Tomorrow's markets today:

Scaling up demand for climate neutral basic materials and products

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Foreword

The climate transition is an unprecedented shift in our societies and economies. A wholesale reinvention that cuts across almost everything we do, deliberately and intentionally driven by policymakers, by innovation, by business and finance, and by public concern – and all to be achieved in little more than a generation.

While this is potentially a daunting prospect, the logic for it in terms of managing and limiting huge risk and generating significant benefits and opportunities is clear. And indeed, the evidence so far is that with ingenuity and focus we can deliver this change more quickly and at lower cost than we might have foreseen. This is why, even in a world that is grappling with a global pandemic and huge consequent economic disruption, we are seeing more and more countries, cities, regions, investors and businesses commit themselves to a net zero future.

Europe is a pathfinder on this journey, with many of the most mature and well-developed policies and approaches to driving decarbonisation in the world. As the EU stands ready to deliver the next round of key policies in support of this transition, and also works to update its industrial strategy and other key policies, there is an important discussion to be had about how policies that shape and create market demand can be used to drive change.

Designed right, these policies can leverage the EU's status as one of the world's largest markets to accelerate innovation and investment into low carbon solutions globally. These policies have particular potential to support the transformation of industrial sectors, where the costs of updating production methods or developing new approaches are high for the producers of primary materials, but much more affordable as a cost to end-consumers of the final products.

At Agora Energiewende, one of Europe's leading think tanks on climate-related issues, and at CLG Europe, a cross-sectoral group of leading European businesses supporting the transition to a climate neutral economy, we have both identified that this is a key and underexplored topic.

We have therefore been very pleased to pool our efforts to develop this report, Tomorrow's Markets Today, which explores the potential for demand-led policies to help support industries providing climate neutral materials. We hope that it will prove interesting and useful to EU policymakers working on the wide range of upcoming legislative initiatives and for businesses involved in the relevant industrial ecosystems to understand this potential and help them work together to unlock it.

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Summary of key findings

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Accelerating the transition of energy-intensive basic materials industries to climate neutrality is becoming an increasingly urgent matter. In the EU, direct (Scope 1) emissions from basic materials such as iron and steel, cement and non-metallic minerals, basic chemicals, aluminium, and (pulp and paper) account for approximately 16 per cent of net annual greenhouse gas (GHG) emissions, while globally the amount is around 20 per cent. Given the life cycle of assets within these industries, the EU has just one investment cycle to shift production processes to achieve domestic climate neutrality by 2050. Climate neutrality for basic materials is only achievable through a mix of strategies including circularity, material substitution and innovative zero carbon production for virgin materials. More efficient use of materials in final products can also help to reduce emissions from basic materials, but does not alone constitute a sufficient mechanism to achieve climate neutrality.

Enabling investment in climate neutral and circular production requires robust demand for climate neutral and circular basic materials and resulting final products. The industrial transition will require several enabling conditions to be met, including the development of key infrastructure, de-risking, support mechanisms for deploying breakthrough technologies at large scale and addressing carbon leakage risks. However, a robust long-term business case for clean production investments depends on market-based demand for products made from the efficient use of climate neutral materials. Such demand is crucial to the overall industrial transition strategy of the EU: executed correctly, it can create economic incentives for increased material efficiency in manufacturing, increased use of circular materials, and provide the often-missing business case for large investments in the production of climate neutral materials.

Progressive industrial companies are working to foster demand for climate neutral basic materials and final products, yet they face several barriers that they cannot solve in isolation.

For basic materials producers, there is often insufficient consumer demand for products made with climate neutral or circular materials. Low demand is the result of several factors, which differ depending on the sector or material. These can include higher cost of climate-friendly materials, lack of familiarity or engagement with new materials among downstream users, or lack of transparency and clear benchmarks for potential purchasers to compare different 'low carbon' alternatives.

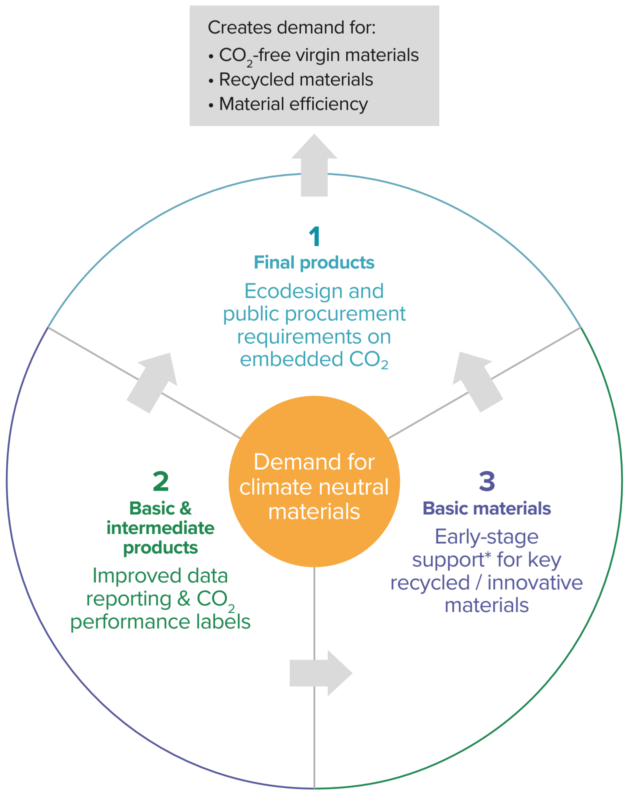
For final product manufacturers, there is an inability to effectively market products made from climate neutral materials due to a fundamental lack of high-quality, comparable data on embedded emissions in upstream basic materials and intermediate products. Such data is essential for consumer-facing companies to reliably market cleaner products. It is also critical that manufacturers are able to differentiate between high and low carbon materials from upstream suppliers.

In the absence of robust regulations, downstream companies can face significant challenges to coordinate and incentivise upstream suppliers to produce climate neutral basic materials and intermediate products. In some cases, such as with certain recycled materials, there is 'pent-up demand' due to barriers on the supply side of the market. A lack of abundantly available, high-quality recyclable materials remains a significant issue.

To help European industries tackle these barriers, there is a vital role for EU policies that harmonise incentives and data across the internal market. Three types of policy interventions needed to address this challenge are described briefly below. Figure S1 illustrates the interlinkages between these elements.

- Firstly, **EU product policies should integrate embedded life cycle CO_2 limits on final products that are material intensive**, ensuring these are reduced over time. Doing so can help induce a willingness to pay for climate neutral material solutions from the final producer and thus promote competition between a full range of decarbonisation actions through the value chain – including climate neutral and circular materials, innovative substitute materials as well as material efficiency. Such policies might be implemented through the EU's upcoming revision of the Ecodesign Directive, the Construction Product Regulation (CPR) and public procurement requirements via the Energy Performance of Buildings Directive. However, the limits on embedded life cycle CO_2 must be applied in a manner that is consistent with attempts to minimise operational emissions from final products, such as cars and buildings.
- The second policy priority is to **significantly improve the availability, quality and comparability of data on embedded life cycle emissions** in basic materials and intermediate products. Legislation placing limits on embedded carbon cannot effectively operate without strict requirements ensuring high-quality product emissions data encompassing the relevant value chains. Incentivising the use of Environmental Product Declarations in key value chains and further standardisation and harmonisation of reporting requirements under the EU's Environmental Footprinting standards for key products[3] are essential delivery tools. However, new, dedicated information tools must sit alongside additional data to assist companies when comparing the CO_2 performance of competing materials. To this end, standardised labelling and data comparison tools, similar to those used under the Energy Performance Labelling scheme, are necessary.
- Thirdly, there is a need for EU and national institutions to **temporarily intervene to support early investments in new and innovative solutions**. Such policies are relevant where certain high-potential technologies or other solutions face significant barriers to enter the relevant markets in early phases of their development. For example, when capital-intensive or large-scale infrastructure-dependent solutions face prohibitive investment risks, or where there is a lack of familiarity with innovative materials due to purchaser conservatism. If such problems are not tackled by other policy interventions, and if the risks of market distortions from technology-specific support are low, then demand guarantees can be necessary. However, the risks of such technology-specific policies must be carefully balanced against the rewards and should ultimately be seen only as a temporary bridge to long-term technology-neutral solutions, such as carbon pricing or embedded carbon requirements on final products. Where appropriate, the EU should promote such policies by obligations for circular materials in relevant sectoral waste legislation, by reforming certain product norms for construction products, and via public procurement obligations under sectoral legislation.

Figure S1: Three policy priorities to scale demand for climate neutral materials and products



* NB. Such policies should be temporary and designed only to overcome barriers to market entry to avoid distortions of competition between materials.

Source: CISL, Agora Energiewende (2021)

Glossary

For the purposes of the discussion in this report, the key terms below are used with the following intended meaning. Note that some of these definitions may differ slightly from their use in other contexts:

Carbon Contracts-for-Difference (CCfDs) – Government-backed cost support instruments to provide an effective minimum carbon price guarantee. This is to de-risk and support the higher production costs of climate neutral breakthrough technology projects to produce energy-intensive basic materials.

Climate neutral basic materials – Basic materials produced (and managed at end of life) in a manner consistent with a climate neutral economy. This includes innovative alternative materials, recycled basic materials and virgin materials produced through innovative processes.

Climate neutral products – Products that contain basic materials that are produced in a manner consistent with a climate neutral economy and limiting total embedded life cycle carbon emissions in the product. This condition can be achieved by replacing energy-intensive basic materials with decarbonised virgin materials, recycled basic materials, innovative alternative materials or a combination of these.

CO_2 performance labelling – Labels, or other purchaser-relevant product information, attached to the sale of basic materials, intermediate or final products, and rating the level of embedded GHG emissions performance of the sold product.

CO_2 performance requirements – Legal obligations attached to the sale of basic materials, intermediate or final products, regarding the level of embedded GHG emissions performance of the sold product.

Embedded carbon emissions – The total (life cycle) emissions of greenhouse gases associated with the production, consumption and disposal of materials used to manufacture or build a given product. (See also the definition of "life cycle emissions").

Energy-intensive basic materials – Material inputs into manufacturing and construction value chains, such as iron and steel and ferro-alloys, aluminium, cement and concrete, glass, brick and ceramics, wood, pulp and paper, and a range of basic chemicals, such as olefins, polyolefins and aromatics. These products are intensive in energy or process emissions of greenhouse gases or both.

Green premium – The addition to the price required to be paid by purchasers of basic materials or related goods for the manufacturer to recover the full cost of producing goods with a higher environmental quality than the market standard.

Industry – The activities of value chains producing and using basic materials to produce intermediate or final products.

Lead markets – Markets that are created or supported by dedicated public policies to spur innovation by encouraging a leading share of market participants to adopt a certain type of product, material or a new design.

Life cycle emissions – The combined Scope 1, 2 and 3 emissions of given products from the beginning of the production value chain to the disposal of the final goods by the relevant consumer. Note that other definitions exist, reflecting possible extensions beyond this scope (e.g. to the second life of a recycled product).

Material efficiency – Using materials to produce final products in a way that improves or, ideally, maximises, the overall material resource productivity for the economy.

Material substitution – A practice of replacing materials with higher embedded greenhouse gas emissions with net zero or lower carbon materials in a given manufacturing or construction application. This may include intra-material optimisation, such as using a type of cement or steel with lower carbon emissions for a given required structural performance. However, it is more commonly used to refer to a practice where an energy-intensive basic material (such as steel, cement, or plastic) is replaced with an innovative alternative, such as a wood-fibre based material.

Material types:

Virgin (or primary) materials – Basic materials produced for the first time from newly extracted raw materials, as opposed to recycled materials.

Circular (or secondary) materials – Basic materials recovered from the end-of-life of manufactured or constructed goods and remanufactured to reproduce a recycled version of the given basic material.

Policy tools:

Demand-side policy tools – Policy measures that can induce an increase in market demand for particular products or services – in the case of this report climate neutral, or non-carbon intensive, materials. These tools include policies such as product labelling, standards or certification benchmarks, public procurement requirements, ecodesign or embedded emissions requirements on final or intermediate products in the value chain, quota obligations, or other financial incentives for purchasers of such materials.

Supply-side policy tools – Measures that can induce an increase in the market supply of particular products or services – in the case of this report climate neutral, or non-carbon intensive, materials. These tools include, among other things, innovation funding, financial support for commercialisation of key technologies, investments in infrastructure, the removal of regulatory constraints on the marketing of certain low or high carbon materials.

Scope 1, 2 and 3 emissions – Emissions are broken down into three categories by the Greenhouse Gas Protocol to better understand their source. Scope 1 refers to all 'direct' emissions from the activities of an organisation under their control. Scope 2 refers to 'indirect' emissions related specifically to electricity production that is then purchased and used by an organisation. Scope 3 refers to all other indirect emissions from an organisation's activities occurring from sources that they do not own or control. This includes all inputs into their production process from the relevant value chain in which they operate, including travel, procurement of materials and intermediate goods, waste and water.

Stages of production:

Basic materials – Materials such as steel, cement, plastic and aluminium that are traded and typically used as inputs to intermediate products, such as components that are used in the manufacturing of a car, or final products, such as a house. Because of their positioning in a product supply chain, basic materials are referred to as **'upstream'**.

Intermediate products – Semi-finished manufacturing or construction inputs into final consumer products. Because of their position in a product supply chain, intermediate products are referred to as **'midstream'**.

Final products – Products intended for end consumers, sold directly to households, businesses or governments. Because of their position at the end of a product supply chain, final products are referred to as **'downstream'**.

