies**;
2. **the liberalisation of energy markets**, to stimulate economic growth and eradicate energy poverty;
3. **the promotion of solutions designed to reduce the environmental impact of energy production and use**, especially to tackle climate change and air pollution;
4. **global action** involving all stakeholders to rise to the energy and environment challenges.

72 - The founding members are: Austria, Belgium, Canada, Denmark, Germany, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway (in virtue of a special agreement), Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. Other countries have since joined the IEA: Greece (1976), New Zealand (1977), Australia (1979), Portugal (1981), Finland (1992), France (1992), Hungary (1997), Czech Republic (2001), South Korea (2002), Slovakia (2007), Poland (2008), Estonia (2014) and more recently Mexico (2018).

73 - See the IEA website: https://www.iea.org/about/ourmission/.
74 - Associate members: Brazil, China, India, Indonesia, Morocco, Singapore and Thailand.

The IEA's activities are increasingly centred on issues related to the energy transition and limiting GHG emissions from energy sources[75].

Some observers emphasise the potential incompatibility between this direction and the IEA's first two objectives (securing energy supply and promoting the liberalisation of the energy markets)[76].

Activities

The IEA's activities focus on the publication of analyses, forecasts (of production and consumption) and statistics on the energy sector. Its most important publications are the *World Energy Outlook*, the IEA Market Reports, the *Key World Energy Statistics* and the *Monthly Oil Data Service*.

The IEA's publications are relayed and used by a wide range of economic and political actors, making the agency a benchmark for energy issues.

For example, organisations such as the US government's *Energy Information Administration* (EIA), certain oil companies and the OPEC regularly publish the IEA's energy forecasts and the agency remains the natural yardstick for stakeholders in the energy industry.

Governance and budget

The IEA is officially an inter-governmental organisation reporting to the OECD. Given the eminently strategic role that energy plays in the economy and international relations, the agency's governance is sometimes a delicate task, especially when it comes to the relative weighting of each country and the role played by stakeholders from the energy industry.

The IEA's **Governing Board** is made up of senior officials from the member countries and meets three or four times a year. It is the agency's main decision-making body.

Every two years, the energy ministers from each member country meet at the **IEA Ministerial Meeting** during which the agency's main strategic priorities are set.

Companies are also frequently consulted and involved in the IEA's activities via the **Energy Business Council (EBC)**[77].

The EBC is comprised of representatives from companies in the energy sector and industry, as well as financial institutions. It is the body through which the IEA interacts with energy businesses.

The EBC has two main objectives: (1) enable interactive discussions between companies and member states' representatives, and (2) provide a critical analysis of the agency's work and make sure it remains relevant for companies[78]. The IEA indicates that EBC member companies are highly involved in preparing the *World Energy Outlook* (WEO), one of the agency's annual report.

Most of the EBC member companies are significant hydrocarbon producers or consumers or funders of the energy industry[79]. These companies are invited to the various meetings and gatherings organised by the IEA, including governing board meetings[80]. Thirty or so companies are involved in all[81].

The IEA also interacts with industry through the Renewables Industry Advisory Board, the Coal Industry Advisory Board and the Electricity Security Advisory Panel.

The IEA's annual budget came to €27.8 million in 2018. The budget is audited every year by the auditing body of one of the member countries. Revenues from the IEA's publications finance more than one fifth of the annual budget[82].

75 - One of the IEA's declared objectives is to "promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change". In fact, there is an increasing number of specialists in renewable energies, energy efficiency and environmental economics on the IEA's teams.

76 - The NGO Oil Change International points out that securing energy supplies – in the IEA's interpretation (i.e. uninterrupted availability of energy sources at an affordable price) – leans towards the upholding of the current production system (power generation and transmission infrastructures are long-term assets) and that the liberalisation of energy markets encourages use of fossil energies (large volumes, big businesses).

77 - See the IEA website: https://www.iea.org/about/structure/.

78 - "One of the most important objectives of the EBC meetings is to provide feedback on IEA activities, with a specific focus on IEA publications such as Medium-Term Market Reports, the World Energy Outlook (WEO), Global Energy Investment Report (GEIR) and Energy Technology Perspectives (ETP)", at https://www.iea.org/energybusinesscouncil/.

79 - See the list of members.

80 - "CEOs and Chairpersons of EBC member companies regularly participate in biennial IEA Ministerial meetings", https://www.iea.org/energybusinesscouncil/.

81 - The last high-level meeting on 7-8 November 2017 brought together representatives of the 30 member countries and of the associate countries (including China and India), along with CEOs from 30 top energy companies.

82 - See the IEA website: https://www.iea.org/about/structure/.

b —— Selection criteria and list of scenarios studied

The scenarios studied were selected on the basis of the following criteria:

1. publicly available scenarios;
2. scenarios published by a well-reputed organisation legitimate to speak on energy or climate issues and already used by economic operators;
3. scenarios using publicly available data (free-of-charge or otherwise);
4. scenarios updated on a regular basis.

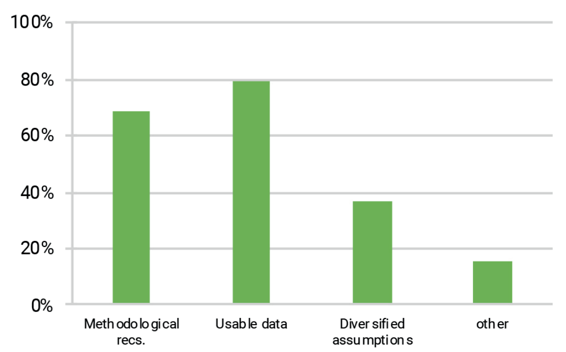
These selection criteria are largely inspired by those recommended in the TCFD's Technical Supplement[83]. They encompass the main energy/climate scenarios generally deemed to be legitimate and usable by non-academic actors.

Box 14: The public energy/climate scenarios in French companies today

Out of a panel of 30 AFEP member companies (from different sectors) surveyed for the study, almost **one third of them said that they use public scenarios** in their analysis of energy/climate issues.

The other companies on the panel said that methodological recommendations on use of public energy/climate scenarios and the publication of data more adapted to their activities would facilitate their use of public scenarios.

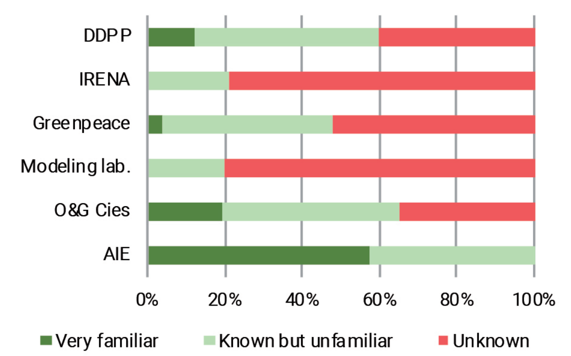
Figure 19 : Percentage of companies on the AFEP panel that say the factor in question could facilitate use of public energy/climate scenarios in their analysis of the energy/climate issues.



Total : 30 compagnies

The scenarios produced by the IEA (WEO 2018 and ETP 2017) are by far the best-known scenarios among the companies surveyed, followed by those produced by the oil companies.

Figure 20 : Percentage of companies surveyed stating they are very familiar with the public energy/climate scenarios presented by the TCFD in its Technical Supplement/aware of them but not very familiar with them/not aware of them.



Total : 30 compagnies

With the exception of the *World Energy Council* and the oil companies, the scenarios listed above are also mentioned in the documents published by the TCFD[84].

83 - See "The use of scenario analysis in disclosure of climate related risks and opportunities", TCFD (2017).

84 - It is worth nothing, however, that in the Technical Supplement to the final report, the scenarios from IPCC Working Group 3 are not mentioned. This omission was subsequently corrected at the conference organised jointly by the TCFD and the Bank of England bringing together issuers, scenario authors and investors.

Figure 21: List of scenarios studied.

Transition scenarios	Acronym	Authors	Study including the scenario	Baseline scenario	Models used	Horizons	Temperature in 2100
New Policy Scenario	IEA-NPS	IEA	World Energy Outlook 2018	Current Policy Scenario (CPS)	WEM	2040	Sup. à 2°C
Sustainable Development Scenario	IEA-SDS	IEA	World Energy Outlook 2018	Current Policy Scenario (CPS)	WEM	2040	2°C
2°C Scenario	IEA-2DS	IEA	Energy Technology Perspectives 2017	Reference Technology Scenario (RTS)	TIMES	2060	2°C
Beyond 2°C Scenario	IEA-B2DS	IEA	Energy Technology Perspectives 2017	Reference Technology Scenario (RTS)	TIMES	2060	<2°C
SSP1 marker - 2.6 - Green growth	SSP1-2.6	PBL	IPCC AR6 WGIII	SSP1 marker - Baseline	IMAGE	2100	2°C
SSP2 marker - 2.6 - Middle of the road	SSP2-2.6	IIASA	IPCC AR6 WGIII	SSP2 marker - Baseline	MESSAGE-GLOBIOM	2100	2°C
SSP3 marker - 3.4 - Regional rivalry	SSP3-3.4	NIES	IPCC AR6 WGIII	SSP3 marker - Baseline	AIM/CGE	2100	>2°C
SSP4 marker - 2.6 - Inequality	SSP4-2.6	PNNL	IPCC AR6 WGIII	SSP4 marker - Baseline	GCAM	2100	2°C
SSP5 marker - 2.6 - Fossil fuels dev.	SSP5-2.6	PIK	IPCC AR6 WGIII	SSP5 marker - Baseline	REMIND-MAgPIE	2100	2°C
SR15 - Scenario P1 (LED)	SR15-P1	IIASA	IPCC SR 1.5	SSP2 marker - Baseline	MESSAGE-GLOBIOM	2100	<2°C
SR15 - Scenario P2 (SSP1 marker)	SR15-P2	PBL	IPCC SR 1.5	SSP1 marker - Baseline	IMAGE	2100	<2°C
SR15 - Scenario P3 (SSP2 marker)	SR15-P3	IIASA	IPCC SR 1.5	SSP2 marker - Baseline	MESSAGE-GLOBIOM	2100	<2°C
SR15 - Scenario P4 (SSP5 marker)	SR15-P4	PIK	IPCC SR 1.5	SSP5 marker - Baseline	REMIND-MAgPIE	2100	<2°C
[R]evolution	GrP - Rev	Greenpeace	Energy [R]evolution	Baseline scenario	MESAP/PlaNet	2050	2°C
Remap	IRENA-Remap	IRENA	Global energy transformation	Baseline scenario	E3ME	2050	2°C
Modern Jazz	WEC - MJ	WEC	The grand transition – scénario 2016	N/A	GMM	2060	>2°C
Unfinished Symphony	WEC – US	WEC	The grand transition – scénario 2016	N/A	GMM	2060	>2°C
Hard Rock	WEC - HR	WEC	The grand transition – scénario 2016	N/A	GMM	2060	2°C
Ocean scenario	Ocean	Shell	New lens scenarios	N/A	In house model	2070	>2°C
Mountain scenario	Montain	Shell	New lens scenarios	N/A	In house model	2070	>2°C
Sky scenario	Shell-Sky	Shell	New lens scenarios	N/A	In house model	2070	2°C
Rivalry scenario	Equinor - Rivalry	Equinor	Energy perspectives 2018	N/A	In house model	2050	>2°C
Renewal scenario	Equinor - Renewal	Equinor	Energy perspectives 2018	N/A	In house model	2050	2°C
Reform scenario	Equinor - Reform	Equinor	Energy perspectives 2018	N/A	In house model		>2°C
EFT scenario	BP-EFT	BP	BP Energy Outlook 2018	N/A	In house model	2040	2°C

Box 15: The Shared Socio-economic Pathways (SSPs)

The SSPs are scenarios developed by research facilities (IAMC) as part of the IPCC's work. These scenarios project how **socio-economic systems**, **energy systems**, land use, air pollution and GHG emissions could evolve. They **are built around five narratives** that each describe a different socio-economic context and **include quantitative projections** for the main variables (economic, demographic, energy and environment) consistent with the narratives.

Five families of SSP have been established. They each include:

1. **A baseline scenario** which projects a future where there are no additional policies to limit global warming or improve adaptability.
2. **Several "*transition*" scenarios** produced by combining the baseline scenarios with a set of political measures (*Shared Political Assumptions*, SPAs) designed to mitigate the effects of climate change and help reach GHG emissions and concentration levels compatible with the RCPs (principally 2.6 W/m² ~ 2°C and 1.9 W/m² ~ 1.5°C).

Each family of SSPs is based on a narrative giving a qualitative description of developments in the global socio-economic context. Each of the five narratives sets out to describe a world in which the political, social, economic and/or technical trends are likely, to a certain extent, to make mitigation of and adaptation to climate change more difficult, but **does not explicitly take climate change itself into account**. The "challenges" linked to mitigation and/or adaptation concern the social, economic, political and technical aspects of society.

In summary:

- two of the narratives describe futures where the adaptation and mitigation challenges are of a low (SSP1) or high (SSP3) level;
- two asymmetrical cases describe futures where high-level mitigation challenges are combined with low-level adaptation challenges (SSP5) and vice versa (SSP4);
- a "middle-of-the-road" case describes a world where the adaptation and mitigation challenges are both moderate (SSP2).

These five narratives are common to the "baseline" scenarios and the "transition" scenarios (see Box 19: SSPs' underlying narratives, p. 76, for more details on the narrative content).

The aforementioned narratives are supplemented by quantitative projections:

- for the *baseline scenarios*, these projections do not incorporate measures to cap GHG emissions;
- the transition scenarios incorporate measures to cap emissions[85] (SPAs).

These quantitative projects are made using simulation models (IAM, see Part 8.B.1.d, p. 63) developed by IAMC members. We are particularly interested in the following narrative/model pairings:

- **SSP1 projections**: the *IMAGE* model from *PBL*;
- **SSP2 projections**: the *MESSAGE-GLOBIOM* model from *IIASA*;
- **SSP3 projections**: the *AIM/CGE* model from *NIES*;
- **SSP4 projections**: the *GCAM* model from *PNNL*;
- **SSP5 projections**: the *REMIND-MAgPIE* model from *PIK*.

The (baseline and transition) scenarios resulting from these SSP/model pairings and a defined set of assumptions are known as ***SSP "marker" scenarios***.

In addition to these SSP marker scenarios, several hundred scenarios have been produced, resulting from other SSP/model pairings and other assumptions[86].

85 - The final report will cover the mechanisms applied to incorporate the measures.
86 - All the scenarios analysed by the IPCC and the related data (for which the sectoral and geographic resolution is defined to a varying degree) are available publicly. See, for example, the SSP database and the 1.5°C scenario database.

Box 16: The IEA scenarios

The IEA produces two families of scenario, which differ in several respects – most notably the model and the assumptions on which they are based, or their objective.

The first family of scenarios is that from the World Energy Outlook (WEO). This is the IEA's best-known and most widely recognised study. The WEO is publish annually in November and contains several scenarios on the evolution of energy supply and demand. It provides an analysis of energy and investment policies for economic and political decision-makers.

The first edition of the *World Energy Outlook* was published in 1994 and it provided an outlook of the energy system up until 2010. A new edition was published every year, except in 1997.

To develop the scenarios described in the WEO, the IEA's staff used a simulation model known as the World Energy Model (WEM), which uses past trends and exogenous economic (GDP) and demographic projections to produce a cost-optimised projection of supply and demand for energy for several sectors of the economy and several regions. Over its 24 years of existence, the WEM has been considerably enhanced and become more elaborate.

The time horizon considered by the WEO has also gradually increased over the years[87]. Hence, the 2018 WEO looks forward to 2040.

Historically, the WEO sets out a baseline scenario (ongoing trends) and one or several *alternative policy* scenarios in which new directions are tested.

As global awareness of the challenges presented by climate change has increased, the IEA has gradually updated the content and direction of the WEO scenarios. Scenarios taking the GHG concentration goals into account were thus included in the 2008 WEO (*550* and *450 scenario*). Since then, each new edition has included this kind of scenario.

The 2018 WEO contains three main scenarios:

- *The Current Policy Scenario* (CPS), which is the WEO baseline scenario and does not envisage any new actions beyond 2017 (other than those implemented before then);
- The *New Policy Scenario* (NPS), which is exploratory and incorporates countries' commitments under the Paris Agreement (*Nationally Determined Contributions*). According to IEA, this scenario is designed to measure the consequences of these commitments with no specific goals having to be reached[88];
- *The Sustainable Development Scenario* (SDS), which was first introduced in the 2017 WEO and which is the successor to the "*450 scenario*" in that it describes a world in which the 2°C threshold is respected.

We can see that the importance placed on the "low-carbon" scenario has increased over time. Whereas, in 2017, the NPS scenario was seen as central to the WEO[89], the 2018 publication was readjusted with more focus on the SDS scenario and a chapter devoted to it.

The second family of scenarios is the Energy Technology Perspectives (ETP). This study was produced at the request of the G8 after the 2005 Gleneagles summit (see Part 8.B.2.c, p. 71). Its goal is to analyse the opportunities and challenges arising from the roll-out of technical solutions in the energy sector and, more precisely, their breakthrough potential with regard to the climate goals.

In 2017, there were three scenarios in this study:

- The *RTS* (Reference Technology Scenario), which is quite close to the WEO New Policy Scenario;
- The *2DS* (2°C Scenario) scenario, which complies with the 2°C warming threshold;
- The *B2DS* (Beyond 2°C Scenario), which projects warming well below 2°C.

The three scenarios in this family, published on an annual basis, are devised by a different team and are based on a different model (TIMES). The ETP was last published in 2017.

87 - For publications between 1998 and 2001, the time horizon was 2020. From 2002 to 2009, it was 2030; from 2010 to 2013, it was 2035. Since 2014, the WEO has adopted a horizon of 2040.

88 - On p. 29, the 2018 WEO states: "Where commitments are aspirational, this scenario makes a judgement as to the likelihood of those commitments being met in full. It does not focus on achieving any particular outcome: it simply looks forward on the basis of announced policy ambitions".

89 - The 2017 WEO states: "The New Policies Scenario is the central scenario of this Outlook, and aims to provide a sense of where today's policy ambitions seem likely to take the energy sector".

Box 17: 1.5°C scenarios from the IPCC "Special Report on Global Warming of 1.5ºC" (SR-1.5, 2018)

In October 2018, the IPCC published its "Special Report on Global Warming of 1.5°C", assessing the impacts of warming of 1.5°C consistent with the goal of the Paris Agreement on the climate, signed in 2015.

This document sets out four scenarios, each depicting a CO_2 emissions trajectory combined with a set of socio-economic determinants. They are scenarios P1, P2, P3 and P4.

- **P1 Scenario** (*low energy demand*) projects low worldwide demand for energy, considering profound social and institutional transformation with regard to how energy services are produced and consumed. The very detailed scenario narrative puts special focus on these aspects. In addition, scenario P1 can be included in the SSP2 family of scenarios, with which it shares certain elements of the narrative and the main input assumptions (particularly population and GDP).
- **P2 Scenario** belongs to the SSP1 family of scenarios. It is built around the same narrative and the same input assumptions but targets a rise in temperature limited to 1.5°C (1.9 W/m² of radiative forcing).
- **P3 Scenario** belongs to the SSP2 family of scenarios. It is built around the same narrative and the same input assumptions but targets a rise in temperature limited to 1.5°C (1.9 W/m² of radiative forcing).
- **P4 Scenario** belongs to the SSP5 family of scenarios. It is built around the same narrative and the same input assumptions but targets a rise in temperature limited to 1.5°C (1.9 W/m² of radiative forcing).

c — How are these public energy/climate scenarios used today?

Since their emergence in the 1970s, the energy/climate scenarios have been used for various purposes. As mentioned above, how the scenarios are being used considerably influences the way they are built, especially when it comes to selecting a model to underpin them.

The energy/climate scenarios are used in "exploratory" academic research into climate issues. The scenarios thus aim to answer questions such as "*what are the (climate) impacts on a given socio-economic pathway?*". This approach formed part of the IPCC's process when producing the "*Special Report on Emissions Scenarios*"[90] (SRES) at the start of the 2000s. This type of use mainly concerns academics and the scenarios produced by research facilities.

The energy/climate scenarios are used to assess (present or future) policies designed to mitigate climate change. This was the case of the scenarios studied by IPCC Working Group 3. This type of use has developed since 2008 with the introduction of the *Representative Concentration Pathways* (RCPs) and Shared Socio-economic Pathways (SSPs) (see Box 15: The Shared Socio-economic Pathways (SSPs), p.69).

This is also one of the goals of the scenarios produced by the IEA (since 2008, with the publication of the first "*450 scenario*"), for the *World Energy Outlook* and the *Energy Technology Perspectives*. The latter study was published in response to a call from the countries present at the 2005 G8 Gleneagles summit, which mandated the IEA to produce scenarios describing the path to a "clean, clever, competitive energy future"[91].

Here the scenarios aim to answer questions such as "*which route do we need to take to reach this objective?*" or "*what technological choices and which policies are needed to reach a specific warming target?*".

This type of use concerns academics and, more marginally, political and economic operators.

The energy/climate scenarios are used by companies in the energy sector and in sectors that are very big energy consumers (raw material extraction, etc.) to feed into

90 - Special Report on Emissions Scenarios, GIEC, 2000.

91 - "The IEA will advise on alternative energy scenarios and strategies aimed at a clean clever and competitive energy future". Gleneagles G8 summit, 8 July 2005 – "Climate Change, Clean Energy and Sustainable Development".

their strategies. This type of use depends on the reason why the scenarios – initially designed for energy sector stakeholders – were created (especially the IEA scenarios). Over recent years, energy/climate scenarios, adapted to the issues encountered in these sectors, are frequently quoted in annual reports to justify certain strategic orientations[92], or certain decisions, especially where investments are concerned[93]. Generally speaking, this type of use could expand to other sectors, especially the financial realm[94], to demonstrate that strategies are consistent with the goal to limit GHG emissions (see Part 10.C, p. 110).

Energy/climate scenarios are used by public bodies in certain decision-making processes. These scenarios may contain reference elements of use to the public institutions when making decisions on the authorisation or refusal of an infrastructure project, for example[95].

The analysis tools[96] that have emerged since COP21 often make use of energy/climate scenarios (see Part 9.C.3, p. 102).

The last three types of use make almost exclusive use of the IEA scenarios. The agency benefits from a great credibility among political and economic operators concerned with energy issues. The inclusion of the transition and GHG emissions challenges have also helped to establish the IEA as an authority on these issues.

In fact, the IEA has (1) around ten years' experience in the matter (first transition scenario published in the 2008 WEO); (2) recognised expertise in terms of energy; (3) considerable means in terms of expertise at its disposal.

All of this led the TCFD to put strong emphasis on the IEA scenarios in its final report.[97] Some rating agencies refer only to these scenarios in their methodological documents (see Part 10.C, p. 110). These scenarios thus already dominate the institutional framework for action against climate change, a position that is likely to be reinforced in the future.

The IEA scenarios are also the most familiar standards among companies (see Box 14: The public energy/climate scenarios in French companies today, p. 67).

92 - In its "2018 Climate Report", Total says, for example, "We believe that oil and gas will continue to play an essential role in the coming decades, as reflected in all the IEA scenarios. We are therefore maintaining a policy of selective investment in our core businesses that will be critical for long-term performance." Similar examples can be found in the "Off Track" report (2018) from the NGO Oil Change International.

93 - In its 2018 Energy & Carbon Summary report, Exxon says: "Considering the IEA's Sustainable Development Scenario (a 2°C scenario), the IEA estimates that almost $14 trillion of investment will be needed for oil and natural gas supply between 2017 and 2040".

94 - Barclays bank says that it used the 2015 WEO scenarios to analyse its exposure to the transition risks.

95 - See the "Off Track" report (2018) by NGO Oil Change International.

96 - See, for example: the Science Based Targets (SBT) initiative, the ACT project (ADEME and CDP) and the Energy Transition Risks Project.

97 - The final report of the TCFD states the following: "The most well-known and widely used and reviewed scenarios for transition to a low carbon economy are those prepared by the IEA. A majority of analyses conducted by academic and industry analysts are built upon or compared with the IEA scenarios."

