PACTA for Banks Scenarios

Supporting document to the formatted scenarios provided as part of the PACTA for Banks toolkit

Date: 10/10/2022

Version: 1.3.1*

*Version control based on Semverdoc (https://semverdoc.org/) – older versions are available upon request from 2DII. Please request via banks@2degrees-investing.org

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1. Introduction

The PACTA for Banks methodology relies on the measurement of the alignment of climate-relevant sectors in a portfolio with decarbonization scenarios. Scenarios provide important insight into potential future decarbonization pathways that have the potential to achieve the scale of climate change mitigation required to limit the global temperature rise. Used in the context of PACTA for Banks they can help users understand their contributions to climate change but also, importantly, to develop strategies based on insight into the transitions and investments that will need to be made in the real economy.

PACTA for Banks is an open-source methodology and as such is scenario agnostic, allowing for the use of any scenario. However, to be used in PACTA a scenario must have a sufficient level of data granularity. To overcome this issue and to allow users to get started using PACTA, 2DII provides a preselected set of third-party decarbonization scenarios prepared to be used with the PACTA for Banks toolkit. The scenarios are formatted in such a way as to be read into the PACTA for Banks software.

Decarbonization scenarios are developed to meet specific carbon budgets and climate mitigation objectives. To do this they also rely on a series of modelling assumptions and expert judgements about possible futures. The set of scenarios provided in PACTA covers a range of climate change mitigation outcomes, but most importantly ones that look to achieve the goals set out by the Paris Agreement. They also reflect different assumptions and expert judgements about decarbonization pathways to reach these outcomes.

This document gives a brief introduction to climate change scenarios in general, a description of the scenarios included in the toolkit, and explains the methodology used to convert the scenario raw data from third parties' publications into scenarios ready to be used in the PACTA analysis. Note that this document should be read in conjunction with the PACTA for Banks methodology document, which is cited throughout. There is also a wide range of literature and guidance on the development and use of both climate and energy scenarios, to which this document only provides a starting point. We recommend further familiarizing yourself with guidance and recommendations on how scenarios can be used.

The PACTA toolkit contains a collection of scenarios which can be used in the PACTA for Banks Software available at https://www.transitionmonitor.com/pacta-for-banks/.

2. What are decarbonization scenarios?

Climate change mitigation and transition scenarios, herein referred to as decarbonization scenarios, provide one possible pathway for the technology deployment and/or carbon emission that one or multiple sectors and the economy as a whole may follow to reach a targeted goal. These scenarios generally combine modelling of:

- the energy sector, using energy system models (ESM) such as the IEA's World Energy Model (WEM) [1],
- the economy, using models such as the Joint Research Centre's GEM-E3 model [2] and
- the global geophysical system and carbon cycles, using climate models such as MAGICC [3]

Integrated Assessment Models (IAM) [4] that combine this socio-economic, political and physical climate modelling are then used to explore assumptions about how we will use and manage our energy resources and the associated remaining carbon dioxide emissions budget in the future.

These decarbonization scenarios take as their starting point geophysical climate change models developed by the IPCC (Intergovernmental Panel on Climate Change) and other climate scientists. Physical models have been developed that anticipate a range of expected degrees of warming, referred to as the average global mean temperature rise, with the focus usually on the year 2100. Amongst the range of geophysical and IAM scenarios in the IPCC's database global warming is modelled with a statistical range from 7.8 degrees Celsius down to 1.0 degrees Celsius, each with their

[1] WEO model document can be found here https://www.iea.org/reports/world-energy-model

[2] An overview of the GEM-E3 model can be found here https://joint-research-centre.ec.europa.eu/gem-e3_en

[3] A description of the MAGICC model can be found here http://wiki.magicc.org/index.php?title=Model_Description

[4] How are IAM used to study climate change: https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change

associated CO_2 concentration pathways and budgets, as well as an estimate of the probability of achieving the average global mean temperature in 2100. So, when a PACTA for Banks user chooses a decarbonization scenario they are also choosing a background ´remaining´ CO_2 budget that has been taken from a physical climate change model. Some of the main terminology used in relation to climate scenario modelling is defined in Box 1.

There is also now an increasing focus on how the remaining carbon budget is managed in time. An important consideration is whether there is any projected 'overshoot' of this budget prior to 2050, given that early emissions have a greater cumulative impact than late emissions, particularly prior to 2030. The point in time when net zero emissions is achieved is also a consideration, as it is generally defined as when direct emissions by society are compensated by emissions removed by nature and, potentially in the future on a large scale, using technology (see the IPCC definition below).

The decarbonization scenarios provided as part of the PACTA for Banks toolkit either look to translate macro-economic and sectoral carbon budgets into technology pathways for climate critical sectors or to work back from a ´normative´ climate change goal (e.g. 1.5°C average mean global temperature in 2100). These pathways describe the scale and pace of change that would need to be achieved and, with varying degrees of uncertainty, the mix of technologies that will require financing and investment. Note however that for some sectors, technology pathways are not so well defined and hence carbon budgets can only be set at the sector level. This is the case at the moment for the steel, cement and aviation sectors.

Box 1. Definition of key terms used in relation to scenarios

Scenario: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships (IPCC 2022)

Pathway: A temporal evolution of a set of mitigation scenario features, such as greenhouse gas emissions and socio-economic development, towards a future state. Pathways can include narratives of potential futures and solution-oriented decision-making processes to achieve desirable societal goals. They can involve various dynamics, goals and actors across different scales.

Remaining CO_2 budget: Estimated cumulative net global anthropogenic CO_2 emissions from a start year (usually 2018 onwards) to the time that anthropogenic CO_2 emissions reach net zero that would result, at a stated level of confidence, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions.

Net zero emissions: Net zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by natural and anthropogenic CO_2 removals over a specified period. Net zero CO_2 emissions are also referred to as carbon neutrality.

Temperature overshoot: The temporary exceedance of a specified level of global warming, such as 1.5°C. Overshoot implies a peak followed by a decline in global warming, achieved through anthropogenic removal of CO_2 exceeding remaining CO_2 emissions globally. Low or no overshoot scenarios are defined by the IPCC as 1.5°C pathways with a >33% level of confidence, with exceedance potentially reaching 1.6-1.7°C for a temporary period of time.

Integrated Assessment Model: IAMs integrate knowledge from two or more domains into a single framework. They are one of the main tools for undertaking integrated assessments. They may include representations of: multiple sectors of the economy, such as energy, land use and land-use change; interactions between sectors; the economy as a whole; associated GHG emissions and sinks; and reduced representations of the climate system.

Energy System Model: ESMs are used to project the future energy demand and supply of a country or a region. They are also used to simulate policy, economic and technology choices that may influence future energy demand and supply, and hence investments in energy systems, including energy efficiency policies.

Earth System Model: Also referred to as climate models, they are coupled atmosphere–ocean general circulation models in which a representation of the carbon cycle is included, allowing for interactive calculation of atmospheric CO_2 or compatible emissions. Additional components (e.g., atmospheric chemistry, ice sheets, dynamic vegetation, nitrogen cycle, but also urban or crop models) may be included. See also Climate model.

Source: adapted from the IPCC Glossary — Global Warming of 1.5 ºC (ipcc.ch)

3. How can scenarios be used?

Decarbonization scenarios provide potential future pathways to reach a certain goal (e.g. Paris Agreement targets). They do NOT claim to predict the future. As described in the Climate Scenario Primer,[5] 'Human-made climate change is driven by a myriad of societal factors over decades and centuries to come'. The future development of most of these factors is deeply uncertain and will be shaped by our actions. It is thus futile to ask, "What will happen?" and try to predict future climate change. But the future, while inherently uncertain, is not entirely unknowable and in fact can be influenced.

