Decarbonisation pathways portal

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Introduction

REINVENT's Decarbonisation pathways portal is an online resource that synthesises the insights from the project in a reader-friendly format. Integrated into the project's website, the portal contains 13 questions on decarbonisation, which are structured along three themes:

- 1 overarching question that brings all other questions together to address what will make deep decarbonisation a reality [Q1];
- 4 questions are devoted to **sectors** that have been in focus of the project – plastics, pulp & paper, steel and meat & dairy [Q2-Q5];
- 4 questions are devoted to different **actors** and their roles in driving decarbonisation – the industry, governments, consumers and movements, and institutional investors [Q6-Q9];
- 4 questions are devoted to **logics of change** – efficiency, reduced demand, circular economy and finance [Q10-Q13].

The portal is available here: https://www.reinvent-project.eu/decarbonisation-portal. The main page welcomes the guests and contains click-through images with questions. Each question has its own page, with layout similar to a newspaper article, supported by visual images that speak to the topic.

Each question in the portal has been addressed in a clear and concise manner, giving a short answer drawing on the insights from REINVENT's work. The texts are complemented by the various work that has been done in the project – key deliverables, case studies, publications and also graphic visualisations of these. Some texts are also supported by selected references to publications outside the project.

The portal is aimed at all stakeholder groups of REINVENT (see D7.2 Updated DACS) – from industry experts and policy-makers working on decarbonisation to public interested in the topic. The answers have been written so that those working closely with the theme can be informed from reading them, but also avoiding jargon as much as possible so that other readers could also follow the texts. The extra materials allow the readers to delve deeper into the topics that are of interest to them.

It is key to REINVENT's Dissemination and Communication Strategy (D7.2). It will be launched after the summer break, to coincide with active times of different stakeholders for the project. The launch will be done via the project's twitter account, and communicated via various channels. The 13 answers will be published one after another, supported by extra information that can be found on the portal.

Before the launch, polishing and enrichment of the content is to take place. For example, once REINVENT's policy briefs are completed (D5.4, D6.4, due on 31 July 2020), they will also be integrated into the portal. When launched, the portal will appear in the main menu of the project's website, and also a link to it will appear on the main page. Currently the link to the portal is not visible on the website to avoid prior communication.

The rest of this document contains the 13 texts that constitute the portal, listing the documents that complement each. References to REINVENT's work are indicated in square brackets [],

other references in round brackets (). Please note that content in this document will have differences from the online version, as the latter is likely to be updated and adjusted when preparing the launch. Each question below has a hyperlink that takes the reader to the respective page, but these may also change, hence check the website or contact us if you encounter problems with finding the respective page.

Q1. What will make deep decarbonisation a reality?

Deep decarbonisation, meaning a society where greenhouse gas emissions are drastically reduced, requires manifold changes across economies and societies. These range from altered consumption patterns and using less materials **[Q11]** to technological shifts in the production of steel, paper, plastics, and food. For these purposeful changes to happen, an important step is to create a clear direction and shared vision for the development of society and industry towards decarbonisation **[Q6]**. It is not only for the EU, national governments, and industry **[Q7]** to drive this change, but also consumers, institutional investors, social movements and other actors **[Q8, Q9]**.

Efforts to reduce emissions include those which seek to reduce demand for raw materials or products and thus also for energy, increased circularity, energy and materials efficiency, electrification, and fuel switching, as well as carbon dioxide utilisation and storage (CCUS). Demand reduction, efficiency and circularity are important strategies to reduce the need for primary materials production **[Q10, Q12]**. The exact configurations of solutions vary across sectors and contexts, but electrification, fuel switching and CCUS will be necessary to reach zero or negative emissions in several sectors, and reducing primary production will mean less pressure on natural resources. Similarly, dietary shifts in combination with technology change can reduce agricultural emissions and pressure on land use **[Q3]**. Decarbonisation will not be achieved by industry alone. New social actors and developments can be observed in the field of plastics **[Q2]** and food **[Q3]**, for example, which initiate and perpetuate a change in social norms and culture that shape the demand for goods. Such initiatives motivate many people to think more deeply about a sustainable world and to work for climate protection, whether in their business, private lives or in organised community actions.