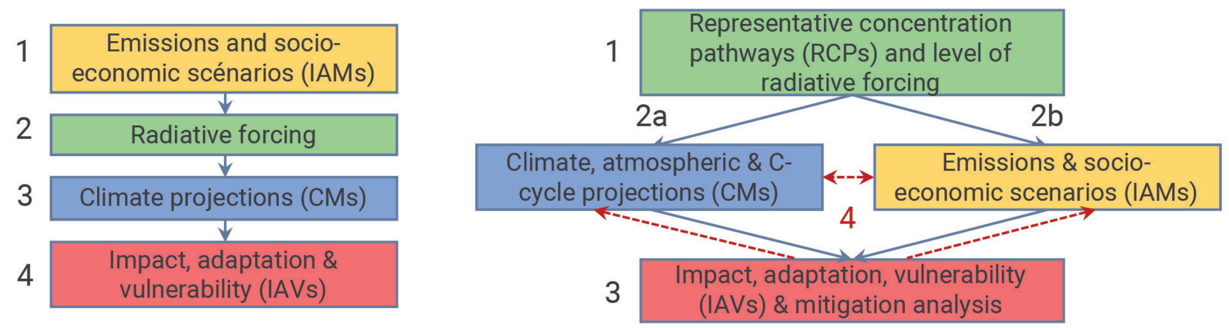
Box 18: The IPCC's use of scenarios

Scenario evaluation is one aspect of the IPCC's work. The process of building and assessing scenarios has evolved since the fifth Assessment Report (2014). While in the two previous reports (AR3 and AR4), a sequential approach was applied[98], the new procedure focuses on a "parallel" approach involving different specialists **to speed up the assessment process, which was deemed too long with the original methods.**

This process[99] can be broken down as follows:

1. **Definition of the four greenhouse gas emissions and concentrations pathways: the *"Representative Concentration Pathways"* (RCPs)** (see Part 8.A, p. 55).
2. **These RCPs are then used simultaneously by the various teams of experts, including climatologists, economists and adaptation specialists.**
   a. *Climatologists* deduce global and regional **climate projections** (*Climate Modelling* or CM) using the four RCPs.
   b. *Economists* establish scenarios exploring all the possible technological and socio-economic developments compatible with the RCPs: *the Shared Socio-economic Pathways* (SSPs). **The SSPs were produced to supplement the RCPs with various socio-economic elements** concerning mitigation of and adaptation to climate change. These scenarios include five different narratives and project the development of the socio-economic system, energy systems, land use, air pollution and GHG emissions (see Box 19: SSPs' underlying narratives, p. 76).
3. **Researchers specialised in impacts, adaptation and vulnerability** (IAVs) to climate change determine the priorities for scenario evaluation and application.
4. **The projections made by climatologists (CM) and economists (SSPs) are incorporated** into a consistent set of scenarios for use in analysing the impacts of climate change and adaptation measures (Impacts, Adaptation and Vulnerability, or IAVs), most notably by IPCC Working Group 2.

Figure 22: IPCC approaches to the development of global scenarios in AR4 (left) and AR5 (right)



Source IPCC

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98 - As part of the Special Report on Emission Scenarios (SRES), four families of scenarios were developed, characterised by socio-economic scenarios projecting different development pathways. The resulting climate scenarios were then applied to research on impacts, adaptations and vulnerability (IAVs). This sequential approach – from socio-economic factors and emissions to climate projections, including impact assessment – was not deemed very efficient, given the time taken to conduct the analysis, and thus abandoned.

99 - For more details on this process, see the documentation available on the IPCC website and the paper from the CIRED "Les nouveaux scénarios socio-économiques pour la recherche sur le changement climatique" (Guivarch and Rozenberg, 2013).

3 Analysis of the public energy/climate scenarios and areas for improvement

The analysis below follows the different *"interpretation aids"* in Part 8.B.1 "*How to read a public energy/climate scenario*". It is based on the data made available by the authors of the public energy/climate scenarios listed in Part 8.B.2.b *"Selection criteria and list of scenarios studied"*, and on the historical data series for which the development methodology is detailed in the appendices to the report (see Appendix 3: Development of historical series, p. 119).

a — Data access is limited

The quantitative data and qualitative information provided by scenario authors provide the raw material for scenario analysis work.

This raw material is usually presented by the scenario author in a specifically-structured document and may be accompanied by appendices such as tables setting out the quantitative data.

First observation: results are presented in a disparate manner and data access is sometimes restricted.

The presentation of the results from the study of a scenarios family, i.e. the structure of the document published and its content, reflects the question that the scenarios are supposed to answer and the target audience for whom the results are intended. As these questions and targets vary from one study to another, the presentation structure chosen by scenario authors also varies considerably.

There is thus a big difference between the structure of the documents presenting the results of the SSP scenarios analysed by the IPPC, currently aimed at an academic audience, and that of the document setting out the *World Energy Outlook* results, published by the IEA and intended for an audience of experts from the energy sector.

Generally speaking, the presentation of scenarios is rarely "linear" (i.e. broken down according to scenario structure: narrative, assumptions, model, results), which means the data and information is dispersed throughout the document. While this situation arises from legitimate editorial choices, it cannot be said to facilitate the use of scenarios by actors such as companies.

For example, there is a lack of clarity over the scope covered by CO_2 emissions in certain scenarios, for example the *World Energy Outlook*. It is not therefore always easy to identify whether the authors have considered CO_2 emissions from hydrocarbon combustion, industrial processes or land use.

Finally, the quantitative data published are not always accessible in an easy-to-use format (like a *Microsoft Excel* spreadsheet). In several cases (e.g. IRENA scenarios, Greenpeace scenarios and WEC scenarios), the date is only available in *Adobe PDF* format. Data shown in graphs cannot always be accessed either.

Second observation: the availability of certain data of interest for companies (e.g. the production volumes of goods and services) is limited, and their sectoral and geographic resolution is disparate.

In theory, the scenario author should be able to provide as much data as the model used is able to produce. Among the various data that the company could need, we can differentiate between:

1. data that the scenario author could disclose but does not;
2. data that the scenario author does not disclose and does not wish to disclose (confidential to the model);
3. data that the scenario author does not disclose because the model used does not produce it.

The latter two categories mainly depend on the model used, but there is room for improvement concerning the availability of data in the first category. This situation is again linked to the objective and the current target audience of energy/climate scenarios.

Data describing demand (in volume) for the main materials (production of steel, cement or chemical products, minerals or materials) and for the main goods and services that consume final energy (cars, housing surface area, etc.) are rarely available or easily accessible in the scenarios studied. So are data describing trends in transport flows (passengers, freight, air traffic, etc.).

Yet the availability of this kind of data is crucial to facilitating the use of energy/climate scenarios for many companies (see Box 14: The public energy/climate scenarios in French companies today, p. 67). The ETP scenarios published by the IEA are currently the most frequently used by economic operators. They are also the scenarios that provide the greatest level of detail on the data mentioned above.

Scenario authors indicate that they are ready to enter into in-depth discussions with companies and business sectors to get a better understanding of the type of data they need to use their scenarios.

Finally, the geographic and sectoral resolution of the accessible data differs widely from one scenario to another. This is partly due to the fact that scenario authors do not publish all their data for a variety of reasons (editorial choices, purpose of the scenario, etc.), and partly because of the limits inherent to the models on which the scenarios are based. Overall, the models used enable users to break information down into more than ten geographic regions (sometimes more) and into the main sectors and sub-sectors of energy consumption (transport, power generation and industry). However, the "other" sectors of the economy are more aggregated or not modelled. This is largely explained by the origin of these models, initially designed to analyse energy issues[100].

b — The quality of the narratives varies widely

First observation: only some of the scenarios studied are based on an explicit, detailed narrative.

Of the scenarios studied, only the *SSP scenarios*, the *SR-15* scenarios, the *WEC scenarios*, the *Shell scenarios* and the *Equinor scenarios* are based on **explicit, detailed narratives.** For these scenarios, the input assumptions are consistent with the narratives.

For example, the three *WEC scenarios* describe three different futures: a future in which the energy/climate issues are relatively well managed, mainly using market mechanisms (*Modern Jazz*), a future in which these issues are successfully managed, mainly using public policy mechanisms (Unfinished Symphony), and a future in which the energy/climate issues are not successfully handled and which describes a fractured world (*Hard Rock*).

These narratives are each set out in detail according to the main social, political, economic, technical and environmental determinants mentioned in Part 6.B "*The main environment-related determinants to be considered in an energy/climate scenario*".

The other scenarios studied **are based on very restricted and relatively inexplicit narrative elements.**

100 - See "Note d'analyse sur les enjeux de modélisation" [Analytical Note on the Challenges of Modelling], The Shift Project (2019).

Second observation: for the scenarios that are not based on an explicit, detailed analysis, a neutral, socio-economic pathway without disruptions is implied.

The lack of narrative indicates that the choice of the most structuring assumptions (GDP, population, technical advances) does not fit into any global coherence framework.

The narratives suggested by these scenarios describe a future in which the main paradigms are not challenged (economic and demographic growth, political and geopolitical balance, behaviour). In the case where climate objectives are met, they illustrate a relatively cooperative world highly mobilised to cap GHG emissions, mainly through energy efficiency measures enabled by technical progress.

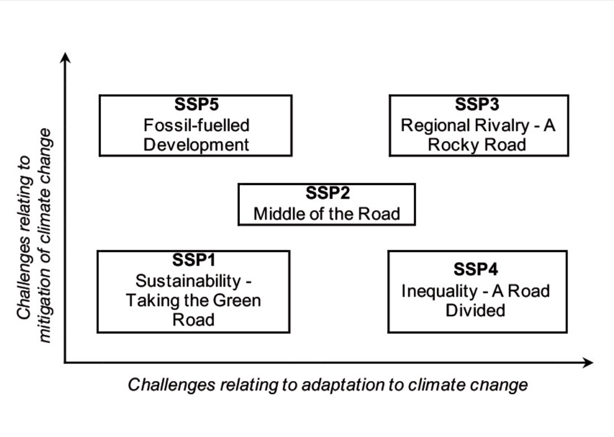
Changes in behaviour and other reversals of non-energy-related trends are not taken into consideration.

Third observation: with the exception of the *SSP scenarios*, the socio-economic pathways that make it possible to reach ambitious climate goals are relatively similar, with no notion of disruption.

For most scenarios, the rapid reduction of CO_2 emissions occurs only (explicitly or implicitly) in the context of a future marked by strong international cooperation focused on energy/climate issues, significant technical progress dispersed far and wide thanks to full globalisation, and a gradual reduction in inequalities between the world's countries.

The *SSP scenarios* and the *SR-1.5 scenarios* are based on more contrasted narratives that combine several trends (see Box 19 : SSPs' underlying narratives p. 76).

Box 19: SSPs' underlying narratives



SSP1: Sustainability—Taking the green road

The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Increasing evidence of and accounting for the social, cultural, and economic costs of environmental degradation and inequality drive this shift. Management of the global commons slowly improves, facilitated by increasingly effective and persistent cooperation and collaboration of local, national, and international organizations and institutions, the private sector, and civil society. Educational and health investments accelerate the demographic transition, leading to a relatively low population. Beginning with current high-income countries, the emphasis on economic growth shifts toward a broader emphasis on human well-being, even at the expense of somewhat slower economic growth over the longer term. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Investment in environmental technology and changes in tax structures lead to improved resource efficiency, reducing overall energy and resource use and improving environmental conditions over the longer term. Increased investment, financial incentives and changing perceptions make renewable energy more attractive. Consumption is oriented toward low material growth and lower resource and energy intensity. The combination of directed development of environmentally friendly technologies, a favorable outlook for renewable energy, institutions that can facilitate international cooperation, and relatively low energy demand results in relatively low challenges to mitigation. At the same time, the improvements in human well-being, along with strong and flexible global, regional, and national institutions imply low challenges to adaptation.

SSP2: Middle of the road

The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Most economies are politically stable. Globally connected markets function imperfectly. Global and national institutions work toward but make slow progress in achieving sustainable development goals, including improved living conditions and access to education, safe water, and health care. Technological development proceeds apace, but without fundamental breakthroughs. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Even though fossil fuel dependency decreases slowly, there is no reluctance to use unconventional fossil resources. Global population growth is moderate and levels off in the second half of the century as a consequence of completion of the demographic transition. However, education investments are not high enough to accelerate the transition to low fertility rates in low-income countries and to rapidly slow population growth. This growth, along with income inequality that persists or improves only slowly, continuing societal stratification, and limited social cohesion, maintain challenges to reducing vulnerability to societal and environmental changes and constrain significant advances in sustainable development. These moderate development trends leave the world, on average, facing moderate challenges to mitigation and adaptation, but with significant heterogeneities across and within countries.

SSP3: Regional rivalry—A rocky road

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. This trend is reinforced by the limited number of comparatively weak global institutions, with uneven coordination and cooperation for addressing environmental and other global concerns. Policies shift over time to become increasingly oriented toward national and regional security issues, including barriers to trade, particularly in the energy resource and agricultural markets. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development, and in several regions move toward more authoritarian forms of government with highly regulated economies. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time, especially in developing countries. There are pockets of extreme poverty alongside pockets of moderate wealth, with many countries struggling to maintain living standards and provide access to safe water, improved sanitation, and health care for disadvantaged populations. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions. The combination of impeded development and limited environmental concern results in poor progress toward sustainability. Population growth is low in industrialized and high in developing countries. Growing resource intensity and fossil fuel dependency along with difficulty in achieving international cooperation and slow technological change imply high challenges to mitigation. The limited progress on human development, slow income growth, and lack of effective institutions, especially those that can act across regions, implies high challenges to adaptation for many groups in all regions.

SSP4: Inequality—A road divided

Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally-connected society that is well educated and contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labor intensive, lowtech economy. Power becomes more concentrated in a relatively small political and business elite, even in democratic societies, while vulnerable groups have little representation in national and global institutions. Economic growth is moderate in industrialized and middle-income countries, while low income countries lag behind, in many cases struggling to provide adequate access to water, sanitation and health care for the poor. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. Uncertainty in the fossil fuel markets lead to underinvestment in new resources in many regions of the world. Energy companies hedge against price fluctuations partly through diversifying their energy sources, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle and high income areas. The combination of some development of low carbon supply options and expertise, and a well-integrated international political and business class capable of acting quickly and decisively, implies low challenges to mitigation. Challenges to adaptation are high for the substantial proportions of populations at low levels of development and with limited access to effective institutions for coping with economic or environmental stresses.

SSP5: Fossil-fueled development—Taking the highway

Driven by the economic success of industrialized and emerging economies, this world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated, with interventions focused on maintaining competition and removing institutional barriers to the participation of disadvantaged population groups. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary. While local environmental impacts are addressed effectively by technological solutions, there is relatively little effort to avoid potential global environmental impacts due to a perceived tradeoff with progress on economic development. Global population peaks and declines in the 21st century. Though fertility declines rapidly in developing countries, fertility levels in high income countries are relatively high (at or above replacement level) due to optimistic economic outlooks. International mobili

c — The input assumptions and results are not especially diversified.

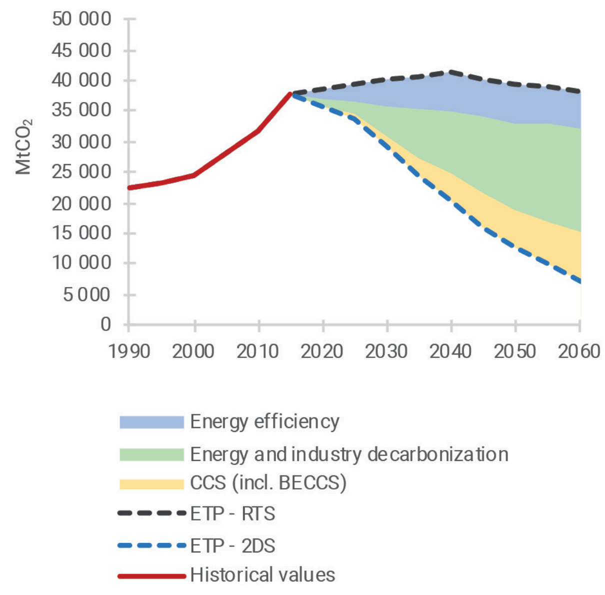
First observation: In most scenario families, some of the most structuring assumptions are shared.

Most scenario families include a baseline scenario (in which either current trends are generally extended or only NDCs are applied), and several alternative scenarios that describe a low-carbon transition. These families most often comprise three scenarios: a baseline scenario, a middle-of-the-road transition scenario (usually 2°C) and an advanced transition scenario (<2°C).

For these families, some of the input assumptions are shared (i.e. they are identical) by all the scenarios. This is linked to why the scenarios were produced in the first place: to enable comparison, all other things being equal, of the impact of climate policies. Scenario authors claim that if parameters as structuring as GDP growth and population (see Part 8.B.1.d Models, p. 63) vary from one scenario in the family to another, the impact of a specific policy (e.g. energy efficiency) can no longer be quantified in a significant manner.

However, some scenario families, such as those developed by *Shell, Equinor* and the *World Energy Council*, apply a different structure. While they may include a baseline scenario, some input assumptions vary from one scenario to another, partially limiting the value of any comparison between them. This situation reflects the more exploratory nature of these stakeholders' approaches.

Figure 23: Projected CO_2 emissions in the 2DS scenario and the 2017 ETP baseline scenario (RTS).



These two scenarios belong to the same family and share the same population and GDP growth assumptions, which enables comparison of the impact of the measures taken in the SDS scenario but not in the RTS on CO_2 emissions.

Source: 2017 ETP and author's calculation.

Second observation: for all scenarios, population is an exogenous variable, which will grow in a relatively regular manner in the future.

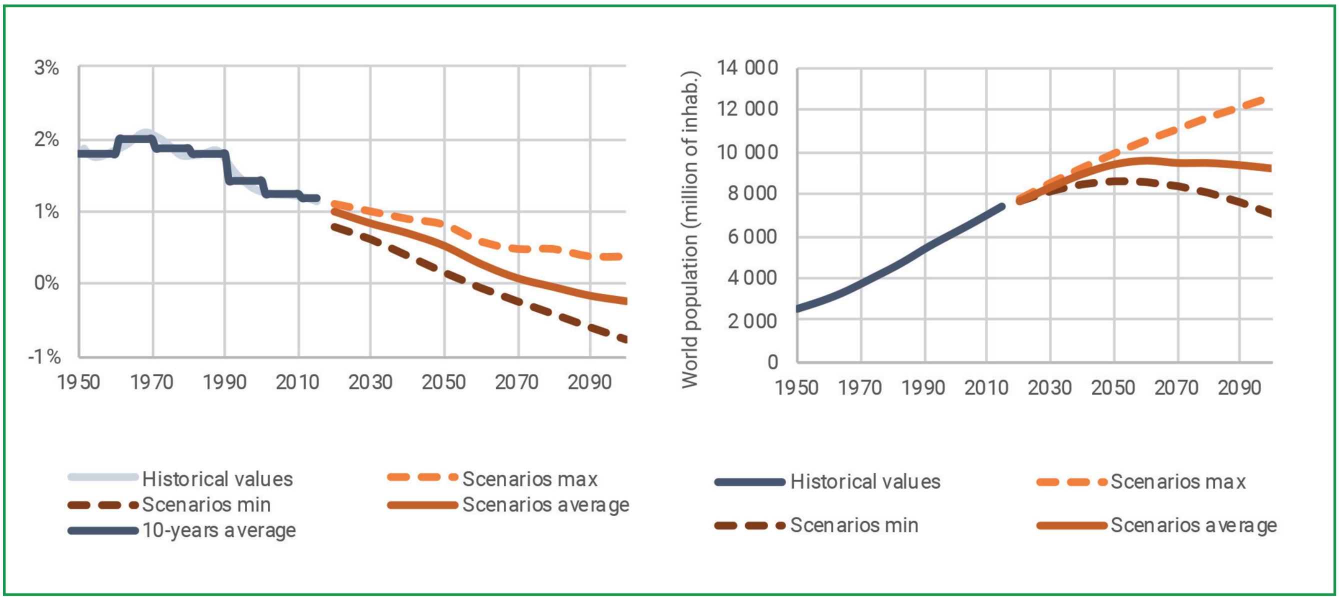
Population size is a highly structuring variable when determining the demand for goods and services, and hence for energy[101].

For all the scenarios studied, **this variable is exogenous**. The values used by scenario authors are also **very homogeneous**. The world population continues to grow at an annual rate of between 0.5% and 1%, below historical trends, to reach 9-9.5 billion inhabitants in 2050 in most scenarios.

These assumptions are very often based on projections made by the population division of the United Nations Department of Economic and Social Affairs (UN DESA), including the average variant taken from its *World Population Prospects*[102] (WPP). Value differences are usually related to the year in which the regularly updated WPP is published.

101 - See "Note d'analyse sur les enjeux de modélisation" [Analytical Note on the Challenges of Modelling], The Shift Project (2019).
102 - See the World Population Prospects website.

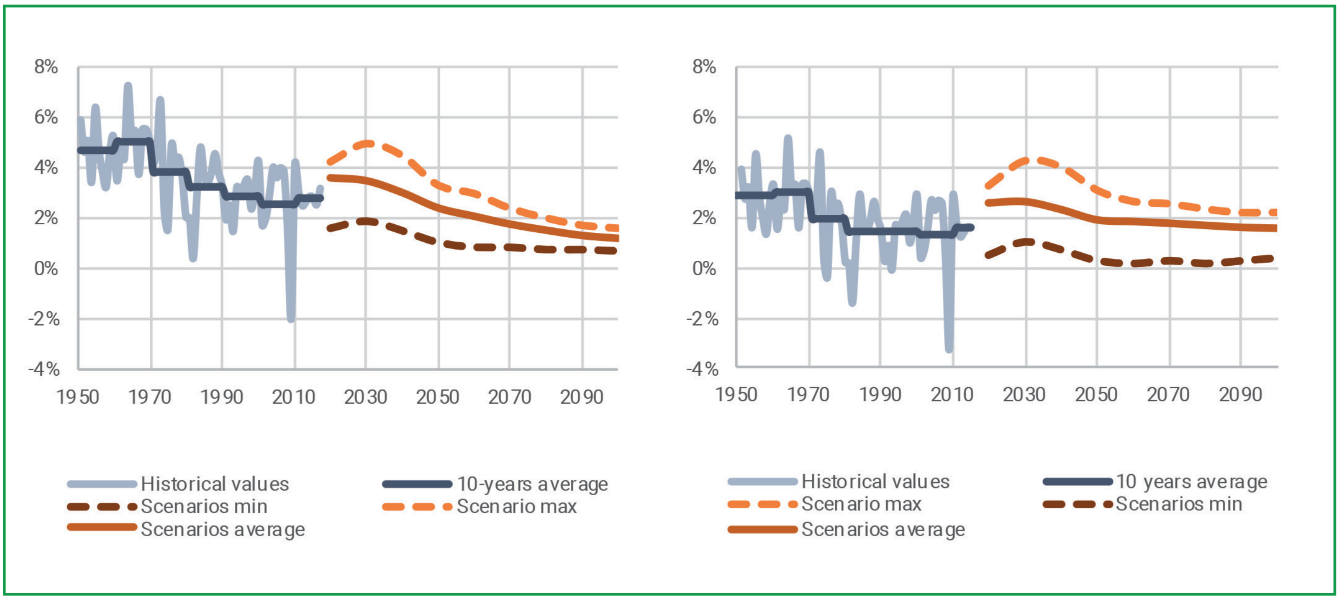
Figure 24: Annual variation (left) and trend in world population in the scenarios studied



The population trend is very similar in the sample of scenarios studied, at least until 2050. The divergences observed beyond that point are related to the SSP scenario, where the assumptions on population growth are highly contrasted.

Source: Author's calculation and documentation from scenario authors; historical values, United Nations

Figure 25: Annual change in GDP (left, in MER) and GDP per capita (right) in the scenarios studied.



In both graphs, the "Scenarios max." curves represent the maximum values of the sample of scenarios studied per year, the "Scenarios min." curves represent the minimum values, and the "Scenarios average" curves represent the average values. For example, in 2030, in the sample of scenarios considered, the minimum annual change in GDP is 2%, the maximum value is 5%, and the sample average is 3.5%.

Source: Scenario authors' documentation and author's calculations.

UN projections do not take into account the physical impacts of climate change[103].

However, the SSP scenarios differ from this set and put forward diversified population projections, each reflecting the narratives on which these scenarios are based.

Third observation: for most scenarios, GDP (and ultimately GDP per capita) is an exogenous variable which will grow in a relatively regular manner in the future, and which is not affected by energy/climate issues.

Like population, GDP is a highly structuring variable when determining the demand for goods and services, and hence for energy[104]. For all the scenarios studied, this variable is exogenous.

With a few exceptions (see below), the values used by the authors of the scenarios studied for the period 2015-2050 are **relatively homogeneous**, **stable** and f**ollow recent trends**. On average, GDP continues to grow at an annual rate of more than 3%[105] over this period (i.e. GDP doubles over 25 years). For scenarios projecting beyond 2050, the trend for this rate converges towards lower growth values, ranging from 0.5% to 1.5%/year in 2100.

These assumptions are often based on baseline projections made by international organisations such as the *OECD*[106], the *IMF*[107] and the *World Bank*[108], which, notwithstanding the limits of the models on which they are based, do not in most cases include energy/climate issues (mitigation or adaptation).

103 - There is no mention of the words "climate" or "climate change" in the main publication or in the methodological documents.
104 - See "Note d'analyse sur les enjeux de modélisation" [Analytical Note on the Challenges of Modelling], The Shift Project (2019).
105 - In some scenarios, the available GDP values are expressed in Purchasing Power Parity (PPP) (this is the case for the 2018 WEO, 2017 ETP and SSP scenarios, for example), while in others, they are expressed in Market Exchange Rate (MER). Expressing GDP in purchasing power parity, i.e. representing the purchasing power of a currency, results in higher GDP values (and variations) than when GDP is expressed as a market exchange rate (most notably due to the development of emerging countries). The figures given are average GDP growth figures for all the scenarios studied, some of which are expressed in PPP or MER. This has little impact on the main argument set out in this section, which states that, overall, the GDP projected by the scenarios remains fairly sustained and similar from one scenario to another.
106 - See OECD Economic Outlook: Statistics and Projections (estimates to 2060). See "The Long View: Scenarios for the World Economy to 2060", OECD (2018): "Perhaps the most important omission is that of the natural environment, including natural resources, air and water quality, the climate, sea levels and so on. Continued warming of the earth's climate, to take one example, could have profound economic effects that vary by region".
107 - See "World Economic Outlook", 2019, IMF, Estimates to 2024. No mention of the risks associated with climate change in the assumptions (see Box A1: Economic Policy Assumptions Underlying the Projections for Selected Economies).
108 - See Global Economic Prospects, Estimates to 2021. While climate change is mentioned as a risk factor for economic growth (16 occurrences of the terms "climate change" for 182 pages), its impact appears marginal at the horizon considered.

