NET ZERO 2050

Funding Innovation to Deliver EU Competitive Climate Leadership

CLIMATE & STRATEGY PARTNERS

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About this Report

This report has been funded by the European Climate Foundation (ECF).It is part of the Net-Zero 2050 series, an initiative of the European Climate Foundation (ECF). Authored by Climate Strategy & Partners with structured contributions from some 50 experts from 39 organisations.

The ambition of the Net-Zero 2050 series is to start building a vision and evidence base for the transition to net zero emission societies in Europe and beyond, by mid-century at the latest. The Paris Agreement commits us to making this transition, and long-term strategic planning shows that many of the decisions and actions needed to get us on track must be taken imminently.

Reports in the series seek to enhance understanding of the implications and opportunities of moving to climate neutrality across the power, industry, buildings, transport, agriculture and forestry sectors; to shed light on some of the near-term choices and actions needed to reach this goal, and to provide a basis for discussion and engagement with stakeholders and policy-makers.

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Climate Strategy is a leading policy advisory and consulting firm in areas of climate finance, innovation, energy efficiency investments and the corporate strategies and Government policies required for the Transition to a net-zero emissions economy. For 9 years, the Climate Strategy team has been providing global companies, banks and Governments advice on how to accelerate the economic transition to a low carbon economy. Climate Strategy's chief executive, Peter Sweatman, has authored or co-authored thirteen white papers, including working with 250 leading industry experts to draft a roadmap entitled "Finance for innovation: Towards the ETS Innovation Fund" in June 2017. Peter Sweatman is rapporteur to the G20's Energy Efficiency Financial Task Group and the EU Commission and UN Environment Finance Initiative's Energy Efficiency Financial Institutions Group (EEFIG). Climate Strategy has supported energy transition policy development in Mexico, France, UK and Spain and continues to implement leading low carbon business solutions for global clients. Two years ago, Climate Strategy launched a subsidiary called Energy Efficiency Capital Advisors which has structured and executed ten energy efficiency placements worth over Euro 30mm from Iberian cities, companies and buildings for international investors.

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Summary for Policymakers

To meet the objectives of the Paris Agreement Europe will need to transition to a net-zero emissions economy by or before 2050[1]. This represents a major transformation. We will need all the technologies that we have today—wind and solar among others—to continue scaling at an exceptional pace, but those alone will not be enough. We also need to rapidly increase the readiness and deployment of the next generation of low-carbon technologies, innovative and enabling business models and customer engagement in all sectors of the economy that use or produce energy: electricity, transportation, manufacturing, materials and construction, and agriculture.

To accomplish this transformation, Europe will need to continue to attract and train world-class scientists and entrepreneurs, to develop the products and solutions that can decarbonize Europe's energy, industrial and agricultural systems. Increased levels of targeted research and innovation ("R&I") funding from public and private sources are required along with more risk-tolerant and patient capital, as well as supportive public policies so that successful projects can be deployed much faster.

As Europe sets out its next research Framework Program Horizon Europe, its next seven-year budget and the set of instruments that will support Europe's decarbonization and growth ambitions, this report builds a set of forward-looking recommendations on how to orient future R&I funding to deliver competitive net-zero decarbonisation. It looks in depth at what it will take to fully decarbonise five sectors: Power, Transport, Buildings, Industry and Agriculture, Forestry and Land Use ("AFOLU") drawing upon understandings and insights created by the low carbon pathways analysis and tools produced as a part of ECF's Net-Zero 2050 series of publications[2]. The experts engaged in this scenario analysis developed 58 "decarbonisation strategies" which combine to provide sector decarbonisation pathways for the five sectors to deliver a net-zero emissions economy in Europe by 2050. These strategies were used as the basic tools to inform an expert survey focused on Europe's R&I investment needs to deliver them. The conclusions of this work are driven by our meta research and assessment of past climate-related public and private R&I investments, combined with the input from 50 experts from 39 institutions working on energy, climate and innovation.

1 Energy & Climate Intelligence Unit. (2018). Net Zero: why? In *Net Zero*. Retrieved from https://eciu.net/briefings/net-zero/net-zero-why

2 ECF Net-Zero Series "Net Zero By 2050: From Whether to How" (2018) Retrieved https://europeanclimate.org/wp-content/uploads/2018/09/NZ2050-from-whether-to-how.pdf

Finding #1: Europe's climate-related R&I investments are not commensurate with the scale of the net-zero challenge

Europe is the third largest investor in research and innovation after China and the US, and it produces one third of all high-quality scientific publications. For this, Europe invests around 2% of GDP, or just over Euro 300 billion annually, in research and innovation across all sectors. European R&I investment is increasing, and in 2017 grew by 7% year-on-year. However, most Member States are still far from reaching their pledges made in 2000 to increase R&I investment intensity across their economies to an aggregate of 3% of EU GDP, to match the R&I intensity of other leading global regions.

Around two thirds of EU R&I investment comes from the private sector, totalling around Euro 200 billion per annum. This R&I investment is highly concentrated, with over 90% coming from just 567 companies. While it is hard to identify[3] the proportion of European R&I that is climate-related from the disclosed numbers, we find that only 3-4% of private R&I investments, or Euro 7.2 billion annually, is being invested by 102 companies directly working in climate-relevant sectors.

Annual public-sector R&I investments in Europe reached Euro 100 billion in recent years. This largely comes from higher education institutions (60%) and national governments (30%), with EU-level R&I programmes contributing just 8% to overall public R&I investment. Here again, it is hard to uncover the share of general public-sector R&I that is climate-related, but – for scale - the 35% climate earmarking of the EU's Horizon 2020 programme alone (Euro 3.8 bn per annum) is equal to half the identifiable private R&I investments flowing into climate-related sectors. This creates a historic opportunity for the EU's planned Horizon Europe programme to focus on decarbonisation and leverage co-funding to enable net-zero emissions outcomes.

Finding #2: Concretely, Europe needs to increase its climate-related R&I in the 2021-27 period by a third to reach the Paris Agreement goals

Closely linked to Finding #1, both the experts responding to this work, and those contributing to ECF's Net-Zero 2050 pathway modelling work[4], believe that Europe should increase its climate-related R&I in the 2021-27 period to allow new innovative technologies, products and businesses the time to scale and deliver the economy-wide decarbonisation required under optimal pathways, and to deliver the maximum societal benefits of this transition. We place the magnitude of this increase at least one third, in line with Member States' year 2000 commitments to increase overall R&I investments to 3% of European GDP by 2020.

3 The proportion of European R&I is hard to identify because many large firms, such as car and chemical manufacturers who invest significant amounts of R&I, do not provide a specific breakdown of the categories in which they invest.

4 ECF Net-Zero Series "From Whether to How" (2018) Retrieved https://europeanclimate.org/wp-content/uploads/2018/09/NZ2050-from-whether-to-how.pdf

Specifically, the expert survey that assessed the detailed R&I priorities for identified net-zero decarbonisation strategies concludes that:

1. **Climate-related R&I investment is key to deliver net zero emissions:** R&I is very relevant in 80% of the component decarbonisation strategies in Power, Transport, Buildings, Industry and Agriculture, Forestry and Land Use to deliver net-zero emissions. Responders to our survey identified that R&I funding needs to increase in three quarters of the strategies to deliver net-zero 2050 outcomes and the contributors to ECF's climate modelling[5] saw the "innovation gap" as being 25% additional innovation over a 75% increase aligned with existing efforts;

2. **Europe can build competitive advantages in many of the decarbonisation pathways:** Experts see opportunities for Europe to build global competitive advantages through R&I investment in all of the five climate-relevant sectors, however this opportunity is not evenly spread and some of the 58 decarbonisation component strategies offer greater potential competitive advantages than others;

3. **Innovation is required at many levels, not just in the production of new technologies:** While experts identify that the largest proportion (40%) of the necessary R&I is required to develop new or improve existing technologies, Europe's decarbonisation challenges also require substantial innovation at the product, business model and societal levels, in turn supporting a more mission-oriented approach to decarbonisation (e.g. full sector decarbonisation or zero-carbon cities);

4. **Public and Private R&I investments need to scale-up together:** Experts identified the need for a balanced instrument mix to fund European decarbonisation split evenly between private and public-sector R&I investment instruments. Experts flagged that just a quarter of identified R&I investments would require public sector grants, meaning that it is equally important to upscale soft loans and risk sharing instruments in order to facilitate an increase in private sector equity and debt products;

5. **Five "sector decarbonisation missions" could help deliver Net-Zero 2050 outcomes:** Experts identified five sector-level missions in Power, Transport, Buildings, Industry and AFOLU that would accelerate their decarbonisation. While it remains unclear whether a sector-level mission is sufficiently broad and ambitious, these can be used to inspire and contribute to an over-arching EU-level mission to deliver the innovation requirements to reach net-zero emissions in the whole economy before 2050.

Europe can build competitive advantages through many of its decarbonisation strategies

5 ibid

Recommendations for Europe's next Research and Innovation support programme

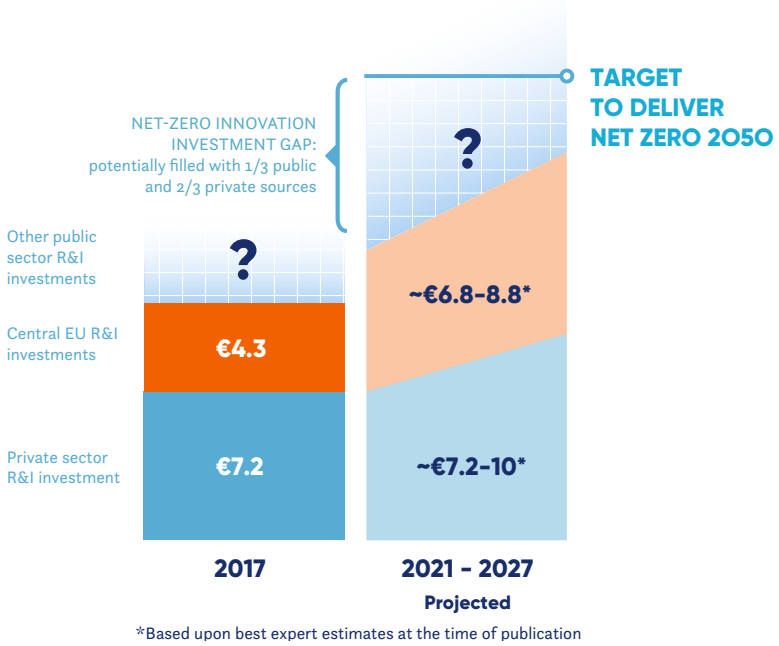
As European institutions prepare to define the scale and shape of its two most important EU-level instruments that will facilitate the identified R&I increase and up-scaling of low carbon assets -- Horizon Europe and InvestEU - the evidence from the experts surveyed supports the following EU-level policy recommendations:

» Horizon Europe's climate-related R&I allocation should increase: R&I invested between 2021-27 is likely to be the last significant R&I funding to have time to deliver new low carbon innovation that can scale-up to deliver a net-zero economy by 2050. ECF's Net-Zero 2050 climate pathway modelling identifies a necessary one third increase in innovation to enable this net-zero decarbonisation by 2050. In this context, Horizon Europe should require nearly half (47%, up a third from 35%) of its funding to be relevant to climate action.

» The climate element and impacts of R&I investments need to be more transparent and tracked in Horizon Europe, but also better disclosed by the private sector: Firstly, a climate impact pathway should be defined for Horizon Europe and its R&I allocations should be tracked against the EU's long-term climate and energy targets, and the Paris Agreement. To deliver this transparency, as a part of the grant agreement, lead beneficiaries of Horizon Europe funding should estimate the climate-relevant percentage of their projects' outcomes. This level of climate-related tracking and transparency should also be a priority for InvestEU and other EU-level funding instruments. This would allow increased connectivity to, and stimulation of the later stage public and private investments which are also required, subsequently to R&I, to deliver successful decarbonisation missions.

» Net-Zero emissions in Europe by 2050 requires concerted collaboration on climate-related R&I collaboration between the public and private sectors: EU-level R&I funding instruments, together with other public sources, should increasingly enable and facilitate increased private sector climate-related R&I. The public sector alone is unable to deliver the product and business model-level innovation and therefore economy-wide transformation required. This means that Horizon Europe, European Innovation Council and the R&I window of InvestEU can use mission-led and sector-level decarbonisation pathways to further direct and increase private sector co-investments through more innovation partnerships and collaborative financing structures. Given the extensive debate on mission scope among experts, and the five "sector level" missions described in this report, perhaps the only EU-level Mission required is that to deliver Net-Zero emissions by 2050.

Chart 1: Climate relevant R&I invesments (€Billions)



Please see Glossary of Terms for formal definitions of key terms used in the text.

Innovation for Decarbonisation

"Research is the process for the creation of ideas and innovation is how we make use of them"

In 2011, the European Commission published its Roadmap[6] for Moving Towards a Competitive Low Carbon Economy in 2050. This document laid out a vision of how to deliver the EU leaders' objective to reduce emissions by 80-95% by 2050 compared to 1990[7]. These EU 2050 emissions reduction targets were set in October 2009, based on 2007 Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4) climate science and a set of core assumptions (technologies, costs, growth, interest rates, innovation etc.) which have evolved considerably in the past decade. In recognition of these new realities, and to align Europe's 2050 targets with the Paris Agreement, in March 2018 the European Council[8] asked the European Commission to produce a new Long-Term Climate Strategy (LTCS) by the first quarter of 2019.

Since these 2050 decarbonisation objectives were set, the cost of delivering solar power and the price of lithium-ion batteries have respectively fallen by 76% and 79%, and the price of wind power has fallen by 38%[9]. Even without additional policy support, global investments in zero emissions power generation are expected to reach $10 trillion (2018-2050) and the rates of innovation and technology cost reductions observed over the last decade (in solar, batteries and wind power) are set to continue[10]. Clearly, the many innovations and technological breakthroughs at all levels within the supply chains of wind and solar power and electric vehicles have, and will continue to, enable the decarbonisation of the European economy. Nevertheless, the question remains: Is this enough?

To meet the targets of the Paris Agreement, and limit global warming to well below 2°C, emissions need to be reduced as fast as possible and all economies will need to reach net-zero emissions[11] as soon as possible in the second half of the century, going net negative soon thereafter[12]. This implies that countries with greater historic responsibility and means should go faster in order to leave more time for poorer countries. A number of countries, including New Zealand, Norway, France, Sweden and Portugal, have already made commitments to reach net zero emissions by or before 2050. To reach net-zero emissions -at an EU-economy wide level by 2050 means delivering successful decarbonisation strategies across five sectors: Power, Transport, Buildings, Industry and AFOLU.

6 European Commission. (2018). The European Commission is looking at cost-efficient ways to make the European economy more climate-friendly and less energy-consuming. In 2050 low-carbon economy. Retrieved from https://ec.europa.eu/clima/policies/strategies/2050_en

7 In October 2009, EU leaders agreed in the European Council Conclusions to reduce GHG emissions by 80-95 percent by 2050 – a target derived from the IPCC's Fourth Assessment Report (AR4 – 2007), that was meant to be consistent with international efforts to limit the global temperature increase to 2°C and is "in the context of necessary reductions according to the IPCC by developed countries as a group". Found here: Council of the European Union. (2009). Council Conclusions on EU position for the Copenhagen Climate Conference (7-18 December 2009). In 2968th ENVIRONMENT Council meeting Luxembourg, 21 October 2009. Retrieved from https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/envir/110634.pdf

8 "The European Council invites the Commission to present by the first quarter of 2019 a proposal for a Strategy for long-term EU greenhouse gas emissions reduction in accordance with the Paris Agreement, taking into account the national plans". Found here: European Council. (2018). European Council meeting (22 March 2018) – Conclusions. Retrieved from http://www.consilium.europa.eu/media/33457/22-euco-final-conclusions-en.pdf

9 Bloomberg NEF. (2018). Tumbling Costs for Wind, Solar, Batteries Are Squeezing Fossil Fuels. In Blog. Retrieved from https://about.bnef.com/blog/tumbling-costs-wind-solar-batteries-squeezing-fossil-fuels/

10 Bloomberg NEF. (2018). Overview. In New Energy Outlook. Retrieved from https://about.bnef.com/new-energy-outlook/

11 Rogelj, J., Popp, A., Calvin, K., Luderer, G., Emmerling, J., Gernaat, D., . . . Fujimori, S. (2018). Scenarios towards limiting global mean temperature increase below 1.5 °C. *Nature Climate Change*, 1758-6798. doi.org/10.1038/s41558-018-0091-3

12 1.5 degrees will require global GHG emissions to reach net zero by 2055-2070. Source: Rogelj et al, Nature Climate Change 2018; van Vuuren et al, Nature Climate Change 2018; Krieger et al, Phil. Trans.,2018;Griscom et al, PNAS, 2018, IPCC, AR5, 2014

Europe is world-class at research, publishing one third of all high-quality scientific publications globally, and setting its record level for patent applications in 2017

The European Commission's 2050 Roadmap[13] from 2011 signalled the need for action in each of these five emitting sectors (described then as "power generation, industry, transport, buildings, construction and agriculture") and noted the differences that exist between sectors in the relative amounts and speeds of potential emissions reductions. Since its 2011 publication, innovation investments, policy progress, zero-carbon asset deployment and consumer trends have shaped the relative decarbonisation performance in each sector, and the relative clarity with which leaders can envision net-zero emissions from each of these segments of their economies. Innovation has driven substantial progress on many fronts, enabling policymakers to embrace greater ambition in delivering clean power or electric transport, and giving them confidence to extend that innovation and transformational experience to other sectors where decarbonisation progress has not been as strong or where the technological solutions are less mature.

In February 2015, the European Commission highlighted five dimensions of its "Energy Union" policy framework. The fifth dimension of Energy Union is: Research, innovation and competitiveness. Research is defined by the Commission as the process of creating ideas, processes, technologies, services or techniques that are new to the world, whereas innovation is defined as introducing something new to a given organisation - but not necessarily new to the world. For innovation to be beneficial, the Commission notes, it must be useful and valuable, and can often be monetised[14].

Energy Union embraces an innovation-led transition to a low carbon economy, guided by EU technological leadership and the development of industrial production capabilities and technology supply chains. This will require a closer collaboration between research, industry, the financing sector and public authorities and an efficient industrial strategy which enables European industry to benefit from first-mover advantages, both domestically and within international technology markets, and which delivers competitiveness and jobs.

As underlined by ECF's Net-Zero 2050 climate pathways and the expert contributions to this report, the transformational change needed to deliver net-zero emission economies cannot rely on technological innovation alone. Innovation must also occur at the societal and cultural level (e.g. in order to address over-consumption, mobility patterns, dietary habits notably meat eating), as well as within the business models, job profiles, products and services which make-up the European economy. Many of these types of innovation can be policy-driven or more appropriately incentivised. Carbon removals will need to be scaled-up in Europe as fast as is sustainably possible in nearly all net-zero scenarios. These, together with future negative emissions technologies, will be needed to provide flexibility for innovation to mature in tougher sectors (e.g. aviation, freight, homes etc.) as well as to underpin the eventual net negative emissions that will be needed.

Europe's world-class research can be amplified by innovation missions

Europe is world-class at research, publishing one third of all high-quality scientific publications globally, and setting its record level (165,590) for patent applications in 2017[15]. However, it is argued that the European economy is not as good as others at promoting, funding and scaling-up these insights and technologies to build market-leading and innovative businesses – at a time when growth tends to be increasingly technology-led[16].

13 European Commission. (2011). COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Energy Roadmap 2050. Retrieved from https://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=pXNYJKSFbLwdq5JBWQ9CvYWyJxD9RF4mnS3ctywT2xXmFYhlnlW1!-868768807?uri=CELEX:52011DC0885

14 European Commission. (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European investment Bank. In Brussels, 25.2.2015 COM(2015) 80 final. Retrieved from https://setis.ec.europa.eu/system/files/integrated_set-plan/communication_energy_union_en.pdf

15 European Patent Office. (2018). Annual Report 2017. [Website]. Retrieved from https://www.epo.org/about-us/annual-reports-statistics/annual-report/2017.html

16 European Commission. (2018). Science, Research and Innovation Performance of the EU 2018 Strengthening the foundations for Europe's future. Retrieved from https://ec.europa.eu/info/sites/info/files/srip-report-full_2018_en.pdf

In the Commission's analysis[17] of Europe's strengths and weaknesses in research and innovation it notes a relative strength in "incremental innovation"[18]. Incremental innovation has been seen in Europe in space, aeronautics, pharmaceuticals, electronics, renewable energy, bio-based industries and advanced manufacturing.

EU Innovation policy, since 2016, has therefore been directed to foster "Open Innovation"[19] – the creation of a positive ecosystem which can more successfully convert Europe's leading research into innovation, and get these results to market.

More recently, EU policymakers have begun to consider "mission oriented" approaches to foster new innovation collaboration among relevant stakeholders and increase public-private sector collaboration. Missions, like the Apollo mission that put a man on the moon, are bold and can activate innovation across sectors, and among multiple actors across multiple disciplines. Missions should also enable bottom-up solutions and experimentation.

> In her strategic recommendations on mission-oriented research and innovation in the EU[20], Professor Mariana Mazzucato identifies a set of criteria for European missions, including being: Bold, inspirational and having a wide societal relevance; Targeted, measurable and time-bounded; including ambitious but realistic research and innovation actions; Cross-disciplines, actors and sectors; and having multiple potential bottom-up solutions. As the first of three examples of a potential EU-wide mission, Professor Mazzucato proposes: Reach a net-zero greenhouse gas emissions balance for 100 European cities by 2030[21] – something which C40 cities have already begun to pledge. Given that 80% of European citizens will live in cities by 2030, and cities are important drivers of innovation, turning 100 cities across Europe into fully carbon-neutral places to live and work, would provide some 40% of European urban citizens with cleaner air and be a major step forward towards achieving the objectives of the Paris Agreement[22].

Using mission-orientation to align public and private sector objectives and resources, supported by bold and ambitious policies designed to decarbonise Europe's economy and deliver net-zero emissions by 2050, is a powerful idea. If European innovation policy can support technological advancement and the full supply chain of innovation through product development, new business models and to economy-wide deployment, then a virtuous circle can be created: breakthrough success will in turn support and encourage more ambitious decarbonisation policies, and so on. Denmark is an example of a country that has been on a mission to deliver renewable energy since the oil-crisis in the 1970s, and certainly with the benefit of hind-sight, Denmark's energy transition appears very "mission-oriented"

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17 European Commission. (2018). A renewed European Agenda for Research and Innovation - Europe's chance to shape its future. In Publications. Retrieved from https://ec.europa.eu/info/publications/renewed-european-agenda-research-and-innovation-europes-chance-shape-its-future_en

18 See Glossary of Terms: the process of adding or sustaining value for existing products, services and processes

19 EU Publications. (2016). Open innovation, open science, open to the world: A vision for Europe. In EU law and publications. Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/3213b335-1cbc-11e6-ba9a-01aa75ed71a1

20 EU Publications. (2017). Mission-oriented research & innovation in the European Union A problem-solving approach to fuel innovation-led growth. In EU law and publications. Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/5b2811d1-16be-11e8-9253-01aa75ed71a1/language-en

21 C40 Cities. (2018). 19 Global Cities Commit to Make New Buildings "Net-Zero Carbon" by 2030. In Media. Retrieved from https://www.c40.org/press_releases/global-cities-commit-to-make-new-buildings-net-zero-carbon-by-2030

22 UNFCCC. (2018). The Paris Agreement. In Process and meetings. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Denmark's "Mission" to reach 100% renewables[23]

» **Bold and with a clear direction, target and time-bounded:** Denmark's energy transition targets 100% renewable energy in all sectors by 2050. By 2020, at least half of Denmark's electricity will be generated by wind power and Danish global wind power leader Vestas has installed 94 GW of wind turbines in 79 countries, more wind power than any other company in the world[24]. By 2050, the country aims to have an energy system independent of fossil fuels. Besides renewables, improvements in energy efficiency and an enabling environment through the coupling of electricity and end-use sectors will be key to achieve this target.