1. Introduction

Achieving a climate neutral, circular and competitive economy requires changes to the ways we produce and consume the basic materials that are essential inputs into manufacturing value chains.[4,5,6,7] These materials include iron and steel and ferro-alloys, aluminium, cement and concrete, glass, brick and ceramics, wood, pulp and paper, and a range of basic chemicals, such as olefins, polyolefins and aromatics. The production of these materials generally requires both high energy inputs and often releases greenhouse gases (GHGs) into the atmosphere during the production process. Production of carbon-intensive basic materials accounted for approximately 16 per cent of direct (Scope 1) annual net GHG emissions in the EU in 2017.[9]

In a climate neutral world, the way basic materials are produced and consumed must be altered. Potential options include a greater focus on circularity, reduced basic material consumption, increased material efficiency, material substitution, increased reuse and recycling as well as climate neutral primary production. Depending on the sectoral context, a combination of the above-mentioned measures should be considered.

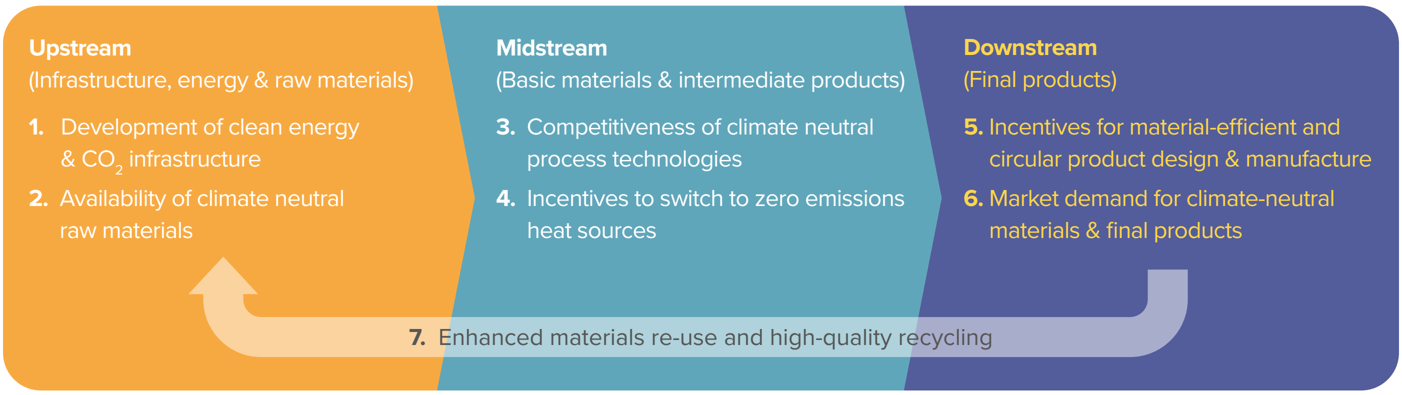
Decarbonising basic materials sectors and value chains is not as simple as merely changing the energy inputs: significant shifts in technology and raw material inputs are also essential if we are to tackle chemical process emissions. These technology shifts necessitate a range of interventions across the entire value chain. These are summarised in Figure 1 and encompass shifts in infrastructure, the development of new process technologies, the creation of incentives for enhanced circularity, material efficiency and material substitution.

As suggested by points 5 and 6 of Figure 1, the existence of market-driven demand for final products made from climate neutral basic materials is an essential condition for the transition to a decarbonised industrial sector. The rationale is basic economics: for manufacturers to invest in climate neutral production processes there needs to be a demand and willingness to pay for these new (and often more expensive) products. Ultimately, economic incentives for climate neutral production must be aligned across the full value chain.

These incentives must flow backwards, from the final consumer-facing product, through the intermediate product producers to the basic materials producers, who in turn pay for the higher cost of clean energy, raw materials and innovative production processes. This point is summarised in Figure 2 using the example of hydrogen-based steel in a car. For the upstream steel producer to manage the higher cost of producing climate neutral steel, there must be a demand and a willingness to pay from the car manufacturer to sell cars with climate neutral steel.

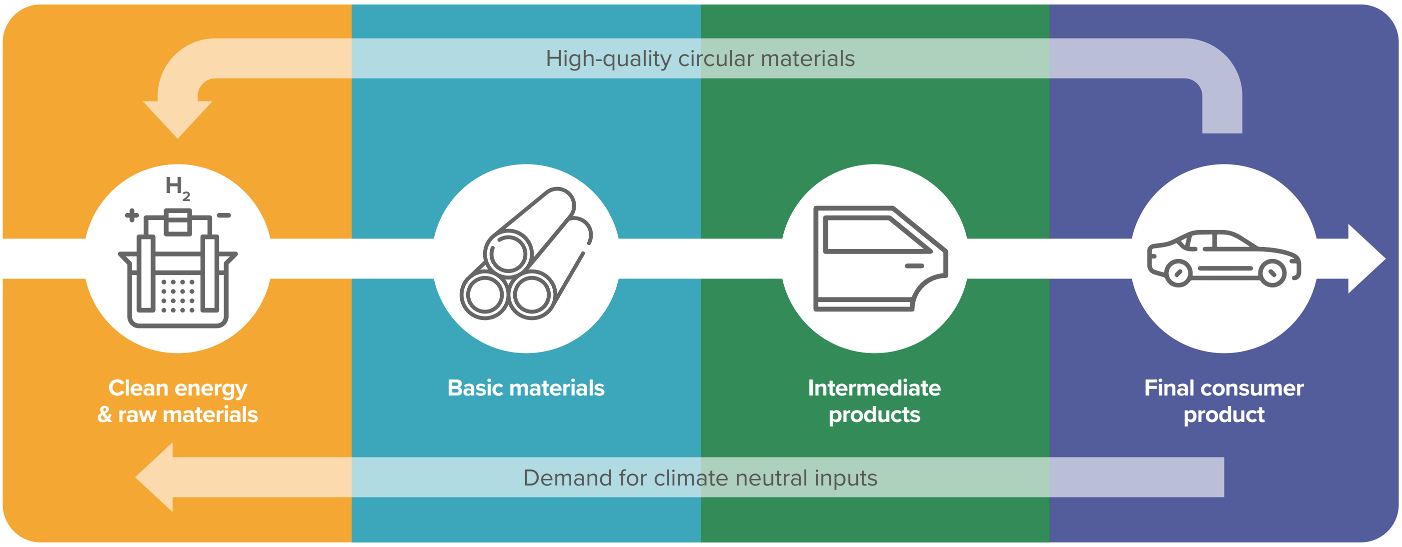
Currently, market demand for climate neutral basic materials and final products remains underdeveloped or even non-existent in some EU product markets. As Section 2 illustrates, there are several barriers that even large progressive European industrial companies face in unlocking sufficient demand to enable a full-scale shift to climate neutral production, supply chains and business models.

Figure 1: Seven key conditions for the transition to a more circular, climate neutral industry



Source: CISL, Agora Energiewende (2021)

Figure 2: Economic incentives for climate neutral value chains must flow backwards from final consumer products to intermediate products, basic materials, etc.



Source: CISL, Agora Energiewende (2021)

This report explores how European policies could be developed to remove these barriers. To gain further insights into these questions, the authors conducted a roundtable and in-depth interviews with representatives from eight leading, progressive European industrial companies. These discussions explored:

- leading practices in industry today to develop climate neutral materials and product brands
- the barriers leading companies face to scale up these initiatives
- concrete options for additional EU policies to address these barriers
- the potential role, and success factors, of such policies in the broader EU policy package for the transition to clean industry.

Section 2 highlights how progressive European industrial companies are trying to create demand for climate neutral basic materials and products, which constitutes a central issue affecting their transition strategies. Section 3 explores the limitations of individual action, identifying the key barriers companies barriers companies face. It makes a case for additional policy implementation to address them. Section 4 goes on to map out industry attitudes to additional EU policies. It also reviews past and present experiences of relevant EU and member state policies to create demand for environmentally friendly products. Finally, Section 5 identifies three key EU policy priorities during this legislative period. Section 5 and the conclusion also highlight specific legislative files for revision under the European industrial strategy[10] in order to integrate policy recommendations.

2. Actions of progressive European industrial companies

HYBRIT pilot plant (Credit: SSAB/Åsa Bäcklin)

This section draws on the roundtable discussion and interviews with progressive European businesses to showcase some of the approaches these businesses have adopted to increase the supply and demand for climate neutral basic materials and products, and why this constitutes an important issue for them.

2.1. Examples of business leadership to create markets

The need for European companies to integrate climate neutral materials and products is not just an abstract idea, as a significant number of major organisations are already taking action to overcome this challenge. Substantial investments are being made by the most progressive upstream material-producing companies to develop, certify and find purchasers of more climate-friendly materials and products.

For example, in the cement and concrete sector, LafargeHolcim has recently developed the ECOPact brand.[11] This new range of low carbon concrete offers purchasers, in a growing number of countries, the possibility to purchase a variant that has between 30 per cent and 100 per cent lower embodied carbon compared to standard CEM I or Ordinary Portland Cement-based concrete. Where regulatory conditions allow, ECOPact products integrate upcycled construction and demolition materials, further closing the resource loop. The ECOPact brand label includes four different sub-labels depending on the reduction of emissions per unit of concrete (-30–50%, -50–70%, -70–90%, or -90–100% (the latter including offsets of the currently remaining unavoidable carbon)).

In the iron and steel production sector, major European companies, such as **SSAB** and **thyssenkrupp** have set goals that will see them begin to produce either climate neutral or very low carbon steel using key breakthrough technologies during the next five to ten years. For instance, under their joint venture '**HYBRIT**', the companies SSAB, LKAB and Vattenfall aim to produce fossil-free steel at commercial scale, policy conditions permitting, by 2026. With similar plans, thyssenkrupp presented its pilot project under the name "tkH2Steel and Carbon2Chem" in July 2019. thyssenkrupp's steel site is already developing its hydrogen pathway with direct reduction. Both companies are actively seeking progressive customers willing to pay a 'green' premium in return for sustainable steel. Indeed, Reuters recently reported that Swedish truck maker AB Volvo and steel maker SSAB had signed an agreement to produce the world's first vehicles made of fossil-free steel, with small-scale serial production expected to start in 2022.[12]

The desire to develop demand for climate-friendly steel products has also led some early adopter companies in the European (and international) steel industry to develop industry standards that offer customers higher transparency. The Responsible Steel Initiative is developing a new 'Responsible Steel Standard 2.0' in 2021, to give future steel purchasers confidence that their steel is produced using a science-based approach in the transition to climate neutrality.[13] Such initiatives highlight the importance, to both the producers and consumers in the relevant value chains, of the need for clear benchmarks and certification of climate-friendly products to increase market demand.

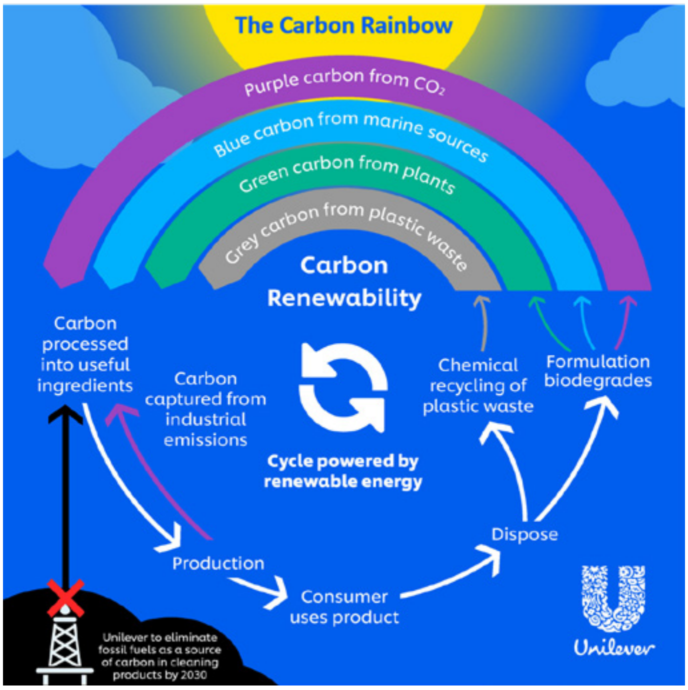
Companies producing innovative materials are also developing markets for their own climate neutral material solutions. **Stora Enso**, a manufacturer of renewable and bio-based packaging, construction and textile materials and solutions, has developed a 'TreeToTextile' brand. This aims to highlight the bio-based and renewable nature of its materials for consumer textiles products. Stora Enso is also marketing innovative, wood-based, alternative construction materials, such as Laminated Veneer Lumber (LVL) and Cross-laminated timber (CLT) products. At the same time, Stora Enso is seeking to reduce the life cycle emissions of its products more generally. It was one of the first companies in its industry to adopt science-based targets (SBTs) in this regard and its current SBT covers paper, pulp and packaging. Like other companies cited here, the development of new climate-friendly materials and products is part of efforts to implement a broader company transition aligned with science-based targets.

At the other end of the value chain, durable goods manufacturers and construction companies have taken significant steps to reduce the embedded carbon emissions in their products. For example, Volvo Cars and Bouygues Construction have set internal targets, based on the science-based targets, to reduce the Scope 3 (ie full life cycle) emissions of their products. Since Scope 3 emissions are 80 per cent of its total carbon footprint, Bouygues Construction has set itself a goal to achieve an overall 30 per cent reduction of its Scope 1, 2 and 3 emissions by 2030. To reach such a target, the company is working on an overall 40 per cent reduction in cement carbon intensity ($kgCO_2e/m^3$) by 2030. Moreover, under its WeWood initiative,[14] Bouygues Construction has committed to having 30 per cent of its building projects from wood-based materials by 2030 in Europe.