Industrial transformation is a relatively new policy challenge, and policy-makers can learn and benefit from current social developments. New challenges, such as the plastic crisis, require mutual and collective learning and capacity building for developing solutions, strategies, and governance **[Q2]**. Current policies have been strong in supporting research and innovation but have paid less attention to creating and reshaping sectors and the required infrastructures needed to implement decarbonisation. For example, this can be done through promoting green protein transitions or creating conditions for investments in fossil-free steelmaking **[Q4]**.

The REINVENT project has shown the complexity and diversity of decarbonisation options across the economy, the importance of contextual factors, financing **[Q13]**, and emerging links between key sectors that will shape the possibilities for change **[Q5]**. We show that carbon pricing is only one of many drivers for decarbonisation, and many more options are more viable. While this project does not have all the answers, it strongly shows that deep decarbonisation requires policy to deliver a clear vision, research and innovation, market

creation, capacity building, international policy coherence and attention to social welfare. For more nuanced and elaborate discussions we welcome you to this portal and our various results.

Q2. Can we live without plastic?

Plastic already makes up 4-8% of global CO_2 emissions, is non-degradable and extremely hard to recycle, contributing simultaneously to climate change, land and ocean pollution. To address environmental harms associated with plastic, we could reduce its usage, primarily among single-use applications, as well as explore bio-based and recycling solutions [REF D.2.3 – Climate innovations in the plastic industry].

Today about 40% of plastic goes into packaging, most of which is single-use or disposed of quickly. Retail relies heavily on this material, but there are signs that times are changing. Zero-waste stores, which sell groceries primarily in bulk and without single-use plastic packaging, are rapidly expanding. While not at the scale to be disruptive to conventional retail, they demonstrate that a different future is possible. Part of the global zero-waste movement, aiming to change lifestyles, provoking public discussion and providing a space for consuming differently, zero-waste stores have the potential to change what we expect from retail. Since the practice of grocery shopping is broadly similar worldwide, if the idea of zero-waste stores takes hold, change could happen quickly. [REF Zero-waste stores].

For the plastic applications that are not so easy to reduce or substitute fully, the question is whether we can live without fossil-based plastic. Many companies experiment with bio-based alternatives, even if their proportion in total plastic production is miniscule so far. Forestry companies have developed new biocomposite materials that blend cellulose fibres, wood particles, and bioplastic or recycled plastic [REF DuraSense case study]. These could be used in automotive panels, upholstery and furniture. Clothes do not have to be fossil-based either. There are outdoor jackets made from castor oil and recycled textile fibres [REF Tierra jacket]. These are niche examples, but to accelerate a large-scale transition away from fossil-plastic, a tax on the carbon content on plastic feedstock would be needed [D3.6 Drivers].

Governance of plastics today is scattered and reactive. Legislation is focused on waste management and reducing plastic pollution [REF Nielsen et al., 2019a]. Bans on certain single-use products such as plastic bags [REF Nielsen et al., 2019b], straws and cutlery exist or are expected, notably in Europe. More ambitious legislation is necessary, not least in addressing the cheap price of fossil plastic production. For example, this could be done through an overhaul of the free allocations of EU ETS (European Union Emission Trading Scheme) emission allowances to the petrochemical industry. Simultaneously it is important to consider potential negative environmental impacts of an increased use and production of alternative materials.

References

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Q3. How far towards the Paris goals would moving away from meat & dairy take us?

The meat and dairy supply chains are responsible for 15% of all greenhouse gas emissions in the European Union [REF aan den Toorn et al. 2020]. The most important activities causing these emissions are enteric fermentation from ruminants, particularly emitted by beef cattle (35%) and dairy cattle (32%), as well as manure management and feed production. To reduce these emissions, there are initiatives focusing on reducing food waste and decarbonising emission sources, but changing diets is essential for reaching the Paris Agreement [REF: Meat & dairy sector report].

