SIP LABS
Sustainable Innovation Pathways

Proof of Concept

Sustainable Innovation Pathways Framework©

October 2022
1st Edition

Foreword

The past three years have been marked by crisis – when in 2020 the COVID-19 Pandemic unfolded, the world came to a halt trying to find new ways to adapt and deal with the virus. Two years later, barely through the rough, the Russian invasion of Ukraine caused great deterioration to peace in Europe and initiated the energy crisis. While both crises have provided a glimpse at the consequences of climate change, they also distracted capital markets and governments to take action against the biggest crises we are facing: catastrophic climate change. Luckily, it is not too late.

Collective action in form of large-scale investments and policy reform will be required to meet net zero targets by 2050 and thereby curb global warming to 1.5°. The estimated price tag? According to various recent reports this could be at 2-3% of global GDP. To put this into perspective: this is less than what some governments spent on bailing out "too big to fail banks" during the financial crisis. But how is this investment best placed to avoid the climate catastrophe?

It is clear that we as a society need to overcome the gridlock caused by 1) uncertainty around the development of decarbonising innovation technologies, 2) lack of industry and technology specific government funding, and 3) barriers faced by capital markets to invest at large scale in innovation enabling net zero targets. This provided us with the motivation to develop the Sustainable Innovation Pathways Framework. It is our ambition to provide both transparency and guidance to enable companies, investors, and policy makers to shift capital where it can help us master the energy transition and meet net zero by 2050. It was also our aim to show that net zero investments are not simply costs – they are investments in new markets and new growth opportunities. By investing in the right decarbonisation pathways, we are investing in our future.

We hope that the next chapters give rise to hope and more importantly initiate action.

Lena-Katharina Gerdes
Strategy Lead
Zurich

The Authors

Dr. Christian Spindler
Quantitative Pathways Lead

Lena-Katharina Gerdes
Strategy Development Lead

Jonathan Blanchard Smith
Futures Scenarios Lead

Executive Summary

Executive Summary

→

The world is heating up. We are already on course to miss the IPCC target of +1.5 degrees. More has to be done - and it will be done through innovation, powered by the actions of governments, industries and companies, and the funds of investors, public and private.

How can these players know what innovations to fund? Or how to report, in a clear and standardised fashion, what progress is already being made? How can they know, in an increasingly uncertain world, whether investments are robust and secure?

Traditional financial models do not encompass the richness of our potential shared future, and the risks and opportunities it contains. Models that combine views of the future and financial metrics are often complex and hard to explain. Early stage technology investments run the risk that the technologies will be in place too late to make an impact on what is becoming an urgent problem.

The Sustainability Innovation Pathway (SIP) Framework aims to address - and solve - these issues in a comprehensive, robust and swift fashion. The framework is based on an intimate understanding of three disciplines:

- Technology readiness and adoption velocity
- Futures and foresight thinking
- Financial modelling

and combines all three to deliver usable, appropriate and timely outputs which can guide investment decisions across government, the private sector and industry.

This paper is a detailed description of the Framework, and describes

- An overview of the SIP Framework
- The strategy objectives of the framework
- The two analytical – qualitative and quantitative – elements of the framework and how they work together
- The future developments of the SIP Framework

Our aim is that, using the framework, companies, investors or governments will better understand their options in facilitating, and more importantly, accelerating decarbonisation. They will be able to, for instance:

Identify the technological innovation(s) with the highest and fastest decarbonisation potential

- Determine the technological innovation(s) that unlock resilience and market leadership
- Quantify the risk and return of specific decarbonisation innovation projects
- Quantify the mitigation effect of innovation investments on the potential value of stranded assets
- Determine the effect of the mass deployment of innovative decarbonisation technologies in one sector on another sector or industry

We know that there are many models for sustainability measurement, and ESG reporting. We believe that the framework is both novel and useful because it:

- Works well to meet investment and reporting needs across the full spectrum of public and private sector
- Benefits from a clear outcome focus
- Is comprehensible and explicable within the boardroom or around a minister's desk as well as it is on a trading floor
- Is extremely flexible - from different possible futures to varying inputs
- Has outputs that are clear, and meet industry standard metrics as well as having the ability to generate client-specific metrics on demand

This is explicitly not a technological assessment report. What we aim to provide is a set of tools, both analytical and strategic. They will support companies, investors, and policy makers to take action, decarbonise, and successfully reach net zero.

Contents

Introduction

To tackle the climate emergency realistically, the world needs to transition its economic and financial systems from being fossil based. We need to focus and thrive, on frameworks and technological systems that enable us to halt, and more importantly, reduce CO_2emissions as soon as possible. In order for our society and economy to thrive in the long run, there needs to be a sustainable pathway and limited global warming to the 1.5° agreed upon in the Paris Agreement. In line with these targets, we often speak of reaching net zero emissions by 2050. To reach net zero emissions globally within the next three decades, major cost reductions and performance improvements of decarbonising technologies will be required. Technological innovation will be key in enabling this transition.

Companies, investors and policy makers often hopefully emphasise the role of innovation in order to reach the necessary decarbonisation targets – especially when it comes to the hard to abate sectors such as heavy industry. However, in the past, new energy technologies took between 20 to 70 years to develop from idea to mass market deployment[1]. Even if innovation velocity has increased in the past years, we remain heavily reliant on technology innovations which are at the large prototype or demonstrator level – also known as technology readiness level (TRL) of 5 or above.

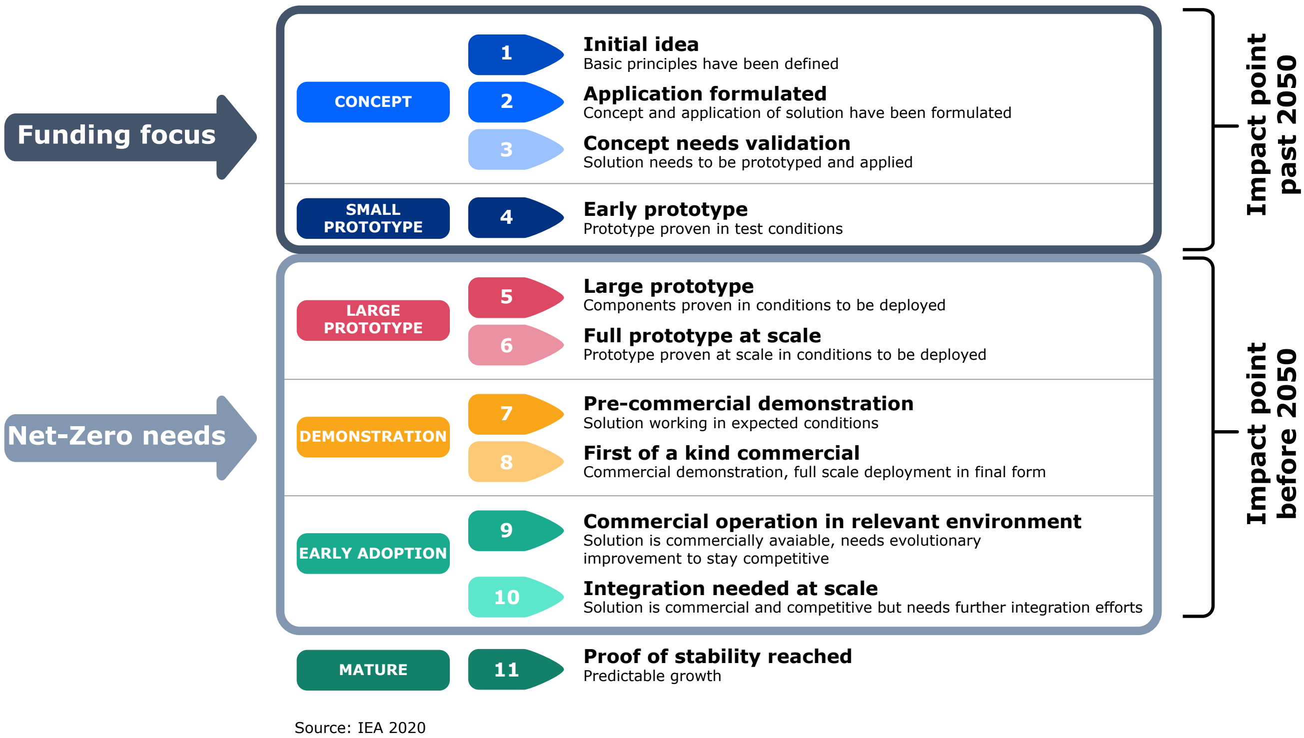


Figure 1 - Technology Readiness Levels (TRL) as applied by the International Energy Agency

[1]International Energy Agency (IEA) (2020), Energy Technology Perspectives 2020, 76

To reach net zero targets, we rely to 41% on innovation technolgoies already in the early adoption phase.

In their Energy Perspectives Report[2], the IEA has considered various climate development scenarios mapped with different innovation paths. Their pathway to net zero relies to 41% on innovation technologies that are already in the early adoption phase, but not yet commercially deployed (TRL 9-10). For the hard to abate sectors such as heavy industry, there is an even bigger reliance on innovation technologies that are only at the large prototype or demonstration stage (TRL 5-8). This exemplifies the urgent need to focus innovation investment on scaling up these innovation technologies to enable net zero pathways.

To reduce costs, improve performance and reach economies of scale for decarbonising technologies, investment needs to focus on deployment of innovations at TRL 5 and above. This is where we observe a critical gridlock – public sector funding for innovation heavily focuses on innovation technologies in the research & development and concept stage (TRL 1-2). From a private sector perspective however, innovation technologies at a prototype or demonstrator level remain too high-risk given deployment uncertainty, high unit costs, lack of scale and therefore overall low levels of return on investment. This poses one of the main burdens to enabling net zero pathways, as the decarbonising impact of those innovations is expected to occur past the critical mark of 2050.

Governments play a crucial role in facilitating and directing innovation funding. They bear the risk of new innovations where the private market cannot assess future demand.

To foster and accelerate innovation, governments play a crucial role in accelerating this innovation in their role as enablers. Governments provide the direction, frameworks and regulations for the private market and society. More directly, governments usually are the biggest source for R&D funding, which is especially critical to support innovation efforts of small and medium sized enterprises. Governments can influence the success of new innovations through several channels. These include for instance public support for certain innovation technologies in specific industrial clusters, investments in enabling infrastructure or steering their public procurement processes accordingly. In a liberal market economy, this provides an essential justification for public intervention, as governments bear the risk of new innovations where the private markets cannot assess the future demand.

What options do companies, investors or governments have when it comes to facilitating, and more importantly, accelerating decarbonisation? In order to vfind a solution, some further key underlying questions need to be urgently addressed

- identifythe technological innovation(s) with the highest and fastest decarbonisation potential?
- determine the technological innovation(s) that unlock resilience and market leadership?
- quantify the risk and return of specific decarbonisation innovation projects?
- quantify the mitigation effect of innovation investments on the potential value of stranded assets?
- determine the effect of the mass deployment of innovative decarbonisation technologies in one sector on another sector or industry?