» **Wide societal relevance and engagement:** From the earliest days of Denmark's energy transition, policy makers understood the importance of giving citizens a stake in clean energy projects. The country created a grant programme in the 1980s that covered 30% of the initial capital costs of wind projects. This has resulted in the development of local cooperatives, giving individuals and households a chance to invest in wind energy projects. Five years after the programme started, the cooperatives' 100,000 investors were responsible for nearly 90% of all turbines installed in Denmark. After more than 10 years, not only do investors have their money back, they also receive a 7% annual return on their investment.

» **Multiple Bottom-up Solutions:** Denmark's decision many years ago to deploy district heating systems is a key element of its energy transition. District systems can be much more efficient than the more common model of having every residence or business provide its own heat through decentralised systems. District systems can be powered from multiple sources including local industry (waste heat), wind and solar systems. An example of a solar-based district heating system is the one located in Dronninglund. It has a capacity of 26 megawatts (MW), covering around 40% of the annual heat demand. Dozens more solar systems have been installed or are in the works across Denmark. Copenhagen also has launched a district cooling system that draws cool water from the city's harbour to pre-chill water destined for buildings with large cooling loads. The city estimates district cooling reduces electricity consumption by 80% compared to conventional air conditioning.

» **Innovation across multiple disciplines, actors and sectors:** Unleashing the creativity of public-sector entrepreneurs has led to innovative solutions for decreasing Denmark's carbon footprint by sector coupling. For example, a local water service company has developed a technology to utilise renewable energy from wastewater, a waste product that is viewed nearly everywhere else as a problem to be managed. The company turned wastewater and other organic material into fertiliser for agricultural crop production, and also managed to produce renewable heat and electricity from it.

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23 Case study adapted from Box 3 in IRENA's publication found here: IRENA. (2017). Accelerating the Energy Transition through Innovation, a working paper based on global REmap analysis. Retrieved from http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA_Energy_Transition_Innovation_2017.pdf

24 Vestas. (2018). [Website]. Retrieved from https://www.vestas.com/

Funding Innovation in Europe

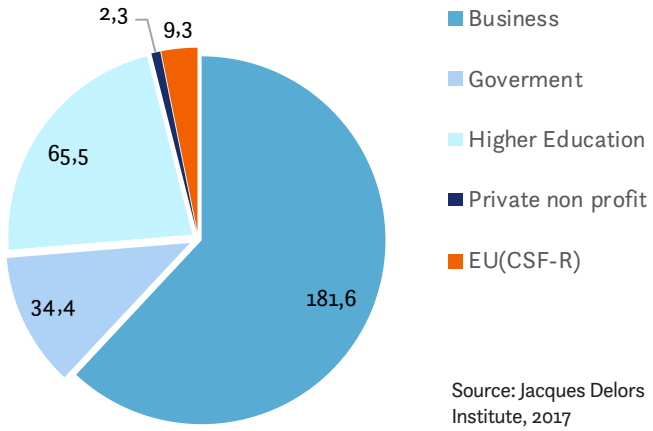
> *"Research is the process of creating ideas, processes, technologies, services or techniques that are new to the world. Innovation introduces something new to a given organisation - but not necessarily new to the world. For innovation to be beneficial, it must be useful and valuable, and can often be monetised."*
>
> Paraphrased from EU Commission definitions taken from Energy Union COM Feb 2015.

With just 7% of the world's population[25], Europe represents nearly 24% of global GDP[26], and the EU accounts for 20% of global research and development (R&D) investment. Specific innovation investments are harder to track and measure than R&D, but as an indication, R&D investments in Europe are estimated at around 2% of GDP[27], or over Euro 300 billion annually.

Around two-thirds of the EU's R&D is invested by companies, totalling some Euro 200 billion annually, but European companies' R&D investment intensity (1.3% of GDP) is lower than their international competitors in China (1.6%), the United States (2%), Japan (2.6%), and South Korea (3.3%)[28]. Public R&D investments in Europe, currently Euro 100 billion annually, are growing and represent a higher percentage of GDP than in most large countries except South Korea. Central EU-level R&D funding is less than 10% of total public European R&D spending[29] as shown in the chart below.

Europe has had a long-standing target to grow its R&D investments to 3% of GDP (1% public and 2% private investment). This was set by the European Commission and endorsed by the European Parliament and EU Council as part of the Lisbon Strategy in 2000, and then reaffirmed in 2010, as one of the five headline targets of the "Europe 2020 Strategy".

Chart 2 : R&D expenditure in the EU by source of funds in 2014 (in billions of euros), of which 3-4% climate-related



Source: Jacques Delors Institute, 2017

25 European Commission. (2018). A renewed European Agenda for Research and Innovation - Europe's chance to shape its future. In Publications. Retrieved from https://ec.europa.eu/info/publications/renewed-european-agenda-research-and-innovation-europes-chance-shape-its-future_en

26 Jacques Delors Institute. (2017). Making the Energy Transition a European Success: Tackling the Democratic, Innovation, Financing and Social Challenges of the Energy Union. Retrieved from http://www.institutdelors.eu/wp-content/uploads/2018/01/makingtheenergytransitionaeuropeansuccess-study-pellerincarlinfernandesrubio-june2017-bd.pdf?pdf=ok

27 European Commission. (2017). LAB – FAB – APP — Investing in the European future we want. Retrieved from http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/hlg_2017_report.pdf

28 European Commission. (2018). A renewed European Agenda for Research and Innovation - Europe's chance to shape its future. In Publications. Retrieved from https://ec.europa.eu/info/publications/renewed-european-agenda-research-and-innovation-europes-chance-shape-its-future_en

29 European Commission. (2017). Prepared by the R&I family DGs Issue paper s for the High-Level Group on maximising the impact of EU research and innovation programmes. Retrieved from https://ec.europa.eu/research/evaluations/pdf/hlg_issue_papers.pdf

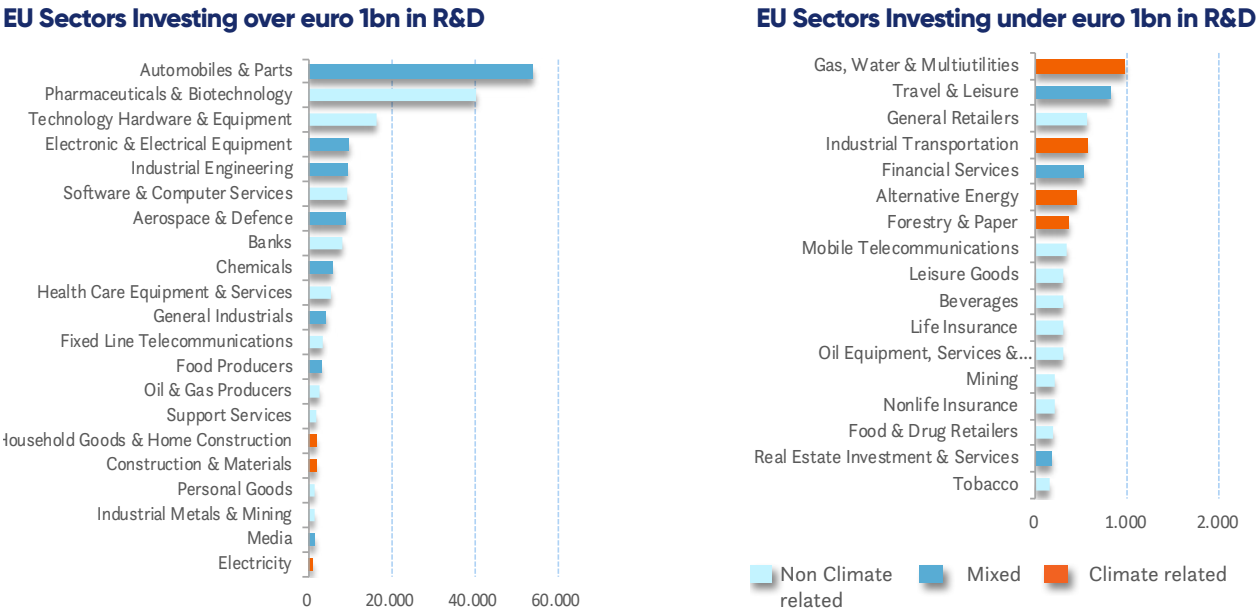
Private Sector Innovation Investment

Global business-funded R&D investments are highly concentrated, with 90% of the world's business-funded R&D being made by 2,500 companies, which together invest a total of €742 billion[30] per annum. Of this, over half is invested by just the top-100 companies, of which 30 are European. R&D investment by large firms in Europe grew faster in 2017 than the global average (+7% vs +5.8%), driven mainly by the ICT, health and automotive sectors. However, tracking private sector R&D spend is a huge challenge, and characterising innovation investments - which can include venture capital and private equity - as well as sub-dividing corporate R&D, is a near impossible task.

Corporate R&D Investment is dominated by a handful of large firms

Among the top 1,000 European companies, investing around Euro 200 billion in R&D, there are just six companies (Vestas, Nordex, SMA Solar Technology, Senvion, Solarworld and Centrotherm) that are explicitly categorised as "Alternative Energy". Together these companies invested Euro 440 million in R&D in 2017[31]. They can be considered the "pure-plays" where clearly 100% of their R&D is climate-related. Among European utilities, there are just two whose R&D investments stand out: Electricite de France (at Euro 660 million) and Iberdrola (at Euro 211 million) in 2017. The remaining 14 EU electricity firms have R&D investments of Euro 10-50 million per annum.

Chart 3: EU Companies, R&D Investments by Sector (in billions of euros)



30 European Commission. (2017). Higher than global average: European companies jack up investment into research and development. In Policies, information and services. Retrieved from http://ec.europa.eu/research/index.cfm?na=na-041217&pg=newsalert&year=2017

31 European Commission. (2017). The 2017 EU Industrial R&D Investment Scoreboard. In Economics of Industrial Research and Innovation. Retrieved from http://iri.jrc.ec.europa.eu/scoreboard17.html

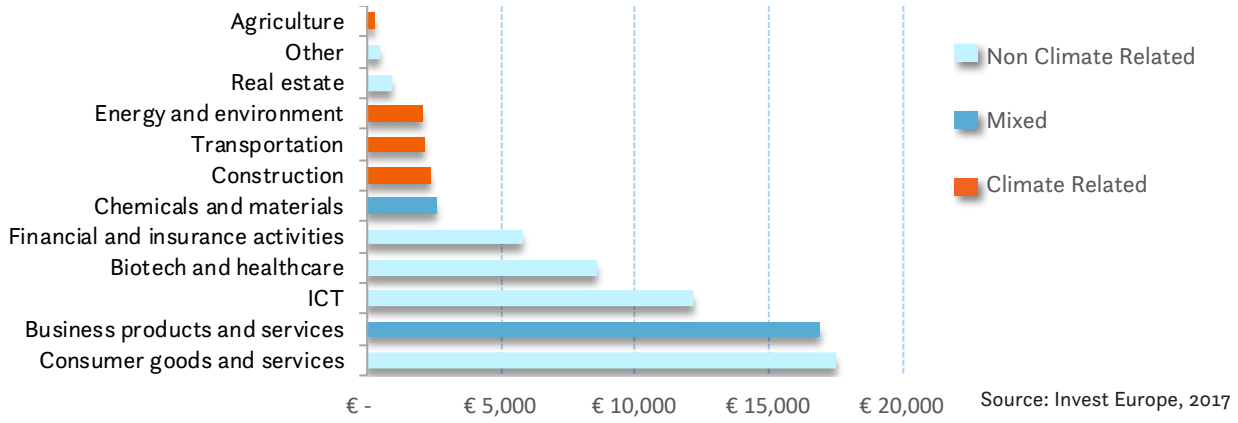
In order to define a climate-relevant universe for tracking private sector R&D investments, we have identified 102 EU companies categorised as Alternative Energy, Electricity, Household Goods & Home Construction, Materials & Construction, Gas, Water & Multiutilities, Industrial Transportation and Forestry & Paper. Chart 3 depicts business-funded R&D expenditure in Europe, divided by sector and coloured by climate-relevance. It shows that the R&D invested by the 102 climate-relevant companies totalled Euro 7.2 billion in 2017.

Private Capital is important but contributes less than 10% of European R&D budgets

The market capitalisation of EU listed companies is over Euro 10 trillion, whereas the total private capital managed in Europe in 2017 was Euro 640 million, i.e. just 6% of the value of EU listed companies[32]. Venture capital (VC), perhaps the most "innovative" source of private capital, totalled euro 6.4 billion in 2017 – which is equivalent to just 3% of listed companies' R&D budgets (and 0.064% of their market capital).

In 2017, 7,000 companies in Europe received a combined total Euro 72 billion of private capital investment, and 87% of these recipients were SMEs (see chart 4). If the same level of R&D investment by privately held companies is assumed as for listed firms (i.e. 2% of their market capitalisation), this implies that aggregate R&D investments made by privately held EU companies are in the region of Euro 12-13 billion per annum. Clearly, R&D spend is a poor proxy for successful innovation, but private-equity backed firms are still a relatively small component, albeit potentially more innovative (Euro for Euro)[33], than publicly listed firms.

Chart 4: Sector distribution of Euro 71 billion private capital invested in Europe in 2017



Source: Invest Europe, 2017

Of the total Euro 72 billion private capital invested in Europe in 2017, Euro 2bn (or 3%) was invested in the "energy and environment" sector, in 300 companies. If we sum climate-related private equity investments, including in Energy & Environment, Agriculture, Transportation and Construction businesses, the total is Euro 6.8 billion – around 10% of the total market. Climate-related sectors tend to have a high capital intensity, compared to biotech, ICT and other services businesses, which explains the high concentration of private capital in those sectors.

32 Aggregate EU company market capitalisation and private capital under management extrapolated from the sources below respectively:

Index Mundi. (2018). European Union - Market capitalization of listed companies: Market capitalization of listed domestic companies (current US$). In Capital Markets. Retrieved from https://www.indexmundi.com/facts/european-union/market-capitalization-of-listed-companies

Invest Europe. (2017). European Private Equity Activity. [Presentation]. Retrieved from https://www.investeurope.eu/media/711867/invest-europe-2017-european-private-equity-activity.pdf

33 Frontier Economics. (2013). Exploring the impact of private equity on economic growth in Europe: A report prepared for the EVCA. Retrieved from https://www.investeurope.eu/media/12929/Frontier-Economics-Report.pdf

Net-zero 2050 pathways require large corporate champions

Europe's tendency toward "incremental innovation" is better understood by observing that 54% of European corporate R&D investment (Euro 108 billion) is directed by 30 companies[34], and Euro 48 billion of this comes from just nine automotive and related parts manufacturers.

Incremental innovation, however, will not deliver the significant transformation of so many sectors that is required to fully decarbonise Europe's economy to net-zero emissions by 2050. European utilities do not rank highly for R&D investment (the highest ranked utility in Europe is EDF at #56 investing Euro 660mm in 2017) and, aside from car manufacturers, the few EU companies investing large amounts in R&D with potentially transformative climate-relevant businesses are: Siemens, Airbus, Philips, and BASF.

Some argue that the economic transformation required to deliver an EU economy with net-zero emissions will be delivered by new innovative, venture capital backed companies whose breakthrough technologies and disruptive business models will unseat the incumbents. As mentioned above, however, venture capital remains under-developed in Europe, with just €6.4 billion invested in the EU, compared to €39.4 billion in the US. European VC funds are also often considered "too small" in size (€56 million on average compared in EU versus €156 million in the US)[35]. In addition, 30% of investments in venture capital funds in Europe come from public sources[36], with large private institutional investors stating small fund size and low returns as the main reasons for their lack of appetite for European VC funds.

The EU is home to 26 "Unicorn start-ups" (start-ups valued at over $1 billion) compared to 109 in the US, and 59 in China[37]. InvestEurope identifies fifty European "Unicorns" created from 2000-2016, however with the exception of Bla-bla-car (shared transport) it is hard to identify any whose business is targeted directly at emissions reductions or climate change. Moreover, researchers at MIT, suggest that the traditional VC may be the wrong finance model to build clean energy innovation[38] due to the high capital intensity required to develop energy assets and the relative competitive advantages (rapid, low cost replication and scalability) for software and biotech innovations.

European VC funds are getting bigger with their average size moving closer to Euro 100mm in 2018[39], and more institutional investors are getting involved to deliver a stronger European ecosystem for start-ups. Nonetheless, venture capital funds are unlikely to be the key vehicles to deliver transformational innovation investments, at the speed and scale necessary to decarbonise Europe's Power, Transport, Buildings, Industry and Agriculture, Forestry and Land Use sectors. The high capital intensity required for the up-scaling of Net-Zero emissions infrastructure and assets suggests a greater application of patient capital and the increased use of risk sharing instruments. Public and private capital will increasingly have to combine to deliver the cost reductions and future markets required to decarbonise at an economy-wide level.

34 In order of R&D Investment (2017): VW, Daimler, Robert Bosch, Astrazeneca, BMW, SANOFi, Siemens, Nokia, Bayer, Fiat Chrysler, Glaxosmithkline, Ericsson, Airbus, Boehringer Sohn, SAP, Continental, Renault, Allergan, Peugeot (PSA), Medtronic Public Limited, Philips, Novo Nordisk, Merck DE, ZF, Volvo, Basf, Telecom Italia, Banco Santander, Deutsche Bank, NXP Semiconductors. Data sourced from European Commission. (2017). 2017 EU Industrial R&D Investment Scoreboard. Retrieved from https://www.kowi.de/Portaldata/2/Resources/fp/2017-EU-Industrial-RD-Investment-Scoreboard.pdf

35 European Commission. (2018). VentureEU: Pan-European Venture Capital Funds-of-Funds Programme. In Press Release Database. Retrieved from http://europa.eu/rapid/press-release_MEMO-18-2764_en.htm

36 European Commission. (2016). Open innovation, open science, open to the world - a vision for Europe. In Policies, information and services. Retrieved from https://ec.europa.eu/digital-single-market/en/news/open-innovation-open-science-open-world-vision-europe

37 European Commission. (2018). A renewed agenda for Research and Innovation Europe's chance to shape its future. Retrieved from https://ec.europa.eu/info/sites/info/files/factsheet-a-_renewed-agenda-for_-research-and-innovation_may_2018.pdf

38 MIT Energy Initiative. (2016). Venture Capital and Cleantech: The Wrong Model for Clean Energy Innovation? Retrieved from https://energy.mit.edu/wp-content/uploads/2016/07/MITEI-WP-2016-06.pdf

39 Interview with Dr. Cornelius Muller, Director of Research at Invest Europe, July 2018.

The scaling-up of Net-Zero emissions infrastructure requires a greater application of patient capital and the increased use of risk sharing instruments

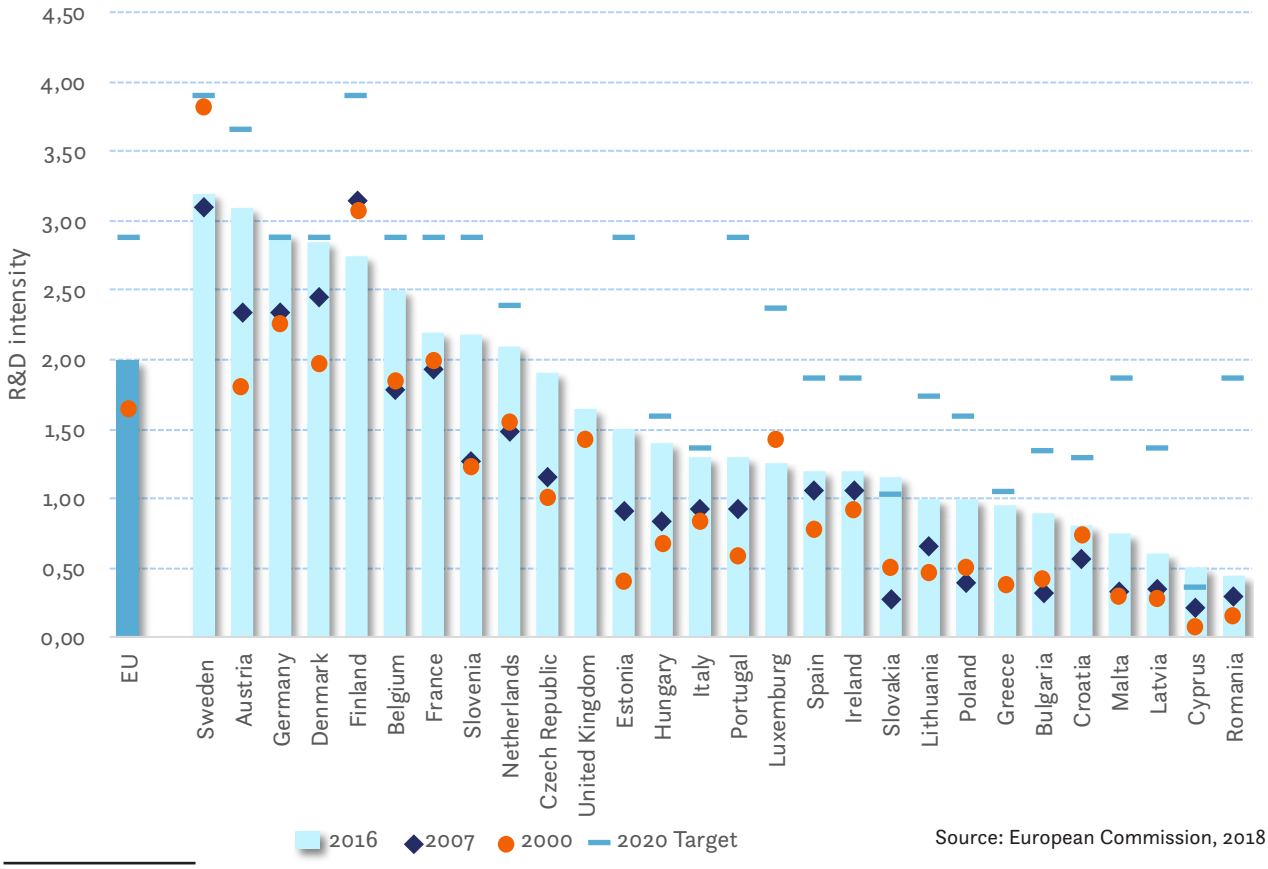
Public Research and Innovation Investments

European public R&D investments total over Euro 100 billion per annum, or 0.7% of EU GDP. While public investment provides a smaller share of Europe's overall R&D budget, it is a key lever to enable and facilitate Europe's decarbonisation alongside and supporting concerted policy action – especially where its leveraging potential can be harnessed. Public R&D investment grew in Europe from 2000-15 and only South Korea has a higher public R&D intensity globally.