Moving away from animal products by radically shifting diets could reduce annual greenhouse gas emissions by a quarter (Stehfest et al., 2009). Alternative protein products generally have lower carbon footprints compared to meat and dairy [REF Meat & dairy sector report], but a more general shift can also benefit health and help to achieve other Sustainable Development Goals, as shown by the findings of the EAT-Lancet Commission. In their proposed diet, consumption of foods such as red meat and sugar is reduced by more than 50% globally, while consumption of fruits, vegetables, nuts and legumes doubles.

In Europe, halving the consumption of beef and dairy products would not only lead to a drastic cut in greenhouse gas emissions (by around 15-40% of total agricultural emissions) but would also reduce the need for importing soya by about 75% as much less feed is needed (Westhoek et al., 2014). Furthermore, animal husbandry is also responsible for about 80% of global agricultural land use – both directly (for pasture) or indirectly (arable land used for feed), so shifting to a more plant-based diet can also lead to using less land, which can reduce deforestation and provide room for reforestation or bio-energy production. For reaching the Paris Agreement, this could also mean that the measures in other sectors (i.e. energy) can be less drastic, reducing either costs (Stehfest et al., 2009) or the need for negative emissions (Van Vuuren et al., 2018).

There are already highly successful initiatives led by producers, where, for example, dairy products are substituted by oat-based alternatives [REF Oatly case study]. Plant-based meat substitutes have also been on the rise in the European Union, driven by consumers and informal governance networks, for example in the Netherlands [REF Tziva et al., 2019] However, governments have been resisting the introduction of consumption taxes on meat and dairy products, due to barriers erected by international regulatory institutions and uncertainties related to the impact of such tools (Bødker et al., 2015; Fellmann et al., 2017). Therefore, the promotion of innovative substitutes can constitute an opportunity to surpass these barriers and contribute to the reduction of meat and dairy consumption.

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Q4. Are new technologies able to create zero-emission steel?

Steel is one of the most used and versatile materials in society, but the making of steel is highly energy-intensive and relies for a large part on coal, making the industry also one of the biggest sources of CO_2 emissions. This poses a grand challenge for deep decarbonisation [REF Steel sector report].

Steel can be manufactured from iron ore, called primary steel, or from scrap, referred to as secondary steel. The production of iron is the largest energy consumer and source of greenhouse gases. Emissions in secondary steel production can be very low, if fossil-free electricity is used. Hence, increasing the use of scrap is one option for decarbonisation. However, the availability of scrap limits the potential of switching to secondary production.

New technologies and ways of making steel exist that can strongly reduce the emissions from primary steelmaking (Lechtenböhmer et al. 2018). European steel producers have begun to consider hydrogen as an energy carrier instead of coal (Arens & Vogl 2019), as for example in the HYBRIT project that aims to develop a fossil-free value chain for steel [REF HYBRIT case study]. Other European innovation projects focus on producing chemicals such as methanol or ethanol from off-gases through carbon capture and utilisation (CCU), or developing smelting reduction technology as an alternative to the blast furnace. Low-emission steel production under the latter technologies depends on the availability of carbon capture technology.

The climate impact of the EU steel industry is governed mainly through the EU Emissions Trading System (ETS). To avoid carbon leakage (where industries move abroad, resulting in a net increase of global greenhouse gas emissions), the steel sector has been granted free emission allowances to cover their emissions. More recently, both industry and policy-makers

have started to advocate a wider set of industrial policy measures, including the creation of markets for 'green' basic materials, exemptions of certain activities from EU State Aid rules, and increased attention to issues of justice in the transition to net-zero emissions (EC 2020).

A transition to net-zero emissions in the steel industry involves both processes of innovation and decline (Rosenbloom et al. 2020). Once new low-emission processes start to diffuse, old emission-intensive production methods need to be phased out in a controlled manner. Innovation and commercialisation of new technologies can be nurtured through policies such as R&D funding, investment grants and the creation of "green" markets for basic materials, while the controlled decline of "old" technology can be addressed through bans, sunset clauses and emission standards. Throughout the transition, increased attention to issues of social justice is needed, as some existing inequalities are likely to be exacerbated and new injustices created as part of the redistribution of burdens and benefits that are inherent in the transition.

