21ST CENTURY CLIMATE INNOVATION ASSESSMENT

Identifying 1.5 °C compatible innovations in the 4th industrial revolution that can deliver what is needed to allow 11 billion people live flourishing lives

MISSION INNOVATION | NET-ZERO COMPATIBLE INNOVATIONS INITIATIVE | IIASA | Tyndall°Centre for Climate Change Research | RI. SE

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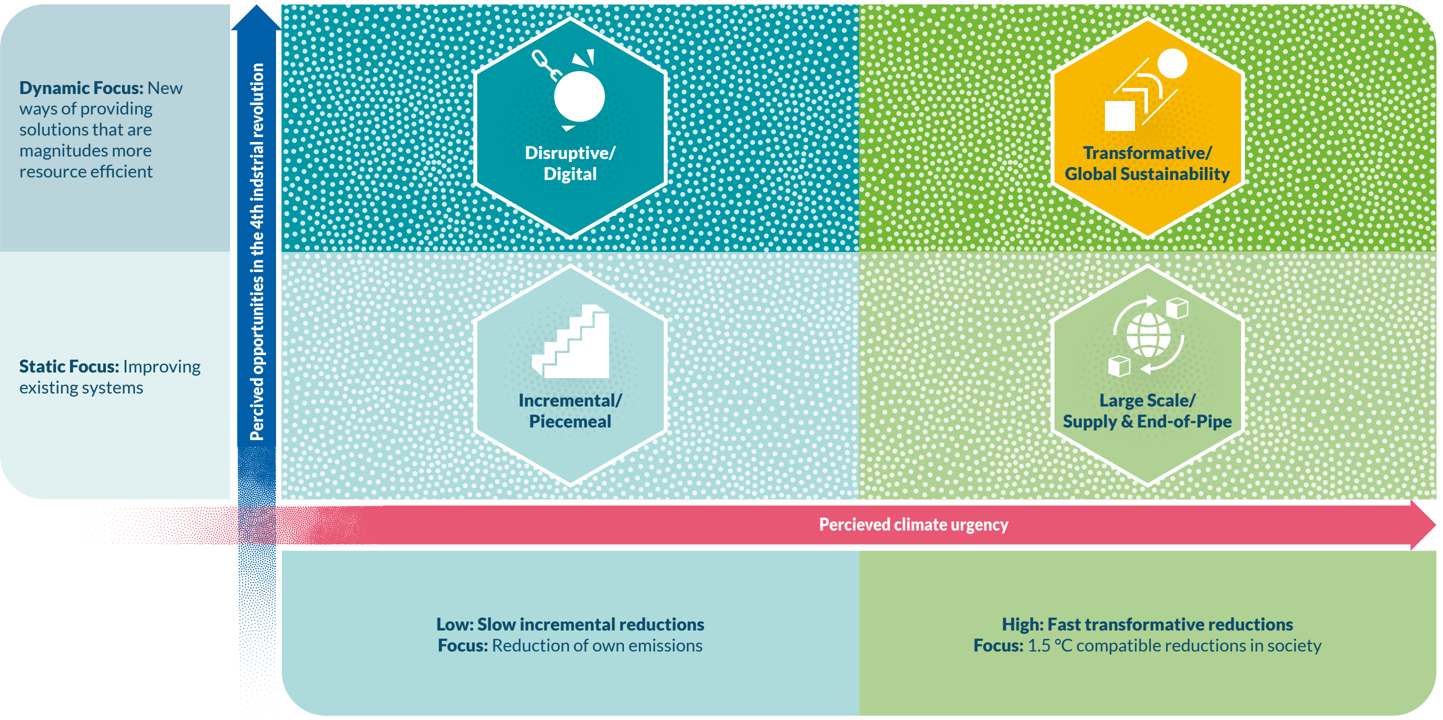
Introduction

Climate change approach matrix



A plethora of initiatives for climate action exist, but almost all are based on a "static problem approach", where focus is on how large companies and cities shall reduce their own emissions. Often this static problem approach results in an "accounting response" where the actual contribution of the company, city, country, etc. to a sustainable future and a 1.5 °C trajectory is less important than the ability to claim some level of carbon reduction, or carbon neutrality, sometimes even through using offsetting.

After the Paris agreement[1] the focus is now shifting from incremental reductions to 1.5 °C pathways. For a static approach that ignores the many opportunities in the 4th industrial revolution[2], a 1.5 °C focus tends to result in dramatic end-of-pipe measures, such as CCS or even geoengineering and massive supply-side measures, such as large-scale biofuel projects. Often in combination with creative accounting with offsetting and strategies betting on a future with large scale, cheap and secure carbon capture.

It is worth noting that many of the current trends are fundamentally unsustainable, e.g. the UN Environment Programme's Global Resources Outlook 2019 noted that:[3]

- **The extraction and processing of materials, fuels and food contribute half of total global greenhouse gas emissions and over 90 percent of biodiversity loss and water stress**
- **Resource extraction has more than tripled since 1970, including a fivefold increase in the use of non-metallic minerals and a 45 percent increase in fossil fuel use**
- **By 2060, global material use could double to 190 billion tonnes (from 92 billion), while greenhouse gas emissions could increase by 43 percent**

In contrast to a static problem approach, there is a growing number of initiatives with a "dynamic approach, but without sustainability focus. These initiatives build on the opportunities provided by the fourth industrial revolution, but without understanding of the deep and fast emissions reductions of greenhouse gases as well as extreme resource efficiency that are needed for global sustainability. Only accelerating the uptake of disruptive solutions, from AI and IoT to sharing platforms and a circular business models, tend to focus on improvement in existing systems, but accelerate unsustainable resource consumption as well as wealth concentration, and is therefore unsustainable.[4]

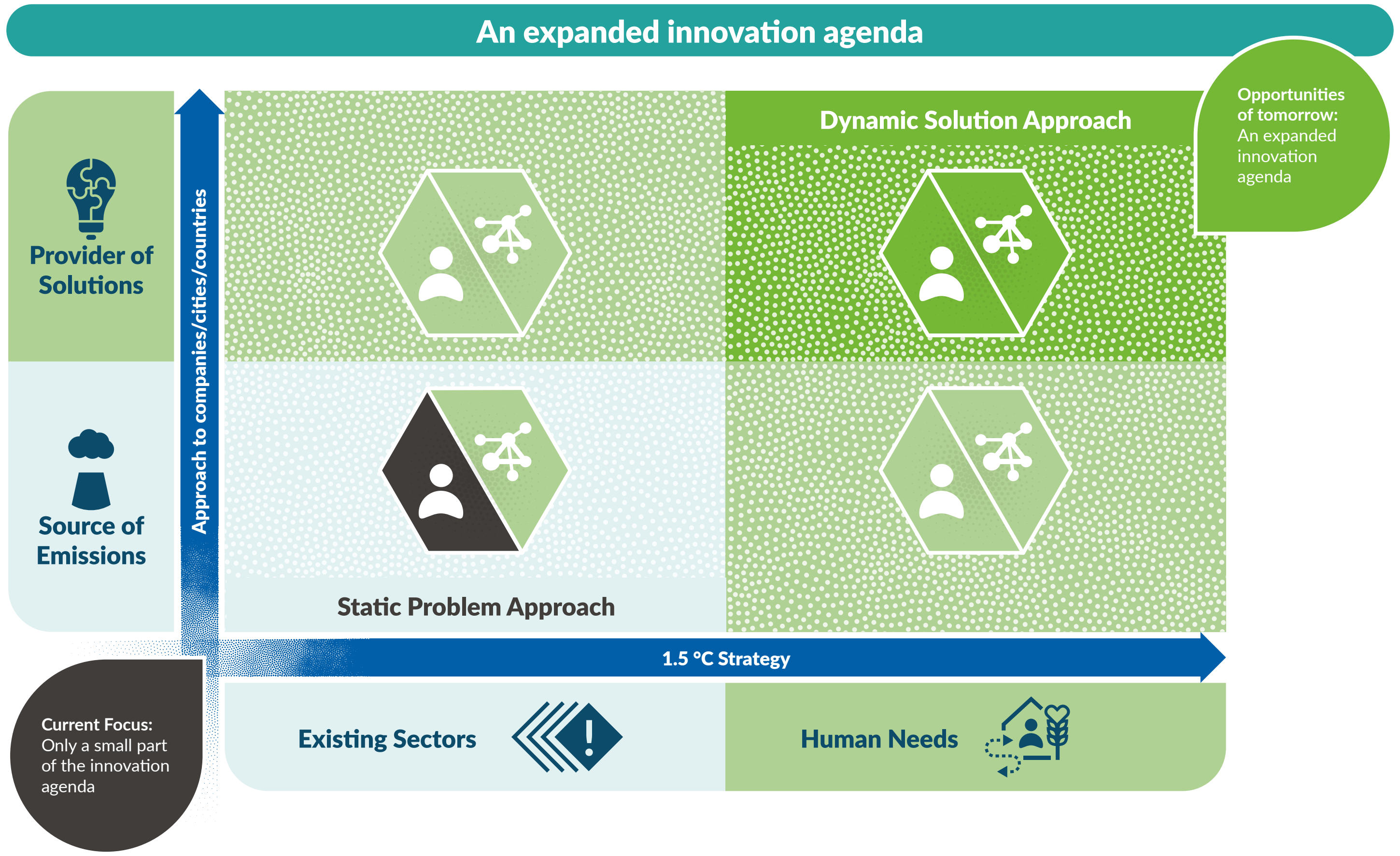
This paper presents a Need-Based Climate Innovation Framework in order to help stakeholders support a "dynamic solutions agenda", based on the opportunities in the fourth industrial revolution, while being guided by the need for deep and fast emission reductions in line with IPCCs 1.5 °C Low-Energy Demand Pathway.[5] Such a dynamic solution approach focuses on how to deliver fossil free solutions to meet human needs in a way that delivers an equitable future society for >11 billion people.

Beyond accelerating 1.5 °C compatible solutions the Need-Based Climate Innovation Framework is a, humble, response to the how get from the current global situation of vast inequalities, excess and inefficient energy-use to one where flourishing living standards are provided universally and efficiently.

The paper is based on research by Professor Charlie Wilson, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich[6] and International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria[7] in collaboration with leading experts around the world in the area of resource efficient low-carbon strategies. The framing and structure are based on work by Dennis Pamlin (lead author) and Jay Hennessy from Mission Innovation's Net-Zero Compatible Initiative[8] and RISE.[9] The work was conducted in close collaboration with Massamba Toye and his team at UNFCCC's Regulatory Development Unit during the development of the UNFCCC Innovation Hub.

An Expanded Innovation Agenda

1



1.1 Why a static problem approach is dominating

In a situation where totally new opportunities, provided by the 4th industrial revolution, meets the urgent need for rapid greenhouse gas (GHG) reductions, there is a need to identify and assess new ways of delivering on core societal needs in ways that can help ensure an equitable and sustainable 1.5 °C future.

Case study 1: Leading investors begin to see the difference between a static problem approach and a dynamic opportunity approach

"[The static reduction/problem approach] focuses on the how not the what.

By 'how', we mean that companies conduct their business in a long-term, responsible way, with regard to all stakeholders. By 'what', we mean that companies produce goods and services aligned with the society we want.

[The static reduction/problem approach] is also anchored to past performance rather than forward-looking. Yet, we know that many sectors need to undergo a profound transition in the coming years to achieve sustainability.

A waste management firm might be doing well on recycling rates, but how will it fare if consumers and policymakers get serious about a zero waste, circular economy? A food producer might be improving its environmental footprint, but is it ready for a switch to healthier diets?"

From Generation Research Centre
https://www.generationim.com/research-centre/insights/system-positive/

However, almost all existing climate initiatives approach large companies, cities and countries only as sources of emissions and ask how they can reduce their own emissions.[10]

Using traditional economic models and tools these initiatives tend to focus on high emitting sectors and explore how to improve existing systems with single technology solutions. This approach can result in significant improvement in existing systems, but it also tends to ignore much more resource efficient and innovative ways of providing for the needs in society.

For example, they tend to focus on biofuel for airplanes rather than virtual meetings as they take current travel trends for granted, improved cars rather than smart city planning as they take current personal car ownership and car centric cities for granted, improved fast food rather than healthy lifestyles with plant-based meals as they take the fast food industries for granted, circular fast-fashion rather than apparel that last and promote/enable sustainable lifestyles as they take a mass consumption society for granted, fossil free steel rather than more efficient ways to provide the solutions that currently use the steel as they take old industries for granted.

The assumption that current ways of providing solutions will stay and then approach stakeholders only as sources of emissions represents a "static problem approach". From such a static problem approach "climate solutions" and "climate innovation" becomes limited to technological measures that reduce emissions from big polluters, or even accounting measures without regards to the actual impact in society (such as offsetting and other ways to claim climate neutrality without supporting a 1.5 °C development path). The aggregated result is business as usual that ignore the enormous potential provided by the 4th industrialisation. Such an approach also makes carbon capture technologies, or even geoengineering, a necessity.

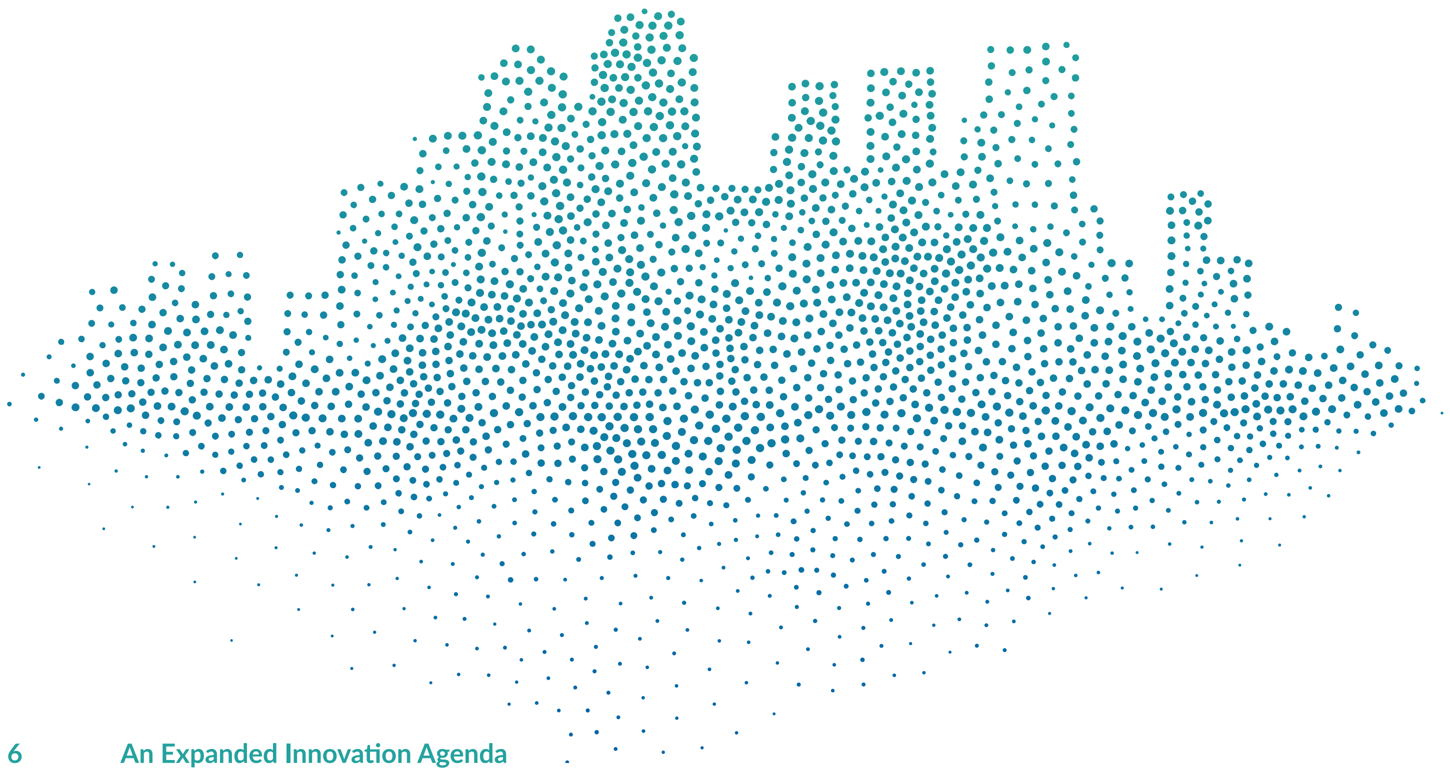
There are good reasons for this static problem approach. Back in the 1990's, when many of the current initiatives were initiated, the focus was on initial reductions and on the major emitters and the opportunities presented by the 4th industrialisation were less known. The goal for most was to support the initial commitments under the Kyoto protocol, ranging from stabilisation to reduction of -20 percent of greenhouse gases, with an average 5 percent emission reduction compared to 1990 levels over the five-year period 2008–2012.[11]

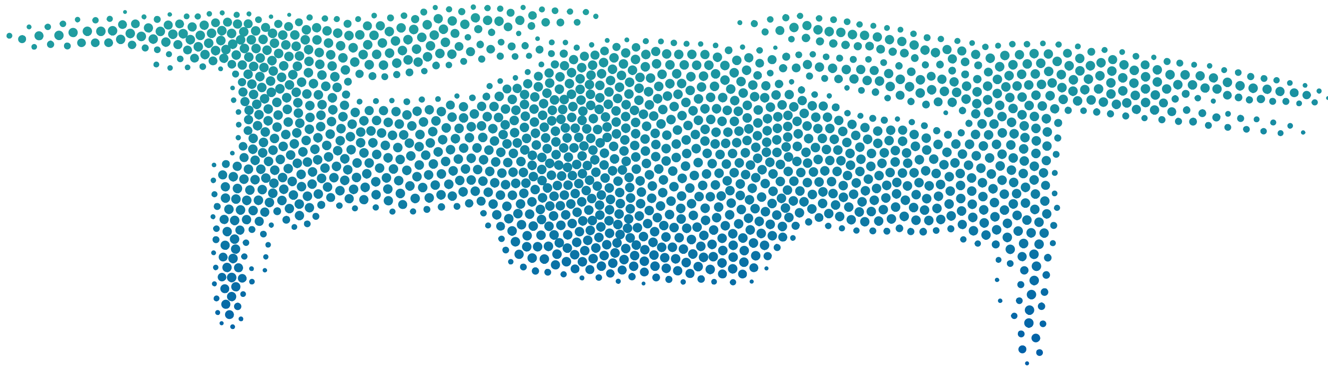
Back during the 1990's the responsibility for the climate change issue was almost exclusively the domain of environmental ministries and their agencies. For many ministries of environment, and the corresponding environmental protection agencies, the goal is to minimise the environmental destruction created by the economic priorities decided by other ministries, such as ministry of industry and ministry of finance. The result is that environmental protection has been an afterthought to economic development, dominated by end-of-pipe solutions.[12]

The limited mandate and a toolbox designed for improvements in existing systems, such as environmental product labels, environmental taxes, best in class, best practice, etc. resulted in improvements like more fuel-efficient fossil cars, less environmentally destructive paper, and less polluting meat production, etc.

However, this combination of tools for incremental improvement created a structure that was never intended to encourage changes beyond improvements in existing systems. Instead, these models and tools tend to ignore, or even undermine, new smart solutions such as teleworking/virtual meetings, digitalisation of information, plant-based healthy lifestyles and new business models based on providing a service rather than selling products.

In a similar way, most environmental organisations relate primarily to companies as the source of problems. Depending on approach they either try to stop those they see destroying the environment (e.g., Greenpeace campaigning against Arctic oil exploration), or they try to engage in dialogue to minimise the damage through round tables with leading companies to develop labels and voluntary commitments that use traditional market mechanisms to optimise existing systems (e.g., WWF through Climate Savers).[13]





The work to limit the negative impact from current structures is very important and should be part of all initiatives for sustainability, but it is only half the story and in a rapidly changing society the focus on existing structures is arguably the less important part.

For climate change there are also additional historical reasons for the dominating focus on companies and cities only as sources of emissions ranging from political, via technological, to social. To reach the initial reductions improvements under the Kyoto protocol incremental improvements in existing systems were enough. The organisations, initiatives, and tools created to support these initial targets were therefore dominated by this "static reduction approach" aimed at large polluters and easy cost-efficient reductions in existing systems. Examples of initiatives based on a static reduction approach include the Greenhouse Gas Protocol[14], the creation of the World Business Council for Sustainable Development[15], and CDP[16]. These initiatives tend to engage those individuals in companies with responsibility for risk and compliance, often linked to PR/marketing.

This "static problem approach" cluster has established well-funded business models and done great work to help recognise the need to report and reduce emissions from their operations (scope 1-3). However, this approach has also led to an accounting focus where companies try to claim "climate neutrality" by using offsetting or hoping for CCS, instead of asking what they are providing to society and how that can be done in an equitable world that can provide flourishing lives for 11 billion people within a few decades. The real urgency for dramatic emission reduction has therefore in many cases been translated into an accounting urgency where **many companies use consultants with a communication focus to find the simplest way to be perceived as reducing emissions by policy makers, investors and the general public, rather than focus on what is needed for society to become sustainable and their role in this transition.**

This static problem approach has also been transferred to cities where many cities today only view themselves as sources of emissions and develop strategies based on this limited innovation agenda, where the only focus is on reducing their own emissions, rather than a dynamic solution agenda where the need for reduced emissions is used to develop and export new innovative solutions.

New initiatives tend to be extrapolation of this static reduction approach, e.g. We Mean Business[17], TCFD[18], EUs taxonomy[19], Race to Zero[20], and Science Based [reduction] Targets.[21] However, both some of the older, as well as an increasing number of the more recent, initiatives are expanding their innovation agenda to also embrace a dynamic solution innovation approach.

1.2 The urgent need for – and new opportunities – for transformative system change

Since the 90s, when much of the current climate work began, the understanding that urgent reductions are needed has increased together with a growing understanding of how serious the climate threat is. Especially an understanding of the uncertainty of the current models and that much worse scenarios exist than those that are usually discussed, together with the growing recognition that tipping-points and feedback mechanisms can accelerate climate change and result in faster and more dramatic changes than the simpler models can cover.[22]

The probability curves for climate impact are something that many dominating stakeholders have avoided as they show climate change as an existential threat. After COVID-19 the understanding for low-probability high-impact scenarios will hopefully make it easier for the general public to understand that the existential threat nature of climate change is important to include in strategies.