[2]International Energy Agency (IEA) (2020), Energy Technology Perspectives 2020, 64

None of these fundamental questions can be answered in silo – instead a holistic approach is required.

To answers these fundamental questions a framework is required that:

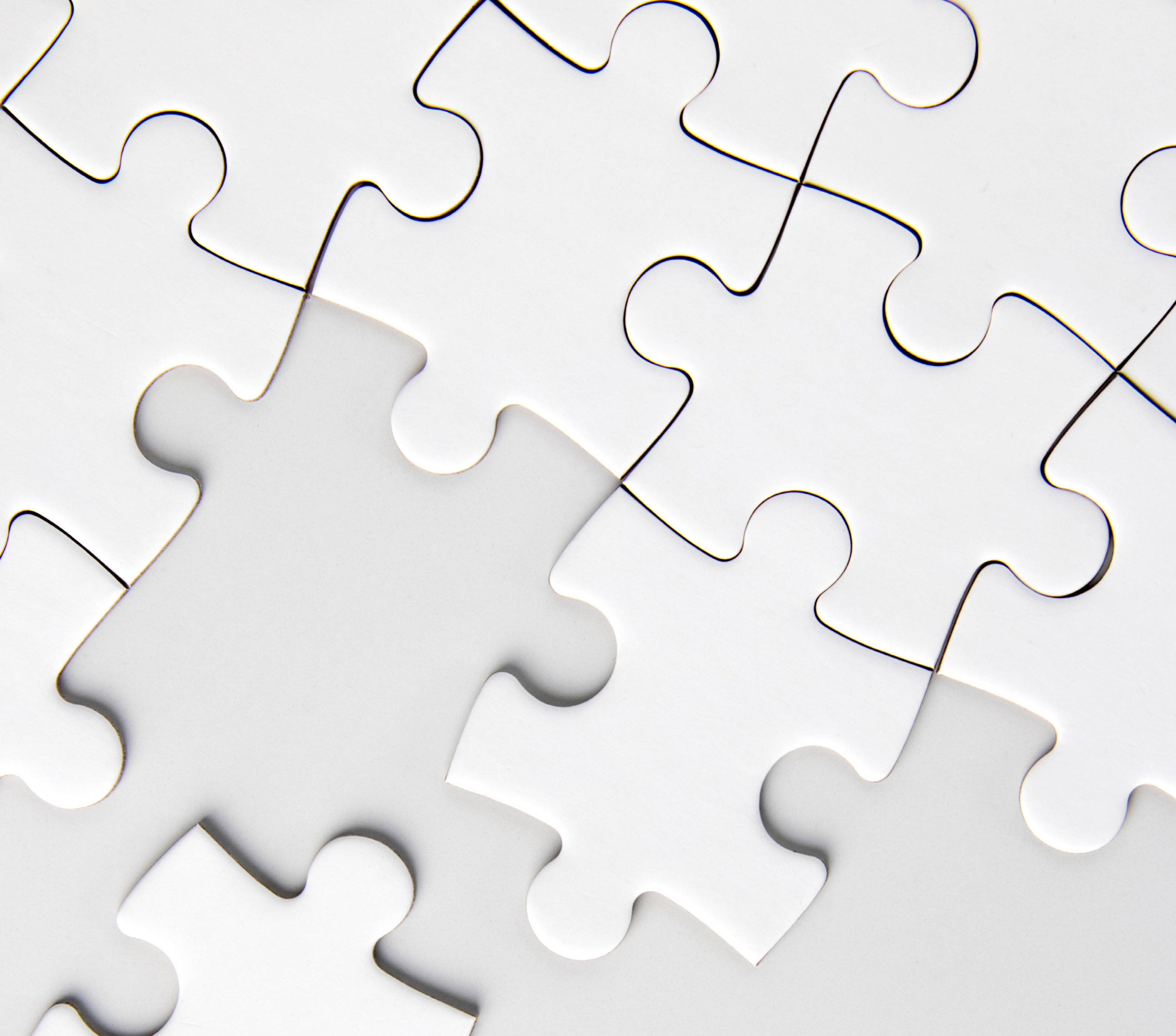
1. combines economic and industry specific factors

2. considers technology specific characteristics

3. acknowledges regulatory & legislative conditions

Driven by these questions and with the aim to unlock this investment gridlock, we developed the Sustainable Innovation Pathways Framework (SIP Framework). The framework consists of a comprehensive set of analytical and strategy tools. These tools, in combination, deliver detailed and actionable decision criteria in industry standard applicable ways. The SIP Framework thereby supports companies, investors, and policy makers as they meet their various challenges, demanded by decarbonisation and net zero.

The following chapters draw on the insights gained throughout a proof-of-concept phase, focussing on the United Kingdom and its *Net Zero 2050* strategy. Chapter 1 will provide an overview of the SIP Framework, followed by Chapter 2 outlining the strategy objectives of the framework. Chapter 3 and 4 will then dive into more detail of the two analytical – qualitative and quantitative – elements of the framework. Finally, Chapter 5 will conclude and comment on the future developments of the SIP Framework.



Chapter 1

The SIP Framework: What can it do and who is it for?

The SIP Framework enables the designing of net zero strategies by qualitatively and quantitatively modelling decarbonisation pathways based on innovation technologies.

The SIP Framework is a practical, comprehensive analytical model, designed to provide companies, investors and policy makers with an tool to:

- consider complex technological developments
- understand how they are best used
- understand their investment requirements and outturns under a variety of conditions
- generate output required for an actionable roadmap

The SIP Framework considers three dimensions: industry specificities, technological development pathways, and domestic policies.

As a consortium we have developed a quantitative, fact-based approach to channel R&D investment into optimal projects and methods for most effective and efficient decarbonisation. The approach is rooted in the combination of possible energy trajectories, political priority-setting and consumer behaviour. The effect of innovation on the evolution of cost and performance of competing technologies can greatly influence the energy trajectories for net zero pathways. Furthermore, these trajectories can be significantly influenced through public policy and changes in consumer choices. When considering a country-specific framework for strategic innovation funding, we consider three relevant dimensions:

- economic sectors with the highest emission intensities and highest absolute emissions or negative impact on sustainability
- technological development pathways of emission reducing technologies and their economic cost curves
- domestic politics and consequences for the population when implementing these new technologies

Industry

Economic Sector/Industry specific

- What are the largest economic sectors (by GDP contribution)?
- Which economic sectors are the biggest polluters (by CO2 emissions)?
- Where lies the biggest decarbonisation potential?
- Where is largest potential for sustainability driven profit/growth? Who are the winners in a 2.0° world?

Innovations

Technology/Innovation specific (Technological Readiness Level (TRL) 5 and above)

- What Innovation/R&D innovation projects with a TRL ≥ 5 are there applicable to the economic sector?
- What is the development timeframe?
- What is the scalability potential?
- Cost vs decarbonisation? (incl. comparison against opportunity cost?)

UK Politics

UK Government specific

- How do the identified innovation project align with the current UK Net-Zero Strategy?
- How can public sector financing reduce investment risk and provide incentives for private sector investment?
- To what extent can the investment cost be carried by the UK population? Compared to the environmental and social cost of business-as-usual?
- How can the UK nation state profit from investing in sustainable innovation projects?

The United Kingdoms Net Zero 2050 Strategy provided a comprehensive set of policies that was leveraged to develop the SIP Framework through a proof-of concept approach

We decided to base this proof-of-concept report on the United Kingdom, as it is one of the few countries with a very defined *2050 Net Zero Strategy*[3]. Following the COVID-19 pandemic, the United Kingdom has committed itself to a "green" recovery strategy and identified the various opportunities this approach has. The *2050 Net Zero Strategy* is further supported by a variety of sustainability focused strategies such as the *Ten Point Plan for a Green Industrial Revolution*[4], the *Innovation Strategy*[5] and the *Net zero Research & Innovation Framework*[6].

"One of the key strengths of the SIP Framework lies in its flexibility and adapatbility, therefore remaining applicable to a vast variety of nations and economies."

Despite the recent turmoil in the UK government, the authors would like to emphasise that the focus of the framework continues to hold. We hope to emphasise the rightfulness of defining and committing to a national net zero strategy and aim to provide further support of such strategies through the output of our framework. Regardless of political developments within the UK, the *Net Zero Strategy* remains one of the few worked out national strategies and serves as a useful template.

A key strength of the framework lies in its flexibility and adapability. It is applicable to a vast variety of nations & economies

Furthermore, the framework is applicable to any nation or geography – the focus on the UK merely serves development purposes to account for policy considerations and guide the required outputs for a macroeconomic analysis. One of the key strengths of the SIP Framework lies in its flexibility and adaptability, therefore remaining applicable to a vast variety of nations or economies.

[3] HMG Department for Business, Environment & Industrial Strategy (2021), Net Zero 2050: Build Back Greener

[4] HMG Department for Business, Environment & Industrial Strategy (2020), The Ten Point Plan for a Green Industrial Revolution

[5] HMG Department for Business, Environment & Industrial Strategy (2021), UK Innovation Strategy: leading the future by creating it

[6] HMG Department for Business, Environment & Industrial Strategy (2021), Net Zero Research and Innovation Framework

The SIP Framework establishes actionable net zero strategies by building upon qualitative futures foresight scenarios and the quantitative modelling of technological decarbonisation pathways

What will the United Kingdom be like in a net zero environment in 2050? How and where do we live? What technologies will dominate our daily lives? How will our society have adapted to climate change and the net zero environment? What will the economic and political environment look like? What circumstances will define the leading market players?

Qualitative Scenario Setting

- Plausible descriptions of future development
- Rich in detail and considering disruptive shocks
- Robust multifactorial analysis of the future

Quantitative Pathway Analysis

- Robust and versatile quantification of the qualitative scenarios
- Quantification of uncertainties
- Modelling of interdependencies across industries

Actionable Net-Zero Strategy

- Making organisations' efforts comparable
- Indicating innovative uptake of technology
- Consideration of implementation challenges and solution approaches

Figure 2 - the three components of the SIP Framework

These are some of the many key questions we need to consider when thinking of a net zero 2050 world. The transformation our economies will undergo is far reaching and will impact everything - from individual households to international relations. To reduce ambiguity around these factors, and to provide a vision on potential answers to these questions, our framework applies qualitative scenario analysis with futures foresight thinking. Starting with our qualitative scenario setting, we can thereby define plausible descriptions of future scenarios which are rich in detail and able to consider disruptive shocks such as the supply chain disruptions or the Russian invasion of Ukraine.

The SIP Framework enables decarbonisation investment decisions today by combining qualitative futures foresights with quantitative scenario analysis.

