Energy Transition Advisers
ETA

PRI CLIMATE THOUGHT LEADERSHIP

Pathways to Net Zero: Scenario Architecture for strategic resilience testing and planning

PRI Principles for Responsible Investment

Supported by:
ClimateWorks FOUNDATION
Bloomberg Philanthropies

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The authors and PRI are, in researching and publication of this paper, grateful for support from Climateworks and Bloomberg Philanthropies.

June 2020

Contents

Executive Summary 4
- Context 4
- What is happening now? 4
- Why is the scenario architecture important? 5

Key variables and metrics for assessing scenario Architecture 6

Introduction 8
- Setting Ambition 8
- Scenarios: The Pathway matters 8
- Scenario Architecture – why it matters 8
- Network for Greening the Financial System (NGFS) Context 10

The existing disclosure context - TCFD 11
- Choosing Pathways to a 1.5°C Net Zero world 12
- Who are the most referenced inter-governmental scenario builders? 12
  - IPCC – the synthesizer of science and scenarios 13
  - International Energy Agency (IEA) 13
  - International Renewable Energy Agency (IRENA) 13
- Intergovernmental Agency Scenarios 14
- Using other sources: PRI existing scenario work for portfolio analysis and company engagement 14
  - The Inevitable Policy Response (IPR) 14

Moving towards 1.5°C: IPCC Special Report on Global Warming of 1.5°C 16
- Scenarios Sourced 16
- P1- P4 Architecture 17
- Negative Emissions Technologies (NETs)/Carbon Dioxide Removal (CDR) are central to understanding outcomes 20
- Net Zero Year around 2050 20
- Impact on existing scenarios 20

Scenario Architecture in more detail: The building blocks for scenarios and understanding the key metrics 21
- Socio economic assumptions 21
- Emissions Pathways 22
- Probabilities and end dates 23
- The big assumptions of Carbon Capture and Storage (CCS) and NETs (Negative Emissions Technologies) – filling the gap 24
- Enriching decarbonisation scenarios with Asset Level Linkage and valuation impacts 25
- Inevitable Policy Response (IPR) Valuation Approach 25
  - Demand destruction 25
  - Demand creation 26
  - Carbon costs & competition 26
  - Abatement 27
  - Competition 27

Key variables and metrics for assessing scenario Architecture 28

Conclusion: Choosing Scenarios for Investors 30
- Agreement to select a single emissions scenario 30
- An agreed set or range of credible Paris Agreement aligned scenarios 30
- Average (Mean) or Median of all PAA “credible” scenarios 31
- Adopting an agreed set of economic/technology scenarios with at least one in common and what are the key options 31

Examples of Scenario Application in Action 32
- Carbon Tracker approach to oil and gas 32
- Carbon Tracker: Using IPR 34
- 2° Investing Initiative (2DII) – Using PACTA 37

APPENDIX IPPC SR1.5°C: Further details 39
- The impacts associated with higher temperature outcomes have increased 39
- Carbon Budgets have been revised upwards 39

Endnotes 42

Executive Summary

Context

Climate change poses a systemic risk to institutional investors. All portfolios are exposed to it, yet the impacts will be uneven across asset classes, sectors and geographies. Understanding how this could play out is of central importance to investors' response to the climate challenge. A key approach is the use of scenario analysis to test the resilience of the portfolio to a number of future states. This can further be developed for financial analysis.

This paper primarily seeks to help investors, both Asset Owners and Asset Managers and their service providers to:

1. understand an end point ambition requires a scenario pathway to be of use in financial analysis;
2. understand the scenario pathway architecture (defined in this paper as key variables, metrics, attributes and drivers) determine the financial impact of any scenario. This can be used to compare and contrast scenarios;
3. understand how climate scenarios can then be used in risk analysis of their own portfolios and engagement with companies following the Paris Agreement and the IPCC SR1.5°C study;
4. understand how scenarios can then become base case forecasts to begin to inform actual business and portfolio planning and decisions using business level metrics such as production, capex and emissions, which leads to action.

- Investors can use scenarios to inform engagement with companies and/or directly to inform their portfolio construction.
- Whatever investors adopt will be of great interest to companies and should certainly be a key input to their own thinking and approach.
- This is also of relevance in a TCFD disclosure/reporting context for investors, as well as the EU sustainable finance taxonomy, which takes a bottom up economic activity approach and has set thresholds following a trajectory consistent with the EU -55% by 2030 and Net Zero by 2050.
- The NGFS and other regulatory bodies, such as EIOPA, are also working on scenarios for full blown stress testing for financial institutions which may have implications for investors too. The classifications of "orderly vs disorderly" and "met vs unmet" will become well used, as will scenarios fitting into that.

What is happening now?

- Currently, investors are focussed on three aspects of climate scenario architecture:
  1. Resilience and risk testing (encouraged by the TCFD) and choosing a scenario as a function of whether it meets a "temperature outcome".
  2. Setting a "net zero target" (usually 2050) associated with that:
     - Whatever temperature outcome we will ultimately achieve, we will have to get to net zero to stabilize temperatures.
     - The sooner we get to net zero the better to reduce the existential threat of climate change.
  3. For financial leaders who are prepared to adopt a climate constraint now in order to influence change this would extend to aligning their portfolio to a scenario/target.
- This approach to choosing scenarios and targets suffers from several challenges:
  - Temperature outcomes may hide fundamental differences in scenario architecture, and therefore near-term pathways, with dramatic ramifications for the actual ambition.
  - Long-term net zero targets are important, but could become "time washing" where long-term goals are set without short-term accountability and the opportunity to verify them.
  - Many of the more ambitious climate constrained scenarios are still considered "pie in the sky" and tail risks, useful for long-term resilience testing, and even adopted by "ambitious investors". However, as such they are not necessarily used by "mainstream" investors in their day to day investment process. This is because many Investors simply have not been convinced of policy and technology assumptions while scenarios architecture for long-term temperature targets tends to assume economically optimal pathways.
  - This also points to looking at scenarios that do not optimise for temperature but set out assumptions that might actually happen.
- These issues can be addressed focusing on the scenario architecture itself, rather than just benchmarking ambition based on the "temperature outcome" of any given scenario and so importantly setting short-term and more realistic goals.

Why is the scenario architecture important?

- "Temperature outcome" optimization as a reference point for "scenario ambition" (e.g. achieving a 1.5°C outcome) hides dramatic differences in the actual underlying pathways. For instance, The Intergovernmental Panel on Climate Change (IPCC) Special Report: Global Warming of 1.5°C (SR1.5°C) is based on a large range of scenarios categorised as 1.5 degrees, highlighting 4 archetypes of we what would term "scenario architecture types" known as P1 (little overshoot of the carbon budget along the way) to P4 (lots of overshoot requiring huge NETs after 2050). The IPCC 1.5 degree scenarios that have a 1.5°C outcome tend to have a Net Zero year around 2050, whether high or low overshoot.
- As a result, we need to consider scenario architecture across key attributes:
  - the speed or slope of the pathway,
  - technology mix,
  - CCS
  - when does the scenario reach "net zero"?
  - what is the "overshoot" that requires addressing?
  - and crucially, Carbon Dioxide Removal Technologies or Negative Emissions Technologies, in essence a least cost option to reach the temperature goal after 2050, which may not prove to be realistic.
- This paper concludes that:
  - The pathway as defined in the "scenario architecture" is crucial for financial analysis.
  - The IEA SDS and B2DS are commonly used as a base case or reference point at present in the context of resilience and stress testing, with further scenarios under development by the NGFS and others 2° Investing Initiative (2DII).
  - Most discussions around net zero treat the "well below 2°C" ambition as a "tail scenario" or something more adapted to stress-testing, rather than base-case planning. One of the reasons for that is that many scenarios that create net zero pathways generally suffer from two flaws, making them less relevant for base case use, namely:
    - Highly unrealistic short-term policy ambition, and
    - "Economic optimization" inconsistent with a more realistic "messy" and disruptive transition.
  - In this context, "mainstream" investor planning or base cases should reflect a policy and techno-economic scenario based on high conviction expectations or forecasts, underpinned by key real-world assumptions.
  - The Inevitable Policy Response Forecast Policy Scenario (IPR FPS), commissioned by PRI, represents this type of policy forecast scenario with a "real world" approach to modelling. IPR FPS tries to solve the problem by creating an alternative relevant base case that reflects the "inevitability" of net zero through the concept of the inevitable policy response (IPR) by 2025, even if the scenario itself does not necessarily meet temperature goals without a second policy ratchet in the medium-term.
  - This type of real-world outlook for planning and portfolio execution then becomes a second step beyond the resilience/stress test risk management approach.
- Further, investors should track short-term progress and ambitions given that such tracking:
  - allows for accountability around actual progress being made;
  - ensures outcomes "stay on schedule" in a way that means goals and targets/ambitions are realistic;
  - ensures the deployment of optimal investing strategies as soon as possible.

Given that all scenarios in the IPR style show that even if FPS is a base case, the "optimal" approach, from a financial and climate perspective for investors believing in net zero and FPS, is to "anticipate" FPS by taking action.

- A number of tools and studies allow investors to do that now. We include a look at the execution through notable examples:
    - 2DII: PACTA (Paris Agreement Capital Transition Assessment)
    - Carbon Tracker: *Breaking the Habit, Handbrake Turn* and *Powering down Coal.*
    - Vivid Economics, and Energy Transition Advisers: The Inevitable Policy Response

Key variables and metrics for assessing scenario Architecture

In terms of architecture (defined in this paper as key variables, metrics, attributes and drivers), we would highlight the following key aspects to any climate scenario pathway in an investor context:

Table 01: Key Variables associated with the emissions pathway

Metrics	Description
Target temperature over pre-industrial levels	This describes the temperature above pre-industrial levels with which the scenario is consistent. In most cases this is a constraint reflected in the carbon budget and so the pathway (or an outcome of assumptions such as with IPR).
Probability of achieving temperature target	This is the probability of achieving a particular temperature outcome. This is a critical datapoint, as the uncertainties within climate science lead to wide ranges of outcomes meaning that a probabilistic presentation is useful.[1]
Carbon emissions budgets	Global warming is fundamentally linked to the absolute concentration of greenhouse gases in the atmosphere. To stabilise global temperature at any level vs pre-industrial, there is then a finite amount of emissions that can be released before net emissions need to reach zero – For CO_2 emmisions this can be referred to as a carbon budget. (see Figure 22 in Appendix).
Scenario start year	This is the year the analysis of the particular scenario model starts.
Emissions peak	This is the year at which emissions peak.
Year temperature target is first reached	This is the year when the temperature target is first reached.
Net Zero Year – emerging as a key metric	This is the year where globally there are zero net emissions which means any residual direct emissions are offset by CDR (e.g. NETS including BECCS).
Overshoot	The degree of temperature overshoot above the set target of the scenario. Overshoot can occur during the pathway time frame.
Return Year	Return year refers to the year when the temperature returns again to target after overshoot.
Scenario transition modelled end year	This is the last year of the detailed modelling in the scenario. At this point the temperature target may not be stable and further assumptions are required to establish that.
Emissions reduction on base year %	This is the percentage reduction of emissions highlighted in the scenario at its end year measured against its base year which is not always the first year of the scenario model. Again this needs to be put in the context of a pathway - the slope of this curve shows timing of impact.

Source: ETA

These emission pathway variables need to be associated with economic and financial variables if to be of use to investors and companies in financial analysis. As the 2DII paper on scenarios points out, this process of translation often leaves gaps in financial risk analysis[2].

Table 02: Associated Key Economic and Financial variables

Metrics	Description
Geography and Sector	The more granularity the more useful for investment analysis.
Geographic Jurisdictions	Countries and regions in scope of analysis.
Key Sectors Covered	The range of sectors included in the scenarios. Note that this includes any references to sectors at any point on the supply chain, thus including end use sectors as well as primary producers.
Key Policy Drivers	
Carbon Prices	Carbon pricing is the most cited policy method to optimise the shift of capital from high to low carbon assets and, because it can be added to the asset level, represents a favourite method for modellers and analysts. Indeed, it is often used as an overall proxy for all policies by modellers. Hence need to identify if endogenous or exogenous to the model.
Key Economic and Financial Variables	This is what drives the economic results of the scenario. They are both inputs and outputs.
Technology Trajectories/ Demand Profiles – see below other key variables	These are not a single datapoint but are a series of (often complex) signposts and datapoints that define how various technologies are developing e.g. volume of electric cars, GW of renewable capacity. These in effect set out production profiles and so reflect expected demand in the economy.
Asset level	For investors and companies, granular real asset data and financial data is needed to apply economic results to portfolios and indeed in engagement with companies. So, this level has to be linked to the technology/demand profiles. An example is Carbon Tracker's "Breaking the Habit" report and the 2DII SEI metrics projects.
Associated Capital Investment	The amount of capital required in order to achieve the various demand/production/ emissions targets.
Stranded Assets	Stranded assets are now generally accepted to be those assets that at some time prior to the end of their economic life (as assumed at the investment decision point), are no longer able to earn an economic return (i.e. meet the company's internal rate of return), as a result of changes associated with the transition to a low-carbon economy (lower than anticipated demand/prices).[3]
Associated Commodity Demand and Prices	Energy scenarios in particular have implications for the broad commodity level analysis in terms of demand/supply and price.
Other Policy Levers	These describe the types of policy needed to incentive investment in new technologies or assets to achieve various emissions reduction targets. IPR sets these policy levers out in detail.[4] In some models these in turn are proxied by a carbon price.
Other Key Technology Variables to Identify	These inputs/assumptions make a substantive difference to the investment outlook in a scenario.
CCS/CCSU	CCS is Carbon Capture and Storage which describes the capture of CO_2 and the subsequent geological storage of those gases. Carbon Capture Storage and Use extends this to using carbon in various technologies.
NETS / CDR	NETS is Negative Emissions Technology (sometimes known as CDR- Carbon Dioxide Removal) which describe any technology or series of processes where there is a reduction in emissions by either capturing the emissions at the point of process of physically extracting the emissions from the atmosphere. BECCS is one form of NETs.
BECCS	BECCS describes capturing CO_2 from bioenergy applications and sequestering it through Carbon Capture and Storage.

Source: ETA

Introduction

This paper primarily seeks to help investors, both Asset Owners and Asset Managers and their service providers, to understand;

1. the background to, and architecture of, key drivers that determine the financial impact of any scenario. These can be used to compare and contrast scenarios;
2. how climate scenarios can be used in risk analysis of their own portfolios and engagement with companies following the Paris Agreement and IPCC SR1.5°C study;
3. how higher probability, in an economic sense, scenarios can become base case forecasts to begin to inform actual business and portfolio planning and decisions through real-world metrics such as production, capex and emissions, culminating in action;
4. that the pathway and detailed metrics to reach an end ambition are key in financial analysis which can be termed the scenario "architecture".

This is relevant for investors in terms of engagement with companies, such as through the CA100+[5], reporting via the TCFD and ultimately in portfolio construction. In doing this, the implications for companies using scenarios and interacting with their investors is implicit.

It therefore builds on the work of the TCFD which has a risk "resilience test" emphasis for companies and investors around disclosure. This can in itself lead to real changes in an operational sense for risk control reasons. It complements the PRI "An asset owners guide to the TCFD recommendations for Asset Owners"[6], linking closely with the Paris Agreement Capital Transition Assessment (PACTA) online climate scenario tool for portfolios.

Indeed some financial institutions may wish to set their portfolios of assets to reflect a set of climate constrained outcomes as a matter of principal rather than as expected outcomes. That could even extend to companies taking action ahead of policy for instance.

In comparison, the Inevitable Policy Response Forecast Policy Scenario (IPR FPS) commissioned by PRI has been specifically designed as a detailed high conviction policy and technology forecast in the real economy for comprehensive base case planning, driving portfolio construction.

These resilience/risk tests and real economy based planning applications above could be seen as two separate steps.

In synthesis, the paper looks at how scenarios, forecasts and global GHG emissions targets interact and can translate into economic and technology pathways which then can be further descaled down to the asset level for use by investors both in i) resilience testing and ii) business planning sense. Investors can use scenarios to both engage with companies and to inform portfolio decisions. In a TCFD context, this leads to disclosure by both companies and investors.

The paper largely maintains a high-level global relevance. Deeper jurisdictional, sector and technological insights should be gained from analysis of the scenario publications themselves as well as understanding the underpinning assumptions related to GDP, just transition, technological readiness and societal readiness.

Setting Ambition

The ambition to reach a Net Zero emissions target (where any residual GHG emissions are balanced by Carbon Dioxide Removal (CDR)[7]) in the context of a 1.5°C temperature outcome, has become a key feature of recent climate engagement by investors with companies. This is reflected in the Investor Agenda supported by PRI. The year 2050 is frequently targeted, as it is the most consistent with many 1.5°C scenarios. Many companies and countries have also set such ambitions.

Climate scenarios look at different (socio-)economic pathways to achieve particular climate outcomes usually expressed as a temperature outcome which is expressed as emissions reductions (e.g. carbon budget). These pathways generally reach "Net Zero years" where the annual emissions curve falls to zero. Mostly they have been associated with "resilience tests" of how business models or portfolios might be affected by these scenarios, notably by the TCFD. This implies that actors often see them as the extreme stress test like "tail events" of low economic probability.