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Q5. Can pulp and paper pioneer decarbonisation and help other industries?

The pulp and paper industry has reduced its own carbon footprint significantly over the past decades. Pulp production, which used to rely on large volumes of petroleum and other fossil energy, has through process redesign and energy efficiency improvements become self-sufficient on energy. In fact, pulp mills today even provide energy in the form of heat and power to local communities. Paper production has a large energy demand for heating and drying and still uses natural gas extensively to provide that energy. There are however good opportunities for the industry to provide low-carbon solutions for several parts of our economies [REF Paper sector report].

Firstly, new types of paper-based materials are being developed which can allow for paper to substitute other materials with higher carbon footprints, such as paper bottles for soda and other drinks. Secondly, cellulose (wood) fibres can be used for non-traditional purposes to substitute other types of fibres. There is therefore a renewed and growing interest in using

cellulose fibres for textile production, where they can substitute fibres made from polyester or nylon (which are fossil-based plastics), or using cellulose as a component in bio-composites which mix plastics and fibres [REF Durasense]. Thirdly, the by-products from pulping, e.g. lignin and hemicellulose which are the other components of wood, can be used for production of different types of bio-based chemicals, plastics, or fuels in so-called biorefineries [REF Lignoboost innovation biography]. Biorefineries would transform traditional pulp mills into advanced factories producing multiple materials and products from wood, instead of just paper and energy.

Finally, pulp mills that combust bark and other wood residues for production of heat and power could capture the CO_2 produced in combustion. Capturing the CO_2 and storing it using CCS (Carbon Capture and Storage) technology would effectively produce a carbon sink as the carbon in the wood was captured from the atmosphere during the growth phase. Questions still remain about the feasibility of this solution, called BECCS (Bio-Energy with Carbon Capture and Storage), compared to the others mentioned above, as well as the interest of pulp and paper firms to engage in developing these technologies.

The pulp and paper industry has been regulated strictly for decades regarding several types of emissions but not their greenhouse gas emissions until EU ETS in 2005. The ETS has however had limited effect as a decarbonisation driver in the industry as the free allocations have been generous. Policies and support schemes have assisted energy efficiency improvements of mills, and other policies have pushed the recycling of paper. Bioeconomy policies have focused solely on biofuels, which is thus what until recently has been most interesting for biorefineries, but recently new product categories are gaining traction due to pressure on sectors such as textiles and plastics.

Q6. Is the industry ready for change?

Energy-intensive industries are often described as difficult to decarbonise as they are characterised by high energy-related and process emissions that are not easy to reduce. They traditionally focused on improving energy efficiency, but the Paris Agreement has served as a "wake-up call" for many, making it clear that much more radical changes would be needed.
Some companies in the basic materials sector have been adopting ambitious targets for decarbonisation and embarking on the development of new, low-carbon process technologies using renewable energy sources like green hydrogen and electricity [REF HYBRIT case study], biofuels [REF Lime kiln case study] as well as fossil-free feedstock [REF Durasense case study]. Despite a variety of technical solutions for the different sectors, several factors will determine whether the industry is really prepared to introduce a transition that will allow them to attain a level well below the 2°C target.

The speed of the research and development scale-up will be crucial: over the course of this decade many companies will face large-scale reinvestment decisions for existing production facilities. It is now important that new low-carbon production technologies are available on an industrial scale and that investment costs quickly become competitive. It is currently still uncertain whether and how innovations can scale-up in this way [REF D6.1].

In addition, industry is still often reluctant to aim for deep decarbonisation, either through a reduction in the demand for materials or a wider use of recycled materials for high-value

purposes. This would also mean a reduction in the consumption of primary materials. In parallel with the increased use of recycled materials, industry should also make greater use of new product lines. For example, alternative and lower-emission products could be complementary to meat and dairy products instead of rejecting them as disruptive innovations brought to the market by new entrants.