Volvo Cars has several short and long-term goals to tackle vehicle life cycle emissions.[15] By 2025 it aims to reduce these by 40 per cent compared to a 2018 (i.e. 40 per cent per car) baseline. Further recycling targets include vehicles manufactured with at least 25 per cent recycled plastics, 25 per cent recycled steel and 40 per cent recycled aluminium by 2025 across its entire product range.

In addition, Polestar (founded by Geely Holding and Volvo Cars) has set a goal of creating the first 'climate neutral car' by 2030.[16] According to the company, the Polestar project takes a cradle to gate approach and will "drive a 'design towards zero' focus" by eliminating emissions from the car's manufacturing phase. The inclusion of embedded emissions from materials is therefore a novel aspect of the Polestar brand compared to other automotive companies, which have tended to focus only on reducing emissions from combustion (eg by developing electric vehicles).

Several leading companies producing non-durable consumer products are also attempting to work with their value chains to develop innovative low carbon or circular material solutions, marketing them direct to consumers. For example, under its Carbon Rainbow methodology,[17] Unilever, a manufacturer of consumer goods, will replace 100 per cent of the carbon



Source: Unilever. Organic chemicals, mostly made from virgin fossil sources and used in Unilever's cleaning products, drive a significant proportion of its scope 3 emissions. Hence, the company developed the 'carbon rainbow', an easy-to-use colour-coded approach to structure the transition from virgin fossil sources to diversified sources of carbon for organic chemical feedstocks.

derived from fossil fuels in its cleaning and laundry product formulations with renewable or recycled carbon. Through the use of renewable or recycled carbon, they expect a reduction of up to 20 per cent of the product formulations' GHG emissions. These efforts to address the hardest to abate emissions in their products go alongside an ambitious material efficiency agenda combined with a programme to source materials from suppliers using decarbonised energy.

Similarly, Coca-Cola European Partners has developed its 'This is Forward' initiative,[18] a sustainability strategy devised by Coca-Cola Western Europe and Coca-Cola European Partners (who are responsible for the value chain in Western Europe, including beverage packaging and materials sourcing). In 2020, Coca-Cola European Partners announced a new Net Zero 2040 ambition to reduce absolute GHG emissions by 30 per cent by 2030 (compared to a 2019 baseline) across its entire value chain, with a particular focus on Scope 3, where its biggest impact occurs. Importantly, the company has noted that mobilising its suppliers is a critical condition for success. Since its own Scope 3 emissions depend on its suppliers, the company aims for 100 per cent of its strategic suppliers to set science-based targets and use 100 per cent renewable electricity by 2023. By sharing their carbon footprint data with CCEP, it can then accurately track reduction progress against targets. This example highlights the critical importance of data availability to achieving such goals (a key theme of this report.)

Credit: LafargeHolcim

2.2. The importance of scaling up demand

The above examples illustrate how, for a number of major, progressive, industrial EU companies, investment in the development of functioning value chains is central to their corporate strategies to decarbonise their business models. These examples also highlight the kinds of transformative actions that European business is capable of more generally, if the right incentives are in place. This report thus develops policy recommendations in Section 5 that show how such initiatives might be not only supported to go further, but also generalised.

Our interviews with industry representatives suggested varying motivations for developing climate-friendly products, internal company targets and sustainability strategies. In general, the following reasons were considered the most important:

- increased awareness among consumers of their products' environmental impacts
- a desire to seize market opportunities and remain competitive in a decarbonising world
- a wish to retain brand loyalty among customers and preserve a social licence to operate for the long term
- increased regulatory or carbon pricing pressures now or in the future
- the growing importance of green financing benchmarks and reporting requirements.

In general, interviewees expect these trends to become stronger drivers of their company's product sustainability initiatives in future. They consistently reported the further development and upscaling of demand for climate neutral basic materials as essential to the success of their climate-friendly product strategies.

However, we must not assume that businesses can deliver the transition to climate neutral basic materials and products in isolation. While all were optimistic about the ability to achieve internal short-term, i.e. 2025 or 2030, climate targets, they also reported significant barriers to scaling up climate neutral solutions beyond these current targets.

Discussions highlighted significant differences between the first steps to decarbonise value chains or products and a company-wide transition towards climate neutrality. They noted that greater policy implementation was essential if they were to achieve longer-term goals. This issue is addressed in the following section.

3. Barriers faced by business and the role of demand-side policies

The interviews highlighted critical barriers to the development of robust value chains for climate neutral materials and final products. These can be grouped into three broad areas:

1. **The missing business case for scaling up deployment of climate neutral technologies**
2. **Non-cost barriers to purchasing climate neutral materials**
3. **The need to unlock a full set of decarbonisation levers along the value chain**, including material efficiency, material circularity and use of climate neutral materials.

In addition, it should be noted that targeted 'supply-side' interventions can help unlock potentially pent-up demand for climate neutral materials. This is especially relevant to recycled materials and is examined in Section 3.4.

3.1. The missing business case for scaling up deployment of climate neutral technologies

One of the key barriers stopping upstream producers of energy-intensive basic materials from decarbonising production is the significantly higher cost of climate neutral production technologies. While this is not necessarily true for high-quality recycled materials, or certain innovative materials such as wood (see discussion in Sections 3.2 and 3.3), it does apply to many basic materials. For example, a recent study by Agora Energiewende[19] estimated that the marginal CO_2 abatement cost of five of the most mature production technologies for climate neutral steel, cement and basic chemicals was between €60 and €230/tCO_2 abated. These numbers generally implied an increase in the cost of producing the relevant basic materials of between 20 per cent and 200 per cent per unit, depending on the material and technology involved. For products sold in highly competitive commodity markets, such cost increments can significantly affect their ability to find mass market competitiveness.

If climate neutral products are to achieve a larger market share over the coming transitional decades, the incremental cost associated with the use of climate neutral basic materials, the so-called 'green premium', must be paid by the purchasers of basic materials. Yet they will only pay this if they can secure benefits, such as marketing the green properties of their climate neutral products for the end consumer, or meeting regulatory requirements to maintain market access.

Interviews suggested that while there may be some niche markets or progressive companies willing to pay a premium for climate neutral materials, it is still far from clear if this is the case for most downstream purchasers. As one interviewee suggested, this may be because efforts have only recently begun to educate consumers about the embedded CO_2 in the products they buy. Other interviewees noted that downstream companies selling mass-marketed products may want to avoid the need to raise prices, as this could negatively affect market share and reduce profit margins. Still other interviewees noted that significant uncertainty over the willingness of the market, as a whole, to pay the green premium makes it impossible for basic materials producers to invest massively into climate neutral breakthrough technologies across their entire operations.

In the short term, innovation support policies can subsidise a part of the missing willingness to pay the green premium. Tools such as Carbon Contracts-for-Difference (CCfDs) have a key role to play here.[19,20,21,22] Such policies could be beneficial, especially during the early phases of the transition, helping producers overcome technology-specific barriers to market entry by providing investment certainty to kick-start strategic technology value chains and infrastructure, such as zero-emission hydrogen[23,24] or carbon capture and storage (CCS). They could also be effective in mitigating project-specific risks attached to first-generation investments in relatively unproven technologies and in reducing the risks attached to carbon price volatility or the failure to find buyers willing to pay the green premium (see Section 5.4). Similar policies to CCfDs in other sectors, including electric vehicle bonus payments, or renewable energy feed-in-premium schemes, have shown high effectiveness.

However, supply-side instruments to 'artificially' fill the market demand gap, while necessary, are likely to be insufficient on their own. As noted by Vogl et al,[20] a complementary use of market-creation policy instruments can reduce the need for government expenditure on subsidies, accelerate the deployment of new production methods and encourage that deployment internationally, reducing competitive pressures. Moreover, even if funded by charges to end consumers of certain products, as the market share of supported projects grows, technology-specific support policies such as CCfDs could, over time, create market distortions, or regulatory capture.

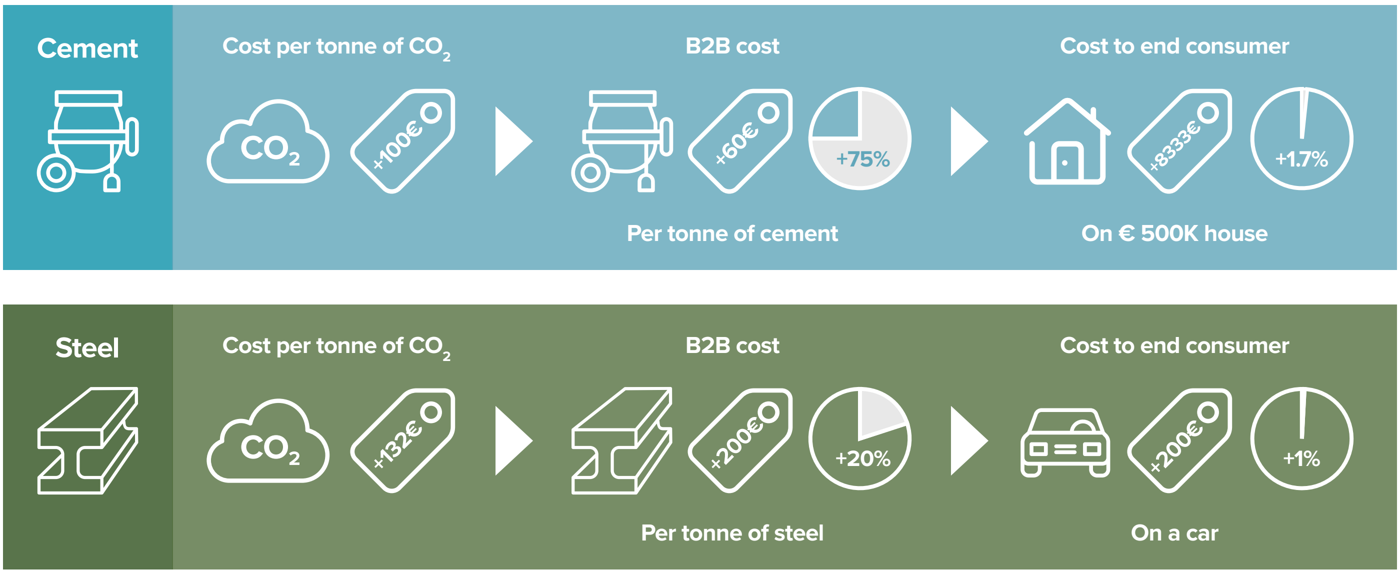
Most importantly, companies looking to invest across their entire asset portfolio to green their operations will need to have confidence that a willingness to pay for climate neutral materials will become market based in the foreseeable future. As one interviewee expressed to the authors: "What we really need is a solid business case, not subsidies", with the former perceived as a more robust and less risky case for scaling up longer-term investment.

In this context, it is reasonable to ask how a 'market-based' system, paying for more expensive climate neutral materials, could work. Certain climate neutral production processes will probably continue to cost significantly more than conventional production processes for the foreseeable future, if not forever. One answer is that the carbon price needs to sufficiently increase the costs of conventional production. However, while the carbon price has a role to play, it also has limitations. The carbon price is a *marginal pricing* instrument that, to date, has tended to drive marginal abatement decisions to balance the short-run supply and demand for EU Emissions Trading System (ETS) emissions allowances. Yet what is needed in the basic material value chains to align with climate neutrality is *non-marginal* change. Radically new technologies, production processes and business models are required, and must be developed urgently, whereas carbon prices are forecast to be too low to drive this change prior to 2030 at least. Furthermore, the history of carbon prices has illustrated their potential for significant volatility based on the impacts of essentially unforeseeable policy, economic and technological developments. By itself, therefore, carbon pricing is generally viewed by progressive industrial companies as only one part of the policy toolkit required to create the missing investment business case.

In this context, for many key value chains, final consumers could pay the green premium for climate neutral materials, assuming the necessary conditions were in place. This is demonstrated in Figure 3, which illustrates how a high incremental cost for the basic materials can still be managed as a minor cost increment for end product consumers. Specifically, the figure shows that, for cement and steel, a carbon abatement cost of €100–132/tCO_2 results in significant incremental costs for the basic materials when sold business-to-business (B2B) in the upstream part of the value chain. It is estimated that a €100–132/t price of carbon, the approximate marginal cost of key climate neutral production technologies in these sectors,[25] would lead to an increase of about 20–75 per cent in the cost of a tonne of steel or cement respectively for the mid-value chain business purchaser (ie the B2B cost). However, as the cement or steel product was gradually transformed and integrated into the final product, this incremental cost would represent a small amount of the total cost of producing the final goods. It is estimated that for a €500,000 home or a €20,000 car, the additional cost of green cement or steel would see a 1–2 per cent respective increase.

While this result does not apply to all material–product combinations, it suggests that many products consumers could pay the green premium without significantly reducing overall demand. Unlocking this potential will necessitate the implementation of enabling conditions and policies. Car manufacturers and construction companies, which must still compete with market rivals that do not source their materials from climate neutral suppliers, may still struggle to maintain profit margins and market share if they adopt 100 per cent climate neutral materials across production. Moreover, as described in Section 3.2, non-cost barriers can also prevent the development of such markets.