In this paper we examine the relationship between ambitions and scenarios and, in particular, how different types of scenarios can be used for not just resilience testing but base case higher economic probability real-world planning applications used by investors (with implications for companies) to Paris Agreement alignment. We look at the key building blocks that determine the shape and impact of scenarios – scenario architecture. We then show how these can be progressed from just disclosure based applications into the financial drivers for action by investors and companies.

Scenarios: The Pathway matters

Following several IPCC working groups, the early focus was on limiting temperature rises to a 2 degrees Celsius limit. The Paris Agreement of 2015 talked of "well below 2°C". The October 2018 IPCC SR1.5°C study aggregated scenarios in the 1.5°C context. This has been associated with a "Net Zero Year (NZY)" focus as exemplified by the Net Zero Asset Owners alliance https://www.unepfi.org/net-zero-alliance/

However, even following upward revisions to carbon budgets in that study, the challenge of reaching a 1.5°C outcome by the end of the century, often with a Net Zero Year of 2050 or before, is still very substantial. For instance, the remaining carbon budget associated with 1.5°C at a 50% chance of success is only around 500GT in 2020, while fossil fuel and industry CO_2 emissions were running at 37Gt CO_2 (total 43GT CO_2)[8] in 2019 before the 2020 Covid19 related drop. Thus there is little more than 12 years to go at current levels[9]. If responsible planners wanted a 66% chance of limiting temperatures to 1.5°C then this would reduce to 340GT meaning around 8 years of emissions left at current levels.

Scenario Architecture – why it matters

While adopting an ambition to reach an end goal such as Net Zero 2050 is laudable, a lack of pathway definition showing how the objective will be achieved leads to potential "greenwashing" by current executives who will not ultimately be there to be accountable – even when executive pay is linked to achieving targets that move towards their own set goals. So some idea of the expected pathway in terms of a scenario and actions to meet that scenario is crucial in order to monitor and verify the action towards that.

The building blocks and assumptions - the "Architecture" - underlying any detailed scenario drive the outcomes that would affect the economy and investors. This concept was described by the World Bank in "A new scenario framework for Climate Change Research: scenario matrix architecture"[10].

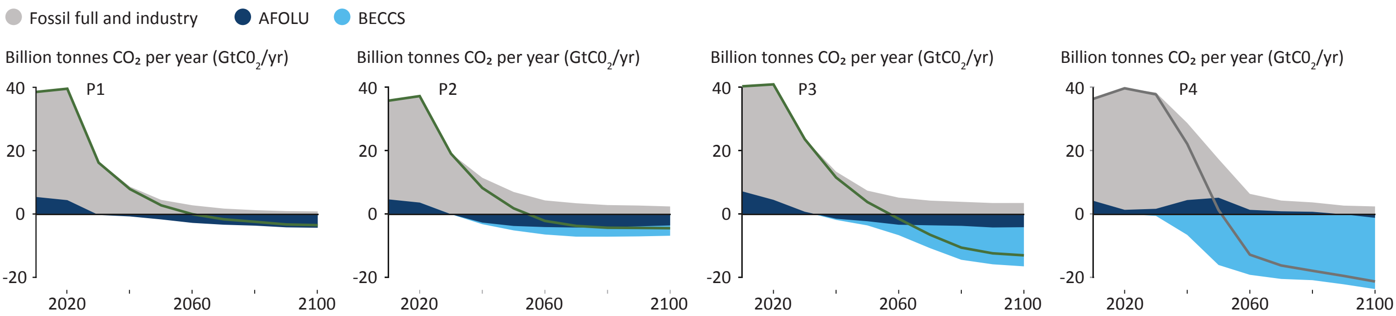
The pathway, not just the end point outcome, becomes key. Differences in technology assumptions, such as Carbon Capture Use and Storage (CCUS), can give big differences to technology deployment in the pathways to a Net Zero year. Perhaps one of the most significant issues is the timing of any policy actions. Assumptions around Carbon Dioxide Withdrawal (CDR) which are often termed Negative Emissions Technologies (NETs) which, generally are assumed post 2050, subtract any "overshoot" (going above 500GT or 1.5°C) of carbon are crucial.

One way to look at this is to imagine a 1.5°C pathway with no or virtually no CCUS and NETs, (which themselves are generally reliant on Bio-Energy CCS or BECCs). The IPCC SR1.5°C study has 4 "archetypes" labelled P1 to P4 which contain various societal, economic and technology assumptions and with a range of carbon overshoot and NETs. P1 has the lowest. But this implies rapid and real economy change with implications for OECD economic growth.

As the IPCC says:

> *All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 GtCO2 over the 21st century. CDR would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5°C following a peak (high confidence). CDR deployment of several hundreds of GtCO2 is subject to multiple feasibility and sustainability constraints (high confidence). Significant near-term emissions reductions and measures to lower energy and land demand can limit CDR deployment to a few hundred GtCO2 without reliance on bioenergy with carbon capture and storage (BECCS) (high confidence)."*

Figure 01: Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Source: IPCC SR1.5°C

Further, many "scenarios" are more theoretical because they make relatively orderly changes towards 1.5°C but the policy assumptions underlying many of them are not in force today or likely to be in the near future. This limits their credibility as being practical for use in base case planning. Over time, policy assumptions in scenarios (as well as technology assumptions) can simply become out of date and the scenario be unrealistic.

While for many this type of scenario analysis is designed to test resilience and be seen in a risk context, for "scenarios" to translate through to comprehensive base case assumptions for investors or business planning tools that companies would use over shorter time frames, realistic timing assumptions on policy action, as well as the technology deployment that underpins the different pathways, are eventually needed. Furthermore, the geo-political and institutional drivers of momentum towards an acceleration point must be understood. This is the reality of any 1.5°C target and the assumptions surrounding it need to be made explicit.

Most "scenarios" do not purport to "forecast" anything. Technology assumptions are often generated to meet a temperature target/carbon budget based on some form of socio-economic optimization. In some, policy assumptions are a mixture of exogenous assumptions on some issues but endogenous requirements to again meet a temperature target.

Further, to be of use to investors, scenarios will then need to express pathways in terms of real-world metrics like production and capex which could be used in business planning and monitoring of alignment.

These issues are addressed further below.

Network for Greening the Financial System (NGFS) Context

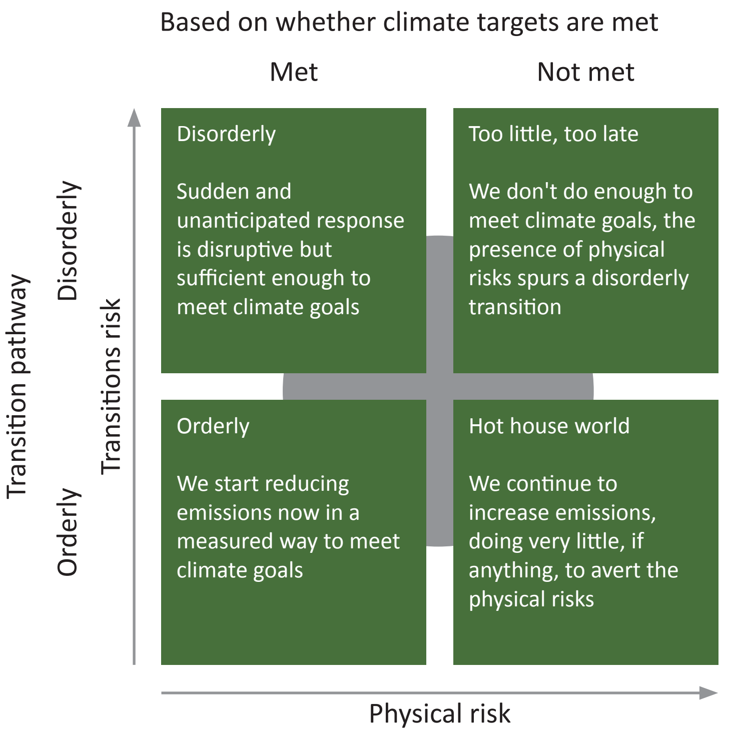
From an investor prospective looking at potential regulatory developments, another important set of classifications is provided by the NGFS[11], a group of regulators and central banks. This is more in the context of resilience and full blown "stress" testing.

Pathway classifications:

- **Orderly** in terms of a transition pathway
- **Disorderly** in terms of a transition pathway
- **Met** (the Paris Agreement) and implications for physical risk
- **Not Met** (the Paris Agreement) and implications for physical risk

In some senses these are a structural aspect of their "architecture". (We note that a Hot House World being considered an "orderly pathway" can seem counter intuitive!)

Figure 02: Strength of response



As often cited by the IEA, climate policy has not acted enough yet[12], so we would argue that any real world planning application would be sitting in the Disorderly and Too little too late quadrants. An Orderly Met scenario seems unlikely at present.

The existing disclosure context - TCFD

The FSB TCFD understood the importance of scenarios for companies and investors in launching its June 2017 report, adding a technical addendum to the report on scenarios. This was before the recent IPCC SR1.5°C analysis. The context has been disclosure but in many ways the idea is to encourage investors and companies (and by implication service providers) to act on climate risks. Mark Carney has also emphasised the importance of that to business planning and implications for financial valuations.[13]

> *"To bring climate risks and resilience into the heart of financial decision-making, climate disclosure must become comprehensive, climate risk management must be transformed, and investing for a two-degree world must go mainstream".*

The PRI guide for Asset Owners implementing TCFD shows the context of climate scenarios for asset owners.[14]

Figure 03: Four step process to integrating climate scenario analysis

Getting started	Become familiar with the TCFD recommendations Investigate approach of peers Identify high risk sectors Ask CIO, consultants & managers to consider climate scenarios
Determine influencing factors	Establish key issues & uncertainties Identify implications for portfolios Develop indicators of change Disclosure in PRI reporting
Utilise specialist tools	Utilise specialist climate scenario tools Evaluate tools & interpret results
Identify responses & report	Identify responses, including tilt towards climate solutions Publish scenarios in annual reports Reassess annually

Source: PRI

There are already a number of important texts for investors regarding scenarios and this paper does not seek to duplicate other reference information. The most important are:

1. TCFD Technical Supplement on Scenarios - https://www.fsb-tcfd.org/publications/final- technical-supplement/
2. CDP Technical Note on Scenario Analysis - https://b8f65cb373b1b7b15feb- c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/guidance_docs/ pdfs/000/001/430/original/CDP-technical-note-scenario-analysis.pdf?1512736385
3. CICERO https://www.cicero.oslo.no/en/climate-finance-main
4. PACTA https://www.transitionmonitor.com

Choosing Pathways to a 1.5°C Net Zero world

A key theme recently has been that emission GHG metrics can be used to set more simply understood ambitions or aspirations where a country, company or investor could aspire to setting a GHG, temperature target and/or a Net Zero Year. But these are only end points unless they specify a pathway. Further, they have no "business metrics", so technology and policy-based pathways (scenarios), constraining production and capex and linked to asset levels, are needed to flesh out the real details. This can then inform actual business decisions that underpin and lead to the desired climate outcome.

We start with the proposition that any end target needs a pathway to be credible for financial analysis

Before the Paris Agreement, the focus was on limiting temperature increase to 2°C. However, the probability of achieving any temperature goal and being considered Paris aligned was never agreed upon but the IEA analysis frequently cites a 50% probability as well as pointing to 66% outcomes.

The December 2015 Paris Agreement[15] talked of "well below 2°C". The language of the Paris Agreement is so critical to any engagement strategy that it warrants full repetition here:

> *"Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change".*

Furrher Article 4 1. laid the foundation for a rapid shift:

> *"In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty."*

However, as the IEA and IRENA commented in their 2017 'Perspectives for the Energy Transition' paper[16] stating:

> *"The Paris Agreement makes reference to keeping temperature rises to "well below 2°C" and pursuing efforts to limit the temperature increase to 1.5°C. However, it offers no clear guidance on what "well below 2°C" means in practice, or what probabilities should be attached to the temperature goals."*

The critical shift to interpreting the Paris Agreement as a target of 1.5°C was aided by the SR1.5°C report discussed below and issued by the IPCC in 2018 and the subsequent use of 1.5°C as a proxy for the ambition of the Paris Agreement especially in civil society.

In terms of existing engagement efforts, it is critical for all stakeholders, particularly the investors themselves, to take a view on what constitutes "Paris Agreement Alignment" (PAA). How does this affect current scenario testing and the scenarios already being used?

Who are the most referenced inter-governmental scenario builders?

Looking at well-known intergovernmental sources of scenarios is a key starting point.

A key issue to note before looking at any scenario is whether it is Energy System based (power, transport, industry related) or includes land use (AFOLU) either directly or the key assumptions on these it makes to reach a Net Zero year. Further, for non-CO_2 emissions such as NOX and methane, what assumptions are made in order to estimate a total emissions outcome which is needed to evaluate any temperature outcome? This can be confusing to trace at times.

The interaction between policy, technology and investment is a highly complex area. With so much at stake and energy being so central to global economics, the IPCC has been an important source of scenario aggregation and setting within a science context. Agencies such as the IEA have grown to become leading analysers of energy markets issuing public reports for a wide range of stakeholders. Land use often becomes a background set of assumptions without much transparency – not in the case of IPR which implicitly models this and interrelates it with energy.

IPCC – the synthesizer of science and scenarios

The Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. The IPCC was set up in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. As such, the IPCC synthesises and aggregates expert opinion from around the world.

The IPCC 5th Working Group assessment met in 2013 and released a new framework of climate scenarios called the RCPs – Representative Concentration Pathways. IPCC scenarios underpin all the IEA and IRENA economic transition scenarios. IPCC scenarios sometimes have limited use for investors because they frequently lack detail required to apply in a portfolio context.

The recently released “Special Report on 1.5°C (SR1.5°C)” provides a list of scenarios used in that aggregation. Indeed, in SR1.5°C even the broad physical climate assumptions in IPCC models (such the basic temperature/probability/carbon budget data) have been re-estimated. See section below for more detail.

International Energy Agency (IEA)

The IEA is the world’s premier energy agency and is used by a wide range of stakeholders for planning purposes. The IEA uses energy system sectoral based models to create optimal least cost economic and technology based pathways (themselves in effect socio economic pathways). Their scenarios differ according to policy assumptions (endogenous and exogenous) with the Stated Policy Scenario (STEPS, which has been renamed from the original New Policies Scenario or NPS) and the Sustainable Development Scenario (SDS) the best known. It draws assumptions on other sectors like land use, methane etc from other sources. The IEA states that Negative Emissions Technologies (NETs) are also required to get to 1.5°C (see further discussion below).

The IEA issues various key reports each year as it sees fit. Its World Energy Outlook (WEO) masthead is the market’s most important annual reference for energy economics. It only extends to a 2050 timeline. It is primarily policy focussed and includes the key Sustainable Development Scenario (SDS). Policy assumptions grew out of the 450PPM temperature constraint and have evolved over time in the SDS.

The IEA also produces the Energy Technologies Perspectives (ETP)[17] which sets out more detailed scenarios, most notably the Below 2 Degrees Scenario (B2DS), last updated in 2017 but expected to be updated in 2020.

The role and influence of the IEA is significant. Since the 1970s and the oil crisis, the IEA has been pivotal in helping to drive energy policy and inform investments in energy and energy related sectors. Since 2007, with the first publication of a 2°C constrained scenario, the IEA has published its energy outlooks and discussion papers in the context of the drive towards a low carbon economy. Importantly, its sectoral work gives great detail for use at the business metric level, particularly around production profiles consistent with climate pathways. In many ways its scenarios have become the default base case or reference source in scenario use.

International Renewable Energy Agency (IRENA)

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. It also provides detailed technology outlooks around renewables in particular.

IRENA's collaboration with the IEA in 2017 for the “Perspectives for the Energy Transition 2017” was an important step to being used more broadly and helping investors understand the wider use of renewables to achieve climate goals. This has been further developed in their Transforming Energy Scenario (TES) in 2020[18].

Intergovernmental Agency Scenarios

A starting point for any look at reference scenarios are the key intergovernmental agencies described above. This also needs to be put in the context of new carbon budget estimates discussed in Appendix.

Table 03: As well as IPPC sources scenarios, the key intergovernmental agency-based scenarios are IEA[19] and IRENA[20] listed below.

Provider	Name	
Commonly used Energy transition scenarios See Appendix for further detail		
IEA	Beyond 2 Degrees Scenario (B2DS)	Produced in 2017. Assumes NETS. Update required
IEA	Energy Technology Perspectives (ETP) 2 Degrees scenario	Contains much detail. NETS. Update uncertain.
IEA	Sustainable Development Scenario (SDS) (WEO)	Includes non-climate goals IEA says can be 1.5°C based on new carbon budgets but NETS unspecified, assumed at around 300GT post-2050.
IEA	New Policy Scenario (NPS) – now changed to Stated Policy Scenario (STEPS)	Consistent with Paris Agreement INDCs aligned more with 2.7- 3°C outcomes
IRENA	Transforming Energy Scenario (TES) 2020	Heavy renewable focus
IPCC P1 1.5°C	IPCC illustrative scenario consistent with 1.5°C as example with no overshoot	Released in SR1.5°C 2018

Source: ETA

In terms of base case or "reference" agency-based scenarios that are Paris Agreement aligned, we would choose to emphasise:

1. **IEA (NPS) STEPS sets a central case base line on announced policies.**
2. **IEA SDS – originally described as 2°C but now described as 1.65°C at 50% probability (with 300GT NETs post 2050) could be 1.5°C or 1.8°C at 66%.**
3. **IEA ETP B2DS – originally 1.75°C at 50%, now estimated to be more like 1. 6°C at 50%.**
4. **IPCC P1 Architecture is a stringent no overshoot 1.5°C at 50%.**
5. **IRENA Transforming Energy Scenario (TES) – well below 2°C with heavy emphasis on renewable scale up no overshoot.**

Again, note most of these require CCS and NETS to achieve their temperature goals.

