Investing in a circular and waste-free Europe

Investing to solve global challenges | SUMMA EQUITY

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Preface

In today's world, the issue of material production and usage has become more pressing than ever. As we face the consequences of decades of uncontrolled waste production and disposal, it is clear that we need to fundamentally change our approach to material use and waste. With increasing waste generation, the current linear model is no longer sustainable. In Europe, environmental pollution to the magnitude of 850 Mt of CO_2e, equivalent to 22% of Europe's total GHG emissions, stems from material production and waste management alone. In addition, biodiversity challenges are accelerating, biological systems are experiencing negative consequences, we are experiencing value losses of more than EUR 70 billion annually from overuse and waste of materials, and we have a significant import dependency. Finding effective solutions to move toward a waste-free economy has become a critical imperative.

Our research and work explore the Theory of Change for achieving a waste-free and circular economy in Europe. It delves into the multidimensional aspects of waste generation from the European material system; the burning platform that is the current linear system; the tipping point and drivers for circularity; and the policies and regulations, technological innovations, behavioral changes, and social attitudes required to deliver on the agenda for change. Drawing on extensive research and expert insights, notably from McKinsey and Material Economics, this piece aims to provide a comprehensive framework for understanding the complexities and nuances of transitioning to a circular economy that minimizes waste and maximizes resource efficiency.

The transition is fully possible with current technologies and the financial and societal payoff would be substantial. But the journey toward a waste-free and circular economy in Europe is not without challenges. It would require a paradigm shift in how we perceive and manage waste and demand coordinated efforts from all stakeholders–governments, policymakers, businesses, investors, communities, and individuals alike. It would necessitate rethinking our production and consumption patterns, reevaluating our waste treatment methods, and reimagining our relationship with resources and the environment. The opportunity for Europe is to create a new paradigm; decreasing CO_2e by 650 Mt is equivalent to reducing 55% of material emissions, and would create jobs for hundreds of thousands of people. This would require an investment of only EUR 230 billion by 2040, but the financial value creation opportunity would be approximately EUR 1.5 trillion, so the return is massive for investors, our society, and our planet.

Our Theory of Change seeks to inspire, provoke thought, and stimulate discussions on the opportunities and pathways to achieve a waste-free and circular economy in Europe. It invites readers to critically reflect on the current state of material consumption and to envision a future where waste is minimized, resources are conserved, and our planet is protected for generations to come. It is our hope that this thought piece will contribute to the ongoing dialogue on sustainable material consumption and inspire action towards building a circular economy that prioritizes waste prevention through reduce, reuse and recycling practices and sustainable waste valorization. Together, we can shape a future where waste is not a problem but a valuable resource for a prosperous, sustainable, and resilient Europe.

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Executive summary

The transition to a circular European economy implies massive shifts in material flows, expansion of reprocessing technologies, and growth in circular business models that reuse products and materials and reduce waste. Investors should consider a EUR 230 billion investment opportunity by 2040 that has many pockets of attractive growth and returns. Summa Equity will "lean in" and invest in this transition, and encourages other companies to do the same.

A material system underpinning prosperity. The modern economy rests on a foundation of major flows of materials and resources. Each European uses, on average, some 2,200 kg of major metals, cement, plastics, fiber, food, glass, wood, and paper per year. These materials in turn underpin major value chains and basic societal functions—from infrastructure and construction to transportation, packaging, and consumer goods. They make up an often-neglected mainstay of prosperity. For example, chemicals, cement, and steel alone are responsible for approximately 7.4 million jobs in the major value chains they serve.

A largely linear current European economy. While the benefits of this resource use are undoubted, there is a catch: Europe's economy is still largely linear. Out of the total annual end-of-life material flows of 530 Mt, around 135 Mt end up in landfills and 170 Mt are incinerated. And out of the approximately 225 Mt that are collected for recycling, 35 Mt leave the EU material system due to exports or process losses. Of the remainder, a large share is downcycled to lower value uses. As a result, recycled content is low, and most products are made of primary (non-recycled) materials. Likewise, resource use has low productivity as major value chains see structural and unnecessary overuse and waste of materials—30% to 40% overuse of key construction materials, 50% yield losses in major manufacturing processes, and 30% waste in the food system. In addition, consumers do not reap the full benefits of key goods due to low levels of repair and reuse and short lifetimes for most consumer products.

Collision course with societal objectives. This linear resource use causes large economic and environmental problems. Some 850 Mt of CO_2 emissions (equivalent to 22% of Europe's total) are released from material production for European use and waste management. There are also serious consequences for biodiversity through large claims on land (for example, 24% of EU27+UK land is covered by crops used for agricultural production), including negative consequences for biological systems, value losses of at least EUR 70 billion annually for the economy, and significant import dependency for key products and raw materials.

A clear shift toward a circular economy, supported by strong fundamentals. EU policymakers, companies, consumers, and investors are now all turning to circular economy strategies to resolve these major issues. And for good reasons:

- Circularity greatly contributes to climate targets, as recycled materials typically have only 5% to 25% of the carbon intensity of primary materials—while avoided materials use can avert still more. In fact, we estimate that Europe can save around 650 Mt of CO_2e from otherwise hard-to-abate sectors by 2040 through circularity initiatives. The European goal of net-zero economy also depends on being more circular.

- Research suggests numerous business opportunities and highly cost-effective options—from reducing food waste to reuse of durable consumer goods to recovery of valuable materials—such that circularity would have a net positive impact on Europe's economy, both with regard to GDP and employment.