Figure 3: How the higher costs of climate neutral basic materials would affect final product prices for consumers



Source: CISL, Agora Energiewende (2021) based on data from ETC[26]

3.2. Non-cost barriers to purchasing climate neutral materials

However, the higher cost of certain climate neutral basic materials is not the only factor that can deter demand for them. Interviews with industrial companies also involved in this project showed that there are also unearthed important *non-cost* barriers to market uptake by potential purchasers. Such barriers can stifle market demand even if the relevant materials are competitive on price.

Depending on the relevant materials and value chains, non-cost barriers identified include:

- A lack of **available data and ability to compare** the green properties of embedded materials or intermediate inputs into certain products. European industrials cited this as probably the biggest single non-cost barrier to enabling higher demand and market competition for lower carbon and climate neutral production inputs. This issue was identified by downstream manufacturers, or users of climate-friendly materials, such as Bouygues Construction, Volvo Cars, Unilever, CCEP and Ball. As explained in Box 1 (below), the current absence of widely available data on embedded CO_2 emissions from many suppliers across the value chain makes it impossible for intermediate and final product purchasers to select and market either climate neutral or more climate friendly products.
- A **lack of understanding or resistance to change** among potential users of low carbon or climate neutral products. Alternative materials, low carbon cement, recycled steel and plastic, or innovative biomaterials used for construction, may have slightly different qualities to conventional primary materials. A lack of knowledge and experience of downstream manufacturers may limit their willingness to adopt these new materials. This is a particular issue with the construction sector's generally conservative approach to the choice of materials and practices, sometimes linked to concerns over potential liability due to material performance problems.
- **Outdated product regulations** can also inhibit the uptake of innovative, climate neutral materials or product material inputs. This is prevalent especially within the construction sector, where outdated and excessively limiting safety norms and standards can place limits on the use of recycled materials, the chemical composition of new cement or concrete types and the ratio of cement to concrete, for example. For instance, a representative of LafargeHolcim noted that one specific cement product incorporating higher shares of recycled materials can be produced and put on the market in Switzerland, but not across the border in EU countries where existing product standards do not allow it.

Cost-focused policy interventions, such as carbon pricing or innovation support, do not help in addressing these non-cost barriers, which require targeted interventions.

Credit: HYBRIT

Box 1: The critical importance of reliable and comparable data to lead market development

The most common concern raised by companies interviewed was the poor quality and availability of data on the embedded emissions in product inputs. This was especially true for downstream value chain companies that are currently unable to make reliable comparisons between the CO_2 content of different inputs or suppliers. This inhibits their ability to market products as low carbon, as they are unable to verify the embedded Scope 3 (life cycle) emissions and thus tend to use higher carbon default values to avoid any legal liability.

Concerns expressed by businesses included:

- A large share of suppliers are failing to produce Environmental Product Declarations (EPDs), which forces downstream producers to rely on national or sectoral average emissions to evaluate the embedded carbon in their inputs, rather than being able to select the best performers as suppliers.
- Methodologies and reporting methods are not harmonised across EPD developers, member states and products, making comparisons difficult even where EPDs are supplied.
- Because EPDs are costly to develop, small and medium-sized enterprises (SMEs), in particular, require strong regulatory or financial incentives to comply.
- Many suppliers do not wish to publish or supply key data to their downstream clients because they are concerned about revealing information to the market about their true CO_2 performance. This can often be a concern for poorer performing companies who, in the absence of being compelled to reveal information, resist this on the basis that doing so could be disadvantageous for them.
- Although the EU has established a methodological standard for Product Environmental Footprint reporting,[3] an absence of sufficient strictly defined Product Category Rules (PCRs) means that material producers and manufacturers are unable to harmonise how data is reported for CO_2-intensive products. In particular, poorer performing suppliers of certain inputs can use creative rule interpretations to achieve a more favourable-seeming product performance compared to the competition.
- In the absence of regulatory incentives, companies with long and complex supply chains are unable to mandate their upstream suppliers to supply the relevant data or otherwise improve data quality by applying strict standards.
- There is no centralised database, or labelling system, to compare EPDs with the performance of alternative suppliers within the value chain, making both benchmarking and competition on CO_2 performance across suppliers problematic. This is particularly challenging for industries, such as construction, where SMEs are common.

The above findings echo the results of other projects looking at this question, such as the MEASURE project.[27] Like this project, MEASURE identified "a number of key barriers to consistent use of sustainability assessment within industry" (p.3), including, among others, the fact that "life-cycle sustainability assessment (LCSA) methods lack standards, databases and mature impact assessment methods."

There are examples of voluntary and mandatory policy initiatives to improve the availability, quality and comparability of data on value chain emissions, such as the World Business Council for Sustainable Development's (WBCSD's) Carbon Transparency Pathfinder initiative. A recent report stated that: "End-to-end value chain transparency on greenhouse gas (GHG) emissions data will likely become a license to operate for organisations in the future."[28] The initiative is working with value chain stakeholders, independent industry bodies and technology companies to develop the methodological and technical infrastructure required to engender transparency.

In 2017, the Task Force on Climate-related Financial Disclosures (TCFD),[29] established by the G20's Financial Stability Board, published recommendations to encourage financial institutions and non-financial companies to disclose information on climate-related risks and opportunities. While this has led to positive global impacts, implementation has been slow. Within the EU[30,31,32] their recommendations have only been partially implemented under the Non-Financial Reporting Directive of 2014. This legislation only sets EU member states general, non-specific requirements to ensure that big businesses report their Scope 1 emissions and other risk-related data. Under the European Green Deal,[33] the European Commission is reviewing it in order to improve the harmonisation of data reporting. If adopted, this should enable larger companies to report their Scope 1 emissions and improve data availability.

To fully address interviewees' concerns, several related elements have been identified. The reporting of Scope 3 emissions alongside Scope 1 is required. Smaller companies, or those outside the EU, which supply EU companies should be targeted. Reporting requirements would need to produce product-specific data, based on facility-specific information, to fully support competition between high and low carbon suppliers of basic materials and intermediate inputs.

The EU has also been developing voluntary Product Category Rules (PCRs) for its Product Environmental Footprint (PEF) reporting standard. While these trials have been useful, the PEF remains a non-binding requirement and many PCRs are unavailable for key carbon-intensive basic materials or intermediate and final products containing large amounts of CO_2-intensive basic materials. Significant work is needed to fill the missing data gaps identified.

3.3. The need to unlock a full set of decarbonisation levers along the value chain

A further barrier to developing value chains using climate neutral materials is the high **transaction costs of coordinating** the adoption of new climate neutral material solutions across complex value chains.

In the construction and automotive industries, a range of interventions could improve the circularity of material use, material efficiency, the adoption of innovative materials and the substitution of high carbon materials with lower carbon alternatives. Interviewees from these sectors highlighted that many of these interventions would require the alignment of incentives and the development of new technical capacity across long and complex value chains. The high transaction costs of coordinating efforts presents a challenge for big companies and could be prohibitive for smaller ones.

Decarbonisation of upstream products and materials (such as steel) that are used as inputs for downstream products (such as cars) can be supported by tackling the 'demand side' of the market, ie by creating demand for final and intermediate products that are manufactured using climate neutral material inputs. A range of important CO_2 abatement levels exist along the value chain, including:

- **more efficient use of materials** in product design, manufacturing or construction
- **material substitution** using low carbon alternatives (decarbonised materials, or entirely new materials that can perform a similar function)
- **optimisation** of the application of different material sub-types (eg different concrete types) depending on CO_2 intensity to better match required performance
- **increased use of high-quality recycled materials.**

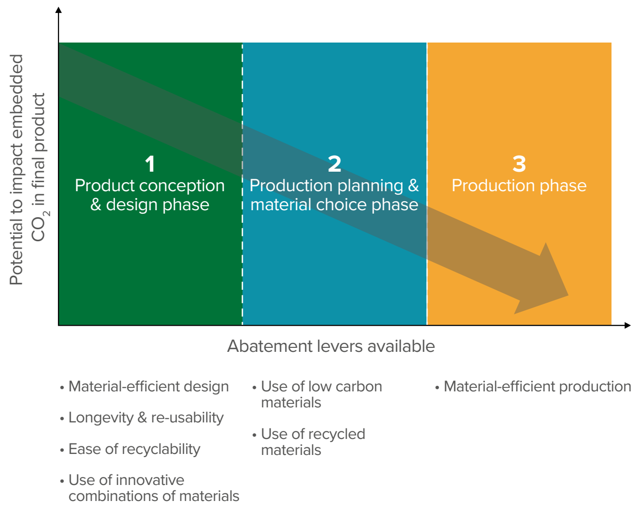
Activating these levers can significantly reduce the life cycle CO_2 emissions of construction and manufactured products. A 2018 study by Material Economics[34] found that material efficiency would allow the same material service or utility to be provided to consumers while reducing total emissions from cement, steel and chemicals collectively by 31 per cent by 2050, compared to a baseline scenario. It also found that an additional 25 per cent reduction in baseline emissions could be achieved by enhancing the quality and quantity of recycled materials.

Similarly, a report by the International Resource Panel for the UN Environment Programme in 2020[35] found that for the building sector alone, "strategies with significant potential [to reduce emissions] include more intensive use of homes (up to 70% reduction in emissions by 2050 in the G7), designing buildings using less material (8–10% by 2050 in the G7), and the use of sustainably harvested timber (1–8% by 2050 in the G7)" (p.2).

The same study also argued that "improved recycling could reduce GHG emissions by 14–18% by 2050 in the G7", with the cumulative savings from all of these strategies in the period 2016–50 amounting to 5–7 Gt CO_2e.[36]

It is, therefore, crucial to design policies that help unlock these different potentials, but this involves implementing various actions across the entire value chain. As illustrated in Figure 4, many abatement levers, such as material efficiency, product longevity, reparability and recyclability, can only be fully activated during the product (or project) conception or design phase. As one moves along the project or manufacturing process towards final production, the number of options to reduce emissions, while still relevant, is gradually reduced, because of the previous decisions taken. There is a need for transparent alignment of economic incentives to enable all actors along the value chain to play their part.

Figure 4: How incentives to reduce embedded CO_2 in final products creates opportunities to unlock a full set of abatement levers



Source: CISL, Agora Energiewende (2021)

As discussed in Sections 4.2 and 5.1, one key set of policies to unlock these abatement options along the value chain is the implementation of policies that place limits on embedded carbon within final products, based on the life-cycle emissions of the constituent materials and of the final product itself. Such policies create incentives to reduce the embedded life cycle carbon in the final product for it to gain market access. This, in turn, creates strong and clear incentives for suppliers of basic material and intermediate products along the value chain to reduce their own emissions to maintain (or improve) their existing positions within the relevant value chains. If the policies are designed fairly and effectively, incentives effectively flow back up the value chain, from the final product, through intermediates, to the basic materials producers and suppliers of raw materials and energy. However, the limits on embedded life cycle carbon should be designed in such a way as to support broader decarbonisation objectives, including attempts to minimise operational emissions from durable consumer goods. Failing to do this could have the unintended consequence of driving changes in performance that undermine other objectives, such as energy or CO_2 efficiency in use.

3.4. Supply-side barriers and 'pent up' demand

The previous section highlighted the potential significance of limits on embedded life cycle CO_2 policies to unlock a full set of abatement incentives, including material efficiency, the use of higher rates of circular materials and the decarbonisation of (virgin) key materials. To be practically effective and efficient, a range of further conditions need to be met. Some, such as availability of high-quality and comparable data, were mentioned in Section 2.2.

An additional challenge is that certain innovative and circular materials solutions face supply-side barriers to market. For climate neutral materials, barriers to supply must be addressed in parallel to those measures that generate higher levels of demand.

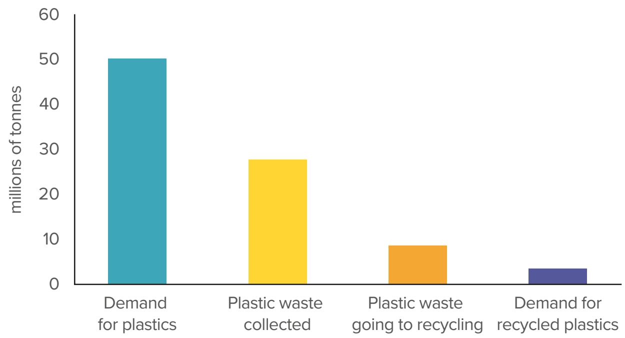
One issue is the development of recycled plastics, aluminium and other circular materials. As of 2016, recycled plastics only accounted for about 8 per cent of total plastic demand (Figure 5). Purchasers of plastics cite several critical barriers that either limit or, if removed, could help to increase their demand.[37]

These include:

- a lack of collection of plastic waste (see Figure 5)
- misallocation of collected plastic waste to general waste rather than recycling
- contamination of recycled plastic waste at the manufacturing, consumer use or end-of-life collection phase (leading to downgrading)
- missing or underfunded separate collection, sorting, recycling and processing infrastructure
- missing disincentives for incineration of plastic waste
- concerns about access to recycled materials (and increasing competition for them), which can limit potential 'closed loop' recycling value chains.

All of these factors are identified as currently limiting the supply of high-quality recyclable plastics into truly circular value chains.

Figure 5: Comparison of plastics demand vs. recycled plastics supply vs. recycled plastics demand



Source: CISL, Agora Energiewende (2021), based on data from European Commission[37]

Alongside plastics, products such as steel, aluminium and concrete have relatively high absolute rates of recycling or reuse, but there is often significant downcycling. Higher rates of *closed loop* secondary material use in new products could be achieved by improving the quality of secondary materials supplied to the market to avoid downcycling them into low-value applications.