Despite the robustness that the multifactorial analysis of the qualitative scenario analysis provides, these scenarios do not provide numerical values or ranking of technology options required by corporates, investors or policy makers. Stakeholders need to make investment decisions today that places them on the right pathways for net zero 2050 scenarios. The SIP Framework enables this by combining the qualitative, futures foresight approach with quantitative scenario analysis. The quantitative scenario analysis involves the identification of innovation technologies at the prototype level or above that have a strong decarbonisation potential and derives development pathways. These pathways include the assessment of their scale potential based on different investment levels and the resulting abatement curves. Different pathways are then generated based on re-running the assessment for a variety of appropriate scenarios that are aligned with the futures foresight scenarios. By constructing this bridge between quantitative and qualitative scenario analysis for decarbonising innovation technologies, the

This approach established a three-dimensional model capable of considering and analysing the interdependencies between industries.

SIP Framework is able to account for the richness of the many possible future net zero worlds while considering alternative approaches and therefore avoiding the danger of single point forecasts. Furthermore, the combination of the approaches creates a three-dimensional model that is capable of considering and analysing the interdependencies between industries, and therefore the effect of the deployment of certain decarbonising technologies on other industries.

The third component of the framework considers the output of the qualitative and quantitative scenario analysis to design and formulate an actionable net zero strategy. This third element is vital, as it makes the various organisations' or investors' efforts comparable. Furthermore, by considering various innovation technologies and their interdependencies, the strategy forming also shows the innovative uptake of technologies. Finally, the framework includes various regulatory and legislative factors in its consideration of implementation challenges and solution approaches.

This framework was designed for companies, investors and policy makers to make informed investment decisions on sustainable innovation technologies and thereby guide their decarbonisation strategies

We designed the framework to be applicable and usable for three main stakeholders:

1. Companies needing to decarbonise and transform their business models.

2. Investors and investment analysts wanting to account the quantified impact of investments in decarbonisation innovation technologies in their valuation models.

3. Governments and policy makers aiming to provide net zero funding in a more efficient way and monitor the effectiveness of their policies.

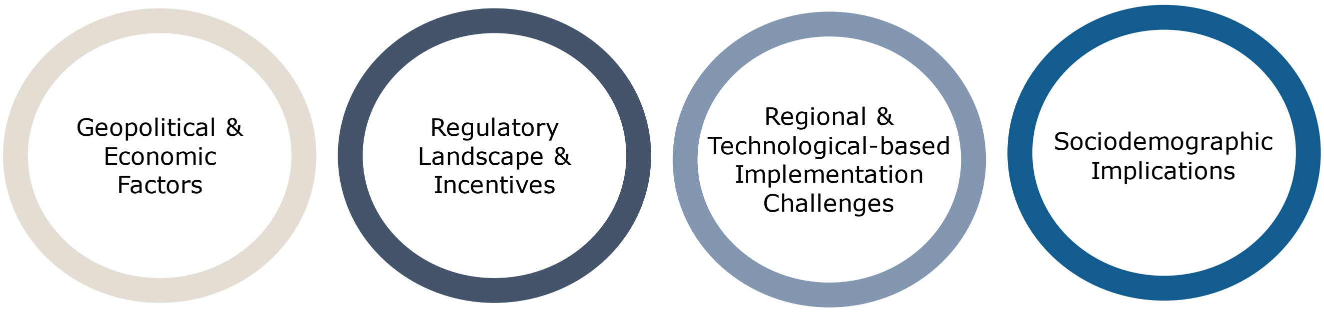
Chapter 2

Defining an actionable net zero 2050 strategy using the SIP Framework

The SIP Framework develops decarbonization strategies by leveraging the insights gained from its qualitative and quantitative analysis, thereby accommodating economic, regulatory, and environmental factors.

The qualitative and quantitative analysis components of the SIP Framework generate valuable outputs that provide direction, financial and decarbonisation potential metrics. By generating these values, the SIP Framework increases transparency and enables the comparison of various transition pathways to net zero. However, on its own these metrics will not enable companies to master the transformation, which brings us to the overall aim of the SIP Framework: defining an actionable net zero strategy.

The strategy design will differ based on the end user; however, the framework will consider several external key components in the strategy design:



Naturally, the target outcomes will differ between public market and private market participants leveraging the SIP Framework. Nonetheless, the framework delivers key components that will enable the definition and implementation of an actionable and quantified net zero strategy.

For policy makers and governments, the SIP Framework addresses following key questions and outcomes that can be embedded to further direct public policy and guide net zero funding in a concise and measurable manner:

Public Sector

Guiding Questions

- What innovations/technologies can the public sector support through public spending?
- Which innovations support the green transition of the UK economy to become resilient and competitive in the long run?
- How can regulation be adapted to enable companies to reach their sustainability goals?
- What needs to be done in order to convince private sector to also take on risk?
- What can government do to better invite and leverage private sector financing for its net zero innovation programs?

→

Guiding Outcomes

- Alignment of sustainability and decarbonisation goals with domestic politics and government goals (incl. socio-economic effects)
- Tailoring policy/funding to targeted innovation projects
- National / international collaboration potential for sustainability innovation projects on decarbonisation
- Alignment of economic growth potential with decarbonisation goals
- Guidance for policy-making to enable and accommodate private sector decarbonisation based on quantitative and qualitative scenario analysis

For companies needing to decarbonise or for investors seeking to value decarbonisation pathways, the SIP Framework addresses following questions and generates key strategic considerations:

Private Sector

Guiding Questions

- How can companies (i.e. my company) meet sustainability and net-zero targets?
- Which innovation projects combine decarbonisation with sustainable economic growth?
- How & when can they make it a profitable exercise?
- How can companies quantify their market externalities and manage these in their net-zero strategy?
- How can companies decrease their risk of stranded assets through investing in decarbonisation innovation technologies?
- How can companies integrate sustainability targets as core components in their corporate strategy?
- How can companies effectively communicate

→

Guiding Outcomes

- Financial valuation / Cost & Benefit calculation on corporate and industry level (incl. cost for doing nothing)
- Sustainable economic growth potential (incentives, new markets, etc.)
- Identification of technological pathways and investment opportunities
- Identification of companies/projects delivering innovation technology
- Future analysis/updates to reflect technological breakthroughs and policy development
- Regulatory alignment of decarbonisation pathways
- Financing mechanisms to support the corporate transition

Overall, we see high potential for companies with high greenhouse gas emitting business models to strongly benefit from implementing decarbonization pathways at the core of their corporate strategy and investment scope. While pressure from the public sector is increasing, as for example evident from the various net zero approaches introduced by the UK government, regulatory incentives and the commitment of large multinational corporations to net zero supply chains also provide sufficient ground for strong disruptions in all industries.

Reducing exposure to stranded assets and building long-term resilience are key objectives of the SIP strategy design.

While transforming business models to align with decarbonisation pathways may be costly, these investment costs stand in no relation to the costs of business as usual and consequential damages caused by climate change. Furthermore, investing in clean energy or new sustainable businesses alone will not be sufficient, as it will not reduce the exposure to and value of potential stranded assets.

The SIP Framework directly addresses these pain points and actively integrates the outputs generated in the qualitative and quantitative scenario analysis of the framework in the strategy definition. Overall, the strategy definition will pursue four key objectives:

1. Leveraging sustainable innovation technology investments to transform existing business models and thereby reduce the exposure or value of potential stranded assets
2. Consideration of potential alternative negative externalities in choice of decarbonisation pathways
3. Enablement of continuous quantification of impact and decarbonisation potential in line with regulatory and capital market reporting standards
4. Seizing new future growth markets through sustainable business model transformation

Leveraging the SIP Framework to define a blue ocean strategy and find new markets and a competitive market position

As we will outline in the next chapter, there are various possibilities of what a net zero business environment can look like. This flexibility provides businesses with the opportunity to define the boundaries and rules of competition in future markets, thereby enabling companies to find so-called blue oceans. Blue oceans describe uncontested markets in which new demand is invented and captured[7]. Considering the insights on the scalability potential and in-depth quantified demand forecasts for certain innovation technologies that the SIP Framework can generate, blue ocean strategies can be derived. In consequence, the SIP Framework enables not only informed decarbonisation strategies, but also offers insights to finding new markets and enabling competitive positioning.

What are externalities?

We refer to externalities as any costs of corporate actions that are not internalised in financial terms. For instance, carbon emissions cause climate change, which leads to well-discussed costs of its physical and societal impacts. Other externalities, such as water consumption, also leads to costs which are not fully internalised, such as water pollution or shortages for which the water consumer may not be fully accountable.

What is CO_2e?[8]

Carbon dioxide is the most important greenhouse gas among a set of gases that contribute to global warming. Other prominent greenhouse gases are methane (CH_4) and nitrous oxide (N_2O). Their effect on global warming can be described by a factor difference to the effect of CO_2. In case of methane, this factor is 29, indicating that one unit of methane released to the atmosphere has a 29 times higher global warming potential than the same unit of CO_2. In order to deal with only a single number for the combined effect of different greenhouse gases in a process, the individual contributions are summarised as CO_2 equivalents, or CO_2e.

Investors will also benefit from this transition – the SIP Framework enables the necessary transparency to enable investors to quantify and measure the positive impact of sustainable innovation technology investments. The SIP Framework purposefully translates the decarbonisation impact into traditional financial metrics, in order to allow

1) companies to communicate their net zero strategy and progress in understandable manner towards capital markets and

2) for investors to understand the positive impact (or negative impact of business as usual) on company and investment valuations

As investment in decarbonisation innovation is required to grow at record levels within the next decade(s), the SIP Framework therefore encourages and enables the financial impact assessment and thereby enables more certain and guided investment strategies.

[7] Chan Kim, W. and Maurborgne, R., (2004): Blue Ocean Strategy

[8] IPCC (2018): Annex I: Glossary

Chapter 3

Envisioning a net zero 2050 world using Qualitative Futures Foresight Scenarios

In order to decide for the right pathway to net zero by 2050, we must have an understanding of what kind of environment we will be operating in. Qualitative futures foresight analysis allows us to consider a variety of net zero 2050 scenarios accommodating a range of economic, political and socioeconomic factors.

Creating a number of possible "futures", scenario development permits the examination of uncertainty

Scenarios do not predict the future, in the same manner that single point forecasts try to do. Instead, they are a robust way of understanding how the future may develop under a number of differing parameters. By creating a number of possible "futures", scenario development permits the examination of uncertainty, the challenging of assumptions, and the creation of plans, all of which go to form a far more robust strategic framework for governments and companies. Scenarios are valuable in considering such factors as resource demand; technological development; market size; and so on, and in minimising the risk of "black swan" events by anticipating what those events may be before they happen, and preparing for them.

The term "scenario" is contested. In futures thinking, scenarios are rigorously developed views of the future, developed through a combination of data gathering, workshops, and co-creation. They are expressed in text, on film, through illustrations and roleplaying. Most importantly, they are qualitative.