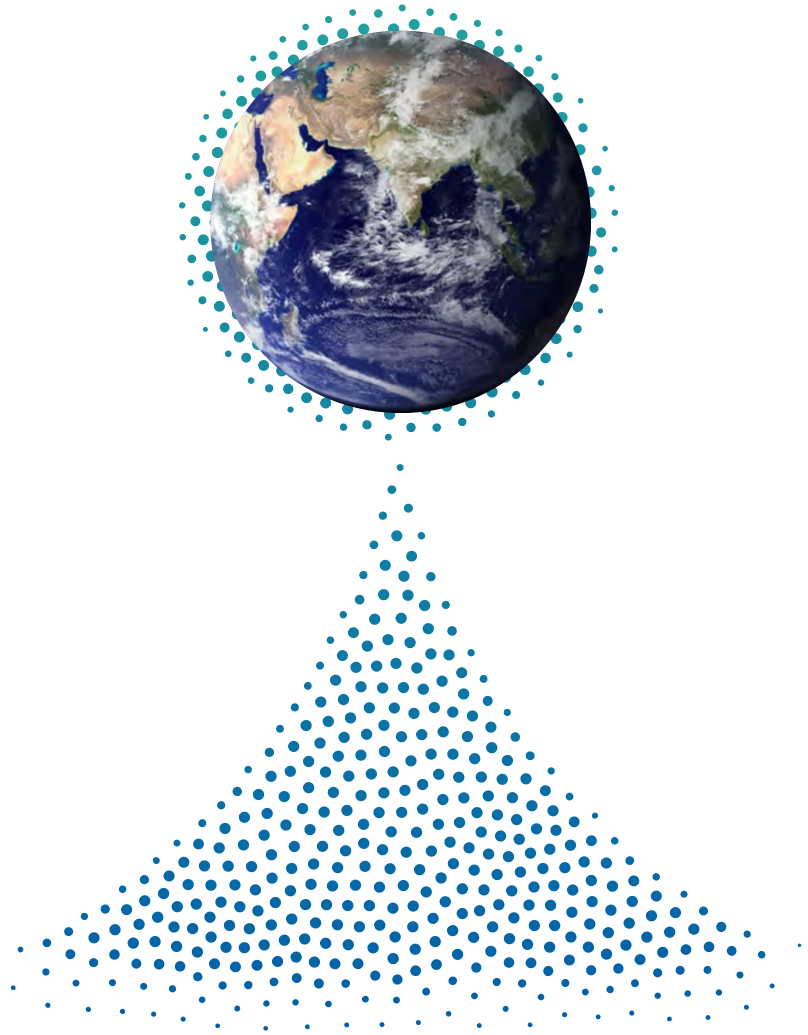
Few seem to understand that the current "carbon budgets" and policy recommendations are based on models and assessments that do not include these uncertainties and tipping points. Even fewer know that many recent studies show that we have no budget at all left, but are getting deeper into the extreme danger zone with each GHG molecule.[23]

The latest IPCCC report on the physical science highlights the importance of tipping points, but even more important would be if the upcoming IPCCC report about mitigation embraces the innovation potential, that was introduced in the historic Low-Energy-Demand/P1 pathway from the IPCC 1.5 °C special report. This could help move the world move beyond old linear models and assumptions.[24]

The world is now in the middle of a societal transformation of historic magnitudes where many experts foresee the fastest and most transformative changes in human history. This change can be described from many different perspectives, with the term "4th industrial revolution", used by many in the business community.[25]

Others have covered related rapid changes in our society and used different terms, including the post-industrial society[26], information age and network society[27], experience economy[28], and ecological civilisation[29]. While different groups and experts focus on different aspects, a common theme by many is the convergence of new technologies, new business models and new values in society, allowing us to provide solutions to human needs in fundamentally new ways.[30]

The transformations described above, and the need for rapid reductions of GHG emissions require us to change perspective, from only improvements in existing systems to transformative system change. One of the best descriptions of such a transformation with a dynamic solution approach was in IPCC's 1.5 °C special report.[31] It is called P1, the Low-Energy-Demand (LED) pathway. In the other end of the spectrum P4 was presented as a pathway representing the most static problem approach with focus on supply-side and end-of pipe solutions.



Today, opportunities exist to provide for human needs in fundamentally new ways that are compatible with a 1.5 °C LED agenda, while also deliver on the other major global sustainability challenges, including biodiversity and poverty reduction.[32]

1.3 Three steps towards a dynamic solution approach for 11 billion people

1 Move beyond a static problem approach: Acknowledge the limitations

The static problem approach assumes that the world in 50 years will stay basically the same and therefore asks the companies and sectors that are the current sources of emissions to commit to zero carbon targets for 2040-50. The results are strategies assuming a need for very high increases in renewable energy, far from what is sustainable as well as assuming exponential growth of CCS, even though the development of CCS has constantly underperformed and even supporters recognise the limited role it can have by 2050, as even IEA (an organisation with strong supply side focus and strong support for CCS), have noted "years of slow progress".[33]

There are still good reasons to explore different technical ways to capture carbon, but only as an insurance if a smarter and more sustainable agenda that also delivers on other sustainability goals fails. The challenge is that many are assuming that CCS is a must and therefore strengthen a business-as-usual pathway, along the lines of the P4 pathway in IPCCs 1.5 °C special report.[34]

Negative emissions can still be delivered through natural sinks, and especially important contribution can be provided by land-use change due to less meat consumption and resource intensive lifestyles.[35]

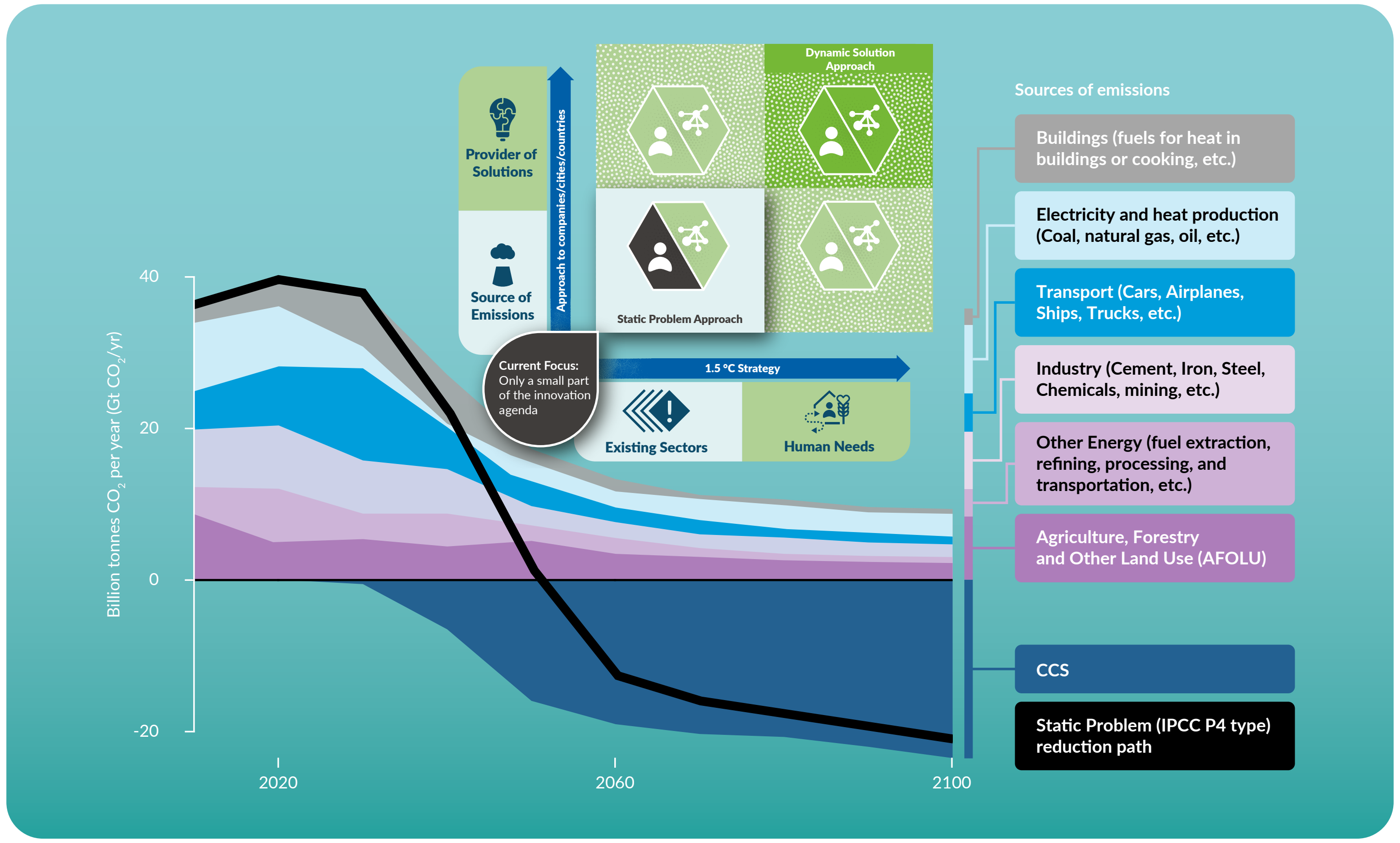
The argument is therefore not against CCS or other end-of-pipe solutions, it is against the limited innovation agenda that assume business and usual and makes CCS and other end-or-pipe solutions, necessary parts to stay below 1.5 °C.

2 A dynamic solution approach: Focus on needs

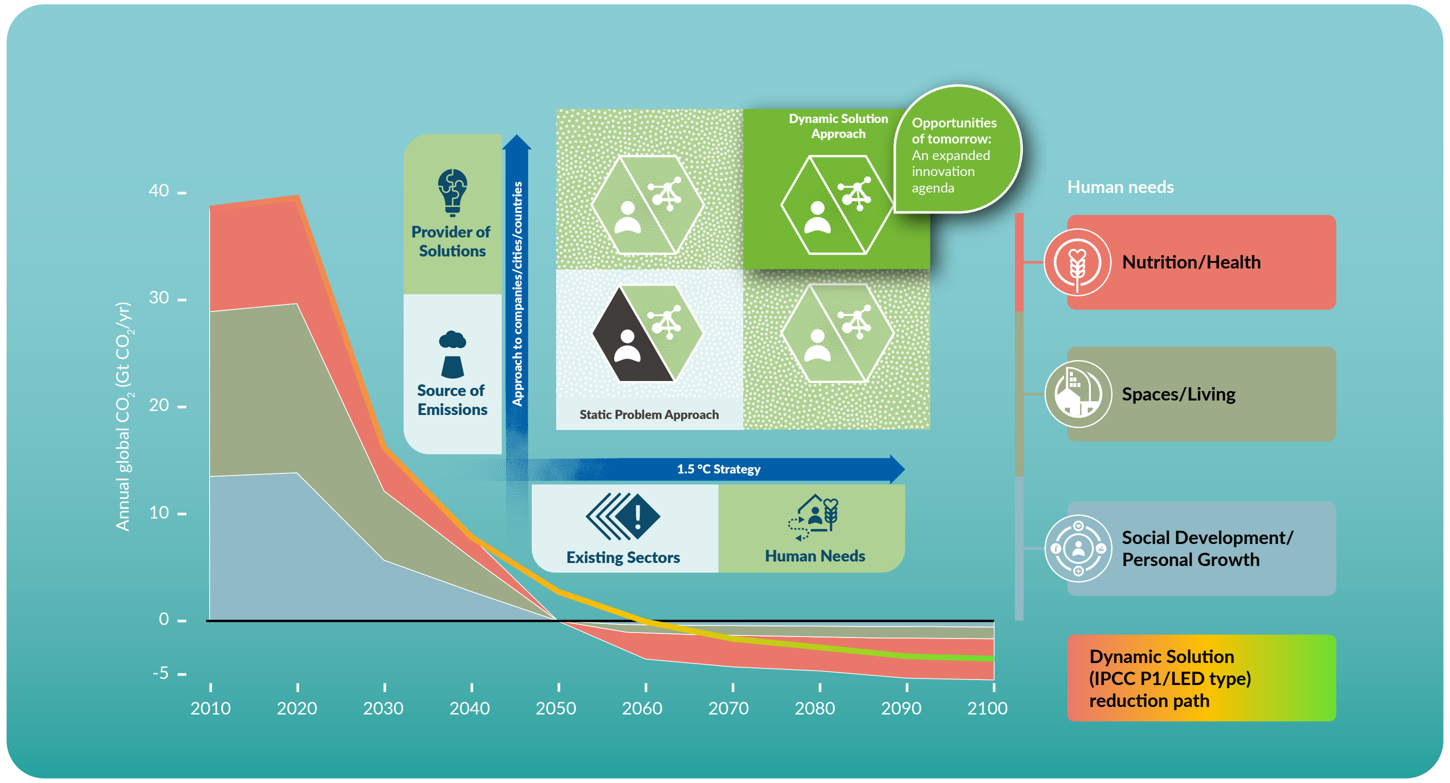
A dynamic solution approach focuses on how to provide what people need in a way that is sustainable in an equitable world. By embracing the opportunities for transformative system solutions that are magnitudes more resource efficient, such a dynamic solution approach provides the opportunity to move beyond a focus on when ecological systems will collapse and to focus instead on what positive future we want to have.

By using data that is structured around needs, it is possible to connect global emissions and a traditional static problem approach to human needs and a dynamic solution approach on an overarching level. More work is however needed as the science relating to human needs and the accelerated technology development is constantly creating new opportunities.

A static problem approach



A dynamic solution approach

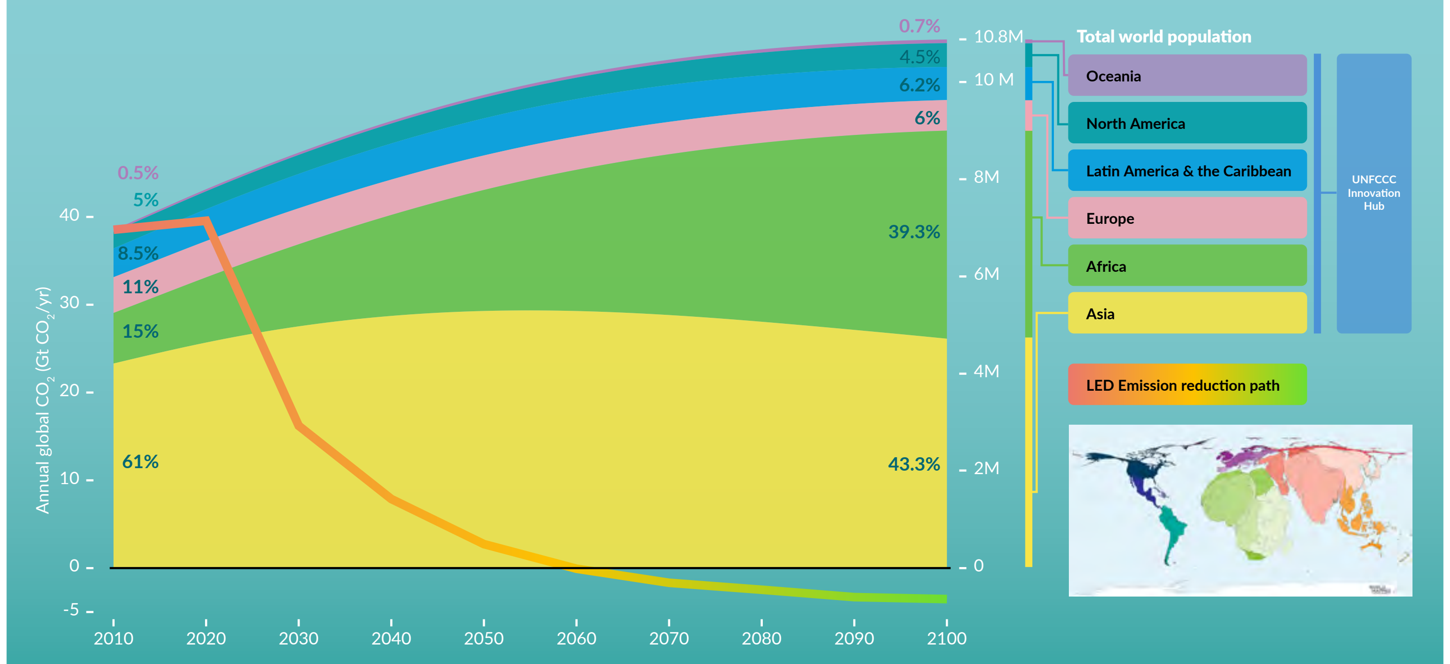


3 A global equity perspective with flourishing lives for 11 billion people: Global sustainability

For a human need perspective, it becomes clear that any assessment of a sustainable climate solution must be viewed from a global perspective. Using the UN population division and assuming some margin for 2050 the solutions that are sustainable must be compatible with an equitable world with 11 billion. For a sustainable world by 2050 resource efficiency and affordability must be at the core to ensure a flourishing life for everyone.

Supply and end-of-pipe solutions like accelerated use of biofuels and CCS linked to the current resource inefficient system, will either require large proportions to live in extrema poverty so a few can afford extreme luxury, or result in continued biodiversity loss eventually resulting in ecosystem collapse with consequences on the same scale as extreme climate change, most likely both. A need-based dynamic solution approach can provide an equitable future for 11 billion people and a resource efficiency compatible with an Half-Earth approach to biodiversity.[36]

An eleven billion citizen filter for resource efficiency and affordability



Case Study: Nutrition/Health

Understanding a human need approach with focus on equity for 11 billion people can be difficult as a technology problem approach that focus on how rich countries can achieve net-zero emission in creative ways has dominated for so long. Below is a brief overview using nutrition/health as a case study.

The health and nutrition area, as many other key areas in today's society, is filled with extreme contrasts.

About 800 million people worldwide lack food. Many more have deficiencies in essential nutrients. 76% of the world's population gets most of its daily nutrients from plants.[37] In parallel worldwide obesity has nearly tripled since 1975. In 2016, more than 1.9 billion adults, 18 years and older, were overweight. Of these over 650 million were obese.

39% of adults aged 18 years and over were overweight in 2016, and 13% were obese. Most of the world's population live in countries where overweight and obesity kills more people than underweight.[38]

In a future where 11 billion should be able to live flourishing lives the world needs to be able to provide healthy nutrition for everyone. Accelerating sustainable health and nutrition solutions require more than improvement of existing systems.

From a need perspective two parallel strategies must be pursued regardless of area:

- Elimination of excess in providing the need
- Resource efficient ways to provide the need

Strand 1: Sufficient amount (of Nutrition)

For all needs the first question is if too much is provided to meet the need. As humanity has struggled with deficiency in almost all areas though history most of our institutions are still focused on producing more of everything and growth is still generally seen as a good thing. In nature continued growth always leads to collapse, either on a macro scale when a species eventually collapses, or on a micro level when uncontrolled growing cells result in cancer.[39]

The long history of deficit, combined with a culture that often celebrates extreme excess as something positive, is probably also why many think the most obvious solution to a problem is to produce more of something else, from medicine to gym memberships, rather than ask of the systems focus on delivering more products, rather than meeting human needs, is part of the problem.

Applying a dynamic solution approach to deliver a sustainable nutrition and health system for sufficiency requires us to ask if excess amounts of nutrition are provided. And, if excess amounts are consumed, we need solutions to provide optimal resources.

As with many challenges today, nutrition is an area where we have moved from a situation where scarcity was the major challenge to one where we have too much is now rapidly growing as a problem. According to the WTO, obesity has reached epidemic proportions globally, with at least 2.8 million people dying each year as a result of being overweight or obese.[40]

In addition this situation also results in lower life quality due to both in the global north and the global south.[41]

Ensuring a healthy amount of nutrition is a very interesting innovation area where marketing, as well as any places where nutrition is provided, have an important role to play. There are many stakeholders in the nutrition/health space and new innovative ways to support healthy levels of intake of nutrition are needed.

If the world were to reduce the excess consumption, the emissions compared with a business-as-usual scenario would be reduced by more than 30%.

Another way to deliver sufficient amounts, is to ensure that the delivery system is efficient. If large amounts of what is produced to meet the need is wasted a new system is required. In the area of nutrition and health FAO estimate that around one third of the world's food is lost or wasted every year.[42] Food is wasted in many ways:

Fresh produce that deviates from what is considered optimal, for example in terms of shape, size and colour, is often removed from the supply chain during sorting operations.

- **Foods that are close to, at or beyond the "best-before" date are often discarded by retailers and consumers.**
- **Large quantities of wholesome edible food are often unused or left over and discarded from household kitchens and eating establishments.**

Efficient delivery requires a combination of technical and social innovations that can help reduce waste to a minimum, from what is seen as attractive food and knowledge about how long food can be healthy to how access to nutrition can be provided with minimum waste and smart storage/packaging.

If the world were to reduce the food wasted, the emissions compared with a business-as-usual scenario would be reduced by almost 30%.

Strand 2: The most resource efficient way to provide the need (resource efficient protein and healthy lifestyles)

From a need perspective a fundamental challenge is to explore how the need can be met with high quality and minimum of resources in a sustainable way.