Scenarios are important because they can be used to explore "What can happen?" and even "What should happen?" given the fact that we are able to shape our future. As has been highlighted by the Task Force on Climate-related Financial Disclosures (TCFD) they can allow us to 'challenge conventional wisdom about the future' given the scale and complexity of the changes required. But at the same time it is important to remember that:

1) these scenarios are not predictions of the future. Rather, they are depictions of what the future may look like.
2) there are different assumptions behind each scenario – assumptions can be related to socioeconomic, political or climatic factors and it is important to understand these when interpreting PACTA results.
3) there is usually a stated probability of achieving a specific climate outcome, with most scenarios being based on a relatively conservative 50% or 65% confidence interval.
4) PACTA is scenario agnostic, so any scenario or set of scenarios can be used to measure the alignment of a bank's portfolio. As PACTA aims to measure alignment to the Paris Agreement, it is imperative that at least one scenario used is "Paris aligned" i.e. well below 2^{o}C above pre-industrial levels.

Picking up on the first point that scenarios are not predictions or projections of the future, it is important to have some basic considerations in mind when working with them. Box 2 below highlights five key pointers to bear in mind when using scenarios and we additionally recommend that PACTA users critically compare and contrast different scenarios based on their climate goals and their assumptions.

Box 2. Key pointers on how best to make use of decarbonization scenarios

The Financial Stability Board's TCFD recommends the use of scenarios as a tool to understand the strategic implications of climate change risks and opportunities for businesses, their strategies and their financial performance [6]. Their careful use can potentially inform activities such as disclosures, target setting, transition planning, capital allocation decisions and engagement with investees and counterparties that are misaligned or that have potential.

Scenarios should be used to '*enhance critical strategic thinking'* and importantly in order to *'challenge conventional wisdom about the future'* thereby allowing contrasting different possible futures to be analyzed. In particular they highlight the need for the scenarios selected to be:

1. Plausible. They should be based on a credible technical and socio-economic narrative.
2. Distinctive. They should allow for comparison between different combinations of influencing factors.
3. Consistent. They should have a strong internal logic and each action should have a reaction.
4. Relevant. They should each contribute specific insights into the future strategic implications of climate-related risks and opportunities.
5. Challenging. They should challenge conventional wisdom and explore alternative assumptions about the future.

Once a scenario has been selected, the Institute for Climate Economics (I4CE) emphasizes the importance of correctly interpreting climate scenarios. They provide a framework for doing so, which they illustrate by applying it to a

[5] The SENSES Toolkit, *Climate change scenario primer*, https://climatescenarios.org/primer
[6] TCFD, *The Use of Scenario Analysis in Disclosure of Climate Related Risks and Opportunities – Technical Supplement*, June 2017

number of scenarios, including those of the IEA as provided as part of PACTA for Banks [7]. (see footnotes to read the full report)

A further step which is suggested in guidance developed by the Institut Louis Bachelier, is to compare the alignment of counterparties against different scenarios with the same goal [8]. By doing this it is possible to be further informed about the possible future risks, uncertainties and opportunities.

All scenarios provided as part of PACTA for Banks contain a series of critical parameters and assumptions that define the key drivers and development pathways over the scenario's timeframe. Examples of the key assumptions behind a number of important scenarios are provided in Table 1.

When choosing to use a specific scenario for a sector or at portfolio level we recommend considering the following questions:

- What are your strategic objectives for climate change mitigation and on what time scale?
- Does the policy context in your country or region mean that certain scenarios are incompatible or not ambitious enough?
- Do you need to measure alignment at a global or regional level?
- Does the scenario cover the sectors you are interested in and is the scenario based on a credible and up to date decarbonisation pathways and technology roadmaps for the sector?
- Does the scenario developer provide a set of scenarios with different ambition levels, thereby allowing for the relative distance from climate change mitigation goals to be evaluated?

How does the scenario account for the future role of certain technologies such as nuclear power generation, Carbon Capture Utilisation & Storage (CCUS), as well as the use of nature-based solutions such as forestry? Each scenario represents a certain view on how decarbonisation could take place., Because of this it is recommended that PACTA users compare the alignment trajectories given by different scenarios for the same sector. This will allow for a comparison of different scenario decarbonisation pathways based on varying model assumptions. For example, to the market take-up of new technologies such as electric vehicles or the assumed role of energy efficiency in reducing the energy intensity of industry. This in turn suggests a focus on the following further questions:

- For a given sector, by how much can assumptions for the contribution of energy efficiency and demand reduction vary between scenarios?
- For a given sector by how much can market assumptions for the growth in the production, sales or installation of new technologies vary between scenarios?
- For a given sector what is the balance between commercially available and prospective new technologies, and how fast are stranded technologies and assets removed from the market?
- To what extent would you like to identify opportunities to support technologies that are currently still under development?

How the regional dimension of climate change mitigation is addressed within scenarios is also an important consideration. Here are some further questions to prompt a better understanding:

- To what extent are economic assumptions relating to, for example, carbon pricing applied differently at a regional level?
- To what extent are emerging economies given more allowance to use fossil fuel energy, or to transition more slowly in some sectors, in the near-term in support of economic development goals?

[7] I4CE, *Understanding transition scenarios – eight steps for reading and interpreting these scenarios*, November 2019

[8] See the chapter in the Institut Louis Bachelier et al. (2020) *alignment cookbook* on choosing one or several scenarios and associated trajectories.

- How is the concept of a 'just transition' [9] factored into the development of the scenario as a whole and each sectoral pathway?

A further aspect of scenarios is how major disruptive events such as the Covid 19 pandemic and the Ukraine-Russia energy crisis can be accounted for. Box 3 provides a brief discussion of how these types of events have been incorporated into modelling assumptions by scenario developers.

Box 3 Accounting for major disruptive events in the PACTA alignment assessment

Climate scenarios are designed to explore potential future pathways to achieve climate goals. If there are changes in the economic assumptions that underpin modelling of the projected pathway then these pathways will need to be recalibrated by the scenario developer. The scenarios provided for use with PACTA are generally updated on a 12-month cycle. Any major change in the modelling assumptions will likely therefore be accounted for in the next iteration of the scenario publication and dataset.

For example, if the scenario originally assumed that CO_2 emissions from the power sector in Europe would remain constant for the next 5 years, then the current European energy crisis – which could see a short-term increase in the use of coal power generation – would require a recalibration of this assumption. This may then result in adjustments to the pathway for the power sector. As the crisis with its related economic implications and policy response is ongoing, it is difficult to fully assess the likely impact that this will have on the carbon budget and hence the associated recalibration of the climate scenario models.

Another recent example comes from the transport sector, and in particular aviation, where the COVID 19 pandemic led to scenario developers making assumptions about the post-pandemic recovery to the 'new normal'. Both the IEA and JRC introduced into their Autumn 2020 and 2021 scenario iterations new assumptions about the likely rate of recovery in passenger journeys to pre-pandemic levels, as well as potentially more permanent changes in travel patterns and modes that may have been triggered by the pandemic. These new assumptions will be tested in subsequent iterations going forward. Until these new scenarios were made available some banks, for example, were using aviation emissions figures for 2019 as a pre-pandemic benchmark.

The reflection of unforeseen disruptive events in the next iteration of scenarios will depend on the timing of their development and release. This means that a PACTA alignment assessment should be updated based on new scenarios that introduce assumptions about the impact of the disruption as and when they are ready.