This raises the question whether energy-intensive industries are really ready for disruptive changes or whether these changes still have to be imposed on them from outside, for example by political governance mechanisms. However, the latter need to be designed quickly to enable the economic viability of new low-carbon technologies (including carbon taxes and border adjustment, public procurement and low-carbon material quotas, etc.). Policies should also focus on the demand side, by creating stronger incentives and rules for the use of recycled and fossil-free products.

Q7. What can governments do to make a difference?

Governments are key political actors in decarbonisation governance by providing the necessary legitimacy, regulatory frameworks, and political and socio-economic conditions that can support deep and fair transformations across every single economic sector in all EU countries. So far, however, governmental policies have not necessarily had the desired impact on the magnitude and complexity of the challenge. To make a difference, governments need to do the following.

First, directionality is a key element. Governments adopting a long-term and ambitious vision and strategy based on regulatory frameworks and subsidies are proven more effective in guiding industries and sectors towards decarbonisation and environmental transformation more generally [REF Drivers of Low Carbon Innovation Report, D3.6]. Public funding can be a significant driver for decarbonisation especially in terms of investments in research, development and innovation that can ensure benefits for societies and help mitigate prohibitive levels of business risk. Likewise, government rulings including those for carbon pricing, green certification, and enabling acts of legislation that mandate action on decarbonisation, set carbon budgets and legally-binding targets are very important for fostering decarbonisation transformations [REF Finance Sector Report].

Second, to drive decarbonisation, a systemic and holistic approach across all sectors and supply chains is more desirable than a piecemeal approach. For plastics, for example, policy responses adopting such an approach would address the entire value chain from production to waste and recycling [REF Plastics Sector Report]. Likewise, different forms of support or collaboration (either in addition to funding/regulation or as solitary measures) with a broader set of societal actors can help foster decarbonisation innovations and transitions in a concerted way [REF Drivers of Low Carbon Innovation Report, D3.6]. For example, governments establish platforms to promote cooperation between academia and industry [Tierra case study] and bring key stakeholders together [REF Carbon2Chem case study]. They can also support innovations by becoming “first customers” for start-up technologies [REF MX3D case study], setting higher environmental standards and promoting the idea of a green economy [REF DOCOL case study].

Third, rethinking the role of the broader political economy and especially the finance sector is key. One way to do so is to reconsider terms such as risk and impact to recognise not only the impact of investments on climate change (and therefore the need for decarbonisation) but also the impacts on the financial system by leaving climate risks unaddressed. In this context, governments can mainstream climate risk disclosures to enable investors to make informed decisions and to facilitate the development of new metrics and approaches that contribute to mainstreaming climate considerations [REF Financing Net Zero report].

In short, the governance challenge for governments is to adopt long-term horizons in planning, act concertedly and in collaboration with each other and broader societal actors, and change current thinking about the relationship between climate change and decarbonisation pathways and the broader political economy.

Q8. Do institutional investors hold the key for a low-carbon future?

Alongside the technical, social and political challenges that decarbonisation poses, in the past few years the significant issue of how a transition to a low-carbon future can be financed has come to take centre stage. As diverse public and private actors have sought to respond to this challenge, we have witnessed the growth of what we call *carbon finance* [REF Bridge et al., 2019] – including well-established markets for trading emissions rights and ecosystem services, investments in 'natural capital' for carbon storage, various banking activities that include green loans and mortgages and so on, alongside private investment that either explicitly commits capital to green projects or seeks to divest from assets associated with the fossil fuel economy.

Institutional investors (which include e.g. insurance companies, pension funds, sovereign wealth funds) have been central to the growth of carbon finance. The Institutional Investors Group on Climate Change, a European body, counts 230 members in 16 countries with assets worth more than $30 trillion in its membership proactively seeking to invest in the low-carbon transition. Despite the significant numbers involved, the finances mobilised by institutional investors towards the low-carbon transition are still relatively small compared to ongoing public and private investments in the high-carbon economy. Rather than being because of the *quantity* of finance that institutional investors have brought to the table, their significance might instead be assessed in terms of how their role at the forefront of pioneering new ways of understanding the *quality* of investment in low-carbon terms [REF Financing Net Zero report].