- Finally, a more circular economy contributes to Europe's strategic autonomy, reducing import dependency and geopolitical risks by lowering the total amount of materials needed for economic prosperity and by drawing on resources already available within Europe.

The circular economy is scaling massively in the 2020s. The sentiment among many market participants is that Europe's circular ambitions are now on the cusp of a massive acceleration. This inflection point results from the combination of several strong forces:

1. **The EU is setting ambitious circular targets,** which have translated into concrete strategies in sectors such as packaging, textiles, food, and waste handling. For example, policies now require 30% to 35% recycled content in various types of plastic packaging, a 50% reduction in food waste for European countries by 2030, and a near-complete phaseout of landfills in the 2030s.

2. **CO_2 regulation is evolving to strongly support recycled materials.** In the last four years, CO_2 prices have more than tripled from EUR 20/t to EUR 30/t to today's EUR 75/t to EUR 90/t. We estimate this will reach EUR 100/t to EUR 130/t by 2030. Meanwhile, reforms including import tariffs mean that these prices will directly impact product prices for carbon-intensive materials as well as waste management. For plastics, for example, this will add around 30% to 40% to the lifecycle cost, making recycled production a more viable option.

3. **Consumer and value chain pressures are turning to circularity.** Leading companies in automotive, consumer goods, and construction are targeting net-zero supply chains, with circularity an indispensable part of plans to get there. This emerging demand is driving real market impacts; recycled PET plastic traded at an average 40% premium compared to the same quality virgin PET in 2021, for example.

4. **Supply security is top of mind.** The current energy shock has resulted in an unprecedented focus on mobilizing energy resources. Waste is the largest near-term source of additional sustainable biomass to replace imported fossil resources for heat, power, and eventually also products such as aviation fuel or chemicals. EU import dependency is already forcing strict recycling targets for sensitive metals and minerals (for example, battery materials), while key industries (such as steel and chemicals) are rebuilding their asset base to make recycling the basis of their future production.

5. **Recycled material technologies and markets are maturing quickly,** as entrepreneurs and incumbents race to meet demand for high-quality recycled materials. Key technologies include chemical plastics recycling, LIBS-based advanced metal sorting, reprocessing of polyester and cotton, advanced product and material tracking systems, and others.

6. **Digitization enabling at-scale repair and reuse of durable** consumer products and advanced waste prevention. In high-end fashion, consumer electronics, office furniture, and other categories, fast-growing circular businesses are taking market share via consumer-convenient digital platforms.

What the future might hold: An enormous recasting of European markets for materials, waste, and physical products. The shift from linear to circular will mean profound changes for most European industries dealing with physical materials and products: a major shift from primary to secondary material production, new business models to reduce and reuse materials and products, and different end-of-life treatment practices. We estimate that these circular markets can reach EUR 820 billion in annual renenues by 2040, contributing to 650 Mt of CO_2e savings, a reduction of 55% from a business as usual scenario. At the highest level, the transition includes:

- **Circular business models: Scaling of circular business models for valuable consumer and business products.** The last few years have seen digital circular business models scaling fast for valuable products with low wear and tear. Key segments include transportation, high-end fashion, consumer electronics, IT equipment for businesses, office furniture, and secondhand platforms (such as TB Auctions). This is only the beginning, as there is enormous scope for these and other durable product categories to circulate with longer lifetimes, including via new service-based business models. According to our estimates, such circular business models could create revenues of approximately EUR 265 billion by 2030 and EUR 450 billion by 2040, which would in turn represent up to 15% of the physical consumer goods market by 2030.

- **Material efficiency: Businesses that reduce waste in food and industrial materials.** Large structural overuse in materials and resources can be addressed in major sectors, from manufacturing via product-as-a-service models or additive manufacturing; to packaging via new delivery models; to construction via prefabrication, high-strength materials, and more sophisticated design; to mobility via rental and sharing models; to food (food worth more than EUR 130 billion is wasted each year). All told, some 150 Mt of food and material use can be avoided without compromising service. In the Nordics, for instance, the Summa portfolio company Holdbart helps wholesalers and retailers sell close-to-expiration food products.

- **Recycling: Creation of a circular European materials backbone.** No major material flow will be untouched as Europe turns to recycling as a major source of its future raw materials. Another 130 Mt of waste will be diverted from landfilling and incineration, while changes to design, separation, and sorting make for higher-value material recovery in metals, plastics, and more. In parallel, European chemicals, steel, and other industries will build out a new asset base centered on recycling for input, while new material flows such as plastics and textile fibers will be recycled at scale for the first time ever.

For the waste management industry, this will mean more sophisticated waste sorting and more high-value reprocessing into materials that can compete with virgin materials—as exemplified by Sweden-based waste management provider Sortera. This material reprocessing industry could double from EUR 55 billion today to more than EUR 100 billion by 2030 and double again by 2040, reaching as high as EUR 210 billion.

- **Handling residual waste: Turning waste into valuable feedstocks and energy.** Three trends are set to transform waste from a costly problem into a valuable feedstock and energy source: 1) residual waste will become increasingly bio-based as fossil-based materials such as plastics and textiles are sorted out from waste streams, 2) biomass will increase in value as it will become a scarce resource for industries such as the chemical sector, aviation, and niche energy applications, and 3) new emerging technologies (gasification, fermentation, CCU, plasma-based technologies, and more) can use waste and emissions from waste treatment as bio-based feedstocks to create advanced fuels and chemicals, such as sustainable aviation fuels (SAFs), methanol, and methane. This could substantially increase the valorization of residual waste, creating a market worth approximately EUR 55 billion by 2040, compared to EUR 12 billion today.