The current main driver of emissions from the nutrition heath area is to a large extent linked to how we provide protein rich food. Meat and dairy specifically account for around 14.5% of global greenhouse gas emissions, according to the UN's Food and Agricultural Organization (FAO).[43]

In the area of nutrition and health basic science make it easy to see that delivering protein from plant-based sources are in most cases magnitudes more resource efficient as a lot of resources are lost when plants are converted to tissue by animals.[44] There are also opportunities to provide proteins and other nutrients in new innovative ways, from synthetic meat to convert more basic molecules to different form of nutrition.[45]

How innovation in the nutrition/health area affects or encourages an exponential uptake of a plant-based, or plant-dominated, diet is therefore the first question to ask all stakeholders in the nutrition/health area, together with the question of possible innovations in to provide protein and other nutrients in new innovative ways. Synthetic meat seems to be more of a long-term option though due to the existing high energy use something that recent studies have highlighted.[46]

The switch away from livestock is not only positive for the climate, but also has significant health benefits. A large body of evidence has shown that higher consumption of red meat, especially processed red meat, is associated with higher risk of type 2 diabetes, cardiovascular disease, certain types of cancers including those of the colon and rectum, and premature death.[47]

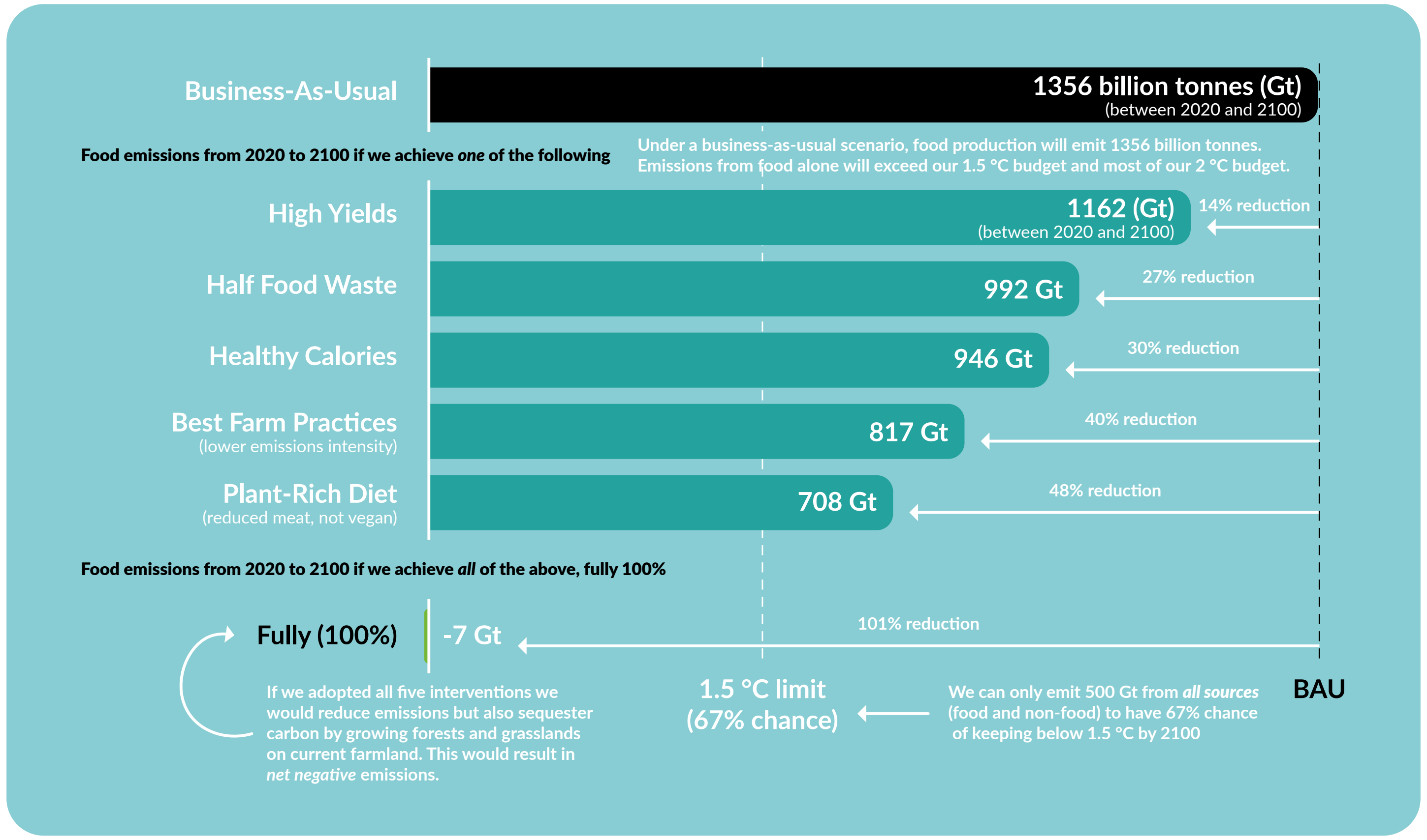
Nutrition and health innovation is not only about more resource efficient substitutes to meat and diary, but rather about innovations making healthy resource efficient food more accessible and desirable. This requires innovation and action in areas from how food is portrayed on TV and film to how hotels, companies, and sport clubs can provide healthy nutrition. There are for example significant "gender differences in meat consumption and openness to vegetarianism" as recent studies have indicated.[48] Such cultural and social challenges require more than the typical technology innovations that are currently dominating the climate innovation ecosystem, and the innovation ecosystem overall.

Supporting strand: Providing a sustainable supply structure: Smart production and increased efficiency of production

As for all sustainable solutions the structure for proving must be sustainable. The production and delivery of the nutrition and health must be sustainable, but most climate data related to nutrition/health focus on the production and improvement in existing systems. There are however some sources that have a more systemic approach that can provide an overview of the key sources of emissions.

A dynamic solution agenda for nutrition and health

https://ourworldindata.org/food-emissions-carbon-budget – Licensed under CC-BY by the author Hannah Richie



Multiple need strand: Encouraging transformative system solutions

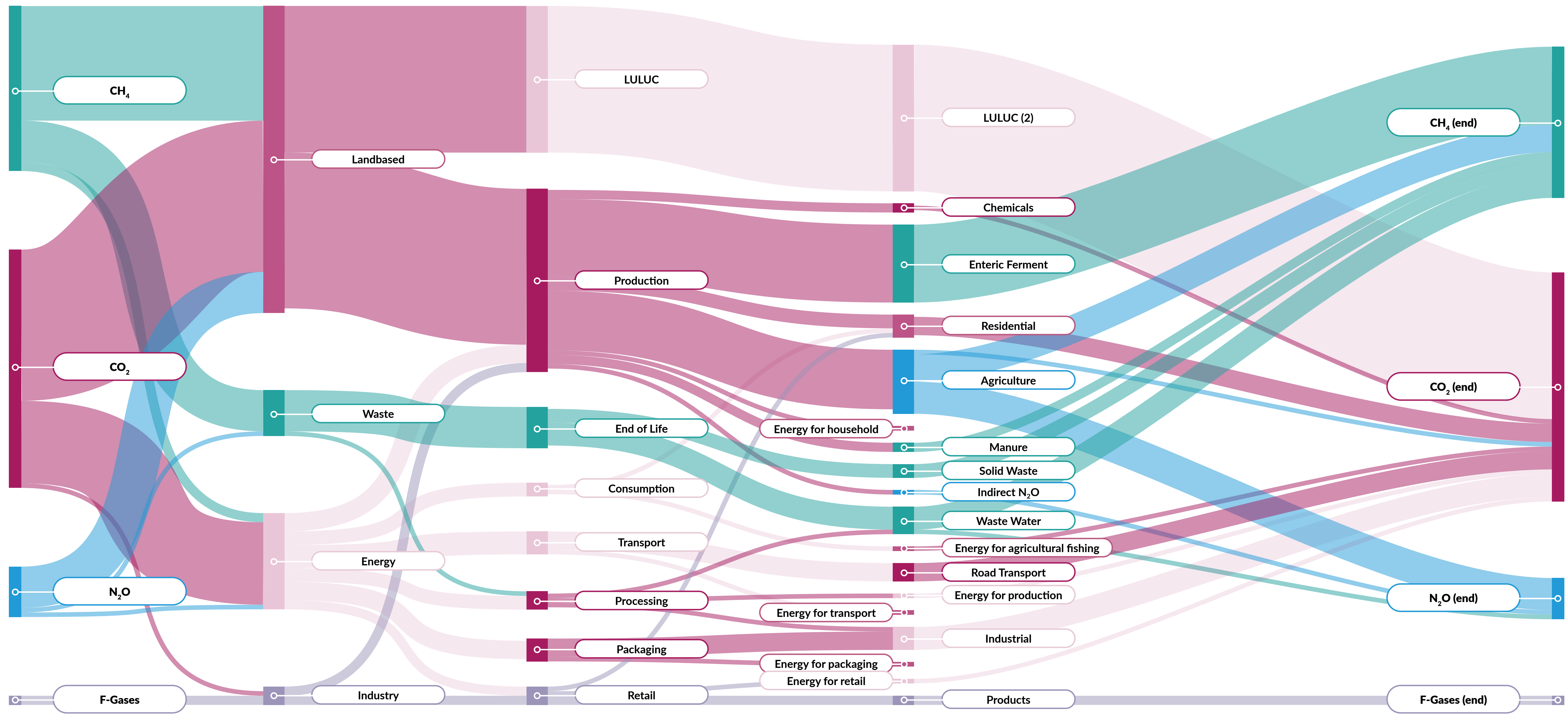
A new generation of entrepreneurs (and intrapreneurs) are using converging technologies and new business models that often allow them to deliver solutions that deliver on multiple needs. These solutions do not have to be driven by carbon in any way but still deliver solutions that are very significant. Many current health solutions focus on plant-based food for health reasons and that make the sufficient aspect key, as well as more walking and biking that also provide important contributions to reduced emissions. Even more transformative are solutions that also encourage empowerment and increased focus on areas such as art and science beyond a consumption perspective as part of a more healthy and flourishing life.

> *"Happy people tend not to value material possessions highly, are less affected my advertising and propaganda, are not driven by desire for power and achievement. Why would they? They are happy already, right? The prospect of a society of happy people should be enough to send shivers down the spine of our productive system, built on ever-escalating consumption, on never satisfied desire."*
>
> **Mihaly Csikszentmihalyi**
> *The Future of Happiness, 2002*

Greenhouse gas emissions from the food system in 2015
https://www.carbonbrief.org/food-systems-responsible-for-one-third-of-human-caused-emissions

Key:

CH_4 | CO_2 | N_2O | F-Gases



Focus on Needs and Solution Providers

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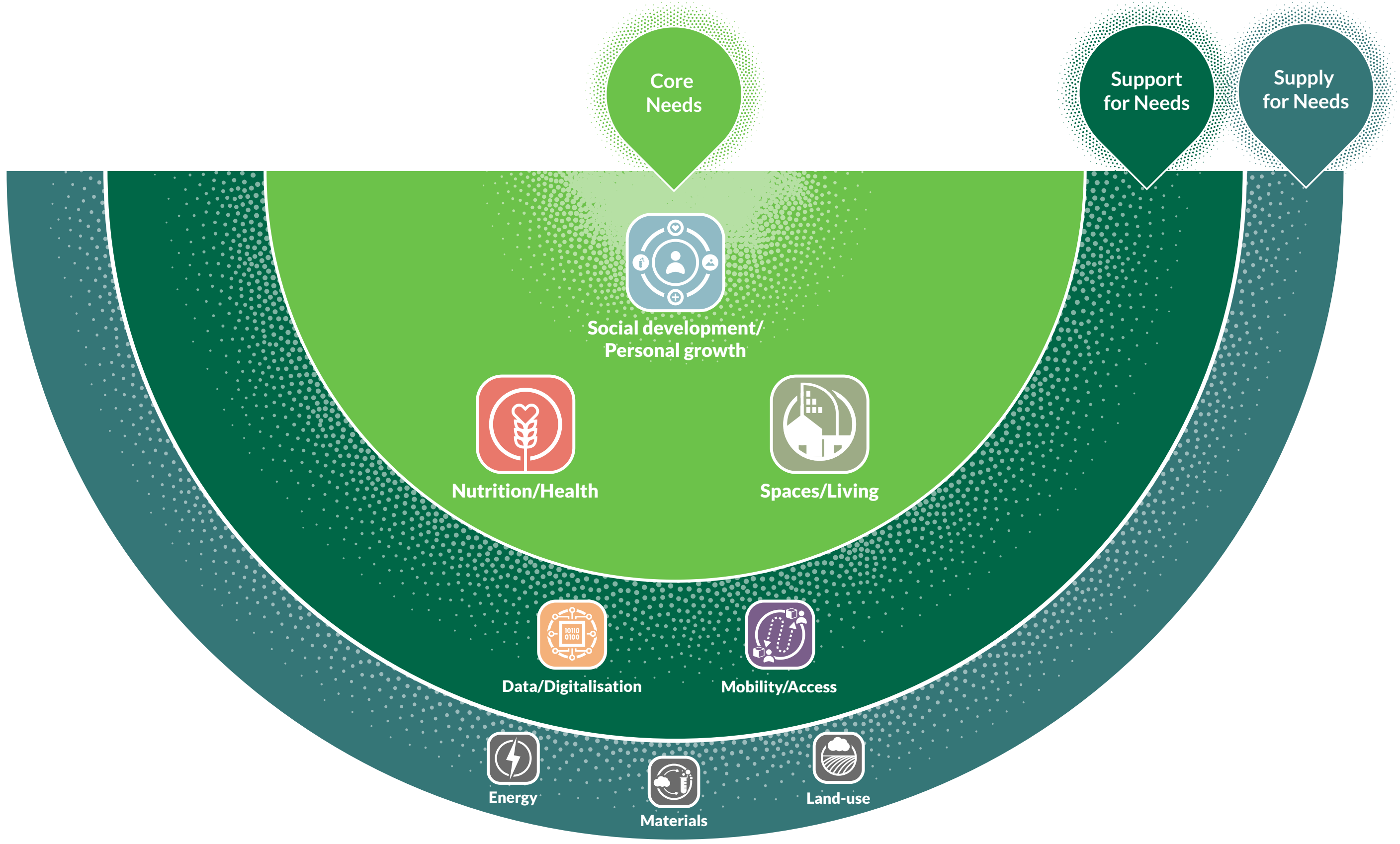
Human needs, support for needs and supply for needs



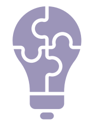
From stakeholders as sources of emissions to providers of solutions (footprint to handprint), and from existing sectors to human needs

When a dynamic approach, embracing the opportunities provided in the 4th industrial revolution, is combined with an urgency for climate action required to stay below 1.5 °C, an expanded innovation agenda with focus on solution providers and human needs emerges. This is an agenda that promotes new opportunities to deliver the solutions needed in line with IPCC's 1.5 °C Low-Energy-Demand (LED) pathway, rather than only asking current emitters to reduce their emissions.

An expanded climate innovation agenda requires three major changes compared with the current static problem agenda with a focus on existing sectors:

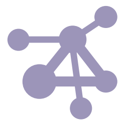
Human needs

First, the strategy does not focus on existing sectors, but instead on human needs and how new solutions can be provided for those instead of only improving the way exiting sectors operate.



Solution providers

Second, companies, cities, and countries are no longer only seen as sources of emissions, but instead primarily as potential providers of new for a better world using the opportunities provided by the 4th industrial revolution.



Clusters

Third, instead of a focus on individual stakeholders/groups and what they can do within the existing system, the focus is on combined efforts through clusters of stakeholders that are required to deliver what is needed, including transformative changes in business models, financial tools, and policies at both the micro and macro scales delivered by enablers that usually are ignored when climate solutions are discussed. This requires institutional structures and tools to shift away from managing risks and support incremental incentives towards more transformative approaches.

2.1 Beyond less than half the story

The first and most obvious weakness with a static reduction approach is the fact that it is only considers companies, cities and countries as sources of emissions. With such an approach the best thing a company, city and country, is to get to zero emissions according to a framework that allow them to feel that they have reduced the risk enough. This is where offsetting, and ignoring large parts of scope 3 emissions happen, and where the best thing that can be done is to embrace some kind of "science based [reduction] target".

The strong focus on zero as the only goal has resulted in creative accounting, especially by companies, where offsetting and other tools are used so they can report "carbon neutral" results, and where companies look for different ways to reach zero in their accounting instead of focusing on how they can deliver solutions though their core business in line with their value proposition.

In the same way as companies and cities have a budget where they include both strategies for increases in income and reduction of expenses, they should also have a strategy for what they can do to help reduce emissions from how they are currently do things, but even more important a strategy linked to their core value proposition, i.e. how they can reduce emissions by providing society with sustainable solutions that address human needs. Instead of the current logic that tend to start with the reduction of emissions from operation, a proper strategy should start with what is needed in society and then ask how that can be provided in a sustainable way. This is why a new generation of tools and initiatives focus on stakeholders as solution providers, including Missions Innovation's work to assess 1.5 °C compatibility among start-ups promoted by incubators[49] to IClima that focus on solution providers[50].

Assessing the impact from the products the companies will sell in the future, and how cities can export tomorrows solutions are basic questions for a dynamic solution agenda. In both cases, companies and cities, the institutions created to accelerate the uptake of a new solution are at the centre, i.e. incubators, R&D departments and innovation hubs.

There is also a fundamental impact imbalance between emission reductions from operations and avoided emissions in society as a driver for innovation and legacy. As mentioned above, for scope 1-3 emission reductions the best a company or a city can do is to reach zero. A solution approach with a focus on the avoided emissions linked to sales of new solutions can have an almost infinite impact.

2.2 The reason companies and cities exist

The reason a company exists is to deliver a service to society, not to reduce emissions in its supply chain, or buy offsetting to claim carbon neutrality. The main innovation skills in companies are therefore linked to its capacity to deliver solutions for society.

A dynamic solution agenda is directly linked to the value proposition and mission of a company, i.e. the reason the company exists. Many companies are struggling with this basic question as their products are often creating significant problems in society. The simple way out is to say that the "market decides", or "if we do not sell this someone else will". Companies with such a reactive approach tend to embrace the climate neutral risk approach, as they can hide a lack of value provided to society by claiming that they show climate leadership when they reduce the impact from their operation linked to products that are making the world worse.

Increasingly companies are rethinking their value proposition and experts are challenging business models that are fundamentally unsustainable (from fossil fuel extraction and airlines with fleets of airplanes equipped with internal combustion engines to fast fashion and fast-food companies). Even stakeholders that have been proponents of "the business of business is business", such as the BRT in the US, are now acknowledging the need for companies to show what value they provide to society.[51]

The focus on core business has resulted in a situation where the Financial Times seems to have a better understanding of the hypocrisy in the business community and what is needed than many sustainability consultants with a static risk perspective that are selling carbon accounting, PR advice and offsetting to companies that must fundamentally change their business model to be sustainable, such as fast-fashion companies and airlines.[52]

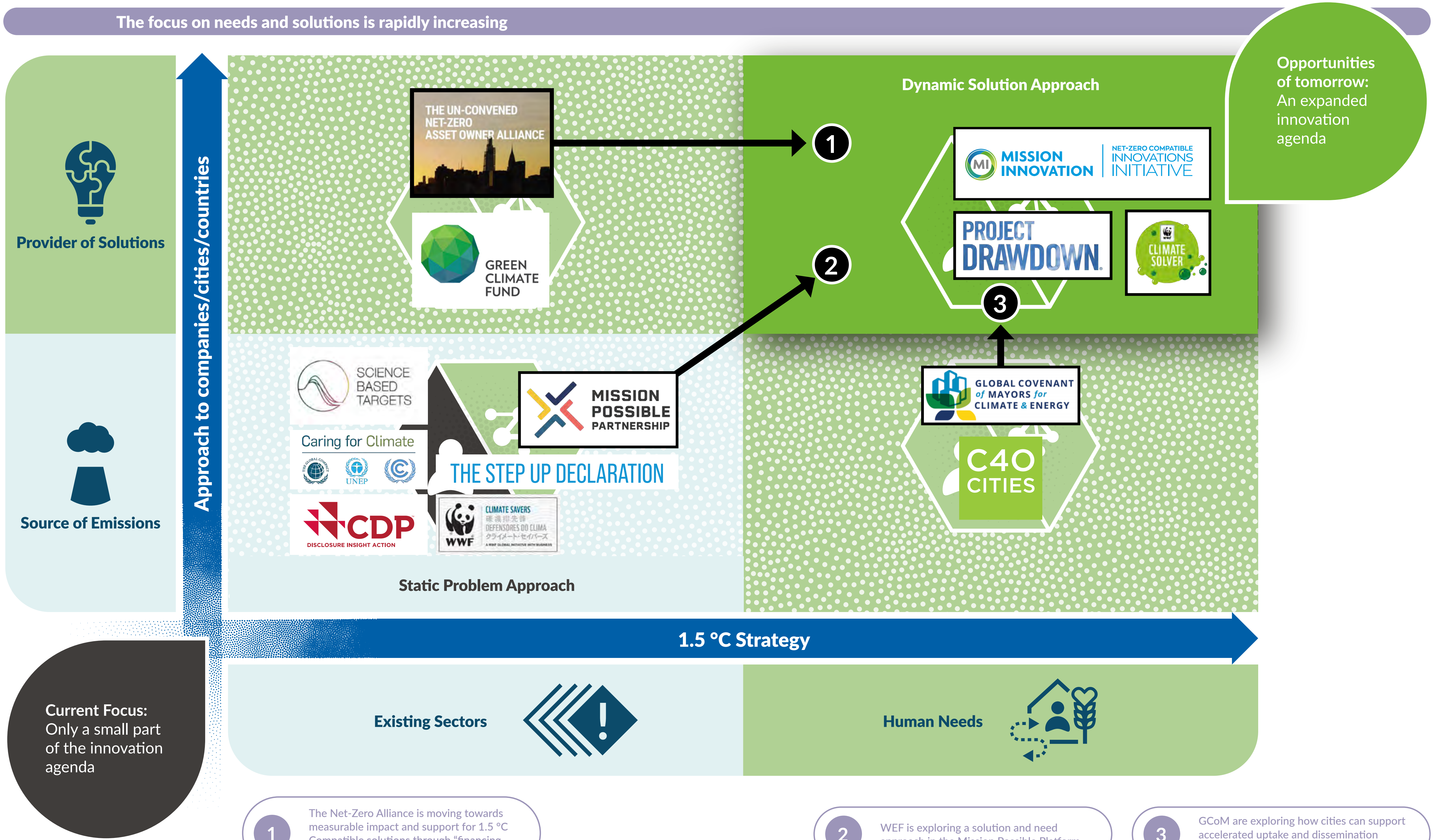
In the same way, the purpose of a city is not to reduce emissions, but to provide the citizens with the opportunists to live flourishing lives and be creative so they can help the world become a better place. Instead of buying offsets or ask people to not do certain things, the city has an opportunity to create incentives and set targets for solutions that are globally sustainable and export those, rather than focus on the emissions from their geographic areas.

By only approaching companies and cities as sources of emissions, rather than (potential) providers of sustainable solutions in new innovative ways many of the leading climate initiatives dramatically limit the scope of innovation to a small set of innovations with limited impact.

Such a static problem approach also tends to limit the responsibility for climate innovation to risk and compliance experts, often together with PR departments, where the main goal is the capacity to report that they should not be blamed for emissions. These are positions/roles that, in most cases, are far from the strategy discussions and are tasked with doing what they can within the existing strategy that the company, or city, has adopted based on their core value proposition (to sell products that customers need in the case of companies, and to provide a flourishing life for citizens in the case of cities). A dynamic solution approach instead links to the core purpose of the company, what they provide to society and what investments that are needed to be relevant on the market tomorrow, and thereby puts innovation and sales at the core.

An initial scanning in the preparation for the UNFCCC innovation hub identified several initiatives that currently have a static problem approach now moving towards a dynamic solution approach (see image for how some of the different initiatives are repositioning themselves). The assessment is not scientific and is based on interviews with a few key stakeholders, and should only be seen as indicative.

It is highly likely that all of the initiatives below are exploring a dynamic solution agenda. In the same way that Kodak had access to the digital camera the knowledge of what is the future is not the same as the capacity to be a part of it unless the business model changes and with revenues depending on a static problem approach it will be difficult for many existing stakeholders to move beyond this.