On the one hand, institutional investors have become important market actors in stabilising green bonds – a fixed-income debt instrument which funds investment in a specified project or a set of multiple projects undertaken by their issuer - by developing and using standards that create a shared understanding of what 'green' investments can and should involve. On the other hand, institutional investors – particularly faith-based groups, educational institutions

and public sector organisations – have been important in establishing the qualities of assets that make them unattractive investments and in calling for and taking steps towards divesting from high-carbon companies. This has generated new ways of thinking about what the risks of investment are under conditions of climate change and has opened up the debate about what does and does not constitute a 'good' investment.

To date however, these efforts have not been channelled towards the basic materials sectors. Equally, while the long-term nature of their investment strategies and public profile may suggest that they will seek to move away from high-carbon assets more readily than other investors – and indeed many are beginning to do so – we also see that they are dependent on the actions of other financial actors, especially stock exchanges which make up a large part of their investment portfolios, and on how risk and return are calculated [REF Financing Net Zero report]. This suggests that unlocking the potential of institutional investors will depend on wider efforts to 'green finance' in which the financial sector as a whole comes to embed carbon as a critical issue around what counts as an asset and how both private and public returns on investment are calculated come to be rethought.

References

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Q9. Are consumers and movements pushing for decarbonisation of basic materials?

Consumers and movements are key actors in sustainability transitions and transformations. Green consumption practices, reduced levels of consumption, and collective demand for broader behavioural and systemic changes in sustainability practices can generate large and cumulative impacts across markets, innovation systems, and habits, and push for more ambitious and concerted governmental action. There is then a big potential for transformative change if consumers and movements push for decarbonisation of basic materials in key economic sectors.

Meat and dairy is a key sector in this respect. Campaigns for reducing meat consumption, such as 'Meat Free Mondays', and support for alternative sources of protein, as well as the increase of meat and milk substitutes have been on the rise [REF Sectoral Report Meat & Dairy]. Although cultural entrenchment, such as taste, texture, or meat masculinities, and the broader political economy of meat and dairy sectors can be constraining factors, there is increasing awareness and growth of alternative lifestyles and habits among consumer groups [REF Tziva et al. 2019]. Beyond consumption, reduced food waste can have a big impact on decarbonisation. Various movements generating awareness and providing guidelines that can help reduce food waste exist throughout Europe, such as *Slow Europe*, *This is Rubbish*, *Interreg*, and others.

Similarly, reduced plastic consumption has gained considerable traction amongst NGOs and civil society, with a large number of campaigns devoted to reducing plastic use, plastic-free stores and a broader zero-waste movement [REF Zero-waste stores]. On the other hand, this is challenged by plastic producers and large retailers, who argue for continuous use of plastics and a focus on recycling instead. The role of consumers and movements is, however, harder to discern when it comes to basic materials such as steel and paper. In the realm of finance, divestment campaigns focus on encouraging investors to move away from fossil fuels to alternative sources of energy [REF Sectoral Report Finance]. To date almost 900 institutions across the world, representing funds of over 6 trillion USD have made some form of divestment commitment with faith-based organisations making up the largest group of organisations that have committed to divest.

In short, consumers and movements are actively pushing for decarbonisation in many economic and finance sectors, albeit to a different extent. A key governance challenge is to harness the power of consumers and movements to push for broader systemic transformations and change instead of prioritising change of individual habits, for example. Although harmonisation across movements is not the key here, collaboration, learning and concerted action could be decisive factors for bringing about deep and sustained transformation.

References:

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Q10. Will making industrial processes more energy efficient lead to decarbonisation?

Cost savings have been a strong driving force for energy efficiency for several decades, especially in the energy-intensive industry. Energy efficiency aims to reduce energy consumption in industrial processes by developing and using new methods or technologies, and also optimising existing industrial processes. Government energy efficiency policies have been used for decades to further incentivise and support energy efficiency in industry (e.g., through R&D, audit programs, standardised energy management systems, and voluntary agreements) and is an established policy field.