Using other sources: PRI existing scenario work for portfolio analysis and company engagement

PRI currently has two main methodologies for using scenarios demonstrated on its website which will be updated overtime to reflect emerging views of the carbon budget and one under development:

- **Breaking the Habit**[21]

This has been developed for oil and gas companies by Carbon Tracker to match the potential supply at a company and project level consistent with scenarios such as the IEA SDS and IEA B2DS on a cost-optimised basis. It is a part of the CA100+ verification process. This work is set out in more detail below. Handbrake Turn[22] extended this to looking at the IPR FPS.

- **PACTA**[23]

This has been developed by 2DII to test the portfolios of investors in terms of alignment against a number of the scenarios outlined above. This work is set out in more detail below.

The Inevitable Policy Response (IPR)

The PRI commissioned Vivid Economics and Energy Transition Advisers (ETA) to develop the Inevitable Policy Response (IPR), which was initially released at the PRI in Person in September 2018 and further developed through 2019-20[24]. It sets out a first wave set of realistic policies and technology pathways over the 2020s – with the expectation of further as yet not fully defined policy action during the 2030s.

The Inevitable Policy Response develops what can be termed a "scenario" using realistic high conviction policy and technology assumptions. Hence we call that a "Forecast Policy Scenario". This is aimed at getting companies and investors to adopt the FPS as a business planning framework.

Many scenarios optimise for a temperature outcome and policy in particular is derived from what is required to get there, often in terms of an endogenous carbon price which can be a proxy for all climate policy. IPR is an alternative approach – to forecast a technology and policy outcome and see what the results look like for the economy and investors. It represents a first best estimate of policy up to 2025 as a start to any serious transition pathway but requires further policy action in the 2030s to become fully Paris compliant, in terms of "well below 2°C", longer term. As discussed, this can be considered a "disorderly" transition pathway between Met/Unmet outcomes.

The Inevitable Policy Response https://www.unpri.org/inevitable-policy-response/what-is-the-inevitable-policy-response/4787.article is a collaboration between the UN PRI, Energy Transition Advisers, Vivid Economics and experts which has developed a framework and within that a "Forecast Policy Scenario" based on latest technology trends but crucially, a high conviction forceful policy responses by the 2025 Paris Agreement ratchet.

As with the IEA SDS, the detailed analysis extends to 2050. While it does not set out to reach a particular temperature outcome, the policy outcomes by 2025 are still ambitious and so it represents a first phase of any likely attempt to reach well below 2°C. The outlook states that a second policy response would be required in the 2030s to really achieve that.

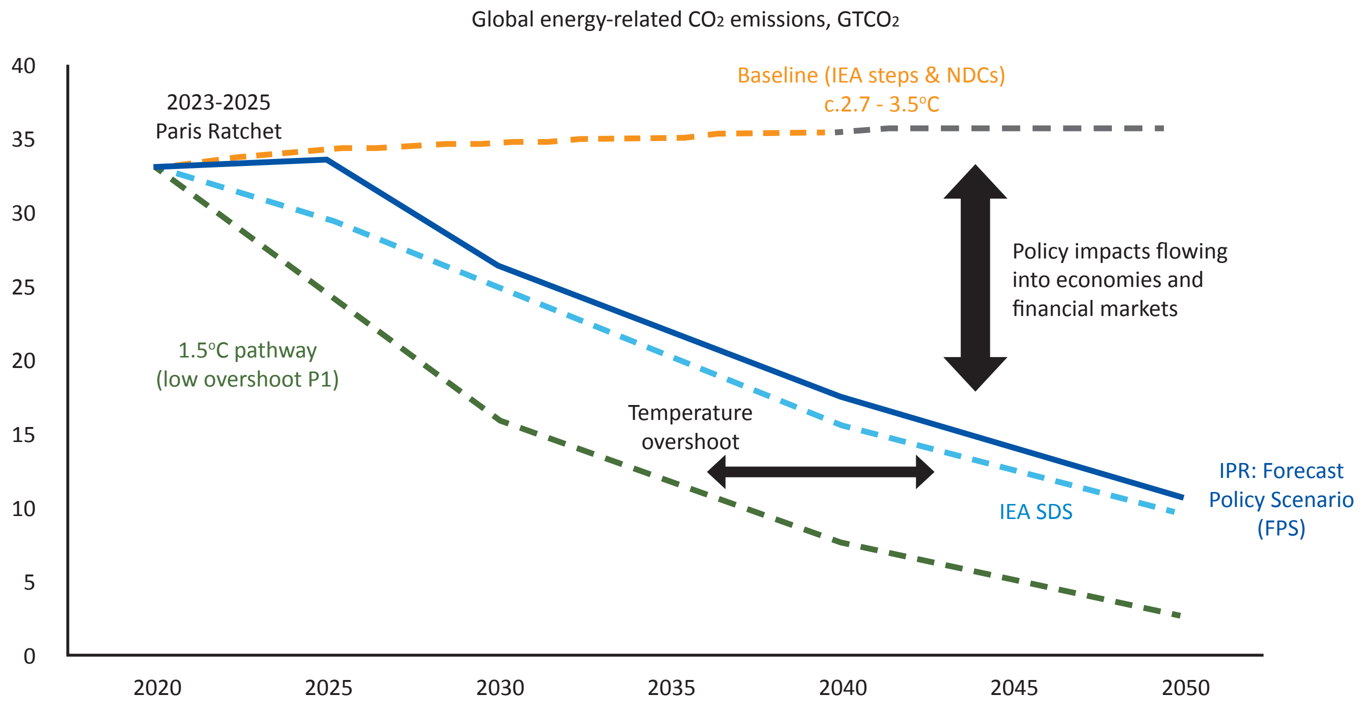
A forecast differs from a scenario in terms of probability or degree of confidence in the economic assumptions and outcomes. Forecasts are designed to be used in business planning and portfolio assessments rather than scenarios used in particular for stress testing.

IPR extends from the macroeconomic level down to asset level data for many sectors and include an integrated land use module.

Asset level data is important for any detailed planning and actions the investors or companies would take.

Land use is a crucial element that is often just a side assumption in energy based models (as per IEA SDS).

Figure 04: Reaching a 1.5 degrees outcome is a far bigger challenge - but should remain the Aspiration



Source: Vivid, ETA IPR

Importantly IPR FPS along with the IEA B2DS should also be seen as input to the PRI engagement work including the CA100+ whose stated second key objective calls for investors to ask companies to align their business models with "well below 2°C". Again IPR represents first the policy in that journey.

Moving towards 1.5°C: IPCC Special Report on Global Warming of 1.5°C

While it did not specifically endorse a 1.5°C target, a seminal report by the IPCC in 2018 has shifted the civil society focus of emissions targets in the ESG world and increasingly in investor and company thinking from the former 2°C focus to 1.5°C, with the majority of actors shifting to this framing. It is frequently expressed in Net Zero 2050 terms, raising the issue of what pathways to take.

In October 2018, the IPCC released a final document called Special Report on Global Warming of 1.5°C - Summary for Policymakers (SR1.5°C)[25] with a number of deeper chapters underlying that.[26] The IPPC SR1.5°C is an important move forward as it contains many scenarios with the focus on 1.5°C with an associated Net Zero Year around 2050.

> *"This report responds to the invitation for IPCC ... to provide a Special Report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways contained in the Decision of the 21st Conference of Parties of the United Nations Framework Convention on Climate Change to adopt the Paris Agreement."*

The reports in total are highly detailed and cover many interesting and important topics. Drawing out the impacts of this analysis for decision makers, for the purpose of this document we can identify the following features:

1. Gives impetus to advocates using Net Zero 2050 in target setting, even if the pathway analysis is often overlooked.
2. Many analysts such as Carbon Tracker or 2DII still use "well below 2°C" as their central definition for Paris Agreement Aligned scenarios. This includes looking at 1.5°C options and P1 (see below) is cited by Carbon Tracker.
3. The impacts associated with higher and indeed lower temperature outcomes have increased.
4. Carbon Budgets were revised upwards.
5. It drives home how assumptions about Negative Emissions Technologies (NETs) are important in pathways.

The impact of this on setting standards for ambition is that the increased climate sensitivity and damages at that level encourage civil society to make 1.5°C the new normal for a "safe" temperature target formally occupied by the "well below 2°C" ambition. **For analysts and investors, a range of outcomes is still relevant.**

Scenarios Sourced

As described, the IPCC sources scenarios from the climate science community and aggregates them. In this instance it gathered the following:

Table 04: Classification of pathway in SR1.5°C , along with the number of available pathways in each class.

The definition of each class is based on probabilities derived from the MAGICC model in a setup identical to ARS WGII (Clake et al,2014), as detailed in supplementary Material 2.5M.1.4.

Pathway group	Pathway Class	Pathway Selection Criteria and Description	Number of Scenarios	Number of Scenarios
1.5°C or 1.5°C-consistent**	Below-1.5°C	Pathways limiting peak warming to below 1.5°C during the entire 21st century with 50–66% likelihood*	9	90
	1.5°C-low-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a 50–67% probability of temporarily overshooting that level earlier, generally implying less than 0.1°C higher peak warming than Below-1.5°C pathways	44	
	1.5°C-high-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a greater than 67% probability of temporarily overshooting that level earlier, generally implying 0.1–0.4°C higher peak warming than Below-1.5°C pathways	37	
2°C or 2°C-consistent	Lower-2°C	Pathways limiting peak warming to below 2°C during the entire 21st century with greater than 66% likelihood	74	132
	Higher-2°C	Pathways assessed to keep peak warming to below 2°C during the entire 21st century with 50–66% likelihood	58	

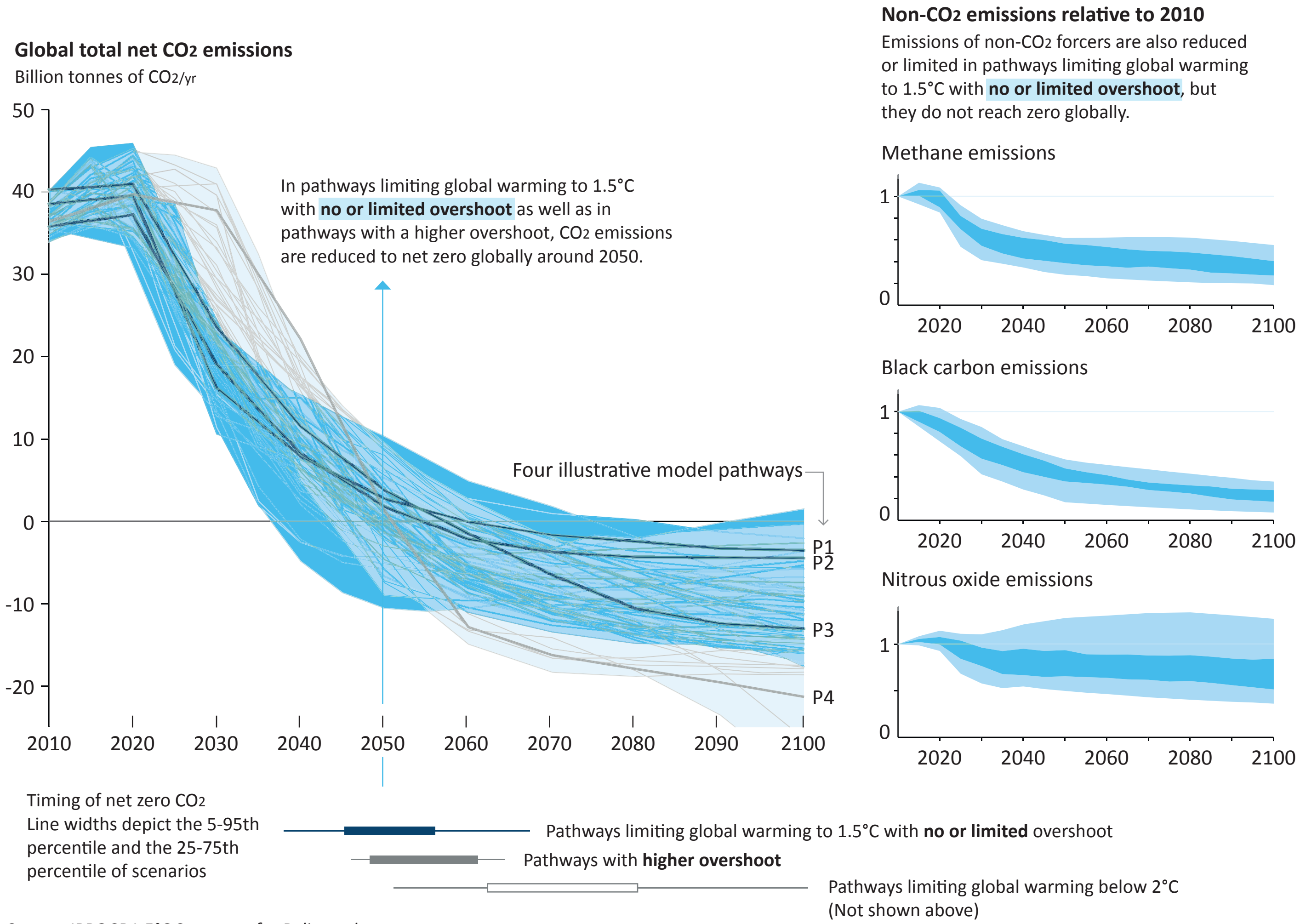
* No pathways were available that achieve a greater than 66% probability of limiting warming below 1.5°C during the entire 21st century based on the MAGICC model projections.

** This chapter uses the term 1.5°C-consistent pathways to refer to pathways with no overshoot, with limited (low) overshoot, and with high overshoot. However, the Summary for Policymakers focusses on pathways with no or limited (low) overshoot.

Source: IPCC special report on Global Warming of 1.5°C

Figure 05: Global emissions pathway characteristics

General characteristics of the evolution of anthropogenic net emissions of CO_2, and total emissions of methane, black carbon, and nitrous oxide in model pathways that limit global warming to 1.5°C with no or limited overshoot. Net emissions are defined as anthropogenic emissions reduced by anthropogenic removals. Reductions in net emissions can be achieved through different portfolios of mitigation measures illustrated below.



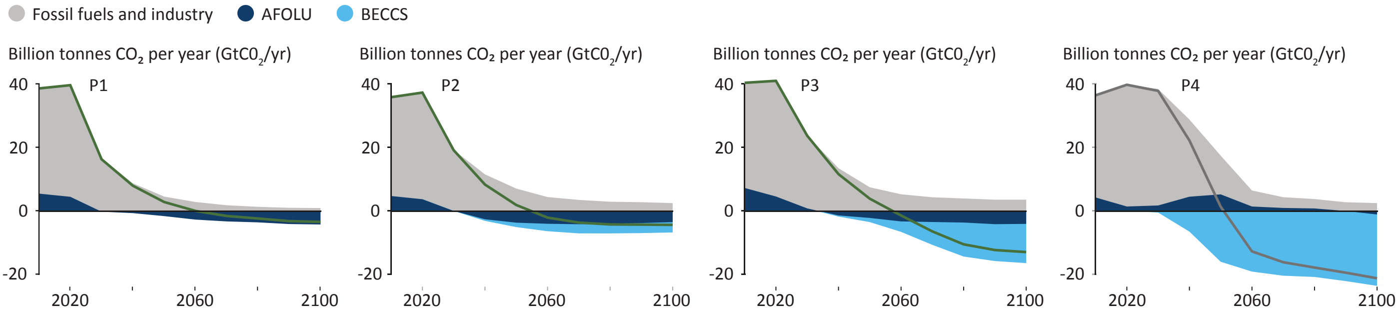
Source: IPPC SR1.5°C Summary for Policymakers

P1- P4 Architecture

This leads the IPCC to develop a key set of what could be termed "architectures" (a concept floated by the World Bank[27]) which show how different types of pathways can get to a Net Zero year around 2050 and achieve 1.5°C. This is incredibly useful in understanding why the pathways to the same goal can be so different and for investors that would be key. CCS and NETS give a very different impact than just a near straight line approach.

The IPPCC describes what we would say as the architecture in terms of four archetype scenarios: P1-P4. These are mostly defined as different socioeconomic groups where the amount of NETs is very different among other things. As such they do have overall economic parameters associated with them. But they need adapting for financial scenario analysis. We propose P1 as an example of a virtually no overshoot scenario is worth considering.