1 The Net-Zero Alliance is moving towards measurable impact and support for 1.5 °C Compatible solutions through "financing the transition"

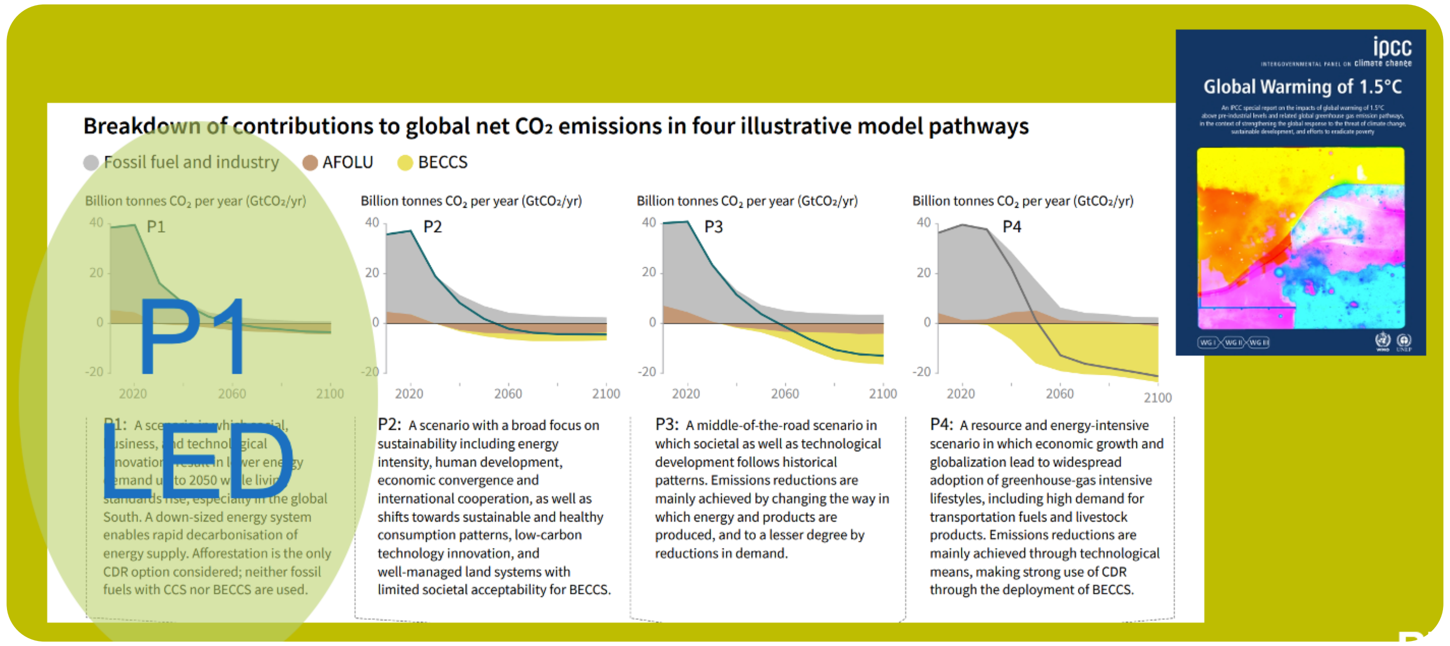
2 WEF is exploring a solution and need approach in the Mission Possible Platform

3 GCoM are exploring how cities can support accelerated uptake and dissemination of solutions

IPCC's 1.5 °C LED Pathway as Reference for Climate Alignment[53]

3

Low-Energy Demand (LED): Innovation focus



Embracing the 4th industrial revolution with a focus on needs and solutions

At the UNFCCC's 21st Conference of the Parties (COP21) in Paris, the world agreed to hold the global temperature rise this century to "well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C."

Based on this agreement, the IPCC profiled ninety pathways in its special 1.5 °C report.[54] Four key pathways (P1 to P4) were presented based on different assumptions, including the degree of business model innovation and the use of smart solutions in different areas of business and society.[55]

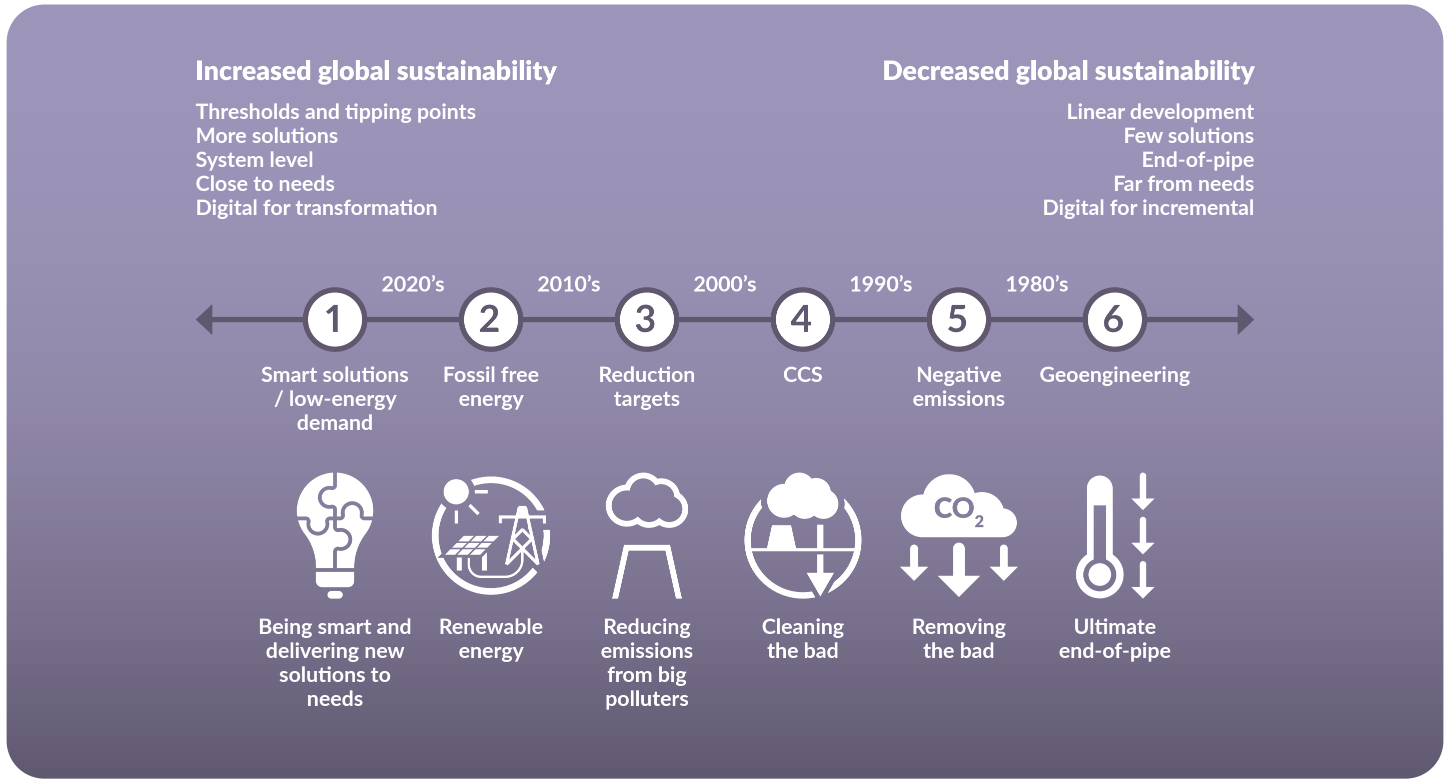
The two main differences between the pathways are:

- The dependence on large scale technical solutions, especially for carbon capture, storage and removal: lowest in P1 and highest in P4.
- The degree of business model innovation, global sustainability, number of innovations, synergies with other global sustainability goals: lowest in P4 and highest in P1.

While IPCC included a specific Low-Energy-Demand pathway there are many ways to deliver on such a pathway. P1, or the Low Energy Demand (LED) pathways, are innovation-driven and focused on new smart ways of delivering our needs based on existing solutions and business models. To deliver the solutions needed for a LED pathway it is important to move from individual technologies to system solutions, as transformative change is needed for a resource efficient low-carbon pathway. These resource efficient and often decentralised solutions is also the main reason the pathway delivers best across the other Sustainable Development Goals (SDGs).[56]

Pathways P2 to P4 increasingly depend on carbon capture technologies, such as bioenergy with carbon capture and storage (BECCS), carbon capture and storage (CCS) and direct air capture (DAC). These pathways are also increasingly closer to business-as-usual (BAU), i.e. increasingly inefficient and resource intensive ways of delivering solutions in society. Such pathways therefore also require much larger amounts of renewable energy in ways that hamper other sustainability goals such as food security and biodiversity.[57]

Six archetype solutions to a 1.5 °C compatible future



With new opportunities emerging from rapid technological development, changing business models, and societal values, old ways of delivering what is needed in society cannot be taken for granted. For example, a car, or even other forms of physical transport, is no longer needed to access work: now opening a laptop where there is a good broadband connection is enough. In a similar way, most companies need to rethink how they can provide societal needs in a way that is 1.5 °C LED compatible.

The opportunities in a LED pathway require system changes in many dimensions, but it should be noted that the LED pathway in the IPCC report is based on existing best practice. With rapid and fast changes happening due to the 4th industrial revolution the P1 pathway should therefore be seen as a conservative pathway. Approaching the IPCC LED pathway as a conservative assumption is supported by resent research, that will be presented below, showing that the granular solutions that the LED pathway builds on improve much faster than large scale solutions that are often in focus today.[58]

> *Further technological developments and business model innovations – the next practice – are already emerging as key innovation drivers for a new generation of sustainability leaders in cities, companies, NGOs, governments, incubators, and think tanks.*

With COVID-19, there are many policy responses that could accelerate the trends towards a P1 pathway, but there are also responses that will result in lock-in and a continued focus on end-of-pipe solutions – for example, on CCS – and an increased reliance on biofuel as a substitution for fossil fuel in existing inefficient systems such as keep on flying on the current scale, or even increase flying, with airplanes using combustible fuels.

Even if the kind of solutions that the IPCC LED pathway includes are new to many of the dominating stakeholders in the energy system and climate discussion, it should be noted that it is based on conservative assumptions. It does not assume any new solutions, only scaling of existing solutions. With many new technologies, business models and policy innovations rapidly emerging, the uptake of these solutions will accelerate.

Such an acceleration of new innovations will make it much easier to achieve the 1.5 °C goal especially if business, policy makers, financial stakeholders and media increase their understanding and focus on such solutions.

The 1.5 °C compatibility is best used together with an assessment of avoided emissions, i.e. assessing the contributions to avoided emissions in society (absolute reductions in rich parts of the world and relative reductions in poor parts of the world). However, a focus on only avoided emissions tends to result in a focus on those start-ups/innovations with the largest short-term reductions, but ignores the risk of high-carbon lock-in. A focus on maximum emissions reduction also tends to focus on the most simple and cost-efficient solutions that are easy to assess, currently electric mobility and renewables, while ignoring more complex areas that result in transformative system change and therefore are more difficult to assess.

Combined, the factors above provide five key arguments for a LED/P1 pathway as the default option for all relevant future policies, investment strategies and innovation initiatives. Something that is already happening in processes from the UNFCCC Innovation Hub to the Net-Zero Asset Owner Alliance.

3.1 Accelerated sustainable technology and business model innovation

The first argument for LED as the default option is that it supports sustainable technology and business model innovation. Currently, many low-carbon strategies and roadmaps are being developed by groups representing old industries that are resource intensive and large emitters.

Many of these plans are based on the assumption that those companies will continue with similar business models, while using CCS and offsetting when improvements in existing systems are not sufficient.[59] These plans tend to exclude new smart ways of providing the same service, especially more resource efficient solutions that would reduce the use of their current products (e.g. cars, airplanes, steel, cement, fast fashion, and fast food). Supporting such plans with offsetting, CCS and/or BECCS will result in a significant risk of excluding/undermining new smart solutions. In contrast, a focus on the 1.5 °C LED pathway supports innovation through a broad acceleration of solutions in society, based on needs, and supports business model innovation that shifts thinking from products to services. Instead of a focus only on how carbon-intensive industries can reduce their emissions, a LED focus also considers companies as solution providers. This focus on needs also encourages new cross-sectoral collaborations, e.g. for net-positive energy districts.[60]

3.2 Increased support for the Sustainable Development Goals (SDGs)

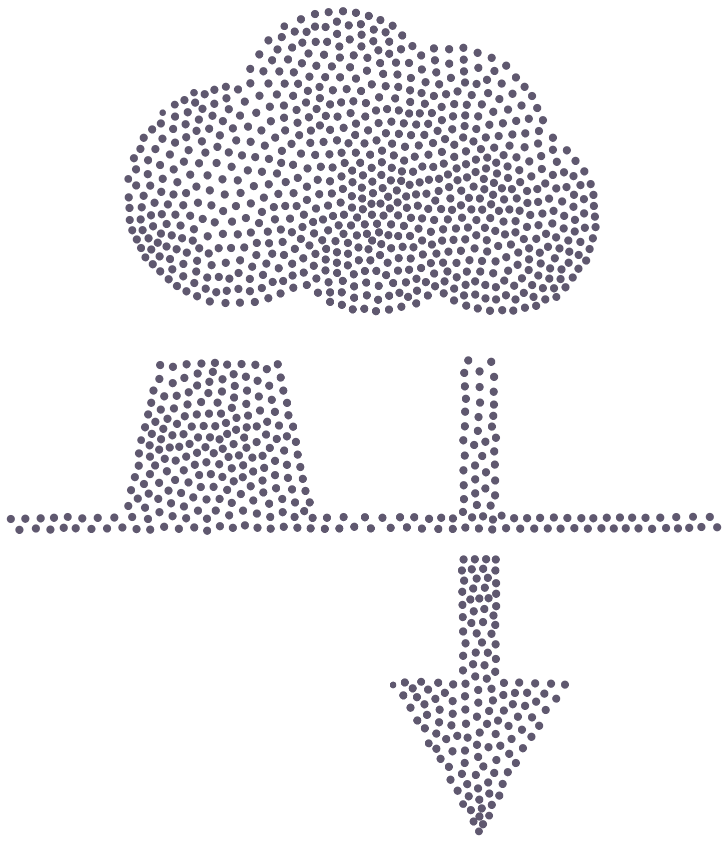
The second argument is that a LED pathway has the strongest synergies with other SDGs. As the IPCC states: Choices about mitigation portfolios for limiting warming to 1.5 °C can positively or negatively impact the achievement of other societal objectives, such as sustainable development (high confidence).

In particular, demand-side and efficiency measures, and lifestyle choices that limit energy-, resource-, and GHG-intensive food demand support sustainable development.[61] "LED pathways show the largest number of synergies and the least number of potential trade-offs […]. In general, pathways with emphasis on demand reductions and policies that incentivize behavioural change, sustainable consumption patterns, healthy diets and relatively low use of CDR (or only afforestation) show relatively more synergies with individual SDGs than other pathways."[62] Avoiding dangerous climate change is extremely important, but it must be done in a way that also avoids ecosystem collapse, reverses the unsustainable use of resources, and addresses global inequity.[63] In addition to delivering reduced emissions on the scale and speed needed, the LED pathway also supports a more resilient and resource efficient circular economy.[64]

3.3 Reduced dependence on large scale unproven technologies with significant probability of failure

The third argument for LED as the default option is that a focus on LED reduces dependence on unproven technology. As the IPCC states: "[Carbon dioxide removal] CDR deployed at scale is unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5 °C.

CDR is needed less in pathways with particularly strong emphasis on energy efficiency and low demand. The scale and type of CDR deployment varies widely across 1.5 °C pathways, with different consequences for achieving sustainable development objectives."[65] The IPCC LED pathway is based on existing technologies and business models at scale and does not depend on CDR technologies at all.[66]



This is not an argument against all forms of carbon capture and storage to reduce – or even achieve negative – emissions in all contexts, but it is a strong argument to develop strategies and policies based on the assumption that:

- **CCS might not happen on a scale that is relevant**

  There is a significant probability that CCS and associated technologies might not deliver any significant contributions in the time needed. Even mainstream organizations with a track record of supporting CCS, such as the IEA, have noted that the operationalization of CCS technology is very far from earlier estimations. In a recent report, the IEA wrote that, in order to deliver relevant contributions, CCS would have to grow more than 100 times in ten years and that is not a scenario that is globally sustainable.[67] The default assumption should therefore be that CCS will not deliver any emission reductions and all CCS-related reductions that take place will be additional to a resource efficient and just transition to a low-carbon society. "Two large-scale CCS power projects are currently in operation with a combined capture capacity of 2.4 $MtCO_2$ per year. This is well off track to reach the 2030 SDS level of 310 $MtCO_2$ per year."

- **Resources are better used elsewhere**

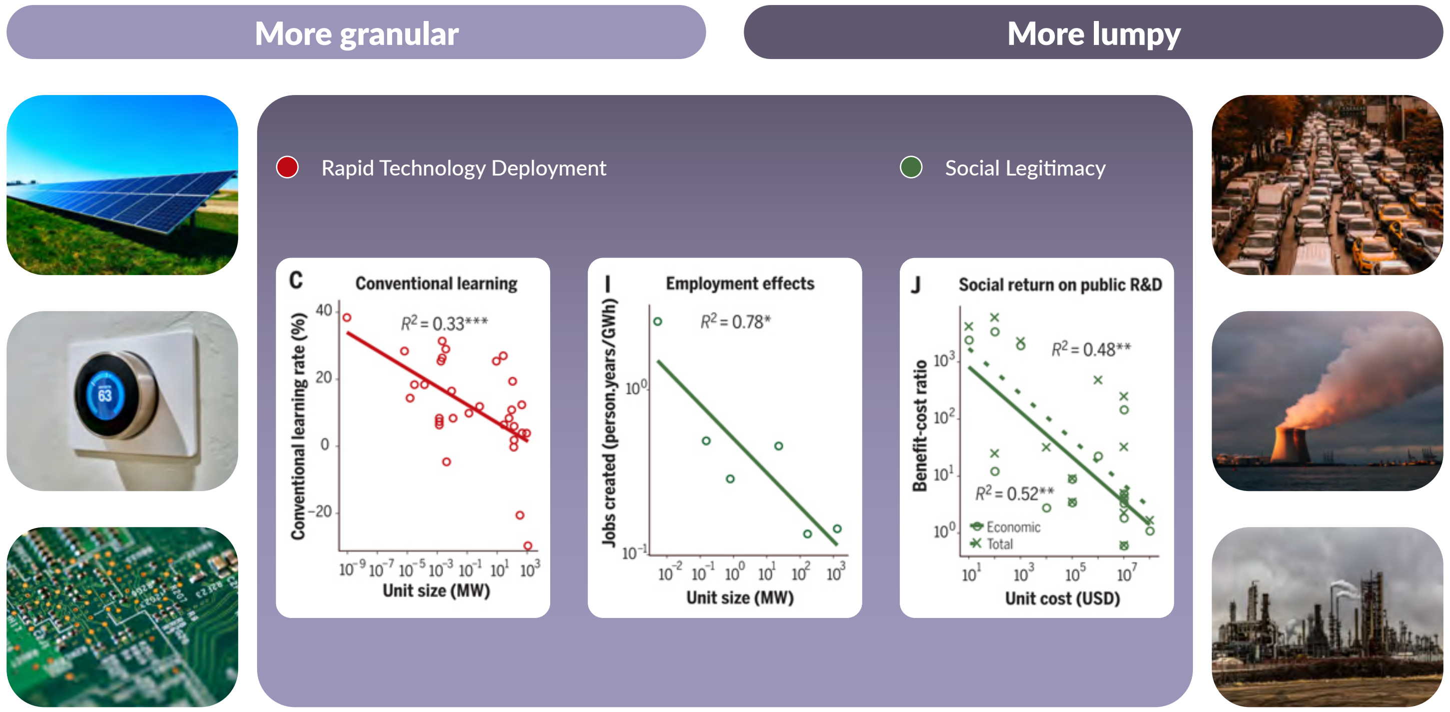
  Investments in carbon capture technologies might use resources that could be better used to deliver smarter, more resource efficient and sustainable solutions. A strategy with a strong focus on carbon capture could also create a political situation where innovation initiatives and incentive structures focus only on improvement in existing systems, and not on system innovation. The resources in the fossil fuel industry could also be used to help them move towards sustainable business models where they provide energy, and related services such as temperature and lighting, as a service.

3.4 Rapid technology deployment with granular solutions, compared with lumpy[68]

Rapid technology deployment depends, inter alia, on short diffusion timescales, attractive risk profiles for investors, and strong potential for cost and performance improvements). These conditions are interdependent.

Deployment generates experience which feeds back into technology improvement. Improving competitiveness and reducing investment risk stimulates adoption and compresses the time taken for technologies to diffuse through markets. Clear expectations for market growth attract further investment and strengthen the rationale for policy support. These dynamics of cumulative causation are evident in recent trajectories of rapid solar PV deployment.

> **Granular vs. lumpy**
>
> *'Granularity' describe technologies in terms of scale – physical, economic, or both. More granular energy technologies have smaller and more variable unit sizes (MW/unit), lower unit investment costs in absolute terms ($/unit), and are more modular or divisible so are more likely to scale through replication. 'Lumpiness' describe the converse: larger units, higher unit investment costs, greater non-divisibility, and more likelihood of up-scaling in unit size. Granular-lumpy is a continuum not a binary categorisation.*



Short diffusion time-scales.

Early research on industrial process innovations found that smaller investment size and higher expected profitability predicted faster diffusion. Energy supply and end-use technologies with lower unit investment costs diffuse more quickly from 1 to 50% market share. Lower unit costs in absolute terms mean access to capital becomes less restricted or specialized, and opportunity costs decrease.

Attractive risk profiles for investors.

Capital cost overruns on new energy infrastructure is a simplified measure of investment risk. Using a dataset of cost overruns in 350 electricity generation projects, we find that investment risk tends to increase for larger hydro, nuclear, and thermal plants but to decrease for larger solar and wind plants. For more granular renewable technologies, modular construction of standardised units means lower investment risks even at larger project sizes.