There is a role for demand-side policies to address these recycled materials challenges. On one level, this is a story of 'pent up' demand due to supply-side barriers (ie infrastructure, collection practices), requiring supply-side solutions. This can be seen as a 'chicken and egg' problem: a lack of economic demand inhibits the development of abundant and high-quality supply, which then inhibits demand. In these cases, targeted interventions may artificially create temporary 'lead markets' for such materials. Section 4 shows how recycled plastic content quotas in PET bottles in the EU and recycled concrete requirements in Switzerland evidence how lead market tools can be effective in helping unlock supply and demand barriers simultaneously.

Coca-Cola European Partners uses 100% rPET in its Smartwater brand as part of its roadmap to reach 50% rPET by 2023 and working towards 100% recycled or renewable plastic in its PET bottles by 2030.

Credit: Coca-Cola European Partners

4. Review of relevant policy experiences

To address the specific barriers identified in Section 3, an overwhelming majority of the interviewees agreed that EU policy instruments could add value, although the specific challenges and needs differed across sectors. Some interviewees, however, noted several caveats and risks to be addressed in the design of policy instruments in order for them to be effective.

This section draws on these interviews to describe what role progressive businesses see EU policy playing in creating demand for climate neutral materials and products, and how existing policies could inform future policy development.

4.1. Progressive business perspectives on the role for EU policy

The interviewees, by and large, expressed the need for demand-side instruments to be designed in a way that drives **technologically neutral competition** when decarbonising the *final product*. Some were concerned that, in the case of some specific national policy instruments, an excessive focus on 'picking winners' from the material supply side was reducing demand for other low carbon products and threatening to stifle innovation. At the same time, however, other interviewees noted that an impetus to develop specific value chains and infrastructure during early stages of market development for certain *materials* would be helpful.

Where the barriers to market entry are high, such as recycled plastics, closed loop aluminium recycling, or recycled concrete, early-stage promotion of a portfolio of potentially key technologies could be of assistance, as they often require the removal of barriers by public authorities.[38] However, interviewees noted that any new obligations on the demand side would need to take due account of **the capacity of the supply side of the market to deliver in the relevant timeframe**. The interviewees also described the need for such policies to avoid the risk of creating undue tension over market availability of supply and highlighted the risk of distortions if such policies failed to include sunset clauses, leading to the 'picking of winners', fundamentally distorting markets over time.

There was a strong consensus among the interviewees that EU-level **life cycle carbon accounting methods and CO_2 performance benchmarks should be harmonised**. As many companies operate across Europe, a patchwork of national reporting and accounting systems was identified as a growing problem.

The interviewees also emphasised that policymakers should be **wary of excessive focus on the carbon price** as a magic bullet. While a carbon price is likely to contribute to reducing the cost gap between climate neutral and high carbon products, it was viewed as insufficient to create the necessary lead markets and address a range of non-cost barriers to decarbonise complex value chains. Identified limitations of carbon pricing as a sufficient basis for investment included:

- the relatively low level of current prices compared to the marginal abatement cost of key climate neutral solutions
- non-price barriers to decarbonising material value chains (eg the high transaction costs of coordinating complex and international value chains)
- the incomplete scope of the EU ETS (which does not cover all competing materials or key levers for abatement such as material efficient and circular product design)
- the inability to pass on the carbon price along the value chain
- the lack of long-term price visibility and the difficult-to-quantify risk associated with future carbon price levels.

4.2. Review of relevant policy experiences

As shown in the preceding section, progressive industrial companies in Europe see the potential for additional EU policies to promote lead markets and scale up demand for climate neutral basic materials and products. But what kinds of policies might these be? And what evidence is there that such policies may be effective? This section provides a brief literature review of cases where demand-creation policies have been used in other parts of energy transition.

CO_2 performance rating labels and data transparency tools

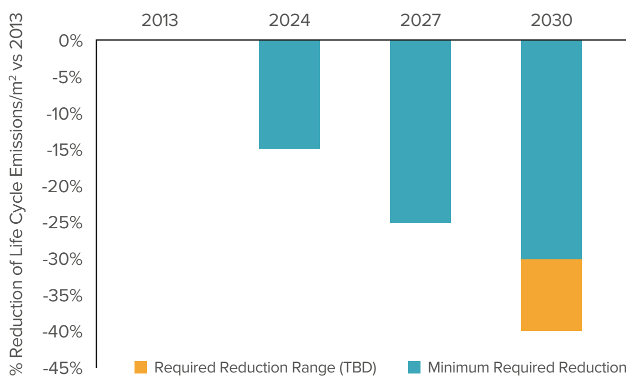
Perhaps the most obvious example is the EU's **Energy Performance Labelling** scheme. Since 1994, the scheme has used mandatory standardised energy performance labels to promote demand for improved energy efficiency performance for a wide range of household appliances and consumer goods, including fridges, washing machines, ovens and light bulbs, etc. There is strong evidence that this scheme induced demand from retailers and consumers for products with a higher energy rating, inspiring innovation from manufacturers. The European Commission reported that, in 2006, roughly two-thirds of refrigerators and washing machines sold were labelled as Class A, whereas over 90 per cent sold in 2017 were labelled A+, A++ or A+++.[39] Under recent revisions to the Energy Performance Labelling Directive, a harmonised database, consumers are able to use QR codes placed on products to obtain more detailed information about a range of aspects of product performance, limiting the need for excessive information on the label itself.[40]

Product design and embedded carbon requirements

The **EU's Ecodesign Directive** goes one step further than energy labelling by setting EU-wide minimum energy performance requirements on energy appliances.[41] This creates demand for more sustainable products by eliminating the less sustainable competition through regulation. Ecodesign has proved effective in tandem with energy labelling requirements, as the latter helps shift the majority of the market to higher performance levels while the former bans low-performance products.[42] From 2021, Ecodesign will integrate circular economy and material efficiency principles within a limited number of products. This will require products to be more reparable and reusable, with spare parts supplied for a minimum period to extend product life.[39]

Embedded life cycle carbon standards or requirements have begun to emerge at the EU member-state level[43] and globally. Bionova[44] reported that over 100 regulatory systems on embodied carbon in materials exist globally, primarily in the construction sector.[45,46] A prominent example of a mandatory embedded carbon scheme is France's new 'RE2020' regulation[47,48] (Figure 6). This requires building constructors to report both total energy consumption performance and total embedded lifecycle emissions in construction materials.[48] The limits for embedded CO_2 emissions are expressed in $kgCO_2/m^2$, with an assumed 50-year building lifetime, and are set to be progressively tightened over time.

Figure 6: Embedded life cycle emissions reductions required in new buildings under French RE2020 law



Source: Actu-Environnement.com[47]

As a result of the RE2020 regulation, French construction companies have revised their approach to new projects, including an increased focus on carbon, and in their interactions with other parts of the value chain, from architects and engineers to materials suppliers.[49] A major criticism of the French scheme is that by departing from established EU life cycle assessment standards in favour of specific materials (ie wood), incentives for innovation and circularity of other materials will be stifled.[50]

France is not alone in implementing national regulations on embedded CO_2 in buildings. In 2018, Sweden's National Board of Housing, Building and Planning introduced mandatory reporting requirements for most buildings and binding limits for climate impacts expressed in $kgCO_2e/m^2$ BTA.[51,52] Since 2015, Denmark has offered a freely available life cycle assessment tool for buildings to monitor and evaluate them before the introduction of mandatory requirements in 2023.[43] Finland launched a public consultation in 2018 on how to approach whole-life carbon footprint assessment for construction, which will become mandatory for new buildings by 2025.[43,53]

Public procurement policies to create 'lead markets'

Another tool used to develop lead markets for climate-friendly materials, or other innovations in the EU, is **green public procurement requirements**. One concrete example of a public procurement system to create lead markets for construction materials with lower embedded carbon in materials in the EU is the Dutch Public Infrastructure Authority. This Authority uses a life cycle assessment tool ('Dubocalc') and a shadow price of €50/tCO_2e to calculate fictive bids and rewards lower carbon conception or materials in the tendering evaluation process. This method is based on the Environmental Product Declaration Standards EN 15804 and EN 15978, with national adaptations.[43] However, researchers have questioned the effectiveness of using shadow carbon prices to monetise the environmental benefits of basic materials due to the extremely low share of embodied carbon costs in total project costs, even at relatively high assumed shadow prices.[19,54] Indeed, the use of shadow prices (albeit in the Dutch case combined with a general declaration on whether abatement practices were adopted for the project) appears to lead to only very marginal improvements in project CO_2 performance, suggesting that other types of public procurement criteria will be needed to drive transformative changes in business practices.

An arguably more successful example of material-specific public procurement policies for recycled materials is Zurich's public construction sector. In 2005 it became mandatory for all public buildings in the city to be built with recycled concrete in line with the SN EN 206:2013 and SIA 2030 standards. Under the city of Zurich's procurement policy, all concrete products must contain at least 25 per cent recycled aggregates in total mass. The city specified that recycled concrete should reach RC-C quality as a minimum for concrete containing 50 per cent virgin aggregate and 50 per cent recycled concrete aggregate (particles from concrete, concrete products, mortar and concrete bricks).[55] The results suggest that this recycled content mandate has been highly effective in creating an efficient recycling industry for concrete recycling in Zurich.[56] It should be noted, however, that applying similar requirements elsewhere would potentially require revisions to national concrete standards.

At state level in the United States, the New York State and the New Jersey Low Embodied Carbon Concrete Leadership Acts (LECCLA)[57] and 'Buy Clean'[58] initiatives require state agencies and departments to factor climate impacts into their selection criteria for concrete procurement. Under LECCLA, the more sustainable a concrete provider's bid is for a state-funded project, the more competitive and likely it will be to secure the contract. In addition, the system allows companies to earn tax credits to eliminate the cost of developing product Environmental Performance Declarations, addressing the issue of data transparency, which is considered a key barrier to low carbon concrete gaining growing market share.

Quota obligations

Mandatory **purchasing quotas** are another demand creation tool previously used by EU policymakers. A well-known example is the use of renewable energy (biofuel) quotas for sellers or distributors of transport fuels under the EU's Fuel Quality and Renewable Energy Directives. From 2003, these policies drove up the share of energy from renewable sources consumed in transport in the EU from 2005 to 2018, from under 2 per cent to over 8.4 per cent in 2019.[59] Although effective at delivering the narrow policy objective as legislated, biofuel quotas have been highly controversial. Key concerns have centred on the indirect effects on land use change of first-generation biofuels, accusations of false certification of imported fuels, and the need to incorporate previously unanticipated alternative fuel technologies, such as e-fuels.

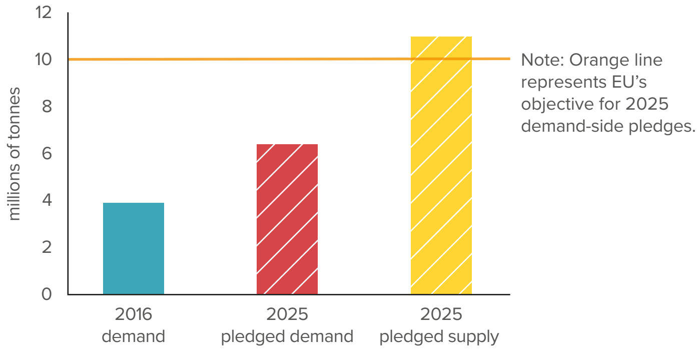
For materials, quotas have been adopted under the EU's recent Single-Use Plastics Directive (2019).[60] This requires the incorporation of at least 25 per cent of recycled plastic in PET beverage bottles sold in the EU from 2025, and at least 30 per cent in all plastic beverage bottles from 2030.[59] Initial evidence suggests that this measure has already been effective at driving demand for recycled PET.[37] The key bottleneck now appears to be a lack of high-quality supply of recycled PET throughout the EU (see Section 3.4), underscoring the importance of addressing demand- and supply-side barriers, in parallel, via an integrated policy package.

Soft coordination tools

In the context of the European Strategy for Plastics in a Circular Economy, the EU has also sought to spur early-stage demand by creating a private sector **pledging system**.[37] One of the rationales for doing so was a lack of demand for recycled plastics, identified by the strategy as a key factor inhibiting the economics of scaling up value chains and investments in high-quality collection and recycling infrastructure. In Annex III of the strategy, the European Commission asked industry to submit voluntary pledges to ensure that, by 2025, products on the EU market contain a total of 10 million tonnes of recycled plastics.

A status review of pledges, in 2019, revealed that the system had led to pledged increases in demand for recycled plastics of approximately 60 per cent by 2025, compared to 2016 levels, with increases across all plastic types. However, it remains to be seen if these pledges will be fully realised as several companies attached specific conditions. The cumulative pledged demand also fell well below the pledged supply of 11 million tonnes by 2025 (see Figure 7).

Figure 7: Pledged increases in demand for recycled plastics vs. historical demand and pledged supply in 2025



Data source: European Commission[37]

Direct financial incentives

Policymakers sometimes offer consumers financial incentives to stimulate demand for climate neutral products. Examples include the use of purchase subsidies for electric vehicles, subsidies and/or net metering incentives for distributed renewable energy, tax credits for the adoption of energy-efficient appliances or favourable financing terms for energy efficiency renovation loans. A general observation is that such policies are often limited by the available budgetary capacity of the relevant national government. Thus, while effective in the presence of generous subsidisation, their capacity to create scalable and predictable markets is typically limited by effective caps on total disbursements and the administrative capacity for making the relevant allocation decisions. Financial support policies make most sense where there are significant early-stage spill-overs to promoting consumer uptake, such as significant economies of scale, or innovation learning curves for the relevant technology or product. The greatest value from these schemes comes when they manage to push a new technology up the diffusion curve to the point that uptake starts expanding rapidly, and increasing use of the new product (such as electric vehicles) forces the supporting infrastructure to be developed, effectively removing some of the non-cost barriers to adoption.