Economic benefits through improved resilience, additional jobs, and consumer benefits. The European economy will benefit from this circular transition in multiple ways:

- Europe's resource disadvantage will be structurally lessened as it structurally substitutes imported resources for advanced data, logistics, and domestic labor. For example, by 2040, end-of-life materials and valorization of waste can provide 60% to 70% of steel, half of aluminum and plastics, 20% of sustainable jet fuel, and some 10 TWh of biomethane.
- Research suggests a circular transition will result in net job creation, as new opportunities in domestic, circular economy value chains will more than offset any losses from reduced consumption.
- Consumers will see improved purchasing power in food, mobility, and durable consumer goods. Waste reduction often pays for itself, while extended lifetimes and more intensive use mean consumers will receive more benefits from the same products. Producing recycled steel, aluminum, glass, and paper will cost less than their carbon-intensive primary counterparts, while upgrading waste is one of the cheapest ways to produce SAFs.

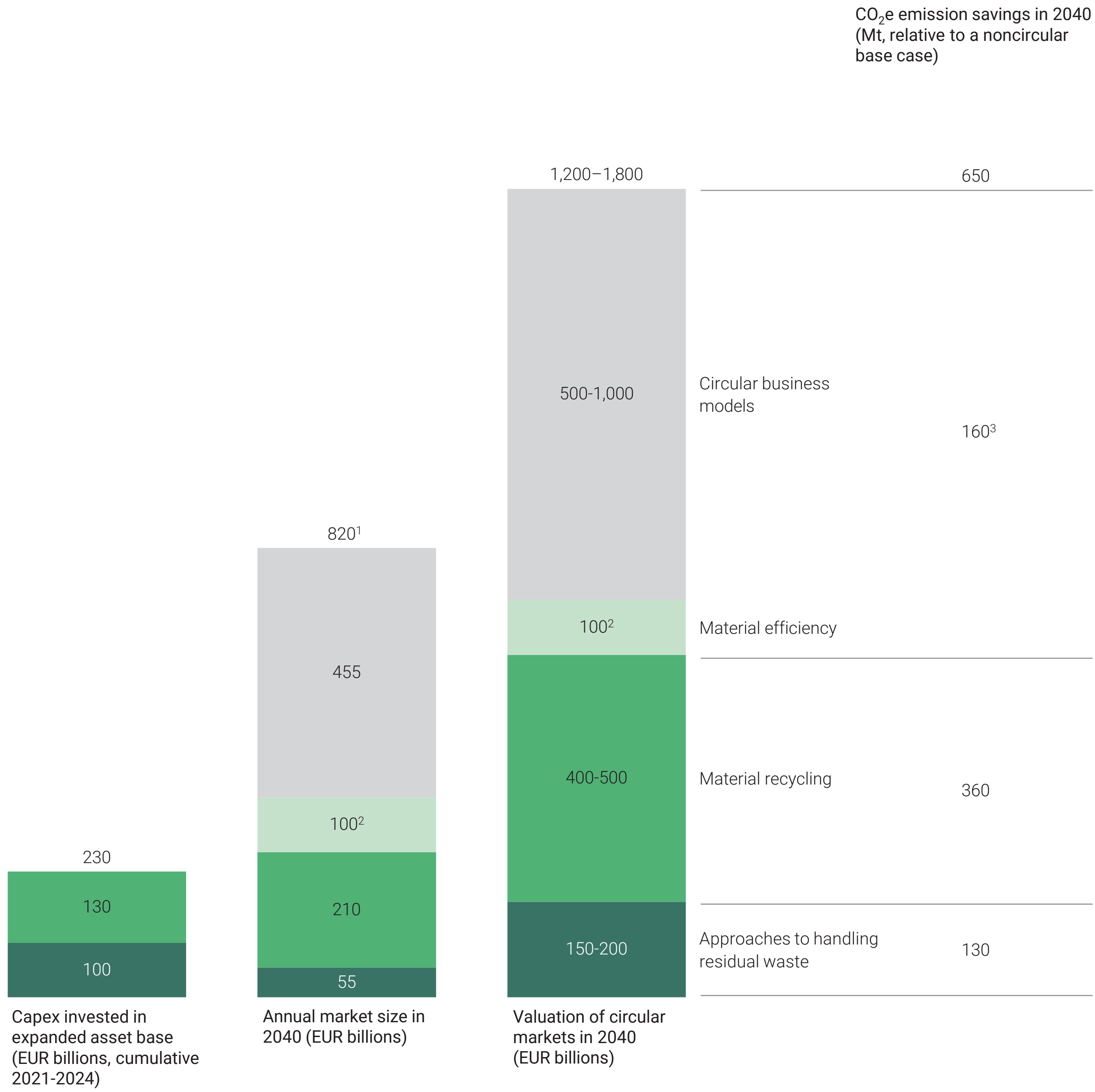
An attractive and sizeable investment opportunity of EUR 230 billion by 2040. The circular transition will require a new asset base. We estimate the cumulative investment needs of EUR 230 billion for physical assets and infrastructure by 2040. These investments can also generate attractive returns, and we estimate that the valuation of these circular markets could be above EUR 1 trillion. Exhibit 1 summarizes the investments, market potential, valuation, and CO_2e savings estimated for the circular economy by 2040.