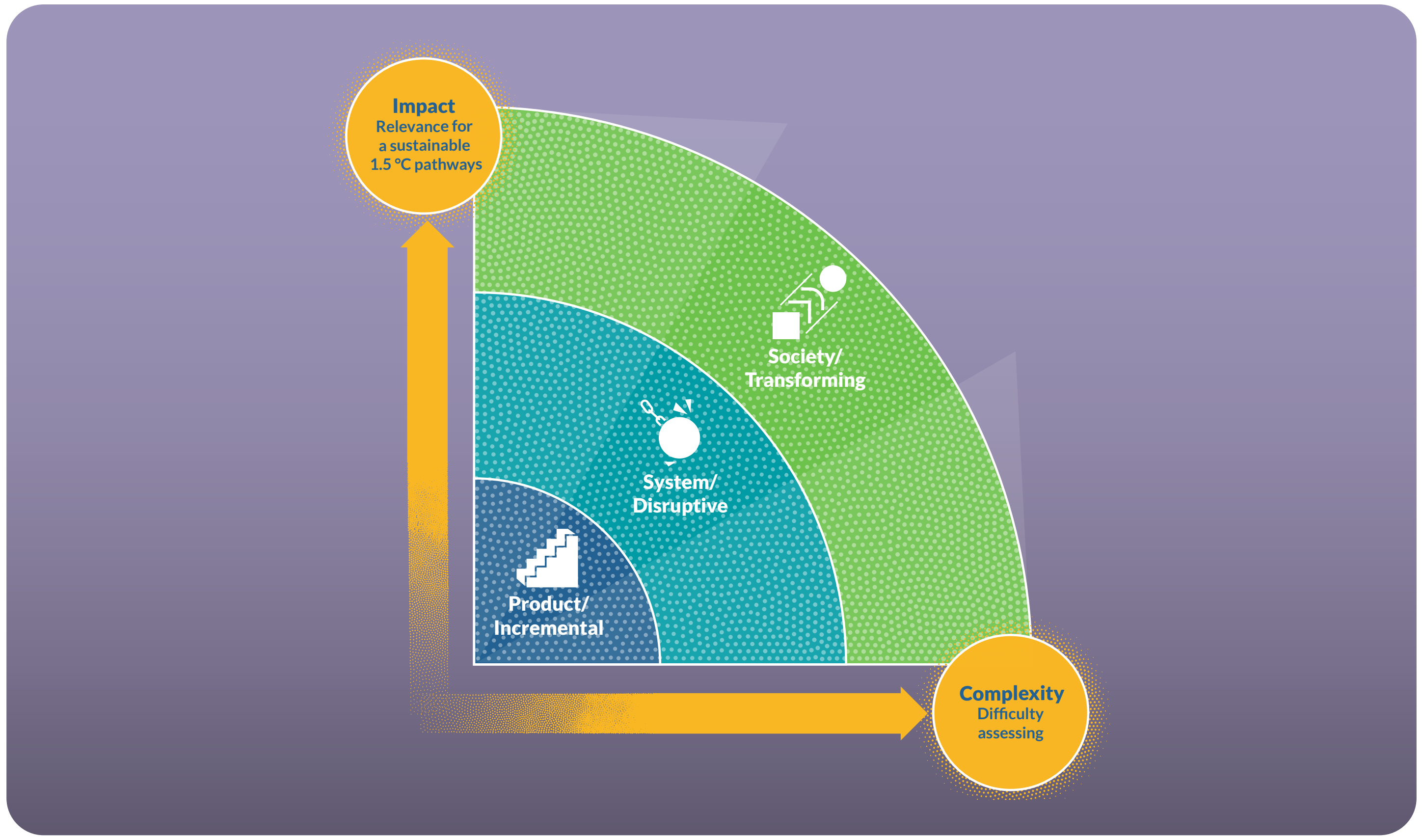
Potential for cost and performance improvements.

Learning describes how cumulative experience with each additional technological unit produced, installed, or used can lead to cost reductions and performance improvements. We show that learning is faster for more granular energy technologies, using two different formulations of the learning rate. In both cases, more granular technologies offer more opportunities for repetitive, replicative experience to drive faster improvement.[69]

3.5 A policy tide towards new ways of delivering on human needs[70]

Throughout the 20th century development of the energy system, this has favoured lumpiness. High upfront costs, non-divisible risks, and high consequences of failure in more lumpy technologies reinforce the rationale for public policy to underwrite returns, collectivise risks, or protect market positions. Publicly-directed innovation efforts historically have also been strongly skewed towards the centralised energy supply. More lumpy technologies are also attractive politically as they demonstrate commitment and materiality (mobilisation of human, financial and physical resources).

Impact – complexity relation



In comparison, heat pumps, rolls of insulation, EV charging points, smart meters, rooftop solar modules and shared 'taxi-buses' are heterogeneous and dispersed throughout the built environment. Coalitions of actors are concentrated in particular sectors like consumer electronics, automotive manufacturing, or power generation. As well as weakening the political economic influence of more granular technologies in low-carbon transformation, it also makes them less analytically tractable as the functions they serve vary so widely.

More recently, however, a confluence of factors including market liberalisation, technological innovation, and digitalisation, has strengthened political economic support for granularity. More granular energy technologies vary in scale, have more heterogeneous applications, and involve a greater diversity of firms and users through which the legitimacy of new technologies is established and resistance from incumbent actors counteracted. By enabling smaller increments of capital investment, more granular technologies de-risk R&D portfolios and open up markets to the destabilising force of new entrants.[71]

Assessing 1.5 °C Compatibility

4

A need-based climate innovation framework in support of 11 billion people living flourishing lives

When a dynamic approach, embracing the opportunities provided in the 4th industrial revolution, is combined with an urgency for climate action required to stay below 1.5 °C, an expanded innovation agenda with focus on solution providers and human needs emerges. This is an agenda that promotes new opportunities to deliver the solutions needed in line with IPCC's 1.5 °C Low-Energy-Demand (LED) pathway, rather than only asking current emitters to reduce their emissions.

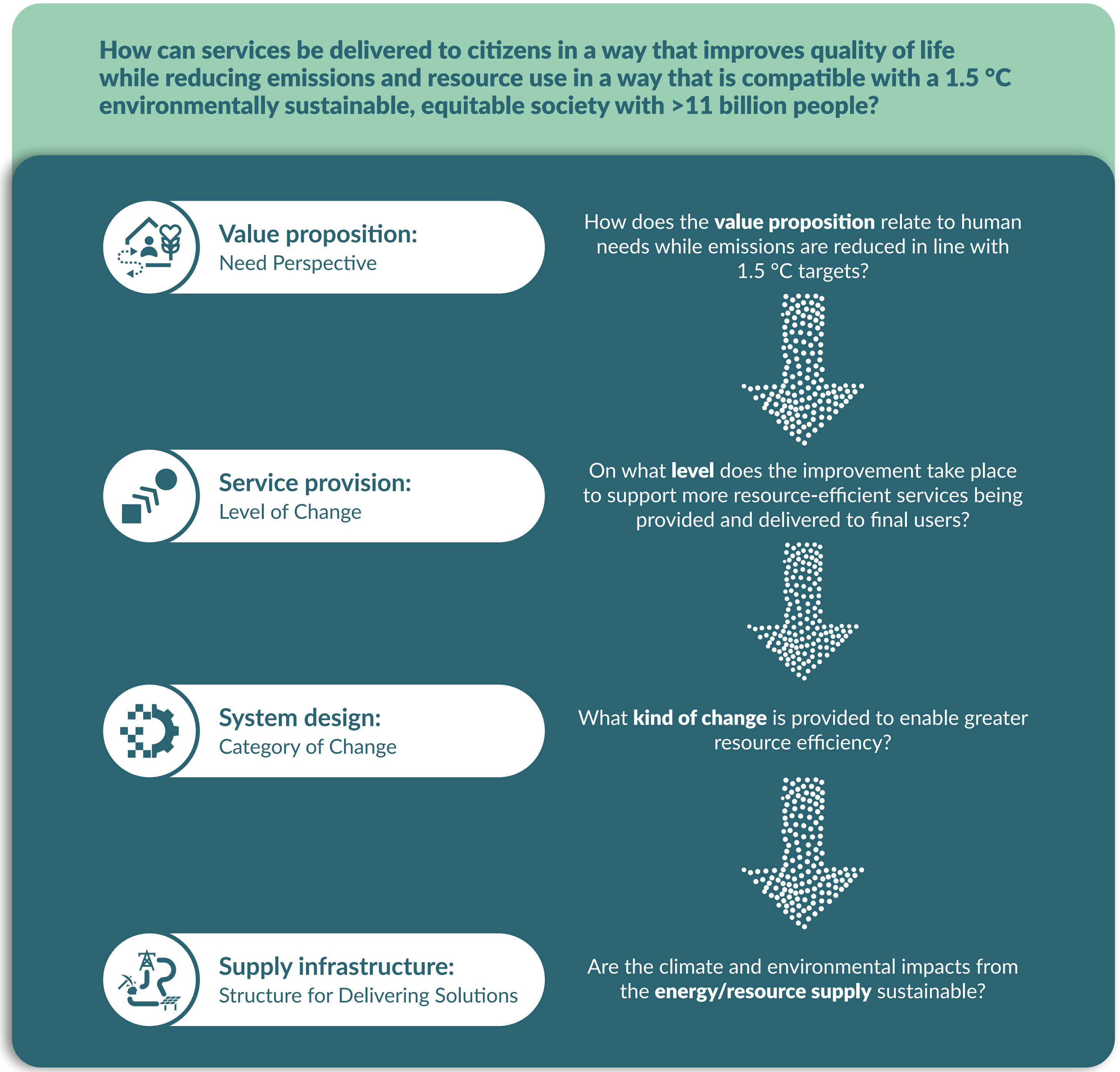
4.1 Structure of the Need-Based Climate Innovation Framework (NCF)

As demonstrated in the earlier chapters most current climate tools and initiatives are based on a static problem-approach with focus on individual sectors. In order to embrace the opportunities in the fourth industrial revolution, support a new generation of solution providers, and deliver a resource efficient and equitable society with the capacity to provide 11 billion citizens with a flourishing life, this limited innovation agenda is not sufficient.

The Need-Based Climate Innovation Framework (NCF) is based on an expanded innovation agenda that:

- **Approaches stakeholders as solution providers using the potential provided by the fourth industrial revolution**
- **Uses human needs and a future with 11 billion citizens with the right to live flourishing lives as a key driver and filter for innovation**
- **Assumes the need for clusters to deliver transformative system change, rather than only improvements in existing systems**

A hierarchy of questions for a need-based innovation agenda, where significant potential exists to deliver on needs in new innovative ways, can be summarised as in the diagram below:



This four-level hierarchy of questions follows a basic insight from systems thinking: start by asking what your system is trying to achieve, then ask what role the solution will have in providing new solutions, then how resource requirements can be minimised to achieve it, and finally ask how the resource use required to provide the solution can be sustainable.[72]

In addition to the hierarchy of questions above, the NCF also includes two more areas, "leadership" and "path", that are important to understand the future compatibility and potential for transformative system change:[73]

Leadership
Trendsetting and Clustering

This area assesses leadership from two perspectives, trendsetting and clustering, in relation to sustainable innovation.

Trendsetting

The trendsetting area assesses if leadership is provided in new areas and the provider of the innovation is seen as a leader in those areas. If key stakeholders see the provider of the solution as an authority with unique knowledge about the area and how it will evolve, and if gatekeepers are likely to seek input from the solutions provider regarding changes in that area, the solution provider is a trendsetter. Trendsetting is both a value in the area where they have been trendsetting, but also on a general level as a stakeholder with the capacity to move into new areas and be successful.

Clustering

The clustering area assesses if new clusters are created, or have the potential to be created, that are capable of delivering significant system solutions that are 1.5 C LED compatible. Leadership requires an active role in establishing clusters. Clusters are groups of stakeholders, often led be intrapreneurs from different organisations that work towards a goal with a strategy developed together. In a time when most existing organisations struggle to make sense of the fourth industrial revolution and the need for transformative change, and existing networks are usually informal or formal collaborations around improvement in existing structures, clusters are a unique opportunity to transcend current limitations. To be identified as having impact in this area, the cluster should show its ability or potential to transcend the limitations of the individual stakeholders through collective action.

Path
Future Trajectory

This area assesses the trajectory path, to identify if it contributes to an acceleration towards a 1.5 °C development path, or if it has a significant probability of contributing to high-carbon lock-in. In a time of rapid changes where the difference between support for acceleration, or contribution to lock-in can be very small.

New values and technologies are supporting clusters of solutions that help each other in new innovative ways. But, with a market that tends to be short-sighted and focus on simple numbers (e.g. companies that want to be able to claim carbon neutrality, or policy makers who want to talk about climate impacts at the next major event) there is a significant risk that innovations are promoted that can reduce emissions quickly, but without considering the long-term consequences.

Two main areas exist for acceleration and lock-in: technology and innovation.

Technology

Technology acceleration happens when an innovation helps accelerate other sustainable technologies, either by enabling an infrastructure that other technologies can use, or bring down prices on sustainable technologies that other solution providers can use.

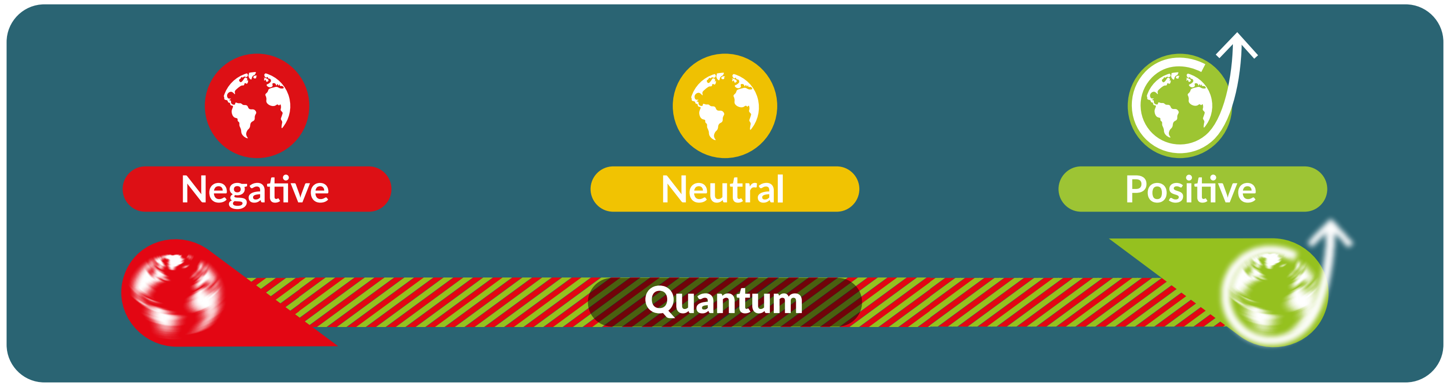
Technology lock-in happens when investments are made to optimize carbon intensive systems, e.g. more resource efficient coal power plants, more efficient oil exploration, more efficient fossil cars, more efficient meat production.[74] Such investment often result in significant initial emission reductions, but due to the cost of the investment the expected lifetime of the system is extended in ways that result in a high-carbon technology lock-in. It is important to stress that investment in initial reduction can be part of a long-term strategy that is 1.5 °C LED compatible, but a strategy to ensure a bridge from the old system to a new sustainable system needs to be in place as an explicit part of the innovation path.

Innovation

Innovation Acceleration happens when new solutions that are 1.5 °C compatible inspire accelerated innovation through structural changes in regulation, development of new business models or R&D structures. For example, a teleworking solution that helps a travel agency become a meeting agency can open the door for other similar changes from products to supply of societal needs. A management consultant, that develops a business model tool to help retailers promote healthy and plant-based diets that are globally sustainable, can help other stakeholders shift focus from improvement in existing sectors to needs in society.

Innovation lock-in happens when a solution to reduce emissions directly and indirectly undermines transformative innovation. The most prominent example is probably Carbon Capture and Storage. Large research and development programs and demonstration facilities for technologies like CCS are often used by large emitters as an argument for not exploring new ways of delivering services. The Innovation lock-in have implications on two levels. First, it undermines business model innovation among the large emitters where they tend to reinforce old models based on volume, rather than a shift towards service and deep technology innovation beyond the specific product they sell today (e.g. cement, steel, and chemicals). The strategy units and R&D departments in these companies usually have much more sustainable and exciting solutions than those known by the outside word.

The aim of 1.5 °C compatible strategies consistent with the global low energy demand (LED) pathway is to deliver useful services effectively and efficiently while consuming dramatically fewer resources.[75]



4.2 Rating criteria: quantum as well as traffic light

The rating of the different assessment criteria uses a traffic light system to assess the innovation's future compatibility in six areas. Green being supportive, yellow for neutral, and red undermining for each of the areas.

In addition to these three traditional assessment criteria the assessment framework also includes a "quantum" category. This category captures the complexity in the fourth industrial revolution and is also meant to highlight the need for system assessments beyond individual innovations and companies. Currently there is a tendency to think that simple lists of technologies and companies can be provided for 1.5 °C compatibility.

Such lists are, in the best cases, snapshots of what the current situation looks like and can help stakeholders shift from problems to solutions and from individual technologies to system solutions. Some lists, like the ones provided by us in Mission Innovation, or Project Drawdown, acknowledge the limits of lists and are part of a broader agenda where problems with other approaches are highlighted.[76] Other lists are more a distraction, or even part of lobby campaigns from vested interests, in relation to 1.5 °C compatibility.[77] The latter category of lists tend to be based on static problem thinking, the same that produced the famous overview of IEA repeatedly underestimating solar growth with simple cost abatement curves based on consultants working for companies without interest in sustainable system change.[78] But even more problematic is that they tend to limit the focus on the supply and end-of pipe side, and ignore new smart ways of providing services.

The inclusion of a "quantum category" in the "Need-Based Climate Innovation Framework" (NCF) is important for two reasons.

First, in relation to the context of an industrial revolution with multiple exponential trends, the inclusion of a quantum category reflects the reality of high complexity of rapidly changing systems with disruptions and tipping points. In order to deliver significant change in such a situation require strategies on multiple levels in parallel, from investors and regulators to companies and incubators.[79] In such a context it is not possible to assess any specific outcome with high certainty as the outcome depends on a multitude of factors that in different combinations can deliver fundamentally different results.

Second, in relation to the innovation itself, it reflects the complex nature of new innovative solutions that are transformative. Such innovations can be implemented in fundamentally different contexts that will result in totally different results. Small strategic changes and new capacity among those leading the innovation can make fundamentally different paths possible or impossible.

The term "quantum category" is in reference to the term in quantum physics, where a quantum state is a mathematical entity that provides a probability distribution for the outcomes of each possible measurement on a system.[80] It is a way to say that very small changes in the context and the innovation itself, often interacting, can result in different outcomes that are either supportive or undermining in relation to 1.5 °C compatibility. Three areas where many of the most exciting innovations exist that also often have quantum characteristics are material innovation, high-tech innovation, and business model innovation. For each innovation an archetypical example is provided based on innovations submitted to Mission Innovation's Net-Zero Compatibility Initiative.[81]

I: Material innovation

Almost all materials, including most chemicals, can be used for multiple applications. Depending on business model and strategy the innovation can be guided towards sustainability to different degrees. Investors, incubators, and regulators have an opportunity to support the use of new materials in sustainable applications and discourage their use in unsustainable applications.

Using the material innovation in unsustainable applications can be considered, especially for start-ups, if it does not result in high-carbon lock-in. Such a bridging strategy can establish credibility and scale the innovation quickly.

For example: a material with very low friction can help enable more resource efficient sustainable energy and mobility systems. But, the same innovation can also be used to support efficient exploration of fossil fuel.

II: High-tech innovation

Many exciting high-tech innovations can be used to optimise and extend the lifetime of existing fossil-based and/or resource intensive systems and thereby result in high-carbon lock-in. But, the same innovation can also help new sustainable system solutions become much more resource efficient and cost competitive.

For example: high-tech innovations that help transform waste heat to electricity can help new integrated and granular solutions use natural fluctuations from sustainable renewable energy into larger systems in smart ways. But, the same innovation can also be linked to old fossil, or resource intensive, systems and thereby contribute to significant high-carbon lock-in. Blockchain is another example of an innovation that both can accelerate unsustainable solutions and reduce transparency, or accelerate new sustainable solutions while providing increased transparency.

III: Business model innovation

Business model innovation based on digital solutions for circularity and sharing are enabling a new generation of business model innovation. Such innovation can allow companies to use connectivity and big data to empower citizens to move from owning products and instead get access to more resource efficient and circular solutions. But, the same innovation can also be used to promote current unsustainable companies by making them look more sustainable by adding some recycling to a fundamentally unsustainable business model. There are also a risk that new ride-sharing solutions undermine healthy lifestyle in a time where many need to walk and exercise more.

For example: a business model innovation for a circular sharing solution can be used to empower citizens to move beyond consumerism and support sustainable production and consumption systems. But, the same innovation can also be used to promote fast fashion companies by adding some second-hand options on an app.

Implementation and flanking measures can change the probability distribution, but will not result in absolute certainty. With policy makers, media and many investors looking for simple solutions there is a significant risk that many of the most important innovations are ignored, or the innovation is reduced to a contribution to an incremental improvement in existing systems.

A human needs structure for innovation

The shift from improvement in existing systems towards human-needs, require a way to structure human needs. To discuss human needs is something that has been at the heart of philosophy, psychology, political science, and many other areas. There are no easy answers, and the question what human needs are is to a large degree subjective. Still all systems make explicit or implicit assumptions regarding human needs and there is enough consensus for a basic framework that can help accelerate global sustainability.

The objective with the human need structure for innovation is not to address all the interesting questions related to human needs, but to expand the innovation space in order to ensure that:

- **Current companies and structures are not taken for granted**

  As current companies and structures, such as governmental agencies and business organisations, employ people and generate they can deploy resources for lobbying and PR. This makes it is easy for governance structures, the financial system and mass media to pay extra attention to the current systems and take them for granted unless there is a structure in place. Emphasising this tendency is that most governance structures, financial structures, and mass media outlets are structured according to traditional sectors.

- **New resource efficient solutions are not excluded because they do not fall inside the way our current society is organised**

  Never have the potential been greater for transformative system solutions with the capacity to contribute to global sustainability, but many of them do not fit current structures for governmental support and “innovation initiatives and agencies” risk undermining innovation by focusing on existing sectors instead of human needs.

Rather than an attempt to present a comprehensive way to understand human needs the human need structure for innovation provides an opportunity for policy makers, media, academics, thought leaders, etc. to structure their work and assess their contribution in relation to human needs rather than improvement in existing structures.

Human needs can be categorised in many ways. The structure used for the Need-Based Innovation Framework is based on an amalgamation of UN’s work with Human Needs and human development[82], Max-Neef’s Fundamental human needs[83], Maslow’s hierarchy of needs[84], and the Global Footprint Network.[85]

Politically the work by the UN Human Development Report has led the way to define needs on a global level, initially through the Human Development Index (HDI)[86] and complementing initiatives like the Social Progress Indicator (SPI).[87] These initiatives has helped establish a global consensus regarding core aspects of human needs. Focus has so far been on what is needed to move out of poverty, rather than what is needed for a good flourishing life.

In addition to the general frameworks and political processes above, resent research linking human wellbeing to climate emissions and material use as also been used, e.g. the article by Decent Living Standards: Material Prerequisites for Human Wellbeing by Narasimha D. Rao & Jihoon Min.[88] This article was also instrumental for the ground-breaking article “Providing decent living with minimum energy: A global scenario”, by Joel Millward-Hopkinsa, Julia K. Steinberger, Narasimha D. Rao and Yannick Oswalda[89] that the human need-structure builds on.

Two main challenges emerge when structures for needs are established. What different relations to human needs exist, and how should the different needs be structured under each?

1 Different relation to needs

The Human-Need Structure use a structure where the actual **core human needs** are at the centre to separate them from other areas in society, that only have an indirect relation to human needs. The first indirect category are innovations that has the **potential to provide support core human needs**, such mobility/access and data/digitalisation. As well as these that are even further removed core human needs and have **the potential to provide supplies for core human needs**, such as materials and energy. Currently many initiatives assume that we need electrification of current transport systems, keep (or even expand) the production of materials like concrete and steel rather than explore ways that human needs can be provided for with new recourse efficient and fossil free innovations.