4. The pre-selected scenarios

A number of scenarios has been pre-prepared for use in the PACTA for Banks toolkit. The scenarios and the organizations that have developed them are as follows:

- The International Energy Agency (IEA): The World Energy Outlook (WEO) and Energy Technology Perspectives (ETP) scenario sets, including the Net Zero by 2050 scenario.
- The European Commission's Joint Research Centre (JRC): the Global Energy and Climate Outlook (GECO) scenario set, including a 1.5°C scenario.
- The Institute for Sustainable Futures (ISF): the sectoral pathways to net zero emissions developed for the Net Zero Asset Owners Alliance (NZAOA) [10].

The majority of the scenarios provided by 2DII in the PACTA for Banks toolkit are developed by the International Energy Agency (IEA). Contrasting 1.5 °C, net zero scenarios developed by the IEA, the JRC and ISF are provided. Each of these

[9] A 'just transition' is defined by the ILO as '*greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities and leaving no one behind*.'

[10] The NZAOA commissioned the Institute for Sustainable Futures (ISF) at the University of Technology Sydney (UTS) to apply their One Earth Climate Model to specific high emitting sectors. The scenario documentation can be found here: https://www.unepfi.org/wordpress/wp-content/uploads/2020/12/OECM-Sector-Pathways-Report-FINAL-20201208.pdf

scenarios contain some important differences in the modelling assumptions which we will highlight later in this section. It is advisable to read the full documentation and assumptions behind each model before making decisions based on alignment to the respective scenarios (links are provided below).

It is also important to note that it is not possible to access the raw data underlying each of the scenarios as part of the PACTA for Banks toolkit. Instead, if required, you can access it though a paid contract with the International Energy Agency. The data underlying the GECO scenarios, as well as the IEA and ISF net zero scenarios is, however, free to obtain as of the time of writing.

4.1 The IEA scenarios

The IEA scenarios form part of two linked but separate energy models and publications, the Energy Technology Perspectives (ETP) and the World Energy Outlook (WEO). The Net Zero 2050 scenario forms an extension of the WEO, which is updated to its 2021 edition in this release, and has its own supporting documentation [11]. Both are based on the IEA World Energy Model (WEM).

The WEO provides insight into the energy sector, with a focus on pathways for the fossil fuel and power generation sectors. The ETP covers the buildings, transport and heavy industrial sectors. In PACTA, it is used for industry and transport, namely the steel, cement and automotive sectors. It provides pathways with a time horizon from 2017 to 2070. In contrast, the WEO only extends until 2050.

The WEO and ETP each provide sets of scenarios, covering current stated policies, orderly policy transitions in response to the Paris Agreement, as well as ambitious sustainable development and net zero transitions towards meeting specific climate goals. The IEA scenarios therefore allow for a selection to be based on the overall strategic objectives for climate mitigation and the extent to which each scenario deviates from current climate change policies. The main differences are summarized below and in table 1. The table provides a comparison on the main fundamentals of the IEA WEO SDS Paris aligned scenario and the three 1.5°C, net zero scenarios of the IEA, the JRC and the ISF.

Energy Technology Perspective (ETP) 2017

The ETP 2017 is a legacy scenario set that continues to be provided in order to support the tracking of performance against it’s 2 Degrees and Beyond 2 Degrees scenarios, the later being a forerunner to the Net Zero Emissions by 2050 scenario published in 2020. It has also been, until the inclusion in this release of GECO scenario sets, an important reference scenario set for the automotive sector. It consists of three contrasting scenarios:

The Reference Technology Scenario (RTS): This is a baseline scenario that considers ambitions as reflected by current policies. This scenario misses the targets set in the Paris Agreement but is considerably better than a business as usual scenario, with a modelled outcome of limiting global temperature rise to 2.7°C by 2100. The RTS is similar to the STEPS scenario in the WEO (discussed below). (IEA, 2017)

The 2 Degrees Scenario (2DS): This scenario sets out a rapid decarbonization pathway in line with the Paris Agreement. It is not as ambitious as the B2DS described below. If all the targets are achieved as set out by this scenario there would be at least a 50% chance of limiting global temperature rise to 2°C by 2100. (IEA 2017)

The Beyond 2 Degrees Scenario (B2DS): This scenario aims to limit with a 50% chance global temperature rise to 1.75°C above pre-industrial levels. This scenario does not necessarily follow the most economically efficient pathway. However, it does not depend on the breakthrough of unforeseen technologies. i.e. all technologies included in the ETP are already commercially available or will be within the time frame of the scenario.[12] Energy sector emissions are anticipated to reach net zero around 2060, achieved through a heavy reliance on bioenergy with carbon capture and storage. (IEA, 2017)

IEA, Energy Technology Perspective (2017)

[11] IEA, Net Zero 2050, published May 2021 https://www.iea.org/reports/net-zero-by-2050

[12] Note that this is what the authors (i.e. the IEA) define as being breakthrough or unforeseen technologies. This is of course subjective so it should be noted as an assumption.

Energy Technology Perspectives (ETP) 2020

This update of the ETP modelling and scenario set is broadly consistent with the 2019 edition of the World Energy Outlook (WEO). The time horizon has been extended from 2060 to 2070 and the modelling incorporates updated assumptions for gross domestic product (GDP) and energy prices to reflect the effects of the global Covid-19 pandemic. In line with the WEO 2019, the baseline scenario was changed to the Stated Policies Scenario and the two Paris aligned scenarios replaced by the new Sustainable Development Scenario (SDS).

The **Stated Policies Scenario:** This scenario takes into account the influence of energy and climate related policy commitments that have already been made of which have been announced, as of 2019. This includes Nationally Determined Contributions under the Paris Agreement. It is intended to provide a baseline against which the additional policy actions and measures contained within the more ambitious Sustainable Development Scenario can be benchmarked.

Sustainable Development Scenario (SDS): This scenario aims to meet stricter sustainable development goals. This requires rapid and widespread changes across all parts of the energy system. It is aligned with the goals set out in the Paris Agreement, with a 50% chance of limiting global temperature rise to 1.65°C by the end of the century, as well as objectives related to universal energy access and cleaner air. These efforts are shared amongst multiple fuels and technologies. (IEA, 2019)

IEA, Energy Technology Perspectives (2020)

World Energy Outlook (WEO) 2019

The WEO 2019 is a legacy scenario set that continues to be provided in order to support the tracking of performance against the original assumptions contained within its three scenarios. It is also important to note that WEO 2019 are ETP 2020 are consistent and therefore complement each other in terms of their background modelling.

Current Policies Scenario (CPS): This is a 'business as usual' scenario, i.e. it explores what the future may look like based on what is happening today and assuming no policy changes. In the CPS energy demand rises by 1.3% each year to 2040. This scenario would represent a 50% chance of limiting global temperature rise to 3.2°C by 2100. (IEA, 2019)

Stated Policies Scenario (STEPS): This scenario incorporates policies declared today (2019). The goal with this is to assess what the world may look like in the future based on policies that have currently been announced. In contrast to the CPS, in the STEPS energy demand rises by 1% per year until 2040. More than half of this growth in demand is met by solar photovoltaics (PV) while natural gas enabled by trade in liquefied natural gas (LNG) accounts for a third. Oil demand plateaus in 2030. Despite this, the global economic and population growth means that there is no peak in global emissions ahead of 2040 and hence globally shared sustainability goals (like those set out in the Paris Agreement) are missed. If all the targets are achieved as set out by this scenario there would be at least a 50% chance of limiting global temperature rise to 2.7°C by 2100. (IEA, 2019)

Sustainable Development Scenario (SDS): This scenario aims to meet stricter sustainable development goals. This requires rapid and widespread changes across all parts of the energy system. It is aligned with the goals set out in the Paris Agreement, with a 50% chance of limiting global temperature rise to below 1.65°C by the end of the century, as well as objectives related to universal energy access and cleaner air. These efforts are shared amongst multiple fuels and technologies. (IEA, 2019)

IEA, World Energy Outlook (2019)

World Energy Outlook (WEO) 2020 and 2021

In these subsequent updates of the WEO the STEPS and SDS scenarios were continued in 2020 and 2021. Changes and updates to the assumptions were made to both these main scenarios, which were described under the previous description of WEO 2019.