Energy efficiency is one possibility in a broader menu of options to decarbonise industry, including materials demand management and efficiency [REF DOCOL Case], circular economy, fuel switching (REF Lime kiln case), direct and indirect electrification [REF HYBRIT case], and carbon capture, utilisation and storage (CCUS). Energy efficiency should always be a priority, as recognised by the "energy efficiency first" principle adopted in the EU Industrial Strategy. Using less energy reduces strain on the energy system and energy sources, whether renewable or other. It leads to emission reductions when fossil fuels are used, directly or indirectly. However, energy efficiency does not in itself lead to zero emissions.

In most cases, energy efficiency will help decarbonisation. The pulp and paper industry is case in point – energy efficiency has helped kraft pulp mills become self-sufficient, using biomass by-products for energy, and eliminated the need to purchase extra fuel [REF Paper Sector report). Another example is strip casting [REF Castrip case], which by casting steel to near final shape avoids fossil fuel use during hot rolling. High temperature industrial heat pumps are an energy efficiency technology that can facilitate electrification by reducing the cost of electricity-based heat production. However, care should be taken so that energy efficiency does not create lock-in into existing processes. Energy efficiency may help reach short-term emission reduction targets but does not necessarily pave the way for deep decarbonisation through entirely new processes and feedstocks.

To transform to a climate-neutral economy in 2050, the question is how more fundamental process innovations can be applied in industry and implemented on a large scale. This may include new value chains and new couplings between industry and the electricity sector as well as new couplings between industrial sub-sectors (e.g., chemicals and forestry) [REF biogenic workshop report].

Q11. Can we go to deep decarbonisation without reducing demand?

It appears impossible to achieve deep decarbonisation without dietary shifts away from emissions-intensive meat and dairy products. In the case of basic materials, technical fixes and sustained demand levels may be conceivable in theory, at least in the European context. Per capita demand for materials such as steel, paper and plastics has already stopped growing here. However, increasing the global per capita use to European levels is untenable since it would put tremendous pressure on resources and the environment. The urgency of reducing emissions is a strong argument for finding ways to reduce per capita demand for fossil-based materials, in addition to decarbonising supply chains.

Firstly, demand for fossil-based materials can be reduced through changes in consumption patterns, for example, shifting to plant-based diets [REF Tziva et al, 2019] or avoiding unnecessary packaging. Supply-side initiatives such as plastic-free stores create spaces that both satisfy and promote new ways of consuming [REF Zero-waste stores]. Secondly, demand for materials can be reduced through material efficiency and design, e.g. using light-weight steel constructions [REF MX3D]. Thirdly, material substitution will reduce demand for a specific material and increase demand for its substitute. For example, fossil-based plastic can be replaced by bio-based plastic [REF Tierra's Deterra jacket] or paper [REF DuraSense], and milk can be substituted by oat-based products [REF Oatly].

However, environmental implications of reducing demand are not straightforward. Reduced or paper packaging can also shorten a product's shelf live, replacing steel can lead to pressure on biomass resources, and using a substitute material might bring other environmental problems like loss of biodiversity. Thus, while alternatives that enable reduced use of materials are important for deep decarbonisation, they also require further research and cautious implementation.

Material demand today is governed mainly in indirect ways. Targeting consumer demand directly may negatively affect less well-off population groups and does not necessarily change the path dependency of fossil-based supply [REF Chertkovskaya et al., 2020; Nielsen et al., 2019a]. There are private governance initiatives where stakeholders join forces to promote, for example, protein-based diets [REF Green Protein Alliance] or voluntary certification schemes in construction [REF BREAM]. However, more concerted governance effort is needed for deep decarbonisation. City planning, building codes and restricting planned obsolescence would be important areas for such effort.

[Other references: Plastics sector report, Meat&dairy sector report]

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Q12. Would circular economy approaches secure a way towards decarbonisation?

Great hope is pinned on the idea of a circular economy to provide the remedy for the problem modern economies have with resource depletion, waste management, and greenhouse gas emissions. Indeed, a shift in the way that we use materials is essential to reduce the production and consumption of energy and carbon-intensive materials. Primary production of steel, plastics and paper emit large amounts of CO_2 and reusing or recycling these materials is in most cases connected to significant changes in the carbon footprint of their applications.