□ □ □

The way forward: An agenda for change. The scenario outlined in the report offers an attractive vision for European business and society. Nonetheless, achieving it will require concerted action to overcome many barriers. As we set out in the remainder of this report, shifting waste and linear business models is a "wicked problem" and will require close collaboration between European companies, policymakers, and investors. Companies will need to significantly enhance value chain collaborations, redirect their investments to the new asset base needed, and relentlessly innovate their business models to capture the circularity value available. Policymakers need to create a common vision via clear policy targets, systematically leveling the playing field for circular solutions, and putting in place the enabling infrastructure, innovation systems, and inputs. Investors, too, need to participate to enable the suite of venture, growth, and infrastructure finance needed.

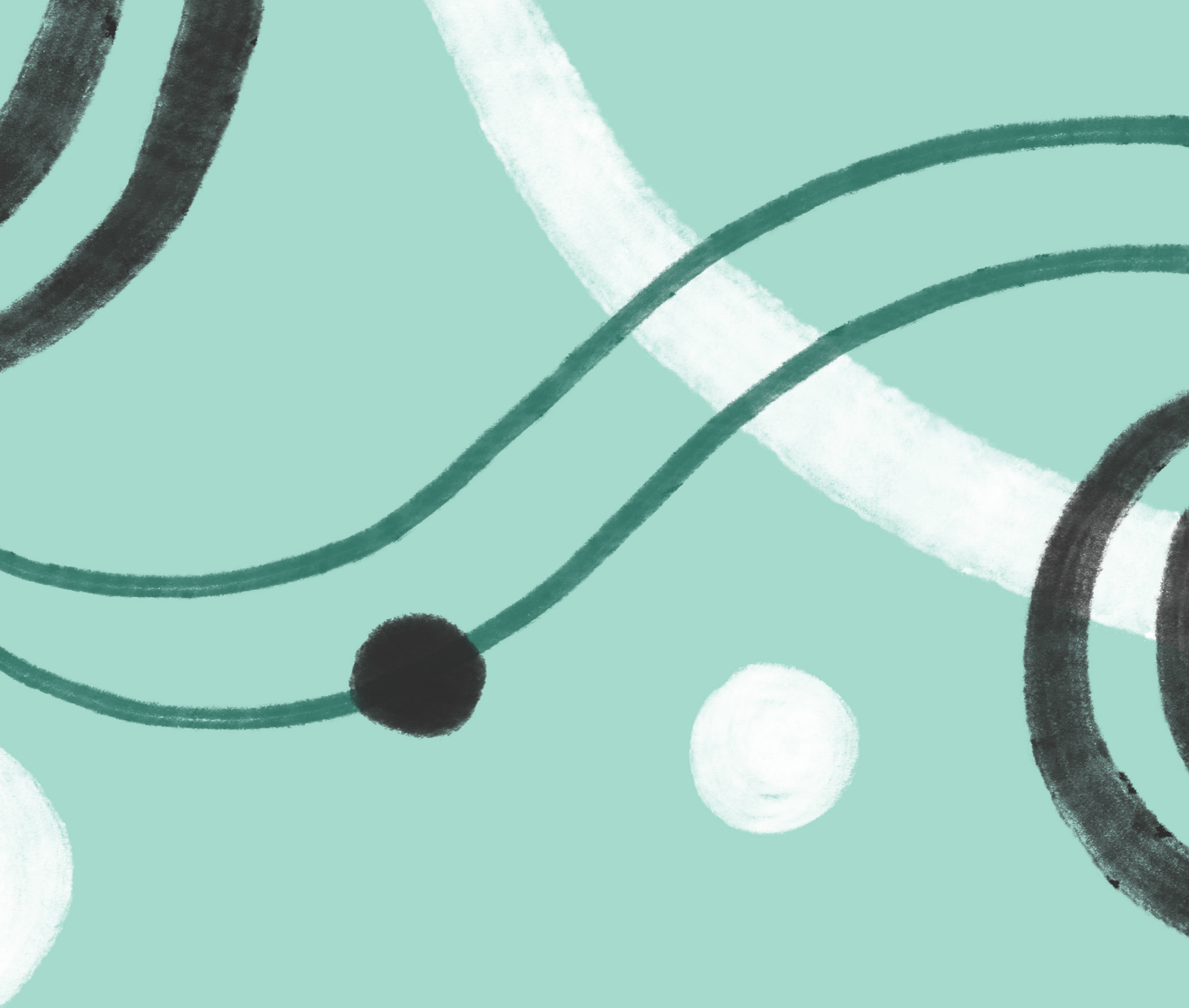
It is rare that new industries of the scale described above are created with such strong fundamentals and universal support from policymakers, investors, industry, and consumers. Summa Equity plans to play an active role in creating this industry and encourages others to do the same.

Exhibit 1:
The EUR 820 billion circular market could cut 650 Mt CO_2e emissions by 2040



1. The circular market (annual revenues) is ~EUR 160 bn already today (the largest markets include recommerce for fashion and electronics, and recycling of steel)
2. Material efficiency refers to material reuse and reduction, resulting in lower material consumption—there is no revenue generation in this activity and hence the revenue figure is better explained as economic value, which is also kept constant in the valuation
3. The CO_2e savings from both circular business models and material efficiency are achieved through reduced demand for virgin material production and have not been separately estimated but contribute to the same reduction. Note that emission reductions from circular business models not attributable to material savings are not included. E.g., mobility sharing may reduce the total fuel consumption, or accelerate the transition to electric vehicles. Resulting CO_2e savings are not included in this paper

Source: Summa Equity analysis building on multiple sources[1]



A burning platform: The case for near-term change

A modern economy depends on the creation, use, and disposal of large flows of materials such as steel, aluminum, cement, wood, paper, plastic, glass, textiles, and food. This material system is a fundamental but often overlooked enabler of economic prosperity and wealth as it is critical to all major value chains and industries. However, this system is on a collision course with other societal priorities, such as reduced climate impact, increased biodiversity, and sustainable resource use. Additionally, a great deal of economic value is lost to incineration and landfills each year. The situation is untenable, and the system needs to change.