The new Net Zero Emissions by 2050 scenario was introduced for the first time as a concept in the WEO 2020, then as a separate publication based on a fully modelled scenario in May 2021 and subsequently with minor updates as part of WEO 2021. Note that the WEO 2021 SDS and NZE assumptions are documented and compared as part of Table 1 below.

Net Zero Emissions by 2050 (NZE) This scenario extends the SDS scenario in order to target net-zero emissions. The scenario responds to the increasing number of countries and companies that have made commitments to reach net zero emissions earlier combined with the aim of limiting the rise in global temperatures to 1.5°C by the end of the century (with a 50% probability). In particular it explores the actions needed in the period to 2030 in order to be on track to achieve net zero emissions by 2050, including the need to end new fossil fuel exploitation from 2021 onwards and to avoid stranded assets across sectors. The original May 2021 documentation is provided below, as many of the scenario and sectoral pathway assumptions remain unchanged.

IEA, World Energy Outlook (2020)

IEA, World Energy Outlook (2021)

IEA, Net Zero by 2050 (2021)

4.2 The European Commission's Joint Research Centre (JRC) scenarios

The scenarios of the European Commission are developed by the Joint Research Centre, which is the Commission's science service in support of policy making. The scenario set is published as part of the JRC's annual Global Energy and Climate Outlook (GECO). The GECO has a basis in energy-economic models that are used by the JRC to inform policy making by the Commission, combining the use of a global energy model (POLES) and a global economic model (GEM-E3). The tool live MAGICC was used to model the global warming implications. It provides pathways for all PACTA sectors, with the exception of cement.

Global Energy and Climate Outlook (GECO) 2021

The 2021 edition of the Global Energy and Climate Outlook (GECO) is provided. This edition is timely because it takes stock of the potential impact of policy updates made by G20 countries ahead of and during the 2021 United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) in Glasgow, including nationally determined contributions (NDCs) and long-term net-zero emission targets. The time horizon extends to 2070. The focus on G20 emitters is accompanied by detailed modelling and analysis of how each country can achieve its climate goals.

Current Policy (CurPol) This scenario models at a macro-economic level the effect of enacting current policies that have already been adopted up until 2019. If there are NDC targets at national level but no policies, then these are not taken into account. Macro-economic projections for GDP and population growth are combined with the modelled effects of policies on energy prices and technology development and deployment in order to then make projections for changes in energy systems and CO_2 emissions. The effects of the Covid-19 pandemic on the energy system are factored into the modelling of growth and in particular on the transport sector. The global temperature outcome of the scenario is not specifically stated in the scenario literature, but the charts indicate greater than 3°C [13].

1.5°C Unified (Unif) This scenario represents an economically efficient pathway to achieving 1.5°C. The scenario assumes low overshoot by 2050 (1.7°C) with global net-zero GHG emissions reached before 2070. It assumes application of a single global carbon price from 2021 onwards and that this functions as the main policy driver. It has a limited reliance on carbon capture and storage technologies and does not consider financial transfers between countries to implement mitigation measures. If all the targets are achieved as set out by this scenario there would be at least a 50% chance of limiting global temperature rise to 1.5°C by 2100.

JRC, Global Energy and Climate Outlook (2021)

[13] See Figure 3 on page 13 of Keramidas et al, *Global Energy and Climate Outlook 2021: Advancing towards climate neutrality*, EUR 30861 EN, Publications Office of the European Union, Luxembourg, 2021,

4.3 Institute for Sustainable Futures scenario

Sectoral pathways to Net Zero emissions: This scenario was created upon the request of the Net Zero Asset Owners Alliance (NZAOA). It presents a contrasting net zero scenario to that of the IEA, with a focus on existing, mature technologies, the exclusion of carbon capture technologies to achieve net zero and greater overall investment in renewable energy and demand-side efficiency. The scenario is an output of the One Earth Climate Model (OECM). The main scenario assumptions are documented as part of Table 1 below. If all the targets are achieved as set out by this scenario there would be at least a 66% chance of limiting global temperature rise to 1.5°C by 2100. Users of this scenario are encouraged to look at the ISF NZ scenario documentation.

ISF, Sectoral Pathways to Net Zero Emissions (2020)

Table 1. Comparison of the main modelling parameters and assumptions underpinning the four Paris Aligned scenarios

The main scenario parameters and assumptions		IEA WEO 2021 SDS scenario	IEA Net Zero by 2050 scenario	ISF Net Zero scenario	JRC GECO 1.5°C Unified scenario
Overall scenario targets	Average global temperature target in 2100	1.6°C	1.4°C	1.5°C	1.5°C
	Probability of achieving warming goal by 2100	50%	50%	66%	50%
	Overshoot before 2050 (temperature reached)	Low overshoot (1.7°C)	No overshoot (1.5°C)	No overshoot (<1.5°C)	Low overshoot (1.7°C)
	Global annual CO_2 emissions [1]	27 Gt CO_2 in 2030 Net zero in 2070	21 Gt CO_2 in 2030 Net zero in 2050	12.2 GtCO_2 in 2030 Net Zero in 2050	39.1 GtCO_2 in 2030 Net zero before 2070
	Cumulative global CO_2 budget for whole time horizon	790 Gt CO_2	500 GtCO_2 (2020-2100)	450 GtCO_2	500 GtCO_2 (2018-2100)
Coverage	PACTA sectors for which alignment can be measured	Fossil fuel, power	Fossil fuel, power, automotive (LDV)	Fossil fuel, power, cement, steel and aviation	Fossil fuel, power, automotive (LDV, HDV), steel and aviation
	Geographical resolution [2]	Regional pathway for power only. Global pathway for fossil fuels.	Global pathway	Global, EU and North America pathways. Regional pathways for power.	Global pathway with regional pathways for power
	Time horizon and intervals [2]	10-year intervals through to 2070	10-year intervals through to 2050	5-year intervals through to 2050	5-year intervals through to 2050
Model uncertainty	Physical climate change scenario or model used	Modelled based on emissions using the MAGICC climate model	Modelled based on emissions using the MAGICC climate model	Modelled based on emissions using the MAGICC climate model	Modelled based on emissions using the MAGICC climate model
	Main identified sources of model uncertainty	Covid uncertainties, behavioral changes, CCUS for fossil fuels	Behavioral change, bioenergy, CCUS for fossil fuels	Behavioral change, large-scale deployment of renewables [4]	Carbon price and mitigation policies
	Main assumptions on technology maturity	60-65% of required CO_2 reductions are from technologies currently commercially deployed.	50-60% of required CO_2 reductions are from technologies currently at demonstration or prototype stage.	Only considers theoretical technologies that have demonstrated proof of concept.	A technology learning-curve approach is applied.
	Sectors or technologies for which a sensitivity	Delayed Recovery Scenario, All Electric Case (for road transport)	Behavioural changes, bioenergy, CCUS for fossil fuels	-	-