In some cases, however, GDP projections diverge from the expected continuation of the trend. This is particularly true for the scenarios based on detailed narratives describing a future in which economic activity is disrupted by political and social factors (*Equinor* scenarios, *WEC* scenarios, *SSP*[109]). The GDP trend (upwards or downwards) reflects the narrative in these cases.

In most scenario families, GDP assumptions are shared. On the other hand, for some families (e.g. the *Equinor* scenarios, *WEC* scenarios, *SSP* and *Shell* scenarios), the assumptions on GDP trends differ from one scenario to another.

Fourth observation: in all scenarios aimed at meeting a climate goal, GDP energy intensity improves rapidly and very significantly. Generally, there are few explanations to support such an improvement.

Primary energy production is an **endogenous variable** and is part of the scenario results. In the future trend for this variable, there are disparities depending on the temperature warming target set in the scenarios.

The 2°C scenarios project a rapid, homogeneous and significant overall decline in the growth of primary energy production. On average, this production increases by only **0.8%/year up to 2020 and by 0.5%/year thereafter**.

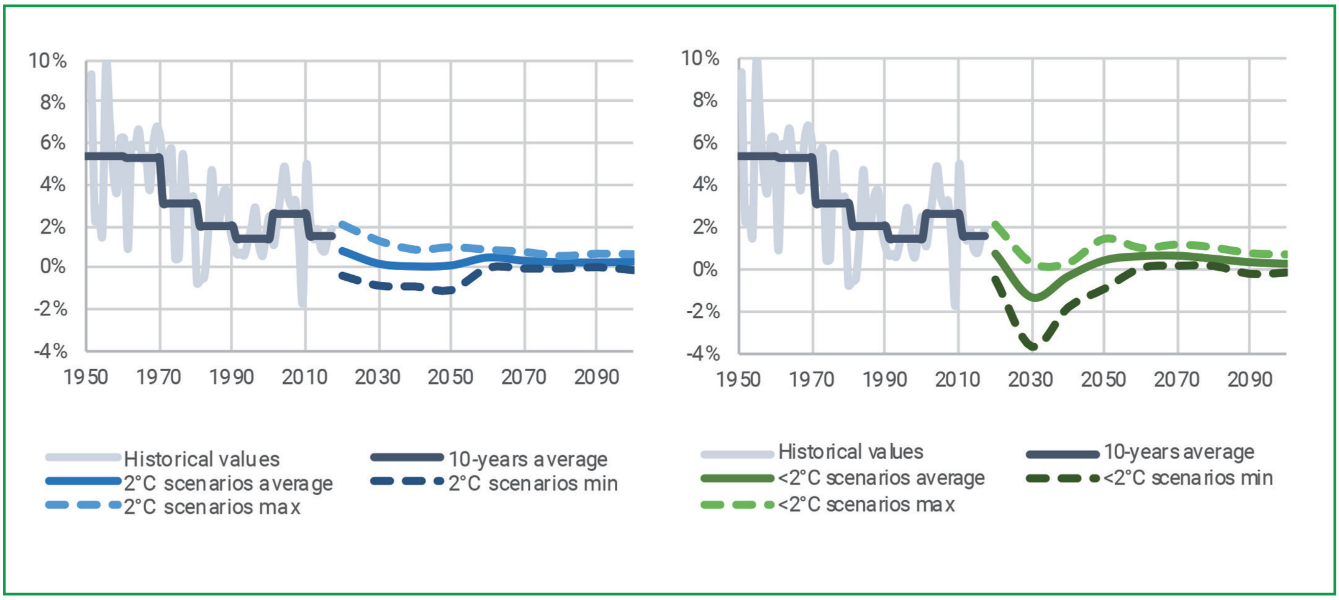
The phenomenon is even more marked in the 1.5°C scenarios where primary energy production decreases by an average 0.5% to 1.5% per year from 2020 to 2040.

These results, combined with **growth in economic activity** (i.e. growing demand for goods and services and an increasing number of machines in operation), lead to **a very significant and unprececented reduction, of GDP energy intensity.**

On average, the 2°C scenarios thus project a decrease in GDP energy intensity of between **-2.5%/year and -3%/year from 2020 to 2050**, i.e. almost twice the historical values[110]. The 1.5°C scenarios project a decrease in GDP energy intensity averaging at -5%/year between 2020 and 2030.

109 - For the SSP scenarios, each has an exogenous GDP projection specific to its narrative. These projections are based on the OECD's ENV-Growth model. See "Long-term economic growth projections in the Shared Socioeconomic Pathways", Dellink et al. (2015).
110 - These results indicate only one trend. We draw the reader's attention once again to the distinction between the expression of GDP values in PPP or MER. The historical energy intensity values mentioned (and presented in the graphs above) are derived from GDP values expressed in MER. If the GDP values used were expressed in PPP, the gap between historical GDP energy intensity values and future values would probably be smaller. We do not however challenge the observation made, namely that the energy intensity projected by the scenarios remains significantly higher than the historical values.

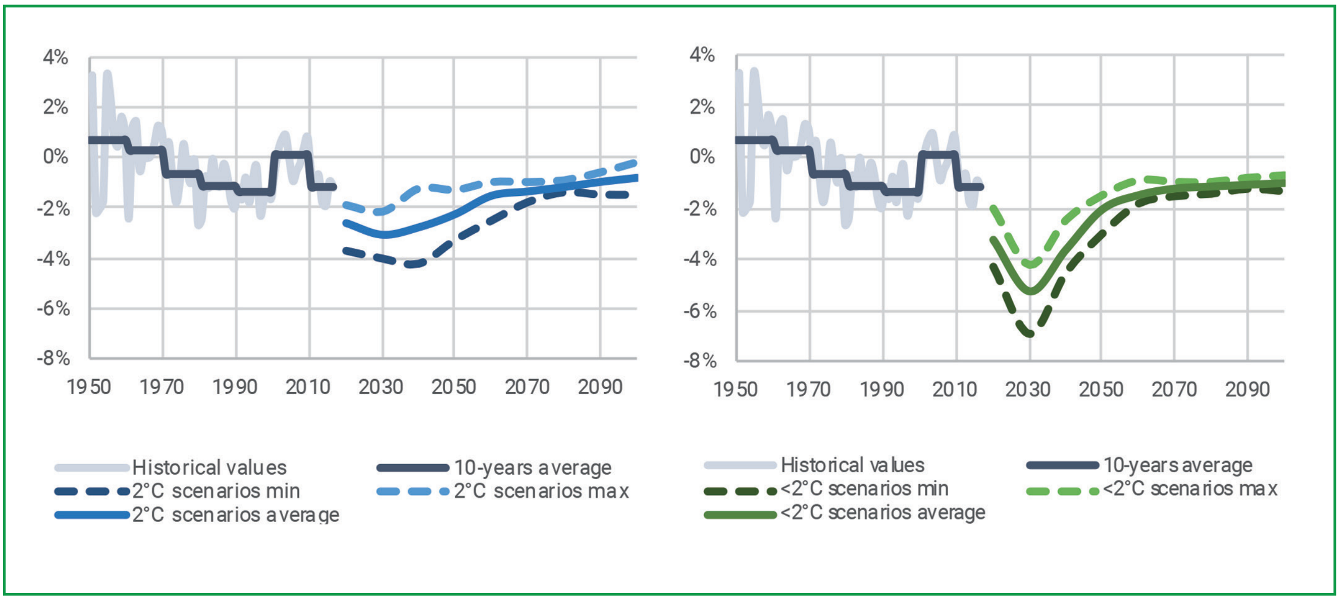
Figure 26: Annual variation in primary energy production projected by the 2°C scenarios (left) and 1.5°C scenarios (right).



In both graphs, the "Scenarios max." curves represent the maximum values of the sample of scenarios considered per year, the "Scenarios min." curves represent the minimum values, and the "Scenarios average" curves represent the average values. For the 2°C scenarios, we can see that future primary energy production is on average relatively stable from 2020 onwards. In the <2°C scenarios, this production is, on average, projected to fall between 2020 and 2040.

Source: Scenario authors' documentation and author's calculations.

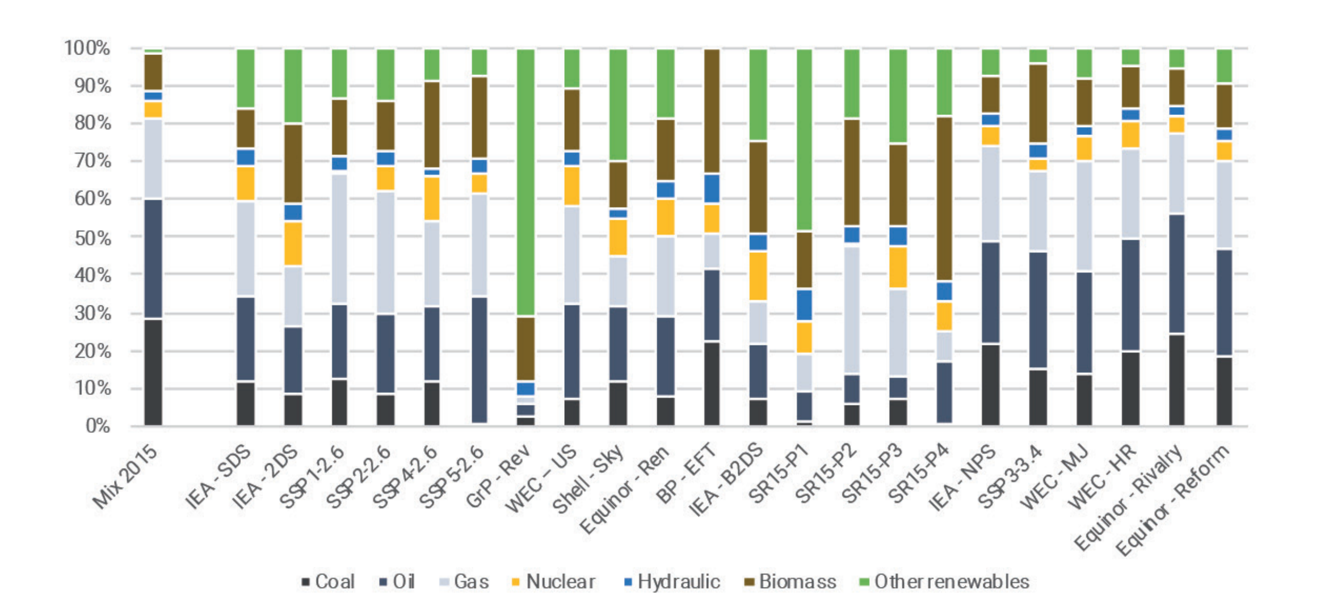
Figure 27: Annual variation in (primary) energy intensity of GDP projected by the 2°C scenarios (left) and 1.5°C scenarios (right).



In both graphs, the "Scenarios max." curves represent the maximum values of the sample of scenarios considered per year, the "Scenarios min." curves represent the minimum values, and the "Scenarios average" curves represent the average values. For the 2°C scenarios, we can see that the reduction in GDP energy intensity is much lower than the historic values, especially for the period 2020-2050. In the <2°C scenarios, the situation is even more pronounced with a maximum reduction around 2030.

Source: Scenario authors' documentation and author's calculations.

Figure 28: Global primary energy production mix in 2050 in the scenarios studied.



The "Other REn" category most notably includes solar, wind and geothermal energy. The "Biomass" category includes wood, biogas, biofuels and waste. It should be noted that the energy mixes in the 2018 WEO scenarios (SDS and NPS) and the EFT scenario in the BP 2018 Energy Outlook are the energy mixes for 2040 as these scenarios do not project beyond 2040.

Source: Scenario authors' documentation and author's calculations.

This kind of reduction in GDP energy intensity is partly linked to the exogenous nature of GDP, whose the increasing future values do not take into account energy/climate issues in most of the scenarios studied.

Such values also imply an equally significant improvement in energy efficiency and thus in technological progress. The technical, economic, political and societal feasibility of such an improvement is rarely questioned.

Finally, in most scenarios, the rebound effect is taken into account only marginally by the scenario authors, even though this phenomenon is frequently observed in cases where energy efficiency improves (see Box 10: The rebound effect, p. 59).

Fifth observation: the carbon intensity of energy is reduced in most scenarios aimed at meeting a climate goal by reducing fossil energy use.

Among the scenarios aimed at meeting a climate goal, changes in the primary energy mix, which currently consists of more than 80% fossil energy (see Part 3.A.1. p. 17), are generally characterised by a relatively rapid reduction in the share of fossil fuels. This reduction is to the benefit of low-carbon energies (renewables, bioenergy and nuclear), mainly through an electrification of uses.

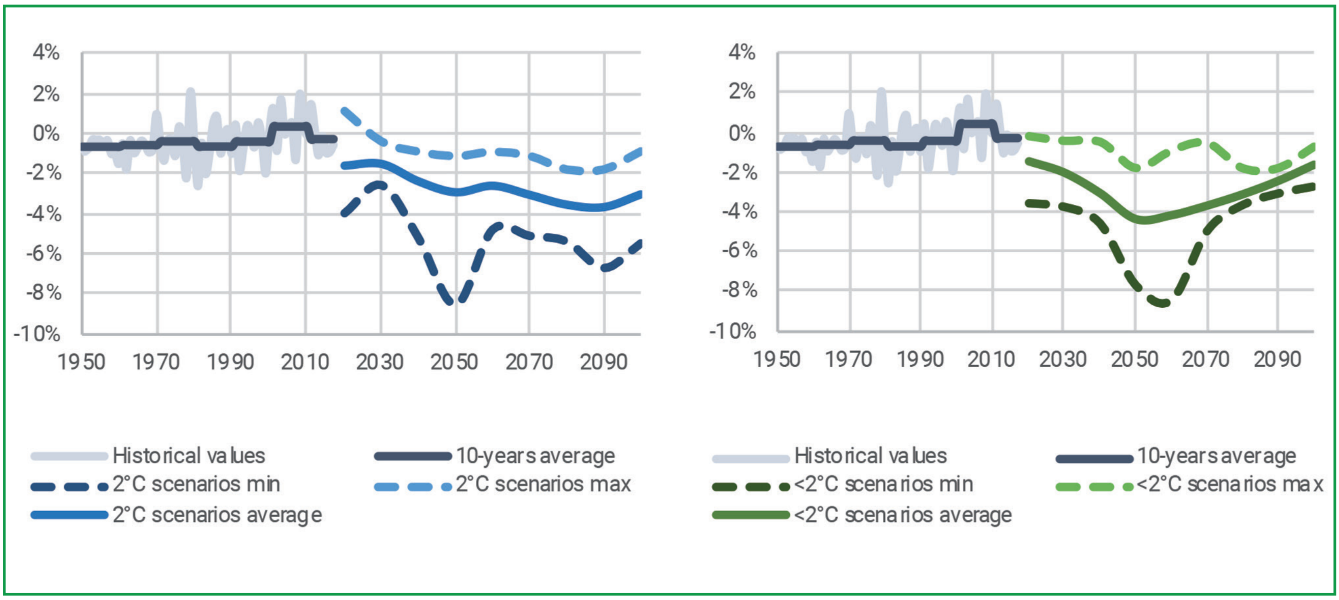
The future share of each energy source in the energy mix naturally varies from one scenario to another, because these aspects are determined by the choices made by the scenario authors (e.g. content of the narrative) and the objective of the scenario[111].

Generally, apart from certain scenarios based on a specific narrative (e.g. SSP5-2.6), coal and oil production is significantly and rapidly reduced (in the 2°C scenarios over 2015-2050, by an average of ~ -4%/year to ~1%/year respectively).

It should be noted that for **most scenarios, the (relatively rapid) decline in the use of hydrocarbons does not affect economic growth**, even though economic activity has historically been and remains dimensioned by the use of these energies (especially production and distribution systems, see Part 8.B.1.b, p. 57).

111 - The Greenpeace [R]evolution scenario aims to demonstrate the possibility of the emergence of an energy system based almost exclusively on renewable energies. It projects a very significant reduction in the share of fossil fuels and an exit from nuclear power by 2050.

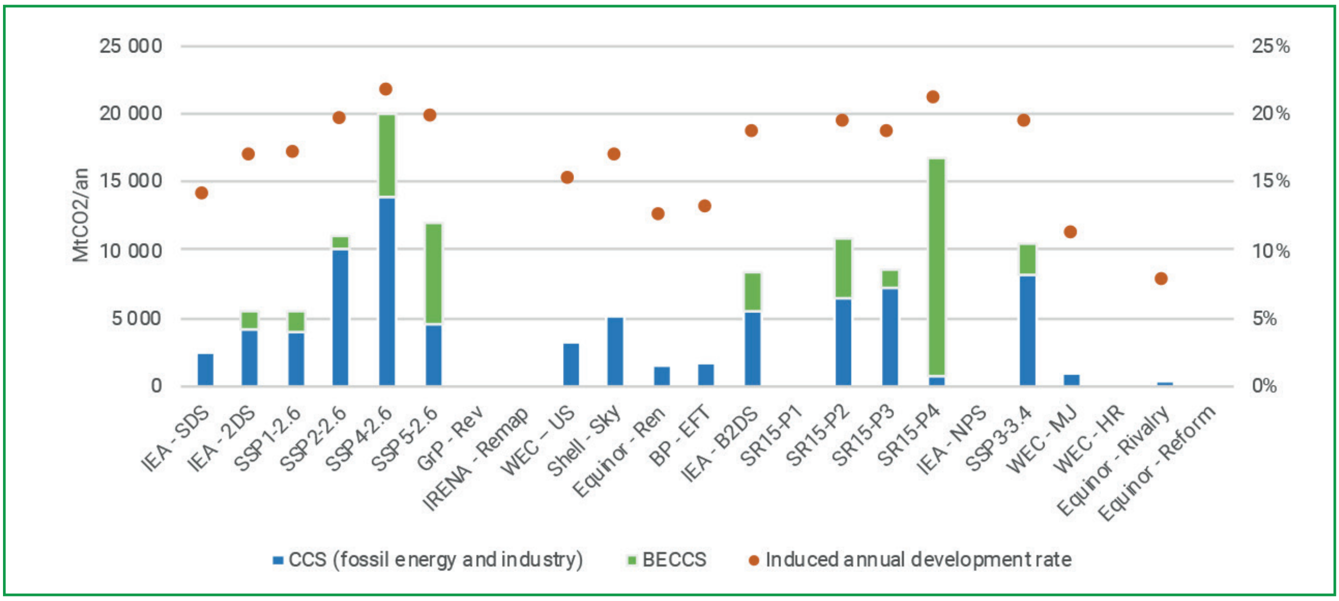
Figure 29: Annual variation in primary energy CO2 intensity projected by the 2°C scenarios (left) and the 1.5°C scenarios (right)



In both graphs, the "Scenarios max." curves represent the maximum values of the sample of scenarios considered per year, the "Scenarios min." curves represent the minimum values, and the "Scenarios average" curves represent the average values. Not surprisingly, the reduction in the carbon intensity of energy (excluding CCS) is more pronounced in the <2°C scenarios. The maximum reduction observed on the left-hand graph (2°C scenarios) is linked to the Greenpeace [R]evolution scenario, which projects an almost complete decarbonisation of the energy system by 2050, without use of CCS.

Source: Scenario authors' documentation and author's calculations.

Figure 30: Installed CCS and BECCS capacity in 2050 projected by the studied scenarios and induced annual development rate.



Most of the 2°C and <2°C scenarios are, to varying degrees, based on carbon storage technologies. On the right axis, the red dots show the presumed annual development rate of these technologies by 2050 considering that in 2017, 30 $MtCO_2$ were stored worldwide.

Source: Scenario authors' documentation and author's calculations.

Apart from a few exceptions (*Greenpeace* and *IRENA*), the share of nuclear energy in the primary energy production mix increases overall in most of the 2°C and <2°C scenarios.

Generally speaking, the *carbon intensity of energy*, excluding **CO_2 emissions captured and stored (CCS)**, decreases significantly in the 2°C scenarios, falling by an average 2-3% per year between 2020 and 2050. This reduction is more pronounced for the <2°C scenarios.

Sixth observation: In most scenarios aimed at meeting a climate goal, carbon neutrality is reached between 2050 and 2100. *Artificial carbon capture and storage* (CCS) is often used.

Under the combined effect of variations in the factors in the Kaya equation (described above), CO_2 emissions decrease significantly. Between 2017 and 2050, the average reduction in CO_2 emissions (excluding CCS) is achieved at a rate of -2%/year for the 2°C scenarios and 3.5%/year for the <2°C scenarios. Apart from a few scenarios in which this fall in emissions is much more pronounced (*SR15-P1* and Greenpeace *[R]evolution*), all the 2°C and <2°C scenarios incorporate the use of carbon capture and storage (CCS), in varying proportions.

The expected pace and scale of deployment of storage technologies, including the use of bioenergy (BECCS[112]), must be compared against their current development: 30 $MtCO_2$ in 2017, for total CO_2 emissions of 42 $GtCO_2$ that same year[113] (see Part 3.A.3, p. 19). Similar objections can be made about the likelihood of the pace at which bioenergy will be deployed on a large scale.

All the 2°C and <2°C scenarios project (or show a general trend towards) the attainment of carbon neutrality between 2050 and 2100.

The estimated cumulation of CO_2 emissions since 2016 ranges from 650 $GtCO_2$ to 1,200 $GtCO_2$ by 2050 for the 2°C scenarios, and from 600-850 $MtCO_2$ for the <2°C scenarios.

112 - Bioenergy with carbon capture and storage (BECCS) consists in capturing and storing the CO_2 emitted by use of bioenergy (e.g. biogas and biofuels). See "Box 2.1 - Bioenergy and BECCS Deployment in Integrated Assessment Modelling" in the IPCC "Special Report on Global Warming of 1.5ºC" for more details.
113 - See IEA: https://www.iea.org/topics/carbon-capture-and-storage/.

d — The models have their limitations

Note: The following is a summary of the analytical note on the challenges of modelling, produced by The Shift Project in liaison with IFPEN[114].

First observation: the complexity of the models and the sometimes-limited transparency make it difficult to interpret the results properly.

As they developed, the models used to construct energy/climate scenarios have become increasingly complex in an attempt to provide the best possible representation of the interactions between the economic, energy and climate systems.

This complexity first relates to the structure of the models (formulation and resolution of the equations that link the variables). This structure is based on a large number of relatively complex equations, involving a high number of variables and parameters. These equations remain difficult to assess individually (for example, some of them are created for the purposes of the model, with no clear theoretical or empirical basis) or even globally. The complexity also refers to the very large amount of data handled and produced by the model, thanks to the improved computing power of these tools.

More broadly speaking, there is room for improvement in terms of the transparency and clarity of the models' structure. For example, it is regrettable that there is a lack of clear, instructive and accessible documentation that would help assess the functioning and performance of the various models.

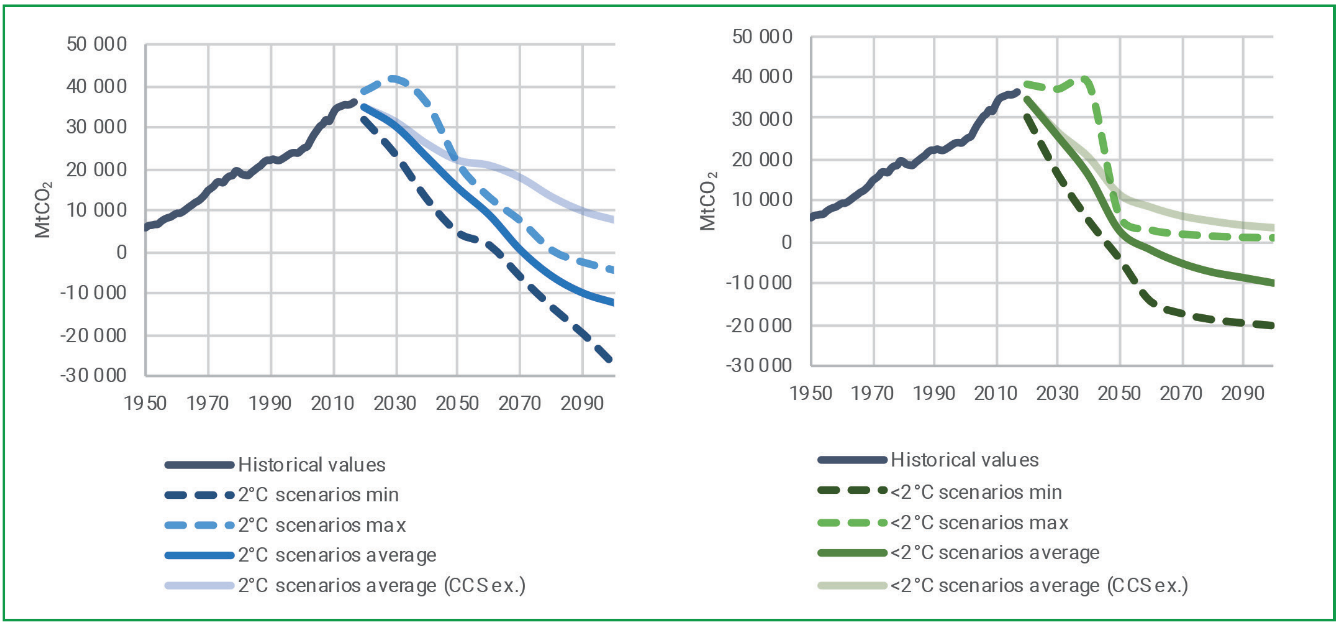
This is particularly critical as these models appear to enjoy "scientific" credibility among non-initiated users, prompting them to base their analyses on their results without applying a critical approach beforehand.