"Scenarios are valuable in considering such factors as resource demand, technological development, market size, and in minimising the risk of black swan events."

Outside of the future thinking and foresight space, however, a "scenario" tends to be a view of the future. The models thus created tend to be based on financial inputs and have financial outputs. These "scenarios" vary the input data or assumptions - for instance, the "high/medium/low" projections that a business may use in its budget creation process. These models are quantitative.

The SIP Framework maps the qualitative outputs to the quantitative model, in a way which captures the many variabilities of the future. By building more robust inputs, based on deep thinking about the future, the quantitative phase is based on better data at the outset.

The SIP Framework has three main inputs for its scenario creation process at this stage. They are:

Intergovernmental Panel on Climate Change[9]

The IPCC is the gold standard for understanding the impact that global warming will have on the planet. It is supported by a comprehensive, wide ranging and well thought through set of scenarios. They are, though, complex, and their level of detail in itself makes them difficult to adapt to company- or resource-level applications. They do have a detailed methodology for translating qualitative inputs to quantitative ones, but again, these are difficult to apply externally.

[9] IPCC - the Intergovernmental Panel on Climate Change

European Commission SAFIRE Project[10]

The scenarios created for the SAFIRE project provide the principal input for the qualitative analysis of the SIP Framework. Produced by a coalition of organisations for the European Commission's Research and Innovation Directorate, they encompass 44 discrete scenarios: one set each for ten world regions, and an overarching scenario set. The scenarios have been extensively peer-reviewed, are available to the public, and are in use for the EC`s Horizon Europe programme.

The focus on research and innovation makes them especially applicable to the SIP Framework, since many of the underlying requirements map exactly. A further advantage ist that they are supported by a significant horizon scanning programme. The scenarios in the SAFIRE project were generated by SAMI Consulting, one of the partners in the SIP Framework initiative.

The development of the scenario "Journey Game" is novel to the SAFIRE project, and valuable for the SIP Framework: it allows the development of a path through scenarios based on time - in other words, for a scenario set whose endpoint is 2040, it is possible to map progress of a nation (or a company, or a technology or resource) through the scenario set in five or ten year increments. This will be especially useful in understanding the impact of the development and adoption of sustainable innovation technologies and in the development of net zero approaches.

Fit for 55[11]

The EU has set itself the target of reaching net zero carbon emissions by 2050. This target is part of the European Green Deal. To facilitate the necessary steep but gradual drop of greenhouse gas emissions, the EU set the intermediate goal to reduce emissions by at least 55% by 2030, compared to 1990 levels. The legislative framework, under which the EU will revise climate, energy and transport-related rulings, is called 'Fit for 55 package'. The package will align current laws with the ambitions for 2030 and 2050, and it will contain some new initiatives to facilitate the goals. EU member states are given these new rules and updates of EU legislation as an enabler to take concrete measures to reduce emissions and decarbonise the economy.

The Fit for 55 package is applicable for the SIP Framework due to its comprehensive nature and its ability to anticipate regulatory change.

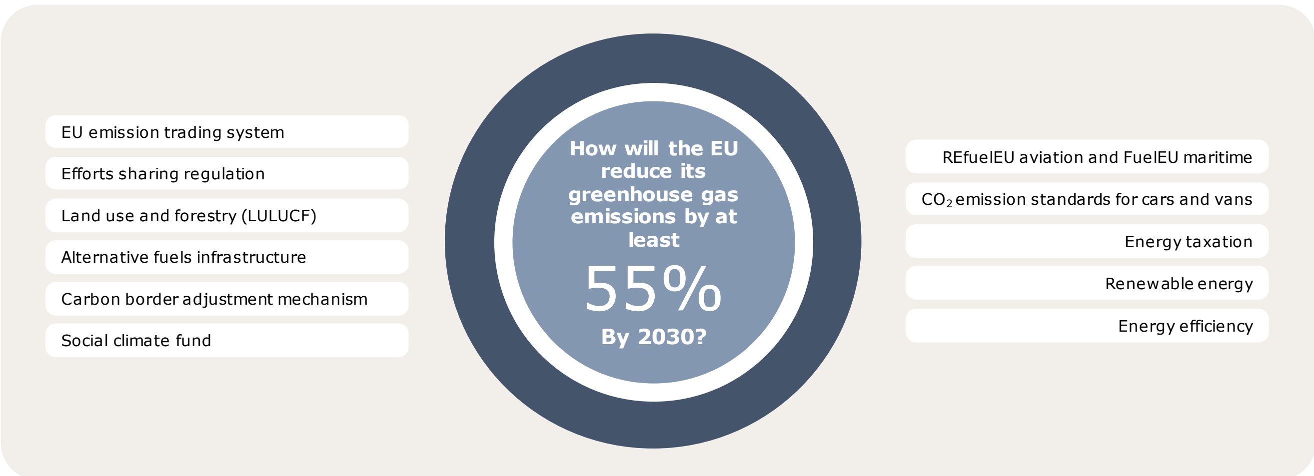


Figure 3 - the components included in the EU Fit for 55 package

[10] European Commission's Research and Innovation Directorate (2021): Strategic Intelligent Foresight System for European Union Research and Innovation (SAFIRE)

[11] European Union (2022): Fit for 55

Other sources

It is the aim of the qualitative scenarios stage of the project to horizon scan throughout the project itself. Horizon scanning allows the project to incorporate new information, anticipate upcoming change, and understand other inputs. The principal aim is to incorporate alternative scenario sets, of which there are many. Some examples include[12].

- IEA Net Zero by 2050
- BP Net Zero in 2050
- Shell Sky 1.5
- Bloomberg New Energy Outlook 2021
- IRENA shipping scenarioWorld Energy Council

The SIP Framework incorporates both scenarios and models of the future in order to gain the broadest view and range of source data as possible.

To generate the qualitative scenarios, the SIP Framework draws upon the accredited scenario generation process established by SAMI. The process is split in four main stages and can be tailored to the end users needs.

The standard scenario generation process involves *Research*, *Analysis*, and *Sense Making*.

The qualitative scenario generation builds on the accredtied approach by SAMI and involves three phases.

The *Research Phase* involves contextual analyses with three perspectives: Macro, Micro and Internal. The macro, **Drivers for Change**, analysis provides a context for understanding the wider national and international environment based around PESTLE (Political, Economic, Social, Technological, Legal and Environmental) analysis; the micro, **Near**, analysis shows current trends, policies and attitudes; and the **Internal** analysis looks at how affected organisations work and react to change.

These analyses are undertaken using a mix of Future and Foresight tools and techniques. They are likely to include (this is by no means an exclusive list):

- an intense period of **Horizon Scanning**. Compile a detailed set of factors, to identify both strong and weak signals of change, disruption and/or transformation.

- **SAMI Seven Questions** interviews broadened out to include a wider range of internal and external stakeholders, subject to the sensitivity of the project

- A **Crowdsourcing Approach** for a wider group of stakeholders

[12] International Chamber of Shipping (2022):
Fuelling the Fourth Propulsion Revolution: An Opportunity for All

The *Research Phase* leads to the use of other formal futures tools for the *Analysis Phase* to identify the implications and decision factors for the policy issue. These include, but are not limited to:

- **Drivers for Change Analysis and Prioritisation:** to identify the predetermined elements and critical unertainties
- **Three Horizons Review:** to place pre-determined drivers in a timeline of potential future development
- **Force Field Analysis:** based questions identify issues supporting or opposing the issue so bringing challenge to the work
- **Early Systems Thinking:** review to identify key trends and dependencies across the piece, which may include the organisation, government, the private and public sector, interest groups and the public. This is designed to avoid unintended consequences for decisions taken subsequently.
- **Construction of Scenarios:** Whilst there are a number of models for scenario development, the SIP Framework uses a four quadrant scenario cross for the base scenarios. It is possible to develop this, for specific subjects or clients, to a three-dimensional scenario space.

"Scenario development permits the examination of uncertainty, the challenging of assumptions and the creation of plans."

The *Sense Making Phase* focuses on the 'so what?' question, to translate findings and analysis into options and actions. The foresight approach can help to define the capacity building, adaptive governance models and so on. This phase could include:

- **Wind Tunnelling** of the current and proposed policy changes against the scenarios, to identify which elements of current policy are robust, and which options for change will best succeed.
- **SWOT Analysis** based on the *Research Phase*: What are the opportunities for, and threats to, the proposed policy change? What are the strengths we can play to, to make it happen, and what are the things that need to change in terms of ways of working, influencing operations and so on? This moves us towards action planning and the development of an *Adaptive Plan*.
- **Road Mapping & Backcasting**, which allow a forward look (working from where we are) and back planning (working from where we want to be) to contribute to the plan to deliver the outcomes desired.

Within the European Commission's SAFIRE project, a similar approach to the above was followed: "The project began with a horizon scan to identify trends and emerging changes relevant to research and innovation in ten world regions. Based on those trends and patterns emerging from them, four over-arching global scenarios were developed based on:

- whether protectionism or globalism will characterise international relations in years to come, and
- whether in the face of global crises people and nations are inclined to transform geopolitical and economic systems or to carry on with business as usual.

"**Wireframe scenarios" are created** enabling an easy comparison of the various four scenarios while adding a global and regional dimension.

Based on the above described analyses, certain 'wireframe scenarios' were created, listing basic characteristics of each scenario for easy comparisons across the four scenarios. The November 2019 scenarios workshop contributed additional details to the global and regional scenarios[13]".

The SIP Framework follows the standard methodology, enriched by the SAFIRE approach, as it provides a methodology that is clear, well understood and in use in multiple projects worldwide on a daily basis.