	analysis is carried out				
Socio-economic assumptions	Global population	9.2 billion (2040)	8.5 billion (2030) 9.6 billion (2050)	7.7 billion (2030) 9.7 billion (2050)	8.5 billion (2030)
	Economic growth (2020 baseline)	+3.0% GDP per year (to 2050)	+45% GDP (2020-2030) +100% GDP (2020-2050)	+100% GDP (2020-2050)	+2.5% GDP per year (to 2050) +137% GDP (2020-2050)
	Carbon price geography	Regional variation in pricing	Regional variation in pricing	Minimum global CO_2 price	Single global carbon price
	Indirect/shadow carbon price [5]	63$ tCO_2 (2025) 140$/$tCO_2$ (2040)	130$ tCO_2 (2030) 250$/$tCO_2$ (2050)	-	-
	Incorporates Covid-19 pandemic recovery assumptions?	Yes, integrated into economic growth and sectoral recovery assumptions	Yes, integrated into economic growth and sectoral recovery assumptions	2 base years included (one without COVID effect, and one with estimation of COVID effect) – not included in the projection	Yes, integrated into economic growth and sectoral recovery assumptions
Energy model assumptions	Primary Energy demand reduction	17% less in 2030 compared to 2019	7% less in 2050 compared to 2020	8% less in 2050 compared to 2020	7% less in 2050 compared to 2020
	Fossil fuel use and exploitation	Fossil fuel share in the primary energy mix falls around 70% by 2030	No new development or exploitation from 2020 onwards.	Emissions from fossil fuel must decline by more than half by 2030.	Fossil fuel share in the primary energy mix falls around 70% by 2050
	The role of renewable energy	Renewable energy generation share increases from 30% in 2019 to 40% in 2030	Renewable energy generation is 60% of global power generation by 2030	Renewable energy generation share increases from 30% in 2019 to 40% in 2025	Renewable energy accounts for 78% of global power generation in 2050.
	The role of nuclear energy	36% growth in nuclear capacity by 2040	76% growth in nuclear capacity by 2040	No new nuclear power stations	337% growth in nuclear capacity by 2040.
	The role of carbon capture utilization and storage	2.9 Gt CO_2 after 2050	7.6 Gt CO_2 in 2050	No use of the technology	4.6 Gt CO_2 in 2050
	The role of bioenergy with carbon capture and storage (BECCS) [6]	Small level of BECCS is included.	-	BECCS is excluded	BECCS is assumed to play an important role in some countries.
	Land use implications of bioenergy production	-	+24% increase from 2020 to 2050	-	-
	Use of nature-based solutions as offsets [7]	80-240 Gt CO_2 in 2050	No offsets assumed	152 Gt CO_2 in 2050	Use of forest management to mitigate emissions.
Notes:					

1. This represents the absolute CO_2 emissions target that needs to be achieved to maintain alignment with the scenario carbon budget in 2030 and 2050. These targets are taken from the carbon budget corresponding to the scenario. This carbon budget is taken from modelling using the MAGICC tool. The timing of emissions reductions and the carbon budget drawdown up to 2030 makes a significant impact on the probability of achieving a climate goal, emphasising the importance of contrasting different scenarios.
2. Regional pathways can be economically defined (e.g. OECD/non-OECD) or geographically defined, which may include continental regions (e.g. Asia, South America) as well as countries as regions (e.g. China, India)
3. To plot alignment trajectories a linear interpolation is made between the data points in the scenario. Ideally this should be for the 5-year time horizon but in some cases a 10- year horizon has to be used.
4. This scenario specifically excludes or minimises the reliance on technologies with a high degree of uncertainty, specifically CCUS, large hydropower and nuclear power.
5. The shadow carbon price is the pricing factored into economic decision making, thereby making high carbon technologies less competitive.
6. Bioenergy with carbon capture and storage (BECCS) is the combination of heat and power generation using bioenergy sources such as biomass with the use of technologies to capture and store the CO_2 emissions from combustion.
7. Nature-based solutions are carbon sinks of natural origin, such as forests or plantations, that are conserved, restored or better managed in order to achieve a net reduction in CO_2 emissions.

5. Methodology for converting the scenarios into PACTA input files

The following section covers how the data from the scenario developers is converted into the input files that are provided as part of the PACTA for Banks toolkit.

While the methodologies to convert the scenarios into PACTA inputs are already defined, i.e. the use of the market share approach (see section 1.10 of the PACTA for Banks methodology document), for some sectors (mainly steel, cement and automotive) 2DII sometimes has to make some additional assumptions when preparing the scenario files. These are documented below and should allow a user to obtain the same PACTA scenario file from the scenario developer's data.

It follows that a user may also choose their own assumptions and can still use the scenario in PACTA as long as the methodology set out in the PACTA methodology document is adhered to. Note that the user would then need to substitute the raw scenario data provided with their own calculations for the appropriate sector. It is also important that these assumptions are documented in the same way that they are here.

5.1 Power and Fossil Fuels

For these sectors, the technology roadmaps taken from the IEA WEO, JRC GECO and the ISF One Earth Climate Model (OECM) models provide the data points required to determine the sectors technology mix and to make alignment measurements using PACTA – namely the installed power generation capacities for the different technologies and the production volumes for oil, natural gas and coal based on the proxy of primary energy supply [14].

The market share approach is used to attribute the macro-economic decarbonization trajectories of the scenario to micro-economic actors (i.e. companies). The formula used to calculate target trajectories for each micro-economic actor is different for high carbon and low carbon technologies. De9rcarbon technologies follow the overall rate of decline of the market for the technology in the scenario whereas low carbon technologies must, regardless of their starting point, make investments in new capacity in proportion to their size and what is anticipated for the sector as a whole [15].

Please refer to section 2.3 of the PACTA for Banks Methodology document for a full description.

5.2 Automotive

For this sector, the technology roadmaps provided by the **IEA NZE** and **GECO** models provide data points that can be used as the basis for determining the sector technology mix and to make alignment measurements using PACTA. Both scenarios provide future anticipated sales volumes for vehicles. At a global level, these sales are taken as a proxy for the production volumes of Internal Combustion Engine (ICE), hybrid and Electric Vehicles (EV). As in both cases data points are not provided for 2027 (corresponding to the 5 years production forecast time horizon), interpolation has to be used to obtain values for this and the intermediate years.

Like the fossil fuel and power sectors, the market share approach is used to attribute the macro-economic decarbonization trajectories of the scenario to micro-economic actors (companies, bank portfolios, etc.). The formula used to calculate target trajectories for each micro-economic actor is different for high carbon ICE and low carbon hybrid and EV technologies. High carbon technologies follow the overall rate of decline of the market for the technology in the scenario whereas low carbon hybrid and EV production must, regardless of each companies starting point, make investments in new production in proportion to their production capacity and the proportional increase in production anticipated for the sector as a whole.

[14] Note that in the WEO data set there has been a shift from consumption of primary energy to the supply of primary energy, which is considered to be an improved proxy for production.

[15] See section 2.4 on p48 of the PACTA for Banks methodology document for a more detailed explanation as to how the scenario benchmark targets are calculated.

For IEA NZE

In the IEA NZE documentation, the following data points are provided:

- total electric car sales in 2020 and 2030 [16],
- the proportion that these sales represent of Light Duty Vehicle (LDV) sales in 2020 and 2030 [17], and
- the proportion of the LDV electric car sales in 2020 and 2030 that are battery electric and plug-in hybrid electric.

This allows the remaining proportion of ICE LDV sales to be determined, as well as the sales volumes of battery electric ('electric vehicles' in PACTA) and plug-in hybrid electric vehicles ('hybrid' in PACTA).