Figure 06: Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	Interquartile range
Pathway classification	**No or low overshoot**	**No or low overshoot**	**No or low overshoot**	**Highovershoot**	**No or loq overshoot**
CO_2 emission change in 2030 (% rel to 2010)	-58	-47	-41	4	4
↳ in 2050 (% rel to 2010)	-93	-95	-91	-97	-97
Kyoto-GHG emissions* in 2030 (% rel to 2010)	-50	-49	-35	-2	-2
↳ in 2050 (% rel to 2010)	-82	-89	-78	-80	-80
Final energy demand** in 2030 (% rel to 2010)	-15	-5	17	39	39
↳ in 2050 (% rel to 2010)	-32	2	21	44	44
Renewable share in electricity in 2030 (%)	60	58	48	25	25
↳ in 2050 (%)	77	81	63	70	70
Primary energy from coal in 2030 (% rel to 2010)	-78	-61	-75	-59	-59
↳ in 2050 (% rel to 2010)	-97	-77	-73	-97	-97
from oil in 2030 (% rel to 2010)	-37	-13	-3	86	86
↳ in 2050 (% rel to 2010)	-87	-50	-81	-32	-32
from gas in 2030 (% rel to 2010)	-25	-20	33	37	37
↳ in 2050 (% rel to 2010)	-74	-53	21	-48	-48
from nuclear in 2030 (% rel to 2010)	59	83	98	106	106
↳ in 2050 (% rel to 2010)	150	98	501	468	468
from biomass in 2030 (% rel to 2010)	-11	0	36	-1	-1
↳ in 2050 (% rel to 2010)	-16	49	121	418	418
from non-biomass renewables in 2030 (% rel to 2010)	430	470	315	110	110
↳ in 2050 (% rel to 2010)	833	1327	878	1137	1137
Cumulative CCS until 2100 ($GtC0_2$)	0	348	687	1218	1218
↳ of which BECCS ($GtC0_2$)	0	151	414	1191	1191
Land area of bioenergy crops in 2050 (million km²)	0.2	0.9	2.8	7.2	7.2
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24	-48	1	14	14
in 2050 (% rel to 2010)	-33	-69	-23	2	2
Agricultural N_20 emissions in 2030 (% rel to 2010)	5	-26	15	3	3
in 2050 (% rel to 2010)	6	-26	0	39	39

Source: IPCC SR1.5°C
NOTE: Indicators have been selected to show global trends identified by the Chapter 2 assessment. National and sectoral characteristics can differ substantially from the global trends shown above.

** Kyoto-gas emissions are based on IPCC Second Assessment Report GWP-100*
*** Changes in energy demand are associated with improvements in energy efficiency and behaviour change.*

Figure 07: Carbon Dioxide Removal (CDR) or Negative Emission Technologies (NETs) mainly consist of:

A. Afforestation & reforestation

Tech readiness
Ready for large-scale deployment

Side effects

Trend after 2050
Cost
Potential

Permanence
Reversible

B. Bioenergy carbon capture & storage

Tech readiness
Only 1 full scale demonstration

Side effects
N_2O

Trend after 2050
Cost
Potential

Permanence
Stable

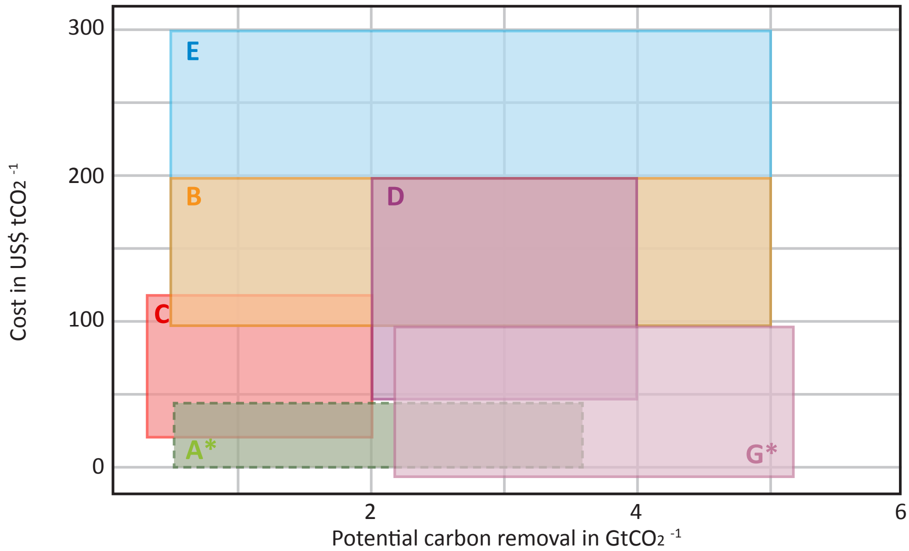
C. Biochar

Tech readiness
Limited pyrolysis capacity

Side effects
N_2O

Trend after 2050
Cost
Potential

Permanence
Stable



D. Enhanced weathering

Tech readiness
Limited mineral production

Side effects

Trend after 2050
Cost
Potential

Permanence
Stable

E. Direct air capture

Tech readiness
Deployed in niche markets

Side effects
?

Trend after 2050
Cost
Potential

Permanence
Stable

F. Ocean fertilisation

Tech readiness
10s of small demonstrations

Side effects
N_2O

Trend after 2050
Cost
Potential

Permanence
Stable but uncertain

G. Soil carbon sequestration

Tech readiness
Ready for large-scale deployment

Side effects
N_2O

Trend after 2050
Cost
Potential

Permanence
Reversible

Side-effects[28]

(Positive, risk of negative)

Air pollution · Albedo · Biodiversity · Ecosystem changes · Food security

Ground/water pollution · Mining and extraction · Soil quality · N_2O Trace GHGs

Source: CarbonBrief[25]

These can be deployed at any time. If deployed early they can avoid overshoot (see discussion below), or if deployed later can offset that overshoot.

In IPCC SR1.5°C only nine scenarios avoided overshoot to achieve 1.5°C. As the IPCC says:

> *"All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 GtCO2 over the 21st century.*
>
> *CDR would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5°C following a peak (high confidence). CDR deployment of several hundreds of $GtCO_2$ is subject to multiple feasibility and sustainability constraints (high confidence). Significant near-term emissions reductions and measures to lower energy and land demand can limit CDR deployment to a few hundred $GtCO_2$ without reliance on bioenergy with carbon capture and storage (BECCS) (high confidence)."*

See Appendix for more detail.

Further we note that many scientists fear an overshoot itself will then cause tipping points in the earth systems meaning that NETs will not be effective in addressing an overshoot[29].

Net Zero Year around 2050

Most scenarios arrive at the Net Zero year between 2040 and 2060 clustered around 2050. For those who wish to focus on this as an emission ambition target in terms of CO_2 this has generally been interpreted as adopting a Zero Net Emissions target around 2050.

Impact on existing scenarios

In summary, we would draw the following conclusions about the SR1.5°C study:

1. The increased damage assessments call for a push towards a 1.5°C temperature target at 50- 66% probability.
2. The associated upward revisions in carbon budgets help make existing scenarios such as the IEA "well below 2°C", indeed they would claim 1.5°C depending on NET assumptions.
3. The new set of scenarios gathered together by the IPCC are usable if the detailed economic factors are made available. UNEP used a mean of these in their Production Gap report 2019.[30]
4. The large volume of NETs/CDR is a challenge for realistic forecasting as discussed below.

Scenario Architecture in more detail: The building blocks for scenarios and understanding the key metrics

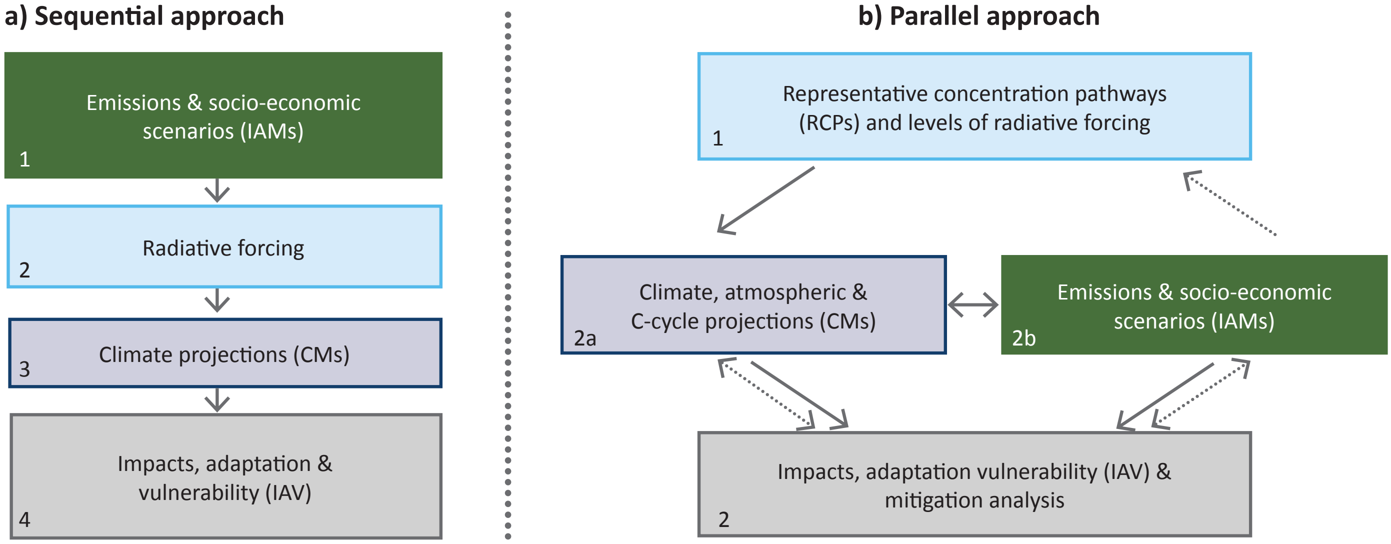
The notion of scenario architecture was floated by the World bank in: *A new scenario framework for Climate Change Research: scenario matrix architecture.*[31]

Climate change scenarios are fundamentally scientific based being driven by the relationship between greenhouse gases, temperature rise and probability of achieving the temperature rise but these also rely on socio-economic assumptions. These socio-economic assumptions seek to lay out how our economic systems would add to the cumulative and growing greenhouse gas inventory but also how these economic systems could evolve and indeed respond to greenhouse gas restraints. Apart from general macro-economic assumptions on population and GDP, it is the constraints delivered ultimately by policy and technology opportunities that drive the shape of the metrics of any scenario.

Socio economic assumptions

In 2013, for its Fifth Assessment Report (AR5), the IPCC approach was solidified by selecting a variety of end points, creating four specific emissions trajectories from the four end points and then working backwards along a series of possible or "representative" emission pathways. These RCP's (Representative Concentration Pathways) have been the mainstay of IPCC scenarios since AR5. They use what is termed a "parallel" approach to estimation.

Figure 08: IPPC Representative Concentration Pathways Approaches



Source: Beginner's Guide to Representation Concentration Pathways, Sceptical Science[32]

The IPCC highlights these differences in the following way stating:

> *"There are several primary groups who study the effects of climate change. Climate Model (CM) groups study the effects of global warming on the climate itself and how our emissions affect the environment. Integrated Assessment Model (IAM) groups combine information from diverse fields of study, primarily to assess the relationship between emissions and socio-economic scenarios. A third group studies Impacts, Adaptation and Vulnerabilities (IAV), often at regional scales, drawing on disciplines and research traditions including social sciences, economics, engineering, and the natural sciences."*

The IPCC IAMS (Integrated Assessment Models) in 2000 were the first to look at more detailed economic assumptions such as population, GDP and the level of integration, policy impacts, technologies and resource usage in the global economy and how various "stories" were used to then input into physical climate models. IAMs do this by combining key elements of biophysical and economic systems into one integrated system. This modelling approach is integrated because environmental problems do not respect the borders between academic disciplines.

Integrated assessment models therefore integrate knowledge from two or more domains into a single framework. Integrated modelling is referred to as assessment because the activity aims to generate useful information for policy making, rather than to advance knowledge for knowledge's sake. Integrated assessment modelling is that part of integrated assessment that relies on the use of numerical models[33].

Furthermore, climate IAMs have both a land system and an energy system component. Since Agriculture, Forestry and other Land Use (AFOLU) is approximately 25% of emissions, this is critical to understanding the whole climate system. Energy only models have to start with AFOLU assumptions to derive their specific energy related carbon budgets.

All of the IPCC sourced scenarios are IAM derived based as shown in SR1.5°C above.

However, in many cases IAMs still do not output useful economic variables for financial analysis where demand/production and price profiles of key technologies are crucial. Well known economic scenarios generated by the IEA and IRENA take the IPCC AR5 emission scenarios as a series of starting points, constraints or targets in order to then analyse detailed potential policy and technology pathways to meet those emission outcomes at a sectoral level. These more detailed economic approaches represent how to deliver an emissions outcome and so are of greater utility to market participants, albeit still fraught with limitations, given their original use case for policymakers.

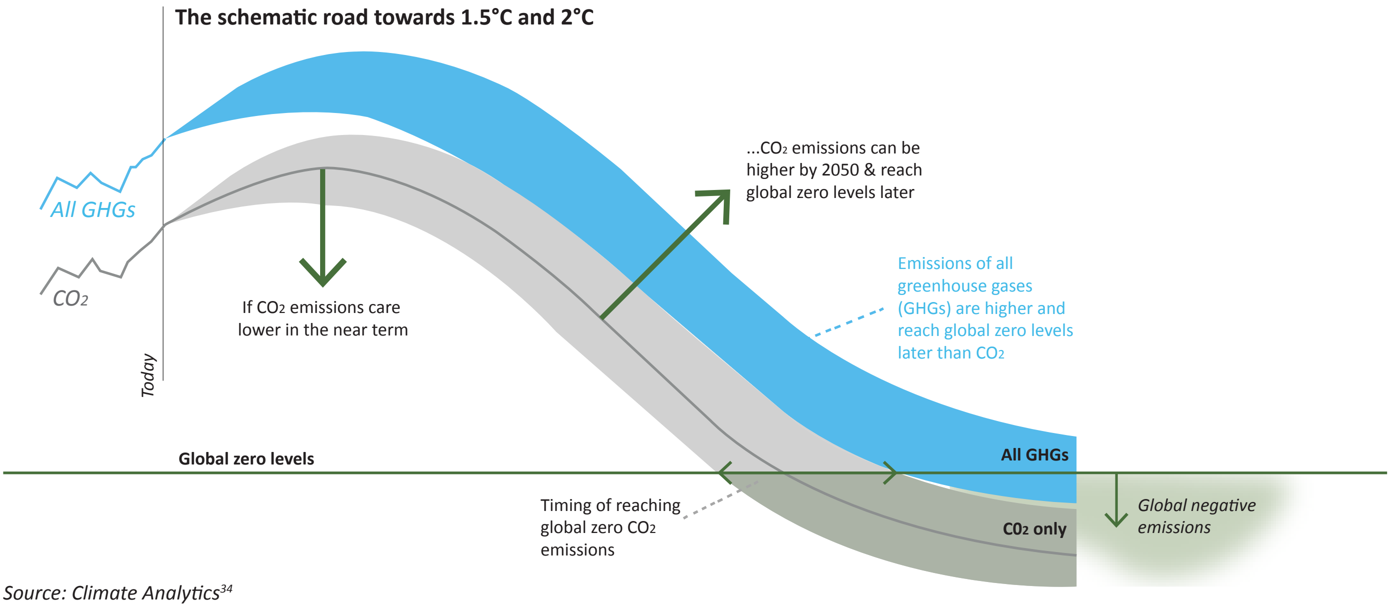
Importantly IAMs often set out to optimise policy to achieve a temperature constraint on top of the socio-economic inputs. The models solve for an optimised socio-economic (least cost) approach to achieve the temperature outcome and endogenously solve the required policy in terms of carbon prices. Some do mix in certain exogenous policy assumptions. This contrasts with IPR which seeks to input policy and technology assumptions and let the emissions and temperature outcome emerge.

Emissions Pathways

Most models will produce an emissions pathway - how to get from the starting point to the end point year by year - within the context of the above discussion.

Figure 09: The schematic road towards 1.5°C and 2°C

Temperature stabilisation implies zero CO_2 emissions
Holding warming below 2°C, or more stringently, returning global warming to below 1.5°C by 2100 implies a limit on the total amount of carbon-dioxide (CO_2) emissions that can ever be emitted into the atmosphere. Because of this limited carbon budget and historical emissions, global CO_2 emissions have to become zero at some point.



Source: Climate Analytics[34]

Zero carbon emissions are defined as zero global anthropogenic CO_2 emissions. Global zero carbon emissions does not mean that carbon emissions have to be zero everywhere, but means that any remaining anthropogenic CO_2 emissions in one region, or sector, are compensated by the same amount of 'negative' anthropogenic CO_2 emissions elsewhere. Negative CO_2 emissions are a result of a process such as the use of Carbon Dioxide Removal (CDR) technologies that permanently removes CO_2 from the Earth's atmosphere, storing it in a geological reservoir on a timescale of thousands of years. In addition, scenarios also assume anthropogenically enhanced uptake of CO_2 by the terrestrial biosphere, for example, through afforestation, resulting in increased storage of carbon. The net input of CO_2 to the atmosphere due to human activities globally thus remains zero. If the global amount of CO_2 storage is larger than the global CO_2 emissions then global negative emissions are achieved.