2 Need structure

The core needs are divided into what is often referred to as "fundamental, or physical, needs", those that are required for not dying or physically suffer (e.g. shelter/living and nutrition/health, needs low on the well known Maslow's hierarchy of needs), and "higher, or social, needs," that refer to those that make life worth living and contribute to the evolution of our society (e,g, social development and personal growth), needs that are high on Maslow's hierarchy of needs, as well as needs on a societal level such as art and science). The next category is "potential support for core human needs". Here mobility/access and data/digitalisation belongs. These areas are necessary for a sustainable society, but can be provided in many different ways and does not have an intrinsic value, only in relation to the human needs they support. Products such as cars for example does not have any intrinsic value, they can provide access to different services, from shelter and nutrition to exercise and art, but they can also be used to transport lobbyists and PR experts that work to undermine climate science. Even for the actual needs, these can be proved in many other and more sustainable ways today, from teleworking and local vertical farming that make physical transport unnecessary, to delivery of medicine by drones and local art exhibitions that is made available with smart city planning. Human needs describes the point at which individuals and households "consume" services that make up the functions of daily life. This is the ultimate purpose of the service-provisioning systems that convert energy and resource inputs into a useful form available to citizens. Systems that support and enable are important, but many systems today, from transportation (in the shape of cars and airplanes) to material (such as cement and steel) are taken for granted instead of the human needs that is the ultimate goal.

A category of "extended needs" has also been added two address to challenges transcending the classical human needs. This category includes:

1 Avoiding existential risks

That capture one of the most important risk categories, but also most ignored. There are at least 12 global risks that threaten human civilisation and while the probability for all of them are small, the impact can – for all practical purposes – be seen as infinite.[90]

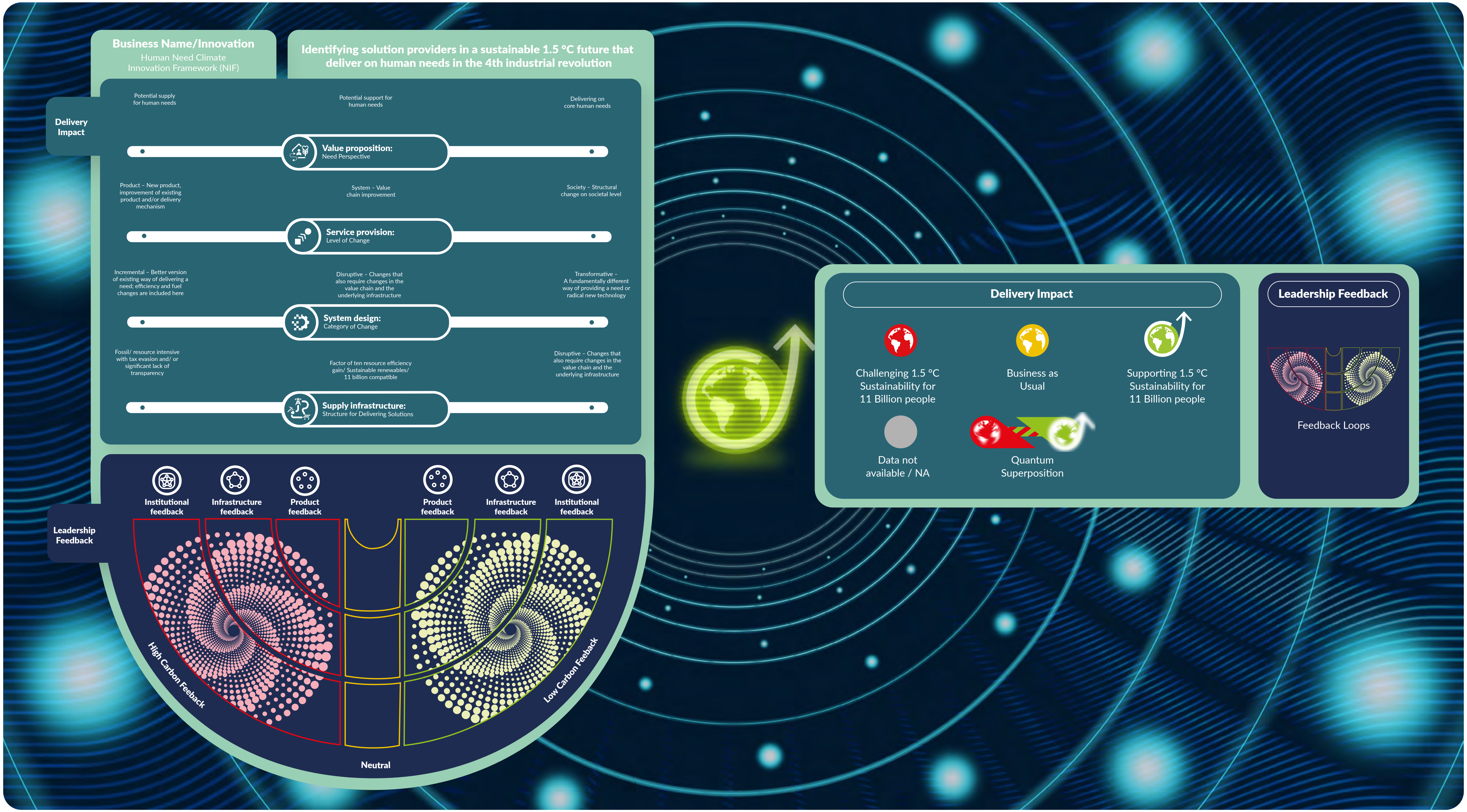
2 Nature/biodiversity

While human needs are important, there is also non-human life that has value. While most studies discussing the value of nature tend to have an anthropocentric perspective, a growing number also view non-human life and even ecosystems as having intrinsic value.[91]

The human-need structure presented in this paper will evolve, and increased granularity is expected as better data and understanding what kind of specific needs that require innovation. Currently the structure allows for a new generation of solutions in all key areas for needs.

4.3 Need-based innovation framework categories

The hierarchy of questions ('Delivery/Impact') and additional areas ('Leadership/ Feedback') are assessed using the following criteria shown in the diagram below and on the following pages.



Delivery Impact

I. Value proposition

Need Perspective

What the innovation is trying to achieve in relation to human needs in an equitable world with 11 billion people.

Potential supply for human needs.

Potential support for human needs.

Delivering on core human needs.

This area covers the focus of the innovation and how it relates to human needs in society based on the value proposition of the company/city promoting the innovation. It indicates whether the focus is on innovations delivering directly on human needs, or the innovation is providing support for needs, or is providing products with an unclear relation to human needs.

An innovation that uses drones to deliver medicine is from this perspective an innovation that deliver access to health, but a car manufacturer just delivering cars **or access to cars are providing potential support for access to needs.**

In addition to the different need categories the innovations relation to extended needs will also be assessed where applicable, i.e. if the innovation can provide significant contributions to reduced existential risks, or if it provide significant contributions to increased probability for existential risks. Or, if the innovation can provide significant contributions to a Half-Earth future, or if it provides significant contributions toward ecosystem collapses and worsening humanities relation to nature.

For example: In the first case, a residential roof-mounted solar panel providing electricity for light and heat/cool in a living space is directly related to core human needs. Whereas a data farm that provides heating delivered to final users through a district heating network, as a by-product of providing data services, is supporting core human needs but it is not the primary purpose of the data farm. Lastly, an innovation that provides a new battery technology that can be a component in different energy storage applications, is not directly linked to human needs, so is only supply based, i.e. with an unclear link to human needs.

Smart energy solutions that are extremely resource efficient can help reduce the dependency on biomaterial and thereby both contribute to reduced biodiversity loss and reduce zoonotic spillover, i.e. when viruses jump from animals to people.[92]

The 1.5 °C LED framework highlights two associated 1.5 °C strategies relating to needs.

Appeal:

How can resource-efficient services for core needs be made more appealing for users, or how can support/supply for needs be linked to needs in a way that encourages sustainable ways of providing solutions for needs? For example:

- **Can business model innovation deliver stronger consumer value propositions for resource-efficient services?**
- **Can the functionality of goods and services be increased so fewer things are required to deliver the same user benefits?**

Consumption patterns:

How can users' consumption practices become less resource-intensive, including providing for needs in fundamentally new ways?

Guiding questions:

- Can utilisation rates (or load factors) be increased to reduce overall demand for resource-intensive goods and infrastructure?
- Can 'usership' of services displace ownership of goods to improve the efficiency with which resource-intensive goods and infrastructure are used?

Delivery Impact

II. Service Provision

Level of Change

What level of change the innovation is targeting

Product: New product, improvement of existing product/ delivery mechanism.

System: Value chain improvement.

Society: Structural change on societal level.

Innovations that are useful services that primarily meet or support human needs can be provided to final users via different levels of change. This area covers what level of change the innovation is supporting. On the most basic level a product, or an existing way of delivering a product, is the focus. The next system level indicates an improvement on a system level where a whole value change is improved, and the society level indicates if the innovation delivers structural change on a societal level.

For example: An international financial initiative that provides loans and support to clusters of companies who eliminate unnecessary physical transportation and instead support a network city planning and network of 3D printers to eliminate the need for physical mobility is change at the *societal* level. A distributed ledger technology that is used to enable energy trading of micro-generation sources for final users is supporting change at the system level. A renewable micro-generator replacing fossil-fuelled alternatives is an improvement at a *product* level. Note that a new resource-efficient mobility/access solution for delivering food, for example via drones, may be *quantum* since the change may undermine sustainable mobility of nutrition if it is part of a system that delivers nutrition that has been transported by airplane. Such a solution can also support system solution by encouraging sufficient plant and season-based nutrition, but it can also undermine human needs by accelerate the uptake of unhealthy meat based fast food.

The 1.5 °C LED framework highlights two 1.5 °C strategies relating to diffusion potentials, energy efficiencies, and dematerialisation.

Diffusion potentials:

How can the potential for more resource-efficient services to diffuse beyond a product level, via system and society level, be clearly established?

Energy and resource efficiencies:

How can the energy and resources required to deliver a useful service be significantly reduced?

Guiding questions:

- **Can innovative business models and forms of service delivery be shown to be scalable from product to system and from system to society?**
- **Can the appeal of more resource-efficient services be demonstrated among different users in a range of contexts allowing the innovation to support change beyond individual products?**
- **Can the energy-conversion efficiency of devices be improved in ways that improve systems and/or society beyond the individual product?**
- **Can losses and waste be reduced or eliminated throughout the systems that convert energy and resources to provide for human needs?**
- **Can different forms of service be delivered that are more resource efficient and contribute to change on higher levels?**

Delivery Impact

III. System design
Category of Change

What kind of change the innovation is contributing to (technology and market)

Incremental: Better version of existing way of delivering a need; efficiency and fuel changes are included here.

Disruptive: Changes that also require changes in the value chain and the underlying infrastructure.

Transformative: A fundamentally different way of providing a need or radical new technology.

How can service-provisioning systems be designed to enable greater resource efficiency? This area focuses specifically on the system design and technology that the innovation is based on.

- *Incremental* includes innovations that improve the efficiency of a dominating technology/way of providing a need, or provides a fuel shift.
- *Disruptive* is when changes to the current solutions also require changes in the value chain and the underlying supportive infrastructure. E.g. from a fossil car to electric.
- *Transformative* are innovations that deliver societal needs in totally new ways in relation to what is the current dominating way of providing the need. For the current system where access over short distances is provided by car ownership and over long distances by airplanes, transformative solutions include 3D printers, virtual meetings, drones and new innovative city planning. In this category radical new technologies are also included, e.g. graphene, nanotechnology, quantum computers, crispr, etc. where they are judged to provide a tangible benefit.

For example: vertical indoor farming for food production through distributed deployment close to or within the premises of the final user with integrated health coaching is transformative in relation to traditional agriculture and health approaches. Whereas providing off-grid solar powered indoor cooking based on a rental service is disruptive when replacing outdoor solid/liquid fuel-based cooking. A software-based electricity consumption modelling and optimisation system for industrial users is incremental.

Changes in design that are disruptive or transformative can lead to magnitudes greater resource efficiency. Service-provisioning systems are made up of a complex of technologies, organisations, infrastructures and institutions that make services available to final users. The service-provisioning system for mobility is quite different from the service-provisioning system for cooking or cooling. But certain generalisable characteristics of service-provisioning systems help enable greater resource efficiency.

The 1.5 C LED framework highlights three strategies, relating to digitalisation, dematerialisation, and decentralisation.

Digitalisation:

How can digitalisation and data improve the resource efficiency of service-provisioning systems?

Decentralisation:

How can deployment and use of distributed resources improve the efficiency of service-provisioning systems?

De-materialisation:

How can the material resources required to deliver a useful service be reduced on different levels?

Guiding questions:

- Can digital or digitally-enabled goods and services reduce the resources required to provide useful services to final users?
- Can digital data be analysed and applied to make service provision more resource efficient?
- Can an existing need be provided for without a product (e.g. steaming of music instead of distribution of records)?
- Can the underlying infrastructure required be reduced significantly (e.g. broadband cables and services needed for virtual meetings providing access to a conference substituting the underlying infrastructure needed for flying to a conference that include everything from airports, hotels, and conference buildings)
- Can society overall become more resource efficient (e.g. empowering lifestyle without much material consumption such as hiking, climbing, painting, theatre, theoretical research compared with de-powering consumption, driven by the urge to be accepted by others, such as fast fashion and other sectors driven by impulse consumption, as well as luxury consumption such as yachts and shopping trips to cities on other contents)
- Can small-scale modular technologies and infrastructure be deployed rapidly and effectively?
- Can large numbers of distributed resources be efficiently coordinated and managed?
- Will the innovation requite large-scale infrastructure and make use of other innovations more difficult?

Delivery Impact

IV. Supply infrastructure

Structure for Delivering Solutions

What requirements for natural resources and energy exists for providing the solution

Strengthening unsustainable structures: Fossil and/or resource intensive.

Linear Improvement: Increased renewable use and resource efficiency.

Zero carbon/11 bn resource efficiency: Factor of ten resource efficiency gain/ Sustainable renewables.

This area indicates whether the start-up/innovation uses or supports dependency on *fossil fuels*, or is *neutral* to what type of energy is used or supplied, or if it supports sustainable renewable energy.

For example: a new type of solar panel that based on resource efficient recycled materials may be *sustainable renewable*, whereas a switch from a diesel-powered micro-generator to a solar and battery solution may be *neutral* since it is currently unsustainable in terms of resource use, and finally a technology to convert fossil-based waste products, for example plastics, into a fuel is *resource intensive*.

Today energy supply (e.g., rigs, refineries, power plants) and industrial processes (e.g., cement, steel, manufacturing) convert energy and materials into intermediate or final goods (e.g., plastics or cars) as well as infrastructure and other 'capital formation' that are part of service-provisioning systems (e.g., roads, phone networks, hospitals, universities). Resource conversion 'upstream' in the energy supply and industrial sectors accounts for the majority of greenhouse gas emissions in most companies.

The 1.5 °C LED framework highlights two 1.5 °C strategies, relating to decarbonisation and the material economy for the structure required for delivering solutions.

Decarbonisation:

How can the use of carbon-emitting resources be reduced and ultimately eliminated?

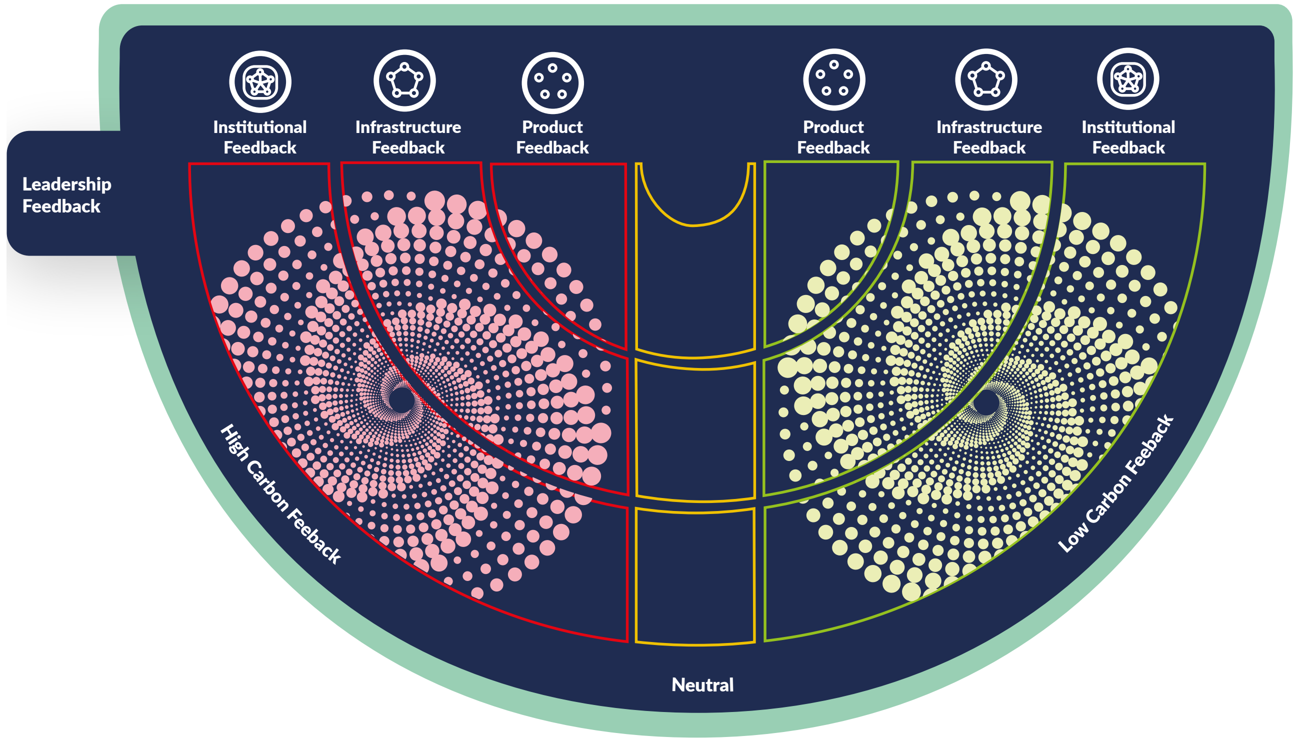
Material economy:

How can the use of material resources be reduced and made less impactful?

Guiding questions:

- Can the use of carbon-emitting resources be replaced or avoided in the energy supply?
- Can low-carbon infrastructure be deployed rapidly and effectively at scale?
- Can the use of carbon-emitting resources be replaced or avoided in industrial facilities and processes?
- Can industrial production processes be more resource efficient?
- Can the circular reuse and recycling of materials and products be improved to reduce demands on new resource extraction and land conversion?

Innovations and three categories of feedback



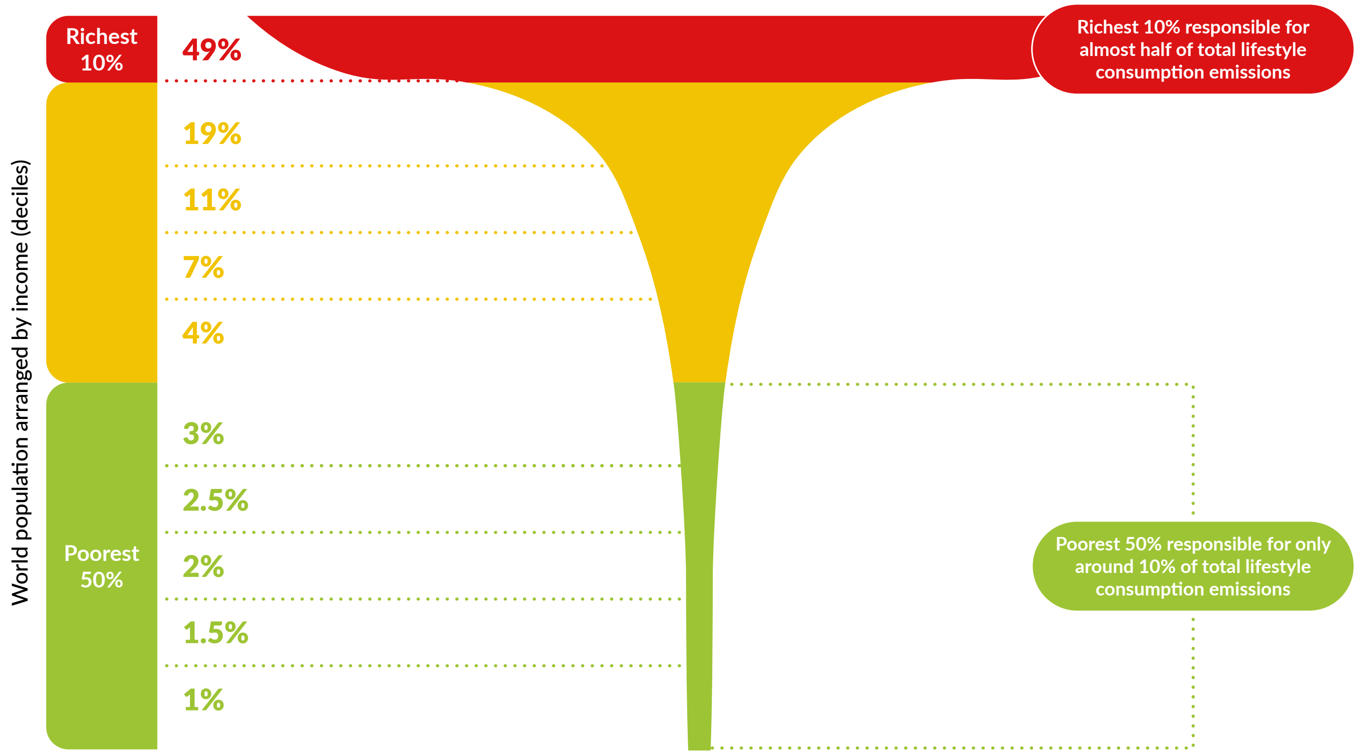
Leadership and feedback

The necessary exponential uptake of sustainable 1.5 °C innovations require innovations on an unprecedented scale. Rapid emission reductions are needed on a global scale and innovations are required to ensure avoided emissions for future development to allow poor people move out of poverty. Assessments indicate that the carbon emissions of richest 1 percent are more than double the emissions of the poorest half of humanity and as data clearly indicates the global climate work must work on two parallel fronts.[93]

First, large parts of the global population need transformative system innovations in order to urgently move out of poverty and towards flourishing lifestyles while avoiding emission increases. Second, the affluent population currently contributing the bulk of emissions also need transformative system innovations to deliver the emission reductions needed.

Only with positive feedback loops that help accelerate an exponential uptake of 1.5 °C compatible system solutions is it possible to deliver the extremely resource efficient solutions needed for a future capable of delivering flourishing lifestyles for equitable future with 11 billion people.