1

Understanding the European material system

Material use forms the foundation of our economy. Extraction of raw materials and production of major industrial materials comprises the backbone of industry, making available major metals, cement, plastics, and more. These, in turn, find their homes in key products and structures in infrastructure, buildings, transportation, machinery, packaging, and consumer goods. As products reach their end of life, they need to be properly managed; some are reused or recycled, but the remainder are handled as residual waste. This material system is fundamental to fulfilling the most basic human needs of transportation, shelter, nutrition, and more, and vastly improves and simplifies the lives of the half a billion people living in Europe (the EU27+UK).

For a long time, European resource use grew rapidly. For example, steel use more than doubled between 1960 and 2000, while plastics use grew more than fivefold.[2] However, total material use has plateaued while the economy continues to grow. Total waste generation is still growing at around 0.8% per year, which is slower than the economy.

However, this plateau in material use occurred at a high level—and at a scale often hidden from view. Every year, around 170 Mt of steel is used in construction, automotive, machinery, and other industries—underpinning a total steel stock in the economy of some 12 t of steel per capita.[3] Around 170 Mt of cement is used in concrete for construction and infrastructure, while approximately 55 Mt of plastics is used in packaging to keep food fresh, protect consumer goods, store liquids, and more. Large amounts of paper and board, wood, textiles, rubber, glass, and various other metals and chemicals are also used. Altogether, the European economy requires almost 1,100 Mt of the eleven materials that are in the scope of this report—some 2,200 kg per person per year—while it generates more than half a billion tons of waste (Exhibit 2 and 4).[4]