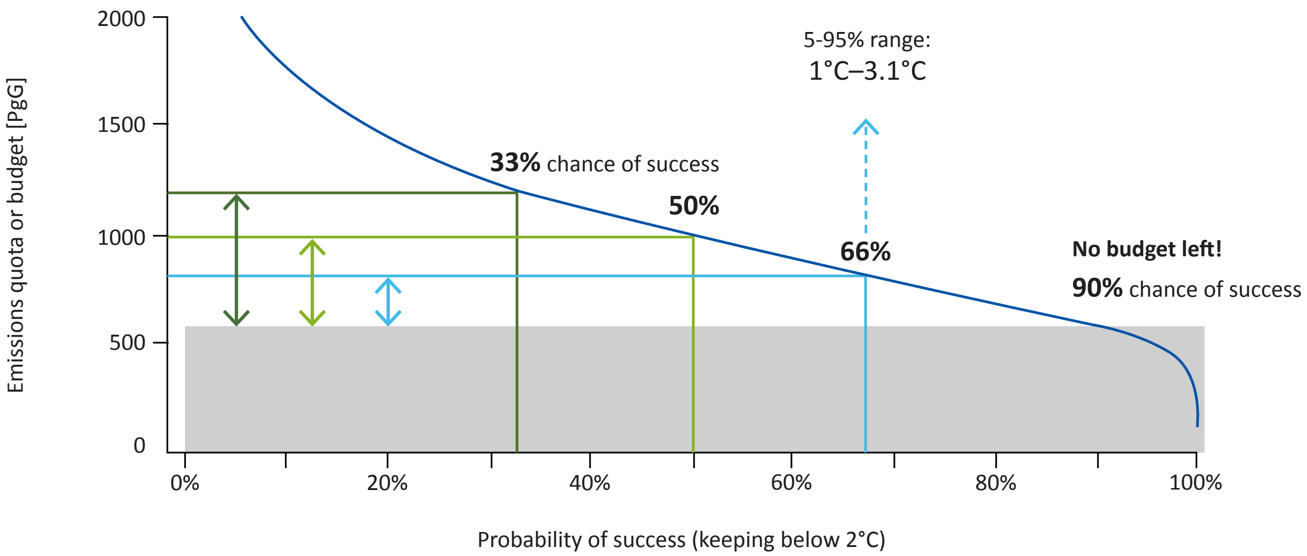
1. Allocation over time reflects at least some basic socio-economic indicators such as population growth and more sophisticated models include many more variables to drive the pathway.
2. Peak warming is approximately proportional to cumulative (total) emissions.[35]
3. Warming is largely independent of the emission profile, although the degree of overshoot can affect the outcome through feedback loops.
4. More emissions early implies stronger reductions later or negative emissions implementation.
5. Any temperature target implies a finite limit in cumulative CO_2 emissions. This can be thought of as the Carbon Budget. This is purely a physical and carbon cycle problem.[36]
6. The relationship between carbon budgets and temperature outcomes is highly complex and has recently been re-estimated based on observations in SR1.5°C as discussed below. This could change back up again in the IPCC AR6 according to some sources.[37]
7. Zero Net Year for emissions is now favoured by many as a key variable to focus on as exemplified in the Asset Owners Net Zero Alliance.

Probabilities and end dates

A key assumption for any climate scenario is the probability of achieving the temperature outcome, which can then be expressed as a "carbon budget" in GT of CO_2 equivalent. This is often not well emphasized and missed by those who are not technically versed or used to reading these climate scenarios. Many scenarios emphasise a 50% probability, some go to 66% or higher. The higher the probability for a given temperature target the lower the actual available carbon budget.

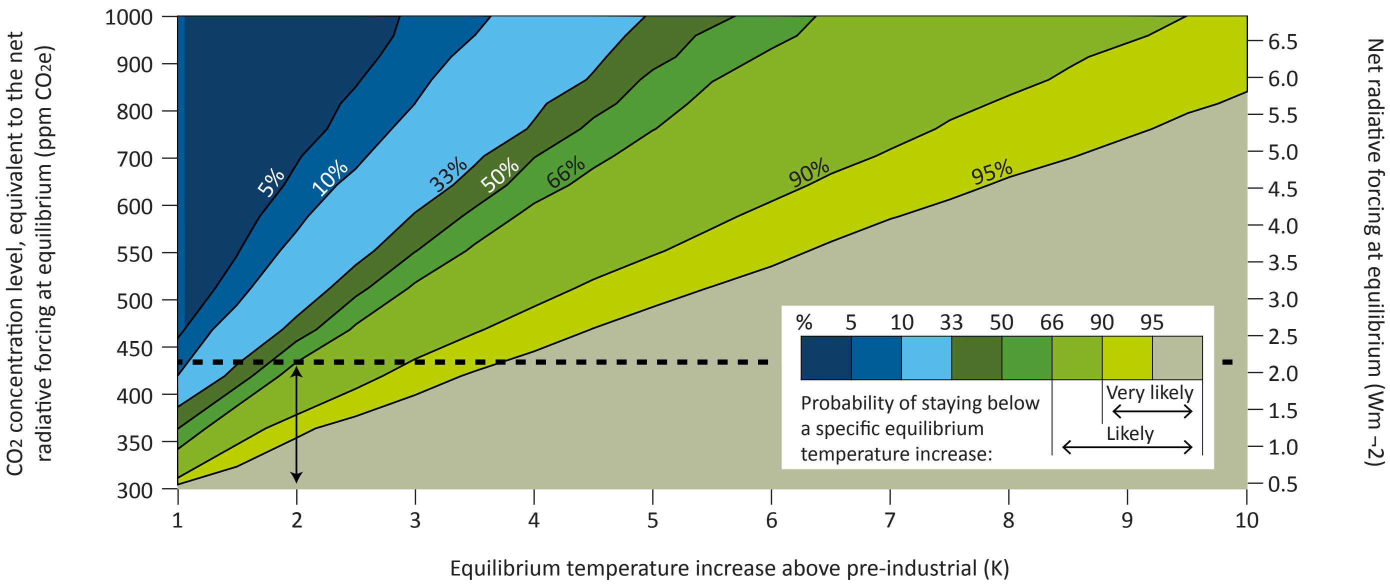
Also, it should be noted that in terms of reaching a particular temperature target, the IPCC in general aggregates models with emissions out to 2100 which can be then classified as 2°C or below. The major agency scenarios that are most commonly referenced all end somewhere between 2040 and 2060. As a result they have to make assumptions post 2050 to justify a particular temperature outcome. IEA SDS trends their energy model results to 2070 and then assumes around 300GT of NETs post 2050 to be consistent with 1.5°C .[38]

Figure 10: 2°C carbon budget and probability of success



Source: Raupach (2013, unpublished), based on Raupach, M.R., I.N. Harman and J.G. Canadell (2011) "Global climate goals for temperature, concentrations, emissions and cumulative emissions".

Figure 11: Temperature increase (°C) above pre-industrial



Source: Global warming under old and new scenarios using IPCC climate sensitivity range estimates[39]

The big assumptions of Carbon Capture and Storage (CCS) and NETS (Negative Emissions Technologies) – filling the gap

Economic/technology focussed scenarios assume a range of policy and technology assumptions that radically alter the nature of engagement with companies in particular sectors and perhaps even different companies within a single sector.

In particular, as discussed above, many scenarios use assumptions about Carbon Capture Use and Storage and Use (CCUS) that allow more fossil fuels to be supplied to the energy system for longer, affecting near term change for the fossil fuel supply sectors and Negative Emission Technologies (NETs) or also called Carbon Dioxide Removal (CDR) that allow ALL emissions to continue longer without drastic cuts, affecting near term ambition for the entire system/all sectors. According to the American University:

> *"Some proposed methods of carbon removal include: planting vast new forests; growing or collecting biomass to produce bioenergy and then capturing and storing the resulting carbon emissions; restoring degraded coastal wetlands; building machines to capture CO_2 directly from ambient air and store it underground; spreading powdered rock that would absorb CO_2 from the air; various methods of storing carbon in the oceans; and managing agricultural lands to increase their soil carbon content"*[40].

The most cited source of these by climate modellers are Bio Energy and CCS or BECCS (which are subject to land use constraints as discussed in IPR FPS) but there is increasing talk of Direct Air Capture. Currently, CCS technology is not at commercial scale and not competitive with alternative mitigation technologies such as renewables. Many investors are aware of this and are naturally sceptical about the use of CCS and NETS going forward and yet they form the basis of growth forecasts for many high carbon exposed companies.

The amount of feasible CDR/NETS – particularly BECCs – remains very uncertain. Maximums have been estimated, see Fuss et al (2018)[41] and IPR FPS [42].

Papers such as the review of NETS by the European Academies' Science Advisory Council (EASAC)[43], show why caution is warranted. Many of the NETs including reforestation, afforestation, carbon- friendly agriculture, bioenergy with carbon capture and storage (BECCs), enhanced weathering, ocean fertilisation, or direct air capture and carbon storage (DACCs) are highly unproven at scale with BECCS proving a major land use issue with a wide range of unintended consequences on the eco-system.

The constraints faced by implementing or retrofitting fossil fuel power CCS compared to BECCS are quite different, even though the storage issues are similar. However, these are the best assumptions available in many modellers view right now.

CCS assumptions have also been questioned by investors and other commentators. However, there are some key reports that point to the opportunity for CCS retrofit, particularly in China where there is so much reliance on coal[44] whilst pointing out that there is:

"painfully slow progress towards deployment of CCS with four large-scale CCS projects awaiting final investment decisions."

The IEA states:

"In total, some 310 gigawatts (GW) of existing coalfired power capacity meet a number of basic criteria for being suitable for a retrofit."

But the IEA also indicates that only 19% might have high suitability[45]. Whilst time moves on, the gap between Chinese renewables costs and CCS retrofit costs narrows [46]:

> *"China is perilously close to surpassing a crucial 'reference' carbon emission budget while India will do so over time as emissions continue to grow, throwing a focus on additional climate action where a critical choice is looming between carbon mitigation with or without large-scale carbon capture and storage (CCS)."*

The implications for scenarios to become more credible by having a lower reliance on CCS are highly significant. Only a few scenarios (for example the IPCC P1 scenario) with a "well below 2°C" outcome as defined in the Paris Agreement do not rely on CCS and/or NETs post 2050.

This shows a scaling of renewables and other supporting or clean technologies that is a long way beyond the most optimistic commentators when considering current trends.

However, a transition acceleration shift driven by physical impacts or tightening scientific data could drive these scenarios more into focus. Ultimately, if major climate impacts occur, governments may be faced with certain major trade-offs between economic growth and emissions reductions not dissimilar to those being discussed under COVID-19. Mitigation is cheaper than adaptation. Such an approach would be consistent with classical risk management methodology as for example described by Bob Litterman[47] in terms of applying a hard brake to deal with uncertainty.

The TCFD framework underpins the business model test approach to engagement with companies by identifying the types of risks which investors should encourage companies to test their business models against. This leads to evaluation of risk.

Importantly, because NETs are often assumed in the 2050-2100 time frame at the "back end" of a scenario, these can become a least cost solution to get to a particular temperature outcome. So, a scenario could be made to look 1.5°C by relying on increasing NETs beyond the end-point of the main scenario analysis as with IEA SDS.

Enriching decarbonisation scenarios with Asset Level Linkage and valuation impacts

Particularly for use by investors, it then comes the critical stage of downscaling these higher-level outputs to interact with company disclosure at an asset level (usually not deep enough) or independent asset-based databases and analysis. Two groups that have specialized in this are Carbon Tracker in its 2 Degrees of Separation and Breaking the Habit works and 2DII in the SEIM/PACTA work found on the PRI website. The Inevitable Policy Response sets out potential valuation impacts coming from this on major asset classes from a bottom up driven asset level basis. We are unaware of other studies that go to this level.

Drawing from the summary tables 1 and 2 above on metrics, based on scenario temperature and carbon GT budget, key variables required for financial analysis are:

1. Demand profile by sector and geography where available
2. Price profiles of relevant products

These are tested against the expected production and capex of a company based on:

1. A dynamic supply cost curve based on individual assets, or
2. A fair market share assumption of production in industries where cost differentials are less pronounced

Indeed, it is at this level of production/sales and capex, which can be thought of as the evolution of the capital stock, that it is possible to measure the progress of a company towards Paris Agreement Alignment and the targets that companies do set are in these business terms.

In addition to the commercial databases for commodities offered by Wood MacKenzie and Rystad, there is an increasing focus on creating better access and integration of asset level data. Initiatives by SSEE and 2DII[48,49] in 2016 sought to examine the gaps in asset level data and how to plug them. This led in early 2018 to the Asset Level Data Initiative between SSEE, 2DII, CDP and Stanford[50]:

> *"ADI is non-commercial research-based initiative to support the bringing together of existing asset-level data with new sources of data. It supports efforts to collect, verify, and distribute asset-level data on all companies in key sectors globally, regardless of whether they disclose or not. The three objectives of the ADI are to drive the use of asset-level data; improve access to asset-level data; and improve the quality of asset-level data. The development of the ADI is driven by five use cases: asset managers, asset owners, citizen savers, regulators, and policymakers and civil society".*

This has become the Spatial Finance Initiative[51].

Inevitable Policy Response (IPR) Valuation Approach[52]

IPR seeks to make a full valuation analysis for investors at a portfolio level.

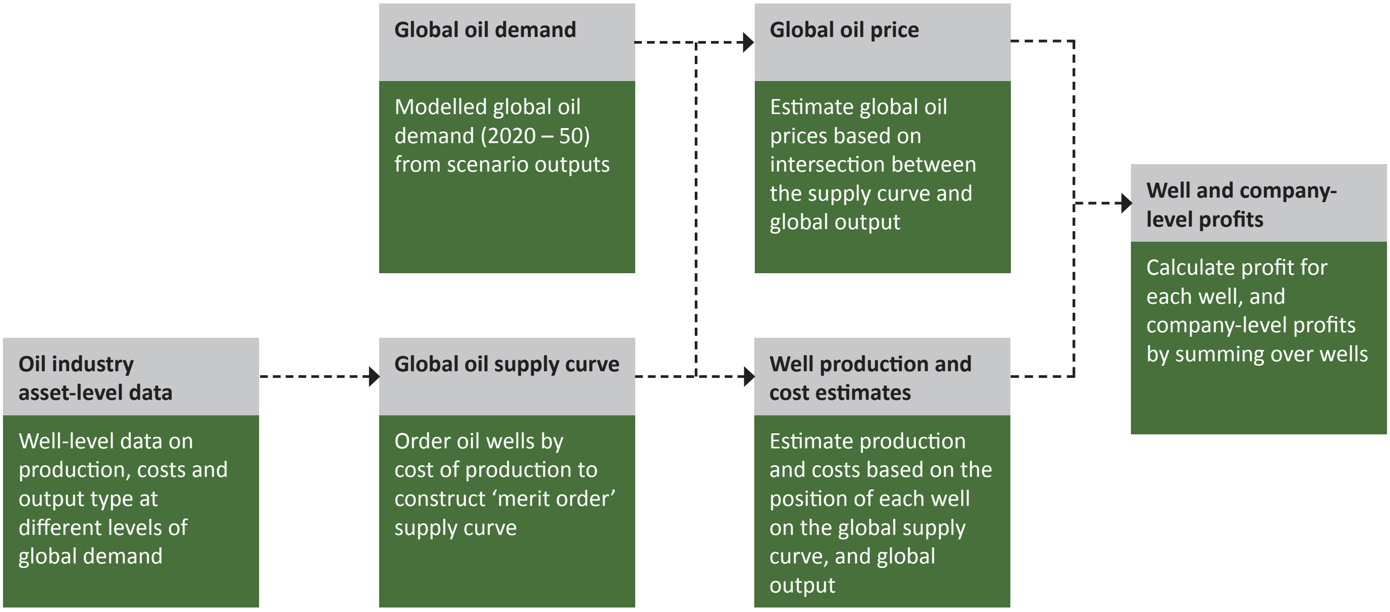
On the asset level, demand destruction, demand creation and cost and competition are important drivers of value and of informing decarbonisation scenarios.

Demand destruction

Within scenarios, there will be demand destruction particularly for emissions intensive products, e.g. fossil fuels and associated sectors, as well as ICEs.

Asset level modelling provides information of impacts of falling output, due to differences in costs of production, initial profit margins, portfolio composition and time horizons. This is illustrated in Figure 12 for an oil company.

Figure 12: Overview of demand destruction an illustrative oil company.



Source: Vivid Economics

In the ICE vehicle manufacturing sector, the modelling uses sector decline projections to forecast the changes to future company revenues. Scenario outputs will include the decline in demand for ICE vehicles, which are then used to estimate future company revenues from ICE-related business segments based on this sectoral decline.

Demand creation

Within and across sectors, there will also be demand creation, e.g. for renewable equipment, EV and battery cell manufacturing, biofuels and green minerals. Renewables include wind turbines, solar panels and hydroelectric power generation equipment. Green minerals consist of cobalt, copper, lithium, nickel and silver (ore).