5. Policy priorities and options for the EU

This section outlines a list of policy options available to create markets and a pathway to scaling up demand for climate neutral and circular basic materials and related products. These options are based on the analysis and evidence presented in Sections 2, 3 and 4, including evidence gathered from the above-mentioned in-depth interviews. However, these policy options do not necessarily reflect the views of any individual company.

To structure the presentation of these options, the analysis has been divided into three mutually supporting policy needs, discussed in turn. These are:

1. **Unlocking abatement incentives along the value chain**
2. **Improving product embedded GHG data availability and comparability**
3. **Overcoming market entry barriers to circular or innovative materials**

In addition there is a fourth challenge, which is ensuring that action to address these needs is aligned throughout the value chain. Finally, this section brings these different interventions together in a simple overview.

5.1. Unlocking abatement incentives along the value chain

Policy option: put embedded life cycle CO_2 limits on final products

A common theme across the interviews, and in the analysis presented above, is that demand-creation incentives need to focus on the embedded life cycle emissions in the final products that use carbon-intensive basic materials. This policy option proposes that the EU should place maximum global embedded CO_2 or GHG[71] limits on all final products that are material intensive and ensure that these limits decline over time. Based on the data presented in Figure 8, the key targets should focus, initially, on the most CO_2-intensive material-rich products such as:

- buildings and construction activities
- passenger cars and other motor vehicles
- packaging.

At the EU level, these policies might be pursued via revision of the Ecodesign Directive, the Construction Product Regulation and via the Energy Performance of Buildings Directive.

Embedded CO_2 limit policies can help to induce a willingness to pay and can technically create a requirement to pay for climate neutral material solutions across the value chain, since all producers and sellers of the final product on EU markets would have to pay the additional green premium involved in meeting the embedded CO_2 limit thresholds. As noted in Section 3, for many products, the ultimate price increases for consumers would be a small part of final product prices.

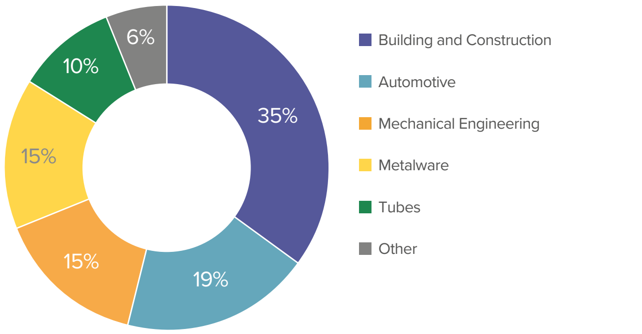
Embedded CO_2 limit policies thus offer a plausible way to ensure that consumers and markets integrate the cost of climate neutral production of basic materials and related products over time and across the value chain. They will also help strengthen the medium and long term business case for scaling up investment into climate neutral technologies, as the limits on embedded CO_2 are tightened over time while aid payments are phased out. Their creation would help increase the supply of climate neutral virgin materials as well as encouraging producers to devise material-efficient product designs to optimise material choices based on CO_2 intensity, while also increasing the use of circular materials. Technology-neutral incentives could be created for alternative materials to then compete to supply the value chain with low risks of market distortion.

In addition, limits on embedded life cycle CO_2 must be applied in a manner that is consistent with attempts to minimise operational emissions from final products, such as cars and buildings. As the simplest way to reduce overall material emissions would be to reduce material used, a blunt approach could simply skew the market towards less material-intensive options, which may undermine attempts to improve the insulating properties of building materials.

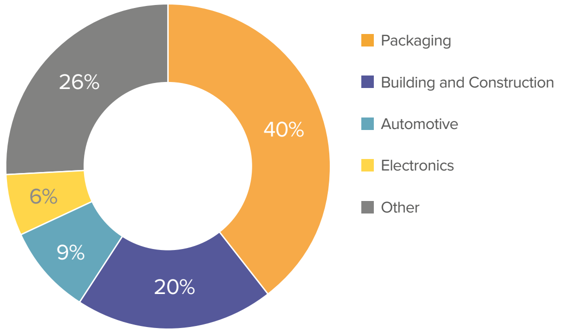
To maximise the scale of the relevant product markets, embedded CO_2 limit policies should apply to both private and public markets. For example, in addition to Ecodesign requirements limiting embedded CO_2 in the relevant final products sold in private markets, public procurement requirements would need to be set and defined along similar lines. For relevant products (such as construction and public works and vehicle fleets), the EU should ensure, via relevant sectoral legislation, that mandatory public procurement requirements are set. Requirements could mandate that public calls for tender, above certain cost thresholds, must include award criteria favouring contractors offering outstanding embedded life cycle carbon and energy efficiency performance.

Figure 8: Which products consume the bulk of CO_2-intensive basic materials in Europe?

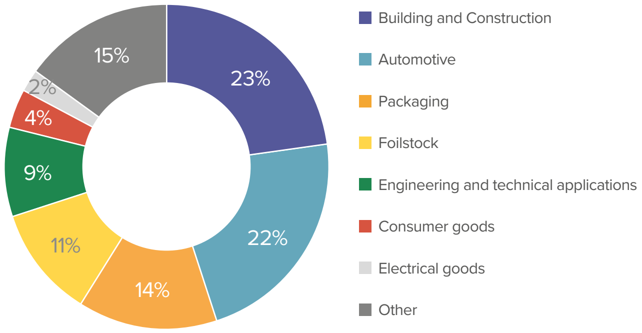
8.a. Steel use by final product (by weight)



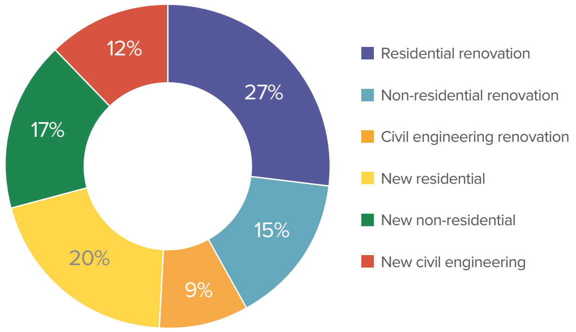
8.b. Plastic use by final product (by weight)



8.c. Aluminium use by final product (by weight)



8.d. Construction activity by market segment (by value)



Sources: Material Economics[34]; Cembureau (2017)[62]; EUROFER[63]; European Aluminium Association[64]

As the discussion in Section 4.2 highlighted, a key requirement for public procurement policies aimed at reducing embedded emissions is for the award criteria not to rely solely on shadow pricing of CO_2 or the Most Economically Attractive Tender (MEAT) system, the default process in the EU. A key success factor in public procurement policies for reduced embedded carbon is therefore that the award criteria either a) set minimum technical specifications to be met (eg tCO_2e/m^3 of floor space) or b) place enough weight on the embedded life cycle CO_2 performance for it to have a substantial effect on the outcome of the tender competition.

It would also be advisable if public procurement award criteria, relating to embedded carbon, aim for a significantly better level of performance than the market standard. A potential advantage of public procurement projects is the possibility for public project clients to immediately aim for deeper reductions in emissions than required by private market best practice, and to incentivise the use of recycled and innovative materials or design approaches. In doing so, public procurement requirements could help to create lead markets and thus familiarise suppliers and project developers with new and innovative practices, which can, in turn, be scaled up for the private sector.

5.2. Improving product embedded GHG data availability and comparability

For embedded GHG requirements to be effective, several other key conditions would need to be met. As noted earlier, significant improvements in the quality and comparability of embedded (life cycle) emissions data on intermediate products will be essential to support transparent competition between alternative climate neutral basic materials and intermediate products.

This issue is summarised in Figure 9, which illustrates the hypothetical example of climate neutral steel production used in intermediate inputs for car production. The arrows in the figure highlight important 'flows' essential to facilitate embedded GHG requirement policies. Climate neutral materials need to flow from upstream to downstream. To facilitate this flow, demand (and thus economic incentives) need to flow back from the downstream to the upstream segments of the supply chain. To facilitate this demand, sufficiently precise and comparable data on the embedded carbon in the materials must also be transmitted down the value chain.

As noted earlier in this report, some suppliers do not wish to publish or supply key data to their downstream clients because they are concerned about revealing information to the market about their true CO_2 performance. Consequently, they can either decide not to provide full transparency on embedded

CO_2 data or they can exploit uncertainties about definitions in existing reporting standards to provide an overly favourable representation of their true performance.

The measures outlined below thus seek to address these problems by requiring certain data to be provided for key value chains and by harmonising reporting standards and removing excessive degrees of freedom when reporting data.

Policy option: require Environmental Performance Declarations for key value chains and improved harmonisation of reporting requirements for specific products

The EU could take measures to require certain companies to produce to produce Environmental Performance Declarations (EPDs) for key value chains. The current revision of the Non-financial Reporting Directive (NFRD), under the Green Deal, could contribute towards this by requiring producers of inputs within high embedded CO_2 emission value chains, such as construction and automotive industries, to evaluate their Scope 1, 2 and 3 product emissions at site specific level. They could then be required to produce and provide product specific EPDs upon request to downstream purchasers. To reduce the cost of producing EPDs, especially for SMEs, the EU could encourage member states provide tax credits to offset the cost of EPD development. In addition, the EU could support the emergence of high-quality EPD reporting by setting a timeline to implement mandatory embedded CO_2 limits for key final products (as proposed in Section 5.1).

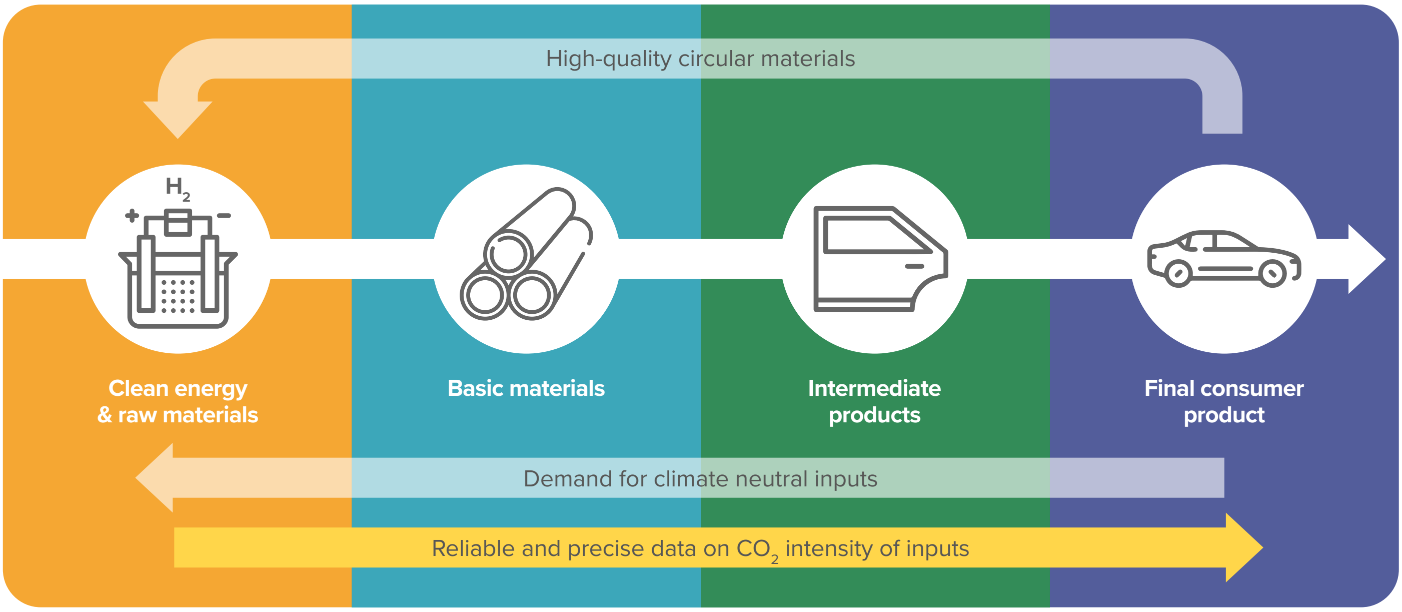
Furthermore, the EU could work to further improve and harmonise embedded CO_2 reporting requirements for specific products. Specifically, it could continue to expand the existing Product Environmental Footprint standards[3] with a range of new Product Category Rules to also include the most carbon-intensive material inputs and intermediate products in key value chains for industries including construction, automotive manufacturing and packaging.

Policy option: develop a standardised rating system and information tools for comparison for CO_2 performance of basic materials (similar to Energy Performance Rating labels)

While necessary, additional data is not sufficient to promote increased demand and competition for climate neutral materials along product value chains. Additional data must also contain information tools to enable easy comparison of the CO_2 performance of competing materials. Otherwise, companies looking to source climate-friendly materials may find themselves lost in a sea of data, unable to accurately compare competing products and choose the most climate-friendly options. This is of particular concern to SMEs that may struggle to conduct detailed market surveys and gauge which suppliers are the best performing without access to a reliable and standardised label or other information tool.