Total waste generation is still growing at around

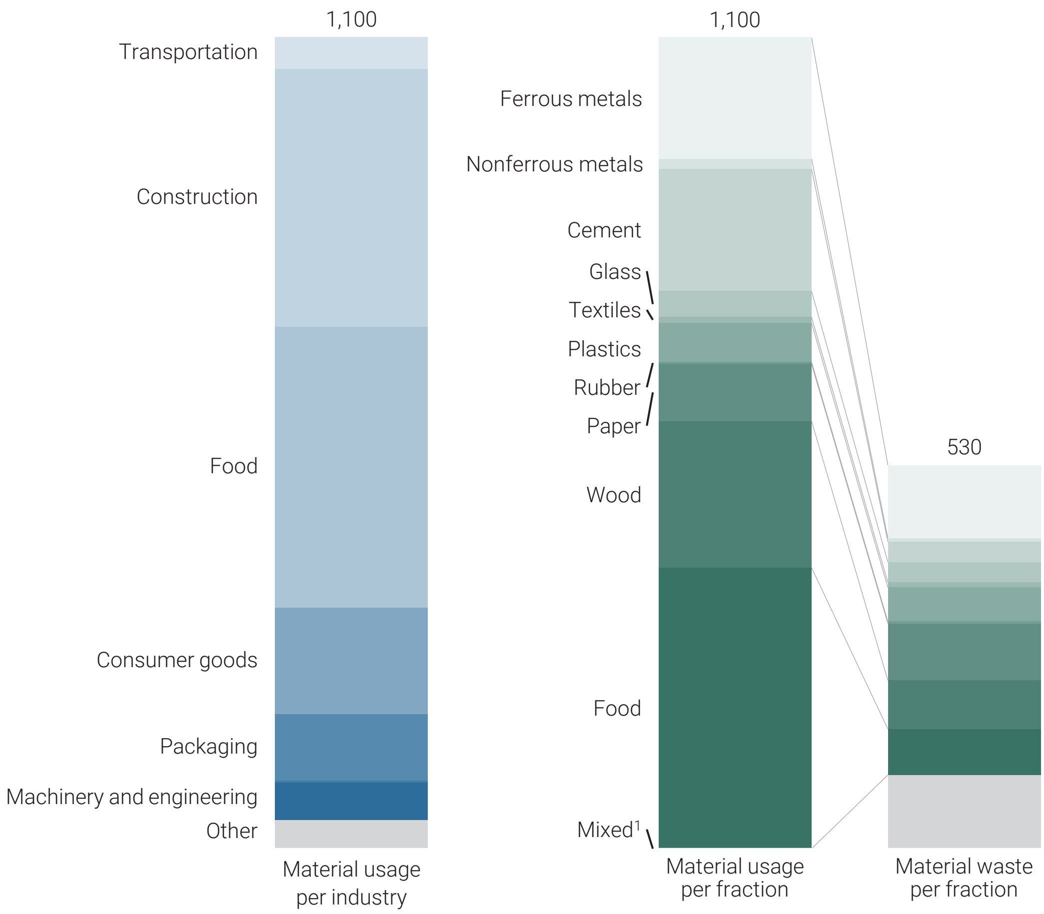
0.8%

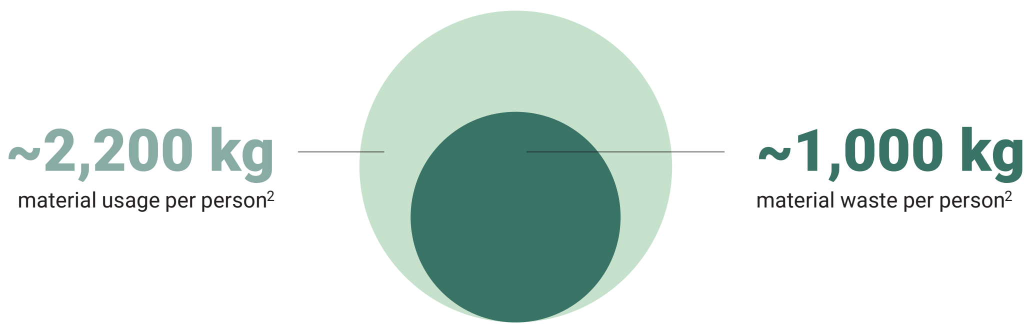
per year.

Is this volume of resource use necessary to support the underlying economy? Looking at all the major sectors and ma-

Exhibit 2:
The striking size of the EU material system

Estimated annual material usage and waste volumes in the EU27+UK (Mt, 2021)





1. Unspecified waste that cannot be linked to any specific material, including sludges
2. Not including aggregates, concrete (only cement included), rocks, stones, soil, dirt, chemicals, or medical waste

Source: Summa Equity analysis building on multiple sources[5]

terials, we find it is not. On the contrary, our use of materials and products often has low productivity and high waste (Exhibit 3).

First, current business models often fail to get the full value out of the products and structures we make. Products (such as electronics) and structures such as buildings are discarded or demolished far before the end of their technical life. Likewise, major capital assets and durables are poorly utilized; cars, for example, are stationary 95% of the time. At worst, products are directly wasted before they are even used—for example, EUR 130 billion of food is wasted and up to EUR 20 billion of electronics and fashion are discarded in customer returns or as unsold goods.[6]

Second, there is structural overuse of materials in major value chains. In construction, it would be possible to use 50% less steel and replace 50% of clinker in cement without compromising structural requirements via better, optimized design.[7] Likewise, major yield losses in manufacturing can be prevented via advanced techniques. For example, only some 50% of primary aluminum directly ends up in final products.[8]

Third, end-of-life materials are only partially recycled. Large categories are not recycled at all—including textiles and rare-earth metals—while only 13% of plastics are recycled. Moreover, there is widespread downcycling where large values are lost (for example, technical food-grade plastics become cheap bulk materials used in basic products). Even steel and aluminum, which are relatively successfully recycled, can be contaminated by copper and other elements, which limits the second or third use of the metals. Europe also exports 20% of its steel scrap, as it lacks the capacity to process it.

Fourth, end-of-life handling of residual waste is inefficient. One-third is burnt, often with low efficiency and value in the associated energy recovery. 25% is sent to landfills, where the high original values are turned into an environmental liability.

Exhibit 3:
Four structural inefficiencies in the material system, with examples

Examples of structural inefficiencies in the EU27+UK material system

1

We do not get the full value out of the products and structures we make

Cars are stationary **95%** of the time

15-20% of food is wasted annually, worth **~EUR 130 bn**

Electronics and fashion worth **~EUR 20 bn** are discarded and destroyed as unsold goods and customer returns

2

There is structural overuse of materials

In construction, up to **100%** overuse of steel and cement due to poorly optimized designs

~60% of European office space is unoccupied even during working hours

3

End-of-life materials are only partially recycled and often downcycled

Major categories are **barely recycled at all**—including textiles and rare-earth metals

Plastics are only **13%** recycled and often downcycled to much lower value

High-recycling materials, such as aluminum, are **still largely one-way systems**–second life is as cast aluminum rather than back to the original higher-value product