Second observation: the modelling of the economic system has intrinsic limitations.

The lack of framework for evaluating the structure of models gives the modeller a relatively large degree of freedom when **choosing the parameters and form of the equations used** to describe socio-economic relationships. Some equations and parameters are thus determined by econometric analysis of historical data and tend to overestimate how similar the future will be to the recent past. Others are arbitrarily determined and subject to uncertainty.

114 - See "Note d'analyse sur les enjeux de modélisation" [Analytical Note on the Challenges of Modelling], The Shift Project (2019).

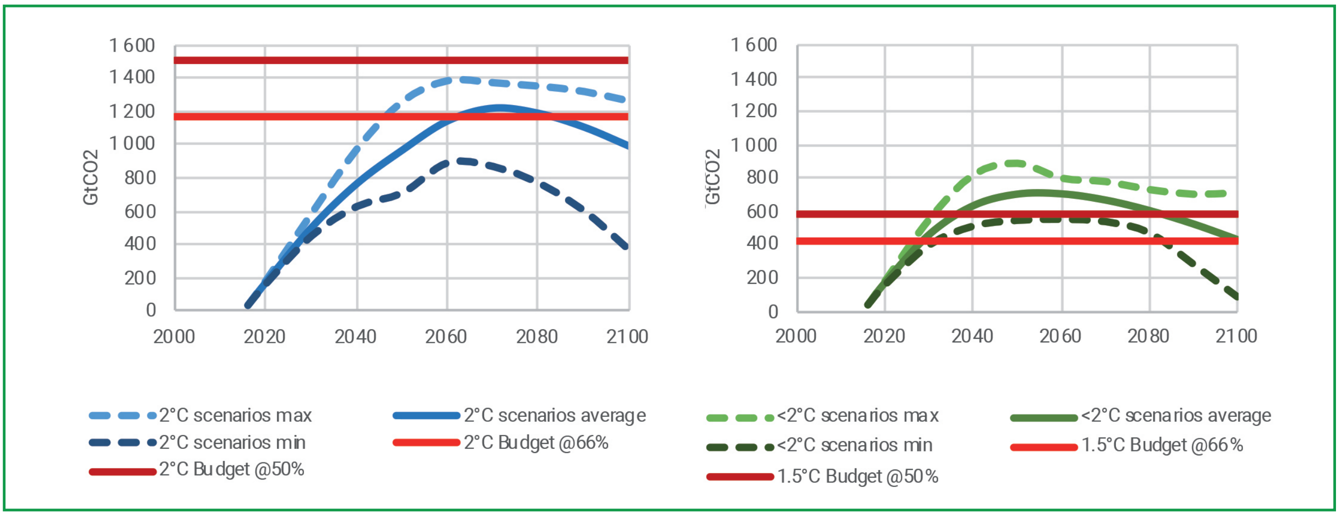
Figure 31: CO_2 emissions (AFOLU excl.) projected by the 2°C scenarios (left) and 1.5°C scenarios (right) studied



In both graphs, the "Scenarios max." curves represent the maximum values of the sample of scenarios considered per year, the "Scenarios min." curves represent the minimum values, and the "Scenarios average" curves represent the average values. The impact of CCS deployment on the CO_2 emissions curve can be seen in both graphs above.

Source: Scenario authors' documentation and author's calculations.

Figure 32: Cumulative CO_2 emissions (related to energy and industrial uses) in the 2°C scenarios (left) and 1.5°C scenarios (right) studied.



In both graphs, the "Scenarios max." curves represent the maximum values of the sample of scenarios considered per year, the "Scenarios min." curves represent the minimum values, and the "Scenarios average" curves represent the average values. The light red line shows the carbon budget for which there is a 66% chance of limiting global warming to 2°C (left) and 1.5°C (right), while the dark red line shows the carbon budget for which the chances are 50% (see Part 3.1.3, p. 14). Cumulative emissions decrease when more CO_2 is removed than emitted, most notably through artificial capture and sequestration (CCS). The light red lines show the carbon budget with a 66% chance of limiting global warming to 1.5°C (right) and 2°C (left). The dark red lines show a probability of 50%.

Source: Scenario authors' documentation and author's calculations.

Some socio-economic variables and parameters play **a very important role** in the model results. This is the case with the **discount rate**, which determines the timing of investments, especially those allocated to the energy transition, the benefits of which are expected in the long term. It is also the case **for economic growth, population growth and urbanisation rates**, which contribute significantly to determining final and primary energy demand. Finally, energy prices (especially fossil fuels) play a key role in most models, but their determination rarely reflects reality.

Moreover, the modelling exercise is based for most models on achieving a macro-economic balance (overall or partially) and optimised use of resources (capital, production, income). Agents (individuals, states, companies, etc.) are considered rational (they each act independently, based on comprehensive information, to maximise their well-being (consumers) or their profits (producers)) and the goods and services they consume are considered commensurable. As a result, **there is no unused capacity or waste of resources in these models**. This inevitably leads to **potentially significant differences with reality, which must be taken into account when interpreting the results**.

Finally, the financial system is not represented in any model. While this modelling is highly complex, omitting the financial system has a number of consequences, including the failure to take into account market instability and its impact on the economy (e.g. the 2008 financial crisis), the price formation of certain commodities (e.g. futures markets for oil) and the instability that climate change could create, particularly through the depreciation of fossil fuel assets (*Stranded Assets*).

Third observation: the impacts of climate change on the socio-economic system are not modelled.

To date, very few models have taken into account the physical consequences of climate change on the economic system. This means that for most models, particularly those on which the scenarios studied are based, the socio-economic and energy projections made have limitations. This is especially true in cases where GHG emissions would not be reduced. This also leads to discrimination against investments to mitigate the effects of climate change in the modelling process.

When these impacts are taken into account, one or more "damage" functions (which, for example, make it possible to link higher temperatures and economic losses) are usually applied. However, these damage functions are difficult to use and subject to very high uncertainty. On the one hand, theoretical knowledge about their formulation remains limited to date and, on the other hand, the lack of historical data complicates their calibration. As things stand, when damage functions are used in an integrated assessment model, these functions and their parameters are defined relatively arbitrarily by the modeller.

Fourth observation: control of the rebound effect is only marginally or not at all taken into account in most models.

This complex phenomenon, which at least partially wipes out the gains associated with energy efficiency improvements (see Box 10: The rebound effect, p. 59), remains very marginal in the models, particularly in its indirect form. In most cases, this is related to the structure of the models themselves.

When taken into account, the phenomenon is generally controlled in the form of an additional carbon tax aimed at raising fuel prices (especially when they fall with demand).

The fact that the rebound effect is not incorporated into the models leads to an overestimate of energy savings, and thus an underestimate of energy demand.

We can draw two conclusions from the above:

1. **by design, the models cannot truly represent the disorder that may reign in energy/climate issue management (no climate feedback, balanced system, etc.);**
2. **the results produced by the models, which are inevitably approximate, should be interpreted according to the nature of the model (the need for which it was created, the modelling and resolution paradigms on which it is based). More transparency and guidance from the modelling community could lead to a better interpretation of the results by uninitiated users.**

e — The impact of climate change and the "physical limits" are poorly taken into account

Most of the scenarios studied describe futures that are not marked by climate change.

Among other things, this means that for all the scenarios studied, the "physical" consequences of climate change on the economic system are not taken into account, either in the narrative or in the input assumptions.

This is most notably the case for the baseline scenarios in each family. By design, they do not envisage any specific

Box 20: Encouraging discussion between companies and scenario authors

The results of the survey conducted among the AFEP business panel (see Box 14: The public energy/climate scenarios in French companies today, p. 67), indicate that **a very large portion of them (88%) believe that they need several scenarios with contrasted assumptions** for scenario analysis.

The companies surveyed consider that all categories of assumptions should be more diversified, with the exception of demographic assumptions (the evolution of which is more inertial).

Almost three-quarters of the companies on the panel are in favour of establishing a dialogue with scenario authors.

Figure 34: Percentage of companies on the panel that believe the considered assumptions should be more diversified.

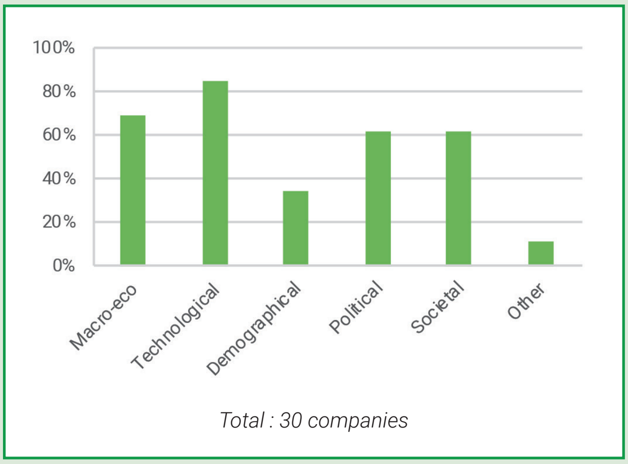


Figure 33: Percentage of companies on the panel that believe the scenarios they use (or could use) should include contrasted sets of assumptions.

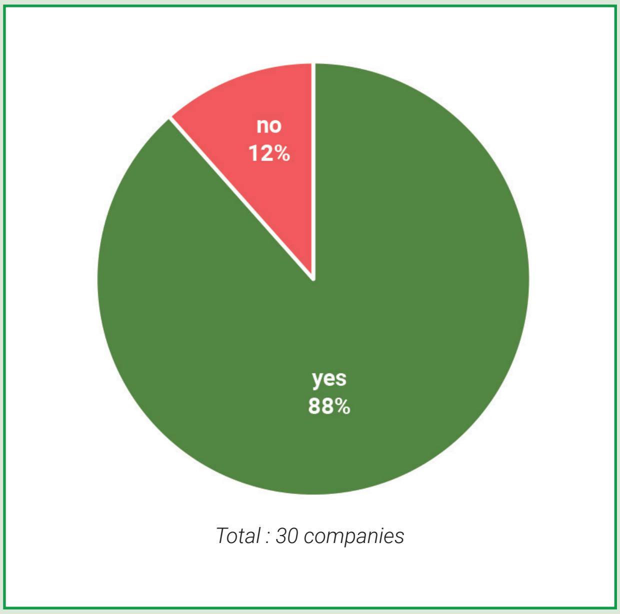
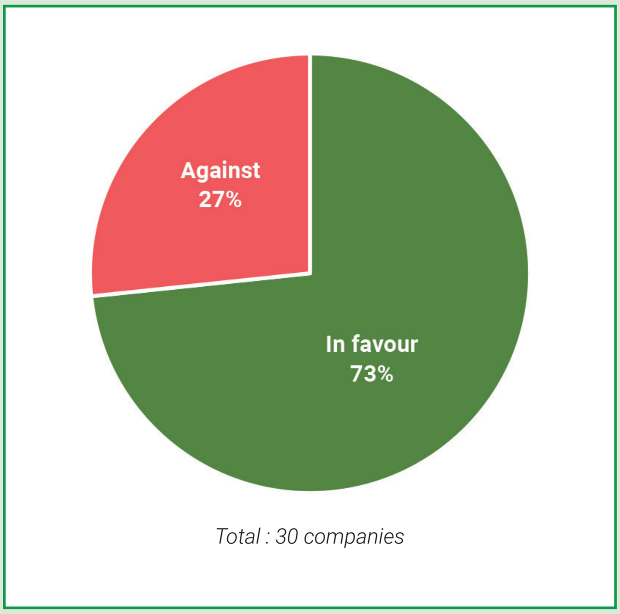


Figure 35: Percentage of companies on the panel in favour of or against dialogue with scenario authors.



action to significantly reduce CO_2 emissions, which in the future reach very high levels and consequently lead to global warming well above 2°C. While the repercussions of such warming on the socio-economic system could be very significant, they are not taken into account in the input assumptions of these scenarios.

For example, the narratives of the *SSP scenarios*, which are common to the baseline and transition scenarios, describe several futures in which societies are structurally prepared, to varying degrees, to address the adaptation challenges, but do not mention the physical consequences of climate change (Riahi, 2016). The *CPS scenario*, the baseline scenario of the *World Energy Outlook*, does not take into account adaptation issues or their consequences on the stability of the economic system, even though the CO_2 emissions trajectory it describes could lead to a warming well above 3°C.

Once again, this situation is linked to the reasons why these scenarios were developed in the first place.

It also applies to all the 2°C scenarios, even though changes to the climate will be significant at this level of temperature increase.

The availability of energy sources and raw materials needed to meet a general increase in demand for goods and services and the energy transition are rarely mentioned in most of the scenarios studied.

The reduction in CO_2 emissions envisaged in all transition scenarios requires a gradual fall in the share of hydrocarbons in the primary energy mix. The availability of hydrocarbon reserves in such a transition is not questioned by the scriptwriters, except to a certain extent by the IEA and the oil groups. It would be plausible to assume that this transition will occur faster ("*peak demand*") than a decline (inevitable in the long term) in world hydrocarbon production ("*peak oil*"), but it is a hypothesis that merits careful and detailed consideration[115].

Some scenarios (*SSP5-2.6* and *SR15-P4*) project significantly increasing world oil production until 2040, with a peak at more than 150 million barrels per day (respectively 165 MMbpd for SSP5-2.6 in 2040, and up to 150 MMbpd in 2030 for SR15-P4). These production levels should be compared with the level and real growth rate of this production (~ 90 Mbpd, ~ +1%/year between 2005 and 2015[116]).

115 - For information, see "Is investment in fossil fuel supply out of step with consumption trends?", summary for decision-makers in the 2018 World Energy Outlook (p. 28), IEA (2018).
116 - See IEA Statistics – Oil Total primary energy supply.

Moreover, while most scenarios project widespread electrification of energy uses, potentially consuming high volumes of relatively rare materials (see Part 8.B.1.c, p. 61), very few of them raise the issue of the availability of adequate material stocks to meet the projected demand.

C

What future for the public energy/ climate scenarios?

The IEA scenarios, among the most frequently used by economic operators, will evolve.

The IEA informed the authors of this report that the ETP scenarios will no longer be published in the same format, and in the future will focus on specific sector-based and technological analyses (energy system developments, carbon capture and storage, engine efficiency, new materials, etc.). While the 2DS scenario is now widely used by many organisations (mainly because of the level of detail it contains), the IEA indicated that the WEO SDS scenario will now be the benchmark for a low-carbon scenario. In the future, the level of detail in this scenario could be similar to the current 2DS scenario.

The large AFEP member companies are in favour of establishing a more in-depth dialogue with scenario authors to encourage the development of scenarios that match their requirements more closely, both in terms of narratives, assumptions and data produced (see below).

Given the difficulties encountered by companies in using public energy/climate scenarios, several stakeholders would like to see the development of shared "macro-scenarios" that could be used directly or help the various users in building their own scenarios.

In its second report evaluating the implementation of its recommendations[117], the TCFD devotes a long chapter to scenario analysis and notes that:

117 - See TCFD 2019 Status Report (June 2019).

"Many existing scenarios, such as those developed by the IEA and IPCC, are largely intended for policy and research purposes; they do not lend themselves easily to business-specific applications in different sectors."

Such findings were also made by the companies participating in the joint TCFD and Bank of England conference in November 2017.

Several financial and non-financial stakeholders thus support the development and use of macro-scenarios (*standard scenarios*) in which certain assumptions (socio-economic, political and institutional, or technical) would be shared and from which "sub-scenarios" could be derived, adapted to each stakeholder (or sector)[118].

The TCFD identifies this issue as critical for the deployment of scenario analysis and indicates that it could devote part of its future work to the development of energy/climate scenarios adapted to corporate use[119].

Financial regulators and banking regulators in particular also suggest developing macro-scenarios used by financial operators (see Part 10.A, p. 107).

However, given their visibility among economic operators (see Box 14: The public energy/climate scenarios in French companies today, p. 67 and the previous paragraph), the authority from which the IEA benefits on these topics, and the expertise and resources at its disposal, the scenarios that the agency produces could become the benchmark macro-scenarios used by economic operators (see Part 10.C, p. 110).

The development of macro-scenarios should be considered in relation to the need for comparability of information published by companies (see Part 10.B, p. 109).

118 - See for example the summary of the TCFD-BoE conference (November 2017): "Possibly establishing a process to agree on (a range of) 'anchor scenarios', i.e. scenarios that are internally consistent and have relevant and highly transparent assumptions (on technology, policy and socio-economic developments). Firms could then use these anchor scenarios to explain how their own scenarios differ, improving comparability"; or the last TCFD evaluation report (May 2019): "Furthermore, several survey respondents (both preparers and users) indicated that the use of 'standard' scenarios would be beneficial".

119 - See the TCFD evaluation report (May 2019): "To promote greater adoption of climate-related scenario analysis by companies, the Task Force is considering additional work in the following two areas: additional process guidance around how to introduce and conduct climate-related scenario analysis and business-relevant and accessible scenarios. [...] More business-relevant scenarios may spur additional adoption of scenario analysis by lowering implementation costs, improving understanding, and furthering comparability".

D

How to use public energy/climate scenarios at this stage?

1 Suggested procedure

Public energy/climate scenarios remain a relevant resource for companies to use when assessing the resilience of their business model in the context of energy/climate issues. However, for many companies, this type of use remains a challenge as these scenarios can appear far removed from their activity (see Box 14: The public energy/climate scenarios in French companies today, p. 67).

For a company, evaluating the resilience of its business model and strategy based on public energy/climate scenarios means projecting its business plan into the future described by those scenarios.

In practice, this means outsourcing work to model how its business plan will evolve, which can be relatively complex and draws on interacting variables. Outsourcing this work also means subscribing to the narrative and set of assumptions chosen by the selected scenario author.

The procedure suggested below can be applied to all companies. It is split into three stages. An example application is provided in Part 8.D.2 (p. 91).

Stage 1: Identify the critical variables for the company in the context of energy/climate mitigation and adaptation issues.

This stage, already discussed in Chapter 4 and Chapter 5, means identifying the main critical variables that shape the resilience of the company's activities and markets to the transformations induced by climate change and the low-carbon transition.

Once this stage has been completed, the company will have identified its main critical variables in the context of energy/climate issues.

Stage 2: Analyse trends in the company's main critical variables under transition scenarios that describe this development.

Among the qualitative and quantitative information described in the public energy/climate scenarios, companies may find some of the variables critical to its business plan previously identified, by market and geographical area.

The first step in this stage is thus to identify the families of energy/climate scenarios that describe the greatest number of critical variables for the company, matching its sectoral and geographic resolution as closely as possible. An assessment of the overall consistency of the identified scenarios can then be carried out.

Finally, the company should analyse how the critical variables described in these scenarios evolve, to identify how its activities may be affected in the future described by the scenario, and how the demand for its products and services could evolve (see Box 8: Air Liquide, p. 52).

In order to cover the widest possible spectrum, at least three scenarios should be used, each leading to a specific increase in global temperature: a <2°C scenario (strong transition); a "medium warming" scenario (limited transition) and a "strong warming" scenario (no transition). Each of these scenarios could come from the same family of scenarios, or from different families.

Lastly, the company should identify the qualitative and quantitative information that the selected scenarios may include and that may be useful for the analysis (narrative, context).

Once this stage is completed, the company will have:
- **identified the families of energy/climate scenarios that describe the trends for its main critical variables in the context of transition energy/climate issues;**
- **assessed the overall consistency of the scenarios that make up those families;**
- **selected three transition scenarios, each describing a different future and leading to a different increase in global temperature;**
- **envisaged how its activities and the demand for its products and services could be affected by the transition energy/climate issues.**

Stage 3: Analyse the trends for the company's main critical variables under the transition scenarios that describe this development.

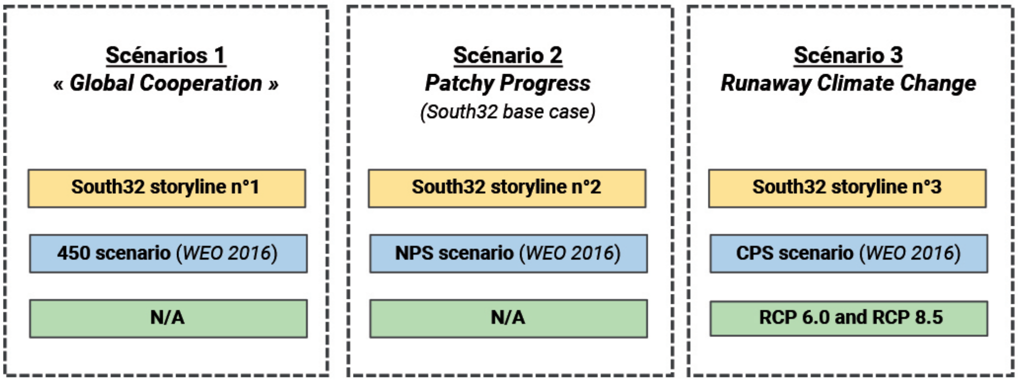
Public energy-climate scenarios focus on transition issues. They do not integrate the physical consequences of climate change. Their analysis does not therefore help us make sense of these fundamental issues for the future of companies' activities.

Nonetheless, each of the transition scenarios selected in stage 2 projects a CO_2 emissions pathway leading to a specific temperature increase. It is thus possible to reconcile these pathways with those described in the RCPs.

Type of transition scenario	Cumulative CO_2 emissions in 2050 (transition scenario)	Corresponding RCP
2°C or <2°C transition scenarios (strong transition)	~ 1000 $GtCO_2$	RCP 2.6
>2°C transition scenarios (limited transition)	~ 1500 $GtCO_2$	RCP 4.5 or RCP 6.0
Scenarios for transition much higher than 2°C (no transition)	~ 2000 $GtCO_2$	RCP 8.5

The company can use this match to measure how vulnerable its activities are to different climate phenomena up to 2050, depending on their location (using the various studies that deal with the impact of climate change according to a certain level of radiative forcing, including those from IPCC Working Groups 1 and 2)[120].

120 - The TCFD discusses these aspects in the Technical Supplement to its final report (Appendix 1, Part 2 "Physical scenarios").



Most notably, the sensitivity of the company's activities to the following phenomena may be analysed:

- increase in the intensity and frequency of heatwaves;
- increase in the duration and frequency of drought;
- increased rainfall and flooding;
- rising sea level (including coastal erosion and submergence);
- increase in the intensity and frequency of extreme weather events.

Once this stage is completed, the company will have:
- **identified, for each transition scenario it selected, the associated RCP;**
- **identified the phenomena brought about by climate change to which its activities and the demand for its products and services are vulnerable;**
- **looked at how the phenomena will evolve in the future, and how its activities and the demand for its products and services could be affected.**

2 Case study: Scenario analysis process deployed by the company South32

In its second evaluation report, the TCFD provides several examples of good practise by businesses (BHP, Oil Search, Rio Tinto, Unilever, OP Trust, BlueScope Steel Ltd.) that implement scenario analysis. The reader can refer to this and possibly draw inspiration from it. The process implemented by South32, described in Box 21: South32 below, is another example of what can be done.

In 2018, South32 (see Box 7, p. 51) published a "climate report" in which it described its scenario analysis process. The company analyses the resilience of its business model to energy/climate mitigation and adaptation issues based on three scenarios.

Each of these scenarios is composed of quantitative elements from a transitional energy/climate scenario and, in one case, elements from "climate" scenarios. The scenarios also include a narrative specific to the company's activities and consistent with the aforementioned elements.

- Scenarios 1 and 2 describe a relatively marked transition, but do not include any physical consequences of climate change, at least up to 2040.
- Scenario 3 describes a future marked by climate change in which no transition policy is pursued.

These scenarios are deliberately extreme in order to clearly emphasise the particularities of the futures considered. Scenario 2 – *Patchy Progress* – is used as the base case in this analysis.

a —— Transition risk analysis

For this purpose, South32 uses the scenario in which these risks are most marked, i.e. scenario 1 – *Global Cooperation* – and follows four steps:

- **Step 1: identification of the company's main critical variables with regard to transition issues**

"Our methodology is built around the existing valuation models and scenario-based analysis used in our strategic planning process. This considers ***major variables such as the outlook for commodities, the development of technology, the needs of societies, consumer behavior***

and the ability of the environment to continue providing the natural resources and ecosystem services that we and the world need to continue to thrive" (p.29).

- **Step 2: qualitative evaluation of changes in these variables in the scenario**

"As a first step in evaluating comparative portfolio resilience, we applied the main supply and demand drivers to our existing global commodity models to determine whether the commodity would be advantaged or disadvantaged by the rapid transition involved, relative to the base case. This was a ***qualitative step to frame the subsequent company-specific assessment."*** (p.29).

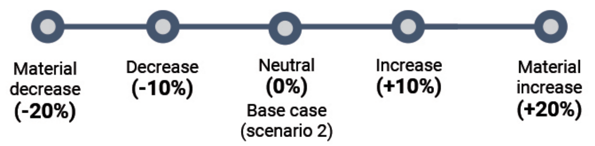
- **Step 3: quantitative evaluation of changes in these variables in the scenario**

"We then undertook a quantitative analysis to assess the scale of this directional impact on South32's specific products and operations. This included factoring in relative demand for our products compared to competitors (e.g. based on chemical composition and supply location) and our position on the cost curve for each of our unique value chains" (p29)

- **Step 4: evaluation of resilience of demand for the company's products.**

"[We] use a fit-for-purpose resilience metric (Figure 4), which focused on the demand for each commodity from each operation in our portfolio. ***Resilience was determined by a quantitative assessment of whether the supply and demand balance increased or decreased*** *(ten per cent either way) or materially increased or decreased (20 per cent either way), relative to our base case forecasts out to 2040."*

Figure 36: Scale of resilience of demand for South32 products to transition risks.