EU Member States are better at Research than Innovation

Two key themes emerge from a high-level review of national R&D funding in the EU: Firstly, R&D intensity is still uneven among EU regions, with investment and research heavily concentrated in Western Europe; and secondly, nearly all member states still fall well short of their individual 2020 3% GDP intensity targets for R&D investment as illustrated in the chart below[40].

Chart 5: R&D intensity 2000, 2007, 2016 and 2020 target



Source: European Commission, 2018

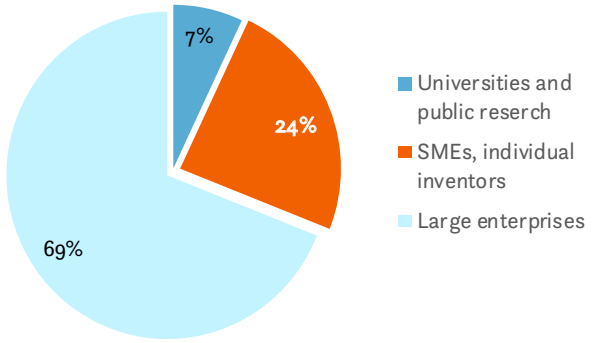
40 European Commission. (2018). Science, Research and Innovation Performance of the EU 2018 Strengthening the foundations for Europe's future. Retrieved from https://ec.europa.eu/info/sites/info/files/srip-report-full_2018_en.pdf

The institutional sources of public R&D funding in Europe are: Higher Education (60%), National Government (30%), EU (8%) and Private non-profits (2%). Basic research is the largest proportion of this spend and, as in most OECD countries, is performed mainly by universities and public research organisations. However, these institutions develop both the new scientific and technological knowledge and the human capital that can develop innovation throughout their careers to benefit the economy and society.

The Commission identifies the need to boost higher education's contribution to innovation specifically in its 2017 communication "on a renewed EU agenda for higher education". This is underscored by the fact that just 7% (as shown on chart 6) of the 165,590 patents applied for in 2017 at the EU Patent Office[41] are from universities and public research institutions. In Europe, too few PhD holders go on to work outside academia, compared to the US and Japan. Applied knowledge and interaction with future employers is recommended as a greater focus in doctoral programmes in higher education to improve innovation outputs[42].

There are thousands of national programmes and mechanisms used by EU Member States to fund innovation and the mapping of these (the "other public R&I") falls outside the scope of this paper, as does a comprehensive analysis of higher education funding. Suffice it to say that many national governments are also experimenting with a wider set of innovation funding instruments (including guarantees, equity and quasi-equity investments and accelerators) than in the past due to fiscal constraints.

Chart 6: Patent Applications in 2017

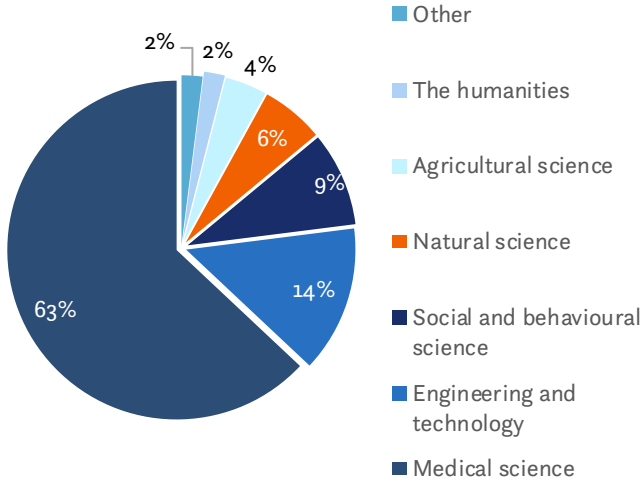


Source: European Patent Office, 2018

European Foundations are not highly focused on climate-related innovation

Looking at philanthropic capital, Europe has a long history of funding research through foundations (especially the UK, Sweden, Denmark and Germany). There are around 1,000 foundations (a category broader than "private non-profits", including company, university and public-sector foundations) funding research and innovation in Europe[43] with total assets of Euro 127 billion and an annual budget reaching Euro 5 billion.

Chart 7: Foundation Funding among EU Members by Reseach Areas



Source: European Commission, 2015

41 European Patent Office. (2018). Facts and figures 2018. The evaluation is based on a representative sample of patent applications treated by the EPO in 2017. It refers to the European Commission definition of SMEs (2003/361/EC). Data available in government and commercial databases as well as on company internet sites are analysed to allocate the applicant to one of the three categories. Depending on the company policy, the cross-ownership criteria can be difficult to evaluate. Retrieved from http://documents.epo.org/projects/babylon/eponet.nsf/0/06F1C17C676C4632C1258247004539D1/$FILE/facts_and_figures_2018_en.pdf

42 European Commission. (2017). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European investment Bank. In Brussels, 30.5.2017 COM(2017) 247 final. Retrieved from https://ec.europa.eu/education/sites/education/files/he-com-2017-247_en.pdf

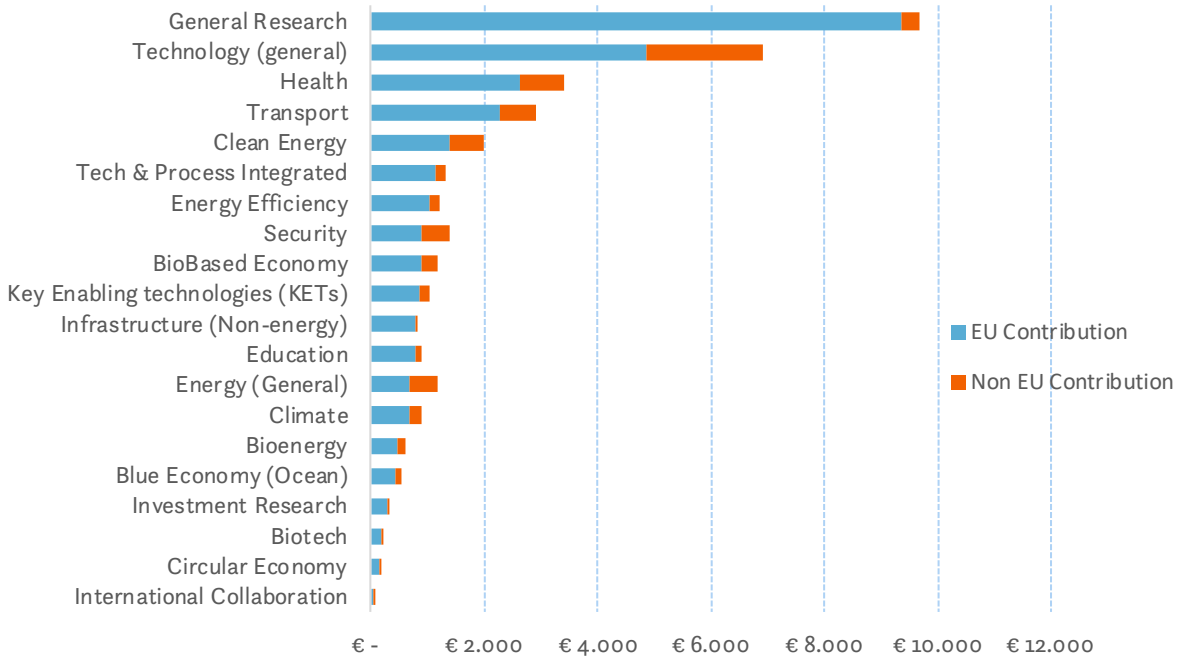
43 European Commission. (2015). Synthesis Report: EUFORI Study European Foundations for Research and Innovation. Retrieved from http://euforistudy.eu/wp-content/uploads/2015/07/Synthesis-Report.pdf

Foundation funding has been stable, and is strongly skewed towards EU Member States with a long tradition of foundation activity and thematically towards medical science (see chart 7). We estimate that foundations' climate-related R&I is likely to represent 10% or less of the total expenditures, a proportion which is broadly in line with the private sector. This would seem to be supported by the fact that much climate-related R&I is "international" or cross-border in nature and 90% of known foundation funding is local and/ or national. It is sometimes argued that additional philanthropy is a path to increased innovation, but it is difficult to identify where this new philanthropic capital will come from in Europe.

EU-level programmes can make a marked impact on climate-related R&I investments

Since 1984, the European Union has funded research and innovation through seven multiannual framework programmes (FP1-FP7) and, currently, Horizon 2020. Horizon 2020 was the biggest EU research and innovation programme ever launched with € 77 billion[44] of funding available from 2014-2020, focused in three pillars: excellent science, industrial leadership and tackling societal challenges. Horizon 2020 specifically targets getting ideas from lab to market, and attracting and working with additional private and national public innovation investments.

Chart 8: Funding of Horizon 2020 Projects in €bn (2014-2018), Category Breakdown



Source: CORDIS, 2018

Climate action is a central driver of Horizon 2020, which was designed to deliver the innovation necessary for a smooth transition to a low-carbon, climate resilient economy. 35% of the Horizon 2020 budget (c. Euro 3,8 billion per annum) is targeted for supporting projects and initiatives in different climate-related research and innovation areas[45] focusing on low-carbon technologies in energy, transport, industry and the construction sectors. In an analysis of over 16,900 Horizon 2020 projects funded over 3.5 years from its launch until 30th June 2018, the EU had contributed close to Euro 30 billion to Euro 37 billions of research and innovation projects[46] as shown in chart 8.

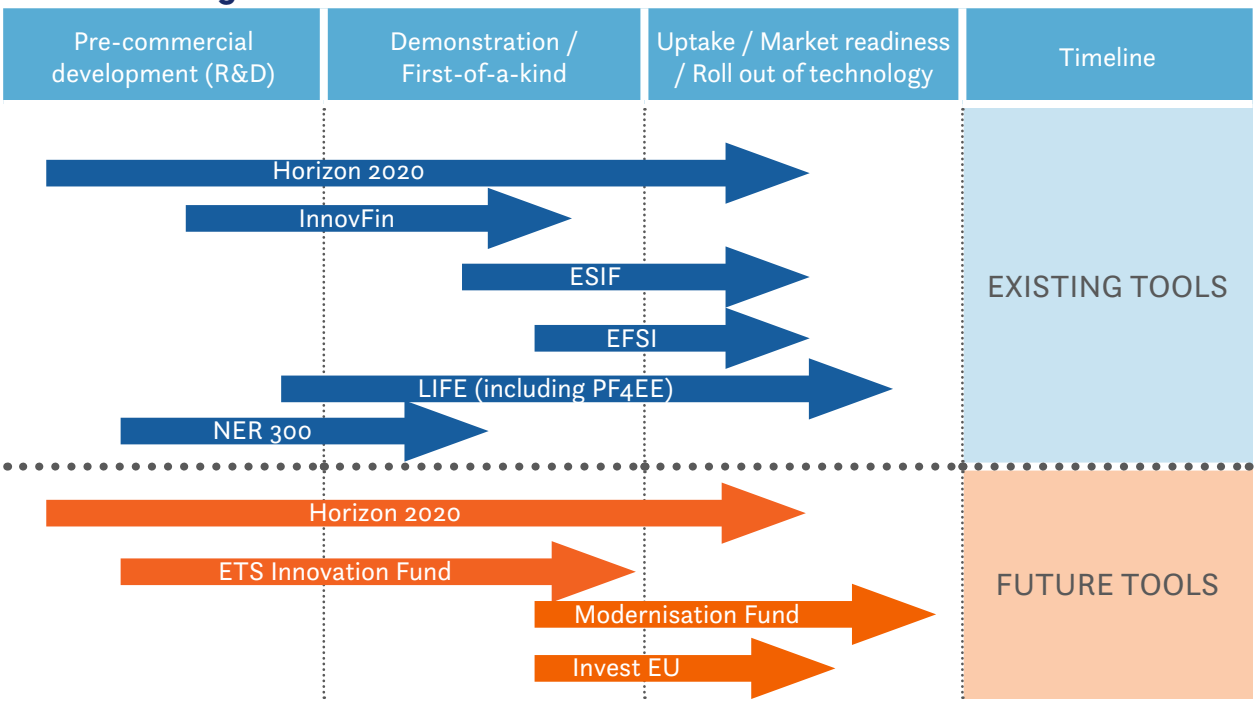
44 European Commission. (2018). Horizon 2020: Funding Areas. In INEA. Retrieved from https://ec.europa.eu/inea/en/horizon-2020

45 European Commission. (2018). International Action on Climate Change. In Policies, information and services. Retrieved from https://ec.europa.eu/clima/policies/international/paris_protocol/energy_en

46 European Commission. (2018). CORDIS - EU research projects under Horizon 2020 (2014-2020). In EU Open Data Portal. Retrieved from https://data.europa.eu/euodp/data/dataset/cordisH2020projects

While Horizon 2020 is the flagship EU R&I programme, there are a number of other EU-level instruments and mechanisms[47] which also support innovative technologies developed through the various phases from lab to market (illustrated in the table below), in addition to which the Commission also provides a series of tools and resources to support innovators[48].

Table 1: EU Programmes for Low-Carbon Innovation



Source: European Commission, 2018

Under Horizon 2020, the European Commission and the European Investment Bank Group (EIB and EIF) launched a new generation of financial instruments and advisory services in 2014, called InnovFin, to help innovative firms access finance more easily[49]. Since launch, EIB and EIF together have funded 110 innovative InnovFin projects with Euro 14 billion, in aggregate. InnovFin has a product designed for Energy Demonstration Projects (InnovFin EDP) to help EIB to finance innovative first-of-a-kind demonstration projects at the pre-commercial stage that contribute to the energy transition, particularly in the fields of renewable energy technologies, smart energy systems, energy storage, and carbon capture utilisation and storage. Having completed its first Euro 10mm loan in July 2016, the anticipated InnovFin EDP budgets target a total Euro 150mm for deployment for the 2019-20[50] time period.

European Structural and Investment Funds (ESIF) are comprised of five EU funds totalling Euro 110 billion from 2014-20. ESIF have "supporting the low carbon economy" as one of their five areas of focus, and have a target for climate action objectives to represent at least 20% of their spending (c. Euro 3 billion per annum).

The European Fund for Strategic Investments (EFSI) provides a first loss guarantee (of Euro 21 billion) that has enabled the EIB to promote, facilitate and invest in Euro 315 billion of strategic and infrastructure investments in Europe.

47 European Commission. (2018). Innovation Fund: Carbon Next Final Conference 17 July 2018 [Presentation]. Retrieved from carbonnext.eu/FinalConference-download-1/_/09_Innovation%2520Fund_DG%2520CLIMA.ppsx

48 European Commission. (2018). Open innovation resources: Policy initiatives, funding schemes and support services related to open innovation. In Policies, information and services. Retrieved from https://ec.europa.eu/info/research-and-innovation/strategy/goals-research-and-innovation-policy/open-innovation-resources_en

49 EIB. (2018). InnovFin – EU Finance for innovators. In What we Offer: Blending. Retrieved from http://www.eib.org/en/products/blending/innovfin/index.htm

50 Horizon 2020 Work Programme 2018 – 2020. (2018). EN Annex 9. Retrieved from https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/06._h2020-arf-2018-2020_06_10_2017_word_for_egreffe_rev2_for_prepublication.pdf

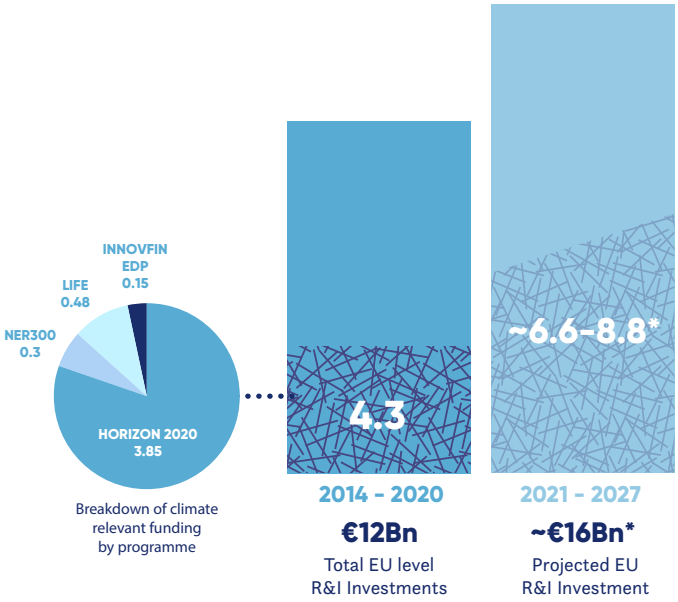
Going forwards, at least 40% of EFSI infrastructure and innovation projects aim to contribute to climate action and EFSI 2.0 will also explicitly target sustainable agriculture, forestry, fisheries and aquaculture[51]. Building upon the success of EFSI, InvestEU will seek to catalyse Euro 650 billion from 2021-27 in sustainable infrastructure; research, innovation and digitisation; small and medium-sized businesses; and social investment and skills; through the provision of Euro 38 billions of EU budget guarantees syndicated to projects through the collaboration of EIB, European international financial institutions and national promotional banks.

The LIFE programme is an EU funding instrument for the environment and climate action that is designed to provide co-financing of projects, with European added value, that contribute to the implementation, updating and development of EU environmental and climate policy and legislation. The 2014-20 LIFE budget is Euro 3.4 billion and it is worth highlighting that its Euro 485 million annual investment is 100% climate-related.

Another EU programme that is 100% climate-related is the NER 300 - a funding programme designed to support innovative low-carbon energy demonstration projects with a focus on the scaling of carbon capture and storage (CCS) and innovative renewable energy (RES) technologies. The NER 300 fund's budget was based upon the sale of 300 million emission allowances from the New Entrants' Reserve (NER) of the third phase of the EU emissions trading system. NER 300 has had an approximate size of Euro 2.1 billion[52], which has levered a larger amount of private sector investment. The size of NER 300's successor (the Innovation Fund) is expected to be between Euro 2-16 billion (depending upon EU ETS phase IV prices achieved for 400 million allowances); at the recent EU allowance price of Euro 20 the new fund would be Euro 8 billon.

Excluding EFSI guarantees and smaller climate related funds and EU-level innovation resources, EU-level climate-related funding from the above sources sums to over Euro 8 billion annually, a figure that exceeds the estimated Euro 7.2 billion annual private sector R&D investments into climate related sectors. EU-level funding can also explicitly target the crowding-in of other public and private sector resources (through instrument choice, institutional collaboration, partnerships, building climate-impact pathways for R&I and mission-oriented sector calls) and. For these reasons, EU-level R&I investments are the crucial lever that can catalyse the decarbonisation of the EU economy to deliver net-zero emissions by 2050.

Chart 9: Climate relevant funding in selected EU R&I programmes (€ billions)



51 European Commission. (2018). EFSI in the environment and resource efficiency sector. In Commission and its Priorities. Retrieved from https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan-europe-juncker-plan/investment-plan-results/efsi-environment-and-resource-efficiency-sector_en

52 Business Europe. (2016). Position Paper: EU ETS Reform: Making the Innovation Fund Fit - For – Purpose. Retrieved from https://www.businesseurope.eu/sites/buseur/files/media/position_papers/iaco/2016-11-02_businesseurope_position_paper_on_the_eu-ets_innovation_fund_-.pdf

EU Climate-related R&I Successes[53]

SOLAR JET FUEL: Researchers have produced 'solar' jet fuel from water and carbon dioxide

EU-funded researchers have successfully demonstrated the entire production chain for renewable kerosene using solar energy. Concentrated sunlight is used to trigger a reaction between CO2 extracted from air with water to produce avionics grade jet fuel. The technology has the potential to provide secure, sustainable and scalable supplies of jet fuel as well as diesel and gasoline, and even plastics.

CLEAN AIR IN CITIES: Fuel cell powered buses for clean public transport

Road traffic pollution is a major problem in many cities. One carbon free approach being tested in cities across Europe is a fleet of hydrogen fuel cell powered buses. They are just like normal buses but are powered by electricity generated using fuel cell technology developed by industry with EU support. These cells only need hydrogen and air and emit harmless water vapour.

GREENER WATER TRANSPORT: Building 100% electric ferries

Europe has around 900 ferries for cargo, cars and passengers, which account for 35 % of the world fleet. For more energy-efficient vessels that emit less carbon dioxide in the future, Norway has launched Europe's first 100% electric ferry and an EU-funded project will demonstrate a 40-km range electric ferry with a speed of 25 km/h, and a capacity of some 30 cars and 200 people to connect the island of Aeroe (DK) to the mainland.

DREAM HOUSE: A new house printed just for you?

3D printing is set to revolutionise the construction industry by allowing the manufacture of adapted building products. An EU-funded project is working towards producing a commercially viable onsite machine combining design parameters with production. It would make the construction industry more cost-effective and resource efficient.

NEVER ENDING BATTERY: EU funding made possible the development of a super battery

EU funding has helped an Estonian company produce an energy storage device called ultracapacitor, which is 100 times more powerful than an ordinary battery, and can withstand one million recharge cycles. Skeletons of ultracapacitors are based on graphene – a two-dimensional form of carbon with remarkable properties. The company has raised €13 million to build a manufacturing facility in Germany capable of producing millions of these new ultracapacitors a year.