4

End-of-life handling of residual waste is insufficient

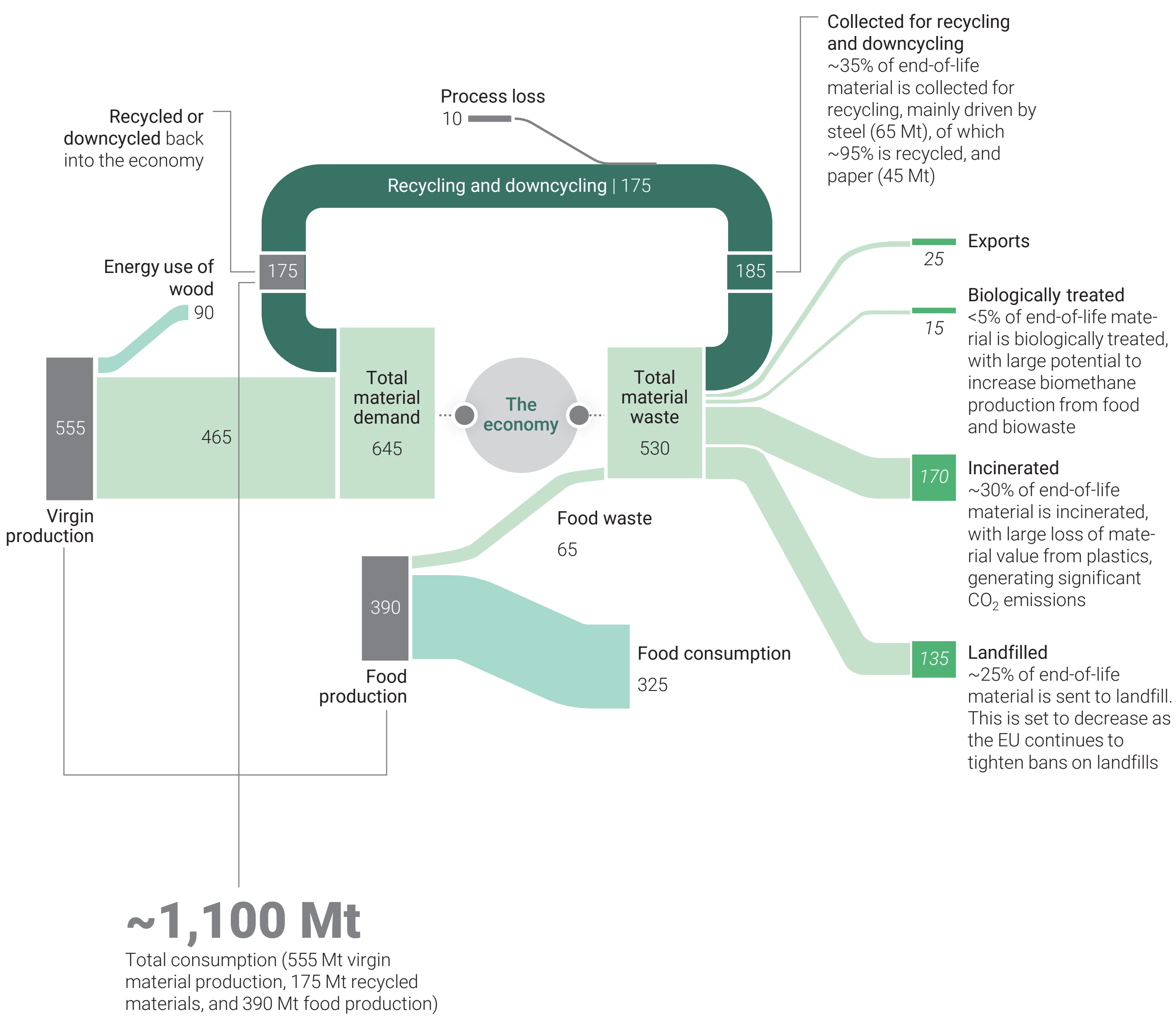
135 Mt of materials go to landfill, causing emissions of **~75 Mt CO_2e**

175 Mt of materials are incinerated, adding another **~105 Mt CO_2e** emissions, primarily through burning plastics

Source: Summa Equity analysis building on multiple sources[9]

Exhibit 4:
A largely linear material system

Illustration of European material flows, EU27+UK (Mt, 2021)



Source: Summa Equity analysis building on multiple sources[10]

Box 1

Scope of this report

This report is primarily written with a focus on major material flows in the economy. These materials underpin industries such as automotive, construction, consumer goods, electronics, and fashion. Therefore, we often also comment on these, both with illustrating examples and with dedicated sections in Chapter 4 on the way forward toward circularity for multiple industries. For materials in scope, we cover emissions from production (both inside and outside Europe) and end-of-life treatment.

Materials in scope are steel, aluminum, cement, plastics, textiles, paper (including cardboard), wood, glass, rubber, and food. These materials contribute roughly 22% of waste, as reported by Eurostat,[11] but they represent almost all of the economic value, as 74% of the total waste are aggregates, mining waste, rocks, stones, soil, and dirt. These represent large volumes but have no direct emissions (not including the energy required to move these masses around) and small to negative economic value (in the sense that they are purely a cost to cover). The remaining 4% is hazardous and medical waste, which are excluded as they require different treatment methods.

Within concrete we are focusing on cement only, which represents 15% of the mass but more than 90% of the carbon footprint.[12]

Within food we have focused on waste only, including what can be done to reduce food waste and what the best uses of unavoidable food waste are. We have not focused on net-zero approaches for food production or agriculture at large (for example, regenerative agriculture or new technologies).

We have not included wastewater and wastewater treatment in the scope of report, yet it is worth noting that it is part of the circular economy in the sense that wastewater sludges can be recovered as feedstock for biomethane production.