The sales are then calculated as follows for each scenario, using % retirement rates interpolated from those provided by the scenario developer and with all changes ($\Delta_{\mathrm{t1-t0}}$) calculated over a 1-year time horizon:

$$\Delta_{\mathrm{t1-t0}} sales^{GECO2021} = \Delta_{\mathrm{t1-t0}} stocks^{GECO2021} + (retireent\ rate\ _{t0}^{GECO\ 2021} * \ stocks_{t0}^{GECO\ 2021})$$

Table 2. IEA NZE Light Duty Vehicle (LDV) data points for the automotive sector

PACTA LDV technologies	**Global sales (millions of vehicles)**			
	2020	**% sales**	**2030**	**% sales**
ICE (including mild hybrid)	106.3	96%	39.4	38.4%
Plug-in electric hybrid	1.3	1.2%	7.2	7.0%
Electric vehicle	3.1	2.8%	56.0	54.6%
Total LDV technologies	*110.7*	*100%*	*102.6*	*100%*

For IEA ETP

In the case of the IEA **ETP 2017** scenario set, neither production nor sales values are provided, only the evolution of the overall stock of vehicles. A conversion must therefore be made to estimate the sales, which requires an estimate of the number of vehicles that are retired in any 1-year interval. This is calculated as follows, using the IEA ETP 2015 global data as the basis and with all changes ($\Delta_{\mathrm{t1-t0}}$) calculated over a 1-year time horizon:

$$\Delta_{\mathrm{t1-t0}} sales^{ETP2017} = \Delta_{\mathrm{t1-t0}} stocks^{ETP2017} + retirements^{ETP2015}$$

where retirements are calculated from the ETP 2015 as follows:

$$retirements^{ETP2015} = \mathrm{sales}^{\mathrm{ETP2015}} - \Delta_{\mathrm{t1-t0}} \mathrm{stocks}^{\mathrm{ETP2015}}$$

The time series of interpolated values for *retirements* $^{ETP\ 2015}$ is provided in the Annex of this report. The retirement values are calculated for the ETP 2015 2DS scenario, as there is no other consistent scenario between the update from ETP 2015 to 2017.

[16] See p-14 of the IEA, Net Zero Energy by 2050 report of May 2021

[17] See p-124, figure 3.23 of the IEA, Net Zero Energy by 2050 report of May 2021

Table 3. Retirement rate time series calculated from ETP 2015 2DS scenario (millions of vehicles) **Technology**

	2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
ICE	48.020	48.020	48.020	48.020	48.020	53.289	53.289	53.289
Hybrid	4.815	4.815	4.815	4.815	4.815	9.913	9.913	9.913
Electric	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fuel Cell	0.000	0.000	0.000	0.000	0.000	0.186	0.186	0.186

5.3 Steel and Cement

For the steel and cement sectors, the preselected scenarios do not currently contain production volumes per technology in the same way that they are provided for the power, fossil fuel and automotive sector. They do however give absolute production and absolute CO_2 emissions at the sector level. Considering this PACTA draws upon a sectoral level metric to measure alignment - the emissions intensity metric (detailed in section 2.4 of the PACTA for Banks methodology document). This metric normalizes CO_2 emissions to a unit of production, in this case 1 tonne of steel or cement. Note that the use of this metric for steel and cement is subject to change as and when technology level production trajectories are made available.

The following section documents how the emissions intensity scenario benchmarks are calculated for the **IEA ETP 2017/2020, IEA NZE 2021, GECO 2021** and **ISF NZ 2020** scenarios respectively. For ETP, the calculations are only made for the scenarios for which data is provided – namely the 2DS (ETP 2017) and SDS (ETP 2020) scenarios. For GECO 2021 it is currently only possible to include steel as cement emissions are currently covered in a border “non-metallic minerals” sector. Meaning the isolation of cement emissions is not feasible.

Calculating scope 1 emission intensity

IEA ETP, IEA NZE and GECO

Material production (Mt) for both cement and crude steel are taken from the scenario dataset. As are Scope 1 (direct) CO_2 emissions (Mt CO_2) from cement and iron and steel processes.

Scope 1 carbon-intensity targets in tons of CO_2 per ton of product for each given year are then calculated as follows:

$$\mathrm{EI}^{\text{Sector scope1}} = \frac{E_t^{\text{Sector } scope \text{ 1}}}{P_t^{\text{Sector}}}$$

Where:

“Sector” denotes the industry,

“EI” is the sector’s scope 1 emissions intensity,

‘E’ is the sector’s absolute emissions (CO_2) in a specific year t and

P is the sector’s production in the same year t.

The same input data and calculation steps are used to calculate steel scope 1 emissions in GECO 2020 and 2021.

ISF NZ

In the case of the ISF NZ scenario, the scope 1 emissions are calculated as follows:

$$Emission\ Intensity = \frac{\sum_{technology} Emission\ intensity_{technology} * Technology\ Mix_{technology}}{Production\ of\ steel}$$

Calculating scope 2 emission intensity

IEA ETP and GECO

To calculate the scope 2 emissions intensities, two inputs are needed:

- The total electricity consumption of the sector being assessed
- The emission intensity of the power sector

The emissions intensity of the global power sector is calculated using the absolute CO_2 emissions as well as the gross electricity generation of the power sector.

Both the direct CO_2 emissions from power generation (in Mt CO_2) as well as the gross electricity generation (in TWh) for the power sector are provided by the respective scenario providers. With these two inputs the emission intensity (g CO_2 /MWh) for power generation is calculated as follows:

$$\mathrm{EI}^{\mathrm{Power}} = \frac{E_t^{Power}}{P_t^{\mathrm{Power}}}$$

Where:

"EI" is the power sector's scope 1 emissions intensity,

'E' is the sector's absolute scope 1 emissions (CO_2) in a specific year t and

P is the sector's power production in the same year t.

Scope 2 absolute emissions for the steel and cement sector are calculated by multiplying the electricity consumption of the respective sector by the power sector emission intensity. In ETP scenarios, the electricity consumption of the steel and cement sectors are provided in units of Mtoe (million tonnes of oil equivalents), so a conversion factor must be used to obtain a value for electricity in TWh:

$$EI^{Sector\ scope\ 2} = \left(E_t^{\mathrm{Scope\ 2\ energy}}.11.63.EI_t^{Sector\ power}\right)$$

where multiplying by 11.63 is converting MToe to Tera Watt hours

IEA NZE 2050

According to the IEA´S NZE scenario there will be a gradual shift in the mix of energy sources used in steel and cement production processes (see Table 4). To calculate the emissions intensities for this scenario, additional assumptions need to be made to the methodology used for IEA ETP, namely, to estimate the scope 3 [18] emissions related to the use of hydrogen as a process gas. Hydrogen can be produced using a number of different processes, each of which have widely differing emissions intensities. Although the use of hydrogen is only expected to play a significant role in the scenario from 2030 onwards, the target emissions intensities later in the scenario will influence the calculation of convergence trajectories that start in 2021. This applies to both steel and cement.

Accounting for emissions from hydrogen production is necessary because of its introduction into the process of both steel and cement, replacing coking coal in the former and fuel to fire kilns in the latter. It follows that the emissions intensity being calculated from the IEA NZE 2050 scenario includes scope 1 emissions which are taken directly from the scenario. The scope 2 emissions associated with direct electrification are calculated the same way as in the IEA ETP

18 World Business Council for Sustainable Development and World Resources Institute, The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard

calculation above. The scope 3 emissions, namely the emissions associated with the production of hydrogen which can then in turn be used in the process of making both steel and cement. Furthermore, the production of hydrogen is anticipated to see a shift in the way it is produced, leading to a decreasing emissions intensity over time. The following is a set of assumptions and methodology to incorporate these scope 3 emission intensities.