Carbon costs & competition

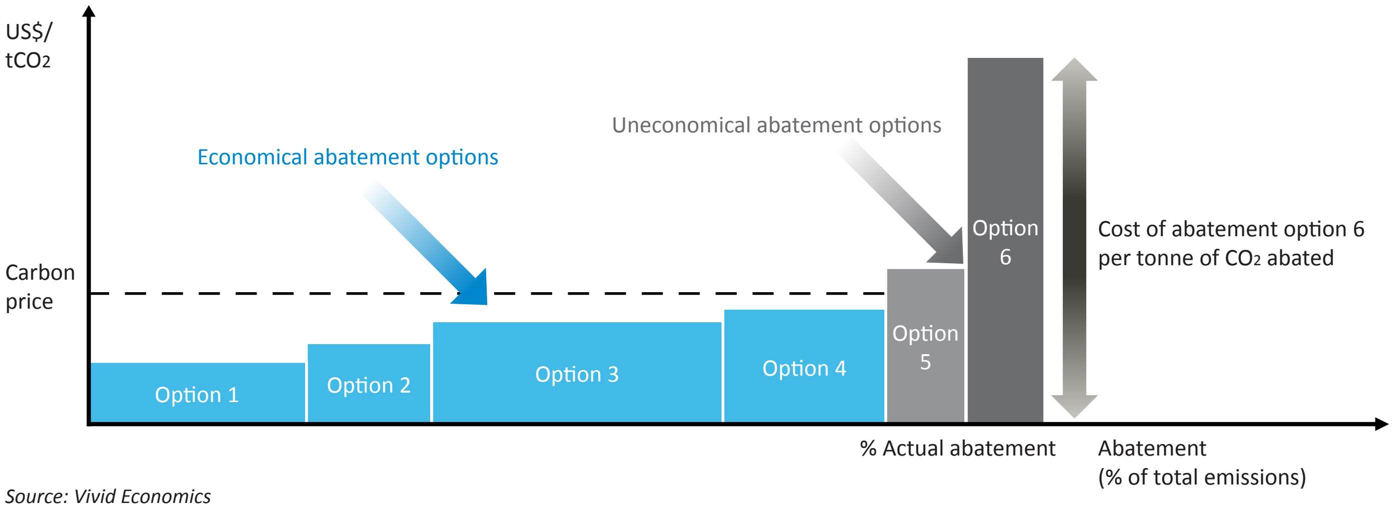
Direct carbon costs

The primary direct shock to assets from transition risk is implicit in carbon pricing. Implicit carbon prices – which include carbon taxes, market-based carbon prices or the cost of complying with other climate change regulations – represent a significant cost shock for emissions intensive companies. Whether prices are imposed through carbon taxes, emissions trading schemes, clean technology subsidies, or other policy mechanisms, they can be summarised by a single carbon price signal. In the first instance, this price assigns a cost to the company's Scope 1 emissions. In the second, carbon pricing increases the price of electricity for all consuming companies as power generators face carbon costs in production and pass these through to consuming firms – this reflects the cost of Scope 2 emissions.

Abatement

The direct carbon pricing impact of transition risk will lead firms to consider which abatement options are available to reduce the cost burden. Figure 13 shows an illustrative abatement cost curve. At the carbon price shown, all companies find it profitable to exercise abatement options 1 – 4, as these options cost less than the carbon price, leading to a cost saving of carbon price net of abatement cost on every unit of avoided emissions. This means that all companies have the same actual abatement as a % of total company emissions.

Figure 13: Illustrative abatement cost curve, with economic level of abatement shown based on a given carbon price



Source: Vivid Economics

Competition

Competition modelling component examines the interplay between risk exposure and company responses in the context of the market, including cost pass-through, exit and market share reallocation. Taking company risk exposure and response examined up until this point as inputs, the competition model estimates the total impact of each scenario on individual companies given the competitive dynamics in the markets in which they are active. This involves aggregating direct and indirect impacts on each company and examining what costs companies can pass through to consumers. Company-level cost pass-through rates are the final piece of information required to determine company-level profit margins and hence profits. These profit figures then lead some firms to exit the market and their market share to be reallocated across remaining firms.

Key variables and metrics for assessing scenario Architecture

In terms of architecture (defined in this paper as key variables, metrics, attributes and drivers), we would highlight the following key aspects to any climate scenario pathway in an investor context:

Table 05: Key Variables associated with the emissions pathway

Metrics	Description
Target temperature over pre-industrial levels	This describes the temperature above pre-industrial levels with which the scenario is consistent. In most cases this is a constraint reflected in the carbon budget and so the pathway (or an outcome of assumptions such as with IPR).
Probability of achieving temperature target	This is the probability of achieving a particular temperature outcome. This is a critical datapoint, as the uncertainties within climate science lead to wide ranges of outcomes meaning that a probabilistic presentation is useful.[53]
Carbon emissions budgets	Global warming is fundamentally linked to the absolute concentration of greenhouse gases in the atmosphere. To stabilise global temperature at any level vs pre-industrial, there is then a finite amount of emissions that can be released before net emissions need to reach zero – For CO_2 emmisions this can be referred to as a carbon budget. (see Figure 22 in Appendix).
Scenario start year	This is the year the analysis of the particular scenario model starts.
Emissions peak	This is the year at which emissions peak.
Year temperature target is first reached	This is the year when the temperature target is first reached.
Net Zero Year – emerging as a key metric	This is the year where globally there are zero net emissions which means any residual direct emissions are offset by CDR (e.g. NETS including BECCS).
Overshoot	The degree of temperature overshoot above the set target of the scenario. Overshoot can occur during the pathway time frame.
Return Year	Return year refers to the year when the temperature returns again to target after overshoot.
Scenario transition modelled end year	This is the last year of the detailed modelling in the scenario. At this point the temperature target may not be stable and further assumptions are required to establish that.
Emissions reduction on base year %	This is the percentage reduction of emissions highlighted in the scenario at its end year measured against its base year which is not always the first year of the scenario model. Again this needs to be put in the context of a pathway - the slope of this curve shows timing of impact.

Source: ETA

These emission pathway variables need to be associated with economic and financial variables if to be of use to investors and companies in financial analysis. As the 2DII paper on scenarios points out, this process of translation often leaves gaps in financial risk analysis.[54]

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Table 06: Associated Key Economic and Financial variables

Metrics	Description
Geography and Sector	The more granularity the more useful for investment analysis.
Geographic Jurisdictions	Countries and regions in scope of analysis.
Key Sectors Covered	The range of sectors included in the scenarios. Note that this includes any references to sectors at any point on the supply chain, thus including end use sectors as well as primary producers.
Key Policy Drivers	
Carbon Prices	Carbon pricing is the most cited policy method to optimise the shift of capital from high to low carbon assets and, because it can be added to the asset level, represents a favourite method for modellers and analysts. Indeed, it is often used as an overall proxy for all policies by modellers. Hence need to identify if endogenous or exogenous to the model.
Key Economic and Financial Variables	This is what drives the economic results of the scenario. They are both inputs and outputs.
Technology Trajectories/ Demand Profiles – see below other key variables	These are not a single datapoint but are a series of (often complex) signposts and datapoints that define how various technologies are developing e.g. volume of electric cars, GW of renewable capacity. These in effect set out production profiles and so reflect expected demand in the economy.
Asset level	For investors and companies, granular real asset data and financial data is needed to apply economic results to portfolios and indeed in engagement with companies. So, this level has to be linked to the technology/demand profiles. An example is Carbon Tracker's “Breaking the Habit” report and the 2DII SEI metrics projects.
Associated Capital Investment	The amount of capital required in order to achieve the various demand/production/ emissions targets.
Stranded Assets	Stranded assets are now generally accepted to be those assets that at some time prior to the end of their economic life (as assumed at the investment decision point), are no longer able to earn an economic return (i.e. meet the company’s internal rate of return), as a result of changes associated with the transition to a low-carbon economy (lower than anticipated demand/prices).[3]
Associated Commodity Demand and Prices	Energy scenarios in particular have implications for the broad commodity level analysis in terms of demand/supply and price.
Other Policy Levers	These describe the types of policy needed to incentive investment in new technologies or assets to achieve various emissions reduction targets. IPR sets these policy levers out in detail.[55] In some models these in turn are proxied by a carbon price.
Other Key Technology Variables to Identify	These inputs/assumptions make a substantive difference to the investment outlook in a scenario.
CCS/CCSU	CCS is Carbon Capture and Storage which describes the capture of CO_2 and the subsequent geological storage of those gases. Carbon Capture Storage and Use extends this to using carbon in various technologies.
NETS / CDR	NETS is Negative Emissions Technology (sometimes known as CDR- Carbon Dioxide Removal) which describe any technology or series of processes where there is a reduction in emissions by either capturing the emissions at the point of process of physically extracting the emissions from the atmosphere. BECCS is one form of NETs.
BECCS	BECCS describes capturing CO_2 from bioenergy applications and sequestering it through Carbon Capture and Storage.

Source: ETA

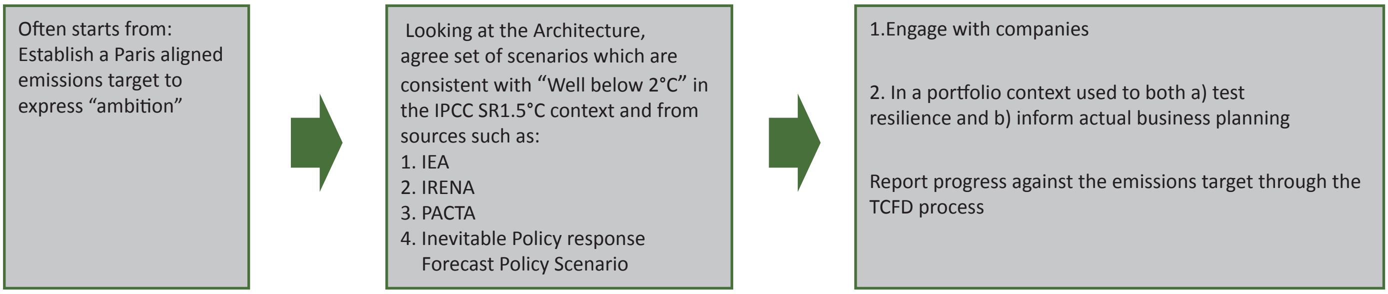
In a follow up paper we intend to compare the IEA SDS with IPR based on these metrics to illustrate different architectures.

Conclusion: Choosing Scenarios for Investors

As discussed, investors can use scenarios to both engage with companies and to inform portfolio decisions. In a TCFD context this leads to disclosure by both companies and investors.

The following implementation steps provide an example of how to use scenarios and targets to implement a Paris Agreement Aligned (PAA) outcome moving towards the 1.5°C temperature target, the major focus in this report.

Figure 14: Overview of scenario implementation in an investor context



Source: ETA

The approach towards scenarios selection is one of the most important strategic decisions for investors and PRI signatories wishing to engage. The first step is to choose a temperature of GHG outcome to target and establish a range of "credible scenarios" consistent with that. As argued above, this is increasingly moving towards 1.5°C outcomes, but certainly consistent with a "well below 2°C" outcome.

The real issue is consistency which leads to the concept of base case or "reference" scenarios that are commonly agreed for use. Clearly testing against the same agreed scenario or set provides better comparable data. For investor portfolio applications, an individual choice can also make sense.

The logical step would be to develop "base case" or "reference scenarios" by agreement and at least see one of them common to all cases. This will need to encompass both the resilience/stress test and business planning application.

There are three approaches to emissions scenarios agreement we can identify that can be used in various ways:

1. Try to get agreement on a single emissions scenario
2. Establish an agreed set or range of credible Paris Agreement aligned scenarios
3. Median or Average scenario parameters from all agreed credible Paris Agreement Aligned transition scenarios

The following issues relate to each of the above:

Agreement to select a single emissions scenario

Since scenarios are highly technology dependent in terms of assumptions like CCS and timing of deployment, selecting just one of these would be contentious. This applies to selecting a single emissions pathway where there are also critical decisions about what temperature target 1.5°C-2°C and the probability 50-66% level.

An agreed set or range of credible Paris Agreement aligned scenarios

Certainly, from a business planning perspective, having flexibility at the sector level in choosing scenarios makes sense. However, in the absence of consistency, companies will cherry pick scenarios that create the most optimistic forecast for their company, making consistent engagement difficult across a range of investors. Any company that is being engaged by investors, who have different or no particular views on scenarios, is likely to argue that, in the absence of consistency, its own optimistic scenario is just as credible.

Therefore, getting investors to agree on a set of agreed reference scenarios and looked at by as many companies as possible would make sense from a consistency point of view and allow for diverse technology paths. There is then a danger of inconsistency when this approach is applied to getting companies to comply with one of these – different investors might then choose different aligned scenarios which would contain trade-offs between competing users of the available carbon budgets e.g. more oil means less coal.

Within the set of scenarios, having at least one that is commonly included would make the most sense for comparability.

Average (Mean) or Median of all PAA "credible" scenarios

Exxon adopted an averaging approach in its 2018 paper but selected a[56] mostly out of date set of scenarios for this purpose, namely the Stanford EMF[57] model rather than some of the more energy specific and up to date IEA or IRENA scenarios that contain updated data on key areas like energy costs. However, creating a range of say Paris Aligned Scenarios and perhaps selecting an average for the demand, price and supply assumptions of those scenarios could be seen as a balanced approach. It is also desirable to understand the range or median of each scenario parameter in addition to the average. The advantage of this would be to have single engagement inputs for demand, supply and price that can be used to negate arguments over a single number for any assumption whilst allowing investors to adopt a single forecast base case for engagement and investors. This forecast base case would be easily adapted for scenario updates by the IPCC, IEA and IRENA and would allow a single output for use in engagement as well as asset allocation.

Adopting an agreed set of economic/technology scenarios with at least one in common and what are the key options

At present, the most commonly used scenarios for a resilience/stress test include the IEA B2DS and IEA SDS

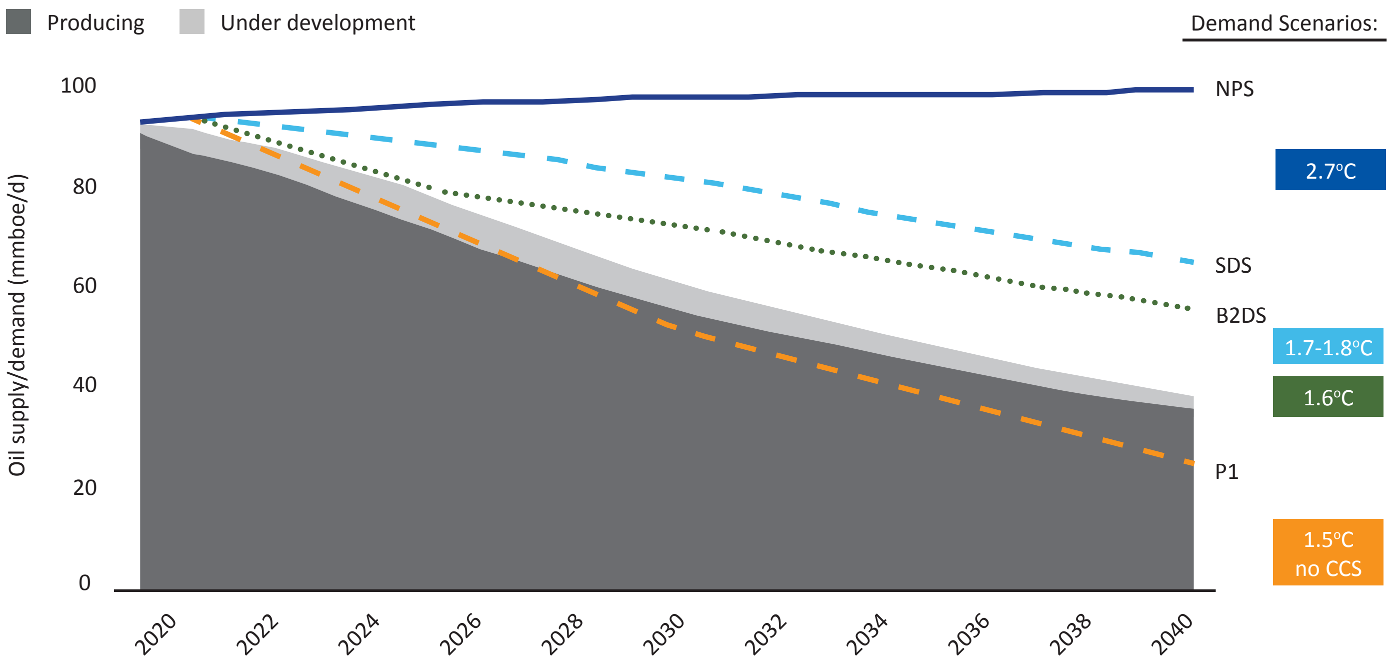
- For planning purposes, the IPR FPS is fit for purpose. As discussed above, any investor or company that wishes to implement action in their asset selection will need to look to something that has high conviction. By acknowledging it is a start on a 1.5°C pathway, IPR represents a first wave policy response to get a possible Paris Aligned outcome underway.

Examples of Scenario Application in Action

Carbon Tracker approach to oil and gas

Carbon Tracker Initiative uses a least-cost methodology to understand the financial implications for different supply options given a range of different scenarios. Scenarios used have included those published in particular by the IEA and IPCC.