Source : South32 Climate change report (2018)

Figure 37: Assessment of the trend in demand for lead from the Cannington production site (Queensland, Australia) in the "Global cooperation" scenario, compared to the base case (Patchy Progress).

Source : South32 Climate change report (2018)

A more detailed analysis of the change in demand for the main commodities most at risk has also been published.

b — Physical risk analysis

For this purpose, South32 uses the scenario in which these risks are most marked, i.e. scenario 3 – *Runaway Climate Change* – and follows three steps:

- **Step 1: selecting the climate scenario that best corresponds to the transition scenario and identifying "climate stress factors"**

"Our methodology is built around Australian climate data projections that are aligned with the Runaway Climate Change scenario, and were largely sourced from the Mining Climate Assessment (MiCA) tool [based on latest IPCC AR5 climate projections data] available through the International Council on Mining and Metals (ICMM) database (using 2035 as a proxy for 2040) and CSIRO (using 2030 and 2050 projections to cross-check *MiCA data). [...]* ***projections were developed for several key measures (for example temperature increase, precipitation etc.) at the locations of each operation****, which will plausibly be operated/ managed by South32 through to 2040, based on their reserve lives and post closure rehabilitation activities."*

- **Step 2: identifying critical variables and vulnerabilities of the company's activities to physical risks**

"Each operation was considered separately, and resilience was assessed across three key impact categories: ***asset integrity and production continuity, maintaining supply chain and logistics, and worker health.*** *A total of 14 drivers were considered to give a range of possible outcomes to 2040".*

- **Step 3: evaluating the resilience of the company's activities at the various production sites**

«Resilience [5 levels from very low to very high resilience] was assessed [...] considering:
> Exposure: A rating of exposure to acute and chronic physical climate change projected for an operation's location
> Sensitivity: A rating to reflect financial or other critical impacts that consider existing operational design, infrastructure and supply chain factors
> Adaptive Capacity: A rating to reflect an operation's capacity to adapt to avoid the critical impacts, based on an understanding of availability, current technology or other adaptation options
The results indicate where we may need to reprioritise our attention on designing and planning for resilience and will form an input into our ongoing planning process as we assess signposts for realising this or other scenarios."

Figure 38: Example of physical risk assessment for the Worsley alumina production site (Australia).

Climate stressor	Examples of impacts considered for all South32 operations	Relative assessment of resilience in 2040 *Runaway Climate change* scenario – Worsley Alumina (Australia)
Changes in extreme weather patterns	Containment failure in dams following intense rainfall	Moderate resilience
	Containment failure in facilities following intense rainfall	High resilience
	River flooding affects mine and processing operations	High resilience
	Cyclones or storms affect port and rail operations	Moderate resilience
Warmer temperatures and lower rainfall	Bushfires affect operations	Moderate resilience
	More dust created by our mining and processing activities	Low resilience
	Droughts affect water supply to operations	Low resilience

Impact category key

Asset integrity and production continuity: Impacts which could directly affect the operation's capacity to operate safely and maintain planned production levels (e.g. direct damage from severe storms, flooding from intense rainfall events, productivity decline from increasing dust creation).

Maintaining supply chain and logistics: Impacts which could materially affect access to critical inputs and delivery of products to key locations (e.g. storms affecting port and rail integrity, drought affecting hydroelectric power supply, heat interrupting flight operations).

Worker health: Impacts on the health and safety of our employees (e.g. heat-related illness, increased malaria risk due to regional climate changes).

Resilience key

High resilience has been attributed where, under this scenario, our operations have been assessed as unlikely to be impacted in 2040 for this driver.

Moderate resilience has been attributed where, under this scenario, our operations have been assessed as may be impacted in 2040 for this driver.

Low resilience has been attributed where, under this scenario, our operations have been assessed as likely to be impacted in 2040 for this driver.

Source : South32 Climate change report (2018)

9 Disclosing information on scenario analysis outside the organisation

For companies, reporting on financial elements related to climate is structured according to TCFD recommendations, particularly where scenario analysis is concerned.

In addition, companies are increasingly asked whether they are aligned with a "2°C limit" – or even a "1.5°C limit" – approach. Today, certain companies – keen to boost their reputations – are tempted to communicate publicly on this matter but have not yet completed any in-depth work.

Disclosing information outside the company prematurely creates a risk for those companies. Beyond the danger of legal action, it can lead the company directors to think that they have already dealt with the energy/climate issues even though they have not yet been added to their company's core strategy.

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A

Analysis of long-term corporate strategies could structure corporate reporting

1 TCFD recommendation on scenario analysis

In its final report published in June 2017, the TCFD put forward eleven recommendations. One of them – Recommendation (c) in the strategy component – concerns "*the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario*". This comes with a recommendation to disclose information.

This disclosure recommendation differs depending on the type of company (financial or otherwise), its business sector (exposed[121] or not) and the level of its revenues (more or less than $1 billion).

> *« For an organization in the initial stages of implementing scenario analysis or* ***with limited exposure to climate-related issues****, the Task Force recommends disclosing how resilient, qualitatively or directionally, the organization's strategy and financial plans may be to a range of relevant climate change scenarios. […].*
>
> *Organizations* ***with more significant exposure to climate-related issues*** *should consider disclosing key assumptions and pathways related to the scenarios they use to allow users to understand the analytical process and its limitations. In particular, it is important to understand the critical parameters and assumptions that materially affect the conclusions drawn […]. »*

Hence, for non-financial companies in exposed sectors, the disclosure recommendations are very specific[122]:

> *« For the climate-related scenarios used, organizations should consider providing information on the following factors to allow investors and others to understand how conclusions were drawn from scenario analysis:*
> - *Critical input parameters, assumptions, and analytical choices for the climate related scenarios used, particularly as they relate to key areas such as policy assumptions, energy deployment pathways, technology pathways, and related timing assumptions.*
> - *Potential qualitative or* ***quantitative financial implications*** *of the climate-related scenarios, if any. »*

Most climate information reporting frameworks now refer to the TCFD recommendation, particularly with regard to scenario analysis.

Since the work of the TCFD, many initiatives have been launched to structure and standardise corporate climate reporting.

One example from public regulators is the work done by the European Commission following the March 2018 Action Plan (see Part 9.A.2, p. 96).

Other regulator actions worthy of note include:
- the *European Financial Reporting Advisory Group* (EFRAG) working group on corporate climate reporting, including a sub-group on scenario analysis;
- the work of the *UK Prudential Regulatory Authority* (PRA), which calls on banks and insurers to carry out scenario analysis following the TCFD's recommendation (see Part 10.A, p. 107);
- the work of the *Network for Greening the Financial System* (NGFS), (see Part 10.A, p. 107) which encourages listed companies to apply TCFD recommendations.

In addition, several non-governmental organisations involved in reporting processes have published studies and launched initiatives to promote the alignment of the various reporting frameworks in existence with TCFD recommendations, including:
- alignment of the CDP Climate Change questionnaire with TCFD recommendations since 2018;
- the *"Better Alignment Project*[123]*"* introduced by the Corporate Reporting Dialogue (CRD) in November 2018. This project, initiated by the *International Integrated Reporting Council* (IIRC), *CDP*, the *Climate Disclosure Standard*

121 - For non-financial companies, the exposed sectors are: the energy industry (power generation; exploration, hydrocarbon production), goods and passenger transport industry (air, road, sea, rail, equipment manufacturers), heavy industry (construction materials, metal mining and production, heavy chemicals, buildings, capital goods) and the agri-food and forestry industry. See TCFD final report (2017).

122 - See TCFD final report appendix "Implementing the Recommendations of the Task Force on Climate related Financial Disclosures".
123 - See the project website.

Board[124] (CDSB), the *Global Reporting Initiative* (GRI) and the *Sustainability Accounting Standards Board* (SASB), aims to establish links between the reporting frameworks of these organisations and the TCFD recommendations and to encourage the standardisation of the climate indicators used;
- the publication of a guide for the implementation of TCFD recommendations by the CDSB and SASB[125].

These are just a few examples. This list is not exhaustive and not all the examples relate specifically to scenario analysis. However, they reflect the momentum around the TCFD recommendations and their use.

2 Revision of the European Directive on the disclosure of non-financial information

Following the European Commission's Action Plan, the revision of the European Commission's guidelines on non-financial reporting includes a "climate" component that takes on board the TCFD recommendations on scenario analysis.

In March 2018, the European Commission published its Action Plan[126] setting out a comprehensive strategy to promote the integration of sustainability and durability issues into the European financial system. The objectives set by the European Commission are divided into ten actions. In Action 9.2, the Commission commits to revising the *Non-Binding Guidelines* (NBGs[127]) of the *Non-Financial Reporting Directive* (NFRD[128]) governing the disclosure of environmental, social and governance-related information. More specifically, Action 9.2 states that the Commission will update the NBGs to "*provide further guidance to companies on how to disclose climate-related information, in line with the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD) and the climate-related metrics developed under the new classification system (see Action 1)*[129]".

Following this Action Plan, the Technical Expert Group on Sustainable Finance (TEG), mandated by the Commission to make proposals, published its final report on climate-related disclosures in January 2019[130].

In this report, the TEG endorsed the TCFD recommendation on scenario analysis:

> *« Scenario analysis is a tool that can be applied to help understand the potential implications of climate change and the resilience of companies to those implications ("strategic resilience"). [...] Given the importance of forward-looking assessments of climate-related risk, scenario analysis is an important and useful tool for a company to use, both for understanding strategic implications of climate-related risks and opportunities and for informing stakeholders about how the company is positioning itself in light of these risks and opportunities ».*

The segmentation of disclosure recommendations set out in the TEG report differs slightly from that proposed by the TCFD. It reiterates the five categories already mentioned in the Non-Binding Guidelines published in 2017, i.e. *Business Model/Policies and Due Diligence Processes/Outcomes/ Principal Risks and their Management/Key Performance Indicators*.

It also distinguishes three types of information corresponding to three levels of disclosure:
- **Type 1:** information that companies *should* disclose ("*high expectation that all reporting companies disclose them*[131]");
- **Type 2:** information that companies *should consider* disclosing ("*expected of companies with significant exposure to climate-related risks and opportunities*[132]");
- **Type 3:** information that companies *may consider* disclosing ("additional or innovative disclosures that provide more enhanced information").

124 - See the CDSB website.
125 - See "TCFD Implementation Guide", SASB and CDSB (2019).
126 - European Commission Action Plan of 8 March 2018.
127 - European Commission, Guidelines on non-financial reporting.
128 - Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial information. In particular, this directive requires "large public-interest entities with more than 500 employees (publicly traded companies, banks and insurance companies) to disclose certain non-financial information".
129 - The scope covered by the NBGs and the NFRD goes beyond that covered by the TCFD (exclusively climate issues), but gives climate issues high priority.

130 - "Report on Climate-related Disclosures", European Commission Expert Group, January 2019.
131 - "The 'general disclosures' (Type 1) refer to information that companies should disclose. At a minimum, a company is expected to report certain disclosures, irrespective of the companies' own assessment." Report on Climate-related Disclosures, European Commission Expert Group, January 2019.
132 - "The 'supplementary disclosures' (Type 2) refer to information that companies should consider reporting on and depend on the company's own assessment of impacts of climate change on its business and of its activity on climate change, carried out autonomously and in consultation with stakeholders. They also depend on the company's exposure to climate-related risks and opportunities as well as maturity vis-à-vis climate change and allow for further development of climate knowledge in the future." Report on Climate-related Disclosures, European Commission Expert Group, January 2019.

Based on this work, the European Commission published the "Guidelines on reporting climate-related information" on 18 June 2019, including how these guidelines correspond to the TCFD recommendations.

Following the publication of the TEG report in January 2019, the Commission ran a public consultation with various stakeholders and, in June 2019, published the "*Guidelines on reporting climate-related information*[133]".

The guidelines published remove the notion of "type of information[134]" and incorporate the five categories mentioned by the TEG (see paragraph above).

More specifically, the "*business model*" category, with "*the description of the company's business model in order to establish a clear link between its activities and climate change*[135]":

> *"Describe the ways in which the company's business model can impact the climate, both positively and negatively.*
> *Describe the resilience of the company's business model and strategy, taking into consideration* ***different climate related scenarios*** *over different time horizons, including at least a 2°C or lower scenario and a greater than 2ºC scenario.* ***[Covers TCFD recommendation Strategy c)]"***

In this document, the European Commission builds on the TCFD recommendations, putting further pressure on companies to assess the resilience of their business model under several scenarios. However, we can see that companies are given greater freedom, particularly with regard to the quantified assessment of the (financial) impacts of energy/climate-related transformations on the company.

Although they are not mandatory at this stage, reporting frameworks, most of which are based on TCFD work, have gradually become more structured and are becoming more harmonised. It is expected that an increasing number of operators, especially regulators (see Part 10.A p.107), will increasingly take them on board and comply with them.

133 - See "Guidelines on reporting climate-related information", European Commission (June 2019). The new guidelines complement the general non-binding guidelines on non-financial reporting adopted by the Commission in 2017, which remain fully applicable.
134 - Considering the January 2019 TEG report, while the inclusion of information relating to TCFD's Strategy Recommendation (c) in type 1 or type 2 was under discussion, the document published by the Commission settles the debate. See "Consultation document on the update of the non-binding guidelines on non-financial reporting" European Commission (March 2019).
135 - "The company should describe its business model in a way that clearly relates its activities to climate change. In describing the effects of climate-related issues on their business model, companies should include consistent and historical disclosures of the following aspects: Describe the significance of climate-related issues for the business model and how strategies might change to address such potential risks (including transition risks and physical risks) and opportunities." Report on Climate-related Disclosures, European Commission Expert Group, January 2019.

Figure 39: Mapping of European Commission NFRD Requirements and TCFD Recommended Disclosures.

			NFRD Elements				
			Business Model	**Policies and Due diligence Processes**	**Outcomes**	**Principal risks and their mgmt.**	**Key performance indicators**
TCFD Recommendations	**Governance**	a/ Board's oversight		●			
		b/ Management's role		●			
	Strategy	a/ Climate-related risks & opportunities				●	
		b/ Impact of climate-related risks & opportunities	●				
		c/ Resilience of the organisation's strategy	●				
	Risks mgmt.	a/ Processes for identifying and assessing				●	
		b/ Processes for managing				●	
		c/ Integration into overall risk management				●	
	Metrics & Targets	a/ Metrics used to assess					●
		b/ GHG emissions			●		
		c/ Targets			●		

Source: European Commission (2019).

B

Companies are asked about their 2°C and 1.5°C alignment

1 A strategic interpretation

An economic operator can be said to be "aligned on **a** 2°C trajectory" if the business model and the strategy it deploys remain robust and efficient throughout **a** process of profound reorganisation of the economic system, in line with the 2°C target.

There are a large number of possible and consistent pathways to the 2°C goal. Each one is influenced to a greater or lesser degree by underlying drivers (demographic, behavioural, political, technical, etc.).

Consistent with this definition, aligning with one (or more) 2°C trajectory(-ies) means conducting scenario-based foresight analysis to answer the following question: "*in the case of a profound transition of the economic system in line with the 2°C target, will my company's business model remain efficient and robust*?". **First and foremost, this is an internal strategic exercise that is intrinsically complex; its application to the climate issue is relatively recent.**

2 A communication resource?

The alignment of a company's strategy on a 2°C trajectory is an indicator that is gradually establishing itself, but does not indicate its "strategic" acceptation.

The financial sphere's rallying around the "climate" issue has noticeably gathered pace since the signing of the Paris Agreement in 2015 and Mark Carney[136]'s speech. As a result, many financial actors are taking a keen interest in the "2°C alignment" of companies and their action to tackle climate change.

In line with this trend, the need to decipher (or justify) a company's 2°C alignment in a **simple and comparable manner** has resulted in a different definition of this concept.

Given that it can be quantified relatively well, the (projected) volume of GHG emissions has emerged as the go-to parameter most often used to determine whether or not an economic operator is aligned on a 2°C trajectory.

An economic operator is said to be "aligned on **a** 2°C trajectory" when the level of effort made and/or envisaged by that operator to reduce its GHG emissions is compatible with **the** (global) 2°C trajectory considered, according to its business sector and geographical area (among other factors). In other words, an actor is aligned on a 2°C trajectory if it complies with the share of the carbon budget it is allocated in accordance with the 2°C (global) trajectory considered.

While this may be a virtuous and, in some respects, relevant exercise, it has its limitations:

1. it qualifies (in the sense defined above) alignment according to a single (and potentially questionable) trajectory;
2. it does not help us understand the energy/climate-related transformations that will affect the company's environment;
3. it can be carried out without first completing real in-depth analysis such as scenario-based foresight analysis.

This approach, adopted by a growing number of stakeholders, has somewhat skewed the initial strategic approach, reversing the logical process that would require strategic analysis to be completed before the communication phase.

136 - Carney, M. (2015) "Breaking the Tragedy of the Horizon – climate change and financial stability", Speech by Mark Carney, Governor of the Bank of England and Chairman of the Financial Stability Board, Lloyd's of London, 29 September 2015.

C

How does a company communicate on in-house scenario analysis?

1 Review of the disclosure of information on scenario analysis

Few companies conduct scenario-based analysis to assess the resilience of their business model then disclose the related information.

Several studies indicate that disclosure of information on scenario analysis conducted by companies remains very limited today.

Take, for example, the study run by I4CE in partnership with CDP in February 2019[137]. Out of more than 2,000 companies that responded to the CDP Climate Change questionnaire:

- only 5% of them implement scenario analysis to assess the resilience of their business model in the context of energy-climate issues;
- half of them are from the energy sector;
- more than half of them are based in Europe.

The study also notes that there is still some confusion about conducting scenario analysis for many companies.

Likewise the TCFD's survey of 200 (non-financial and financial) companies, conducted for its second evaluation[138] report:

- 110 of the companies state that they carry out scenario analysis (57% non-financial, including two thirds of companies in the energy, raw materials production and industry sectors; 43% financial, half of which are banks);
- Of these 110 companies, only 46 disclose information on the resilience of their business model according to energy/climate scenarios.

The reasons for this phenomenon include a lack of methodological recommendations and unsuitable

137 - See Carbon Brief no. 61: "Very few companies make good use of scenarios to anticipate their climate-constrained future", I4CE (2019).
138 - See TCFD 2019 Status Report (June 2019).

external scenarios (see Box 14: The public energy/climate scenarios in French companies today, p. 67).

While most companies support the TCFD's recommendations, some consider that disclosure of information on the resilience of their business model under one or more scenarios can be difficult.

Recommendation (c) of the TCFD Strategy component prompted a number of reactions when it was first published. In its contribution[139] to the public consultation preceding the publication of the TCFD's final report, IHS Markit made several comments on the issues relating to investors' interpretation of information disclosed by companies. For example, IHS Markit points out that this information could trigger confusion for several reasons:

- companies may use different scenarios, with different assumptions, making any comparison difficult;
- some companies that enjoy competitive advantages in some low-carbon futures may prefer to keep this confidential; others may conduct optimistic analyses and be wrongly perceived as low-risk;
- companies that address energy/climate issues could be considered more at risk, whether this is justified or not.

IHS Markit concluded that investors could be misled by the disclosure of information on long-term financial impacts identified in a scenario analysis and disclosed in annual reports; it recommended that this aspect not be mentioned in the TCFD's final report (which was partially the case).

In a statement published in October 2018, the *Association française des entreprises privées* (AFEP) also points out the risks of corporate stakeholders misinterpreting the information disclosed in reference to approaches that continue to be applied in a very diverse manner:

> *« Considering that the recommendations on climate scenarios are still debated, given the high uncertainty of assumptions and risks of misinterpretation by potential users in case of* ***heterogenous approaches between competitors of the same sectors.****"*

The responses to the consultation launched by the European Commission as part of the *NFRD*[140] review (see Part 9.A.2, p. 96) also suggest a certain reluctance on the part of companies to disclose information on the resilience of their business model.

> *"Some respondents welcomed the proposed business model disclosures, and there were a number of suggestions to move some of the Type 2 disclosures to Type 1. Some respondents argued that the number of proposed disclosures was too high and recalled that the NFRD requires a "brief" description of the business model. A number of these respondents proposed that some* ***disclosures should be moved from Type 1 to Type 2****, or deleted entirely.*
>
> *There were a large number of comments about the proposed disclosures on resilience to different climate-change scenarios. Some respondents stressed the importance of this disclosure while others argued* ***that it was very challenging for companies****. There were several calls for further guidance on scenarios."*

2 Disclosing information on in-house scenario-based foresight analysis

Disclosing information on how a company deals with energy/climate issues before carrying out in-house scenario-based foresight analysis can defer adoption of energy/climate issues by company managers, delay their mobilisation or put them in difficulty.

Securing external and comprehensible legitimacy of a company's climate strategy – especially its "2°C alignment" approach – from its stakeholders (investors, financiers, shareholders, rating agencies, clients) and the public is now a key challenge for companies.

The financialisation of the economy, the development of information technologies and social media not only divert managers from forming a long-term vision, but also make it easier to mobilise these stakeholders, raise the possibility of a strong reputational risk for the company and trigger the need for reactive communication.

***"Is your strategy aligned on a 2°C trajectory?"* is therefore a question that stakeholders very often ask companies.**

The strategic exercise is complex and new for many companies, which does not simplify the disclosure of useful and accessible information by a company for its stakeholders. Meanwhile, the latter face difficulties when they need to compare the disclosed information (see Part 10.B, p. 109). Companies are thus sometimes tempted to

139 - See "Climate-Related Financial Risk and the Oil and Gas Sector", IHS Markit (May 2017).
140 - See "Summary Report of the Targeted Consultation on the Update of the Non-Binding Guidelines on Non-Financial Reporting (20 Feb-20 Mar 2019)", June 2019.

use normative 2°C alignment approaches.

When not based on scenario-based foresight analysis upstream, such approaches pose a risk. Without the necessary understanding of the potential changes in the company's corporate environment, constrained by the energy/climate issues, these approaches can only serve as a communication device, with limited strategic scope. They may even delay proper treatment of the energy/climate issues by managers by giving them the impression that they have already done the necessary.

Companies are exposed to reputational risk because of growing public sensitivity to energy/climate issues. Nonetheless, assessing the resilience of a company's business model in coherent scenarios that describe desirable or undesirable futures is an objective and rational approach.

Energy/climate issues are complex and can (legitimately) provoke significant anxiety among the public. Several companies say that disclosing information on the analysis of scenarios describing a future in which the objective of the Paris Agreement would not be achieved exposes them to significant reputational risk.

However, scenario-based foresight analysis is a rational and objective method that includes the observation of several futures, whether they are desirable (compliance with the objectives of the Paris Agreement, for example) or not (chaotic transition or high physical risk), in accordance with the main reporting frameworks and legislation in force.

This aspect should be emphasised more by the public authorities and the TCFD.

When a company has carried out in-house scenario-based foresight analysis, it can adapt the reporting framework proposed by the TCFD or the European Commission "Guidelines on non-financial reporting: Supplement on reporting climate-related information", published on 20 June 2019.

The purpose of conducting scenario-based foresight analysis is to meet a strategic requirement specific to the company, focused on its particular challenges and its environment. Whatever may be the approach (use of internal or external scenarios), it produces a certain number of deliverables (scenarios, new opportunities, action plans, etc.) for use by the company's management bodies.

Some – but not all – of the information contained in these deliverables may be disclosed externally.

Any (partial) disclosure of this information to the markets must comply with the regulations in force and the company's requirements with regard to its stakeholders.

The TCFD and the European Commission's revised guidelines on non-financial reporting to include climate (see Part 9.A.2, p. 96) provide a fairly flexible reporting framework. The company's disclosure of information on the assessment of its business model's resilience under several scenarios could fit into these frameworks without disclosing confidential strategic content or making inappropriate commitments.

The elements publishable by a company could include:

1. **a description of the scenario analysis process implemented by the company to assess the resilience of its business model to energy/climate mitigation (transition risks) and adaptation (physical risks) measures;**
2. **a summary of the narratives (including the main environmental factors) used or produced by the company;**
3. **the public energy/climate scenarios on which the analysis is based, if applicable;**
4. **at least a qualitative summary of the scenario analysis results;**
5. **how often the analysis is updated.**

Box 21: Disclosure of information in South32's climate report

A description of the scenario analysis process	Yes	p.23
A summary of the narratives	Yes	pp.24-26
The public energy/climate scenarios on which the analysis is based	Yes	pp.24-26
At least a qualitative summary of the scenario analysis results	Yes	pp.29-38
How often the analysis is updated	Yes	p.23

Source : South32 Climate change report (2018)

3 The Science Based Targets initiative (SBTi)

The Science Based Targets initiative (SBTi) has gradually established itself as a way of measuring the alignment of a company's objectives on a 2°C trajectory, and its approach is currently being updated to incorporate a 1.5°C trajectory.

a — Presentation of the SBTi

The ***Science Based Targets initiative*** **(SBTi)** was **founded in 2015** by the *CDP*, *WWF*, *WRI* and *UN Global Compact*. The initiative:

- defines and promotes best practises for setting "science-based" greenhouse gas emission reduction targets;
- assesses and approves companies' emission reduction targets;
- identifies and showcases companies that apply science-based reduction targets;
- offers a variety of resources to reduce barriers to the adoption of these targets.