Table 4: Share of direct electrification and "clean" energy sources in the final energy demand in the steel and cement sector[19]:

	2020	2050
Steel	15%	70%[20]
Cement	15%	50%[21]

The IEA NZE documentation provides the anticipated final energy demand for hydrogen in both sectors for 2030 and 2050. The final energy demand for electricity (direct electrification) for the respective sectors is derived in the same manner as for the scenarios above. This figure is then multiplied by the emission intensity of the power sector to give the scope 2 emission intensity from direct electrification:

$$EI^{Sector\ scope\ 2\ \text{direct electrification}} = \left(E_t^{\text{Scope 2 energy direct electrification}}.\,11.63.\,EI_t^{Sector\ power}\right)$$

In order to then obtain the emissions intensity associated with the production of hydrogen in those years two additional assumptions are required:

1. Technology mix: The mix of grey (fossil fuel derived), blue (fossil fuel with CCUS derived) and green (electrolysis with renewable power derived) hydrogen sources.
2. Technology emissions intensity: The CO_2 emissions associated with each tonne of hydrogen used, which is influenced by the technology mix and associated fuels.

The first assumption about the technology mix is made based on the production share of hydrogen technologies. Table 5 provides the assumptions made by the IEA NZE scenario at a global level. ´Grey´ hydrogen production based on natural gas, coal and naphtha is gradually superseded by ´blue´ hydrogen production, whereby CO_2 emissions from the steam reforming of natural gas are captured, and ´green´ hydrogen, whereby renewable electricity is used to split water by electrolysis in order to obtain hydrogen gas. The hydrogen production mix for steel is assumed to reflect these global shifts in the technology used to produce hydrogen.

Table 5. Estimated global hydrogen production for the steel sector by route 2020 - 2050

Production route	**Hydrogen production (MtH_2/yr)**			
	2020	**2030**	**2040**	**2050**
Grey hydrogen *Fossil fuels*	4	5	3	1
Refining CNR	1	1	0	0
Blue hydrogen *with CCUS*	1	6	12	20

[19] This includes energy from waste and hydrogen
[20] See p127 of the IEA, Net Zero Energy by 2050 report of May 2021
[21] See p-129, figure 3.3 of the IEA, Net Zero Energy by 2050 report of May 2021

Green hydrogen *Electricity*	0	7	21	33
Biomass	0	0	0	0
Notes: 1. Catalytic Naphtha Refining (CNR)				

Source: IEA Net Zero by 2050 (2021)

The second set of assumptions about the emissions intensity of the technology mix are made based on a review of literature sources. In table 6, three diverse sources are used to obtain assumptions for the years 2030 and 2050. Several of the values are originally provided in the literature as ranges. In these cases, the midpoint value has been used as the value. Where a range could only be identified for 2020 then an interpolation has been made to obtain the start and end value for 2020 and 2050, with the high-end value used as the start value. The source values were then used to derive discrete values for 2030, 2040 and 2050 using midpoint values and interpolation (see table 7).

Table 6. Source values for the emissions intensity of hydrogen production technologies 2020 - 2050

Hydrogen production route	**Fuel input**	**Emissions intensity in kg CO_2/kg H_2 (by source and year)**				**Production technology**
		Pembina Institute[22]	**RMI** [23]	**Hydrogen Council** [24]		
		2020	**2020**	**2030**	**2050**	
Grey hydrogen	Natural gas	11.3 - 12.1	8 - 12	9.2 - 11	9.2 - 11	Steam reforming of natural gas
	Coal		18 - 20			
Blue Hydrogen	Natural gas	2.3 - 4,1		1.5-3.9	1.5 - 3.9	Steam reforming of natural gas with CCUS
	Coal			3.5-9.2	3.1 - 7.9	Coal gasification with CCUS
Green Hydrogen		0.0 - 0.6		0.3 - 1.0	0.3 - 0.6	Onsite electrolysis of water

Table 7. Assumptions for the emissions intensity of hydrogen production technologies 2020 - 2050

Hydrogen production route	**Fuel input**	**Emissions intensity in kg CO_2/kg H_2**				**Production technology**
		2020	**2030**	**2040**	**2050**	
Grey hydrogen	Natural gas	11.7	10.1	10.1	10.1	Steam reforming of natural gas
	Coal	20.0	19.3	18.7	18.0	

[22] Pembina Institute, *Hydrogen on the path to net-zero emissions: costs and climate benefits*, July 2020
[23] RMI, *Hydrogen´s decarbonization impact for industry: near-term challenges and long-term potential*, Insight brief, January 2020.
[24] Hydrogen Council, Hydrogen decarbonisation pathways – a life cycle assessment, January 2021.

Blue Hydrogen	Natural gas	3.2	2.7	2.7	2.7	Steam reforming of natural gas with CCUS
	Coal		6.4	5.9	5.5	Coal gasification with CCUS
Green Hydrogen		0.6	0.6	0.5	0.45	Onsite electrolysis of water

The assumptions are then brought together in table 8 in order to obtain the scope 2 hydrogen CO_2 emissions. To derive these values, the technology mix is first applied to the annual hydrogen production values given by the IEA for 2020, 2030 and 2050 in table 5. The emissions factors in table 7 are then applied to the resulting production values per hydrogen technology and input fuel to derive the CO_2 emissions in Mtonnes per year. The values for 2040 were obtained by interpolation.

Table 8. Estimation of scope 3 CO_2 emissions from hydrogen production for the steel and cement sectors

Production route	**Hydrogen production for use in the steel and cement sectors (Mtonnes CO_2/yr)**							
	2020		**2030**		**2040**		**2050**	
	Steel	**Cement**	**Steel**	**Cement**	**Steel**	**Cement**	**Steel**	**Cement**
Grey hydrogen *Fossil fuels*	59	0	69	8	47	9	12	3
Refining CNR	9	0	10	1	2	0	0	0
Blue hydrogen *with CCUS*	1	0	37	4	89	15	55	18
Green hydrogen *Electricity*	0	0	4	1	11	3	15	4
Biomass	0	0	0	0	0	0	0	0
Total Mt CO_2 from hydrogen production	**69**	**0**	**121**	**14**	**149**	**27**	**81**	**24**

Finally, the sum of scope 1, 2 and 3(hydrogen) is taken to give the steel and cement emission intensity pathways respectively.

$$Emission\ Intensity = Emission\ Intensity_{Scope\ 1} + Emission\ Intensity_{Scope\ 2} + Emission\ Intensity_{Scope\ 3,Hydrogen}$$

Aviation

For the passenger aviation sector alignment is measured using the emissions intensity metric of tonnes of CO_2 per revenue passenger kilometer (tCO_2/pkm). The two preselected scenarios that cover this sector provide the two main datapoints required to calculate the scenario values – the total fuel consumption of airlines and the total revenue passenger kilometers. The fuel consumption is expressed in different units, hence different conversion factors need to be used, as described below for the JRC GECO and ISF NZ scenarios.