Percentage of CO_2 emissions by world population



Mathematically, positive feedback is defined as:

"a positive loop gain around a closed loop of cause and effect. Positive, or reinforcing, feedback tends to cause system instability. When the loop gain is positive and above 1, there will typically be exponential growth, increasing oscillations, chaotic behaviours, or other divergences from equilibrium. System parameters will typically accelerate in a spiral towards extreme values, which may damage or destroy the existing system, and may end with the system latched into a new stable state."[94]

This mathematical definition captures several key features in a rapid and just transitions towards a sustainable 1.5 °C future, including "positive feedback", "exponential growth", "divergences from equilibrium" and "a new stable state", that will be covered below.

Two types of feedback loops exist that are relevant for a 1.5 °C compatibility assessments:

1 Low-carbon feedback (positive feedback)

A situation where an innovation result in positive feedback loops supporting accelerated avoided emissions. Exponential uptake of innovations with low-carbon feedback are crucial to deliver the transformative system changes needed to reach the significant emission reductions and resource efficiency necessary to avoid dangerous climate change and deliver on global sustainability.

2 High-carbon feedback (negative feedback)

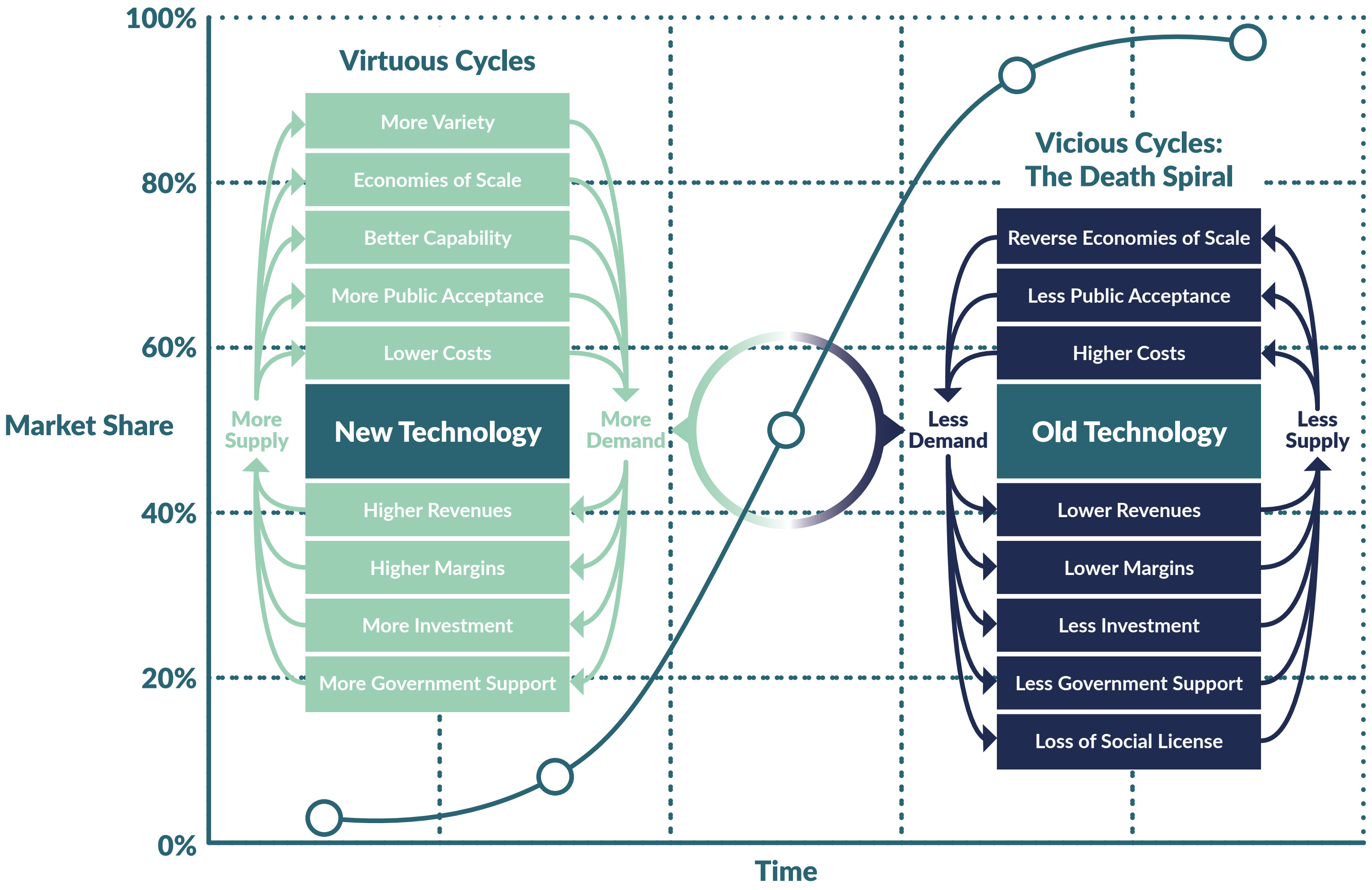
A situation where an innovation result in negative feedback loops supporting lock-in of the existing trends with increased GHG emissions, or an acceleration of emissions, a consequence. A specific case of high-carbon feedback that urgently must be addressed are innovations that help reduce GHG emissions in the short term, but support emissions on a high level over time.

The changes needed for a sustainable 1.5 °C future will require a transformation of society and feedback mechanisms that accelerate avoided emissions must be identified, understood, and supported. With the ongoing 4th industrial revolution and ongoing chocks to the systems there will be damages, or even destructions, of existing systems, on the path towards a more stable and sustainable future. Making things even more challenging is the fact that multiple feedback systems are at play simultaneously, both low- and high-carbon feedback, making it crucial to identify, understand different feedback system; Then in parallel avoid, or eliminate the high-carbon feedbacks, while supporting and accelerating the low-carbon feedbacks.

An increasing number of climate experts and initiatives refer to the need for transformative and exponential change[95], but there is little guidance for how to achieve such change, beyond references to Moore's law[96] and examples of rapidly falling costs due to strategic policy interventions in the number of areas, such as LED's, electro mobility and Solar PV.[97]

Currently few institutional and incentives in the area of climate mitigation identify and support low-carbon feedback loops. RethinkX recent report, "Rethinking Climate Change", is an exception as it presented several potential feedback loops (see illustration below) in a few strategic areas. Still, reports, initiatives, and assessments that include feedback loops for necessary exponential uptake of 1.5 °C compatible solutions are still rare.[98]

Casual feedback loops drive disruption



The importance of including feedback loops in climate and sustainability strategies is hard to overstate. One the one hand, the changes needed to deliver the emission reductions, and secure the avoided emissions, to reach a 1.5 °C goal require transformative action and uptake of new smart solutions needs to be exponential. On the other hand, the opportunities in the fourth industrial revolution and the new digitalised world requires us to understand the network effects[99] and feedback systems in relation to the innovations needed and how these can be directed towards sustainability instead of undermining them.[100]

If feedback effects are ignored, climate strategies are likely to include actions that deliver significant GHG reductions in the near term but are long-term counterproductive as they contribute to high-carbon feedback and result in high-carbon lock-in.[101] I.e., an innovation delivering significant reduced emissions in the short term, such as an improvement in a coal power plant, such an improvement can contribute to high-carbon and resource intensive feedback loops that strengthen existing high carbon structures. They are also likely to focus on large scale supply-side measures and large-scale end-of-pipe solutions.

A key reason that feedback loops are rarely included in existing climate work is that models today used in economic planning, business strategies and even climate strategies assume that almost everything stays the same, ceteris paribus, when innovations are introduced. Many leading experts are also only knowledgeable in neoclassical economic thinking where transformative system change does not exist. This narrow perspective provided a reasonable approximation for much of the 20th century before the digital revolution and the 4th industrial revolution.

Today, a product or service cannot be assumed to be an isolated phenomenon, as it will affect the surroundings when being used. Deploying innovations will affect different parts of society with some products, infrastructures and institutions will be strengthened, while others weakened. Exactly how society will be affected by new solutions is determined by many factors. Carbon feedback can be categorised into three interlinked strategic parts:

1 Product feedback

Assessing the products that will be promoted or discouraged due to the innovation.

2 Infrastructure feedback

Assessing changes in infrastructure that promote or discourage 1.5 °C compatibility due to the innovation. This includes both the physical and structural infrastructure.

3 Institutional feedback

Assessing institutional changes and how this will affect 1.5 °C compatibility due to the innovation.

I. Product Feedback

High-carbon product feedback: Continued, or increased, use of high-carbon products.

Business as usual beyond the deployed product.

Low-carbon product feedback: Additional, or increased, use of 1.5 °C compatible products in support of 11 billion flourishing lifestyles.

Low-carbon product feedback happens when the low-carbon innovation encourages use of more of the same product, or additional low-carbon products, due to establishment of new habits, investments, marketing, or lobbying. Low-carbon product feedback tend to increase when innovations support a shift to a need perspective where access, spaces, nutrition/health is provided in ways that are extremely resource efficient, such as virtual meeting/virtualisations, plant-based resource efficient nutrition, experience based low-material consumption. The feedback can be due to accelerated uptake of a single product, or a cluster of products.

For example: Single product low-carbon feedback: Increased access and use of videoconference equipment can make videoconferencing a more attractive product enabling communication with more people as the innovation follows a network logic where more users make the innovation. The more videoconferencing products that exist the higher the value becomes for those who have one due to the network effect.

For example: Cluster products low-carbon feedback: An innovation for a plant-based protein product can support further uptake of other plant-based sources of nutrition by demonstrating that a plant-based diet can be an attractive way to provide nutrition in a socially acceptable way. In a similar way low-carbon innovations such as solar panels can encourage investment in batteries and electric mobility to establish an independent local energy system with synergies. The most famous example is probably Tesla's integrated strategy with electric vehicles, batteries, and solar PV systems.[102]

High-carbon product feedback happens when the innovation encourages use of additional high-carbon products due to the encouragement of continued use of existing high-carbon products, or the establishment of new habits, investments, marketing, lobbying that are high-carbon. High-carbon product feedback is likely when incremental improvements are provided in areas such as internal combustion cars, energy inefficient buildings with low utility, red meat, and high-consumption lifestyles such as fast fashion. Many existing marketing strategies contribute to high-carbon product feedback by linking and encouraging different unsustainable lifestyles, from car ownerships and long-haul flights to fast fashion and fast food. Encouragement of continued use of unsustainable products with marketing around offsetting, with claims alluding to the unsustainable product as "carbon free/neutral," or even "positive for the climate", is an example of a marketing likely contributing to high-carbon product feedback.

Guiding questions:

- **Can the innovation help accelerate the uptake of other 1.5 °C LED products?**
- **Can the innovation become part of clusters capable of transformative system change in support of 1.5 °C LED pathways?**
- **Will more users make the product more attractive to other users (a network effect tends to accelerate feedback effects)?**
- **Is the innovation part of promotion for high-carbon/resource inefficient solutions?**
- **Can the innovation encourage continued use of high-emitting and resource intensive technologies/lifestyles?**

For example: Single products high-carbon feedback: Incremental improvement in coal power plants with long-term payback resulting in continued use of fossil fuel. In this category a significant proportion of CCS projects can be included as they are used by high emitters as an excuse to not take action and instead argue that such projects are necessity, well aware that non-CCS pathways require investments and policies supporting smart development were current big emitters existing business models have a very limited role to play.[103]

For example: Cluster products high-carbon feedback: Drive-in restaurant for fast food with hamburgers, that advertise with toys for children and links to credit cards that encourage long haul flights is an extreme example of a bundle of unsustainable lifestyle choices combined into an integrated offering that encourages a high-carbon development path.

II. Infrastructure Feedback

High-carbon infrastructure feedback: Continued, or increased, emissions due to use of a high-carbon promoting infrastructure.

Business as usual beyond the deployed product.

Low-carbon infrastructure feedback: Additional, or increased, use of 1.5 °C compatible emission reductions due to additional use of low-carbon promoting infrastructure.

Different infrastructure feedback loops are important as society is experience the 4th industrial revolution. Society is currently in the phase when the digital and physical infrastructure is moving from a situation when the digital infrastructure primarily helped optimising the use of the physical infrastructure and products (think systems to optimise car routes and industrial optimisation with the use of sensors) to a situation where fundamentally new ways of providing needs are emerging where the digital and physical infrastructure needs to be codesigned (think dematerialisation, e.g. streaming of music and a shift from ownership to access e.g. car sharing services, or automatic driving)

While many opportunities exist to deliver needs in extremely resource efficient ways these new ways require new business models, new incentive structures and new regulations. At the same time significant incentives exist to identify low-hanging fruits and claim credits for these emission reductions. The focus on low-hanging fruits and optimisation of existing system often happens without consideration of the underlying infrastructure supported.

Between 2050 and 2100 the possibilities to deliver solutions to human needs are likely to be fundamentally different compared with today, but the in what ways will depend on the choices today. Policies and strategies built on assumptions that society depend on current business models, but with more renewable energy and CCS, will most likely result in high-carbon infrastructure feedback that reduce the innovation space as the underlying infrastructure will focus on improvement in existing systems, rather than new resource efficient solutions that can deliver on our human needs.

Conservative assessments, with focus on improvement in existing systems, have concluded a 15% reduction potential of global emissions with the help of the new digital infrastructure.[104] These 15% are based mainly on optimisation of existing systems and the assessment are done with the help of neo-classical economic models.[105] Assessments based on feedback loops are less common and tend to not include an exact numbers number for specific dates as the focus then is on exponential change with tipping points.[106]

Moving forward assessment of both low- and high-carbon infrastructural feedbacks are important to consider.

Guiding questions:

- Can the innovation support a low- or high-carbon infrastructure that support increased use of low- or high-carbon products
- Can the innovation support 1.5 °C LED compatible underlying infrastructure, or continue supporting existing high carbon/ resource intensive infrastructure?
- Can the innovation be increasingly successful if the requirements for emission reductions are increasingly stringent and in line with a 1.5 °C LED pathway and a low-carbon infrastructure is the new normal?
- Will the innovation contribute to a dematerialisation infrastructure?
- Can the innovation contribute to a sharing/ access infrastructure?
- Can the innovation contribute to high-carbon lock-in?
- Can the innovation contribute to procrastination?
- Can the innovation contribute to distraction?

The first category of low-carbon infrastructure feedback can be called “dematerialisation infrastructure feedback”. This infrastructure feedback happens when an innovation supports an infrastructure that support further dematerialisation. This can happen both trough software innovation and hardware innovation. I.e. when atoms turn into electrons, such as steaming of music, videos and e-books, rather than depending on physical storage, distribution and waste. The infrastructure and tools used, such mobile broadband and mobile devises, are then part of a dematerialisation infrastructure. To be sustainable the dematerialising infrastructure needs to be designed in a modular way that allow for resource efficient use and easy repairability/upgrades. An emerging infrastructure category are platforms as supportive infrastructures that support lifestyles of high-quality but low-material consumption, so called regenerative lifestyles, ranging from outdoor lifestyles to art and science. These platforms combines digital infrastructures for sharing and identifying lifestyle options as well as physical infrastructure that allow for access when that is needed, e.g. though train, bike or walking.[107]

For example: Low-carbon dematerialisation infrastructure feedback: Innovations for virtual meetings that require investments in high-quality broadband and thereby contribute to an infrastructure that allows laptops and mobiles to be connected for many other low-carbon innovations, including tele-working, e-health and e-banking. Such infrastructure feedback support a situation where the infrastructure supported could also deliver emission reductions from innovations such as flexible working, as people could reduce commuting and work from wherever they liked. Investments in videoconferencing innovations could also help to develop technologies to compress and transfer data that, in turn, can be used to dematerialise other parts of the economy. The innovation can be in software, such as compression algorithms that allow better quality call to take place, or in supportive business models that help organisations virtual meetings in an efficient way that increase productivity. The innovation can also be in hardware, such a resource and cost-efficient cameras that allow 11 billion people to access the services they need.

A second category of low-carbon infrastructure feedback can be called "access infrastructure feedback". This institutional feedback happens when an innovation supports an infrastructure that is used for sharing and providing access to products instead of traditional ownership. This can also happen both trough software innovation and hardware innovation.

The first category of high-carbon infrastructure feedback can be called "incremental lock-in infrastructure". Many activities resulting in high-carbon infrastructure feedback are due to attempts to improve existing systems, such as shift from coal to natural (fossil) gas, more fuel-efficient fossil fuel vehicles, incremental energy efficiency in buildings, that are implemented in ways that will result in prolonged use of fundamentally unsustainable underlying infrastructure and their associated products.

For example: Continuing selling cars with a business model based in individual car ownerships require an underlying carbon and resources intensive infrastructure with road, parking spots, fuelling stations, etc that result in a situation where the innovation window is reduced as the default product providing access for people is a car.

The second category of high carbon infrastructure feedback can be called "procrastination lock-in infrastructure". This is when the urgent need for reductions of emissions result in a focus on innovations relating to carbon capture infrastructure that potentially could reduce, or even eliminate, the need for reduced emissions. The investments in innovations linked to carbon capture infrastructure has a significant probability to reduce incentives for transformative system solutions, and thereby generate procrastination, in systems that needs to transform to be sustainable.

For example: CCS infrastructure innovations linked to reducing the need for radical action in sectors such as cement, steel and petrochemicals is an example where procrastination lock-in is likely due to expectations for how the future infrastructure might look like. To avoid procrastination companies in hard to abate sectors should have strategies in place for a possible future without any significant contributing from CCS to avoid the risk of high-carbon lock-in. Investments in CCS infrastructure that are used to undermine sustainable business model and technological innovation be identified with a procrastination assessment. A way to discourage procrastination from CCS infrastructure is to frame the CCS innovations as an insurance if the smart 1.5 °C LED pathways fail and demand that companies participating in publicly funded projects have strategies that includes a non-CCS future.[108]

A final category of high-carbon infrastructure feedback can be called "distraction lock-in". This category of feedback includes many of the innovations in the financial sectors that assess companies from a static risk approach and then provide guidance of exclusion criteria for institutional investors, or green bonds with no or limited additionally. Compared with innovations that support a "financial infrastructure" that deliver 1.5 °C compatible solutions these innovations strengthen an existing infrastructure that encourages fundamentally broken business models and focus on communication opportunity rather than actual measurable impacts in society.[109] Divestments can still be part of campaigns to pressure certain companies and support increased understanding, but that is very different from offering ESG as a way to help reduce emissions and/or support the solutions needed. The lack of actual contributions for such innovations has been increasingly recognised, even by stakeholders from the financial.[110]

For example: Innovations that encourage financial stakeholders to sell green ESG funds to people without any assessment of what climate impact this has in reality, especially when the same financial companies are keeping the existing core business intact.

> *"Immediately after leaving BlackRock, I had reached the conclusion that our work in sustainable investing was like selling wheatgrass to a cancer patient. There's no evidence that wheatgrass will do anything to stop the spread of cancer, but it's tempting to believe it, especially when the doctor is advising chemotherapy.*
>
> *Unfortunately, I now realize that it's worse than I originally thought: the evidence around the deadly distraction made it clear that we weren't just selling the public a wheatgrass placebo as a solution to the onset of cancer. Worse, our lofty and misleading marketing messages were also delaying the patient from undergoing chemotherapy. And all the while, the cancer continues to spread."*
>
> **Tariq Fancy**
> *Ex-CIO for Sustainable Investing at BlackRock*

III. Institutional Feedback

High-carbon feedback: Support for increased emissions due to the institutions strengthened/supported/created.

Business as usual beyond the deployed product.

Low-carbon feedback: Support for avoided emissions due to the institutions changed/supported/created.

Long-term, the institutions in society are defining the overall direction and phase of innovation. Depending on the structure, capacity, mandate, and knowledge different institutions will include, or exclude; support or discourage different innovations and clusters of innovations. The current focus on individual technological innovations providing incremental improvement in existing systems, and how they can be brought over the valley of death, results in a situation where much of existing innovation initiatives are part of the problem rather than part of the necessary transformative system solutions.

The Bertelsmann Stiftung report, "Addressing societal challenges through disruptive technologies", observation is valid for most countries when it comes to existing innovation systems.

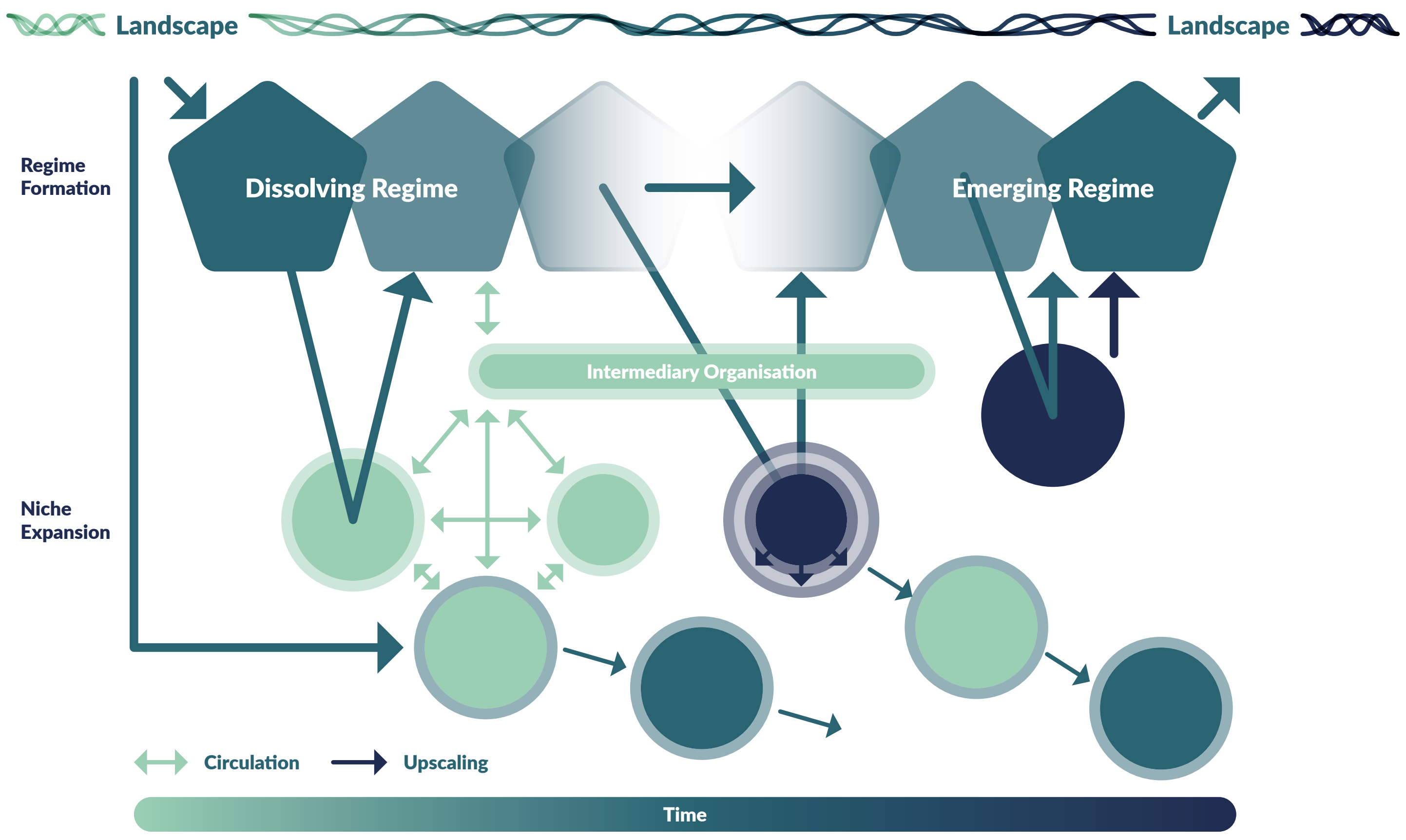
> *"Existing institutional structures promoting (disruptive) innovation […] must be better networked and focused more strongly on facilitating disruptive innovations capable of solving societally relevant problems."*
>
> **Bertelsmann Stiftung**
> *Addressing societal challenges through disruptive technologies*[111]

The need for institutions to change, in order to be able to be able to use the new opportunities in the 4th industrial revolution, as well as solving the global sustainability challenges, are now widely recognized. Reports like the United Nations Research Institute for Social Development report "Policy Innovations for Transformative Change"[112] and academic report like "Transformative outcomes: assessing and reorienting experimentation with transformative innovation policy"[113] all points towards the need to rethink current institutions though a multi-level approach.