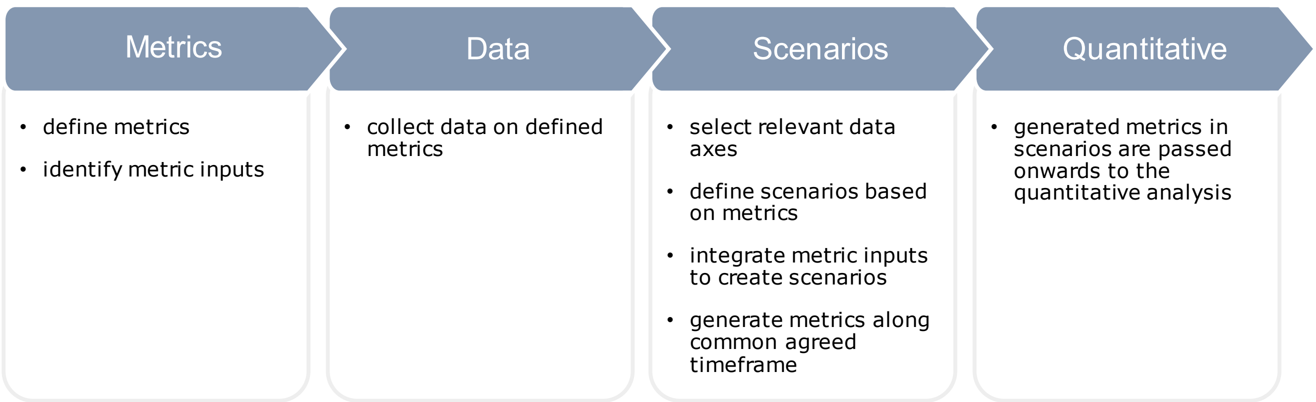
All scenario projects start with a **"key question"** - what is the issue which the process is intended to illuminate? For the SIP Framework, the key question varies according to the purpose:

- Is the aim to develop a general view of an industry? In this case, the framework starts with the understanding of what metrics are needed to generate the scenarios, so that they can be passed seamlessly to the quantitative element, or

- Is the aim to understand a very specific impact of a technology, or of a process? In this case, the scenarios develop that understanding in depth during the scenario creation process, or

- Is the aim to answer questions related to a specific company, government or organisation? In this case, the SIP Framework would start with a 360-degree review of the organisation, so that its activities and impact can be mapped into the scenarios.

The qualitative scenario setting process of the SIP Framework can therefore be described in the following way:



[13]European Commission's Research and Innovation Directorate (2021): SAFIRE

Alternatively, the SIP Framework can develop the qualitative scenarios in the traditional, natural agenda way, by responding to specific client demands, in which case:

Client

- define client specifications based on needs and aims
- define according metrics and metric inputs

Data

- collect data on client specific metrics

Scenarios

- select relevant data axes
- define scenarios based on client specific metrics
- leverage client specific metrics to create scenarios
- generate metrics along common agreed timeframe

Quantitative

- transfer generated metrics onwards to quantitative analysis

For ease, it is also possible to map a company/organisation's activities directly into the project's main scenario set. This is swifter but may lack the granularity of starting from scratch.

The SIP Framework leverages on the tested scenarios developed through the EU Commissions SAFIRE project. These accommodate various geopolitical environments and can account for changing sociodemographic conditions and developments in innovation.

The SIP Framework leverage the EU Comissions SAFIRE scnenarios which consists of 44 discrete scenarios following a common timeline

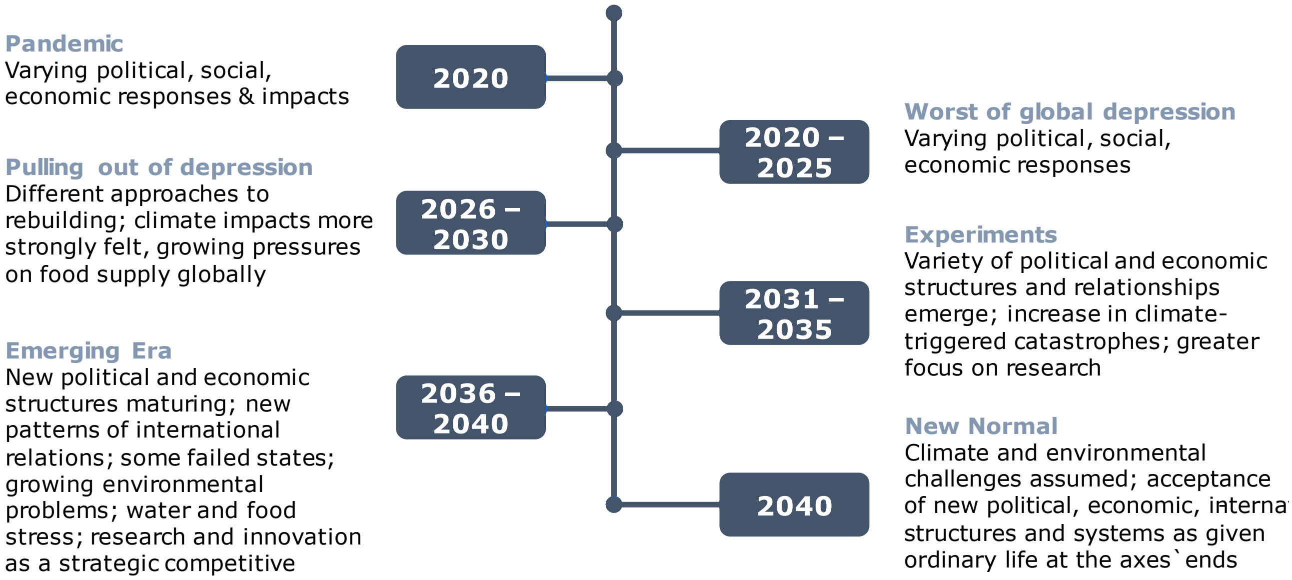
This section further elaborates on the underlying SAFIRE scenarios.

Within the SAFIRE scenario set, there are 44 discrete scenarios: four global scenarios, and four scenarios within each of ten global regions. The global scenarios form the basis for this framework. They work to a common timeline, where:

- the consequences of the pandemic and depression play out across the globe
- climate impacts are more strongly felt as the world leaves the worst of the depressionv
- experiments in, particularly, government, accompany changes in international alliances
- intensifying global warming impacts coincide with the "experimentation" phase settling down
- the evolution of a "new normal" in political, economic and international structures, as well as within social systems.

[14] European Commission's Research and Innovation Directorate (2021): SAFIRE, 33

The SAFIRE timeline[14] is as follows:



The scenarios set out under the SAFIRE report are named and mapped in the following way.

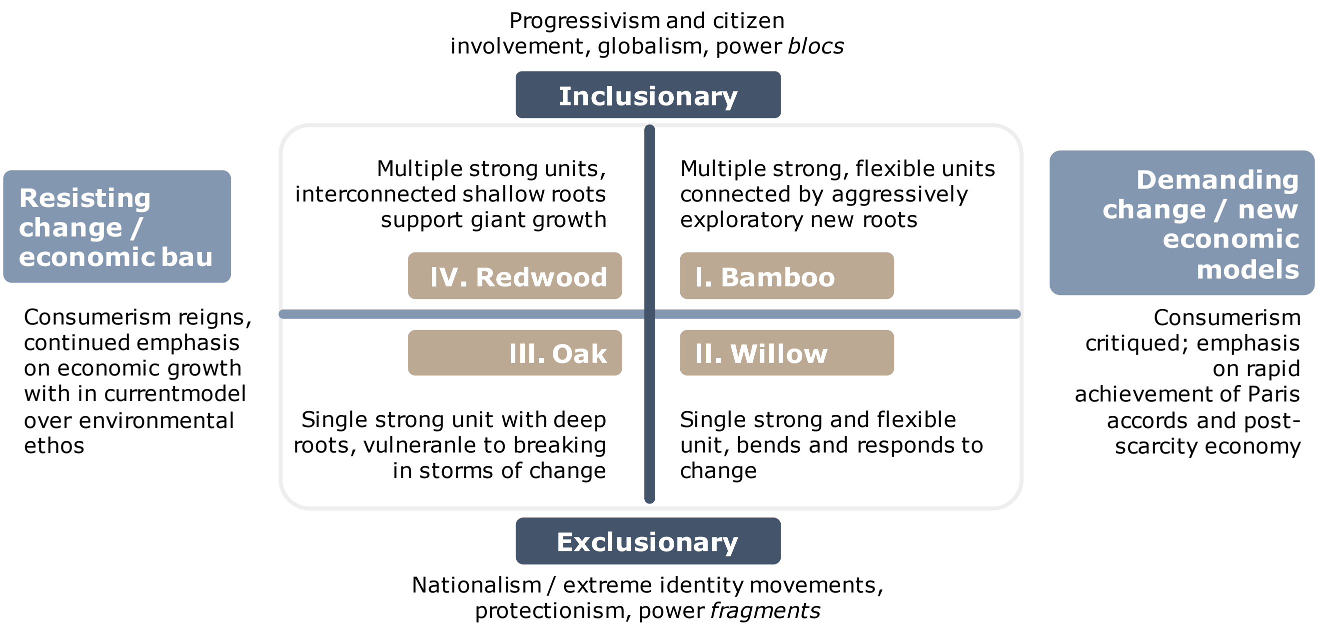


Figure 6 - the SAFIRE scenario set

[15] European Commission's Research and Innovation Directorate (2021): SAFIRE, 33

In more detail, the scenarios can be briefly summarised as follows:

Bamboo

Transforming together

- research becomes an upwelling of collaborative creation – an emergent property of interconnected, dispersed initiatives resulting in new paradigms and innovation. Pure research is re-invigorated, and all the disciplines benefit from the ability of

Axes: globalism and inclination to transform geopolitical and economic systems

Willow

Future as a Fortress

- research becomes a matter of isolated innovation – countries focused on addressing and securing their own needs before the world's, leading to duplication of R&I efforts, but this also allows unique culturally-informed innovations to emerge.

Axes: protectionism and inclination to transform geopolitical and economic systems

Oak

Protectionism Predominant

- research becomes a handmaiden of authoritarian protectionism – countries focused on strategic advantage and outcompeting neighbours. Secrecy and ideology hampers research and the pace of innovation slows.

Axes: protectionism and focus on business as usual

Redwood

Stockholder Society

- research becomes an offshoot of crisis capitalism – multinational corporations focused on reacquiring economic stability and advancing economic and political clout. Research and innovation focus on the Next Big Thing, patents, and profitable insights.

Axes: globalism and focus on business as usual

For the SIP Framework, an additional shared space was developed: essentially, a neutral, fifth, scenario which sits within the centre of the scenario axes and incorporates shared elements of all:

Forrest

The Shared Space / Neutral Scenario

- some elements will happen in every scenario. The key drivers - demographics, climate change, the emergence of biotechnology, the move to a polymodel world - will play out regardless of the individual scenario. We use these elements to create a shared space - essentially, a neutral scenario which contains all the elements, but none to extremes

Axes: an artificially generated space within the scenario set, sitting in the middle of all four scenarios.

As the qualitative scenario analysis is concluded, a list of metrics is generated that builds the bridge to the quantitative analysis. These metrics consider various factors and provide the foundation to translate qualitative norms to quantifiable pathways.

In order for the outputs of the qualitative element of the project to be incorporated into the quantitative, the SIP Framework will define 1) which metrics will be used and 2) what inputs feed into the creation of those metrics.

Each metric has a number of inputs, all of which can be adduced from the scenarios themselves. The values represent the effect of the scenario on the metric - for instance, a scenario where regulatory involvement is light, climate mitigation efforts minimal and the state governance model is right wing, would imply a low value for environmental protections.

There are two ways of doing this: either it is ensured that each scenario specifically includes the metric inputs; or metric components are derived from the scenarios in a more loose, assumptive process.

The framework removes levels of intepretative bias by considering both the metric inputs and components in each scenario.