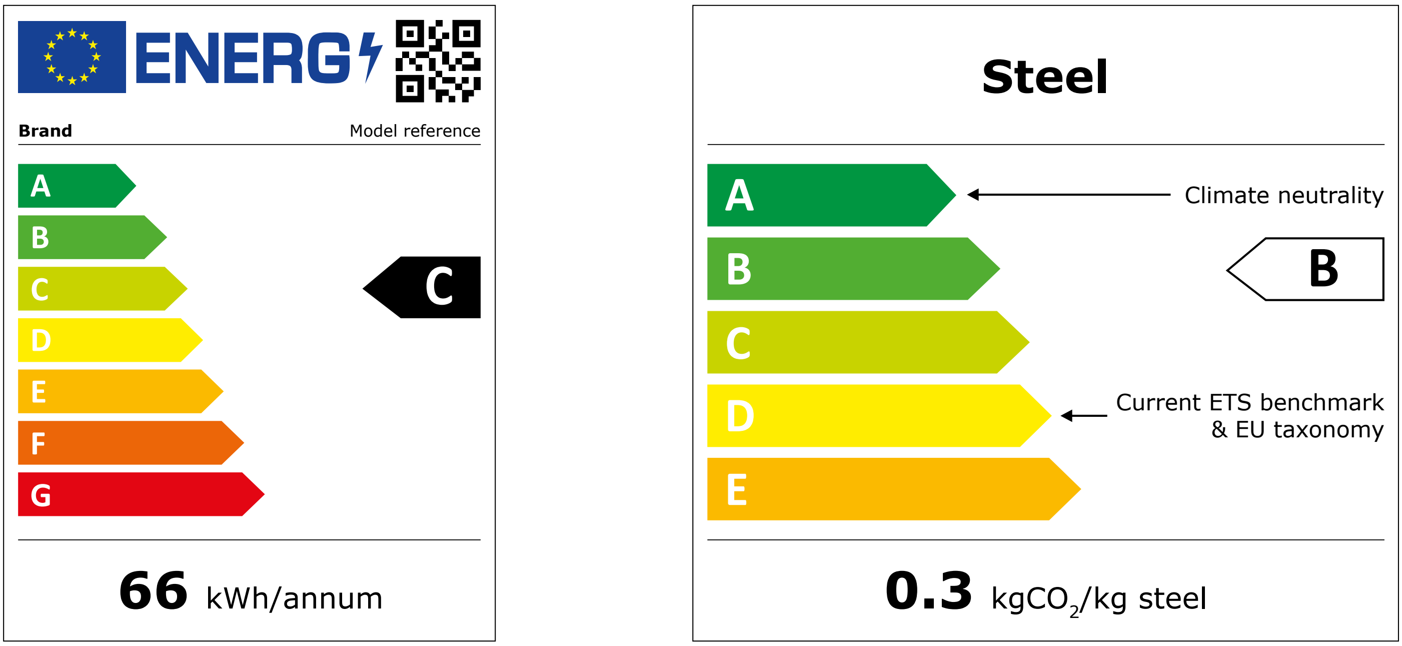
For the most carbon-intensive basic materials, the EU could model its embedded CO_2 data provision on the Energy Performance Rating Labelling Scheme. It could develop standardised CO_2 performance ratings for different materials (and key material sub-categories where necessary). This rating could be included as a 'label' on the relevant product information when the goods are either imported to the EU or transferred from one link in the value chain to another.

Figure 9: Sufficiently precise and comparable data on embedded CO_2 of inputs must flow along the value chain to enable embedded CO_2 limit policies to work effectively



Source: CISL, Agora Energiewende (2021)

Figure 10: Copying the Energy Performance Rating Labels model (left) to make 'material CO_2 performance rating labels'



Source: European Commission[39] (left), authors' own example (right)

'Climate neutral' labels would be based on a progressive rating system similar to the EU Energy Performance Labelling system (see example in Figure 10): a 'D' score might reflect the existing EU ETS benchmarks, while an 'A' might reflect a completely carbon neutral product. The labelling standards themselves would need to take account of the different product sub-categories that have varying CO_2 intensity benchmarks due to different performance or safety requirements. Any methodology would also need to be augmented by standards-setting bodies that calibrate the scores 'A' to 'E', depending on certain product performance parameters.[65] As with Energy Performance Labelling, the CO_2 labels would be a requirement for imported products, which would also require third-party verification by EU accredited auditors. De minimis thresholds could be applied to avoid unnecessary administrative burden on products representing a small fraction of market sales or total CO_2 content.

5.3. Overcoming market entry barriers to circular or innovative materials

The preceding two sub-sections have focused on the role of policies to promote CO_2 limits on embedded carbon in final products and related data needs. However, for such 'technology-neutral' policies focused on competition between different climate neutral materials and solutions to be most effective, in some cases there is a need to remove barriers to market entry for new and innovative solutions. As argued in Section 3, there can be other non-cost barriers stopping certain innovative materials from entering the market and competing with other alternatives.

There are a range of catalysts available to provide this initial 'push', depending on the barrier to market entry. In some cases, especially for virgin materials, project-based technology or infrastructure support may be the most effective and efficient solution. For example, Carbon Contracts for Difference (CCfDs) may provide the necessary business case and de-risking of first investments in large-scale breakthrough technology projects. For recycled materials, barriers may include a lack of high-quality waste collection or sorting and recycling infrastructure, which limits the availability or quality of the feedstock. In such instances, there may be a case-specific justification for targeted and time-limited measures to provide missing demand for first investments.

Policy option: explore minimum content quotas for innovative climate neutral or circular materials

Minimum content quotas could be designed in various ways, depending on whether they are implemented via public procurement or via private sector requirements. Public sector purchasers of basic materials could be required, or would seek through other award criteria, to ensure that a given percentage, or quota, of the materials in their projects are climate neutral. In the private markets approach, producers would be required or incentivised to incorporate a given share of a specific climate neutral material or subset of materials.[66] A quota system would be an assurance of growing market demand and induce either a willingness or requirement to pay the green premium for climate neutral or recycled materials. However, as the quotas are not technology neutral, they should be applied only where they can be rightfully justified, for example to support early-stage development of key solutions.

The general principle of creating a lead market generating quota system for certain key materials is not unheard of in basic materials industries.[67] Material-specific quota systems have been implemented with some success to upscale markets for recycled PET plastics and recycled concrete in Swiss public buildings. In some countries quotas have ensured a minimum share of wood for certain construction projects, kick-starting infant industries. While quotas for a limited initial share of recycled or innovative material content can be effective, quota policies come with risks and challenges. They also proved unpopular with our interviewees for the following reasons:

- Decisions need to be made over which materials to choose. While, in principle, one can specify that quotas should be applied only to strategically relevant solutions facing barriers to market entry, such as low carbon virgin steel, in practice, the political economy of picking winners makes this an imperfect process.
- Setting quotas on individual materials, in a context of today's quickly evolving immature technologies, raises the question of how to define appropriate cut-off thresholds for what level of abatement satisfies 'climate neutral' or 'low carbon-enough' criteria. Setting quotas for one low carbon material raises the question of whether others should receive the same quotas to avoid competitive distortion. The interactions between these issues can lead to complex cross-material disputes over which low carbon thresholds are fair and appropriate for which materials.

While these concerns are legitimate, they do not present a definitive set of reasons to *never* set quotas or promote specific materials in public procurement. In cases involving strategically important materials, the argument can be made that they are justifiable. The above discussion nevertheless highlights two issues: firstly, for any considered material solution under a quota policy, the relevant pros and cons need to be weighed carefully – do the expected benefits outweigh the risks? Would other policies be equally effective but less risky?

Secondly, given the risk of distortions to markets over time, quotas should be designed with clear objectives and sunset clauses, so that they can be phased out once the infant industry has become established. The conditions under which the quotas get withdrawn need to be made explicit at the start, when the quotas are first introduced.

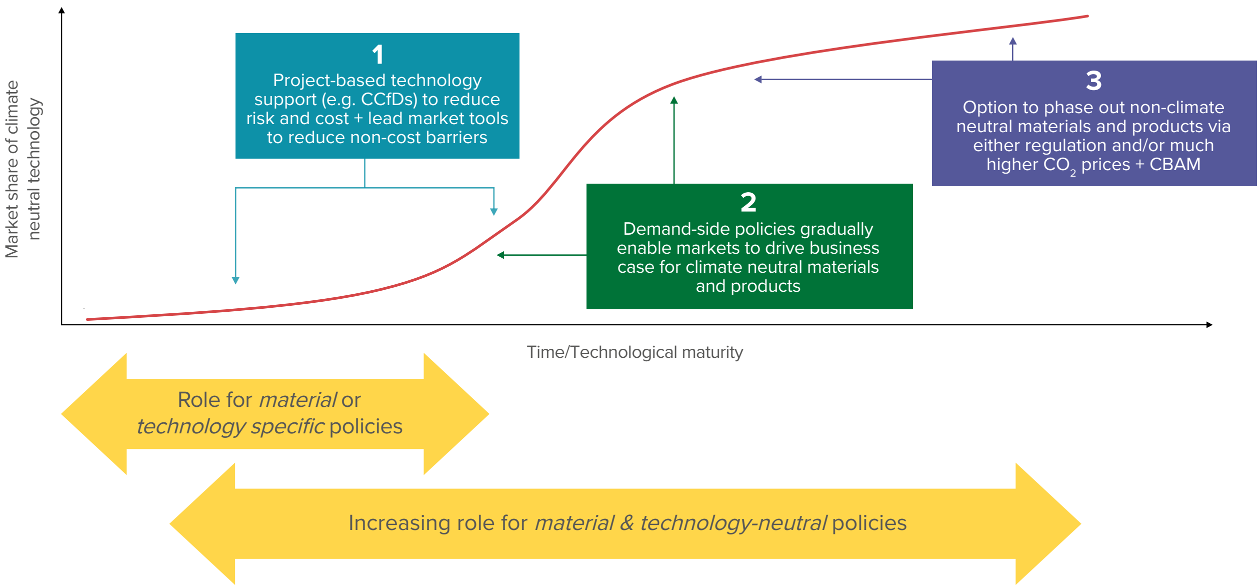
5.4. Coordinating 'supply push' and 'demand pull' policies

Demand creation policies need to be part of a broader package for industry decarbonisation, tackling the upstream (infrastructure), midstream (technology) and downstream (products and markets) elements of the value chain. A key question policymakers should ask is how they promote demand in coordination with other support policies on the 'supply side'.

While every sector or value chain is different, Figure 11 illustrates how different policies, on the supply and demand side, might be combined over time to support an archetypal 'climate neutral technology'. In the development of a technology solution, there can often be barriers to investment and commercial-scale deployment. These might include high cost, technology risk or significant new infrastructure requirements. In the early phase of development, material- or technology-specific support policies can play an important role. They could combine Carbon Contracts for Difference, public financial participation or de-risking of infrastructure investments, as well as lead market tools (such as labelling, public procurement of innovative materials, or even quotas for recycled materials).

As technological maturity develops over time, market demand will increasingly need to support the business case for climate neutral material value chains. While market demand creation policies play a role alongside 'technology push' policies, eventually, demand pull incentives should become the main

Figure 11: The possible role of material-specific vs material-neutral policy drivers at different stages of the transition



Source: CISL, Agora Energiewende (2021)

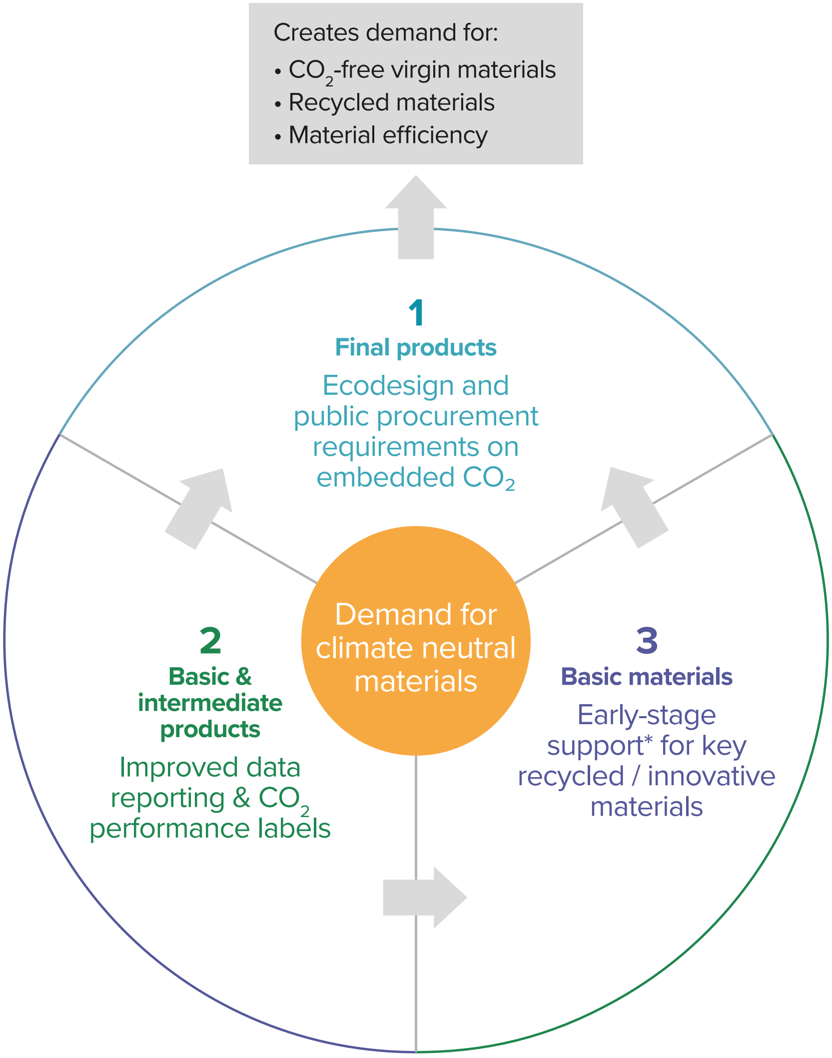
investment driver. At this point, the policies must become technology neutral, focused on embedded carbon in the final product rather than supporting material- or technology-specific solutions (as in the early stage).