Funding for *SBTi* is mainly provided by the *IKEA Foundation, We Mean Business* and the *UPS Foundation*. Additional financing also comes from other companies[141].

From October 2019, the *SBTi* will introduce a target validation fee of USD 4,950 to cover the increasing costs of the validation service.

By June 2019, more than 600 companies had committed to setting science-based emissions reduction targets within the next two years. 202 of those companies have already had their reduction targets validated by the *SBTi*.

Existing methods for setting targets

To set science-based targets to reduce GHG emissions, compatible with the Paris Agreement, a company must ensure that its particular emissions trajectory is consistent with an overall finite GHG emissions budget.

The Paris Agreement actually includes two targets: ideally, to limit global warming to 1.5°C and otherwise to stay well below 2°C. **From October 2019**, companies will need to respect this level of ambition at least (versus 2°C today).

141 - Nike, Target, ClimateWorks Foundation, C&A Corporation, Lenzing, The Bank of New York Mellon, Dutch Platform Carbon Accounting Financials, BMW, Daimler, Deutsche Post DHL, La Poste, Michelin, Renault, SNCF, Volvo.

The SBT initiative thus puts forward **three methods for calculating** "science-based" reduction[142] targets:

- **Absolute-based approach:** the percentage reduction in absolute emissions within a given time horizon is calculated. This is a "contraction" approach, where all companies must reduce their emissions by the same percentage, regardless of the sector/growth path;
- **Sector-based approach:** based on GHG budgets broken down by sector and incorporating technological options and business development prospects. This is a converging approach, where each sector is allocated a GHG emissions budget and then each company can determine its trajectory according to the specific pathway for its area of activity. This approach requires the development of sector-specific methods, which already exist for some sectors (*iron & steel, cement, aluminium, pulp & paper, power generation, service industry/commercial buildings, ground transport operators and vehicle manufacturers*) but still need developing for others;
- **Economic-based approach:** based on a global budget for GHG emissions and a global trajectory of economic activity. It is a "compression" approach, where companies must reduce the carbon intensity of their economic activity in line with the required overall reduction in carbon intensity. It is applicable only for objectives related to scope 3 of the company.

Costs involved

When a company wishes to have its CO_2 emissions reduction targets approved by the SBTi, there are three possibilities:

- **The company simply wants to have the objectives it has calculated in-house approved by the *SBTi***: this will be free-of-charge until September 2019; from October 2019 onwards, it will cost it USD 4,950;
- **The company needs support from a consulting firm to help it set its targets** (which may require calculation of the company's emissions beforehand followed by support with the actions to be taken to reach the targets): the company will need to engage a consultancy for this service, the cost of which will depend on the scope of the work required;

142 - For more details on all these approaches, the reader is invited to consult the following documents:
- *"Foundations of Science-based Target Setting" (April 2019) which describes the SBTi's framework of methodologies and the methods for evaluating the underlying scenarios.*
- *"Science-Based Target Setting Manual" (April 2019) which describes the steps in the target-setting process.*
Further information is also available on the SBTi website.

- **The company aims to work with other stakeholders in its sector to develop a sector-based method as no such methods currently exist:** an investment of €100-150k, potentially split between partner companies, may be required to engage a consulting firm for this task.

b —— *SBTi* analysis

The *SBTi* provides relevant resources as regards the TCFD framework and the recommendations in the "*Metrics and Targets*" component. However, it appears less suitable for the recommendations in the "*Strategy*" component (especially to analyse the resilience of a company's business model to the energy and climate issues).

The *SBT initiative* brings two positive contributions:

- It lets the company **calculate the right order of magnitude for its emissions reduction targets** to make sure that its efforts are compatible with the ambitions of the Paris Agreement. The risks of "greenwashing" are thus considerably reduced when using these calculation methods, which are external to the company, and by having the targets approved by an independent third party. It means that the company's response to Recommendation (c) of the "*Metrics and Targets*" component in the TCFD's recommended reporting framework (green in Figure 1) can be taken seriously;
- Because the initiative involves the entire company and requires the targets to be systematically approved at the most senior level, it can be an **effective way of raising awareness and mobilising people in-house** to reduce the company's GHG emissions. The issue is no longer consigned solely to the experts in the CSR/sustainable development department, because reaching the targets requires the involvement of every department/site in the company.

However, *SBTi* approval of the reduction targets does not provide the company with information on the resilience of its activities in a context where its environment is transformed by energy/climate issues, nor on the potential opportunities. For example, the *SBTi* does not help us understand changes in demand for products marketed by the company, or in its competitive and regulatory context. Nonetheless, these elements are necessary when assessing the resilience of its strategy, informing decisions made by the company's management and ultimately in responding to recommendation (c) in the TCFD's "*Strategy*" component.

The *SBTi's* "flagship" method, the *Sectoral Decarbonization Approach (SDA)*, is sector-based and establishes the carbon budget to be respected to limit the increase in temperatures to 2°C. It is based on a single scenario, certain assumptions of which are debatable.

This sector-based approach may be relevant, but breaking down cumulative emissions by sector according to a single decarbonisation trajectory comes with certain limitations (the 2DS scenario from the ETP 2017 study published by the IEA, see Box 16: The IEA scenarios, p. 70).

On the one hand, the method does not consider the numerous other plausible socio-economic pathways that could potentially lead to different reduction targets.

On the other hand, like all pathways, the one chosen is questionable in its substance, namely in its modelling approach (see Part 8.B.3.d, p. 84) and its input assumptions (see Part 8.B.3.c, p. 78). For example, this pathway implies widespread deployment of CCS (~5.4 $GtCO_2$ captured per year by 2060, i.e. an average deployment rate of these technologies of around 17%/year; see Part 8.B.3.c, p. 78). While there is no guarantee that these technologies will be deployed at the projected rate, basing the calculation of emissions reduction targets for all the world's companies on alignment with such a trajectory comes with the risk that these targets will be underestimated to produce emissions that comply with the goals set in the Paris Agreement.

Because they are designed to be adapted to each company, the *SBTi* methods are complex (with the exception of the absolute value approach).

The legitimate desire to integrate the company's specifics (business sector, initial carbon performance, desired business growth, etc.) has resulted in methods to calculate targets per sector, which require significant development time, yet the goal of setting an emissions reduction target of the **correct order of magnitude** for the chosen time horizon has not changed.

The challenge for a company is to understand how they can reach their target in an operational way and to what extent the decarbonisation of its activities and markets brings risks and opportunities. It seems that the priority for a company is to further its strategic thinking in this way, rather than to mobilise resources – that could appear excessive in some cases – to calculate too precise a target where numerous uncertainties will persist, regardless of what happens.

An expression of linear commitments to reduce GHG emissions does not reflect the inescapably non-linear nature of the company's future transformations.

Figure 40: Relevance of the SBTi to the TCFD framework. In green, what can be established applying the SBTi approach. In red, what cannot be established.

Recommendations and Supporting Recommended Disclosures

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	**Recommended Disclosures**	**Recommended Disclosures**	**Recommended Disclosures**
a) Describe the board's oversight of climate-related risks and opportunities.	a) Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.	a) Describe the organization's processes for identifying and assessing climate-related risks.	a) Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
b) Describe management's role in assessing and managing climate-related risks and opportunities.	b) Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.	b) Describe the organization's processes for managing climate-related risks.	b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
	c) Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management.	c) Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

Source: TCFD final report.

Emission reduction commitments made by companies and approved by the SBTi are often publicly reported as: an emission reduction of -x% by 20YY, i.e. a decrease of -z% per year. Setting out reduction targets this way tends to depict the decarbonisation of the company's activities as a smooth, linear, fluid process, whereas in reality we will observe more of a "step-by-step" transition (e.g. following an investment, restructuring of the business portfolio, implementation of a purchasing strategy, etc.). The methodological framework does not encourage or reflect such a process, yet it is often the disruptive (technical, organisational, etc.) events that push us to deal with these issues. Presenting commitments in terms of "carbon budget available over a given period of time" could help to overcome this pitfall[143].

4 Assessing low-Carbon Transition (ACT)

a — Presentation of the ACT initiative

The ACT (*Assessing low-Carbon Transition*) initiative, launched by ADEME and CDP in 2017, assesses a company's readiness to address the climate challenges, in the context of a 2°C pathway specific to its business sector.

This evaluation is based on the company's quantitative and qualitative replies to a sector-specific questionnaire, which are then compared with a sector benchmark based on the SDA method developed by the *SBTi* (see Part 9.C.3.a, p. 102).

143 - This would mean allocating a carbon budget to an organisation over a given period of time, instead of an annual emissions reduction rate, to better account for step-by-step progress.

The evaluation process delivers three results:

- **A score broken down into three parts:** a performance score (which assesses the position of the company's strategy with regard to the benchmark 2°C trajectory), an evaluation score (which reflects the company's transparency and the consistency of the data it provides) and a trend score (which indicates whether the company is tending towards or away from the pathway);
- **A description of the data** and information on which the assessment is based;
- **An evaluation summary** that sums up the key findings of the study and suggests areas for improvement.

The ACT initiative process is decisively sector-based. To date, the method covers three sectors (vehicle manufacturing, power generation and retail[144]). By 2021, all sectors identified as exposed by the TCFD (see Part 9.A.1, p. 95) should be covered.

The methodology is intended for large companies, mid-caps and SMEs. To use the ACT method, a company must first have conducted a carbon review (or equivalent) and must have short- or medium-term emissions reduction targets.

CDP, a founding member of the initiative, has stated that the strategy for integrating ACT initiative results is now being defined, but it is considering gradually incorporating them into its *Climate Change* questionnaire.

b —— Analysis of the ACT method

The method and results of the ACT initiative are useful in defining climate targets and an action plan.

The methodological framework defined by the ACT initiative can be used to assess the alignment of a company's CO_2 emissions reduction targets and its internal structure (i.e. its investments, R&D budget, etc.) with a given reference framework (a scenario).

The results provide a comprehensive diagnosis of the company's positioning within that framework. A number of pilot companies have confirmed that the methodological framework defined by the ACT initiative has helped them identify the different options at their disposal and potentially gain insight for the development of a low-carbon strategy. The fact that the method is adapted according to the sector also enables a detailed analysis of the company.

The method requires strong involvement from the company because it uses indicators that implicate employees at every level of the organisation, not only in the sustainable development department.

Because the company can adapt to national trajectories, a possibility introduced during a pilot phase with the incorporation of the SNBC (French national low-carbon strategy), it should be possible to use a more diverse range of reference frameworks.

Finally, because there is an external assessment and evaluation score, it is difficult to proceed with "greenwashing".

However, the ACT method does not make it possible to address the TCFD's Strategy recommendations (to analyse the resilience of a company's business model to the energy and climate issues).

The ACT initiative's methodological framework was not designed to measure the resilience of the company's business model under several low-carbon transition scenarios, nor to help the company identify the opportunities and risks associated with such scenarios.

Like the *SBTi*, the use (to date) of a single scenario (the 2DS scenario from the 2017 ETP study published by the IEA, see Box 16: The IEA scenarios, p. 70) to define the reference framework into which the company is projected (carbon budget allocation using the SDA approach, level of investment required, etc.) comes with limitations in that certain assumptions remain debatable and the future studied lacks diversity (see Part 9.C.3.b, p. 103).

144 - The following companies took part in the ACT method test: General Motors, Renault, Honda, Toyota and PSA Peugeot Citroën in the automotive industry; Uniper, SSE, Endesa, AGL, NRG, Enel, Engie and EDF in the power generation sector; Casino Group, J. Front Retailing, Decathlon, the Warehouse Group, Walmart, Carrefour, Woolworths and Kesko in retail.

10 Energy/climate scenarios in the financial sector

Financial stakeholders recognise that energy/climate issues are a considerable source of financial risk. As such, the regulators are starting to encourage assessment of asset portfolio resilience to these risks (stress tests) and raise awareness of the potentially chaotic nature of the transition.
The need to compare companies (and the strategies they announce) easily has pushed most financial operators to opt for methodologies that draw on scenarios shared by all stakeholders. Paradoxically, the comparability criterion for the information published is promoted by the TCFD.
Today, financial operators (rating agencies and investors) rarely ask companies about their scenario-based foresight analysis. In fact, for many of them, the financial materiality of the transition risk does not appear to be significant. However, this kind of question is likely to be raised more frequently in the future.

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A

Action taken by financial regulators

Central banks (and their prudential regulation bodies) are taking action to encourage financial institutions to use scenarios to assess the resilience of their portfolios to these risks. These stakeholders warn of the potentially chaotic nature of the transition.

Central banks (and their prudential regulation bodies) play a very important role in regulating the financial system.

Building on the momentum within the financial sector to address energy and climate issues, some operators joined forces in 2018 within the Network for *Greening the Financial System* (NGFS) to promote the development of recommendations for the entire financial system and best practises among supervisors and central banks[145].

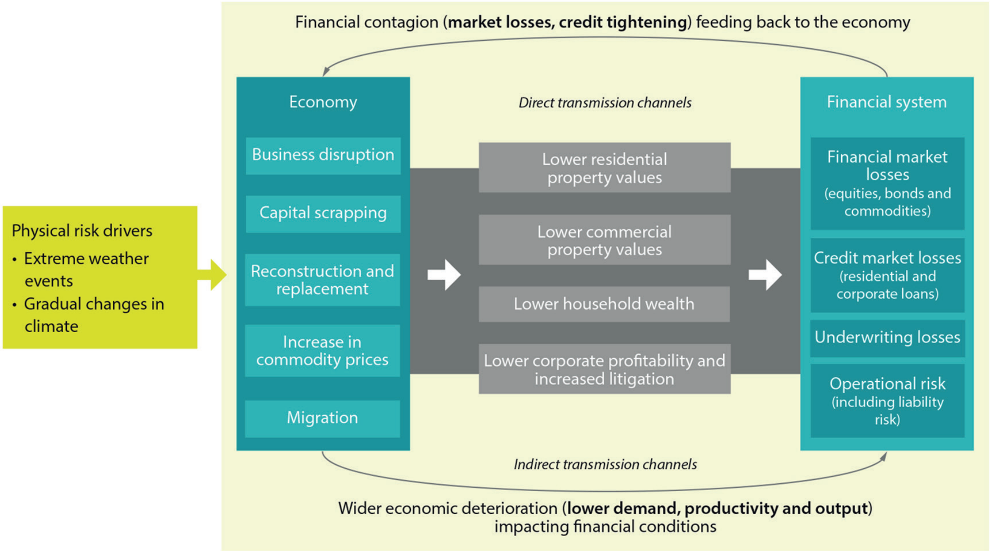
36 central banks are members of the NGFS, whose secretariat is provided by the Banque de France. They acknowledge that:

> *"Climate-related risks are a source of financial risk. It is therefore within the mandates of central banks and supervisors to ensure the financial system is resilient to these risks.[146]"*

In April 2019, the NGFS published its first comprehensive report entitled *"A call for action – Climate change as a source of financial risk"*. This document contains several recommendations, including the use of scenario analysis:

> "Recommendation n°1: Integrating climate-related risks into financial stability monitoring and micro-supervision :
> Important steps in this regard include [...]
> - *conducting quantitative climate-related risk analysis to size the risks across the financial system, using* ***a consistent and comparable set of data-driven scenarios encompassing a range of different plausible future states of the world*** *[...]"*

Figure 41: How climate risk can affect financial stability.



Source: NGFS First Comprehensive Report (2019).

145 - *The Network for Greening the Financial System (NGFS) is an initiative from the Banque de France, launched at the "One Planet Summit" in Paris on 12 December 2017.*

146 - *Voir le premier rapport d'activité du NGFS "A call for action Climate change as a source of financial risk", NGFS (Avril 2019)*

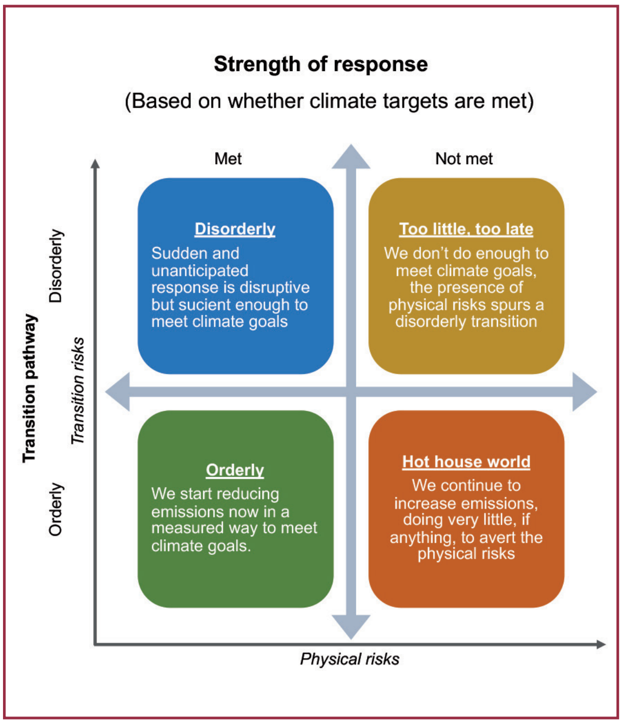
In addition to this recommendation, which complies with the TCFD framework, NGFS members (following the Bank of England, see below) have introduced an important aspect that has often been missing from the discussions so far: recognition of the **potentially chaotic nature of the transition**. There are thus repeated reminders that the risks of disruption to the financial system are greater in cases where decarbonisation occurs in a disorderly and hasty manner, after an excessively long period of inaction.

The NGFS considers that two aspects must be taken into account when assessing the physical and transition risks to the financial system[147]:

- whether or not the climate objectives are met, i.e. the extent of the measures taken to reduce GHG emissions;
- the orderly or disorderly nature of the transition, i.e. whether actions are taken smoothly and predictably.

Four macro-scenarios taking these two dimensions into account are made available for supervisors and may be included in their internal processes, including stress testing.

Figure 42: Four macro-scenarios put forward by the NGFS, taking into account the orderly/disorderly nature of the transition and the attainment/non-attainment of the climate objectives.



Source : NGFS (2019)

The NGFS partly relied on the work done by the Bank of England through the *Prudential Regulation Authority* (PRA), particularly on the integration of the potentially disorderly nature of the transition[148] and on the scenario frameworks used for its stress tests[149]. The PRA also emphasises the need for financial operators to plan for the long term and underscores the qualitative nature of the exercise[150]. In France, the *Autorité de Contrôle Prudentiel et de Résolution* (ACPR) is working in the same direction and recommends that insurers embark on forward-looking analysis of their portfolio[151] and that banks continue their work to implement stress tests[152]. Similarly, the European Insurance and Occupational Pensions Authority (EIOPA), raises the question about the market's[153] consideration of "sustainability" (primarily energy/climate issues) in European regulations.

The NGFS also states that the macro-scenarios described in the Figure 36 could be used by other financial and non-financial stakeholders[154].

Recent work by the TEG to promote the development of green finance in Europe (including taxonomy and indices), and the regulatory changes that could follow, should not overshadow the need to mobilise internal and external resources to permit thorough and long-term analysis of

147 - See "Box 2: Designing a scenario analysis framework for central banks and supervisors", NGFS report (2019).

148 - See "Enhancing banks' and insurers' approaches to managing the financial risks from climate change", PRA Supervisory Statement SS3/19 (2019) and in particular "2.6 […] Financial risks from climate change will be minimised if there is an orderly market transition to a low-carbon world, but the window for an orderly transition is finite and closing" and "3.15 The scenario analysis should, where appropriate, include a […] longer term assessment of the firm's exposure, based on its current business model, of a range of different climate-related scenarios. For example: scenarios based around average global temperature increases consistent with, or in excess of 2˚C; and scenarios where the transition to a low-carbon economy occurs in an orderly manner, or not".

149 - See "Life Insurance Stress Test 2019: Scenario Specification, Guidelines and Instructions", PRA (2019) and "General Insurance Stress Test 2019: Scenario Specification, Guidelines and Instructions", PRA (2019).

150 - Ibid. See "3.15 […] The PRA expects the time horizon of this long-term assessment to be in the order of decades. As with other types of scenario analysis, this is not intended to be a precise forecast, but a qualitative exercise used to inform strategic planning and decision making".

151 - See "Les assureurs français face au risque de changement climatique" [French insurers and the climate change risk], Analyses et synthèses n°102-2019, ACPR (2019) and particularly the Recommendations section "These scenarios can, for example, be based on very different assumptions: rise in temperatures (1.5°C, 2°C or 4°C), a turnaround in public climate policies (with the introduction of binding regulatory standards for example), breakthrough technology (carbon capture), or even a rapid change in consumer behaviour".

152 - See "Les groupes bancaires français face au risque climatique" [The French banks and the climate risk], Analyses et synthèses n°101-2019, ACPR (2019).

153 - See "Consultation Paper on an opinion on sustainability within Solvency II", EIOPA (June 2019).

154 - See "A call for action – Climate change as a source of financial risk", NGFS (April 2019): "Although these scenarios are primarily being developed by central banks and supervisors in support of their own work and objectives, these scenarios may provide a useful input for other stakeholders, such as financial and non-financial firms, in considering how they may be impacted by climate change".

energy/climate issues by financial operators.

The European taxonomy of sustainable activities currently being developed[155] aims to encourage and guide investment towards more sustainable economic activities. While it is a highly relevant, shared tool designed to facilitate decision-making for financial operators, this taxonomy is also a source of simplification that does not aim to stimulate detailed analysis by financial operators of the strategies set out by the companies they finance or in which they invest. The ACPR is clear on this issue, indicating, for example, to insurers (our emphasis added):

> *"The adoption by the European Commission of a taxonomy to clearly define 'green' assets will be a valuable mechanism for carrying out a review of insurers' portfolios on both sides of the balance sheet.* ***However,*** *insurance companies will inevitably have to use scenarios to conduct forward-looking analysis of their portfolios".*

The TEG's[156] work has also involved updating stock market indices to identify ways in which they can better integrate sustainability objectives[157], in a context where index-driven asset management is developing rapidly[158].

Two types of index are put forward:

- *EU Climate Transition Benchmarks (EU CTBs)*: the underlying assets are selected and weighted in such a manner that the resulting portfolio is on a decarbonisation trajectory;
- *EU Paris-aligned Benchmarks (EU PABs)*: the underlying assets are selected and weighted in such a manner that the resulting portfolio's GHG emissions are aligned with the targets of the Paris Climate Agreement.

Beyond the fact that use of indices does not, by design, tend to encourage investors who use them to carry out in-depth analysis of corporate strategy, the inclusion of a company in the basket of values of these indices does not fully reflect all the risks and opportunities to which the company is exposed. In light of its analysis of certain indices[159], EIOPA concludes[160]:

> *« 9.40 Based on the evidence available, the analysis performed by EIOPA concludes that there is no meaningful difference in risk profile for sustainable equities compared to other equities. Depending on additional data which may become available, including on brown assets, it may be possible to better differentiate between the risk profiles of assets based on their sustainability characteristics, at a later date. »*

B

Financial operators and scenario analysis: what are the challenges?

The need to compare companies (and their stated strategies) easily has prompted most financial operators to opt for methodologies that draw on scenarios shared by all stakeholders. Paradoxically, the comparability criterion for the information published is promoted by the TCFD.

Among the basic principles for relevant reporting, the TCFD refers to inter-organisational and cross-sector[161] comparability.

> *« Principle 5: Disclosures should be comparable among organizations within a sector, industry, or portfolio*
> - *Disclosures should allow for meaningful comparisons of strategy, business activities, risks, and performance across organizations and within sectors and jurisdictions.*
> - *The level of detail provided in disclosures should enable comparison and benchmarking of risks across sectors and at the portfolio level, where appropriate. […] »*

When applied to scenario analysis methods, this criterion naturally encourages the **use of energy/climate scenarios that are widely shared by various users** (financial and non-financial companies).

In addition to the otherwise quite understandable need

155 - See "TEG report on EU Taxonomy", TEG (2019).
156 - See "Report on Benchmarks", TEG interim report (June 2019).
157 - See Action 5, "European Commission Action Plan", European Commission (March 2018).
158 - Index-based asset management is becoming mainstream in the financial market. The demand for this management method is growing mainly because asset management companies find it so difficult to outperform benchmark indices (by sector, asset class, etc.) with so-called "active" asset management, and because of the low and declining cost of index-based management.
159 - MSCI World Developed; MSCI World All USD; MSCI Environmental, Dow Jones Sustainability World.
160 - See p. 51 "Consultation Paper on an opinion on sustainability within Solvency II", EIOPA (June 2019).
161 - See Annex 3 of the TCFD final report (2017).

to compare operators with each other, using the same criteria, the use of widely-shared scenarios also has **the advantage of supposedly simplifying the analysis process and reducing the related costs**[162]. The argument of lower analysis costs is particularly convincing at a time when management companies and institutional investors are facing an unprecedented decline in nominal and real bond yields[163], and while the resources mobilised to analyse the energy/climate issues remain limited[164]. .

However, the use of shared macro-scenarios inevitably **limits the variety of future scenarios studied** and thus reduces the scope of an analysis based on such scenarios. This approach also results in **a normative and pre-emptive vision**, whereas the potentially chaotic process of decarbonising the economy ought to prompt forward-looking research.

To analyse energy/climate issues, financial operators are adopting a legitimate sector-based approach.

The different methods used to analyse energy/climate issues are mainly built around business sectors. One reason for this is that some sectors are more directly exposed to such issues than others (see the exposed sectors identified by the TCFD, Part 9.A.1, p. 95).