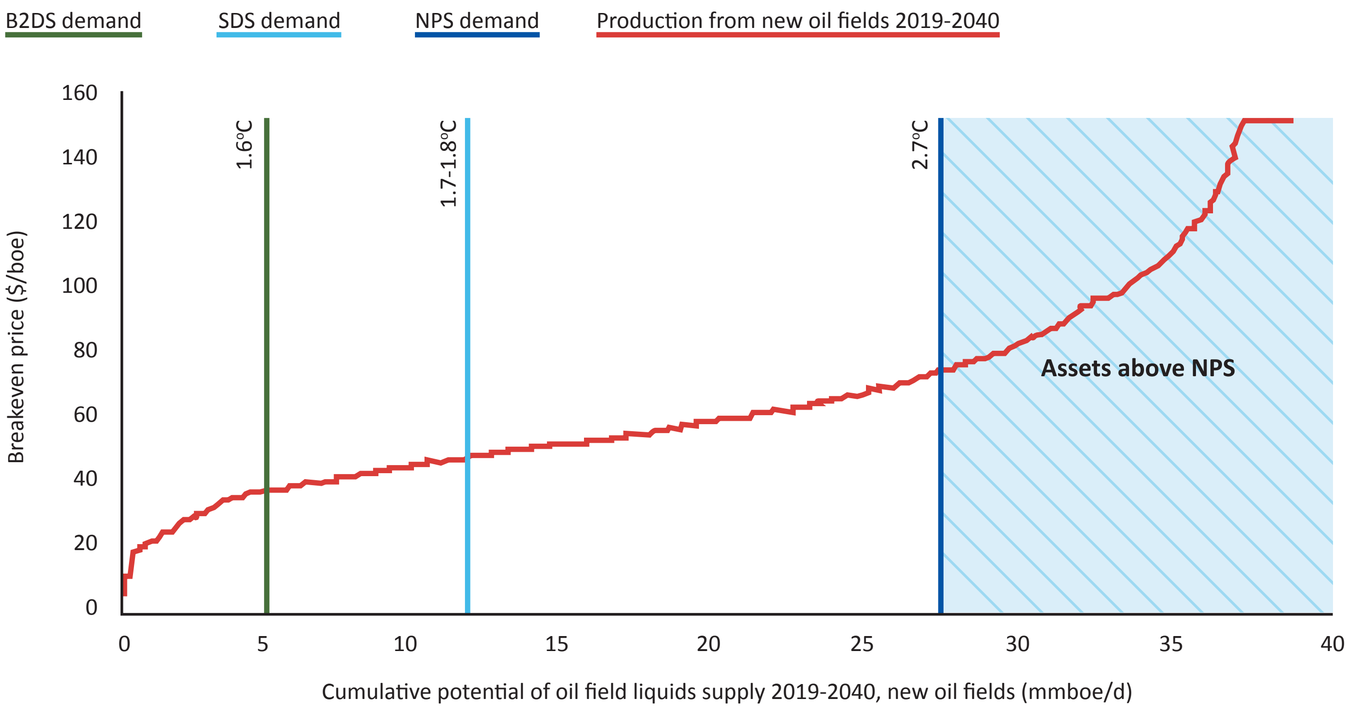
Figure 15: Comparison of demand pathways to post-fid oil production



Source: Rystad Energy, IEA, IPCC, Carbon Tracker analysis

Carbon Tracker's analysis is based on the principle that in conditions of limited demand, the assets that will go ahead will be those that are most competitive in the market in terms of cost, measured in this case through their breakeven prices. This is clearly illustrated through the concept of the cost curve.

Figure 16: Aggregate oil supply and demand under the IPR forecast policy scenario (2019-2025/2026-2040)



Source: Rystad Energy, IEA, Carbon Tracker analysis
Note: Potential oil supply with a breakeven of >$150/boe has been aggregated at that level!

Carbon Tracker has used this approach on both a prospective and retrospective basis – to look at potential projects that companies might sanction which would fall outside/be stranded in a given scenario, and to look at recent sanction activity to look at whether companies are sanctioning projects that are reliant on the failure of Paris in order to generate an economic return. In *Breaking the Habit*, Carbon Tracker noted that all the major oil and gas companies appeared to have sanctioned projects in 2018 and 2019 that fell into this category.

Figure 17: Selected projects sanctioned in 2018 outside 1.7-1.8˚C budget

Project	Resource theme	2019-2030 capex	Country	Partners (*denotes operator)
LNG Canada T1	Conventional (land/shelf)	**$6.5**bn	Canada	**Shell***, Petronas, Mitsubishi Corp, Korea Gas, PetroChina
LNG Canada T2	Conventional (land/shelf)	**$6.5**bn	Canada	**Shell***, Petronas, Mitsubishi Corp, Korea Gas, PetroChina
Gordon/Jansz Stage 2	Deep water	**$3.6**bn	Australia	**Shell, Chevron*, ExxonMobil**, Osaka Gas, Tokyo Gas, Chubu Electric
Aspen Phase 1	Oil sands	**$2.6**bn	Canada	**ExxonMobil***, Imperial Oil
Amoca FFD	Conventional (land/shelf)	**$1.4**bn	Mexico	**Eni*,** Qatar Petroleum
Zinia 2	Deep water	**$1.3**bn	Angola	**BP, ExxonMobil, Total*, Equinor**

Source: Rystad Energy, IEA, Carbon Tracker analysis

As Carbon Tracker's methodology starts off at the project level, determining those projects that fit in a low carbon world and those that don't, these projects can then be aggregated at different levels. In particular, Carbon Tracker has given results at the company level, showing what proportion of a company's available portfolio world fits in a low carbon world on the basis of project-level economics and what proportion doesn't (and hence is at greater risk of stranding).

Table 07: 2019-2030 Potential capex outside given scenarios, All projects (sanctioned and unsanctioned)

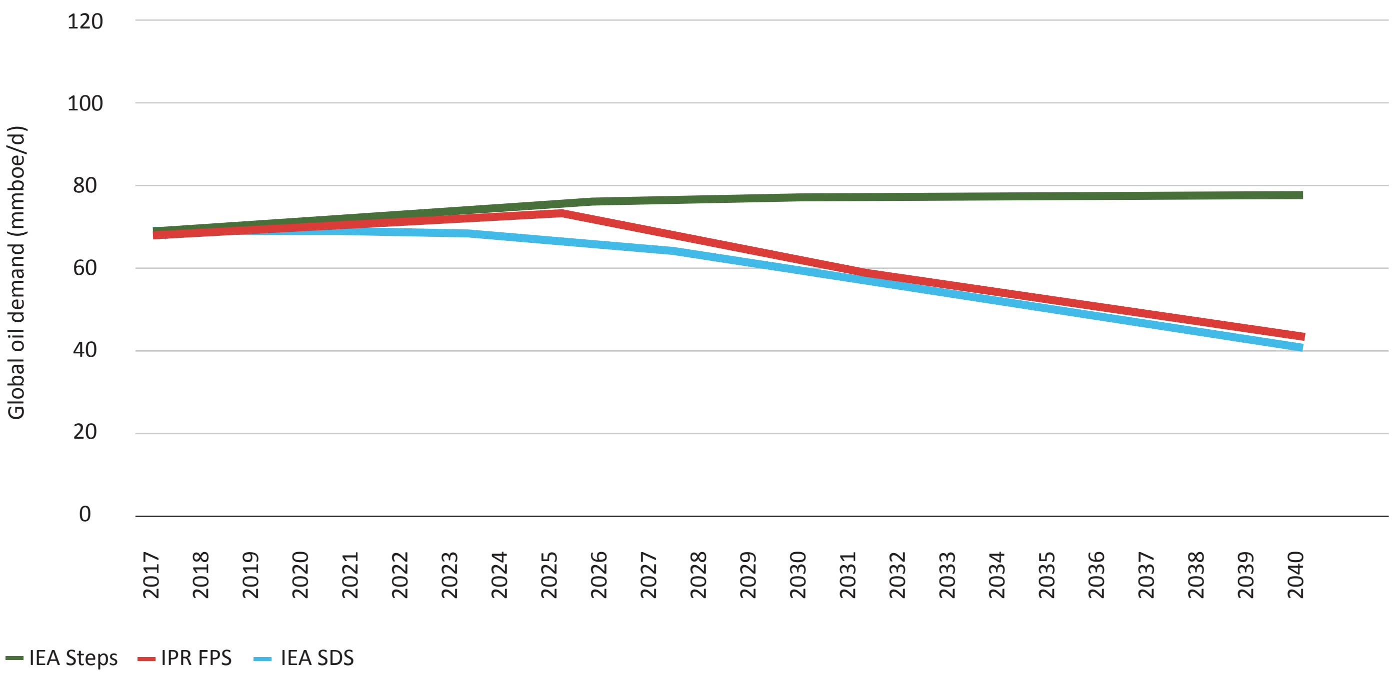
Quartile (4 is highest % of capex outside B2DS budget, 1 is lowest)	Company	% of NPS upstream capex outside B2DS budget (% band)	% of NPS upstream capex outside SDS budget (% band)	Upstream capex excluded as above NPS (shown as % of NPS capex
4	Anadarko	70% - 80%	40% - 50%	40% - 50%
4	Centennial Resource Development	90% - 100%	30% - 40%	0% - 10%
4	Chesapeake	80% - 90%	60% - 70%	40% - 50%
4	Cimarex Energy	80% - 90%	10% - 20%	0% - 10%
4	Concho Resources	90% - 100%	80% - 90%	20% - 30%
4	Continental Resources	80% - 90%	20% - 30%	40% - 50%
4	Crescent Point Energy	80% - 90%	80% - 90%	>100%
4	Diamond back Energy	80% - 90%	60% - 70%	0% - 100%
4	Encana	80% - 90%	70% - 80%	50% - 60%
4	EOG Resources	90% - 100%	60% - 70%	10% - 20%
4	Hess	70% - 80%	50% - 60%	10% - 20%
4	Matador Resources	90% - 100%	60% - 70%	10% - 20%

Source: Rystad Energy, IEA, Carbon Tracker analysis

Carbon Tracker: Using IPR

In a 2020 report *Handbrake Turn*, Carbon Tracker looked at the implications of the IPR FPS demand pathway, using a similar economic modelling approach.

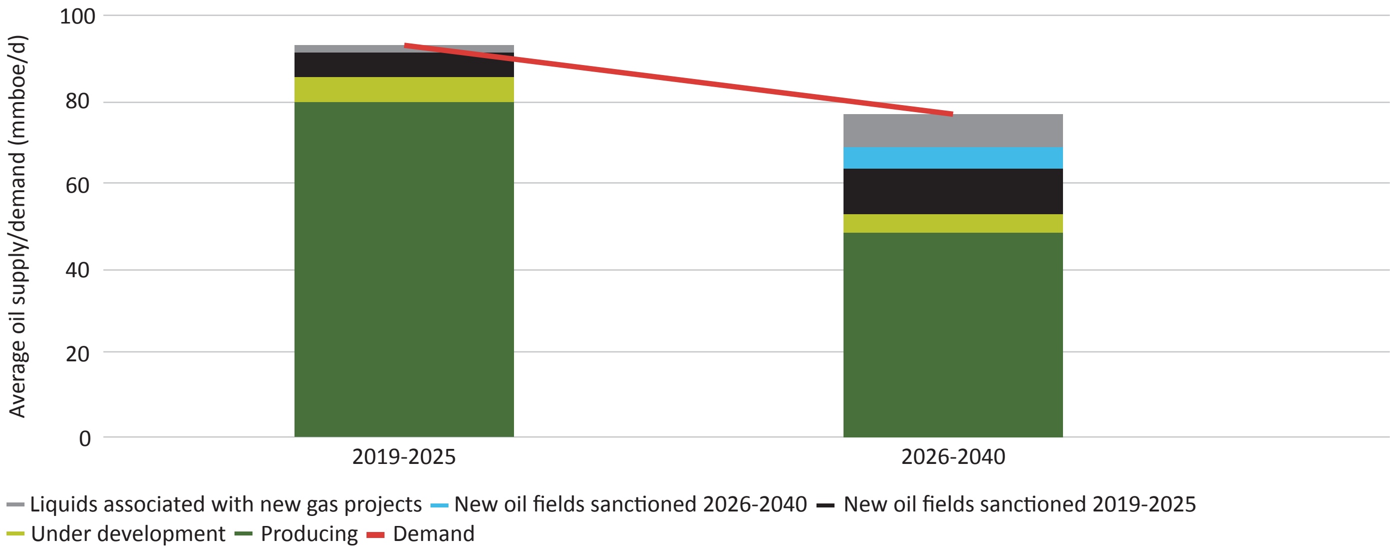
Figure 18: Global oil demand (Excluding biofuels, GTLS and CTLS, refinery gains) under selected scenarios



Source: IEA, IPR, Carbon Tracker analysis

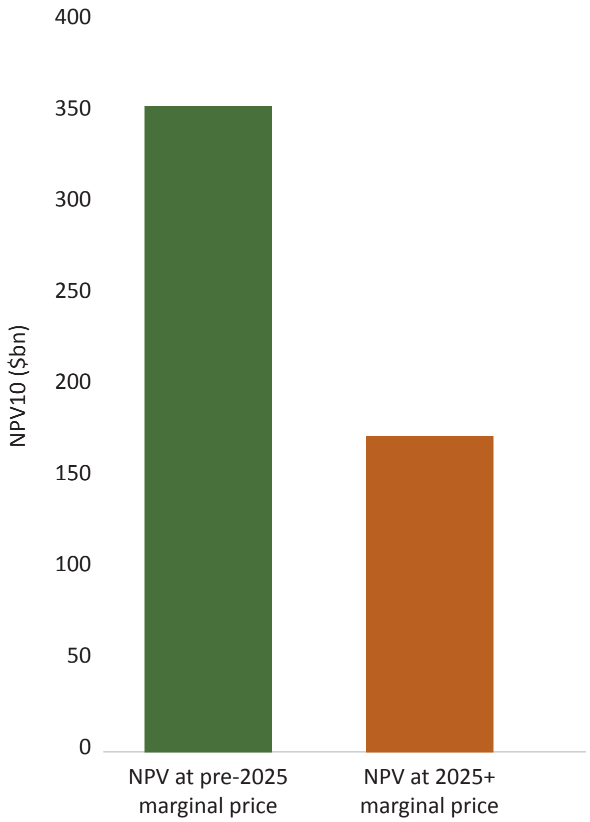
Carbon Tracker looked at the demand as two aggregate periods – pre-IPR and post-IPR, modelling production pathways using a least-cost methodology to determine which projects fit in that scenario. It found that the sharp decline in oil demand post-2025 meant that there is very little space for new oil projects after this point, with associated liquids from more resilient gas demand also offsetting demand for new oil fields.

Figure 19: Aggregate oil supply and demand under the IPR forecast policy scenario (2019-2025/2026-2040)



Source: Rystad Energy, IEA, Carbon Tracker analysis

Figure 20: Indicative NPV10S for unsanctioned oil fields entering production in 2019-2025 at different price levels (Period 1 refers to 2019-2025, period 2 refers to 2026-2040)



Source: Rystad Energy, IPR, Carbon Tracker analysis

Carbon Tracker further estimated an indicative potential impact in terms of net present value, suggesting that a c.20% fall in average oil prices post-IPR would result in a 50% reduction in NPV. This reduction is mitigated by earlier policy action, which both lowers the quantum of assets sanctioned pre-2025 and results in a lower fall in price.

At the company level, Carbon Tracker estimated sensitivity of NPV relative to the market, arguing that companies which had NPVs which are more sensitive to changes in oil price will be more volatile on a forward-looking basis, and hence imply a higher required rate of return/ discount rate (analogous to beta in the capital asset pricing model).

Table 08: Illustrative company NPV sensitivity to marginal prices, sanctioned assets plus unsanctioned assets that enter production in 2019-2025 under the FPS (selected companies)

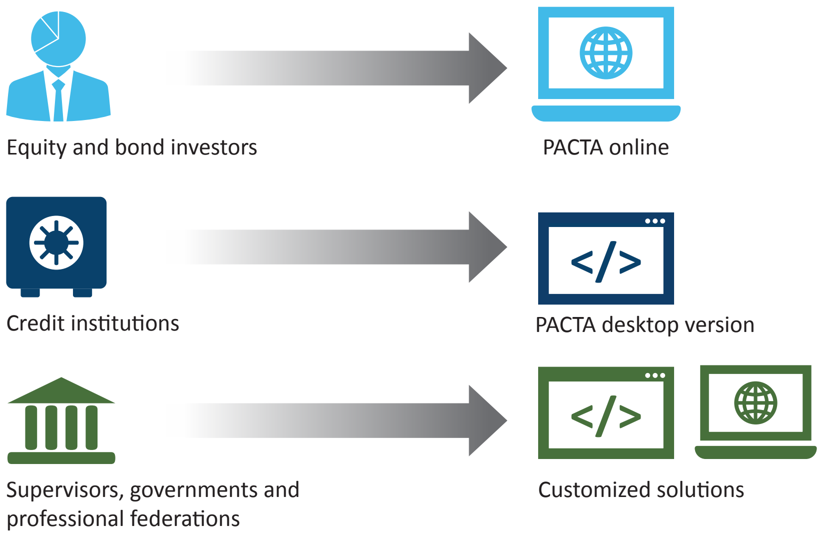
Company	Oil value sensitivity - % change in oil field NPV relative to market	Oil production 2019-2025, (% of total)	Portfolio value sensitivity - % change in portfolio NPV relative to market, assuming gas NPV change=0
Oil and gas industry	1.0	54%	1.0
Suncor Energy	2.0	100%	3.7
EOG Resources	1.2	90%	2.1
Canadian Natural Resources (CNRL)	1.4	78%	2.0
Oxy	1.2	71%	1.6
Tatneft	0.9	100%	1.6
Lukoil	1.0	76%	1.5
ConocoPhillips	1.2	64%	1.5
ExxonMobil	1.4	52%	1.3
Chevron	1.2	57%	1.2
BP	1.1	50%	1.0
BHP	1.3	36%	0.9
Equinor	0.9	54%	0.8
Total	0.9	48%	0.8
Eni	0.9	43%	0.7
Shell	1.0	39%	0.7
Novatek	0.7	3%	0.0

Source: Rystad Energy, IPR, Bloomberg, Carbon Tracker analysis

2° Investing Initiative (2DII) – Using PACTA

In September 2018, the 2° Investing Initiative (2DII) introduced the **Paris Agreement Capital Transition Assessment (PACTA)** tool: a publicly available software that calculates the extent to which corporate capital expenditures and industrial assets behind a given equity, bond, or lending portfolio are aligned with various climate scenarios. The first-of-its-kind software taps into a vast climate-related financial database, which covers more than 30,000 securities, 40,000 companies, and 230,000 energy-related physical assets.