53 European Commission. (2018). A renewed European Agenda for Research and Innovation - Europe's chance to shape its future. In Publications. Retrieved from https://ec.europa.eu/info/publications/renewed-european-agenda-research-and-innovation-europes-chance-shape-its-future_en

Expert Insights into Sectoral Innovation for Decarbonisation Challenges

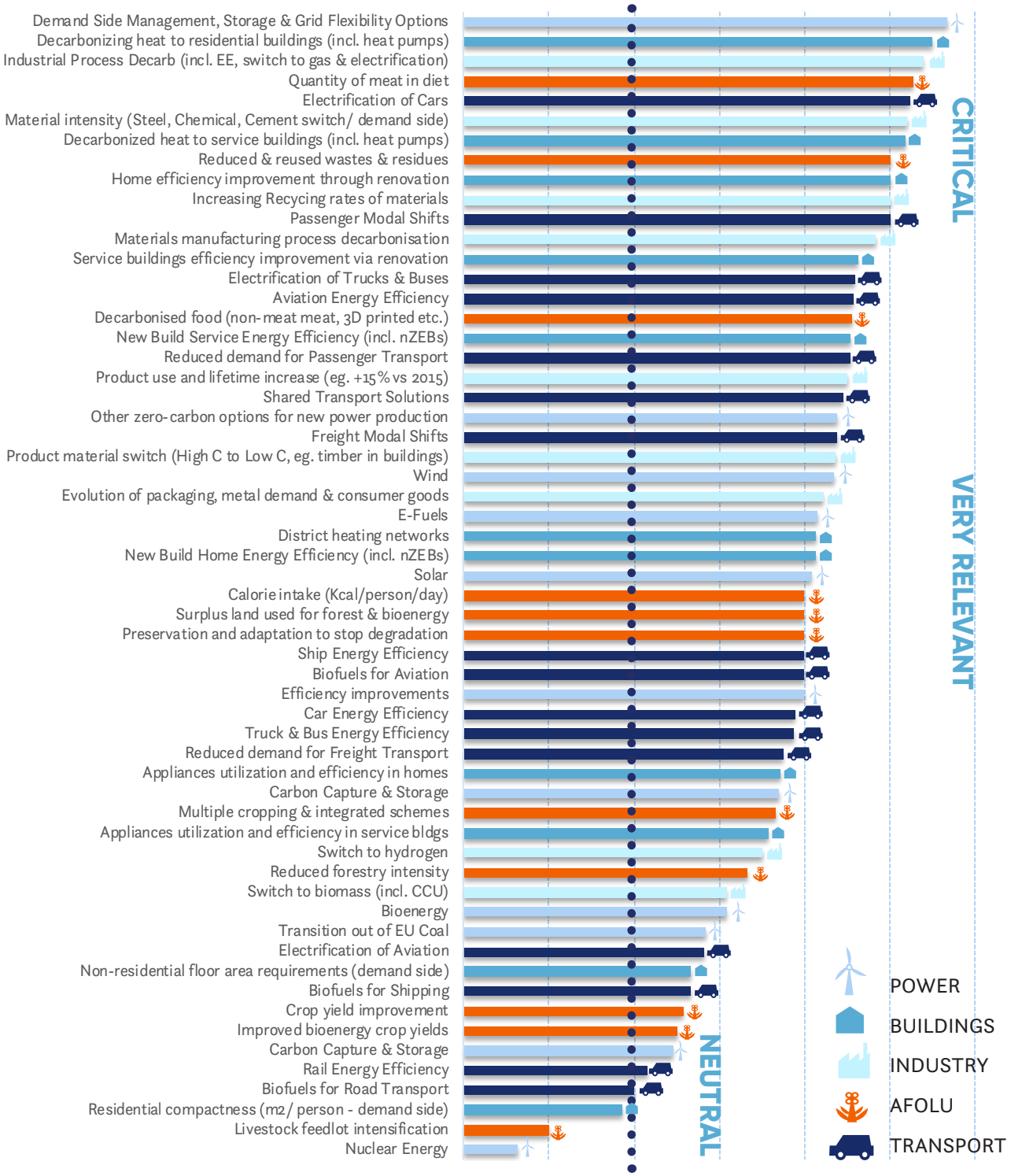
This section summarises the expert views of the innovation requirements to deliver net-zero emissions in Europe by 2050 in five sectors: Power, Transport, Buildings, Industry and AFOLU. It draws from the understandings and insights created by the low carbon pathways analysis and tools produced as a part of ECF's Net-Zero 2050 series of publications. This net-zero 2050 scenario analysis and climate modelling identified 58 "sector decarbonisation strategies" which are those used as inputs to the expert survey for this report. Through inputs into a structured survey, 50 experts from 39 institutions working on energy, climate and innovation related fields provided insights and specific comments that have driven the drafting of the following sector analyses.

A detailed description of the methodology and links to the base Net-Zero 2050 climate pathway modelling is provided in the Appendix to this report, and the full institutional universe of the expert responders to the innovation survey is provided in the acknowledgement section. The first section below summarises the overall findings in aggregate and which is followed by a detailed review of opinions in each of the five sectors.

Innovation is core to delivering Net-Zero emissions in Europe by 2050

Asked to identify where innovation is required, experts identified innovation as critical, or very relevant, to Europe's ability to decarbonise its economy by 2050 in nearly four fifths of the 58 sector decarbonisation strategies identified by ECF's Net-Zero climate modelling community. All 58 sector strategies have been defined through other work to be relevant to the goal of reaching net zero emissions. This perceived relevance of innovation to long-term decarbonisation across the five sectors is shown in chart 10 in priority order.

Chart 10: Relevance of Innovation across Sectors

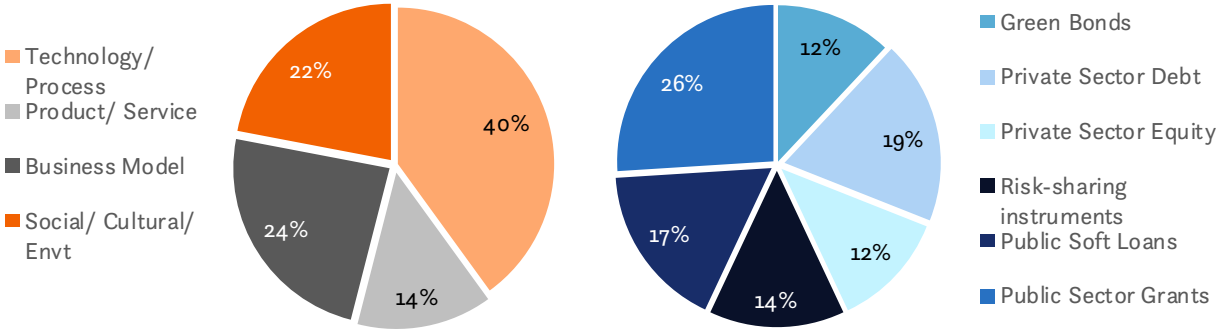


Experts believe that innovation is very relevant across all of the five economic sectors as is shown by the wide spread of colours in chart 10. Demand side management, storage and grid flexibility are narrowly the components of the power sector where innovation is the most critical, followed by decarbonizing heat in residential buildings, the decarbonisation of industrial processes, lowering the quantity of meat in European diets and the electrification of cars. Sector components where innovation was seen as less relevant include nuclear energy, livestock feed intensification, the demand for residential floor space and energy efficiency in rail transport.

In 40% of cases, experts identified that the innovation required is mainly technology or process related. However, significant innovation is clearly also required in product and service design, business models and at a societal level – depending upon the sector and decarbonisation strategy, as further developed in the sectoral analysis that follows.

A conclusion of the report "Net Zero By 2050: From Whether To How", is that commercially available solutions can take us about 75% of the way to net-zero if deployed at scale (later stage innovation: business model and societal innovation). The remaining 25% can be achieved based on known approaches and technologies for which further scaling up and commercialisation is needed (technology, product and business innovation, as defined in this report).

Chart 11: Innovation Type and Financing Instruments



When asked to identify the appropriate financing instruments required to fund the R&I investments in 58 component strategies for the five key sectors, expert opinion supports a balanced approach with just over one quarter (26%) led by public grants, mainly for technology innovation, but with a significant role for public funding in soft loans and risk-sharing instruments. Experts see a leading role for private sector contributions via new equity, debt or through investments in green bonds, and through the private component under risk-sharing instruments supporting the current trend for a diversified and mission-oriented approach to deep decarbonisation.

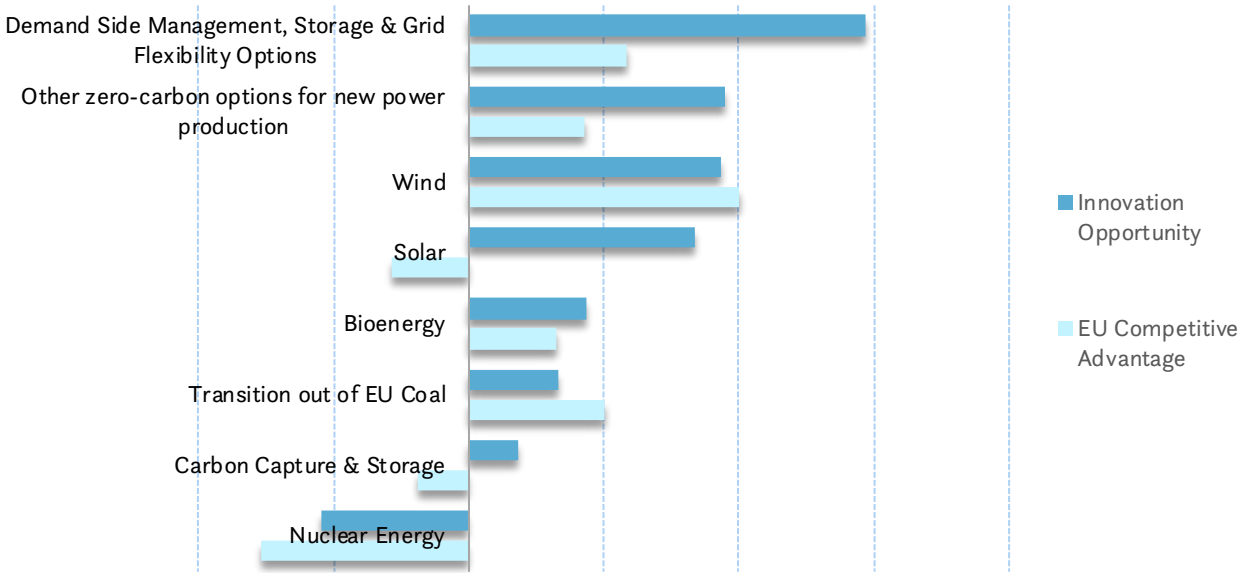
The expert survey also shows in aggregate that there is a global competitive advantage to be gained by Europe in many of the key decarbonisation sectors, although these competitive advantages are not evenly distributed nor necessarily correlated to the strength of the identified sector's innovation needs. Finally, experts see increased innovation investments as necessary in over three quarters of sector strategies to deliver the required levels of decarbonisation to reach net-zero emissions by 2050.

Power:

Smart grids, flexibility and storage innovation leads

Experts recognise the strongest innovation needs in the power sector relate to developing demand side actions in smart grids, flexibility and storage. R&I investments are also highly relevant to support the needed upgrade of Europe's electricity delivery, transmission and distribution infrastructure, to help develop the associated business models that are capable of working with 100% variable power delivered by wind, solar and other zero-carbon options for power generation. Except in solar, experts see a reasonable correlation between the innovation opportunity and the potential to build, or build upon, a European competitive advantage in the respective component strategies required to decarbonise the power sector as shown in chart 12.

Chart 12: Innovation Needs to Decarbonise the Power Sector & their Correlation with an EU Competitive Advantage



Renewable energy is expected to represent the domminant share of the EU's future power supply. Experts noted that solar and wind, particularly offshore, still have the potential for significant cost reductions. Europe is seen as having a leading global position in wind power, which strategic R&I investments can retain and build. In addition, demand-side management, demand reduction (via efficiency) and digitalisation are all seen as core to securing a lead role in the development of innovative integration solutions for wind and solar together into the grid. Experts also believe that:

» **Wind** has scope for improved incremental technology innovation, especially in offshore, and the social barriers to onshore wind– requiring social innovation investment - should not be ignored.

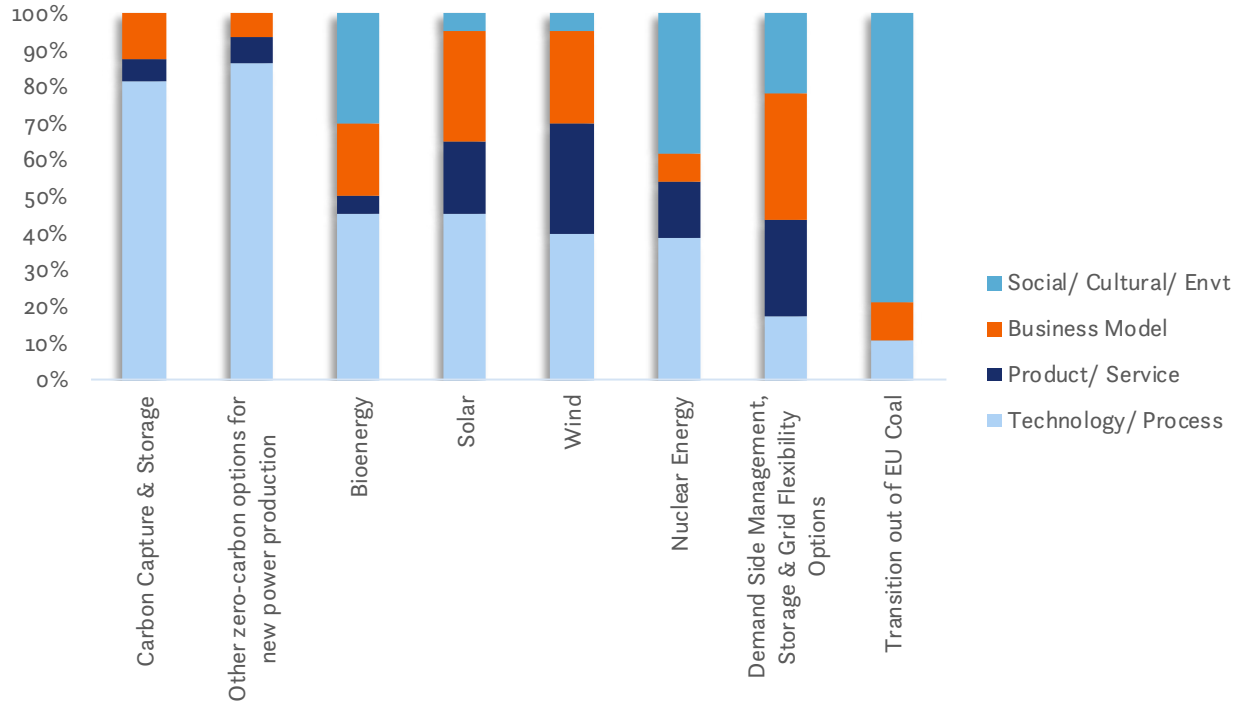
» **Bioenergy** is seen by responders as more of a niche or localised sector where innovation funding maybe better addressed at a national or case-by-case basis.

» **The use of waste heat** from thermal power plants and industry, and thermal storage technologies are key R&I investment areas.

In terms of the type of innovation, experts identified the need to invest in technology innovation for the less mature components of power sector decarbonisation, such as wave energy, geothermal, and tidal power. Incremental technology innovations were seen as required in the more mature technologies of wind, solar and bioenergy, where business model and service innovations are also important. New business models are critical for the integration of renewables, demand management, energy with system services pricing and increased seasonal storage of electricity also identified. While the EU's transition out of coal is clearly not a technological challenge, it was identified as having a social and cultural innovation dimension, not least in relation to the Just Transition. This is a characterisation which experts also saw as relevant for bioenergy and nuclear energy as illustrated in chart 13. Public sector investment is seen as needed to deliver this social innovation.

Experts recognise the strongest innovation needs relate to developing demand side actions in smart grids, flexibility and storage

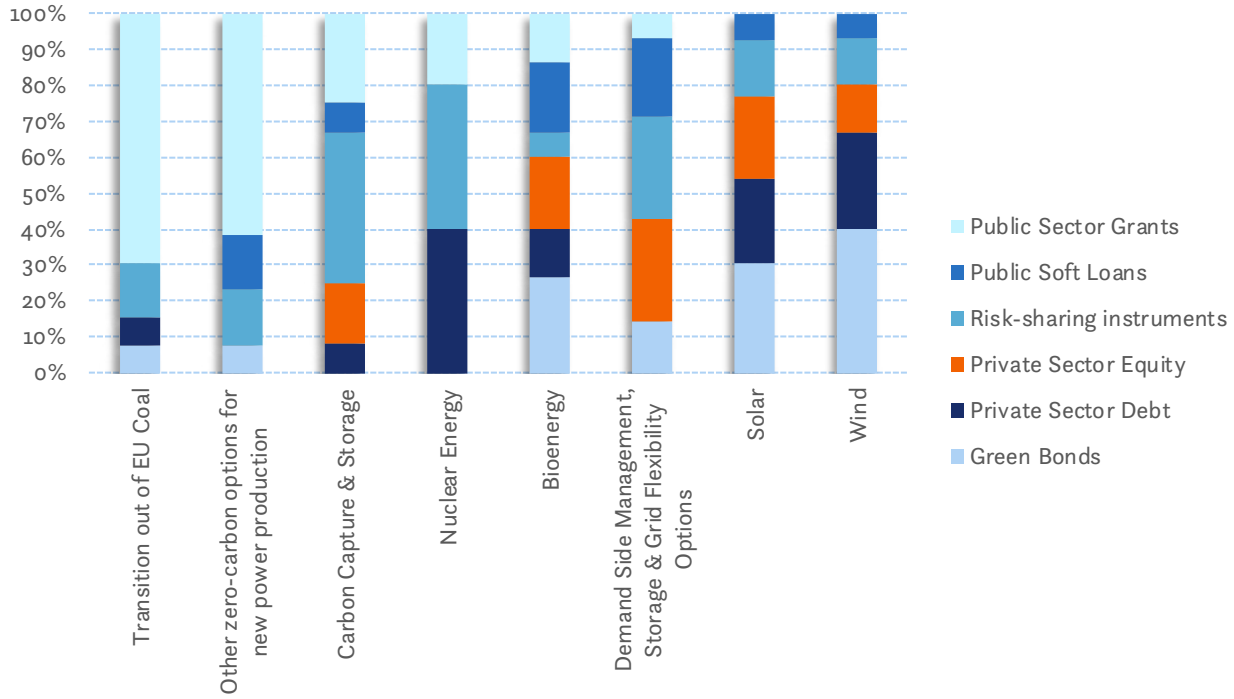
Chart 13: Innovation Type Required for each Component of Power Sector Decarbonisation



Risk-sharing instruments in Chart 14 are viewed as being needed to stimulate innovation in carbon capture and storage (CCS), a technology which needs very large amounts of capital to get to scale. This has to some extent been one of the learnings for the new ETS Innovation Fund which succeeds the NER 300 facility. Note that many experts believe CCS should not be deployed with power in Europe, being essential only for some industrial processes.

The more mainstream renewable technologies require a variety of instruments to stimulate incremental innovation in their supply chain, in order to deliver to growing domestic demand; to stay competitive in a context of increased international competition in cost, and to keep pace with improved reliability/ dispatchability options as shown below in chart 14.

Chart 14: Finance Instruments Identified to Enable Innovation in each Power Sector Component Strategy



Mission to Fully and Affordably Decarbonise EU Electricity 100% by 2040

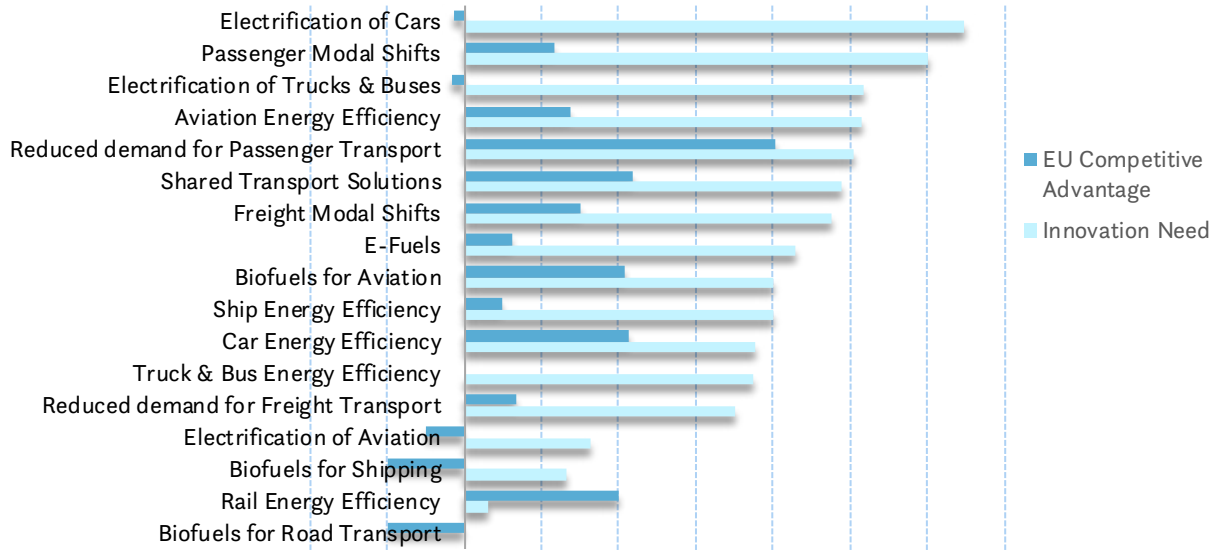
Reaching 100% renewable electricity in Europe at affordable prices was mentioned by several experts as a worthy and charismatic mission that will require broad innovation across supply, transmission and distribution assets, as well as involving multiple sectors on the demand side (including buildings, transport and industry). Some experts preferred the terms "green reliable electricity", "zero-carbon power" or "green power production" and "at a lower cost". Within the context of an overarching electricity decarbonisation, some experts proposed a focus on "decarbonised and integrated smart cities" (as these are hubs for population and demand for power and other energy services) and others were keen to incorporate artificial intelligence and machine learning to deliver energy savings, while others preferred to express the mission in terms of a giga-ton of annual GHG savings by 2030 also levering negative emissions technologies. Some noted that this mission may not be "ambitious enough" to qualify as bold on a cross-sector consideration.