Guiding questions:

- **Can the innovation contribute to a shift in focus in key institutions, from existing sectors to human needs?**
- **Can the innovation contribute to a shift in focus in key institutions, from sources of emissions, to also providers of solutions?**
- **Can the innovation contribute to new tools and methodologies that move beyond neoclassical economic models and embrace tipping points/exponential change in key institutions?**
- **Can incentive structures for 1.5 C LED pathways be created/strengthened, or undermined with incentive structures for a strong supply-side and CCS focus, in key institutions?**
- **Can key institutions include groups supporting a 1.5C LED pathway in development of policies and framework, or can key institutions include only large emitter with strong supply side and CCS?**
- **Can the innovation used to lobby key institutions for increased, or reduced, climate action in line with a 1.5 C LED future?**

Transformative outcomes for expanding & mainstreaming niches



Currently more limited approaches are explored such as "mission oriented innovation"[114] were focus shifts from existing sectors to problems. Such approaches have been explored by multiple stakeholders, but with limited success so far to deliver 1.5 °C compatible innovations, partly due to the fact that the same stakeholders as earlier are involved in similar projects with similar financial conditions and goals. The result so far has been institutions with the same focus on classic technology fixes for existing large polluters without tools and evaluation methods to assess the outcomes in new ways.[115] Still, moving from existing sectors to something else is a step in the right direction for innovation initiatives.

The institutional changes needed for a 21st century innovation ecosystem, and how these changes can be achieved, will be explored in a separate forthcoming report.[116] Here three institutional feedback aspects will be covered:

1. New system boundaries and structures (e.g. Does the institutions focus on solution providers and enablers delivering transformative system change, or only major emitters and providers of renewable energy? Does the institutions use expanded system boundaries that include avoided emissions/scope 4, or are they limited to scope 1-3)

2. New tools and methodologies (e.g. Does the institutions acknowledge and use tools to support tipping-points and exponential changes in ways that support global sustainability, or only improvement of existing systems through tools like environmental product labels, environmental taxes and/or voluntary agreements with big polluters?)

3. New objectives and value propositions (e.g. Does the institutions invite and support stakeholders based on the capacity to deliver solutions to human needs in a sustainable way that would allow 11 billion live flourishing lives, or only those improve existing systems?)

For individual start-ups institutional feedback can be hard to assess as many have not advocacy work and marketing beyond the most basic to ensure survival. In those cases, the area they are active in can be used as a proxy for the institutional feedback assessments. E.g. plant-based healthy nutrition solutions can help accelerate further uptake of sustainable nutritional products and the distribution and financial infrastructure can provide low-carbon infrastructure feedback. For institutional feedback the growing number of start-ups in new areas can help existing institutions find new ways of providing for different human needs in society.

Assessment of institutional feedback is important for incubators, government agencies, ministries, large companies, business groups, and all others that support clusters of solution providers, enablers, and markets. Such organisations and initiatives participate in public events and are involved when institutions evolve where they help shape future initiatives and institutions. The stakeholders with focus on innovation and/or climate solutions are particularly important to assess from an institutional feedback perspective. Existing climate institutions often been created with funding and influence from the big emitters, as this has been the focus so far, rather from a perspective of global sustainability and solution providers. The leadership and staff in many climate and innovation institutions/initiatives were also requited for their knowledge and skills in improvement of existing systems with neoclassical tools, making it hard for them to move from a static problem approach to a dynamic opportunity approach.

Understanding how different innovations can support institutions in becoming part of an accelerated uptake of 1.5 °C compatible solutions in support of a future with 11 billion flourishing lives is an important first step towards an innovation ecosystem for the 21st century.

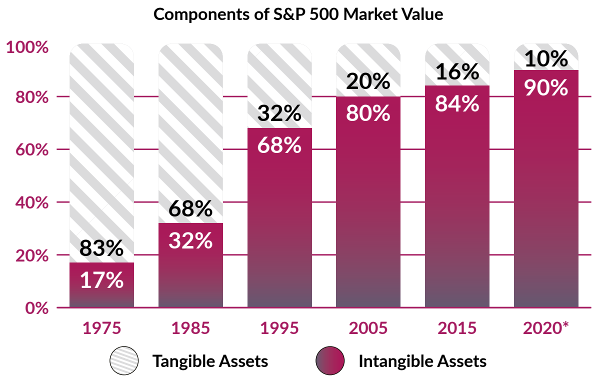
For example: Low-carbon institutional feedback: When video conferencing innovations are implemented in companies, this could support a change in strategy to shift from a product perspective of buying "travels" to a service approach buying "meetings". Such a strategy change could then be applied to other parts of the company and society resulting in a shift from products to services in other areas as well. More business opportunities around different services linked to virtual meetings and more deployment will also increase the likelihood of a stronger united voice in policy discussions. This is key as legislators often want input from different stakeholders and one of the challenges is that few or no representatives from low-carbon business models have been present in discussions so far. In many cases this is because they are busy trying to survive and lack lobby organisations in the world's capital cities. For example, if representatives from the airline industry are the only ones present when incentives for companies to reduce GHG from flying are being developed, it is likely that we will only see offsetting, more efficient engines and biofuels, on the agenda. Investments and rules to ensure higher bandwidth, incentive structures for virtual meetings, support for business models that are built around international collaboration will probably not gain equal support.

For example: High-carbon institutional feedback: When end-of-pipe technology innovations (such as CCS), or supply-side innovations (such as large-scale supply-driven biomass use) are presented as necessary on a large-scale in society institutions working with climate strategies can become shaped in ways that exclude new resource efficient innovations as they do not fit a narrow narrative of climate innovations with strong focus on supply-side and end-of-pipe (such as IPCCs P4 pathway). An opportunity to reduce high-carbon institutional feedback is for institutions to move the focus from sectors and individual sources of emissions to needs in society and how they can be met (such as IPCCs P1 pathway).[117]

4.4 The value of 1.5 °C compatibility: intangible assets and beyond

For most of the 20th century the value of a company was basically the same as the value of the physical, or "tangible", assets: buildings, machines, equipment, etc. With the fourth industrial revolution and a digital knowledge economy this is no longer the case. Today most of the value in the leading companies of the world are not physical but intangible.[118]

From the early 1990's companies in the US have invested more in intangible assets than they have done in tangible assets.[119]



There is no clear correlation between companies with high intangible value and climate compatible companies. The value of many companies with questionable sustainability contributions, such as fast food and fast fashion companies, have significant intangible assets. However, it is worth noting that many of the successful companies that deliver climate solutions, from Tesla and Beyond Meat, derive significant portions of their intangible assets in areas that are linked to the seven areas covered by the Human Need-Based Climate Innovation Framework (NIF).[120]

As noted in a WEF article "a better understanding of the value created out of intangible assets should be of interest to all stakeholders" and provide the following example "Public Private Partnerships (PPPs) that support societally critical innovation that creates long-term value could be accelerated."[121]

For a companies and the 21st century the valuation often depends on how the company is approached. If for example Tesla is seen only as a car company the value tends to be lower, and the value is almost entirely linked to the capacity to sell cars. If Tesla is seen as a company with a mission to "accelerate the world's transition to sustainable energy" the value tends to be higher.[122] The higher value is in that context due to the potential for increased revenues from multiple sources, such as electric cars, but also batteries, renewable energy generation and storage due to the customer relations, goodwill, value of the data they have access to, etc.

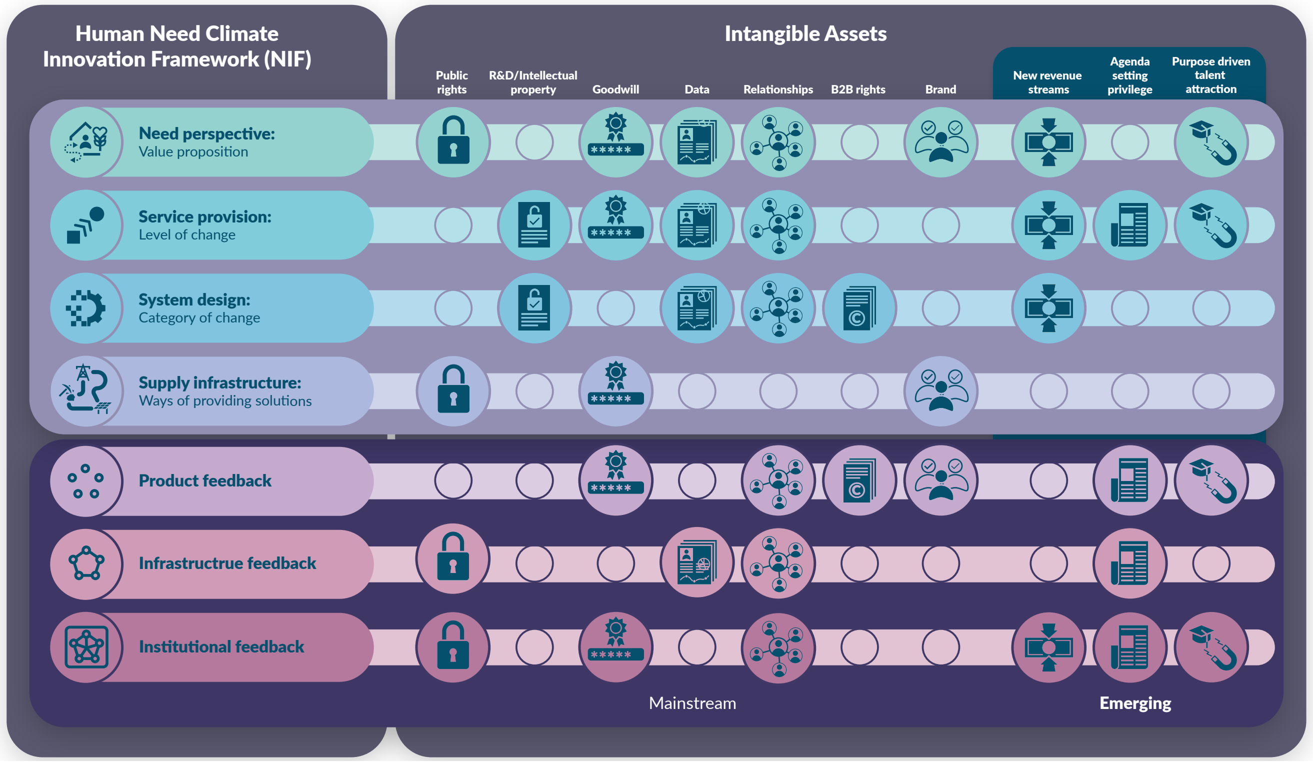
With focus on system change and transformative solutions compared with current ways of providing the need, companies can move beyond multiple individual revenue streams as they capitalise on new synergies, or in the words of Tesla: "Electric cars, batteries, and renewable energy generation and storage already exist independently, but when combined, they become even more powerful."[123]

With companies demonstrating leadership in an area they can also be asked to help shape the energy and transport systems of tomorrow[124], as well as creating a new generation of clusters capable of delivering new system solutions.[125]

While Tesla is a well-known brand that has challenged many investors that initially saw Tesla as a classical car company, there are many more disruptive and successful companies on a more granular level with similar and more innovative approaches in different areas. Investors and policy makers are currently not capable of assessing the value of companies and innovations in the 4th industrial revolution when the world needs dramatic emissions reductions. Current assessment related to sustainability, if any, are focused on ESG assessments, not the impact in society due to the solutions they provide. in a manner that also delivers on, or at least not significantly undermines, the other major sustainability goals such a biodiversity and poverty elimination.

With a new generation of companies emerging, and many existing incumbents struggle to be relevant, key denominators for intangible value over the next decade are captured in the Need-Based Climate Innovation Framework (NIF). Linking 1.5 °C compatibility to intangible assets, and thereby the value of a company, is likely one of the most important questions for a dynamic solution climate agenda beyond the current static problem approach.

Below is a graph mapping the seven areas in the NIF to seven established areas for intangible assets, as well as three that are emerging as important factors.



How companies are valuated and how this relates to their 1.5 °C compatibility and ability to contribute, or undermine, a sustainable future will be one of the key most important issues for the innovation ecosystem in the early 21st century and the financial system in particular.

> *"What is new about today's economy? It is not the role of ideas themselves. The technologies we take for granted — the wheel, fired pottery, the plough or the steam engine — were once brilliant new ideas. What is new about today's economy is that many of our best ideas remain disembodied. The idea is indeed valuable, but it does not take physical form [e.g. research and development, software, databases, artistic creations, designs, branding and business processes]. This changes almost everything."*
>
> **Martin Wolf, FT**[126]

Appendix 1:

A need-based perspective on the 1.5 °C compatibility pathfinder framework

The framework shown in Figure 1 is designed to guide thinking on mitigation strategies for providing and using services more effectively and efficiently while making rapid progress towards the 1.5 °C goal. Useful services are therefore the entry point into this version of the 1.5 °C compatibility framework.

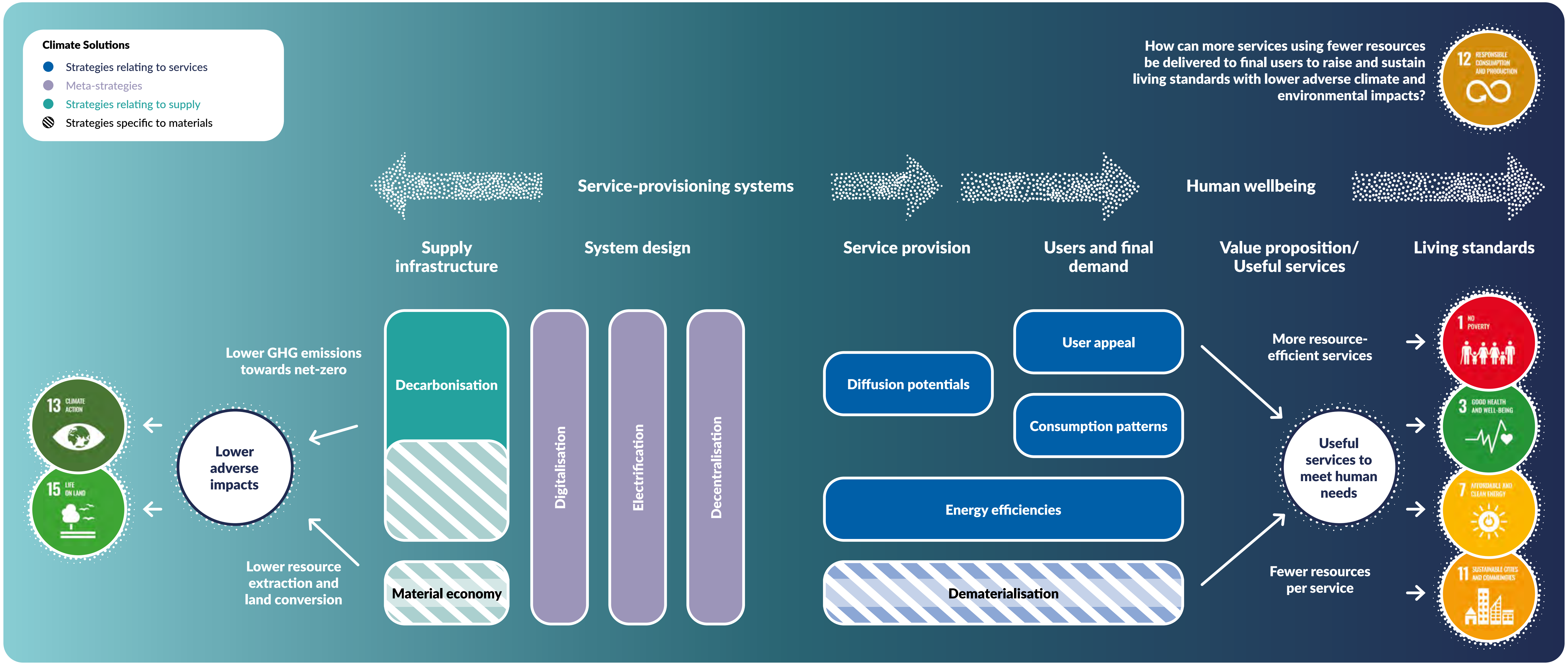
The framework has three stages. First, it explores 'downstream' strategies relating to how services are provided and consumed (Figure 1, **blue boxes**).

Second, it explores broad 'meta' strategies relating to the characteristics of service-provisioning systems (Figure 1, **purple boxes**). Third, it explores 'upstream' strategies relating to energy supply and industrial production (Figure 1, **teal boxes**).

Both the global Low Energy Demand scenario and this 1.5 °C Compatibility Pathfinder Framework take SDG12 on Responsible Consumption and Production as a means of delivering on multiple SDGs in addition to SDG13 on Climate Action. As defined by the United Nations, SDG12 is "*about doing more and better with less: 'more' is delivered in terms of goods and services, with 'less' impact in terms of resource use, environmental degradation, waste and pollution.*"[127]

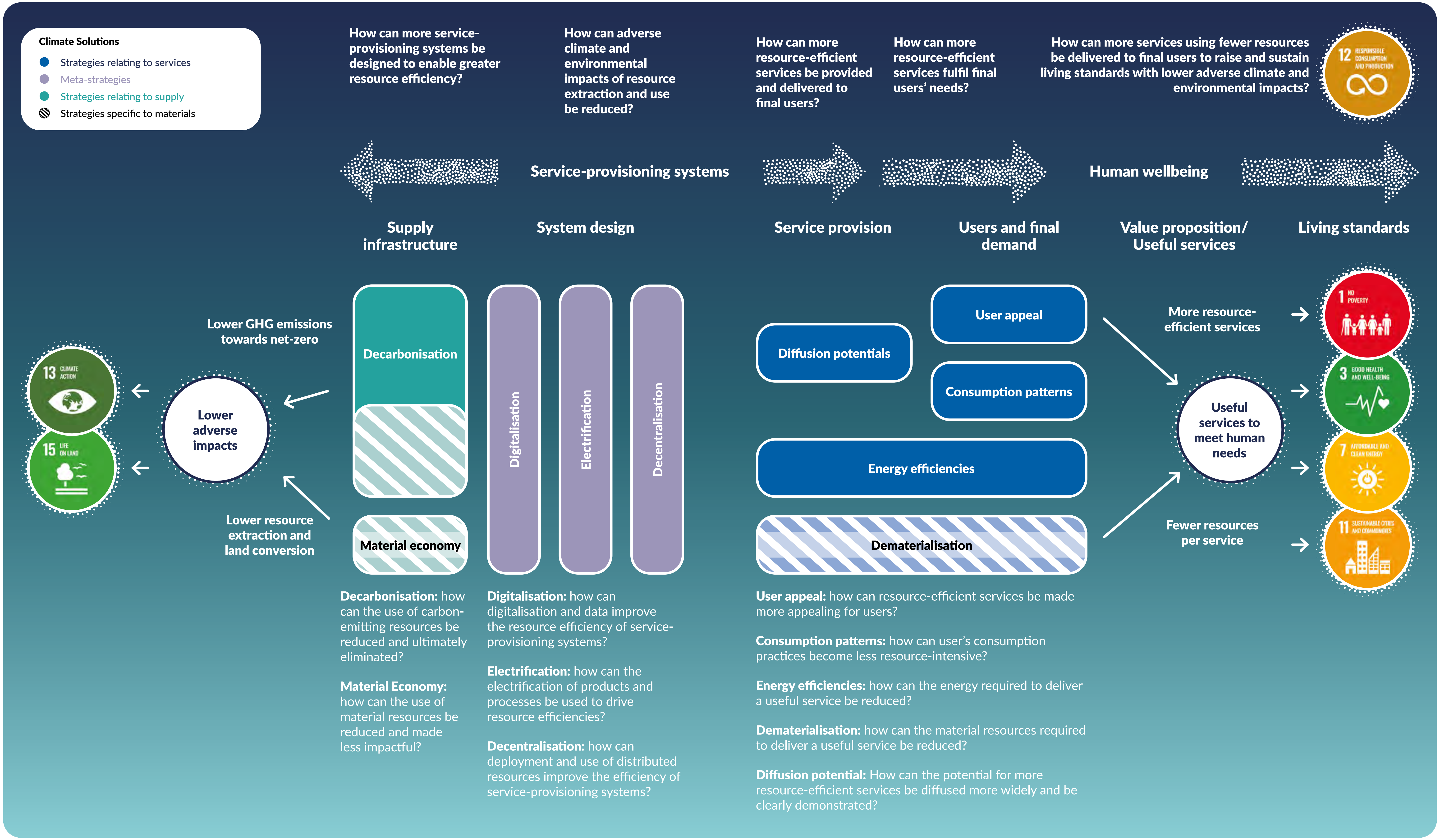
It is important to note that the services-based perspective shown in Figures 1 & 2 does not include policy strategies (specific to public policymakers and regulators), nor does it include specific food and land-use mitigation strategies. Further details on both these can be found in Mission Innovation's 1.5 °C Compatibility Pathfinder Framework.[128]

Figure 1.



A services-based perspective on the 1.5 °C compatibility pathfinder framework with guiding questions at each stage

Figure 2.



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127 Sustainable consumption and production is defined as "the use of services and related products, which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations". In general terms, sustainable consumption and production is about decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles. Sources: UN (https://www.un.org/sustainabledevelopment/sustainable-consumption-production/) and UNEP

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