For GECO

Two data points are provided - the total fuel consumption of passenger airlines in kilotonnes of oil equivalents (ktoe) and the total revenue passenger kilometers flown (million pk/a). In order to derive a scope 1 (direct) emissions intensity expressed in units of tonnes CO_2 per revenue passenger kilometer, the fuel consumption data must first be converted into CO_2 emissions. This is done using a conversion factor to obtain tonnes of jet kerosene from tonnes of oil equivalents, to which the emissions factor for jet kerosene can then be applied.

$$\mathrm{EI}^{\text{Passenger airline}} = \frac{\frac{\text{Fuel consumption (Ktoe)}}{1.0533}.\,1000.\,\mathrm{EI}^{\text{Jet kerosene}}}{A_t^{\text{Passenger km}}}$$

Where:

dividing Ktoe by 1.0533 is converting to ktonnes of jet kerosene

$\mathrm{EI}^{\text{Jet kerosene}}$ = 3.16 tonnes CO_2 emitted per tonne of fuel

$A_t^{\text{Passenger km}}$= Airline activity in passenger kilometers in the year t

For ISF NZ

Two data points are provided - the total jet fuel supplied to passenger airlines in petajoules per year (PJ/a) and the total revenue passenger kilometers flown per year (million pkm/a). In order to derive a scope 1 (direct) emissions intensity expressed in units of tonnes CO_2 per revenue passenger kilometer, the fuel consumption data must first be converted into CO_2 emissions. This is done by applying a conversion factor to petajoules of fuel energy content in order to directly obtain the CO_2 emitted (in tonnes) from the combustion of jet kerosene.

$$\mathrm{EI}^{\text{Passenger airline}} = \frac{(\text{Fuel consumption(PJ)}.\,1000).\,71.4}{A_t^{\text{Passenger km}}}$$

Where:

Multiplying terajoules by 71.4 is converting to tonnes of CO_2 emitted per terajoule of fuel

$A_t^{\text{Passenger km}}$= Airline activity in passenger kilometers in the year t

5.4 Calculating Yearly Targets

For most scenarios, the targets are given at 5 or 10-year time intervals. As PACTA is focused within a 5-year time horizon it is important to compare a portfolio's 5-year production trend / technology mix against targets for each year. To enable this 2DII applies a linear interpolation between the start year of analysis (t0) and data points for the 5th year, or in some cases, the 10th year in the time series.

6. Full summary of the scenarios provided in the PACTA for Banks toolkit

Table 9. The scenarios provided in the PACTA for Banks Tool kit and their sectoral and geographical coverage

Sectors for which alignment is measured using a production volume trajectory

Sector	Scenario Source	Scenario	Region coverage
Power	IEA - WEO -2020	SDS	Advanced Economies, Africa, Asia Pacific, Brazil, Central and South America, China, Developing Economies, European Union, Eurasia, Europe, Global, India, Japan, Middle East, Non OECD, North America, OECD, Russia, South Africa, Southeast Asia, United States
	IEA - WEO -2020	STEPS	Advanced Economies, Africa, Asia Pacific, Brazil, Central and South America, China, Developing Economies, European Union, Eurasia, Europe, Global, India, Japan, Middle East, Non OECD, North America, OECD, Russia, South Africa, Southeast Asia, United States
	IEA - WEO -2020	CPS	Advanced Economies, Africa, Asia Pacific, Brazil, Central and South America, China, Developing Economies, European Union, Eurasia, Europe, Global, India, Japan, Middle East, Non OECD, North America, OECD, Russia, South Africa, Southeast Asia, United States
	IEA - WEO -2021	STEPS	Advanced Economies, Africa, Asia Pacific, Brazil, Central and South America, China, Developing Economies, European Union, Eurasia, Europe, Global, India, Japan, Middle East, Non OECD, North America, OECD, Russia, Southeast Asia, United States
	IEA - WEO -2021	SDS	Advanced Economies, Africa, Asia Pacific, Brazil, Central and South America, China, Developing Economies, European Union, Eurasia, Europe, Global, India, Japan, Middle East, Non OECD, North America, OECD, Russia, Southeast Asia, United States
	IEA - WEO -2021	NZE	Global
	JRC-GECO-2020	GECO_NewNormal	Global
	JRC-GECO-2020	GECO_2C	Global
	JRC-GECO-2020	GECO_1.5C	Global
	JRC-GECO-2021	GECO_CurPol	Global
	JRC-GECO-2021	GECO_1.5 Unif	Global
	ISF-NZ - 2020	NZAOA_1.5	Africa, China, Eurasia/Eastern Europe, Global, India, Latin America, Middle East, Non OECD Asia, OECD Europe, OECD North America, OECD Pacific
Oil and Gas	IEA - WEO -2020	SDS	Global

	IEA - WEO -2020	STEPS	Global
	IEA - WEO -2020	CPS	Global
	IEA - WEO -2021	STEPS	Advanced Economies, Africa, Asia Pacific, Central and South America, Developing Economies, Eurasia, Europe, Middle East, Non OECD, North America, OECD, Non OPEC, OPEC, Global
	IEA - WEO -2021	SDS	Advanced Economies, Africa, Asia Pacific, Central and South America, Developing Economies, Eurasia, Europe, Middle East, Non OECD, North America, OECD, Non OPEC, OPEC, Global
	IEA - WEO -2021	NZE	Global
	JRC-GECO-2020	GECO_1.5C	Global
	JRC-GECO-2020	GECO_2C	Global
	JRC-GECO-2020	GECO_NewNormal	Global
	JRC-GECO-2021	GECO_CurPol	Global
	JRC-GECO-2021	GECO_1.5 Unif	Global
	ISF-NZ - 2020	NZAOA_1.5	Global
Coal	IEA – WEO - 2020	CPS	Global
	IEA – WEO - 2020	STEPS	Global
	IEA – WEO - 2020	SDS	Global
	IEA - WEO -2021	STEPS	Advanced Economies, Africa, Asia Pacific, Central and South America, Developing Economies, Eurasia, Europe, Middle East, Non OECD, North America, OECD, Global
	IEA - WEO -2021	SDS	Advanced Economies, Africa, Asia Pacific, Central and South America, Developing Economies, Eurasia, Europe, Middle East, Non OECD, North America, OECD, Global
	IEA - WEO -2021	NZE	Global
	JRC-GECO-2020	GECO_1.5C	Global
	JRC-GECO-2020	GECO_2C	Global
	JRC-GECO-2020	GECO_NewNormal	Global
	JRC-GECO-2021	GECO_CurPol	Global
	JRC-GECO-2021	GECO_1.5 Unif	Global
	ISF-NZ - 2020	NZAOA_1.5	Global
Automotive	IEA - ETP - 2017	B2DS	Global
	IEA - ETP - 2017	RTS	Global
	IEA - ETP - 2017	2DS	Global
	JRC-GECO-2021	GECO_CurPol	Global
	JRC-GECO-2021	GECO_1.5 Unif	Global
	JRC-GECO-2020	GECO_1.5C	Global
	JRC-GECO-2020	GECO_2C	Global
	JRC-GECO-2020	GECO_NewNormal	Global
	IEA – NZE2050 - 2021	NZE2021	Global

Sectors for which alignment is measured using an emissions intensity metric

Sector	Scenario Source	Scenario	Region coverage
Steel	IEA-ETP-2017	ETP_2DS	Global
	IEA-ETP-2020	ETP_SDS	Global
	JRC-GECO-2021	GECO_CurPol	Global
	JRC-GECO-2021	GECO_1.5 Unif	Global
	JRC-GECO-2020	GECO_1.5C	Global
	JRC-GECO-2020	GECO_2C	Global
	JRC-GECO-2020	GECO_NewNormal	Global
	ISF-NZ - 2020	NZAOA_1.5	Global
	IEA - WEO- 2021	NZE	Global
Cement	IEA-ETP-2017	ETP_2DS	Global
	IEA-ETP-2020	ETP_SDS	Global
	ISF-NZ - 2020	NZAOA_1.5	Global
	IEA - WEO- 2021	NZE	Global
Aviation	JRC-GECO-2021	GECO_CurPol	Global
	JRC-GECO-2021	GECO_1.5 Unif	Global
	JRC-GECO-2020	GECO_1.5C	Global
	JRC-GECO-2020	GECO_2C	Global
	JRC-GECO-2020	GECO_NewNormal	Global
	ISF-NZ - 2020	NZAOA_1.5	Global

Funding Information

This project is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

Supported by:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

based on a decision of the German Bundestag

The views expressed in this report are the sole responsibility of the authors and do not necessarily reflect the views of the funders.