Transport:

Innovation for Electrification and Mobility as a Service

The innovation investment needs and opportunities in the transport sector are highly relevant for Europe. Experts point to a wide range of decarbonisation solutions, with car electrification and modal shifts clearly in the lead. The potential for EU competitive advantage in transport is less well correlated with innovation need than in power or in buildings: For example, experts see stronger EU competitive advantage on the demand side (with the delivery of mobility as a service and shared mobility services) than for pure vehicle electrification. On the other hand, transport energy efficiency (car, truck, bus, ship and aviation) is seen as both clearly needing innovation investment and potentially also delivering an EU competitive advantage. The only innovation potential and possible competitive advantage that experts see relation to biofuels in Europe is for aviation. Chart 15 below illustrates these findings:

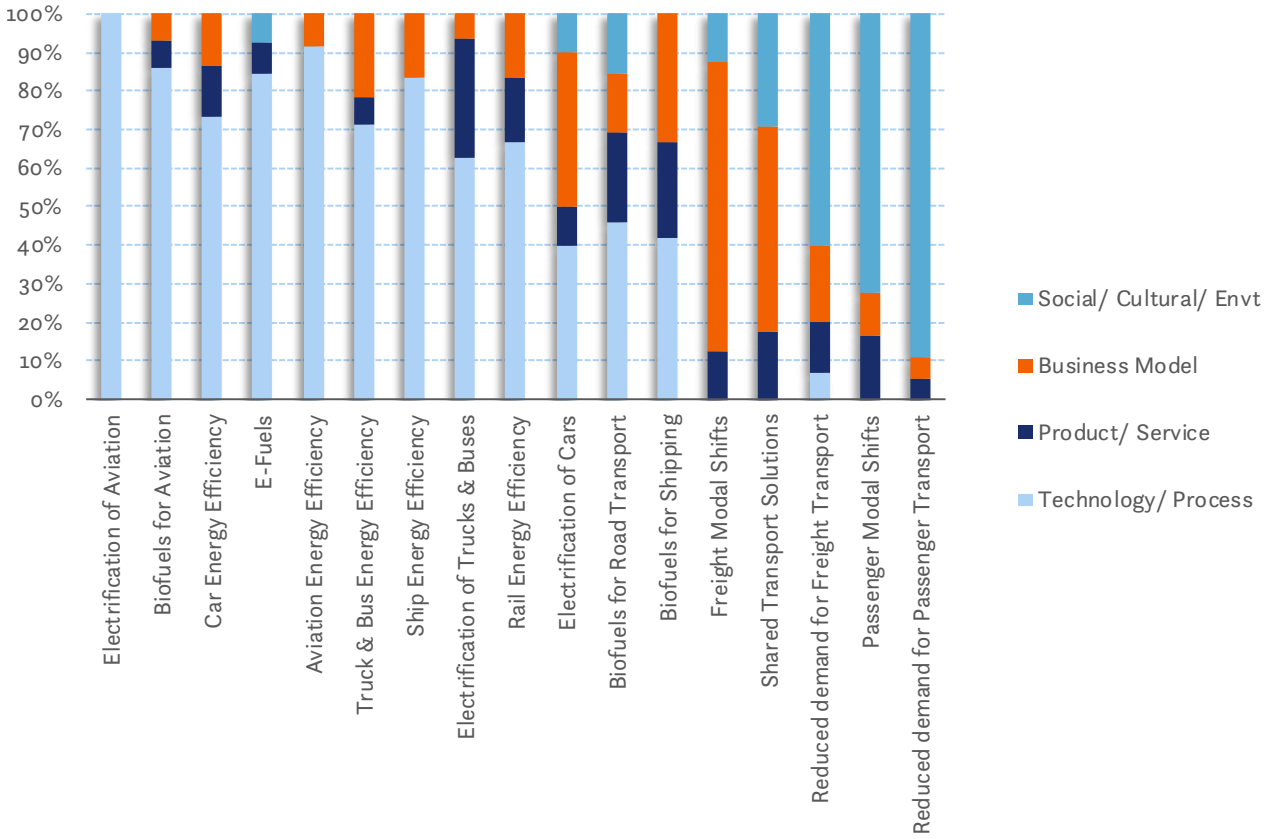
Chart 15: Innovation Needs to Decarbonise the Transport Sector & their Correlation with an EU Competitive Advantage



Experts commented that technology innovation should be an EU investment priority, identifying aviation, shipping, vehicle electrification and tackling the demand-side as key measures. In aviation, experts identified the array of potential zero-carbon aircraft technologies (e.g. electrification, cryogenic hydrogen or ammonia) and the key role that Airbus can play in developing EU innovation leadership there.

The strong need for technology and process innovation is notable from the expert survey, as seen in chart 16 bellow, across many of the transportation sector's decarbonisation pathways. In addition, freight requires business model and social innovation to develop shared transport systems, reduced demand and modal shifts.

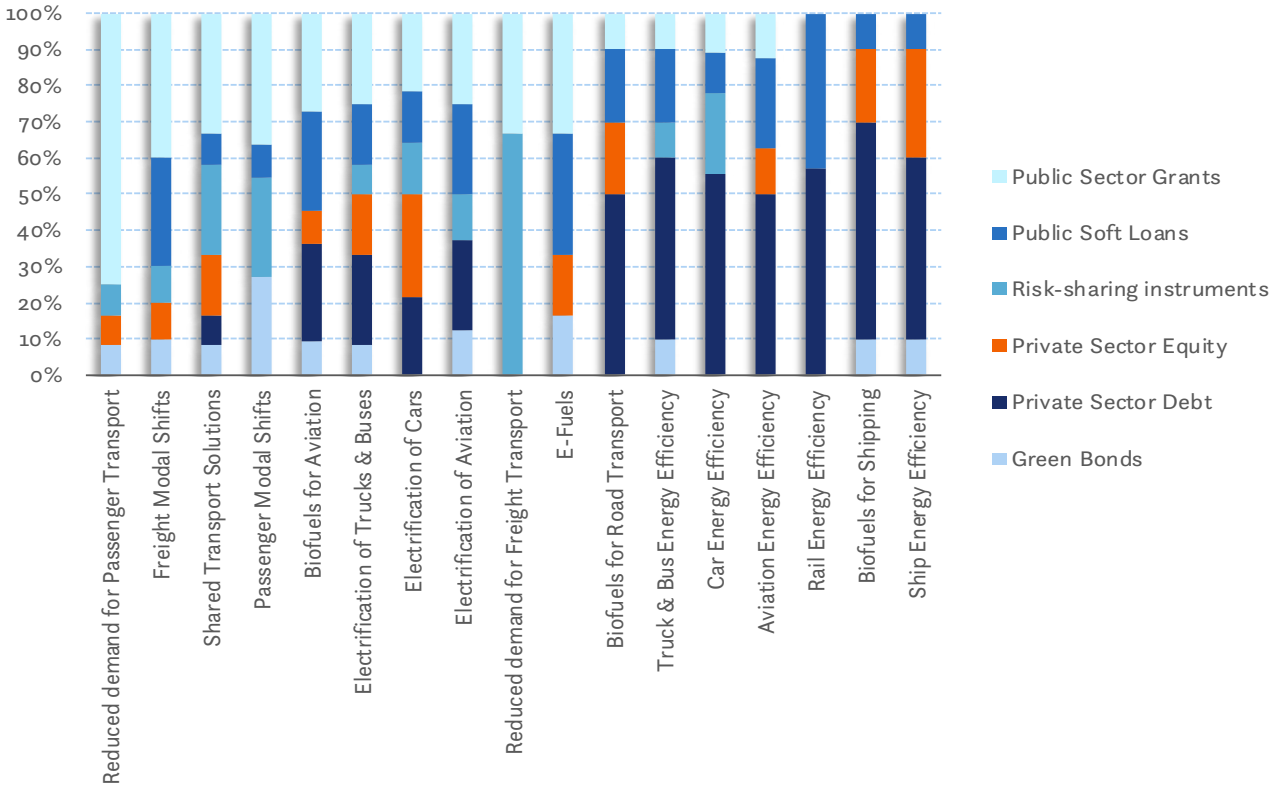
Chart 16: Innovation Type Required for each Component of Transport Sector Decarbonisation



Experts felt that reduced demand for transport can be addressed by business model and social innovation in production and consumption patterns, circular economy and economy of scope. Shared transport solutions and autonomous vehicles were also seen as critical innovations to optimise EU infrastructure and deliver cost effective, low carbon mobility solutions to consumers, as well as the provision of long-term policy signals and objectives for energy efficiency and emissions reductions in every kind of transport mode. Experts noted that a variety of "transport as a service" options can respond to low carbon mobility needs including: shared e-bikes and scooters, various size of e-taxis, and more rail and ship-based alternatives for long-distance journeys, also noting that EU must develop core competences through R&I investment in these sectors.

In freight, the significant proportion of empty vehicles (up to one third) on the road was cited as a clear opportunity for innovative new business models and shared supply chains. Low carbon bioenergy for transport was seen as a scarce resource, also likely needed for biochemical industrial applications, and experts were less optimistic for its development. Land constraints were seen as a barrier to the scaling of crop-based biofuels, meaning that innovation investments would need to focus on cellulosic biofuels or e-fuels.

Chart 17: Finance Instruments Identified to Enable Innovation in each Transport Sector Component Strategy



In terms of expert views on the financial instruments to support investments in decarbonising transportation, public sector grants were only seen as a major factor in the area of reducing demand for mobility in passenger km. For other decarbonisation solutions, grants are seen as a smaller component of largely blended capital instruments and private sector debt and equity solutions with energy efficiency innovation supported mainly by private capital. Chart 17 above illustrates these opinions and the breadth of instrument choice spread across each transport decarbonisation strategy is clear.

Mission to Decarbonise EU passenger Transport by 2040, and EU freight by 2050

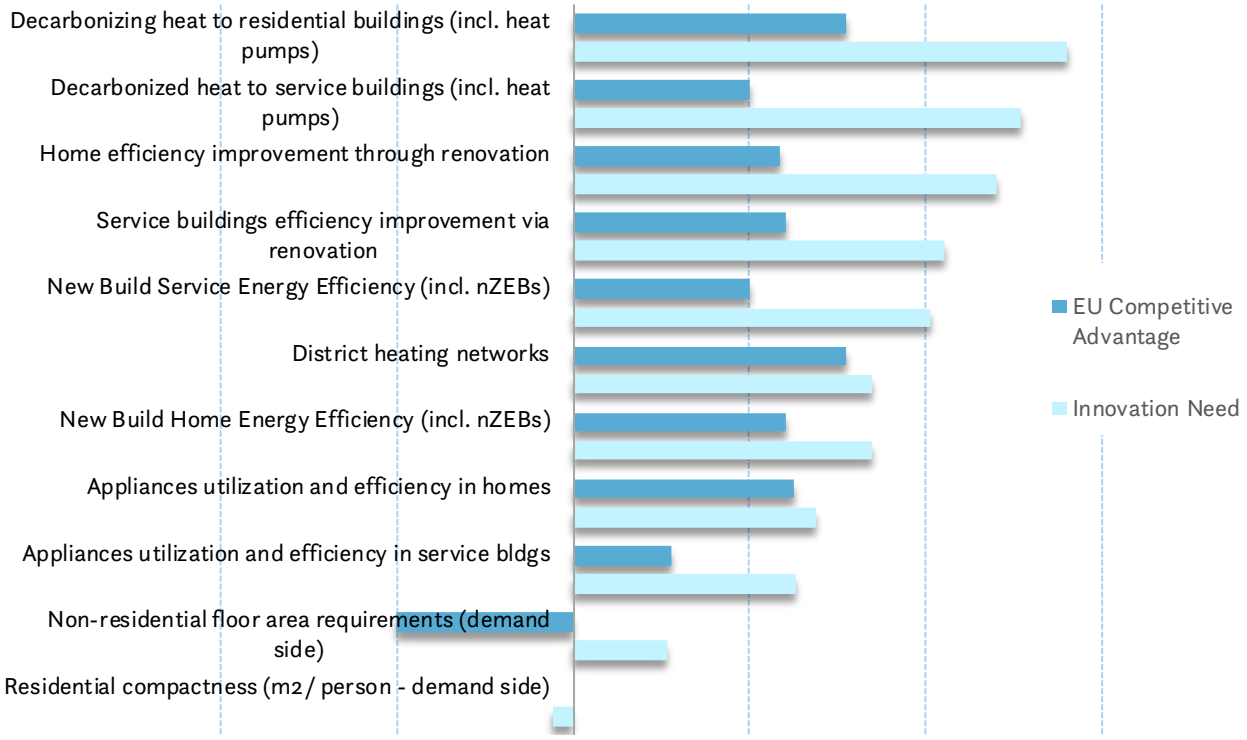
Experts felt that a sector or city-focused transport mission could be a productive way to integrate the various fields, whilst tackling one of the most-pressing issue areas, namely air pollution. It could also help create markets for European mobility as a service ("MaaS") alternatives covering the full spectrum of transport needs. The inclusion of zero-pollution targets from transportation serving cities targeting 2040 for passenger transport and 2050 for freight was proposed. City airports could also be included within the city-transport frame. The development of zero carbon, non-biofuel aircraft could be connected to a system of R&I awards as a mechanism to accelerate the introduction of the first long range zero-carbon commercial aircraft, or the first "land-free" zero-carbon fuel below the price of kerosene.

Buildings:

Business Model and Financial Innovation Challenge

Decarbonising heat for residential and service buildings together with energy efficiency upgrades are seen by experts as the leading areas for R&I investment for the full decarbonisation of Europe's buildings, accompanied by near-zero energy new buildings and district heating. The innovation investment needs and opportunities for the EU to seize a competitive advantage through such investments are probably the best correlated in the buildings sector, as shown in chart 18:

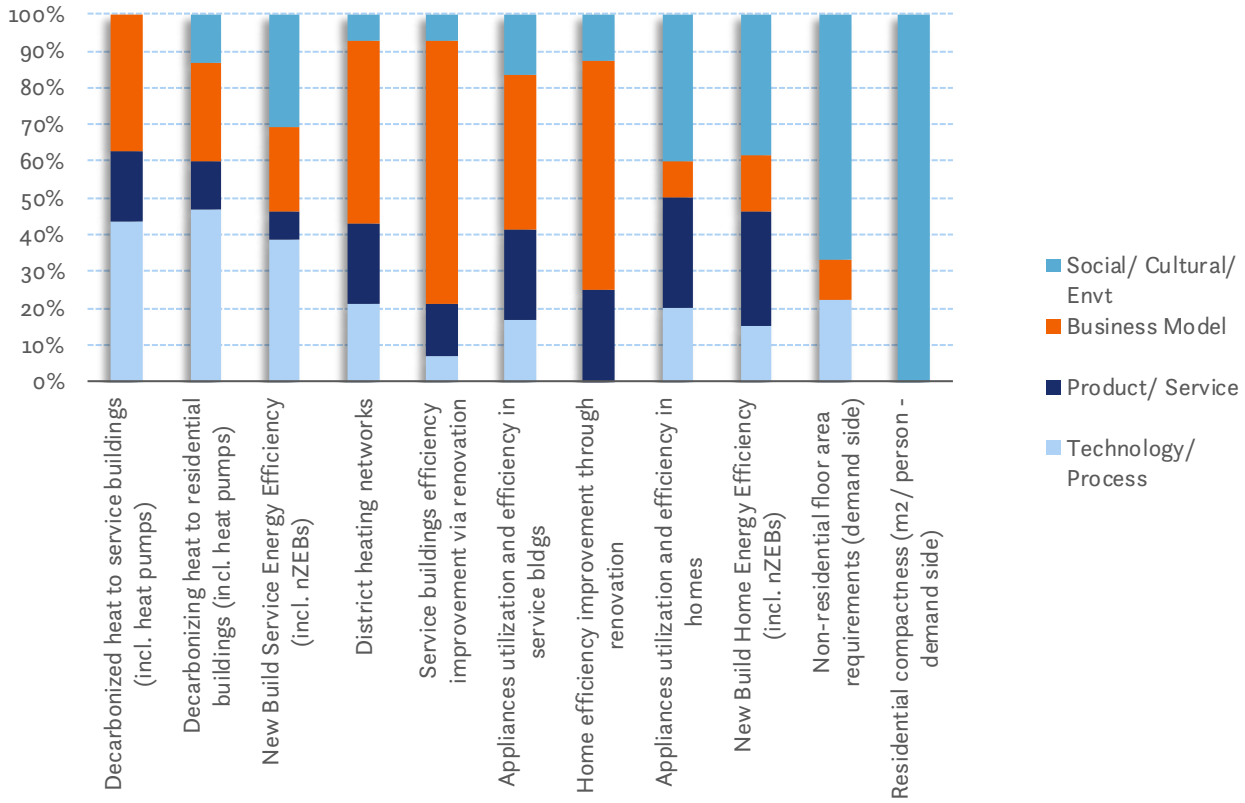
Chart 18: Innovation Needs to Decarbonise the Buildings Sector & their Correlation with an EU Competitive Advantage



Experts noted that the EU has leading providers of heating technologies, yet incremental innovation investments are necessary to increase their efficiency and policies to build their markets. Experts felt that to deliver sustainable buildings, innovative business models are required to boost the uptake of buildings renovation. Stronger links are also required between energy efficiency and sustainability, the improvement of fire safety, mechanical reliability and physical stability of the building in order to deliver long-term decarbonisation with material efficiency.

From a cultural perspective, experts perceive there are still areas where building owners do not consider "community solutions" such as district heating, and prefer individual solutions. This can block or lock-out significant potential for efficiency gains, renewables integration and buildings decarbonisation for multi-owner apartment buildings and cooperatives. In newly constructed homes, there is a more limited need for major technology innovation to build nZEB; but the issue is more related how these new homes are used when delivered as shown in chart 19 below. District heating requires some technology innovation (such as developing low-temperature district heating solutions, large scale heat pumps, better solar thermal panels, refurbishment solutions for older grids). More innovative business models can also facilitate the large scale utilisation of surplus/waste heat and other heat sources.

Chart 19: Innovation Type Required for each Component of Buildings Sector Decarbonisation



In buildings, deep renovations still require significant up-front investments by owners and have long paybacks. Most of the innovation required is business model and financial innovation to ensure that these barriers are removed, and that it is attractive for buildings owners to undertake deep renovations. The availability of tailored financing is one of the main barriers for transition to sustainable and deeply renovated buildings and this is considered a socioeconomic challenge for R&I investments. For example, in the UK, existing buildings are of a relatively low quality, technologies are present, but innovation is needed at the business model and social/cultural level to address the barriers to their sustainable transformation and deep decarbonisation.

Chart 20: Finance Instruments Identified to Enable Innovation in each Buildings Sector Component Strategy

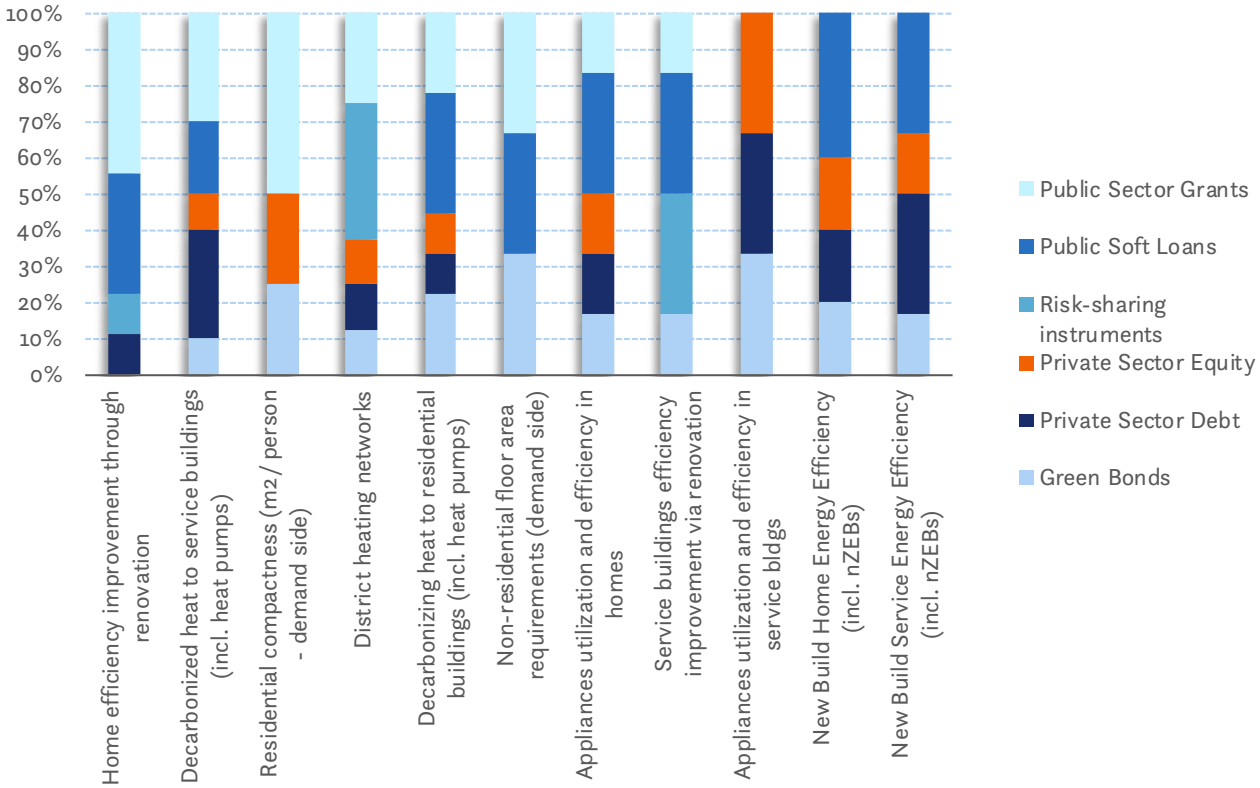


Chart 20 above displays the varied mix of financial instruments experts identify as priority to support the strategies required to decarbonise European buildings. Public sector grants have a relatively low penetration in this sector. Experts see grants required for compactness measures (better use of space) and stimulating deep renovations, as a component of a wider strategy to make financing packages more appealing to different kinds of buildings owners. Soft loans are fairly prevalent in various components as a way to lever private sector finance. Given that Europe needs over Euro 100bn per annum for deep buildings renovation, tailored packages of innovation investments mixing various elements are required to deliver fully decarbonised buildings by 2050.

Mission to fully decarbonise EU Buildings by 2050

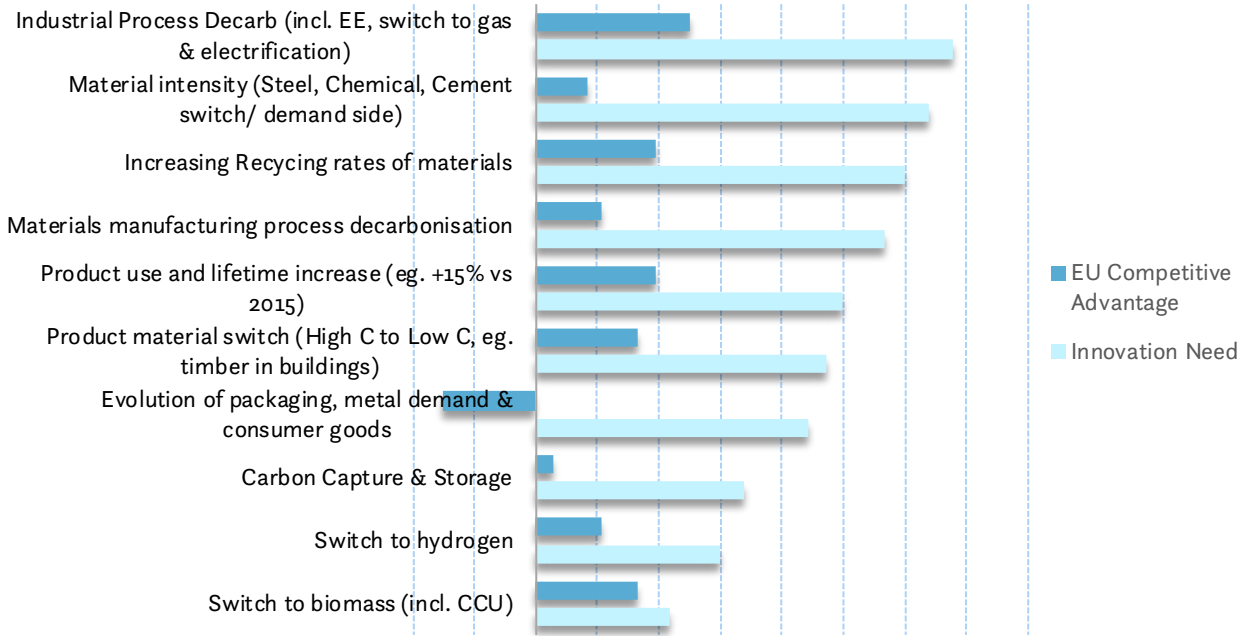
There are two tracks to buildings decarbonisation: The deep renovation of the existing buildings stock to reduce energy demand at source, and the decarbonisation of heating and cooling in buildings. Experts see new build as largely regulated through nZEB standards and buildings codes. However, the supply chains and business models delivering deep renovations need substantial innovation and industrialisation to deliver the 3% stock renovation required to deliver a net-zero emissions economy by 2050. Further, with half of buildings energy demand linked to heating and cooling, the mission-oriented decarbonisation of these elements is a key component to accelerating the delivery of low emissions EU buildings. This mission would engage cross-discipline stakeholders as it involves both energy supply and demand, local planning, business, and citizens. Furthermore, addressing heating and cooling can also support the delivery of zero energy poverty with no European family being left in the cold, say, by the winter of 2030.