The SIP Framework has chosen to combine both approaches in a consistent manner. This ensures that the thinking behind each metric input takes place within the scenario creation process; and, importantly, removes a level of interpretative bias at an early stage, ensuring that the scenarios are developed with the focus in mind.

Each scenario will incorporate elements across the PESTLE approach (Political, Economic, Socio-Cultural, Technological, Legal, Environmental). This serves to provide a logical frame within which to capture not only a comprehensive scenario, but also to ensure that no element is missing which may prejudice the eventual outcome.

At this stage, the outputs of the qualitative analysis can now be translated into metrics which will feed into the quantitative analysis.

- The metrics set is mapped against each scenario (and against the common shared scenario, Forest) and ascribed values.
- Each of the following metrics is evaluated for the industry covered in the analysis (i.e. application of the framework).
- Each metric can be developed at points in time during the scenario period, such as in the years. 2025, 2030, up to 2050.

The metrics that construct the bridge from the qualitative to the quantitative scenario analysis can be summarised in the metric table below.

Metric Name	Representation	Metric Input
Effective Carbon Price	x GBP per t CO_2e	Technological development plus economic situation plus industry standard forward forecasts
Decarbonisation Pathway	t CO_2e emissions in year *y* related to t CO_2e in reference year	Technological development plus social acceptability plus regulatory timetable plus transition to green energy (itself derived from climate change impacts plus political environment)
Innovation Speed	Average years from TRL 6 to TRL 9	Technological development level of state/country plus government investment plus private sector investment plus taxation/incentives such as freeports, low tax zones.
Learning Cost Curve	Average annual % cost degression for CAPEX or OPEX of new technology	Quality of university education , established technological base, take-up rate of new technologies, regulatory landscape expressed as a binary fast vs slow learning cost curve.
Skilled Workforce Demand	Fraction of skilled workforce to deliver anticipated output	Government investment in skills plus workforce availability (from migration + demographics + education)
Economic Growth Rate (for considered industry/firm)	% GDP /% revenues related to value in reference *y*	Industry standard projections + scenario derived economic development expectations
Corporate Governance Compliance	Binary good/poor distinction *(at this stage)*	Compliance with UK FRC Corporate Governance Code, G20/OECD Principles of Corporate Governance + socioeconomic & political approaches
Effective Price on Water Consumption	t of water consumption to produce one unit of output	Technological status-quo plus technological development plus industry standard forward forecasts.

Chapter 4

Sustainable innovation and investment pathways for net zero 2050

Leveraging quantitative scenario analysis, the SIP Framework considers innovation technologies (TRL > 5) and models their scalability, while providing insights on the decarbonisation potential and investment costs. This step provides the quantified metrics required to identify the right investment and innovation pathways today.

Based on the extensive horizon scanning described in the previous chapter, this section is dedicated to apply quantitative scenario analysis and derive investment roadmap recommendations. The section first introduces quantitative scenario analysis, then details the quantitative modelling framework. It further structures the expected outputs to guide towards the industry example given in the next section.

To derive concrete investment decisions from qualitative scenarios, quantification is key.

Designing a holistic decarbonisation roadmap as a company requires a consideration of the interplay of value and cost drivers in qualitative scenarios in a quantitative way. Quantification is required to derive concrete investment decisions from the qualitative narratives about changes in the economic, regulatory and market scope in which the company operates.

There are various approaches to transferring qualitative scenario narratives into quantitative models. Most have in common that they acknowledge that a company cannot be regarded in isolation but must be described in the broader scope of macroeconomic and market conditions. Porter's Five Forces[15] of competition is a strategic tool that represents this observation. The quantitative toolbox of describing a company embedded in a holistic scope, is **system dynamics**.

> "Designing a holistic decarbonisation Roadmap as a company requires a consideration of the interplay of value and cost drivers in qualitative scenarios in a quantitative way."

System dynamics uses mathematical modelling to understand the behaviour of interacting, complex systems, and to provide guidance for decision making in such systems. Within this technique, the model class of Integrated Assessment Models (IAM) have emerged that connect questions on society and economy with environmental aspects such as climate change and biodiversity loss. IAMs are used to inform policy-making in the context of climate change, human and social development. IAMs that contributed to the NGFS[16] scenarios used in the Framework, are MESSAGEix[17] and REMIND[18]

[15] Porter, M. (2008): The Five Competitive Forces That Shape Strategy

[16] Network for Greening the Financial System (NGFS)

[17] International Institute for Applied Systems Analysis (IIASA) (2021): The MESSAGEix framework

[18] Potsdam Institute for Climate Impact Research (2017): REMIND

Next to IAMs, the use of computational general equilibrium (CGE) models would also be possible[19]. One of the most well-known CGE models is global: the GTAP[20] model of world trade.

A third option to describe a company within its broader scope, are Input-Output Tables (IOTs). IOTs are commonly used in the estimation of micro- and macroeconomic costs in disaster impact assessment, but also for impacts of climate change[21].

The SIP Framework uses Input-Output Tables due to efficiency, transparancy, politicial assessment capability, and consideration of climate change.

The SIP Framework uses Input-Output Tables. We rely on IO models for four reasons: (i) IO models are more efficient in that they allow a more detailed coverage for the same resource input (time and cost), (ii) the results derived from IO models are also more transparent for non-experts avoiding the "black-box problem" of CGE models, (iii) CGE models have their great advantages in the assessment of political (mitigation) measures, while the focus here is on particular investment recommendations for companies within the constraint of climate change and climate politics, (iv) also not in focus is the globally different impact of climate change, which have – presumably larger – terms of trade effects to be addressed with multi-country CGE models. Vöhringer et al. (2018) has shown with the application of CGE that the aggregated economic impact of climate change on GDP would be below 0.5% and aggregated welfare change is below 1.5%. Therefore, we place our focus more on bottom-up estimation of climate change and adaptation costs and less on aggregated economic modelling.

What differentiates the SIP Framework approach from other quantitative scenario model approaches?

→ Input-Output tables are dynamic and particularly contain the effect of maturing technology (TRL 6 → TRL 9) and scale effects on cost of technology and process deployment (learning curves)

→ Our modelling framework enables us to consider any financial KPIs and non-financial externalities, even in the social domain

→ Our scenario engine accounts for uncertainty of the future by using a probabilistic approach to propagating the company and its external scope into the future

[19] World Scientific – Connecting Great Minds (2018): Costs and Benefits of Climate Change in Switzerland

[20] Global Trade Analysis Project (GTAP) (2017): GTAP Models: Current GTAP Model

[21] International Atomic Energy Agency (IAEA) (2020): Detailed economic analysis of individual policy instruments and measures for climate change adaptation

Quantitative scenarios are established based on inputs such as the company fundamentals, metrics from the qualitative scenarios, technology assessments and abatement curves. As output, optimal transition pathways considering also other negative externalities are generated.

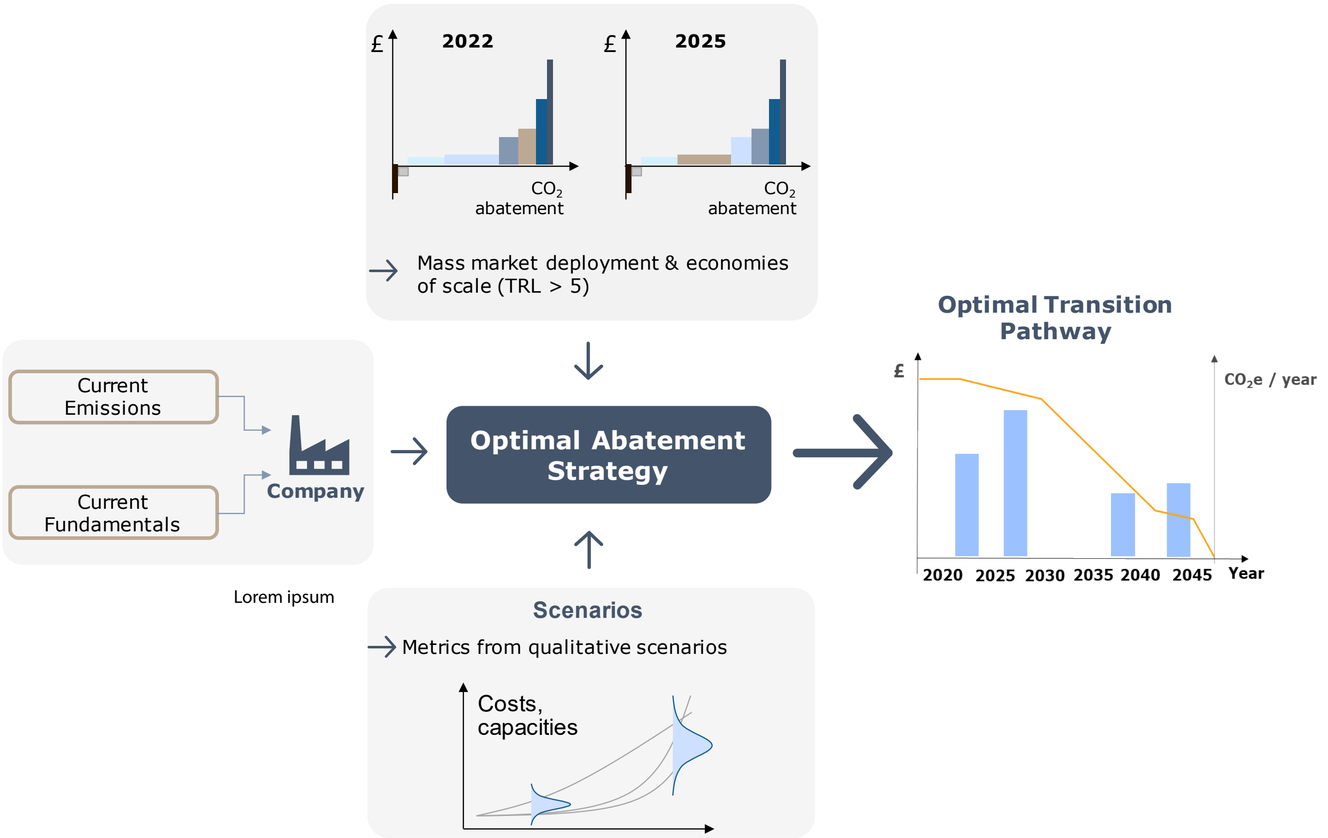


Figure 7 - schema of the quantitative modelling process

This figure shows schematically how the framework quantitatively models investment and decarbonisation pathways for a company.

It starts with the company's Sustainability Twin, a digital characterisation of the company by financial data and externalities. It ends with pathways, concerning investment and product decisions that are optimal to guide the company along the future external constraints of decarbonisation requirements, technological and market change, and competitive pressure.