In the longer term, non-climate neutral production technologies could be phased out, either via the eventual rise in carbon prices (coupled with border carbon adjustments), or through strict product requirements.[42]

5.5. Seeing the whole picture

In thinking about deploying actions to meet the needs explored above, the simplified infographic in Figure 12 has been designed to show how the key actions responding to the three core categories of policy needs fit together and could support each other.

Figure 12: Three policy priorities to scale demand for climate neutral materials and products



* NB. Such policies should be temporary and designed only to overcome barriers to market entry to avoid distortions of competition between materials.

Source: CISL, Agora Energiewende (2021)

6. Conclusions

Credit: scanrail

The transition of basic materials sectors and related products to climate neutrality is a major new frontier that European and global climate policymakers must address. This will require several enabling conditions to be met, including the development of key infrastructure, de-risking, and support for commercialising breakthrough technologies, as well as addressing carbon leakage risks. However, a robust long-term business case for clean production investments, to facilitate industrial transition, cannot occur without market-based demand for products made from climate neutral materials.

Targeted policies can create economic incentives for increased material efficiency and the use of circular materials in manufacturing. These policies can also help create a business case for large-scale investment in the production of innovative climate neutral materials, including low carbon versions of fossil-intensive materials such as steel and cement. Fostering lead markets and policies to create and expand market demand for climate neutral materials and products must be a key priority of the European Green Deal and Green Industrial Strategy.

In this report, the importance of using policy measures to create lead markets and to scale up demand for climate neutral materials and products has been demonstrated by some of the most progressive industrial companies in Europe. There are several reasons why these companies are pursuing strategies to foster demand for such materials and products. The efforts and resources invested in this endeavour by these companies underscore how fundamental the creation of markets and functioning demand for climate neutral materials are to their decarbonisation strategies. These efforts to create markets for innovative climate-friendly products highlight examples of corporate leadership on climate policy, which should be used as a basic template for others to follow.

However, deeper analysis of the experiences of these companies illustrates the limits of autonomous, voluntary action, especially if the private sector acts alone. While much can be achieved in the short term, shifting to the deeper transformations of the basic materials value chains requires several key corporate action barriers to be addressed.

This study has identified a role for well-targeted, non-discriminatory EU policies to address these barriers under three types of broad, and mutually reinforcing, policy interventions:

1. **Policies to unlock incentives along the full value chain via embedded life cycle CO_2 limits on final products**
2. **Measures to improve embedded CO_2 data availability, quality and comparability**
3. **Where appropriate, temporary measures to remove barriers to market entry for recycled or innovative materials**

Under the European Green Deal, there are several policy initiatives that can address these priorities:

- The EU should implement embedded life cycle CO_2 limit requirements on final products containing significant amounts of CO_2-intensive basic materials when the Ecodesign Directive and the Energy Performance of Buildings Directive (EPBD) are revised in 2022.
- Relevant sectoral policies for basic material-rich products, such as the EPBD, should lead member states to develop robust public procurement requirements that reward outstanding and innovative performance to tackle embedded carbon emissions.

- The EU should take measures to ensure more companies in the relevant value chains for material-intensive products produce Environmental Performance Declarations on their inputs and introduce data reporting requirements through revision of the Non-financial Disclosure Regulation and the upcoming legislative initiative on Environmental Claims.
- Further development of the EU's prototype Product Environmental Footprint[3] tools would harmonise reporting requirements and improve the comparability and utility of the reported data. This could include the development of additional Product Category Rules for products rich in CO_2-intensive basic materials.
- The EU could bolster fledgling industry initiatives to facilitate the transparent sourcing of low or climate neutral materials into intermediate and final products along the industrial value chain by developing standardised rating systems for embedded CO_2 performance in basic materials, such as steel, cement, aluminium and plastics. Ratings labels could be used to establish comparison and tracing for CO_2 performance of basic materials from different EU suppliers. This could build on the systems that are already in use for the Energy Performance rating labels and databases for household appliances, and be implemented via the current Environmental Claims Initiative of the Commission, as part of its Sustainable Products Initiative.
- For effective policies focused on competition between different climate neutral materials and solutions, temporary intervention could support early investments in strategically important circular economy and innovative solutions. Where market entry barriers exist for certain solutions, such as enhanced recycling of certain materials, and where the risks of market distortions from technology-specific support are low, certain demand guarantees may be temporarily justified to set minimum content quotas for innovative climate neutral or circular materials, creating lead markets. Companies interviewed for this study were wary of such policies, noting how the inherent risks of technology-specific policies must be balanced against the rewards. Such policies should therefore be time-limited to minimise the risks of undue distortions of competition and avoid placing constraints on scarce resources in unrealistic timeframes.

There are therefore many important opportunities for EU policymakers to begin crafting a well-targeted package of policies to accelerate and foster lead markets for climate neutral and circular materials during this legislative cycle. It is increasingly urgent that scalable lead markets can be established well before 2030, alongside other supply-side policies to promote clean energy infrastructure and the development and up-scaling of breakthrough technologies.

Action must be coordinated at EU level, albeit while respecting the principle of subsidiarity. One risk identified by this study is that of a growing fragmentation of national policies to fill gaps left in the EU policy framework in relation to materials decarbonisation. Pan-European industrial companies and value chains, therefore, require harmonised policies, data and industry standards to invest in climate neutral solutions and business models at scale.

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34 Material Economics. (2018). *The Circular Economy: A powerful Force for Climate Mitigation*. Retrieved from: https://materialeconomics.com/publications/the-circular-economy

35 Hertwich, E., Lifset, R., Pauliuk, S., & Heeren, N. (2020). *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future*. International Resource Panel, United Nations Environment Programme.

36 IRP. (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. Hertwich, E., Lifset, R., Pauliuk, S., Heeren, N. A report of the International Resource Panel. (p. 3). United Nations Environment Programme, Nairobi, Kenya.

37 European Commission. (2019). *Assessment report of the voluntary pledges under Annex III of the European Strategy for Plastics in a Circular Economy*. Brussels, 4.3.2019 SWD(2019) 92. Retrieved from: https://ec.europa.eu/environment/circular-economy/pdf/assessment_voluntary_pledges.PDF

38 In general, therefore, technological neutrality appears to be preferred in relation to decarbonisation of *final* products, while targeted and temporary support for a portfolio of breakthrough solutions for *upstream materials* was also identified as useful.

39 European Commission. (n.d.). *About the energy labelling and ecodesign: Energy savings*. Retrieved from: https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/about_en

40 In parallel to Energy Performance Labelling for household electric goods, the EU has also developed a range of labelling or product information reporting standards for other products and other aspects of environmental performance. These include the Ecolabel standard for foods with outstanding environmental performance, home energy performance certificates, home energy ratings, fuel mix disclosure for electricity, and European tyre and vehicle CO_2 performance labels.

41 European Commission (n.d.). *Sustainable product policy & ecodesign*. https://ec.europa.eu/growth/industry/sustainability/ecodesign_en

42 Gerres, T., M. Haussner, K. Neuhoff, A Pirlot (2019). *Can Governments Ban Materials with Large Carbon Footprint? Legal and Administrative Assessment of Product Carbon Requirements*, DIW Berlin. https://www.diw.de/de/diw_01.c.699293.de/publikationen/diskussionspapiere/2019_1834/can_governments_ban_materials_with_large_carbon_footprint__l___and_administrative_assessment_of_product_carbon_requirements.html

43 Zero Waste Scotland. (2019). *Embodied Carbon. Status Quo and Suggested Roadmap*. Retrieved from: https://zerowastescotland.org.uk/sites/default/files/Embodied_carbon_spreads%20final.pdf

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45 Giesekam, J. (pers. comm 15/07/2020): Interview conducted with Dr. Jannik Giesekam, Research Fellow in Industrial Climate Policy, Leeds University, UK.

46 Giesekam, J. (2016) *The Contribution to UK Climate Mitigation Targets from Reducing Embodied Carbon in the Construction Sector*, University of Leeds, School of Chemical and Process Engineering, Doctoral Training Centre in Low Carbon Technologies. https://etheses.whiterose.ac.uk/15279/1/Jannik_Giesekam_thesis.pdf

47 Actu-Environnement.com. (n.d.). *Constructions neuves : les conséquences de la nouvelle RE 2020 en débat*. Retrieved from: https://www.actu-environnement.com/ae/news/construction-neuve-reglementation-environnementale-RE-2020-36578.php4

48 Ministère de la Transition Ecologique et Solidaire (MTES). (2020). *Réglementation environnementale RE2020*. Retrieved from: https://www.ecologie.gouv.fr/reglementation-environnementale-re2020

49 Pers. comm. Representatives of Bouygues Construction, 2021: Bilateral interview conducted by author with company representatives in 03/2021.

50 Batiactu. (2020). *RE2020: les industriels de la construction dénoncent le calcul carbone et la place du bois*. Retrieved from : https://www.batiactu.com/edito/re2020-industriels-construction-denoncent-calcul-carbone-60723.php

51 BTA refers to 'bruttoarea', which is broadly equivalent to 'gross floor area' (or GFA).

52 Boverket. (2020). *Tidplan for insatser och atgarderinfor krav pa kli- matdeklarationer*. Retrieved from: https://www.boverket.se/sv/om-boverket/publicerat-av-boverket/publikationer/2020/tidplan-for-insatser-ochatgarder-infor-krav-pa-klimatdeklarationer/

53 Meanwhile, the EU itself has been trialling, since 2018, the new LEVEL(s) framework, which attempts to develop a harmonised European methodology for evaluating the sustainability performance of buildings across several indicators, including embedded CO_2 emissions in materials. The EU could potentially build on this framework to introduce mandatory measures as featured in the actions of the above-mentioned member states.

54 Hasanbeiji, A., Becqué, R., & Springer, C. (2019, April). *Curing Carbon from Consumption: The role of Green Public Procurement. Global Efficiency Intelligence*. Retrieved from: https://www.climateworks.org/wp-content/uploads/2019/09/Green-Public-Procurement-Final-28Aug2019.pdf

55 Where technically possible, however, RC-M concrete is preferred. That is, concrete that contains 75 per cent virgin aggregate and 25 per cent mixed demolition aggregate (particles from fired clay bricks and roofing tiles, calcium silicate bricks and non-floating aerated concrete). While RC-M contains a lower rate of recycled aggregate than RC-C, Zurich has chosen to focus on this, in order to incentivise the recovery of this otherwise more difficult to recover mixed demolition waste, which makes up around 60 per cent of Switzerland's 10 million tonnes of mineral construction waste produced each year.

56 European Commission. (2019, May). *A low carbon, circular economy approach to concrete procurement: City of Zurich (Switzerland). GPP In Practice, 88*. Retrieved from: https://ec.europa.eu/environment/gpp/pdf/news_alert/Issue_88_Case_Study_168_Zurich.pdf

57 State of New York. (2021). Senate Act "S00542", AN ACT to amend the state finance law and the tax law, in relation to implementing "The New York State Low Embodied Carbon Concrete Leadership Act". Retrieved from: https://nyassembly.gov/leg/?default_fld=&leg_video=&bn=S00542&term=2021&Summary=Y&Text=Y

58 RICS. (2020, January 24). *The Buy Clean California Act – What can we learn from it?* Retrieved from: https://www.rics.org/pt-br/news-insight/future-of-surveying/sustainability/the-buy-clean-california-act---what-can-we-learn-from-it/ (published: 24/01/2020)

59 European Environment Agency. (n.d.). *Indicator Assessment: Use of renewable energy for transport in Europe*. Retrieved from: https://www.eea.europa.eu/data-and-maps/indicators/use-of-cleaner-and-alternative-fuels-2/assessment

60 Official Journal of the European Union. (2019). Directive 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. Retrieved from: https://eur-lex.europa.eu/eli/dir/2019/904/oj

61 For the following discussion, the terms embedded CO_2, embedded carbon and embedded (GHG) emissions are used interchangeably.

62 European Cement Association (Cembureau). (2017). *Activity Report*. Retrieved from: https://cembureau.eu/media/vxyilmsd/activity-report-2017.pdf

63 EUROFER. (2020). *European Steel in Figures*. Retrieved from: https://www.eurofer.eu/assets/Uploads/European-Steel-in-Figures-2020.pdf

64 European Aluminium. (2020). *Digital Activity Report 2019–2020*. Retrieved from: https://www.european-aluminium.eu/activity-report-2019-2020/market-overview/

65 For instance, in the case of concrete, parameters around mechanical resistance and weather resistance in existing EU concrete norms could be used to recalibrate the A–E CO2 performance scale for the different sub-applications of concrete. Similarly for primary vs. secondary steel, etc.

66 In practice, a quota would need to allow for imported products meeting the same environmental criteria to be non-discriminatory from a World Trade Organization perspective.

67 The Climate Group. (n.d.). *SteelZero*. Retrieved from: https://www.theclimategroup.org/steelzero

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