Industry:

Innovation to deliver "Circularity First"

Experts noticed a very strong need for innovation across the net-zero modelled strategies for industrial decarbonisation, especially in process efficiency, decarbonising materials and increased recycling rates. This is shown in chart 21 below, where experts ranked these components. However, while experts do see the potential to develop EU competitive advantages through pursuing these decarbonisation pathways, there is a weaker correlation evident between innovation need and potential competitive advantage than in other sectors. Experts saw application for mainly technology innovation in carbon capture and storage/ use, and the switch to hydrogen, but they were ranked below other options in the short-term.

Chart 21: Innovation Needs to Decarbonise Industry & their Correlation with an EU Competitive Advantage



For European industry to decarbonize in line with a net-zero pathway by 2050, experts surveyed see the "circular economy" approach as a high priority organising principle, meaning orienting production around products with long life-cycles that are made from recyclable materials, asset sharing, sector coupling, service/ functional economy approaches and the simplification and increased transparency of supply chains.

Experts felt that improved heat utilisation was important and that this could be linked to industry's needs for chilling and heat demands in their different processes and plants. R&I investment plays a crucial role here to improve and develop the new business models and product solutions to enable industrial processes to adopt circular economy principles and tap into their waste heat potential.

Chart 22: Innovation Type Required for each Component of Industry Decarbonisation

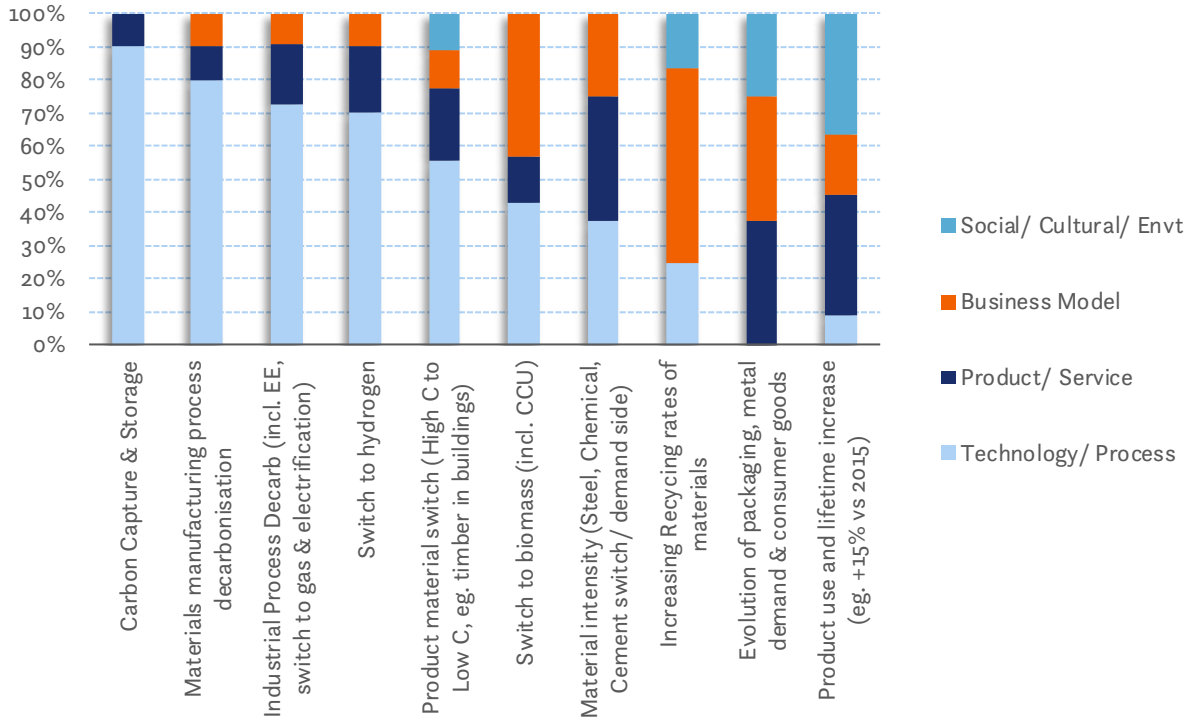
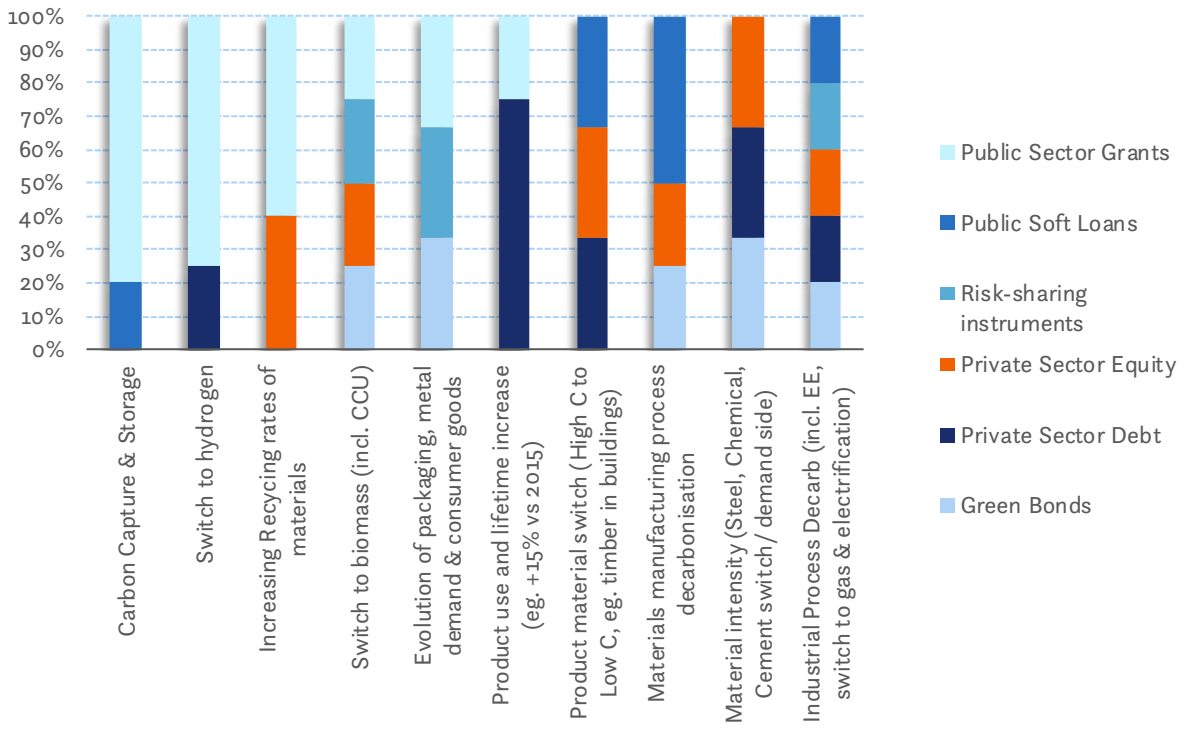


Chart 22 above, shows how technology-led innovation is dominant for over half of the decarbonisation strategies for EU industry. This is especially true for carbon capture and storage, material switching and process decarbonisation and for the use of hydrogen. To achieve circularity, product and business model innovation is required to increase rates of recycling and for dealing with packaging evolution. Social and cultural innovation plays a less important role in the industrial sector, with the exception of decarbonisation strategies that increase product life-cycle and in the evolution of packaging for consumer goods.

A particularly diverse selection of financial instruments are necessary for the delivery of decarbonised industry in Europe, as presented overleaf in chart 23. This reflects the broad spectrum of different challenges in different industrial sub-sectors. Public sector R&I grants can play a large role in accelerating technology innovation for carbon capture and storage/ use and hydrogen – both cross-sectoral technologies – as well as to increase recycling rates. Levering private sector debt and equity are clearly also relevant with industrial counterparties having access to large pools of private capital, but sometimes less appetite for innovation risks, giving rise to an opportunity for risk sharing instruments in R&I as a bridge.

Chart 23: Finance Instruments Identified to Enable Innovation in each Industry Component Strategy



Mission to Reinvent European Industry based upon the "Circularity First" Principle

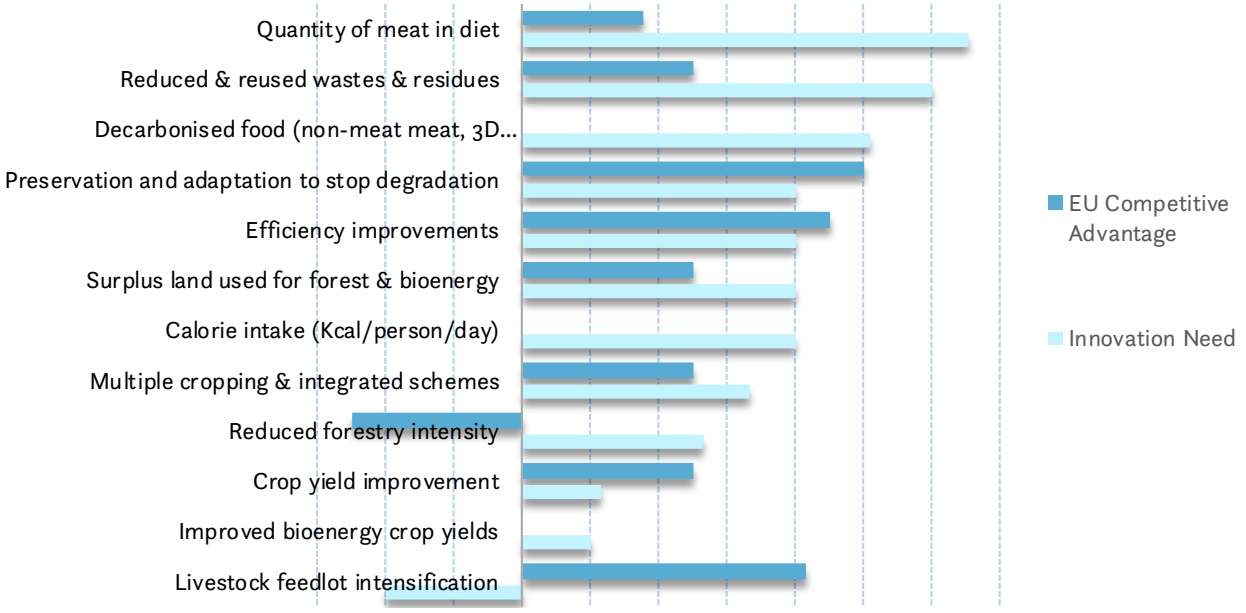
A mission-oriented approach for the industrial sector alone is challenging as it is primarily seen as the means of production whose societal relevance is more related to price, quality and availability of improved goods. A "Circularity First" principle would place a set of new requirements on European industry which would drive players to focus on resource and energy footprints as well as widen producers' considerations and responsibilities for the "in use" phase of its products and product end-of-life. Using waste heat could also be promoted as a segment of this mission as well as giving a more pro-active role for industry in balancing the power markets. Achieving this mission would require a broad societal acceptance, as consumers would need to only buy from those producers who are embedding circularity in their goods – and not from those who do not. This implies a supportive policy framework that robustly enforces a polluter pays principle and labelling and reporting practices. Public procurement could also be a useful policy tool to help drive the market.

Agriculture, Forest, Land-Use & Diet (AFOLU):

Connecting Health and Climate

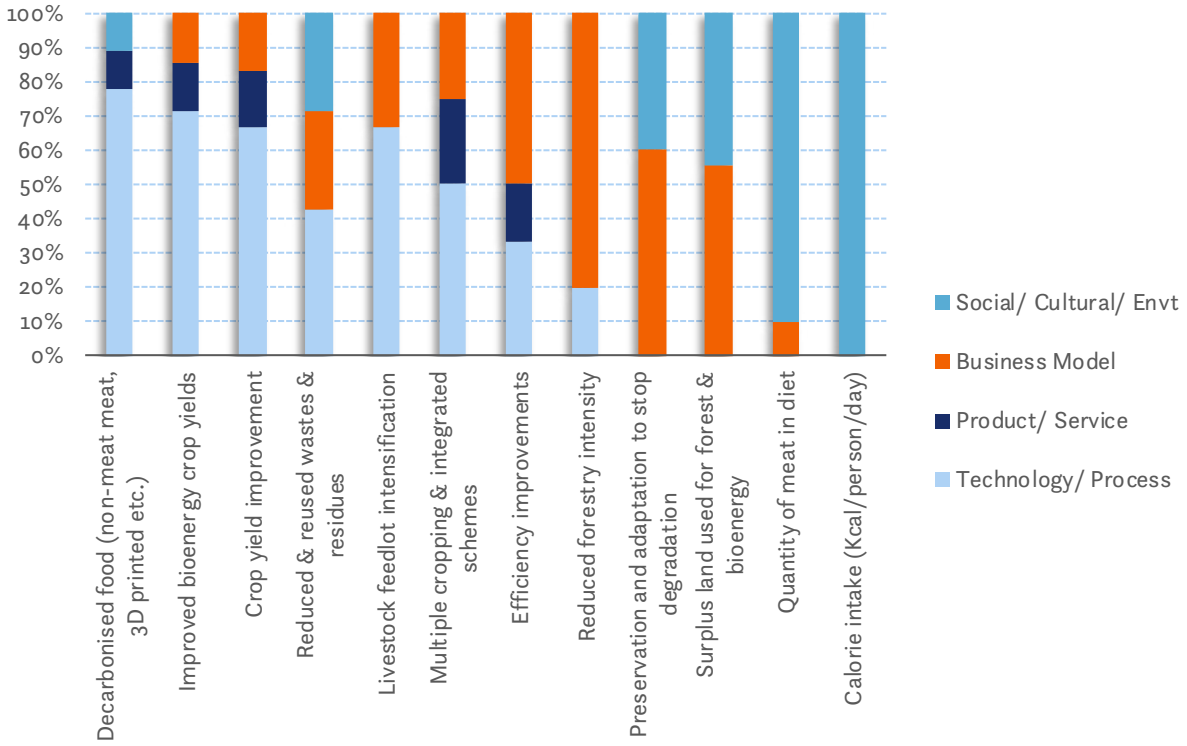
There are clear needs for new and innovative approaches to decarbonise the European AFOLU sectors, as well as addressing the European diet and opportunities for carbon sequestration. In the survey, experts articulated three main levers for which innovation is deemed critical to enable a net-zero emissions economy by 2050: reducing meat consumption, reduced and reused waste, and the decarbonisation of food production. Experts also saw very strong EU competitive advantages to be gained in pursuing specific innovation needs including reduced absolute calorie intake, reforestation of surplus land, efficiency and the prevention of land degradation, as well as food waste recycling as show below in chart 24.

Chart 24: Innovation Needs to Decarbonise AFOLU & their Correlation with an EU Competitive Advantage



Experts clearly observed demand-side issues around diet as the new frontier for social and cultural innovation, as well as being a market opportunity for a new range of innovative low-carbon and healthy foods and production processes. Sequestering more carbon at scale in soils and landscapes is also seen a critical EU competitive advantage through different agricultural practices, agroforestry, and the use of new compounds (like biochar). Experts acknowledge the role sustainable forest management plays across the EU, with forests delivering multiple benefits (social, environmental and economic) as well as carbon sequestration and resilience. They consider that surplus land can be reforested as long as it does not negatively impact biodiversity and is undertaken in an ecologically sustainable way. Biofuels from purpose-grown crops (as opposed to biofuels from wastes and residues) remain polemic and several experts noted that they often increase overall emissions.

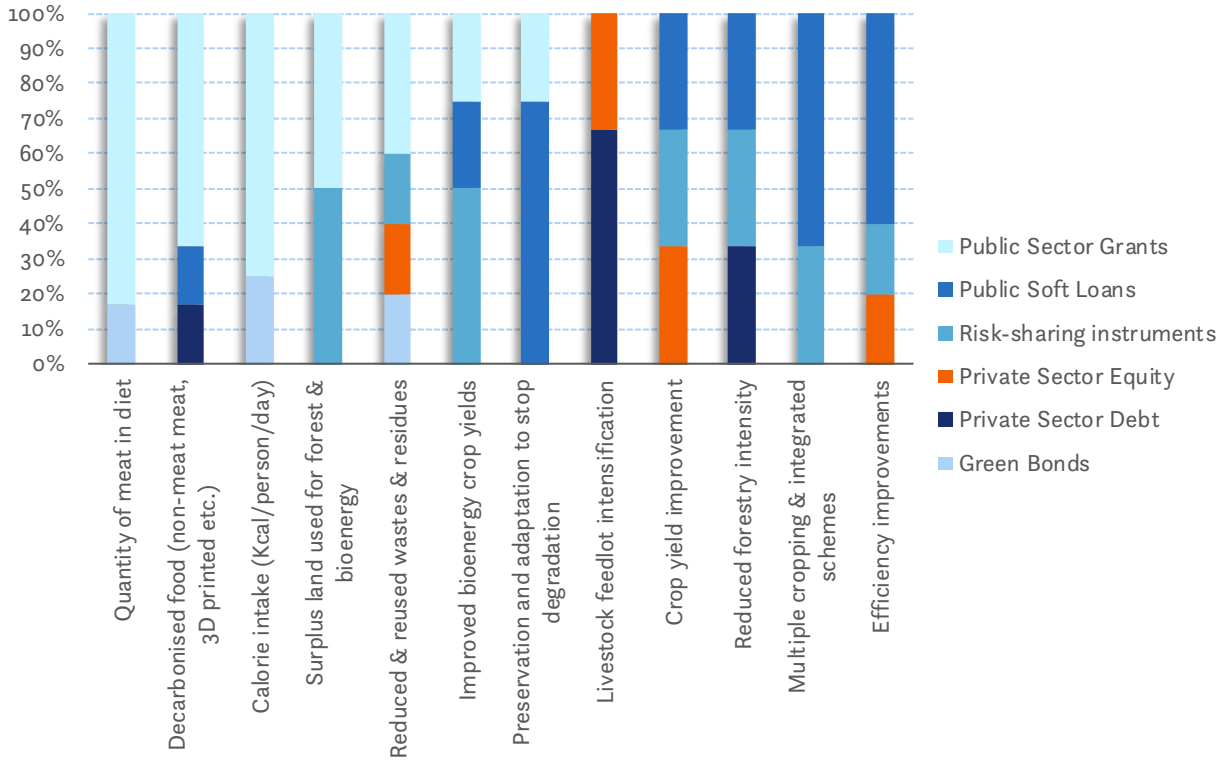
Chart 25: Innovation Type Required for each Component of AFOLU Decarbonisation



Technology innovation is required particularly in decarbonisation strategies relating to the decarbonisation of food, and to deliver enhanced yields in crops, bio energy and livestock. Business model innovation is seen as being most important to deliver efficiency improvements, reduced forestry intensification and for preventing soil degradation, which also requires significant social innovation. Experts were almost unanimous in noting that matters relating to diet (overall calorie intake and the quantity of meat consumed) require wholly social and cultural innovations – as this is neither technology based nor a matter of product or business development.

In terms of funding instruments, illustrated in chart 26, experts felt that AFOLU decarbonisation strategies needed to rely more heavily on public source funding instruments than private. Many of the societal innovation would require public funding and the mix of soft loans and risk sharing instruments is seen as useful for reforestation and agriculture as well as yield improvements, efficiency and livestock related decarbonisation strategies. Interestingly, experts also saw very limited use of green bonds as a source of innovation investments in agriculture, forestry and land-use in Europe. However, some experts believe that an R&I-led approach to improved benchmarking for sustainable forest management across the EU could lead to better models and approaches for how to value, monetise and finance ecosystem services in general, giving access to a wider spectrum of funding sources.

Chart 26: Finance Instruments Identified to Enable Innovation in each AFOLU Component Strategy



"Mission: Healthy Food for a Healthy EU Climate"

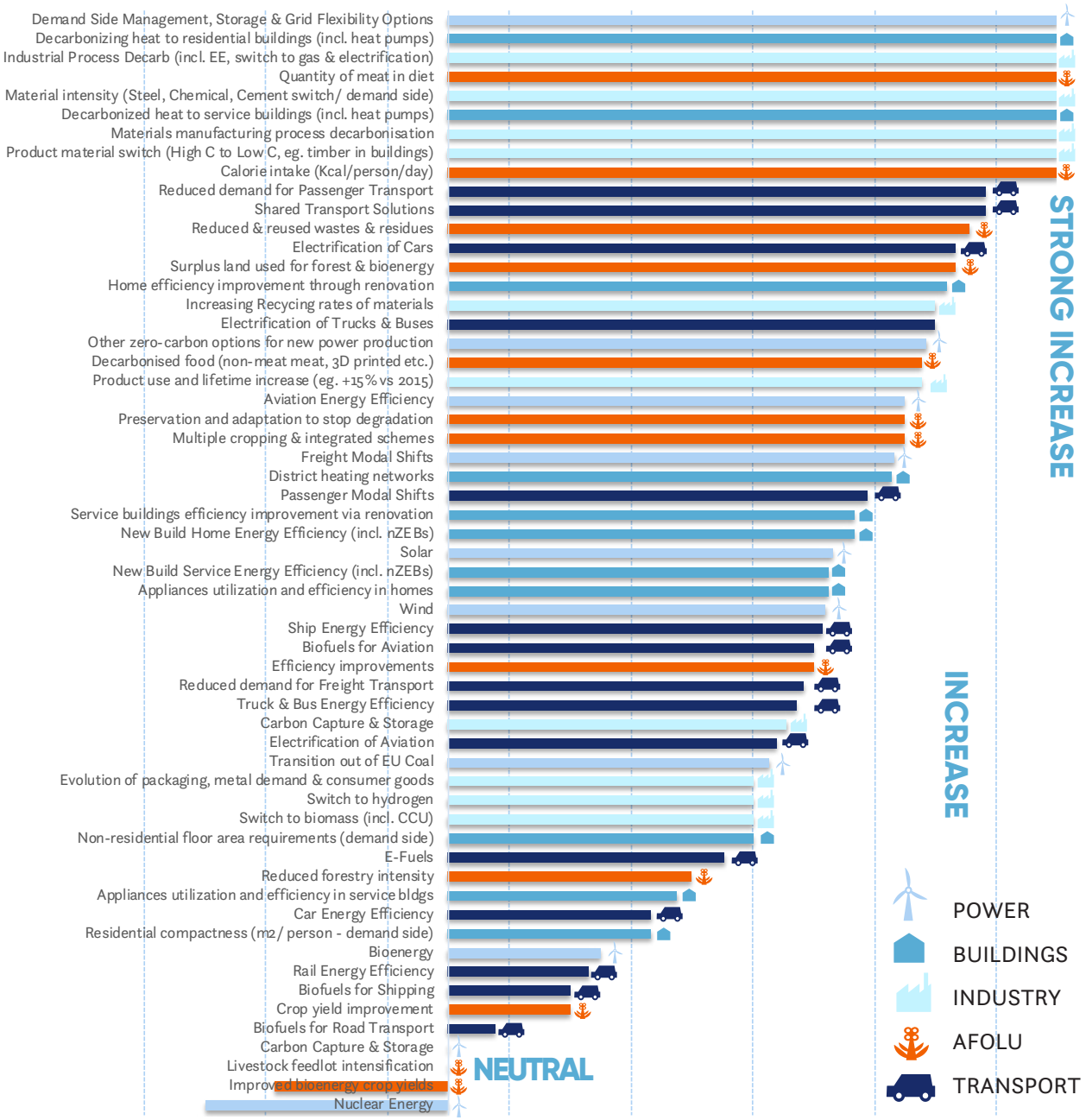
A mission-oriented approach needs to connect overall consumption, meat and dairy share and food waste to improved land management, agriculture practice and efficiency. The concept of connecting healthy eating with a healthy climate would indeed produce multiple benefits for Europeans and our economy. In addition, experts felt that a mission which considers rural livelihoods – whose conservation is essential to having a balanced society – could also provide an innovative axis through which to think about forms of food production and the reinvention of the Common Agricultural Policy ("CAP") to appropriately benefit forestry and biodiversity. Massively reducing waste at all stages in the food production chain is certainly seen as benefitting from mission-orientation. A land use efficiency and footprint principle was proposed to be included as an indicator which might be used to measure mission progress.