In order to move from the left, input, side towards the right, output, side, two additional components are required:

- Quantitative scenarios
- Dynamic abatement options

Within the SIP Framework external drives are informed by the qualitative scenarios and supplemented by the state-of-the-art quantitive pathways.

Quantitative scenarios describe how the external context under which the company operates may change over time. This component represents the outside-in view of the company. The assumption is that a single company has no significant influence on these external drivers. In our study, these changes are informed by the qualitative scenarios described above, and supplemented by state-of-the-art quantitative, techno-economic pathways. Our basis is the scenarios developed by the NGFS, which is enriched by industry specific scenarios.

Abatement curves describe the levers the company itself has to abate CO_2-emissions and other externalities, and thereby mitigate climate related risks such as asset stranding. This component represents the inside-out view of the company, as it contains the options a company has to embrace new technology and processes. In our framework we emphasise that abatement options are dynamically changing due to technological innovation and economies-of-scale.

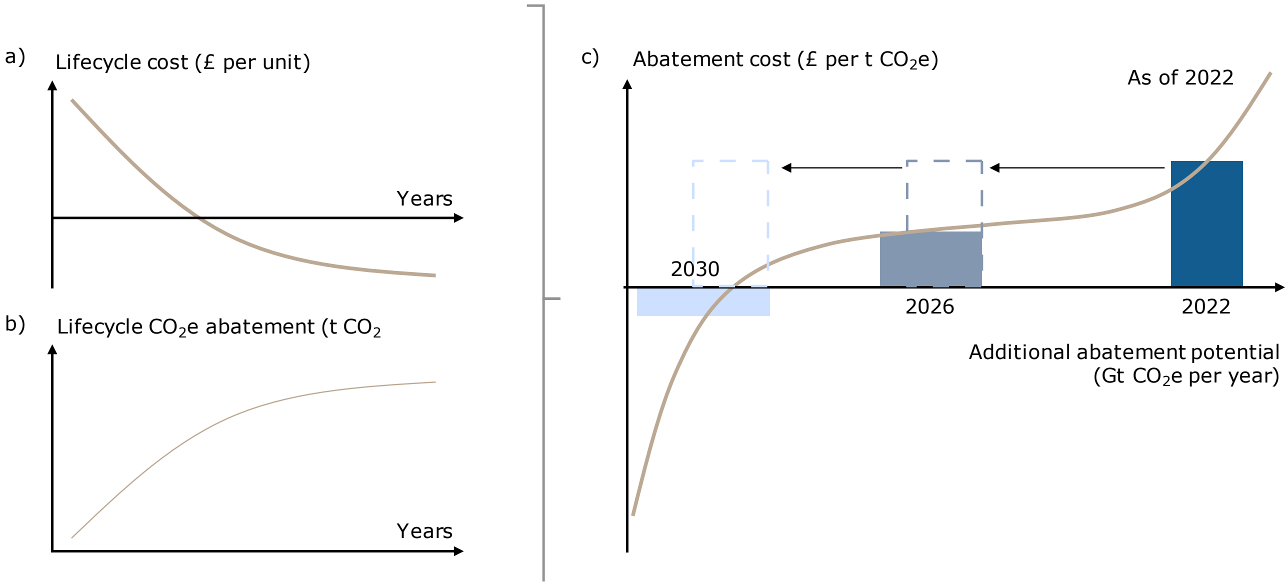


Figure 8 - dynamic abatement options

Abatement cost curves were brought to the attention of the market by McKinsey[22] and indicate options such as technologies and process changes to abate carbon emissions. Typically, abatement cost curves represent snapshots of options at a certain time. We add two features to abatement cost curves to improve the modelling of a company's options.

Abatement curves represent the inside-out view of a company when it comes to decarbonisation options.

First, we make abatement curves time dependent. Both the cost of technology, and the efficiency of a technology to abate carbon emissions, change continuously. This is indicated on the left panel of Figure 8. Figure 8a shows the typical LCOT (total lifecycle cost of deployment and operation of technology) degression of a technology. In late innovation stages (TRL 6-8), the typical cost for deploying and operating a unit of technology is high. In its mature state (TRL 9), the unit cost can already be lower by orders of magnitude. When a technology is deployed and scaled, learnings about how to efficiently produce and operate the technology and underlying processes drive costs further down. Eventually, a technology may exhibit negative cost, for instance when LCOT gets below the benchmark cost of the catered economic activity (Example: Electricity production from solar cells reached and undercut grid parity cost of electricity production in many countries in recent years). Simultaneously, the carbon abatement effectiveness of a technology can increase over time, as indicated in Figure 8b. This may result from either improvement in process energy efficiency (e.g. catalytic efficiency gains in Carbon Capture[23] or from more efficient production and deployment processes of the technology.

[22] McKinsey & Company (2021): Net zero or bust: Beating the abatement cost curve for growth

[23] Massachusetts Institute of Technology (2021): Boosting the efficiency of carbon capture and conversion systems

The impact of both effects combined is shown in Figure 8c), which shows the abatement potential of technology as the width of the bar on the horizontal axis, and the LCOT of a technology as the height of the bar on the vertical axis. Typically, when considering multiple abatement options, these are sorted such that cheapest options appear left, and expensive options appear right on the chart. In this widespread representation of abatement options, a technology's bar may increase in width over time, indicating carbon abatement effectiveness gains. Simultaneously, the bar may decrease in height and eventually turn negative, indicating LCOT efficiency gains.

The SIP Framework simulates a company`s financial & non-financial metrics in the future, under the constraints of accessible abatement options.

In the framework, both the outside-in and the inside-out view of a company's future scenarios and options are considered. Now, scenarios are pathway descriptions of future developments and do not inform about how a company may best position itself. Therefore, we are combining the scenarios with probabilistic modelling, using a Monte Carlo approach to simulate a company's state in a great variety of decisions taken by the company to adapt (i.e., finance and operate) technology. Our framework simulates a company's financial and non-financial metrics in the future, under the constraints of accessible abatement options and the scenarios describing the option space of the company outside-in.

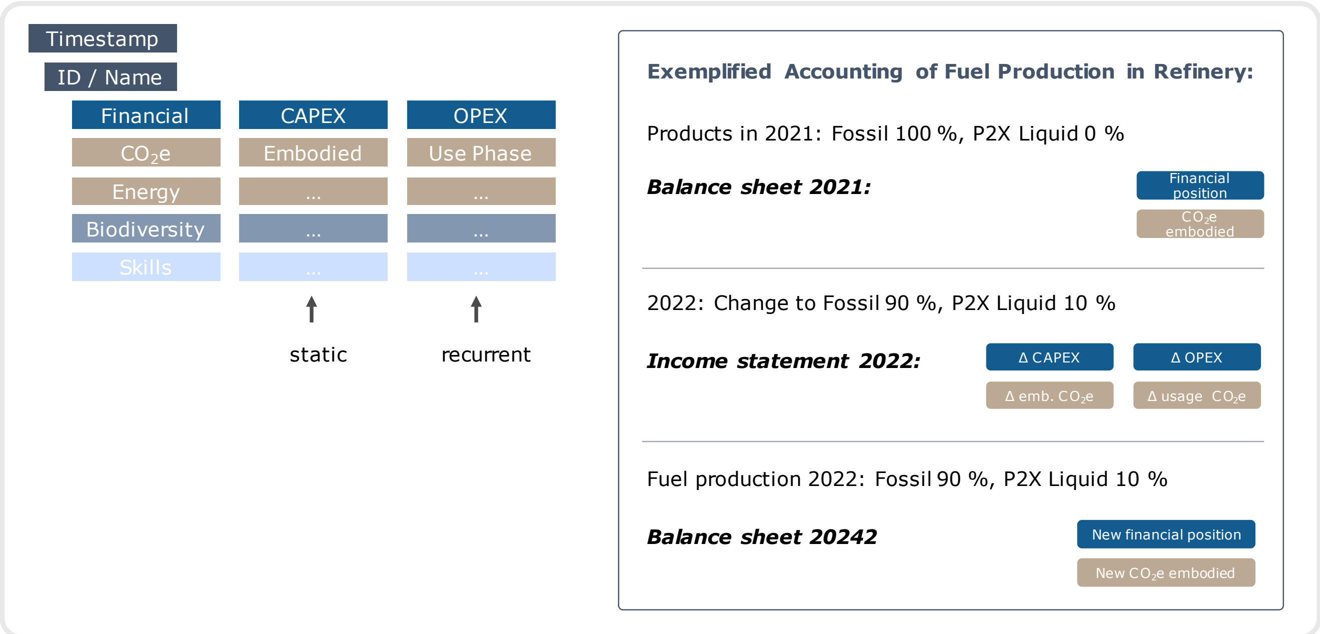


Figure 10 -data structure of a company`s evolution through the SIP lens

One core innovation of our approach is that we create non-financial profit-and-loss statements and balance sheets in the same way as financial profit-and-loss statements and balance sheets are created during the modelling process. Figure 10 schematically shows the technical data structure we employ to this end. In general, we regard any company's state as the sum of its accumulated transactions. A transaction represents any interaction of the company with its external stakeholders. This may be a CAPEX investment in new property, plant and equipment, it may be OPEX for purchasing electricity, or it may even be a training the company offers to upskill its employees.

An inital case study focuses on the Power-to-X economy and investigates its sustainable innovation and investment pathways.

As an example, and an initial case study, we are investigating sustainable innovation and investment pathways for the Power-to-X economy. Power-to-X refers to a family of conversion processes that, in an industrial scale, use electric power to produce chemical energy carriers - ways of storing energy in combustible chemicals such as hydrogen, ammonia, or synthetic fuels. If the electricity is provided either by surplus or by dedicated production from renewable energy sources, Power-to-X can support both, the decarbonization of chemical fuels, and to decouple demand from supply of intermittent renewable electricity.

The left side of Figure 10 shows how any transaction of a company is registered. First, each transaction contains a timestamp and a unique ID. The ID allows to connect a company's transaction with the corresponding transaction of its counterparty, e.g. a power utility or a customer. Each transaction further considers the financial value either as CAPEX or as OPEX, or in case of a sale of the company's goods and services, as static or recurrent income.

Additionally, any externalities to the transactions are monitored in an analogous way: carbon, energy, biodiversity, or social "footprints" associated with the transactions are recorded.

Over any reporting period, all transactions within can be summed up to a holistic profit-and-loss statement for the period. A new holistic balance sheet is calculated from adding the period's profit-and-loss statement to the balance sheet at the beginning of the period[24].

"Any externalities to the transactions are monitored in an analogous way: carbon, energy, biodiversity, or social 'footprints' asscociated with the transactions are recorded"

The right side of Figure 10 outlines an example. A refinery in 2021 has a certain financial position and a corresponding carbon position. If in 2022, the company decides to reduce its fossil fuel production to 90% of total output, and allow for 10% Power-2-Fuel output, this requires installations (ΔCAPEX) in the refinery and changes its operational spending (adding additional power usage), worth ΔOPEX. The installations come with a certain carbon footprint, the so-called "embodied carbon", registered as Δ emb. CO_2e. The production of P2X Fuel results in changed CO_2e emissions along the entire value chain (replacing crude oil with electricity as input, requiring heat to drive the process, and greatly reducing fossil CO_2 production downstream at the customers' side). These changes are registered as Δ usage CO_2e.