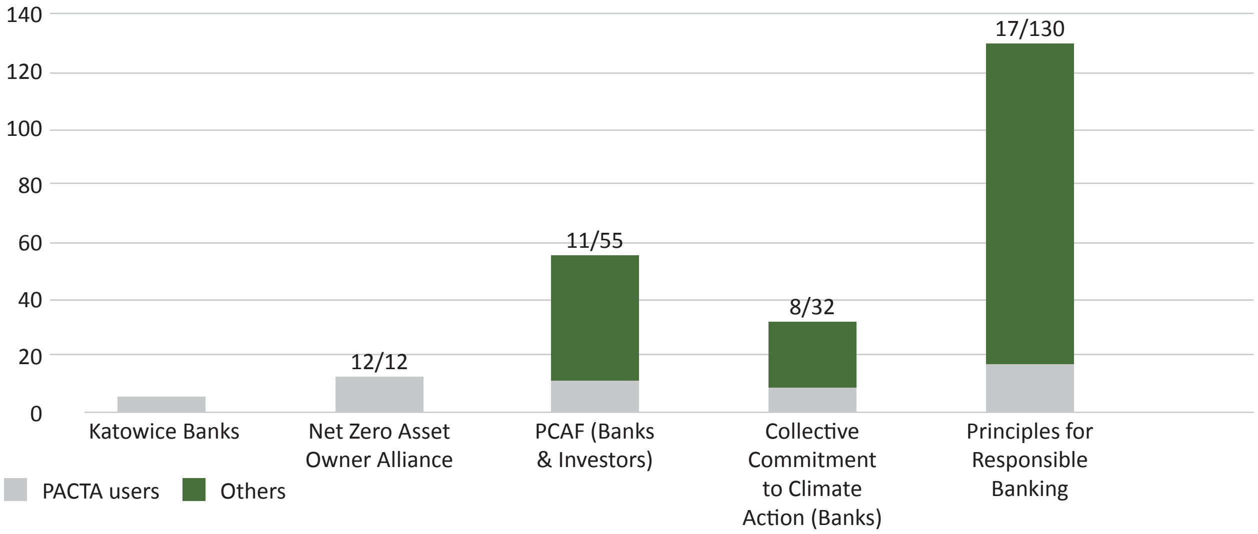
Since the tool was launched on TransitionMonitor.org, more than 2,500 individuals from more than 1,500 institutions have used it to conduct over 10,000 tests. Overall, the total assets under management of financial institutions using the tools amounts to more than USD 61 trillion.



Group	Number of FIs covered	Total assets of the FIs[2]
PACTA equity & bond users	1,227	> USD 69 trillion (analyzed climate relevant scope, based on typical ratios: approx. 13.8 trillion)
PACTA lending users	17 signed up	> USD 18 trillion (analyzed climate relevant scope, based on typical ratios: approx. 550 trillion)
PACTA - all FI users	1,244	> USD 87 trillion (analyzed climate relevant scope, based on typical ratios: approx. 17.4 trillion)
PACTA supervisor and governments (Swiss-Federal Office for the Environment, a European insurance association, Federation of Colombian Insurers (Fasecolde). EIOPA, California Department of Insurance (CDI), & Dutch prudential supervisor)[3]	Approx. 2,600	> USD 14 trillion (analyzed climate relevant scope, based on typical ratios: approx. 2.8 trillion)

By coining the concept of "portfolio alignment with climate goals", and introducing it into voluntary practices and public policies, 2° Investing Initiative also helped empower a number of pledges and commitments that reached a peak at Climate Week NYC 2019. The main pledges are summarized below. A majority of signatories use PACTA to analyze their portfolio.

Figure 21: Adoption by signatories of climate-related pledges



Source: ETA

APPENDIX IPPC SR1.5°C: Further details

The impacts associated with higher temperature outcomes have increased

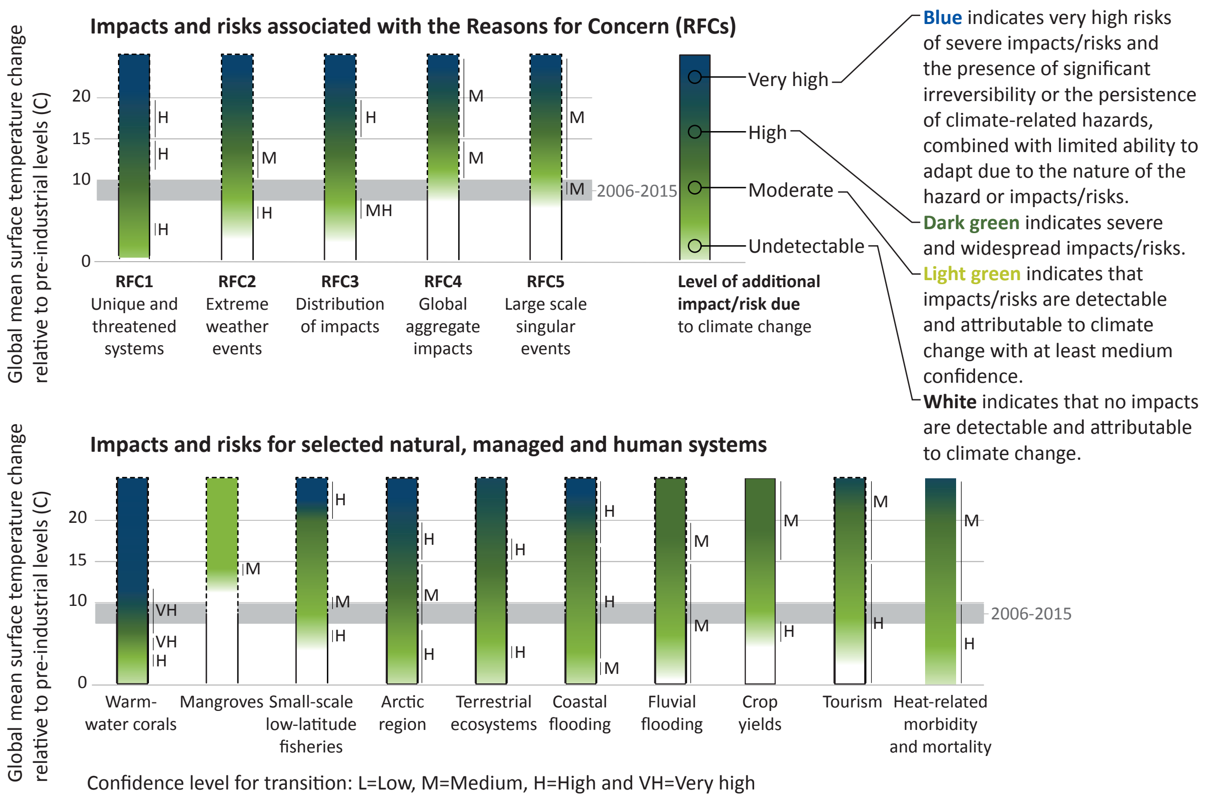
As the IPPC says:

> *"There are multiple lines of evidence that since the AR5 the assessed levels of risk increased for four of the five Reasons for Concern (RFCs) for global warming to 2°C (high confidence). The risk transitions by degrees of global warming are now: from high to very high between 1.5°C and 2°C for RFC1 (Unique and threatened systems) (high confidence); from moderate to high risk between 1.0°C and 1.5°C for RFC2 (Extreme weather events) (medium confidence); from moderate to high risk between 1.5°C and 2°C for RFC3 (Distribution of impacts) (high confidence); from moderate to high risk between 1.5°C and 2.5°C for RFC4 (Global aggregate impacts) (medium confidence); and from moderate to high risk between 1°C and 2.5°C for RFC5 (Large-scale singular events) (medium confidence)."*

This argues strongly for shifting to "well below 2°C" as a target and most likely to 1.5°C.

Figure 22: How the level of global warming affects impacts and/or risks associated with the Reasons for Concern (RFCs) and selected natural, managed and human systems.

Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.



Source: IPCC special report on Global Warming of 1.5°C

Carbon Budgets have been revised upwards

The last time that the IPCC estimated carbon budgets was in AR5. At the heart of climate science is "climate sensitivity" which looks at the relationship between emissions and temperature outcomes In SR1.5°C. Observations for actual temperatures against emissions have been updated leading to lower climate sensitivity between emissions and temperature. There are many complex variables[58, 59] that are examined, the results are shown below. However, we note that there continues to be debate among modellers as to this and AR6 might even revise up again.[60]

Table 09: The assessed remaining carbon budget and its uncertainties

Shaded blue horizontal bands illustrate the uncertainty in historical temperature increase from the 1850–1900 base period until the 2006–2015 period as estimated from global near-surface air temperatures, which impacts the additional warming until a specific temperature limit like 1.5°C or 2°C relative to the 1850–1900 period. Shaded grey cells indicate values for when historical temperature increase is estimated from a blend of near-surface air temperatures over land and sea ice regions and sea-surface temperatures over oceans.

Additional Warming since 2006–2015 [°C]*(1)	Approximate Warming since 1850–1900 [°C]*(1)	Remaining Carbon Budget (Excluding Additional Earth System Feedbacks*(5) [$GtCO_2$ from 1.1.2018]*(2)			Key Uncertainties and Variations*(4)					
		Percentiles of TCRE *(3)			Earth System Feedbacks *(5)	Non-CO_2 scenario variation *(6)	Non-CO_2 forcing and response uncertainty	TCRE distribution uncertainty *(7)	Historical temperature uncertainty *(1)	Recent emissions uncertainty *(8)
		33rd	50th	67th	[$GtCO_2$]	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*	*[$GtCO_2$]*
0.3		290	160	80						
0.4		530	350	230						
0.5		770	530	380						
0.53	~1.5°C	840	580	420	**Budgets on the left are reduced by about –100 on centennial time scales**	±250	–400 to +200	+100 to +200	±250	±20
0.6		1010	710	530						
0.63		1080	770	570						
0.7		1240	900	680						
0.78		1440	1040	800						
0.8		1480	1080	830						
0.9		1720	1260	980						
1		1960	1450	1130						
1.03	~2°C	2030	1500	1170						
1.1		2200	1630	1280						
1.13		2770	1690	1320						
1.2		2440	1820	1430						

Notes:

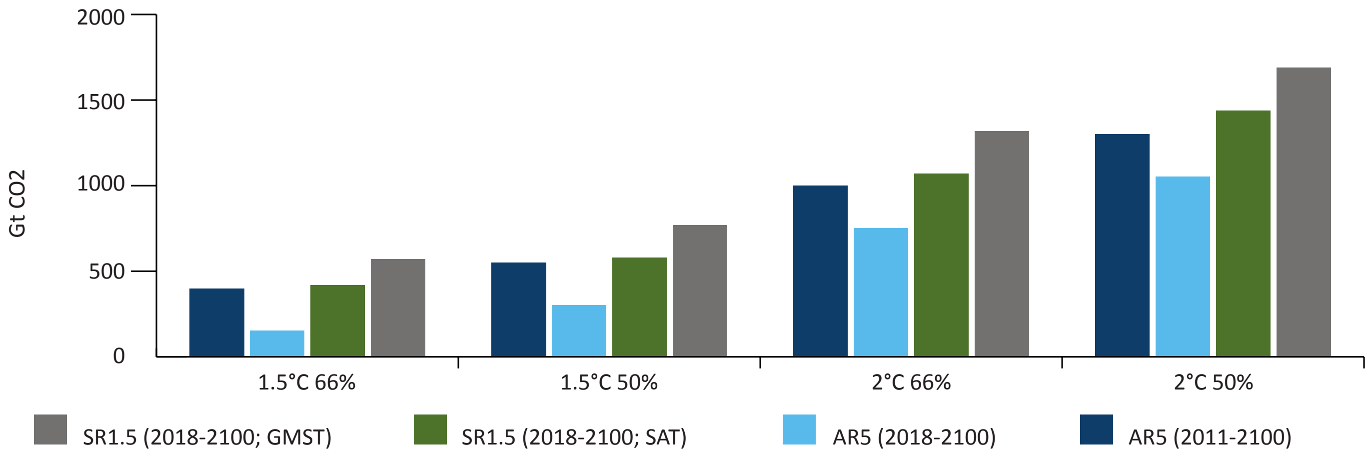
*(1) Chapter 1 has assessed historical warming between the 1850–1900 and 2006–2015 periods to be 0.87°C with a ±0.12°C likely (1-standard deviation) range, and global near-surface air temperature to be 0.97°C. The temperature changes from the 2006–2015 period are expressed in changes of global near-surface air temperature.
*(2) Historical CO_2 emissions since the middle of the 1850–1900 historical base period (mid-1875) are estimated at 1940 $GtCO_2$ (1640–2240 $GtCO_2$, one standard deviation range) until end.
2010. Since 1 January 2011, an additional 290 $GtCO_2$ (270–310 $GtCO_2$, one sigma range) has been emitted until the end of 2017 (Le Quéré et al., 2018).
*(3) TCRE: transient climate response to cumulative emissions of carbon, assessed by AR5 to fall likely between 0.8–2.5°C/1000 PgC (Collins et al., 2013), considering a normal distribution.
consistent with AR5 (Stocker et al., 2013). Values are rounded to the nearest 10 $GtCO_2$.
*(4) Focussing on the impact of various key uncertainties on median budgets for 0.53°C of additional warming.

*(5) Earth system feedbacks include CO_2 released by permafrost thawing or methane released by wetlands, see main text.

*(6) Variations due to different scenario assumptions related to the future evolution of non-CO_2 emissions.

*(7) The distribution of TCRE is not precisely defined. Here the influence of assuming a log normal instead of a normal distribution shown.
*(8) Historical emissions uncertainty reflects the uncertainty in historical emissions since 1 January 2011.
Source: IPCC special report on global warming of 1.5°C

Figure 23: Comparison with previous carbon budgets from the IPCC



Source: ETA, IPPC AR1.5,SR1.5°C

This implies that an AR5 based 2°C 50% scenario, such as IEA SDS, is now closer to a 1.5°C - see below discussion that IEA in fact claims SDS is 1.5°C 50% if NETs are assumed. Note the scientific reasoning for these changes is deep and well set out.

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58. Limiting global warming requires limiting the total cumulative global anthropogenic emissions of CO2 since the preindustrial period, i.e. staying within a total carbon budget (high confidence).13 By the end of 2017, anthropogenic CO2 emissions since the preindustrial period is estimated to have reduced the total carbon budget for 1.5°C by approximately 2200 ± 320 GtCO2 (medium confidence). The associated remaining budget is being depleted by current emissions of 42 ± 3 GtCO2 per year (high confidence). The choice of the measure of global temperature affects the estimated remaining carbon budget. Using global mean surface air temperature, as in AR5, gives an estimate of the remaining carbon budget of 580 GtCO2 for a 50% probability of limiting warming to 1.5°C, and 420 GtCO2 for a 66% probability (medium confidence).14 Alternatively, using GMST gives estimates of 770 and 570 GtCO2, for 50% and 66% probabilities, 15 respectively (medium confidence). Uncertainties in the size of these estimated remaining carbon budgets are substantial and depend on several factors. Uncertainties in the climate response to CO2 and non-CO2 emissions contribute ±400 GtCO2 and the level of historic warming contributes ±250 GtCO2 (medium confidence). Potential additional carbon release from future permafrost thawing and methane release from wetlands would reduce budgets by up to 100 GtCO2 over the course of this century and more thereafter (medium confidence). In addition, the level of non-CO2 mitigation in the future could alter the remaining carbon budget by 250 GtCO2 in either direction (medium confidence).

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Energy Transition Advisors (ETA)

Energy Transition Advisors Pty Ltd is a project driven co-operative platform bringing together thought leaders and analysts focusing on the impact of environmental factors on energy markets. Those affiliated are drawn from the financial sector with significant relevant experience in financial markets, research and advisory.

More information: www.et-advisors.com

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The PRI works with its international network of signatories to put the six Principles for Responsible Investment into practice. Its goals are to understand the investment implications of environmental, social and governance (ESG) issues and to support signatories in integrating these issues into investment and ownership decisions. The PRI acts in the long- term interests of its signatories, of the financial markets and economies in which they operate and ultimately of the environment and society as a whole.

The six Principles for Responsible Investment are a voluntary and aspirational set of investment principles that offer a menu of possible actions for incorporating ESG issues into investment practice. The Principles were developed by investors, for investors. In implementing them, signatories contribute to developing a more sustainable global financial system.

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