Conclusions

Europe needs to substantially increase its climate-related R&I in the period 2021-27 to allow new innovative technologies, products and businesses the time to scale and deliver the economy-wide decarbonisation strategies required to deliver optimal net zero pathways and the maximum societal benefits of this transition.

The clear message from experts is that research and innovation investment all but four strategies need to increase. For 75% of these the increase is strong or marked, as illustrated below in chart 27. Experts were asked to indicate whether R&I investments should increase or decrease compared with the past for each of 58 decarbonisation strategies identified across the five sectors. They were provided with Horizon 2020 R&I allocation data as shown in chart 8 in Section 2 as a reference. This strongly correlates with the conclusion of the ECF Net-Zero 2050 modelling that innovation must increase by around one third from current trajectories.

Chart 27: R&I investments Needs for Decarbonisation Strategies, Order of Magnitude



Overall, the five high-level conclusions from the expert contributions to this report can be summarised as:

1. **Climate-related R&I investment is key to deliver net zero emissions:** R&I is very relevant in 80% of the component decarbonisation strategies in Power, Transport, Buildings, Industry and Agriculture, Forestry and Land Use to deliver net-zero emissions. Responders to our survey identified that R&I funding needs to increase in three quarters of the strategies to deliver net-zero 2050 outcomes and the contributors to ECF's climate modelling[54] saw the "innovation gap" as being 25% additional innovation over a 75% increase aligned with existing efforts;

2. **Europe can build competitive advantages in many of the decarbonisation pathways:** Experts see opportunities for Europe to build global competitive advantages through R&I investment in all of the five climate-relevant sectors, however this opportunity is not evenly spread and some of the 58 decarbonisation component strategies offer greater potential competitive advantages than others;

3. **Innovation is required at many levels, not just in the production of new technologies:** While experts identify that the largest proportion (40%) of the necessary R&I is required to develop new or improve existing technologies, Europe's decarbonisation challenges also require substantial innovation at the product, business model and societal levels, in turn supporting a more mission-oriented approach to decarbonisation (e.g. full sector decarbonisation or zero-carbon cities);

4. **Public and Private R&I investments need to scale-up together:** Experts identified the need for a balanced instrument mix to fund European decarbonisation split evenly between private and public-sector R&I investment instruments. Experts flagged that just a quarter of identified R&I investments would require public sector grants, meaning that it is equally important to upscale soft loans and risk sharing instruments in order to facilitate an increase in private sector equity and debt products;

5. **Five "sector decarbonisation missions"** could help deliver Net-Zero 2050 outcomes: Experts identified five sector-level missions in Power, Transport, Buildings, Industry and AFOLU that would accelerate their decarbonisation. While it remains unclear whether a sector-level mission is sufficiently broad and ambitious, these can be used to inspire and contribute to an over-arching EU-level mission to deliver the innovation requirements to reach net-zero emissions of the whole economy before 2050.

54 ibid

Two of the most important EU-level instruments that can facilitate the identified R&I increase and up-scaling of low carbon assets are Horizon Europe and InvestEU, respectively. Horizon Europe has a proposed Euro 100 billion budget, making it the largest ever European R&I programme. InvestEU seeks to catalyse Euro 650 billion in sustainable infrastructure; research, innovation and digitisation; small and medium-sized businesses; and social investment and skills; through the provision of Euro 38 billions of EU budget guarantees syndicated to projects through the collaboration of EIB, European international financial institutions and national promotional banks. In this context, and considering expert conclusions, the following EU-level policy recommendations are supported:

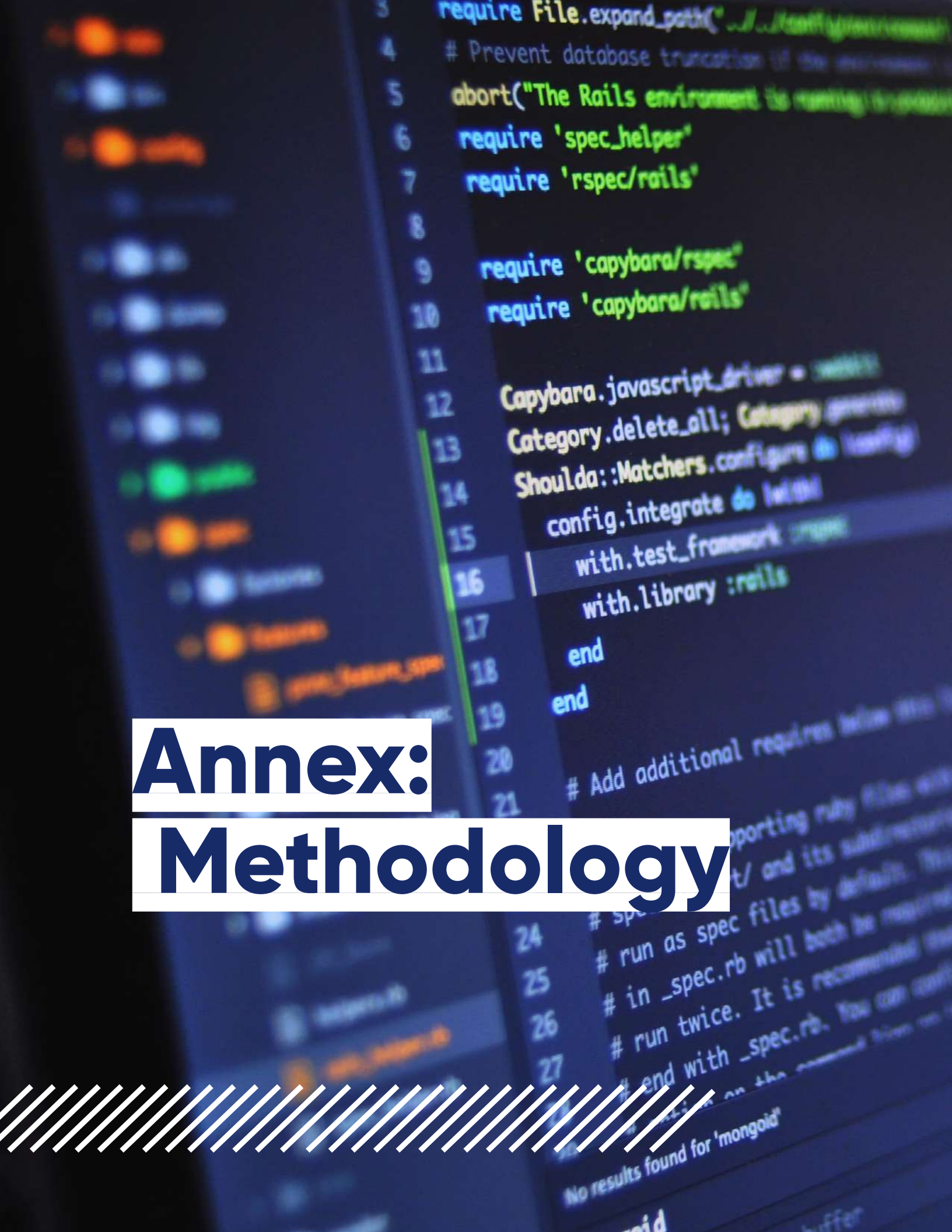
» **Horizon Europe's climate-related R&I allocation should increase:** R&I invested between 2021-27 is likely to be the last significant R&I funding to have time to deliver new low carbon innovation that can scale-up to deliver a net-zero economy by 2050. ECF's Net-Zero 2050 climate pathway modelling identifies a necessary one third increase in innovation to enable this net-zero decarbonisation by 2050. In this context, Horizon Europe should require nearly half (47%, up a third from 35%) of its funding to be relevant to climate action.

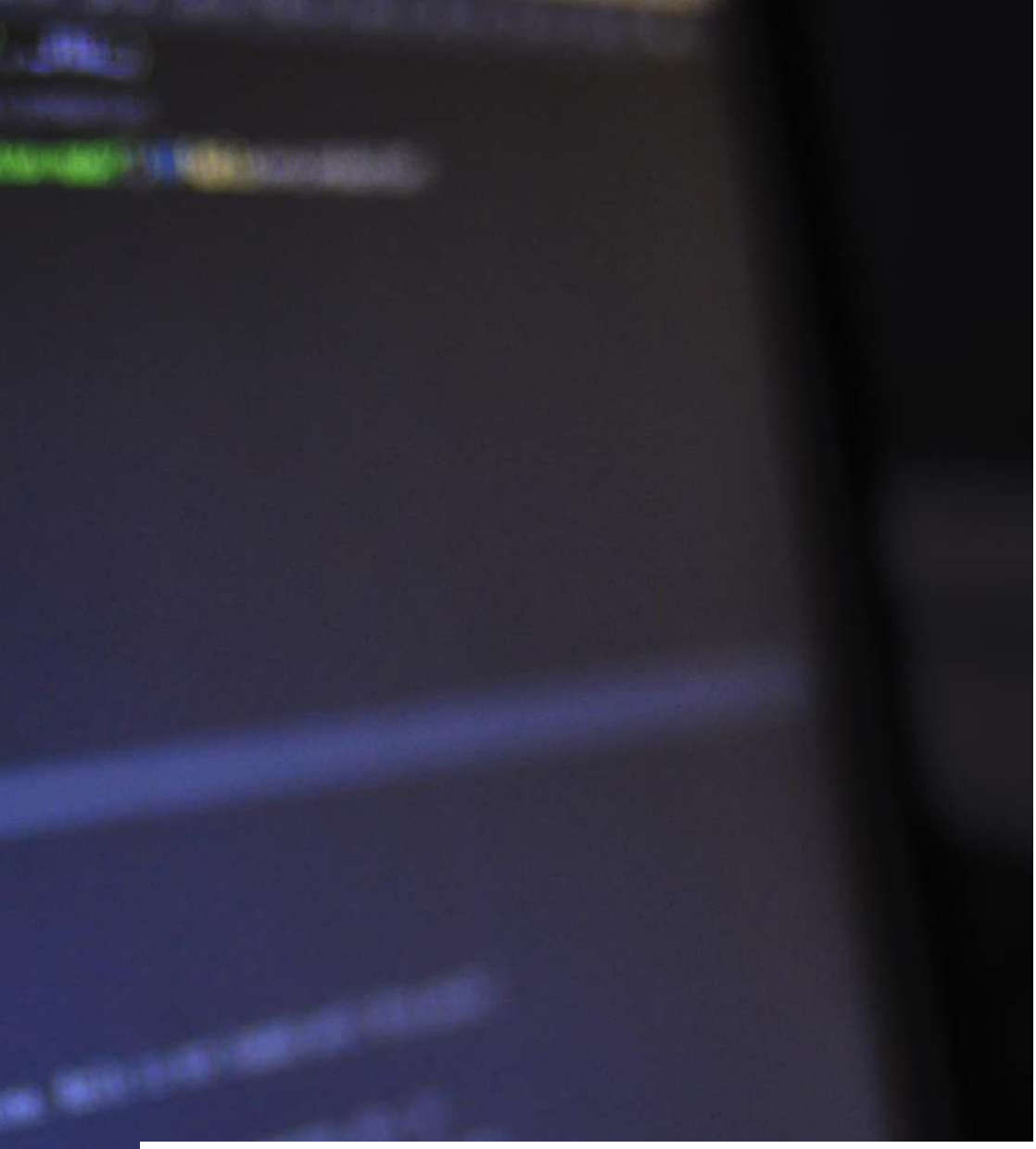
» **The climate element and impacts of R&I investments need to be more transparent and tracked in Horizon Europe, but also better disclosed by the private sector:** Firstly, a climate impact pathway should be defined for Horizon Europe and its R&I allocations should be tracked against the EU's long-term climate and energy targets, and the Paris Agreement. To deliver this transparency, as a part of the grant agreement, lead beneficiaries of Horizon Europe funding should estimate the climate-relevant percentage of their projects' outcomes. This level of climate-related tracking and transparency should also be a priority for InvestEU and other EU-level funding instruments. This would allow increased connectivity to, and stimulation of the later stage public and private investments which are also required, subsequently to R&I, to deliver successful decarbonisation missions.

» **Net-Zero emissions in Europe by 2050 requires concerted collaboration on climate-related R&I collaboration between the public and private sectors:** EU-level R&I funding instruments, together with other public sources, should increasingly enable and facilitate increased private sector climate-related R&I. The public sector alone is unable to deliver the product and business model-level innovation and therefore economy-wide transformation required. This means that Horizon Europe, European Innovation Council and the R&I window of InvestEU can use mission-led and sector-level decarbonisation pathways to further direct and increase private sector co-investments through more innovation partnerships and collaborative financing structures. Given the extensive debate on mission scope among experts, and the five "sector level" missions described in this report, perhaps the only EU-level Mission required is that to deliver Net-Zero emissions by 2050.

Notwithstanding the encouraging progress in several of the five sectors which need to reduce their emissions to net-zero by 2050, the levels of R&I investment to enable the timely delivery of Europe's long-term climate targets and the goals of the Paris Agreement within the constraints of a carbon budget are significant. The faster Europe responds to this challenge, the greater the competitive advantage it can gain and the more time it will have to scale-up the required technologies and deliver the society level benefits of a net-zero emissions economy.

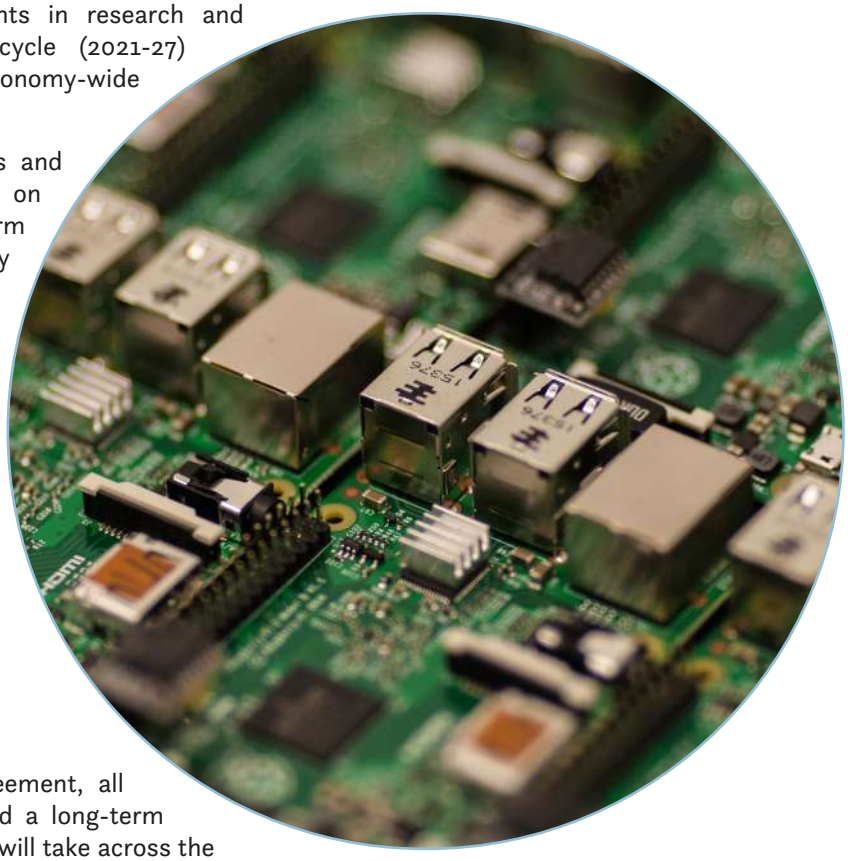
Annex: Methodology





To better understand the role, and need, for innovation in the decarbonisation of the European economy, and to offer timely insights to policymakers designing future research and innovation funding programmes, this report combines a literature review, which focuses on existing funding for climate related innovation, with the results of an online survey of over 100 experts and institutions from four communities: Climate experts reviewing net-zero emissions scenarios for 2050, Energy experts developing energy sector decarbonisation scenarios for 2050, Experts from an ECF deep decarbonisation pathways network and Members of a 2050 platform considering the strategy for long-term EU greenhouse gas emissions reductions.

Europe's long-term decarbonisation challenge can be sub-divided into five segments: Power, Transport, Buildings, Industry and AFOLU (Agriculture, Forest, Land-Use & diet). The expert survey was designed to identify where innovation can best accelerate the low carbon transition in these five sectors. Aligning with the net-zero 2050 modelling architecture (described further in the section below), each segment was further sub-divided into its principal "component parts". In total the survey asked for expert opinions on 58 individual components of the five sector decarbonisation challenge and specifically about how the European Commission's investments in research and innovation in its next budget cycle (2021-27) could accelerate long-term, economy-wide decarbonisation.



This report builds its perspectives and framework to elicit expert opinion on the role for innovation in the long-term decarbonisation of the EU economy on two expert communities contributing to two specific projects modelling a net-zero economy in Europe by 2050 and developing 2050 energy sector decarbonisation scenarios. These two projects whose technical work and participant networks formed the base for this report are briefly described below:

European Net-Zero Emissions Climate Modelling Project

Under Article 4 of the Paris Agreement, all parties are required to put forward a long-term strategy setting out the action they will take across the economy to contribute to the global goals of limiting global average temperature increase to well below 2°C above pre-industrial levels, aiming at 1.5°C. This is likely to mean global emissions falling to net zero by mid-century, with developed countries arriving at this level earlier than the global average – an objective to which 19 countries, including 12 EU Member States have already committed. At the European Council meeting in March 2018, EU Heads of State and Government invited the European Commission to prepare a draft of the EU's collective mid-century strategy by Q1 2019.

The Governance Regulation (part of the EU Clean Energy Package) formalizes the requirement for the Commission to include in its long-term emissions strategy options at least one scenario which would reach net zero emissions within the EU by 2050, and to go into negative emissions thereafter. It also requires the Commission to assess implications of these pathways on global carbon budget and equity. Furthermore, the Environment Ministers of 14 Member States (members of the Green Growth Group) released a statement on 25th June calling on the Commission to include several pathways towards carbon neutrality, including a 1.5 degrees scenario, and at least one pathway towards net zero by 2050 followed by negative emissions.

While the long-term strategy options paper, expected in November, will only be a first approach by the European Commission, it will form the basis of the eventual mid-century strategy that Heads of State will approve in late 2019 / 2020 and submit to the UNFCCC. This in turn will set a 'North Star' for the whole next raft of EU policy-making, covering policy areas from climate governance to energy, to industry and agriculture, at least insofar as they relate to GHG emissions.

As part of ECF's work to establish a vision and evidence base transition to Paris-compatible emissions levels in the EU, in autumn 2017 it commissioned the consultancy Climact to build an economy-wide 2050 Roadmap Tool, that can be used to develop and test possible pathways to net zero emissions by mid-century. The tool incorporates an analytical base of deep dives on particular sectors including power, transport and buildings (Energy 2050), industrial transformation (IT50), agriculture (Agriculture 2050) and on topics including governance for net zero emissions.

The 2050 Roadmap Tool is a calculator which models, at aggregated EU level, the various GHG emitting sectors: transport, power, buildings, industry, AFOLU, and key interactions between them, out to 2050. It is based on the Carbon Transparency Initiative (CTI) model and defines over 50 levers representing key drivers of emissions (e.g. EV uptake, meat consumption etc.). Levers can be set anywhere between level 1 (current practice and policies) to level 4 (best practice and transformational options) for each decarbonisation strategy. By setting different combinations of levers, modellers can create scenarios whose emissions' impact and cost implications are calculated.

A number of leading organisations and experts were consulted during the building of the tool, and were involved in developing the pathways and outputs including: Agora-Energiewende, Climate Strategy, Fraunhofer Institute for Systems and Innovation Research ISI, Friends of the Earth (FoE) UK, Grantham Research Institute - London School of Economics, Iberdrola, Institute for European Environmental Policy (IEEP), Institute for Sustainable Development and International Relations (IDDRI), Stefan Scheuer, Third Generation Environmentalism (E3G), UK Department for Business, Energy and Industrial Strategy (BEIS), and the World Wide Fund for Nature (WWF) European Policy Office. Other organisations consulted include Agora Verkehrswende, Aviation Environment Federation (AEF), Buildings Performance Institute Europe (BPIE), Ecofys, EuroACE, the European Consumer Organisation (BEUC), the European Federation for Transport & Environment (T&E), Fern, Fraunhofer ISI, International Federation of Organic Agriculture Movements – EU (IFOAM-EU), International Institute for Systems Analysis (IIASA), Öko-Institut, Imperial College London (ICL), Open Exp, Stefan Scheuer, and Vrije Universiteit Brussel (VUB) – Institute for European Studies (IES).