In an analogous manner, further externalities can be accounted for.

[24] Note that more complex accounting mechanisms such as amortisation can readily be modelled in this framework. We neglect this additional complexity here to ease understanding.

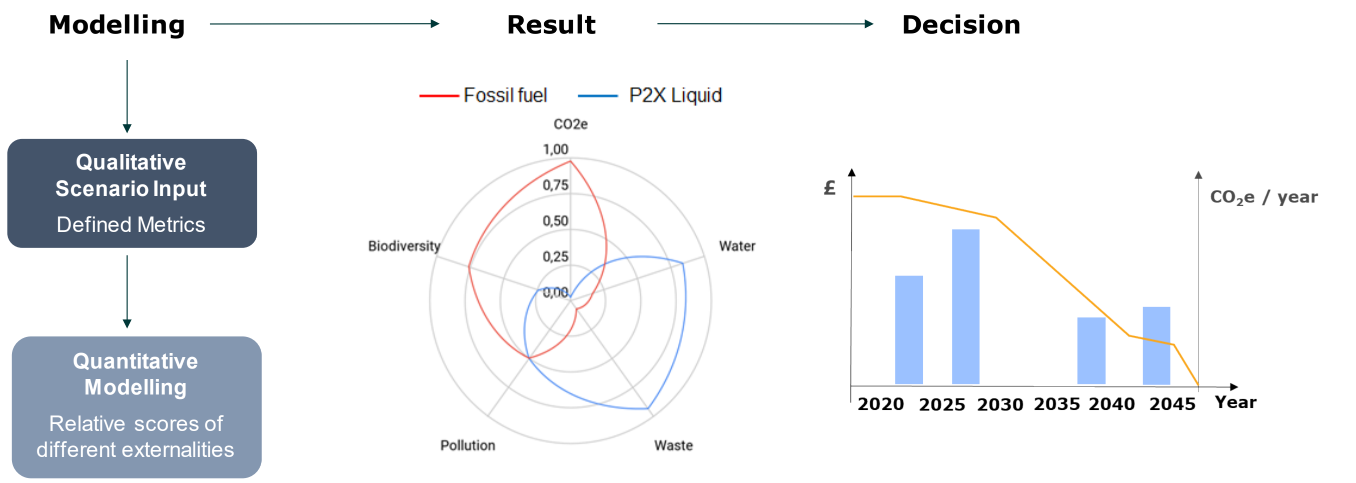


Figure 11 - Interplay of qualitative & quantitative scenarios to enable holistic recommendations for net zero investments

Figure 11 shows the synthesis of our SIP Framework. A deep horizon scanning in a qualitative scenario analysis opens the space of possibilities and likely developments of and for a company under various scenario assumptions (left panel). Metrics are derived from these scenarios that are used as input parameters and pathways in quantitative modelling. The modelling consists of merging said scenarios with dynamic abatement options a company has at hand - considering not just CO_2 and financial implications, but any further externalities of interest (middle panel). Using a probabilistic optimization engine, financial investment and decarbonisation roadmaps are derived for the company.

Generic Data Inputs

- Development of energy prices
- Development of availability and cost of technologies
- Development of prices on carbon and other externalities
- Description of the technologies in terms of cost, energy performance, CO2 lifecycle footprint and non-carbon ecologic and social externalities
- Internal carbon pricing

→

Generic Data Outputs

- CAPEX / OPEX roadmap for a particular business to mitigate risk of stranding of assets or business models getting obsolete
- Optimised decarbonisation roadmap for a particular business process, considering both, mature technologies and technologies that are in late innovation stages
- Balance sheet and profit-loss impact of climate risk mitigation and decarbonisation measures.

Chapter 5

Moving forward

The application of the SIP Framework creates the necessary transparency to scale up investments in decarbonising innovation technologies.

In order to reach global net zero targets amongst all sectors of the UK economy by 2050, large scaleinvestments in sustainability innovations projects will be required. To this day, the majority of innovation funding is allocated to early stage innovation projects in the concept and small prototype phase. In regard to net zero targets, funding too often focuses on single technologies on the quest to find a one-fits-all solution. However, to facilitate the energy transition at the required pace, innovation funding should be industry specific and focus on projects already at a large prototype or demonstration level. This will be key to enabling industrialisation and scalability of decarbonising technologies at the required pace.

With these challenges in mind, the Sustainable Innovation Pathways Framework (SIP) was developed, with a proof-of-concept study focusing on the United Kingdom's commitment to reaching net zero by 2050. The SIP Framework establishes a thorough analytical toolset that enables a ranking of the most promising innovation projects per industry, focusing on the highest emitting and GDP relevant sectors economically. Applicable to company, industry or country level, the framework combines qualitative futures foresight scenarios with quantitative pathways analysis. The resulting output provides corporate leaders, investors and policy makers with the required transparency on factors such as development lead times, pathways for technological scalability and resulting economies of scale depending on varying levels of investment, decarbonisation potential, and the cost of continuing business as usual.

> "Innovation funding should be industry specific and focus on projects already at a large prototype or demonstration level. This will be key to enabling the industrialisation and scalability of decarbonising technologies at the required pace."

On this foundation, decarbonisation strategies can be determined, and net zero policies refined based on key financial metrics, abatement curves and consideration of negative externalities. As outlined at the start of this report, defining a variety of qualitative net zero 2050 scenarios as the foundation of the strategy building, the framework enables the consideration of changes in the geopolitical environment and potential black swan events. On its own, these scenarios however do not allow individual stakeholders to make informed investment decisions today, which are required to advance with decarbonisation pathways.

The SIP Framework bridges this gap by deploying quantitative scenario analysis. By quantitatively deriving the economic cost for a set of industry specific decarbonising innovation projects, the framework enables both the private and public sector to make educated decisions on innovation funding and derive the future pathways that are the most economically and environmentally viable. When considering economic cost, the SIP Framework does not only consider the simple investment costs and resulting economic growth, but also the cost of environmental externalities of continuing with business as usual. As demonstrated throughout this report, the SIP Framework when applied can thereby establish transparency on the true cost to economic growth and society overall of doing nothing, or investing in inefficient innovation projects, compared to the short term investment costs.

The application of the SIP Framework thereby enables the identification of an applicable and industry-specific set of decarbonisation options based on innovation technologies. This transparency and insight will be key to successfully master the energy transition with the impact of transforming the companies and economies to be resilient, sustainable, and profitable in the long run.

Moving forward...

This report introduces the SIP Framework resulting from a proof-of-concept approach. This approach has allowed for various testing scenarios leading to the conclusion that the framework is also applicable to situations other than those given in the proof of concept phase. Nonetheless, the authors have identified several areas for further development to strengthen the frameworks applicability and conciseness. These can be summarised as following:

Build up of an innovation database:

- A key input to the quantitative analysis stage and consequently also the strategy definition are the selected innovation technologies. The identification and analysis of appropriate innovation technologies is expected to be the most time-consuming element as it will initially reflect a case-by-case approach. However, as innovation technologies are analysed and awareness of their influence on other industries is established, these insights in the form of input metrics and domain knowledge can be collected in an innovation database. Thereby, the SIP Framework also builds up on past projects which can be leveraged for various end uses.

- The innovation database will need to feed into the holistic approach described throughout the report, but also be able to focus on the cost-effective transition to net zero carbon emissions, under the simultaneous optimization of other externalities.

- Furthermore, flexibility needs to be maintained to also consider sustainable innovations unrelated to energy sources that thus cover the transition phase. At a later stage these can be updated with a new set of innovations.

Consideration of new innovations and increased innovation velocity:

- Technology is continually evolving. The Framework's use of industry standard databases inevitably accepts a certain lag in time with the data. This is compensated for by means of the horizon scanning process within the qualitative scenario setting whereby "pockets of the future in the present" are captured". To maintain an up-to-date view on this, the process should be regularly updated.

- To also account for changes in innovation velocity or breakthrough innovations resulting in potential paradigm shifts, the SIP Framework analysis is recommended to be updated every five years.

Extension of analysis on cross-sectorial interdependencies:

- One of the main advantages of the SIP Framework lies in its holistic approach. The model is three-dimensional and covers interdependencies between sectors. In this proof-of-concept phase it was however not possible to cover the various industries holistically, but in the case study has rather focused on individual processes therein. As the Framework is more frequently applied and the more data is collected, it can also leverage a greater view of how the interdependencies, as well as the second- and third- order effects, interact.

Over the next months we will publish several case studies, exemplifying how the framework is applicable to different industries.

The SIP Framework was developed by:

Dr. Christian Spindler is co-founder of SIP LABs and responsible for the *Quantitative Pathways* function. Christian served as Senior Manager for IoT & Machine Learning at PricewaterhouseCoopers and gained extensive experience in industrial IoT and processes as Senior Researcher at the global electro-technology company ABB. Christian graduated in physics (PhD) and earned an MBA from the University of St. Gallen. Prior to SIP Labs, Christian founded Sustainaccount, focusing on leveraging AI powered technology and a wealth of data to perform future oriented scenario analysis and optimization pathways.

Visit Profile >

The SIP Framework was developed based on a concept introduced by **Lena-Katharina Gerdes**. Lena is co-founder of SIP Labs and responsible for our *Strategy Development* function. She holds an MSc in Economics & Strategy for Business from Imperial College London and a BA in International Relations & Economics from the University of Reading. In the past, Lena was responsible for the Sustainable Finance & Business Model Transformation function at Eraneos Switzerland. Prior, she worked at Commerzbank London, where she supported the build-up of the equity research function focusing on German small & mid-caps. Subsequently Lena worked as a research assistant at the Centre for Climate Finance & Investment at Imperial College London, where she currently holds an Honorary Practice Associate position.

Visit Profile >

Jonathan Blanchard Smith is co-founder of SIP Labs and leads our Futures Scenarios function. Jonathan holds a MPhil from St Catharine's College, University of Cambridge. In addition to his role at SIP Labs, Jonathan is currently chairman of the Natural Resources Forum, adviser to a humanitarian charity, and marketing Director and Fellow at SAMI Consulting. SAMI Consulting is a leading foresight, futures and strategy consultancy and has delivered over 250 foresight and strategy projects in 21 countries, across the private and public sectors. Jonathan has recently been cospeaker at a series of events on Brexit's implications in Europe, including at the Diplomatic Academy of Vienna and the Austrian Competition Authority.

Visit Profile >

Find out more about SIP Labs and our solutions at www.sip-labs.com