While the incorporation of energy/climate issues by the various sectors will likelyprogress at different rates (the energy sector first of all, then the five sectors identified by the TCFD, with the rest of the economy afterwards), **financial operators will naturally mobilise accordingly**. The positioning of some institutional investors with regard to investment in the coal sector is one example of this[165]. Rating agencies apply the same reasoning and are putting more focus on the exposed sectors[166] (see Part 10.C, p. 110).

This point, together with the context in which financial stakeholders operate (see the previous paragraph), may lead them to consider the business sector first, before looking at the individual strategy of each company when assessing investment portfolio exposure. This bias will be reinforced with the introduction of financial stress tests based on climate scenarios, which tend to apply the sector-based approach[167]. This kind of reasoning may result in disinvestment from certain sectors (e.g. coal) when the specifics of a company are not taken into consideration.

C

Financial operators and scenario analysis: state of play and trends

1 Action taken by the credit rating agencies

Financial rating agencies have a very marked sector-based approach.

Analysis of an issuer's credit risk is partly[168] based on the assessment of its business profile, which covers all the non-financial criteria that may affect the issuer's ability to repay its debt. This part of the rating includes a study of the environment in which the issuer operates (i.e. the markets and countries in which it operates, the level of competition, its competitive advantages, etc.). By design, business profile assessment is strongly linked to the sector of activity: assessing the sector's "health" will affect – positively or negatively – the issuer's final rating.

This approach applies to the assessment of energy/climate risks. Moody's has published several documents evaluating how exposed business sectors that issue debt instruments are to environmental risks[169] (including climate risks) and has identified eleven sectors at very high risk.

162 - See the latest TCFD evaluation report (May 2019): "Such an approach [the use of standard scenarios] may reduce concerns about releasing confidential business information, reduce scenario analysis costs, and improve transparency and comparability of disclosures". See also the debate in the UK on the subject, Environmental Audit Committee of the Parliament, "Greening Finance: embedding sustainability in financial decision making", paragraph 72 (6 Jun 2018).
163 - See "The threat of secular stagnation has not gone away", Financial Times (6 May 2018).
164 - See "Climate Risk Analysis: Stakeholders, Methodologies and Outlook", The Shift Project (2018).
165 - See "To Coal! An Analysis of Life Insurance Investment Policies", Observatory 173 on Climate & Life Insurance, The Shift Project (2018).
166 - See for example "Heat map: 11 sectors with $2.2 trillion debt have elevated environmental risk exposure", Moody's (September 2018).
167 - See "Life Insurance Stress Test 2019: Scenario Specification, Guidelines and Instructions", PRA (2019) and "General Insurance Stress Test 2019: Scenario Specification, Guidelines and Instructions", PRA (2019).
168 - These methodologies take account of financial factors (financial ratios) and also non-financial factors (such as the company's business profile, sector analyses) where such criteria are deemed to be "significant and relevant" (i.e. affecting the issuer's ability to repay its debt on time). See "Climate Risk Analysis: Stakeholders, Methodologies and Outlook", The Shift Project (2018).
169 - See "Heat map: 11 sectors with $2.2 trillion debt have elevated environmental risk exposure", Moody's (2018).

Since the publication of the TCFD recommendations, which they support, the main financial rating agencies have not been very forthcoming on the issues related to energy/climate scenario analysis. They have developed long-term assessment tools, which appear unrelated to their credit rating methodology.

While rating agencies have identified the possible materiality of climate risk and have taken part in the TCFD's work, welcoming the Task Force's recommendations, only limited consideration is given to energy/climate issues in credit rating methodologies at present[170]. This can mainly be explained by the gap between the credit risk occurrence horizon and climate risk occurrence horizon.

The consideration given to such issues depends on the agency's ability to assess an issuer's future financial performance, which decreases significantly beyond a few years given the uncertainty associated with it.

Therefore, at this stage, information concerning any scenario analysis work conducted by an issuer will only have an impact on its credit rating when it is deemed significant and relevant (i.e. if it characterises the issuer's ability to repay its debt within the stated time limits).

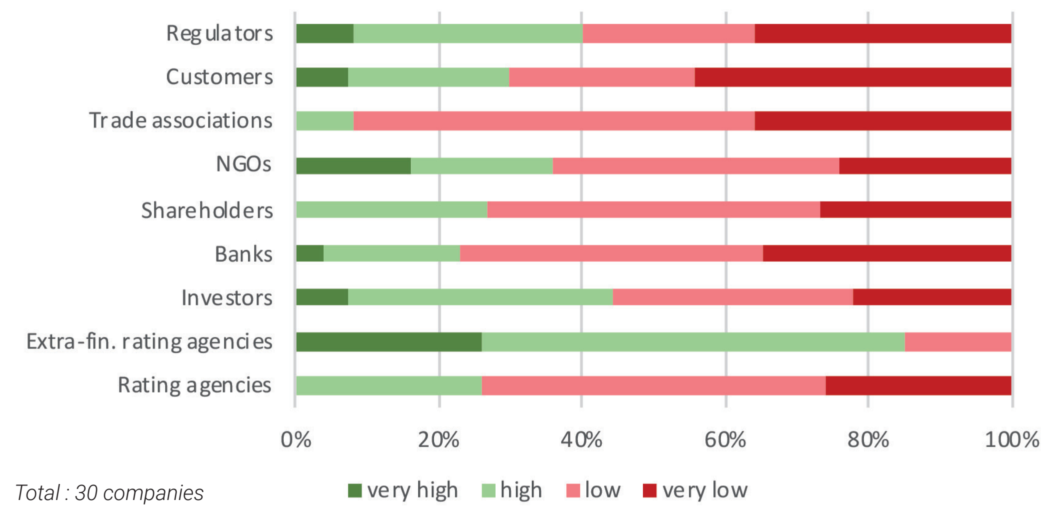
However, agencies are developing tools, unrelated to their credit rating methodology, to assess ESG risks (environmental, social and governance) over the long term, some of which are based on scenarios.

Box 22: Which operators ask companies about scenario analysis?

As part of the study, a panel of 30 AFEP companies (from different sectors) was interviewed on the perceived level of demand from different stakeholders.

According to the companies questioned, demand from financial operators remains limited to date.

Figure 43: Percentage of businesses interviewed who report that stakeholder demand is very high, high, low or very low.



Total : 30 companies

170 - See "Climate Risk Analysis: Stakeholders, Methodologies and Outlook", The Shift Project (2018). This aspect has also been identified by the European Commission: under its Action Plan, it has mandated ESMA (the European Securities and Markets Authority) to investigate how ESG considerations are taken into account by financial rating agencies. See Action 6 of the European Commission's Action Plan.

Moody's has taken the lead in energy/climate issue analysis with the publication (including a request for feedback) in May 2019 of a proposal for a Carbon Transition Assessment (CTA)[171] system based on the IEA scenarios (see Box 24, p. 114).

In April 2019, S&P Global Ratings also published a document describing the system it uses to assess long-term issues (ESG Evaluation[172]), which is less focused on energy/climate issues as it incorporates other ESG aspects.

Box 23: Moody's Carbon Transition Assessment system (under development)

There are several noteworthy points in the document Moody's put to the market:

- the agency stresses that CTAs are not credit risk assessments and will not affect issuers' ratings;
- the CTAs are based on scenario analysis that aims to evaluate a company's positioning with regard to the low-carbon transition;
- CTAs include several time horizons to assess a company's exposure: short, medium (<5 years) and long term (>5 years). The risks associated with each horizon are each equally weighted;
- the information disclosed by companies, which may be incomplete, could be supplemented by sector-based information or information from data providers.

One critical point is that the system developed by Moody's endorses the *World Energy Outlook* scenarios published by the *IEA*[173] (see Box 16: The IEA scenarios, p. 70). The NPS scenario is used to assess medium-term risks and the SDS scenario for long-term risks. What is more, there is no critical analysis of the scenarios on which the CTAs are largely based.

These developments – which are somewhat inconsistent – reflect the rating agencies' intention to better integrate long-term issues into their analyses and to meet the growing market demand for them.

Even though such approaches do not enter the credit rating process at this stage, **this could change in the future.** However, the European regulations, which set the overall conceptual and methodological framework for credit rating agencies, slow down any such process, particularly when it comes to recommendations on the back-testing[174] of credit rating methodologies: since the low-carbon transition is unprecedented (we have no historical data), retrospective assessment is impossible. This regulatory aspect is one of several factors limiting the use of scenario analysis by agencies in their credit rating methodology.

Finally, given the methodological influence that rating agencies have over risk analysis, the use of a single set of scenarios (e.g. IEA scenarios) could catch on with other financial actors (investors, asset managers, etc.), going against the very principles that underpin scenario analysis.

2 Action taken by institutional investors

Transition risk does not appear to have any financial materiality for the main institutional investors and is mainly seen as a reputational risk.

Within the financial sector, awareness of the seriousness and systemic nature of climate risk is growing, as evidenced by an increasing number of reports on the subject[175]. The materiality – in the long term – of physical climate risks is also a widely-shared issue now.[176] However, for institutional investors in 2019, climate risk is mainly expected to arise in the form of transition risk (see Part 3.A.2, p. 18).

Nonetheless, the actual consideration given to this risk, i.e. the implementation of policies and measures to avert it, appears limited at present. This can be seen, for example,

171 - See "Proposed framework to assess carbon risks for high-risk corporate sectors", Moody's (2019).
172 - See "Environmental, Social, And Governance Evaluation Analytical Approach", S&P Global Rating (2019).
173 - Ibid. "In order to score all sectors on the basis of a consistent global environmental outcome, we propose to base our long-term analysis around a more rapid carbon transition, such as that outlined in the International Energy Agency's Sustainable Development Scenario (SDS). The SDS reflects a widely accepted emissions trajectory consistent with a 50% probability of limiting the average global temperature increase to two degrees Celsius".

174 - See Regulation (EC) No 1060/2009 of the European parliament and of the Council of 16 September 2009 on credit rating agencies, European Commission (2009): "(23) Credit rating agencies should use rating methodologies that are rigorous, systematic, continuous and subject to validation including by appropriate historical experience and back-testing. Such a requirement should not, however, provide grounds for interference with the content of credit ratings and methodologies by the competent authorities and the Member States (…)".
175 - Most of these studies are available on the TCFD Knowledge Hub.
176 - See "Getting started on Physical climate risk analysis in finance – Available approaches and the way forward", I4CE (2018).

in the analysis of the solvency reports (SFCR) published in 2019 for ten of the twelve main French life insurance companies, which represent three-quarters of the €1,700 billion invested in life insurance by French households[177].

The teams of experts in charge of risks within these organisations seem to be confronted with a number of challenges when it comes to climate risk:

- the limited progress made to date with the energy transition in France and around the world, limiting the materiality of the transition risk;
- growing awareness of how complex the subject is, three years after the implementation of Article 173, or the launch of the TCFD;
- the difficulties that governments and regulators are having in leading the way, which they see as fraught with pitfalls.

Most notably, the SFCR analysis concludes that risk experts have not identified any present materiality of exposure to transition risk. This risk does not thus appear to fall within the scope of financial risk (by depreciation of investments linked to the low-carbon transition) and there is no mention of "*stranded assets*". Nor does it seem to be a matter of ethics[178] (the exclusion of investments in the thermal coal sector is a step in this direction, but remains very limited).

In the absence of materiality, this transition risk is mainly a reputational risk at present (one of the three risks mentioned by Mark Carney in his speech at Lloyd's of London in 2015), particularly in a context where civil society stakeholders (NGOs, activists, etc.) are putting increasing pressure on financial institutions through the media and social media[179].

Several scenario-based analysis methods have been developed in-house or externally for investors. The trend is now to develop standardised external methods. As such, investors have expressed a need for information from the companies in which they invest.

Investors are both users and issuers of information on energy/climate issues. Depending on the size and diversification of their portfolios, scenario analysis can come with certain methodological difficulties and require significant expertise and resources, yet market context (low rates, fall in management costs, development of passive management) limits the availability of such resources.

There are now several external methodologies, developed by specialist firms for investors, to analyse energy/climate issues using scenarios. They are already in use but still require further work. The main ones are explained in the UNEP FI report, published in May 2019[180]. Some investors are developing their own tools.

These methodologies generally use public energy/climate scenarios (see Chapter 8, p. 54) – most often those published by the IEA (WEO 2018 and ETP 2017) – to assess transition risks. For physical risk assessment, climate scenarios (RCPs, see Part 8.A, p. 55) are used.

To use these methodologies and further develop them, investors need more information from the companies in which they invest, particularly regarding their exposure to climate risks and their capacity to adapt. This information requirement is currently being examined in a study by the think tank I4CE[181].

In some countries, particularly in Europe (United Kingdom, France, the Netherlands, etc.), regulators are gradually introducing "climate stress tests" for investors to measure the resilience of their portfolios under several scenarios (see Part 10.1, p. 108). Alongside the Banque de France's efforts within the NGFS, the topic is also being addressed in France within the framework of the 2019 Energy and Climate Law[182].

177 - See "Deux sons de cloches sur la matérialité du risque climat dans l'assurance vie française" [Two different messages on the materiality of climate risk in French life insurance], Observatory 173 on Climate & Life Insurance, The Shift Project (2019).
178 - See "To Coal! An Analysis of Life Insurance Investment Policies", Observatory 173 on Climate & Life Insurance, The Shift Project (2018).
179 - See, for example, NGO Oxfam's publication on the banks' financing of fossil fuels "Comment les banques françaises financent les énergies fossiles" [How French banks finance fossil fuels], Oxfam (2018).

180 - See "Changing course: A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD", UNEP FI (2019). Also see the Principles for Responsible Investment (PRI) network website, which lists all the scenario analysis methods available for investors.
181 - See "Re-imagining Disclosure for companies and their 2°C strategy" on the I4CE website.
182 - Without pre-empting the future of this legislation, which is still under discussion, we have noted the amendment passed in the Senate in July 2019, which refers to stress tests and climate scenarios for the financial sector, and more specifically calls for the following scenario to be explored: "[...] a sustained, long-term increase in oil prices resulting from global supply constraints due to massive disinvestment in oil exploration and production". See the Senate website for the text of the full amendment: http://www.senat.fr/enseance/2018-2019/658/Amdt_457.html.

Box 24: CDP and scenario analysis

CDP's Climate Change questionnaire has recently evolved to take on board TCFD recommendations, particularly for the exposed sectors identified (see 9.A.1, p. 95). There is guidance for companies responding to the questionnaire in a special guide and a technical note available[183] on the CDP website.

When a company answers question 3.1 (and the dependent sub-questions), CDP puts special focus on the following elements:

- does the organisation use scenario analysis to assess climate-related risks and opportunities?
- does this apply to transition risk and/or physical risk?
- which scenarios are used (public scenarios, variations derived from public scenarios or in-house scenarios)? are these scenarios adapted to the company/its sector/ geographical areas?
- is the company transparent about its use of scenarios (use of results, integration into internal processes, etc.) and the scenarios it uses (parameters, assumptions, time horizon, etc.)?

CDP considers that each company must use scenarios adapted to its level of exposure to climate risk. However, CDP also acknowledges that the comparability of the information disclosed by companies is a critical issue. In this respect, CDP believes that use of at least one scenario common to all companies (which one remains to be established, as there is no consensus on this to date) would facilitate the comparison of their strategies.

Participation in the SBTi (see Part 9.C.3, p. 102) is a key factor in the score obtained by a company responding to the *Climate Change questionnaire*[184]. In the long term, participation in the ACT initiative (co-developed with ADEME, see Part 9.C.4, p. 104) could become another crucial factor.

Finally, CDP is running a project backed by Climate-KIC[185] to promote scenario-based analysis in companies and good reporting practises.

N.B. The above information is based on the documentation available on the CDP website and an interview with CDP's technical director.

183 - See "CDP Technical Note on Scenario Analysis", CDP (2017).

184 - See "CDP Technical Note on Science-Based Targets", CDP (2019): "Science-based targets will be scored in questions C4.1a and C4.1b for 1) Disclosure and Awareness level points, 2) Management points and 3) Leadership points. All companies, regardless of sector, are eligible to earn full points in each level of scoring".

185 - See "Re-imagining Disclosure for companies and their 2°C strategy".

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Appendix 1: List of contacts met

Our sincere thanks go to all participants for being so welcoming and for giving us such high-quality information.

A. Corporate members of the steering committee

Alstom	Camille ROZANES	Sustainability Manager
	Cécile TEXIER	Sustainability & CSR Director
Axa	Sylvain VANSTON	Corporate Responsibility
Bouygues	Fabrice BONNIFET	Sustainable Development & QSE (Quality-Safety-Environment) Director
	Thomas FARFAL	Group CSR Coordinator
CGG	Isabelle LAMBERT	Environment, Sustainable Development and Social Responsibility VP
	Jean-François ROUDAUT	ERM Director
Generali France	Jean-Louis CHARLUTEAU	Director, Reinsurance and Natural Risks, Technical Project Management
	François GARREAU	Head of CSR reporting to the Executive Committee, and President of the Sustainable Development Commission at the FFA
	Julien HAMY	Actuarial Service Manager
LVMH	Sylvie BENARD	Environment Director
	Chloé CIBULKA	Head of Environment, Outlets and Production Sites
Michelin	Jennifer BRAVINDER	Sustainable Development
	Gaël QUEINNEC	Director of Prospective Research
Schneider Electric	Aurélie JARDIN	Head of Institutional Relations, France
	Frédéric PINGLOT	Sustainability Consultant
	Gilles VERMOT-DESROCHES	Sustainable Development Director
Société Générale	Patrice FROISSART	Head of Industrial and Sectoral Studies
	François LETONDU	Head of Macro-sectoral and Macro-financial Analysis
	Emmanuel MARTINEZ	Chief Environmental Economist
Sodexo	Laurent AUZANNEAU	CEO Engineering & Construction Projects Worldwide
	Alina CAZACU	Corporate Responsibility Performance and Metrics Manager
	Anna PETRINI	Environmental Analyst
Suez	Jean-Pierre MAUGENDRE	Sustainable Development Project Director
	Hélène VALADE	Sustainable Development Director
Thales	Sophie LE PENNEC	VP Health, Safety & Environment
	Raphaëlle TISSOT	Environment Project Manager
Unibail-Rodamco-Westfield	Clément JEANNIN	Sustainable Development Director
	Julie VILLET	Director of URW LAb & CSR
Vallourec	Jean-Louis MERVEILLE	Sustainable Development Director
Veolia	Alice PEYRARD	Sustainable Development Department, Director, Climate Commitment

B. Other AFEP member companies met

Air Liquide	Vincent MAGES	Deputy Director of European and International Affairs
	David MENESES	Group VP Sustainability
Esso SAF	Gildas GUILLOSSEAU	Director of Institutional Relations
	Benoit de SAINT SERNIN	Public Affairs Manager
Orange	Jean-Manuel CANET	Senior Manager Environmental Projects
	Philippe TUZZOLINO	Environment Director
Plastic Omnium	Benjamin DUCLOS	Corporate Social Responsibility & HSE Group VP
Saint Gobain	Emmanuel NORMANT	Sustainable Development Director
Solvay	Pascal CHALVON	Chief Sustainability & Energy Officer
	Philippe CHAUVEAU	Head of Climate Strategy, Sustainable Development & Energy
Total	Patrick de DECKER	Senior Climate Advisor
	Bertrand JANUS	Investor Relations, CSR Reporting Manager
Axens*	Eric BENAZI	VP Marketing & External Communication
	Sebastien FRAYSSE	Strategic Marketing Manager

C. Stakeholders in scenario analysis met

ADEME	Edouard FOURDRIN	Climate Project Manager
	Romain POIVET	Climate Project Manager (ACT)
CIRED	Christophe CASSEN	Scientific Coordinator
	Céline GUIVARCH	Economist, Research Director (Ecole des ponts) and member of the HCC
Futuribles	François DE JOUVENEL	CEO
I4CE	Michel CARDONA	Senior Advisor - Financial Sector, Risk and Climate Change
	Aurore COLIN	Research Associate - Territories and Climate
	Romain HUBERT	Project Manager - Finance, Investment and Climate
	Charlotte VAILLES	Project Manager - Industry, Energy and Climate
IDDRI	Henri WAISMAN	Climate Programme - Coordinator of the DDPP initiative
IEA	Timothy GOODSON	Energy Analyst
	Christophe MC GLADE	WEO Senior Analyst
	Laszlo VARRO	Chief Economist
IFPEN	Emmanuel HACHE	Economist, Director of Research
	Gondia SECK	Senior Energy System Analyst
	Marine SIMOEN	Economist Engineer
IRENA	Nicholas WAGNER	Programme Officer - Renewable Energy Roadmaps, REmap
PBL	Mariësse VAN SLUISVELD	Researcher
PIK	Christoph BERTRAM	International Climate Policy Analysis Leader
WWF (SBTi)	Alexander FARSAN	SBTi Coordinator
	Aurélie PONTAL	Partnership Manager

** Axens is not an AFEP member company.*

D. Financial stakeholders met

AXA AM	Lise MORET	Head of Climate Strategy - Responsible Investment
Banque de France	Guillaume RICHET	Green Finance Expert
CDP	Laurent BABIKIAN	Director Investor Engagement Europe
	Steven TEEBE	Managing Director Europe
FFA	Pauline BECQUEY	Sustainable Development Manager
	Aurore GAUFFRE	Investment Manager
Mirova	Ladislas SMIA	Co-head of Responsible Investment Research
Moody's Investors Services	Yasmina SERGHINI	Associate Managing Director, Chair of Moody's ESG working group in EMEA
S&P Global Ratings	Noémie de la GORCE	Associate, Sustainable Finance, Corporate & Infrastructure Ratings
	Mike WILKINS	Managing Director, Head of Sustainable Finance

This section presents the methodology used to construct the historical data series used in the report, most notably in Part 8.

Population

- World population from 1950 to 2017: UN DESA World Population Prospects 2019

GDP

- World GDP from 1950 to 1980: *Maddison project (expressed in market exchange rates (MER))*
- World GDP from 1981 to 2017: *IMF 2018 World Economic Outlook*, gross domestic product, constant prices - percent change (market exchange rates)
- World GDP in 2017 in USD_{2010} (MER): *World Bank*

The value of world GDP used as a benchmark is that of the World Bank in 2017 (expressed in MER): 80,078 billion USD_{2010}.

The full series (1950-2017) is reconstructed using this benchmark, applying the annual rates of change from the two previous series.

Primary energy

- World primary energy production from 1950 to 1965: *Etemad & Luciani (1991)*
- World primary energy production from 1966 to 2017: *BP Statistical Review 2018*

The global primary energy production value used as a benchmark is that derived from the 2018 BP Statistical Review for 2017: 13,511 million tonnes of oil equivalent (Mtoe).

The full series (1950-2017) is reconstructed using this benchmark, applying the annual rates of change from the two previous series.

CO_2 emissions

- CO_2 emissions from 1950 to 2017: Global Carbon Budget

GDP per capita

The series is constructed by dividing world GDP by population for each year between 1950 and 2017. Values are expressed in USD_{2010} per capita.

Energy intensity of GDP

The series is constructed by dividing global primary energy production by global GDP for each year between 1950 and 2017. The values are expressed in Mtoe/USD_{2010}.

Carbon intensity of the primary energy produced

The series is constructed by dividing CO_2 emissions (excluding LULUCF) by world primary energy production for each year between 1950 and 2017. The values are expressed in tCO_2/Mtoe.

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Appendix 4: Acronyms and units used

$GtCO_2$	Billion tonnes of oil equivalent
$MtCO_2$	Million tonnes of carbon dioxide
Mtoe	Million tonnes of oil equivalent
Mbpd	Million barrels per day

2DS	2°C Scenario
ACT	Assessing Carbon Transition
AFEP	French association of large companies (Association française des entreprises privées)
B2DS	Beyond 2°C Scenario
BECCS	Bioenergy with carbon capture and storage
BoE	Bank of England
BP	British Petroleum
CCS	Carbon Capture and Storage
CDP	Carbon Disclosure Project
CDSB	Climate Disclosure Standard Board
CEO	Chief Executive Officer
CM	Climate modelling
CPS	Current Policy Scenario
CRD	Corporate Reporting Dialogue
EBC	Energy Business Council
EFRAG	European Financial Reporting Advisory Group
EIA	Energy Information Administration
EFT	Even Faster Transition
ETP	Energy Technology Perspectives
EXCOM	Executive Committee
GDP	Gross Domestic Product
GEIR	Global Energy Investment Report
GHG	Greenhouse gas
GRI	Global Reporting Initiative
I4CE	Institute for Climate Economics
IAMC	Integrated Assessment Modelling Consortium
IAV	Impacts, Adaptation and Vulnerability
ICMM	International Council on Mining and Metals
IDDRI	Institute for Sustainable Development and International Relations (Institut pour le Développement Durable et les Relations Internationales)
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IIRC	International Integrated Reporting Council
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
MER	Market exchange rate

MiCA	Mining Climate Assessment
Mid-cap	Middle capitalisation
NBGs	Non-Binding Guidelines
NDCs	Nationally determined contributions
NFRD	Non-Financial Reporting Directive
NGFS	Network for Greening the Financial System (French Prudential Supervisory and Resolution Authority)
NIES	National Institute for Environmental Studies (Japan)
NPS	New Policy Scenario
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
PBL	Netherlands Environmental Assessment Agency
PIK	Potsdam Institut für Klimafolgenforschung
PNNL	Pacific Northwest National Laboratory
PPP	Purchasing Power Parity
PRA	British Prudential Regulatory Authority
RCPs	Representative Concentration Pathways
REn	Renewable energies
RTS	Reference Technology Scenario
SASB	Sustainability Accounting Standards Board
SBTi	Science Based Targets initiative
SDA	Sectoral Decarbonization Approach
SDS	Sustainable Development Scenario
SME	Small and Medium Enterprise
SNBC	French National Low Carbon Strategy
SPAs	Shared Political Assumptions
SRES	Special Report on Emissions Scenarios
SSPs	Shared Socio-economic Pathways
UN	United Nations

A. General references

ACPR (2019). Les groupes bancaires français face au risque climatique, Analyse et synthèses n°101-2019. [online] (consulté le 01/09/2019) https://acpr.banque-france.fr/sites/default/files/medias/documents/as_101_risque_climatique_banques_fr.pdf

ACPR (2019). Les assureurs français face au risque de changement climatique, Analyse et synthèses n°102-2019. [online] (consulté le 01/09/2019) https://acpr.banque-france.fr/sites/default/files/medias/documents/as_102_risque_climatique_assurances_fr.pdf

ADEME (2010). Les effets rebond des mesures d'efficacité énergétique : comment les atténuer ? ADEME&VOUS N° 24 - 5 mai 2010.