There are both technological processes and policies in place for recycling these materials, but there are large differences between their effectiveness and potentials. Recovering the materials needs changes in waste management to improve quality and quantity but ultimately it is the design and provision of the products and services that will optimise circular flows.
Very different types of approaches are being labelled as circular economy, and they can make different contributions. Reuse of products is in a way the simplest – yet at the same time often most complicated – option. Packaging-free supermarkets are one example of this approach where customers are encouraged to bring their own packaging from home every time they go shopping [REF Zero-waste stores case study]. The consumer packaging is however commonly only a minor part of the carbon footprint of most value chains, especially for high-carbon foods such as meat or dairy.

Recycling reduces the need for virgin production of materials but is commonly still laborious and fairly energy-intensive. Products have to be collected, transported, sorted, and traded

before they can be used to produce new materials. The appetite of our economies for materials keeps increasing, leading to limited possibilities to supply the demand with recycled ones. Steel is for example recycled to a high degree, but as cities and infrastructures (e.g. power grids and roads) are still expanding, the recycled steel is unable to meet the demand. Steel made from recycled scrap currently only corresponds to a third of European production [REF Steel sector report].

However, not all circles are as certain to result in significant emission reductions. Chemical recycling of plastics is advertised as a circular approach for all plastics (reference Enerkem case study), yet at the cost of large amounts of energy and carbon emissions. If chemical recycling substitutes the recycling of high quality mechanical recycling, the net impact on decarbonisation may in fact be negative. Mechanical recycling of selected plastics typically uses less energy but is only suitable for certain types of plastics. Hence, circular economy approaches need to be well designed to optimise the contribution to decarbonisation. The *European Green Deal* puts a circular economy in the centre, but this is by no means an easy or guaranteed path to decarbonisation.

Q13. Is there a finance gap for decarbonisation and how can we close it?

At first glance it seems obvious that there is a finance gap for decarbonisation. The figures suggested of the volumes of finance needed to decarbonise the economy – in the order of additional 800 billion USD per year (McCollum et al. 2013) – are eye-watering. But on closer inspection, we find that there is not *one* finance gap for decarbonisation but instead a number of different gaps between the availability, type and nature of finance on the one hand and the kinds of projects, innovations and processes that need investment on the other, which add up to make the question of how we finance decarbonisation one of the most challenging we face [REF Bridge et al., 2019].

To start with, there is a finance gap in terms of the sheer volume of investment available for decarbonisation. Public climate finance currently mobilises around 140 billion USD per year with private climate finance amounting to roughly double that amount (Buchner et al. 2017). Despite there being 20 major multilateral funds dedicated to climate change action, these funds have had just under 50 billion USD pledged to them in total, far short of what is thought to be needed to reach the goals of the Paris Agreement. A shortage of public finance for decarbonisation is seen to be particularly important because private finance tends to focus on less risky and more profitable technologies and innovations [REF Finance sector report].

This brings us to a second finance gap – the shortage of investment in decarbonisation beyond renewable energy technologies and energy efficiency measures. In 2016, 93% of climate finance targeted mitigation activities and of those investments, 74% were in renewable energy generation (Buchner et al. 2017). High-cost carbon abatement sectors have not yet been brought within the remit of climate finance, a crucial gap as a decarbonised economy requires that all sectors shift away from fossil fuels, not only the energy, building, and transport sectors [REF Financing Net Zero report].

The limited amount of finance being directed towards decarbonisation in high-energy and material-intensive economies, is at least in part driven by a third finance gap – the difference between the action that needs to be taken and what is considered to be an 'investable project'. Given that innovation in these sectors, especially in the Global North, is likely to be driven by private rather than public investment, how they come to be seen as 'investable' – capable of being counted as saving carbon and as generating a return – matters a great deal [Bridge et al., 2019]. New approaches will be needed within the private finance sector in terms of how being 'investable' is calculated and recognised if this gap is to be closed.

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