As well as making the underlying Roadmap 2050 model available on an open source basis, Climact and the ECF have published a set of example net-zero emissions scenarios to serve as a resource for policy-makers and experts to test possibilities, make comparisons and develop better systems understanding. The accompanying report describing these net-zero emissions pathways was published in September 2018 with the intention to support the Commission's preparation of the options for the EU's mid-century strategy. The report has key conclusions:

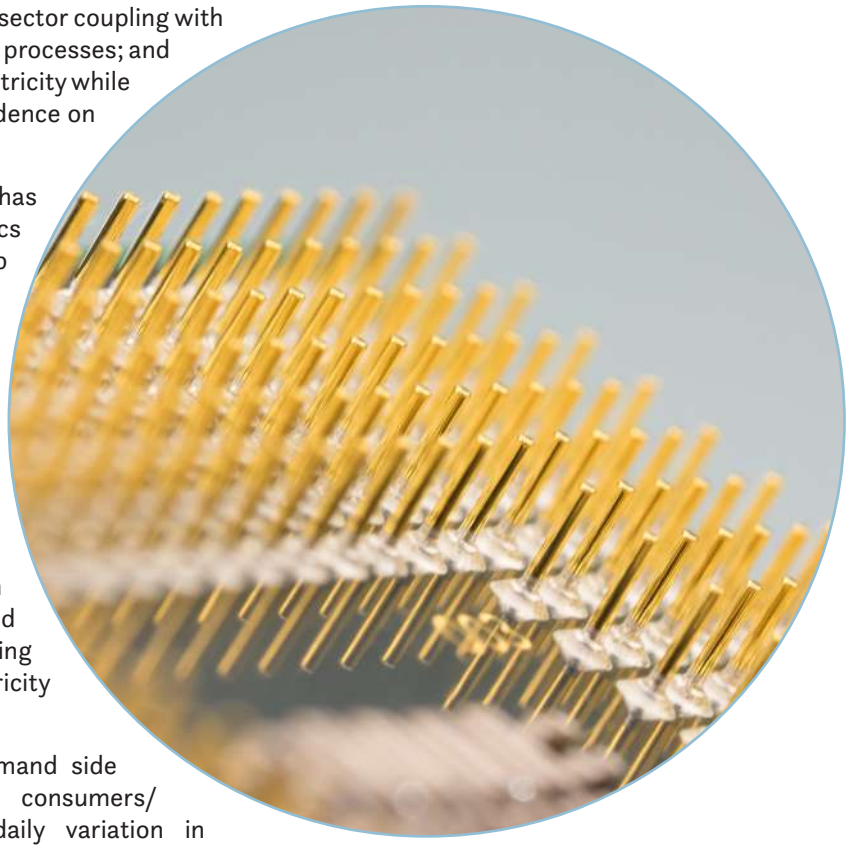
» Reaching net-zero greenhouse gas emissions by 2050 is feasible, but requires strong action across all sectors, widening the range of low carbon options used.

» Net-zero greenhouse gas emissions in 2050 requires an increase in 2030 ambition to set Europe on the right trajectory.

» Net-zero pathways can cost less than business-as-usual and build a more attractive, resilient society.

Energy 2050 Project: Developing zero-carbon energy scenarios for Europe

The progress made in the last decade on improvements to energy efficiency and increasing the share of renewable electricity generation gives rise to a key question: What configurations of zero-carbon energy systems exist that affordably maintain security of supply for Europe? The answer requires consideration of several factors: the role of electrification of loads versus alternative decarbonisation vectors; the tighter sector coupling with mobility, heating and some industrial processes; and maintaining security of supply of electricity while moving away from our heavy dependence on fossil thermal plant.



To answer these key questions, ECF has contracted Cambridge Econometrics and Element Energy to develop decarbonisation options for the whole energy system, and to explore the following:

- the cross sectoral and systemic implications of decarbonisation across heat, power and transport sectors;
- the key role and extent green electricity can decarbonise heat, transport and industrial processes, including its combined impact on electricity supply and infrastructure;
- the positive impact of demand side measures, including: smart consumers/consumption in managing daily variation in demand after supply of variable renewables; and the impact of energy efficiency in buildings on the viability of the green electrification pathways;
- the extent to which energy supply and demand could be matched more effectively by other green energy vectors in meeting seasonal energy demands for heat and in balancing the power system;
- the macro-economic impact on the European economy of different pathways.

The study examines the feasibility of zero carbon energy systems for the EU by 2050 on the basis of a number of different scenarios that explore a wide range of technological options for supply, demand, flexibility and smartness that can be applied to meet this goal. Archetypes were generated and applied across Europe which represented diverse climatic conditions (reflecting renewable energy supply as well as heating demand) and the availability of gas infrastructure (as an alternative means of decarbonizing heating). The model used balances energy for each hour of the year, responding to varying renewable supply and energy demands. To achieve this balance, the model uses a portfolio of flexibility options – demand side response, thermal storage, grid-connected batteries, controlled EV charging & V2G, and interconnectors. Where required, longer timescale/seasonal deficits of energy are balanced using hydrogen as a storage medium.

Each scenario is designed to provide security of energy supply throughout the year – a key challenge with high renewable energy scenarios. Scenarios were compared in terms of: System costs; and macro-economics. They were also compared against a BAU/Current Policies baseline to 2050. A core assumption is that electrification is a primary vector for decarbonisation of demand loads. Smart consumption and energy efficiency within these sectors are included in the scope. The analysis also includes the role that some industrial and commercial processes can play in providing demand response. Scenarios explore the use of other green energy vectors (such as biogas and hydrogen) and e-fuels to support the system where electrification would be costly.

Each scenario is being evaluated not only from an energy systems and climate perspective, but also from a socio-economic perspective to deliver insights into the impact on the economy and employment. For example: while the energy system model might indicate a lower overall cost if energy is imported from outside Europe, this would have an adverse impact at the macroeconomic level.

The project model's integrated treatment of the economy, the energy system and the environment enables it to capture bidirectional linkages and feedbacks between these components. Its high level of disaggregation enables relatively detailed analysis of sectoral effects and it delivers outputs in terms of changes to household budgets, the energy trade balance, consumption, GDP, employment, CO_2, NOx and particulates. The report will be published in late 2018.

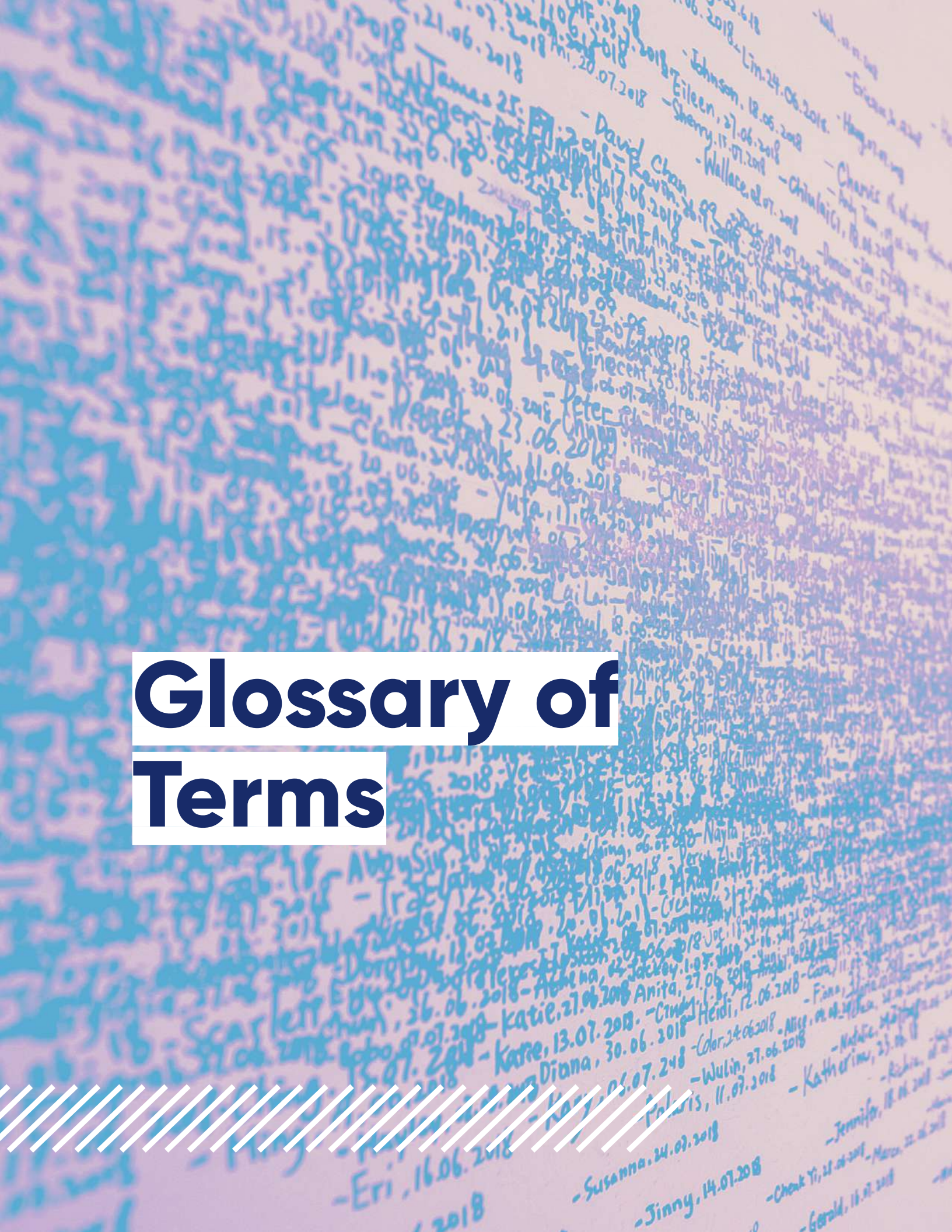
Expert Innovation Survey Structure

Matching the architecture of the net-zero 2050 models, the expert survey was designed to elicit the answers to five questions and the relative prioritisation and scores for each of the 58 sector component decarbonisation strategies. These five questions were:

1. How critical, in your view, is innovation in this component to deliver a net-zero economy in 2050 ?
2. Where in this component's supply chain is innovation most relevant? (I.e. Is it Technology, Product/ Service, Business Model or Social/ Cultural Innovation?)
3. Could innovation investment in this component generate an EU competitive advantage? (either building on an existing one or acting in a space where the lead is yet to be established, globally)
4. Can you pick the funding instrument that would be most effective (or needed) in funding innovation for this component area?
5. Would you increase or decrease FP9 funding for innovation to this component? (Relative to its spending in Horizon 2020 - whose summary allocations were provided, see chart 7 in Section 2 of this report).

Experts were offered the opportunity to elaborate on any of their answers to any of the questions by sector and to identify or describe a potential "EU Mission" or mission orientations which should guide EU-level innovation budgets and priorities in that sector. Experts were informed that mission-oriented innovation should be "ambitious, exploratory and ground-breaking in nature, often cross-disciplinary, targeting a concrete problem/challenge, with a large impact and a well-defined timeframe". Moreover, that missions "have a clearly defined (societal or technological) goal with preferably qualified and/or quantified targets and progress monitored along predefined milestones. Directionality and intentionality of these initiatives is what differentiate them from other types of initiatives, such as systemic or challenge-oriented policies."

Net zero GHG emissions can be confused with net-zero carbon emissions, but when accurately used, means all greenhouse gas emissions decline to zero, as opposed to just carbon dioxide. This is the same concept as net zero carbon emissions but conveys a net zero emissions target for CO_2 and all non-CO_2 gases.



Glossary of Terms

2050 Pathways Platform

The 2050 pathway platform is a multi-stakeholder initiative launched at COP 22 by High-Level Climate Champions Laurence Tubiana and Hakima El Haite to support countries seeking to develop long-term, net zero-GHG, climate-resilient and sustainable-development pathways. Designed as a space for collective problem-solving, the platform will also build a broader constellation of cities, states, and companies engaged in long-term low-emissions planning of their own, and in support of the national strategies.

Business Model[55]

"A business model describes the value an organization offers its customers and illustrates the capabilities and resources required to create, market and deliver this value and to generate profitable, sustainable revenue streams."

Capital Intensive[56]

Capital intensive industries tend to have high levels of operating leverage, which is the ratio of fixed costs to variable costs. As a result, capital intensive industries need a high volume of production to provide an adequate return on investment. This also means that small changes in sales can lead to big changes in profits and return on invested capital.

Carbon Neutrality[57]

Carbon neutrality means annual zero net anthropogenic (human caused or influenced) CO_2 emissions by a certain date. By definition, carbon neutrality means every ton of anthropogenic CO_2 emitted is compensated with an equivalent amount of CO_2 removed (e.g. via carbon sequestration), but this term has been used differently on occasion. For instance, Costa Rica's INDC would "achieve Carbon Neutrality by 2021 with total net emissions comparable to total emissions in 2005," while Ethiopia's goal is to "achieve carbon-neutral middle-income status before 2025" and at the same time "limit its net greenhouse gas (GHG) emissions in 2030 to 145 Mt CO_2e or lower." Instead of aiming at zero net emissions, some countries seem to misinterpret carbon neutrality as stabilizing emissions at a certain level.

Decarbonisation[58]

Decarbonisation is framed around decreasing the ratio of carbon dioxide (CO_2) or all greenhouse gas emissions related to primary energy production. While full decarbonisation means zero unabated (not captured by carbon sequestration or storage) CO_2 emissions from energy generation and industrial processes, decarbonisation doesn't imply zero emissions, as emissions can be balanced by carbon sequestration if adequate reductions or enhanced carbon sinks exist. To effectively communicate the scale of change needed, the term must be accompanied by a timeframe and rates of decarbonisation.

55 Osterwalder, A., Pigneur, Y., & Tucci, C. (2005). Clarifying Business Models: Origins, Present and Future of the Concept. Communications of the Association for Information Systems, Volume 15

56 Investopedia. (2018). Capital Intensive. [Definition]. Retrieved from https://www.investopedia.com/terms/c/capitalintensive.asp

57 WRI. (2015). COP21 Glossary of Terms Guiding the Long-term Emissions-Reduction Goal. In Blog. Retrieved from https://www.wri.org/blog/2015/12/cop21-glossary-terms-guiding-long-term-emissions-reduction-goal

58 WRI. (2015). COP21 Glossary of Terms Guiding the Long-term Emissions-Reduction Goal. In Blog. Retrieved from https://www.wri.org/blog/2015/12/cop21-glossary-terms-guiding-long-term-emissions-reduction-goal

Green Bond[59]

Green bonds were created to fund projects that have positive environmental and/or climate benefits. The majority of the green bonds issued are green "use of proceeds" or asset-linked bonds. Proceeds from these bonds are earmarked for green projects but are backed by the issuer's entire balance sheet.

Horizon Europe[60]

Proposed by the European Commission June 2018, Horizon Europe is an ambitious €100 billion research and innovation programme that will succeed Horizon 2020. Horizon Europe will build on the achievements and success of Horizon 2020 with the intention of keeping the EU at the forefront of global research and innovation. Horizon Europe stands the most ambitious research and innovation programme ever. The proposal was made as part of the EU's proposal for the next EU long-term budget (2021-2027), the multiannual financial framework (MFF).

Incremental Innovation[61]

Improvements to existing products, services and processes for existing markets.

Innovation

Innovation in its raw form is a new idea, device or method, which is often interpreted as the application of better solutions that meet new requirements, unarticulated needs, or existing markets. Innovation can take place through the provision of more-effective technologies, processes, products, services, and/or business models that are made available to markets, governments and society. These components of the "Supply Chain of Innovation" are further defined below.
As reference, the EC for its 1995 Green Paper defined innovation[62] as:

- The renewal and enlargement of the range of products and services and the associated markets;
- The establishment of new methods of production, supply and distribution;
- The introduction of changes in management, work organisation, and the working conditions and skills of the workforce.

Innovation Action[63]

'Innovation action' means an action primarily consisting of activities directly aimed at producing plans and arrangements or designs for new, altered or improved products, processes or services, possibly including prototyping, testing, demonstrating, piloting, large-scale product validation and market replication;

Innovation Need

'Innovation need' is a subjective definition resulting from the consensus opinion of 50 experts consulted for this report. It provides a relative guide to the amount of innovation required in each of 58 identified decarbonisation strategies provided in five sectors by the ECF net-zero 2050 modelling and scenario work;

59 Climate Bonds Initiative. (2018). Explaining green bonds. In Market. Retrieved from https://www.climatebonds.net/market/explaining-green-bonds
60 European Commission. (2018). Horizon Europe - the next research and innovation framework programme. In Policies, Information and services. Retrieved from https://ec.europa.eu/info/designing-next-research-and-innovation-framework-programme/what-shapes-next-framework-programme_en
61 European Commission. (2018). Document 52018SC0307. In EUR-Lex - 52018SC0307 – EN. Retrieved from https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52018SC0307
62 European Commission. (1995). Green Paper on Innovation. Retrieved from http://europa.eu/documents/comm/green_papers/pdf/com95_688_en.pdf
63 European Commission. (2018). Horizon 2020: Rules for Participation and Dissemination - Elements of H2020 Model Grant Agreement. [Presentation]. Retrieved from https://ec.europa.eu/inea/sites/inea/files/a_iatrou_0.pdf

Mission[64]

'Mission' means a portfolio of cross-cluster excellence-driven R&I actions intended to achieve a measurable goal within a set timeframe, and have an impact for science and technology, and/or for society, policy-making and/or diplomacy and citizens and which that could not be achieved through individual actions.

Mission-oriented Approach[65]

This is an approach to policy-making which means setting defined goals, with specific targets and working to achieve them in a set time. A number of missions will be included in Horizon Europe the next framework programme and these will specifically target global challenges. The target would be clearly measurable and need to be achievable with a portfolio of research and innovation measures.

Net zero carbon emissions[66]

Net zero carbon emissions is considered a synonym for carbon neutrality. One key difference, however, is carbon neutrality can be achieved at the domestic level with offsets from other jurisdictions, while net zero emissions does not have the same connotation (though theoretically could be met via offsets). Both terms risk overshooting the carbon budget unless complemented by short-term emissions reduction targets.

Net zero GHG emissions[67]

Net zero GHG emissions can be confused with net-zero carbon emissions, but when accurately used, means all greenhouse gas emissions decline to zero, as opposed to just carbon dioxide. This is the same concept as net zero carbon emissions but conveys a net zero emissions target for CO2 and all non-CO2 gases.

Open Innovation[68]

'Open innovation' represents a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and new collaborative tools;

Private Capital[69]

Private capital: capital from private and institutional investors (such as pension funds, assurances, sovereign wealth funds) in a broad sense, including all those that have significant amounts of assets under management.

Private Equity[70]

"A professionally managed pool of money raised for the sole purpose of making actively-managed direct equity investments in private companies and with a well defined exit strategy (sale or IPO)" (Megginson 2004).

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64 European Parliament. (2018). ***I DRAFT REPORT: on the proposal for a regulation of the European Parliament and of the Council establishing Horizon Europe –the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination (COM(2018)0435–C8-0252/2018–2018/0224(COD)). Retrieved from http://www.europarl.europa.eu/sides/getDoc.do?type=COMPARL&reference=PE-625.305&format=PDF&language=EN&secondRef=01

65 European Commission. (2018). Horizon Europe - the next research and innovation framework programme. In Policies, Information and services. Retrieved from https://ec.europa.eu/info/designing-next-research-and-innovation-framework-programme/what-shapes-next-framework-programme_en

66 WRI. (2015). COP21 Glossary of Terms Guiding the Long-term Emissions-Reduction Goal. In Blog. Retrieved from https://www.wri.org/blog/2015/12/cop21-glossary-terms-guiding-long-term-emissions-reduction-goal

67 Ibid

68 European Commission. (2018). Commission's high-level advisers advocate open research and innovation as essential drivers for growth in Europe. In Policies, Information and services. Retrieved from http://ec.europa.eu/research/index.cfm?&na=na-150517&pg=newsalert&year=2017

69 DIE. (2014). Public Instruments to Leverage Private Capital for Green Investments in Developing Countries. Retrieved from https://www.die-gdi.de/uploads/media/DP_4.2014.pdf

70 Megginson, W. (2004). Towards a Global Model of Venture Capital? Journal of Applied Corporate Finance, 16(1) 8–26.

Research[71]

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. The term R&D covers three activities: basic research, applied research and experimental development.

Supply Chain of Innovation[72]

Refers to an expanded definition of innovation using an analogy with R&D commodities as the outcome of research activities, whose products are patents, technologies, research services, studies, projects, etc. In the case of overall innovation, the supply chain which delivers net-zero 2050 innovation at the economy-wide level is composed of four "innovation types" used to facilitate decarbonisation in five sectors in this report.

Technology innovation[73]

Technological product and process (TPP) innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes

Product innovation[74]

A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. These include significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

Business model innovation[75]

Business model innovation is the art of enhancing advantage and value creation by making simultaneous—and mutually supportive—changes both to an organization's value proposition to customers and to its underlying operating model. At the value proposition level, these changes can address the choice of target segment, product or service offering, and revenue model. At the operating model level, the focus is on how to drive profitability, competitive advantage, and value creation through these decisions on how to deliver the value proposition:

- Where to play along the value chain
- What cost model is needed to ensure attractive returns
- What organizational structure and capabilities are essential to success

Societal Innovation[76]

It refers to a systemic change in the interplay of the state and civil society and is related to social innovation, but differs from it by considering the state to be an important cocreator in achieving sustainable systemic change.

71 OECD. (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development. Retrieved from https://www.oecd-ilibrary.org/science-and-technology/frascati-manual-2015_9789264239012-en

72 Mazzola, E., Bruccoleri, M., & Perrone, G. (2015). Supply chain of innovation and new product development. Journal of Purchasing and Supply Management, 21(4), 273-284.

73 OECD & Eurostat. (2005). Oslo Manual: The measurement of scientific and technological activities: proposed guidelines for collecting and interpreting innovation data. Retrieved from http://ec.europa.eu/eurostat/ramon/statmanuals/files/9205111E.pdf

74 The Innovation Policy Platform. (2018). Product and process innovation. In Product and process innovation. Retrieved from https://www.innovationpolicyplatform.org/content/product-and-process-innovation

75 BCG. (2018). What is Business Model Innovation? In Business Model Innovation. Retrieved from https://www.bcg.com/en-es/capabilities/strategy/business-model-innovation.aspx

76 Lehtola, V. & Ståhle, P. (2014). Societal innovation at the interface of the state and civil society, Innovation: The European Journal of Social Science Research, 27:2, 152-174, DOI: 10.1080/13511610.2014.863995

Unicorn Company[77]

The term refers to any tech startup company that reaches a $1 billion dollar market value as determined by private or public investment.

Venture Capital[78]

Venture capital is a specific type of finance well suited to the requirements of new technology based firms. The combination of research and development, intangible assets, negative earnings, uncertain prospects and absence of a proven track record, which are characteristic of start-up and pre-commercial initiatives, leads to an unacceptably high perception of risk for conventional financial institutions and debt financing. Venture capital addresses the consequent financing gap through equity participation.

77 Investopedia. (2018). Unicorn. [Definition]. Retrieved from https://www.investopedia.com/terms/u/unicorn.asp

78 EIB. (2001). Financing Innovative Firms through Venture Capital. Retrieved from http://www.eib.org/attachments/pj/vencap.pdf

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C40 Cities. (2018). 19 Global Cities Commit to Make New Buildings "Net-Zero Carbon" by 2030. In Media. Retrieved from https://www.c40.org/press_releases/global-cities-commit-to-make-new-buildings-net-zero-carbon-by-2030

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www.europeanclimate.org/net-zero-2050
2050@europeanclimate.org

www.climateestrategy.com
info@climatestrategy.com