ADEME et CDP. Assessing low Carbon Transition. [online] (consulté le 01/09/2019). http://actproject.net/

BASF (2018). BASF Report 2018 : Economic, environmental and social performance. [online] (consulté le 01/09/2019) http://report.basf.com/2018/en/servicepages/downloads/files/BASF_Report_2018.pdf

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. Nature Climate Change, 7(4), 283.

Beyond Ratings (2019). The material scenario of potential carbon border taxes. [online] (consulté le 01/09/2019). https://beyond-ratings.com/publications/the-material-scenario-of-potential-carbon-border-taxes/

Bishop, P., Hines, A., & Collins, T. (2007). The current state of scenario development: an overview of techniques. Foresight, 9(1), 5-25.

Bootz, J. Monti, R. (2008). Proposition d'une typologie des démarches de prospective participative pour les entreprises. Trois cas illustratifs : EDF RαD, AXA France et BASF Agro. Management & Avenir, 19(5), 114-131.

Bouleau, N. (2013). Prix Mondiaux futurs des ressources épuisables (05/07/2013) [online] (consulté le 01/09/2019) http://www.nicolasbouleau.eu/prix-futurs/

BP statistical review 2018 (2018). [online], (données extraites le 20/06/2019). https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Caldara, D., Cavallo, M., et Iacoviello, M. (2016). Oil price elasticities and oil price fluctuations. international finance discussion papers 1173.

Carney, M. (2015). « Breaking the Tragedy of the Horizon – climate change and financial stability", Speech given by Mark Carney, Governor of the Bank of England, Chairman of the Financial Stability Board, Lloyd's of London, 29 September 2015

CDP (2017). CDP Technical Note on Scenario Analysis. [online] (consulté le 01/09/2019). https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/guidance_docs/pdfs/000/001/430/original/CDP-technical-note-scenario-analysis.pdf?1512736385

CDP (2019). CDP Technical note on science-based targets. [online] (consulté le 01/09/2019). https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/guidance_docs/pdfs/000/000/386/original/CDP-technical-note-science-based-targets.pdf?1489587578

CDSB, SASB (2019). « TCFD Implementation Guide, Using SASB Standards and the CDSB Framework to Enhance Climate-Related Financial Disclosures In Mainstream Reporting »

Centre d'étude et de prospective stratégiques. [online] (consulté 01/09/2019). http://www.ceps-oing.org/prospective-strat%C3%A9gique

Climate Disclosure Standards Board. About CDSB [online]. (consulté le 01/09/2019). https://www.cdsb.net/our-story

Conseil d'analyse économique (2018). Avis de tempête sur le commerce international : quelle stratégie pour l'Europe ?. Les notes du conseil d'analyse économique, n° 46, juillet 2018. [online] (consulté le 01/09/2019). http://www.cae-eco.fr/IMG/pdf/cae-note046.pdf

Corporate Reporting Dialogue. Better Alignment Project [online]. (consulté le 01/09/2019). https://corporatereportingdialogue.com/better-alignment-project/

DATAR (1971). Scénario de l'inacceptable, une image de la France en l'an 2000. La documentation française.

EIOPA (2019). Consultation Paper on an opinion on sustainability within Solvency II. [online]. (consulté le 01/09/2019). https://eiopa.europa.eu/Publications/Consultations/EIOPA-BoS-19-241_Consultation_Paper_on_an_opinion_%20on_sustainability_in_Solvency_II.pdf

Entreprendre.fr. Hermès : les secrets d'un géant du luxe. [online] (consulté le 01/09/2019). https://www.entreprendre.fr/hermes-les-secrets-dun-geant-du-luxe/

Etemad, B and Luciani, J (1991). World Energy Production 1800 – 1985, ISBN 2-600-56007-6, Data digitalized and published with agreement of B. Etemad on TSP dataportal [online], (données extraites le 20/06/2019). http://www.tsp-data-portal.org/

EU Technical expert group on sustainable finance (2019). Report on climate-related Disclosures. [online] (consulté le 01/09/2019).

EU Technical expert group on sustainable finance (2019). Interim Report on Benchmarks. [online] (consulté le 01/09/2019)https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/190618-sustainable-finance-teg-report-climate-benchmarks-and-disclosures_en.pdf

EU Technical expert group on sustainable finance (2019). Technical report on Taxonomy. [online] (consulté le 01/09/2019).https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/190618-sustainable-finance-teg-report-taxonomy_en.pdf

European Commission (2009). Regulation (EC) n°1060/2009 of the European parliament and of the council of 16 September 2009 on credit rating agencies. Journal officiel de l'Union européenne. [online], (consulté le 01/09/2019). https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:302:0001:0031:EN:PDF

European Commission (2017). Guidelines on non-financial reporting (methodology for reporting non-financial information) (2017/C 215/01). Journal officiel de l'Union européenne. [online], (consulté le 01/09/2019). https://eur-lex.europa.eu/legal-content/EN/TXT/%20PDF/?uri=CELEX:52017XC0705(01)&from=EN

European Commission (2018). Plan d'action de la Commission européenne pour une finance durable, (8/03/2018), Bruxelles (BEL) [online] (consulté le 01/09/2019) https://eur-lex.europa.eu/legal-content/FR/TXT/PDF/?uri=CELEX:52018DC0097&from=EN

European Commission (2019). Guidelines on non-financial reporting: Supplement on reporting climate-related information". (2019/C 209/01). Journal officiel de l'Union européenne. [online], (consulté le 01/09/2019). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019XC0620(01)

European Commission (2019). Consultation document on the update of the non-binding guidelines on non-financial reporting [online], (consulté le 01/09/2019) https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/2019-non-financial-reporting-guidelines-consultation-document_en.pdf

European Commission (2019) Summary Report of the Targeted Consultation on the Update of the Non-Binding Guidelines on Non-Financial Reporting Financial Reporting (20 February – 20 March 2019) [online], (consulté le 01/09/2019). https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/2019-non-financial-reporting-guidelines-feedback-statement_en.pdf

ExxonMobil (2019). 2019 Energy & Carbon summary [online] (consulté le 01/09/2019). https://cdn.exxonmobil.com/~/media/global/files/energy-and-environment/2018-energy-and-carbon-summary.pdf

Fawcett, N., and Price, S. (2012). World Oil Demand in the short and long run : a cross-country panel analysis", Bank of England and City University.

Futuribles. [online] (consulté le 01/09/2019). https://www.futuribles.com/fr/qui-sommes-nous/

G8 (2005). Official Documents: Gleneagles Summit July 6-8, 2005. [online] (consulté le 01/09/2019) http://www.g8.utoronto.ca/summit/2005gleneagles/index.html

Generali (2017) Intégration des critères ESG et climat dans la politique d'investissement 2017 [online] (consulté le 01/09/2019) https://institutionnel.generali.fr/sites/default/files/rapport_art_173_2017.pdf

Godet, M. et Durance, P. (2011) La prospective stratégique pour les entreprises et territoires. Paris : Dunod 150p.

Guivarch, C., Rozenberg, J. (2013). Les nouveaux scénarios socio-économiques pour la recherche sur lechangement climatique. Pollution Atmosphérique : climat, santé, société, Le Kremlin Bicêtre : RevuePollution atmosphérique, 2013, Numéro Spécial Climat, pp.1-9.

Hache, E. et al (2019). Vers une géopolitique de l'énergie plus complexe ? Revue internationale et stratégique, vol. 113, no. 1, 2019, pp. 71-81.

Hayward, L. (2015). Barclays: $22 trillion in oil revenue at risk from COP-21 negotiations. The Fuse [online], (consulté le 01/09/2019) http://energyfuse.org/barclays-22-tillion-in-oil-revenue-at-risk-from-cop-21-negotiations/

Hallegate, S. (2009). Strategies to adapt to an uncertain climate change. Global Environmental Change 19 (2009) 240–247.

Hugot, J. et Dajud C. U. (2018). Les nouvelles routes polaires changeront peu la géographie du commerce mondial. La lettre du CEPII N°392, October 2018, CEPII.

I4CE (2018). Getting started on Physical climate risk analysis in finance - Available approaches and the way forward. [online] (consulté le 01/09/2019). https://www.i4ce.org/wp-core/wp-content/uploads/2018/12/I4CE-ClimINVEST_2018_Getting-started-on-physical-climate-risk-analysis.pdf

I4CE (2019). Very few companies make good use of scenarios to anticipate their climate-constrained future. [online] (consulté le 01/09/2019). https://www.i4ce.org/wp-core/wp-content/uploads/2019/02/Very-few-companies-make-good-use-of-scenarios-to-anticipate-their-climate-constrained-future.pdf

I4CE. Re-imagining Disclosure for companies and their 2°C strategy. [online] (consulté le 01/09/2019). https://www.i4ce.org/go_project/re-imagining-disclosure-for-companies-and-their-2c-strategy-2/

IHS Markit. (2017). Climate-Related Financial Risk and the Oil and Gas Sector. [online] (consulté le 01/09/2019) https://www.eenews.net/assets/2017/05/17/document_cw_01.pdf

IEA (2017). Energy Technology Perspectives, Paris : Éditions OCDE, Paris/AIE.

IEA (2018). World Energy Outlook 2018, Paris : Éditions OCDE, Paris/AIE.

IEA (2018). World Energy Model [online] (consulté le 01/09/2019) https://www.iea.org/weo/weomodel/

IEA. Carbon capture, utilisation and storage, A critical tool in the climate energy toolbox [online] (consulté le 01/09/2019) https://www.iea.org/topics/carbon-capture-and-storage/

IEA. Statistics, Global energy data at your fingertips [online] (données extraites le 20 juin 2019). https://www.iea.org/statistics/?country=WORLD&year=2016&category=Energy%20supply&indicator=OilProd&mode=chart&dataTable=INDICATORS

IEA. Statistics, Global energy data at your fingertips » (données extraites le 20 juin 2019). https://www.iea.org/statistics/?country=WORLD&year=2016&category=Energy%20supply&indicator=OilProd&mode=chart&dataTable=OIL

IEA. [online] (consulté le 01/09/2019). https://www.iea.org/about/structure/

IFPEN et Ademe (2018). « Quelle criticité du lithium dans un contexte d'électrification du parc automobile mondial ? » IFPEN [online] (consulté le 01/09/2019) http://www.panorama-ifpen.fr/criticite-du-lithium/

IMF World Economic Outlook reports and database (2019). World Economic Outlook, April 2019 Growth Slowdown, Precarious Recovery [online] (consulté le 01/09/2019) (données extraites le 20/06/2019) https://www.imf.org/en/Publications/WEO/Issues/2019/03/28/world-economic-outlook-april-2019#Full%20Report%20and%20Executive%20Summary https://www.imf.org/en/Publications/SPROLLS/world-economic-outlook-databases#sort=%40imfdate%20descending

IPCC (2000). Special report on Emissions scenarios. Cambridge university press, 608p.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. In Press.

IPCC RCP Database (version 2.0). [online] (données extraites le 20 juin 2019). https://tntcat.iiasa.ac.at/RcpDb/dsd?Action=htmlpage&page=welcome

Jean, S., Martin, P., Sapir, A. (2018). Avis de tempête sur le commerce international : quelle stratégie pour l'Europe ? Les notes du conseil d'analyse économique, n° 46 (juillet 2018)

Kaya Y. (1990). Impact of carbon dioxide emission control on GNP Growth: interpretation of proposed scenarios. In: Paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group. Paris, France.

Le Quéré, C. et. al (2018). Global carbon budget 2018. Earth System Science Data, 10(4), 2141-2194.

Lepetit, M. (2018). Méthodologie d'analyse des scénarios utilisés pour l'évaluation des risques liés au climat par une approche paradigmatique PIB-Pétrole. Chaire énergie & prospérité. [online] (consulté le 01/09/2019). http://www.chair-energy-prosperity.org/publications/methodologie-danalyse-scenarios-utilises-levaluation-risques-lies-climat-approche-paradigmatique-pib-petrole/

Lepetit, M. (2018). Sus au charbon, analyse des politiques d'investissement de l'assurance vie française », Observatoire 173 Climat-Assurance vie. [online] (consulté le 01/09/2019). https://theshiftproject.org/wp-content/uploads/2018/10/2018-11-27_Sus-au-charbon-_Observatoire-173-Climat-Assurance-Vie_The-Shift-Project_V2.pdf

Lepetit, M. (2019). « Deux sons de cloches sur la matérialité du « risque climat » dans l'assurance vie française », Observatoire 173 Climat-Assurance vie. [online] (consulté le 01/09/2019). https://theshiftproject.org/wp-content/uploads/2019/07/2019-07_Observatoire-173_Deux-sons-de-cloche-sur-la-mat%C3%A9rialit%C3%A9-du-risque-climat_The-Shift-Project.pdf

Maddison Project Database, version 2013. Bolt, J. and J. L. van Zanden (2014). The Maddison Project: collaborative research on historical national accounts. [online], (données extraites le 20/06/2019)

Martin, W. (2019) « Europe's mightiest river is drying up, most likely causing a recession in Germany. Yes, really" Business Insider France (22/01/2019)

Mietzner, D., & Reger, G. (2005). Advantages and disadvantages of scenario approaches for strategic foresight. International Journal Technology Intelligence and Planning, 1(2), 220-239.

Moodys (2017). Evaluating the impact of climate change on US state and local issuers [online] (consulté le 01/09/2019) http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2017/12/Evaluating-the-impact-of-climate-change-on-US-state-and-local-issuers-11-28-17.pdf

Moody's (2018). Heat map: 11 sectors with $2.2 trillion debt have elevated environmental risk exposure. [online] (consulté le 01/09/2019) https://www.moodys.com/research/Moodys-Eleven-sectors-with-22-trillion-of-debt-have-elevated--PR_389299

Moody's (2019). Proposed framework to assess carbon risks for high-risk corporate sectors. en ligne] (consulté le 01/09/2019) https://www.moodys.com/researchdocumentcontentpage.aspx?docid=PBC_1147814

NGFS (2019). A call for action Climate change as a source of financial risk. [online] (consulté le 01/09/2019). https://www.banque-france.fr/sites/default/files/media/2019/04/17/ngfs_first_comprehensive_report_-_17042019_0.pdf

O'Neill et al. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global Environmental Change 42 (2017) 169–180. http://dx.doi.org/10.1016/j.gloenvcha.2015.01.004

OCDE (2014). Long-term baseline projections, No. 95 (Edition 2014) OECD Economic Outlook: Statistics and Projections (base de données), https://doi.org/10.1787/data-00690-en (données extraites le 20 juin 2019).

OCDE (2018). The long view: scenarios for the world economy to 2060, OECD economic policy paper, July 2018 No. 22. [online]. (consulté le 01/09/2019). https://www.oecd-ilibrary.org/docserver/b4f4e03e-en.pdf?expires=1564066951&id=id&accname=guest&checksum=6BE5A41FDD78B72BE7F3AB416CC8F332

Oil Change International (2018). Off track, How the International Energy Agency guides energy decisisons towards fossil fuel dependence and climate change [online] (consulté le 01/09/2019) http://priceofoil.org/content/uploads/2018/04/OFF-TRACK-the-IEA-Climate-Change.pdf

Oxfam (2018). Comment les banques françaises financent les énergies fossiles. [online] (consulté le 01/09/2019). https://www.oxfamfrance.org/climat-et-energie/comment-les-banques-francaises-financent-les-energies-fossiles/

Présidence de la République française (2017). Initiative pour l'Europe - Discours d'Emmanuel Macron pour une Europe souveraine, unie, démocratique. [online] (consulté le 01/09/2019) https://www.elysee.fr/emmanuel-macron/2017/09/26/initiative-pour-l-europe-discours-d-emmanuel-macron-pour-une-europe-souveraine-unie-democratique

PRI. Directory of climate scenario tools and table of reference climate scenarios [online] (consultee le 01/09/2019). https://www.unpri.org/climate-change/climate-scenario-analysis-/3606.article

Prudential Regulation Authority (2019). Enhancing banks' and insurers' approaches to managing the financial risks from climate change, Supervisory Statement SS3/19. [online] (consulté le 01/09/2019). https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/supervisory-statement/2019/ss319

Prudential Regulation Authority (2019). Life Insurance Stress Test 2019 : Scenario Specification, Guidelines and Instructions. [online] (consulté le 01/09/2019) https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2019/life-insurance-stress-test-2019-scenario-specification-guidelines-and-instructions.pdf

Prudential Regulation Authority (2019). General Insurance Stress Test 2019 : Scenario Specification, Guidelines and Instructions. [online] (consulté le 01/09/2019) https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2019/general-insurance-stress-test-2019-scenario-specification-guidelines-and-instructions.pdf

Putnam, P. C. (1953). Energy in the Future.

Riahi et al. (2016). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications. An overview. Global Environmental Change (2016), http://dx.doi.org/10.1016/j.gloenvcha.2016.05.009

Rogelj, J., D. et al. (2018). Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., et al]. In Press.

Science Based Targets (2019). Foundations of Science-based Target Setting [online], (consulté le 01/09/2019) https://sciencebasedtargets.org/wp-content/uploads/2019/04/foundations-of-SBT-setting.pdf

Science Based Targets (2019). Science-Based Target Setting Manual Setting [online], (consulté le 01/09/2019) https://sciencebasedtargets.org/wp-content/uploads/2017/04/SBTi-manual.pdf

South32 (2018). Our approach to Climate Change. [online] (consulté le 01/09/2019) https://www.south32.net/docs/default-source/exchange-releases/our-approach-to-climate-change-2018.pdf?sfvrsn=337d59e7_6

S&P Global Ratings (2019). Environmental, Social, And Governance Evaluation Analytical Approach. , [online] (consulté le 01/09/2019)

Tavakoli, A. (2017). How Precisely «Kaya Identity» Can Estimate GHG Emissions: A Global Review.

TCFD (2017). Conference on Climate Scenarios, Financial Risk and Strategic Planning – Summary of Day 2 [online] (consulté le 01/09/2019) https://www.fsb-tcfd.org/wp-content/uploads/2017/12/TCFD-and-BoE-Conference-on-Climate-Scenarios-Financial-Risk-and-Strategic-Planning-Day-2-Summary.pdf

TCFD (2017). Final Report : Recommendations of the Task Force on Climate-related Financial Disclosures [online] (consulté le 01/09/2019) https://www.fsb-tcfd.org/publications/final-recommendations-report/

TCFD (2017). Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures [online], (consulté le 01/09/2019) https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Annex-062817.pdf

TCFD (2017). Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities (June 2017) [online] (consulté le 01/09/2019) https://www.fsb-tcfd.org/publications/final-technical-supplement/

TCFD (2019). 2019 Status Report : Task Force on Climate-related Financial Disclosures: Status Report [online] (consulté le 01/09/2019) https://www.fsb.org/wp-content/uploads/P050619.pdf

TCFD Knowledge Hub. [online] (consulté le 01/09/2019). https://www.tcfdhub.org/

The Economist (2018). How to design carbon taxes, The Economist (18/08/2018) [online] (consulté le 01/09/2019) https://www.economist.com/finance-and-economics/2018/08/18/how-to-design-carbon-taxe

The Shift Project (2017). Le scénario des scénarios de l'AIE. [online] (consulté le 01/09/2019) https://theshiftproject.org/article/le-scenario-des-scenarios-de-laie-aie-aie-aie/

The Shift Project (2018). Analyse du risqué climat : acteurs, méthodologies, perspectives. [online] (consulté le 01/09/2019) https://theshiftproject.org/article/analyse-du-risque-climat-une-etude-du-shift-project-en-partenariat-avec-lafep/

The Shift Project (2018). Lean ICT : pour une sobriété numérique [online] (consulté le 01/09/2019) https://theshiftproject.org/article/pour-une-sobriete-numerique-rapport-shift/

The Shift Project (2019). Scénarios et enjeux de modélisation. [online] (consulté le 01/09/2019).

The World Bank Group (2019). Global Economic Prospects [online] (consulté le 01/09/2019) http://www.worldbank.org/en/publication/global-economic-prospects

Total (2018). Intégrer le climat à notre stratégie. [online], (consulté le 01/09/2019) https://www.total.com/sites/default/files/atoms/files/total_climat_2018.pdf

UN DESA (2019). World Population prospects 2019. [online], (donnée extraites le 20/06/2019). https://population.un.org/wpp/

UNEP FI (2019). Changing course : A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD. [online], (consulté le 01/09/2019) https://www.unepfi.org/wordpress/wp-content/uploads/2019/05/TCFD-Changing-Course.pdf

Uria Martinez, R., Leiby, P. N., Oladosu, G. A., Bowman, D., & Johnson, M. (2018). Using Meta-Analysis to Estimate World Oil Demand Elasticity (No. ORNL/TM-2018/1070). Oak Ridge National Lab.(ORNL), Oak Ridge, TN (United States).

Vailles, C. , Métivier, C. (2019). Very few companies make good use of scenarios to anticipate their climate-constrained future. I4CE [online], (consulté le 01/09/2019) https://www.i4ce.org/wp-core/wp-content/uploads/2019/02/Very-few-companies-make-good-use-of-scenarios-to-anticipate-their-climate-constrained-future.pdf

Wack, P. (1985). Scenarios: uncharted waters ahead. Harvard Business Review, September October, - pp. 73 89.

White, L. (1967). The historical roots of our ecologic crisis. Science, 155(3767), 1203-1207.

Wilkes, W. (2019) « Rhine River Could Run Too Low Again for Shipping in Germany » Bloomberg (10/04/2019) [online] (consulté le 01/09/2019) https://www.bloomberg.com/news/articles/2019-04-10/rhine-river-could-run-too-low-again-for-shipping-in-germany?utm_source=CP+Daily&utm_campaign=7b2d26d3c7-CPdaily10042019&utm_medium=email&utm_term=0_a9d8834f72-7b2d26d3c7-110262049

B. Scenario authors' documentation

BP (2019). BP Energy Outlook2018 edition. [online] (consulté le 01/09/2019). https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019.pdf

Calvin et al. (2016). The SSP4: A world of deepening inequality. Global Environmental Change (2016), http://dx.doi.org/10.1016/j.gloenvcha.2016.06.010

Equinor (2018). Energy Perspectives 2018: A call for action. [online] (consulté le 01/09/2019). https://www.equinor.com/en/news/07jun2018-energy-perspectives.html

Fricko et al. (2016). The marker quantification of the Shared Socioeconomic Pathway 2 : A middle-of-the-road scenario for the 21st century. Global Environmental Change 42 (2017) 251–267.

Fujimori et al. (2016). SSP3: AIM implementation of Shared Socioeconomic Pathways. Global Environmental Change 42 (2017) 268–283.

Grubler et al. (2018). A Low Energy Demand Scenario for Meeting the 1.5°C Target and Sustainable Development Goals without Negative Emission Technologies. IIASA.

GWEC – SolarPowerEurope – Greenpeace (2015). Energy [R]evolution scenarios [online] (consulté le 01/09/2019) https://www.duesseldorf.greenpeace.de/sites/www.duesseldorf.greenpeace.de/files/greenpeace_energy-revolution_erneuerbare_2050_20150921.pdf

IEA (2017). Energy Technology Perspectives, Paris : Éditions OCDE, Paris/AIE.

IEA (2018). World Energy Outlook 2018, Paris : Éditions OCDE, Paris/AIE.

IRENA (2018). Global energy transformation: A roadmap to 2050 (2018 edition). [online] (consulté le 01/09/2019). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Apr/IRENA_Global_Energy_Transformation_2019.pdf

Kriegler et al. (2016). Fossil-fueled development (SSP5): An energy and resource intensive scenario for the 21st century. Global Environmental Change 42 (2017) 297–315

Shell (2016). New lens scenarios, A shift in perspective for a world in transition. [online] (consulté le 01/09/2019). https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/new-lenses-on-the-future/_jcr_content/par/relatedtopics.stream/1519787235340/77705819dcc8c77394d9540947e811b8c35bda83/scenarios-newdoc-english.pdf

Shell (2019). Scenario Sky. [online] (consulté le 01/09/2019). https://www.shell.com/promos/business-customers-promos/download-latest-scenario-sky/_jcr_content.stream/1530643931055/eca19f7fc0d20adbe830d3b0b27bcc9ef72198f5/shell-scenario-sky.pdf

Van Vuuren et al. (2016). Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm. Global Environmental Change 42 (2017) 237–250.

World Energy Council (2016). World energy scenarios 2016, the grand transition. [online] (consulté le 01/09/2019). https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Scenarios-2016_Full-Report.pdf

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