A system on a collision course with societal priorities

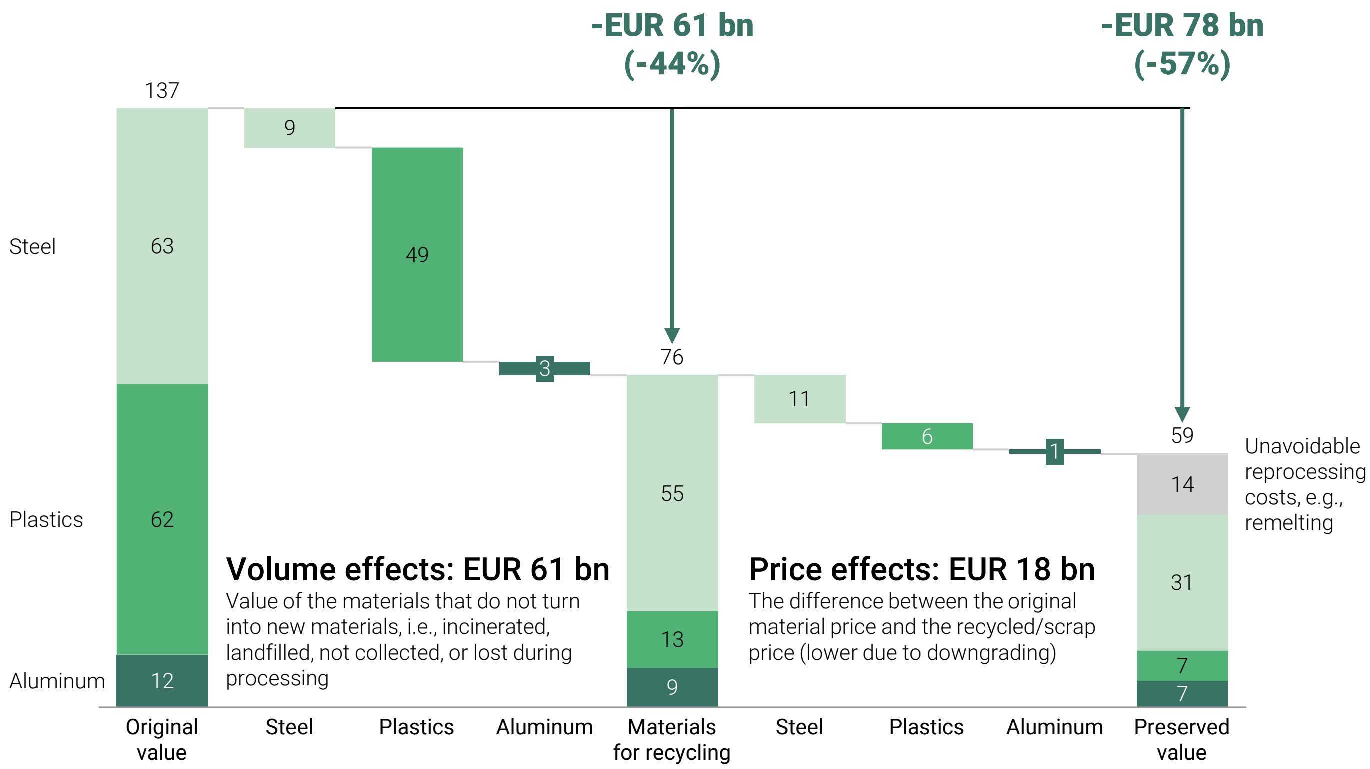
The low productivity and linear nature of the current material system are causing several major problems. In fact, it is on a direct collision course with many of the key challenges Europe now faces.

Economy: The circular economy as a productivity opportunity

First, there are large economic losses at stake as current practices fail to get the value they should out of the products and materials used. For example, even for recyclable materials such as steel, aluminum, and plastics, most of the value is lost after just one use cycle, a loss of EUR 78 billion per year as estimated by Material Economics (Exhibit 5). As noted, similar values of EUR 70 billion per year are lost on food, fashion, and electronics that are discarded without even being used.

Exhibit 5:
Each year the European material system loses over EUR 78 billion

Value losses in the EU material system, 2016 (EUR billions)



Note: Individual numbers do not sum up to totals due to rounding

Source: Material Economics (2020)[13]

Climate: Why a low-CO_2 economy must be circular

Second, the current material system is incompatible with Europe's climate ambitions. Production of materials is hugely emission-intensive: producing 1 t of steel or plastic emits more than 2 t of CO_2, and numbers for materials such as aluminum are higher. Moreover, these are some of the trickiest emissions to cut in the entire economy, as they often arise as an intrinsic part of the chemistry of current processes to make petrochemicals, steel, cement, aluminum, and more.

In total, material production and waste management contribute around 34% of global CO_2 emissions. If not addressed, continued growth of the material system would, by 2050, greatly exceed the global carbon budget allocated for materials (Box 2). In Europe, yearly emissions from production and end-of-life treatment of in-scope materials (excluding food waste) are about 850 Mt of CO_2 equivalents (CO_2e), equal to 1.9 ton per person, or just under 22% of the EU's total greenhouse gas (GHG) emissions. Most of this arises in the production of materials, but landfills and waste incineration also contribute approximately 180 Mt (Exhibit 6).

A more circular economy will help the European industry transition to a net-zero system, reducing the CO_2e emissions left for the energy transition to abate. As we detail in the next chapter, shifting to a more circular economy could reduce material emissions by 55%, in total saving over half a gigaton of CO_2e. Moreover, given the large economic opportunity in a more circular economy, it can be a highly value-creating way of doing so.

Box 2

Materials and the global CO_2 budget: Why a net-zero economy must be circular

With the current linear value chains, material CO_2 emissions alone will become higher than the entire global CO_2 budget for materials—requiring a shift to circularity. The CO_2 budget is how much CO_2e can be emitted by the economy while still achieving the 1.5° Celsius target of the Paris Agreement, which is estimated to be around 800 Gt for industry and energy and 300 Gt for material. It has been estimated that the global demand for material would result in around 900 Gt emissions with the current energy mix and around 650 Gt if zero-carbon energy is achieved.[14]

Large share of emissions cannot be addressed by the energy transition alone. It has been estimated that up to 84% of EU heavy industry emissions are "hard to abate," meaning that the energy transition alone will not abate the emissions. This includes around 248 Mt CO_2 in process emissions, such as carbon used in iron ore reduction and limestone calcination and hydrocarbons used in fuel-grade by-products and in steam cracking. Of this, around 143 Mt CO_2 are from high-temperature heat and 59 Mt CO_2 from end-of-life treatment.[15] While clean energy cannot address these emissions, circularity can, by reducing demand for primary materials, replaced by secondary materials or by increased utilization of existing products and assets. (See Box 4 in Chapter 3 for more details on the levers of circularity.)

Resources: Reducing resource and biodiversity challenges

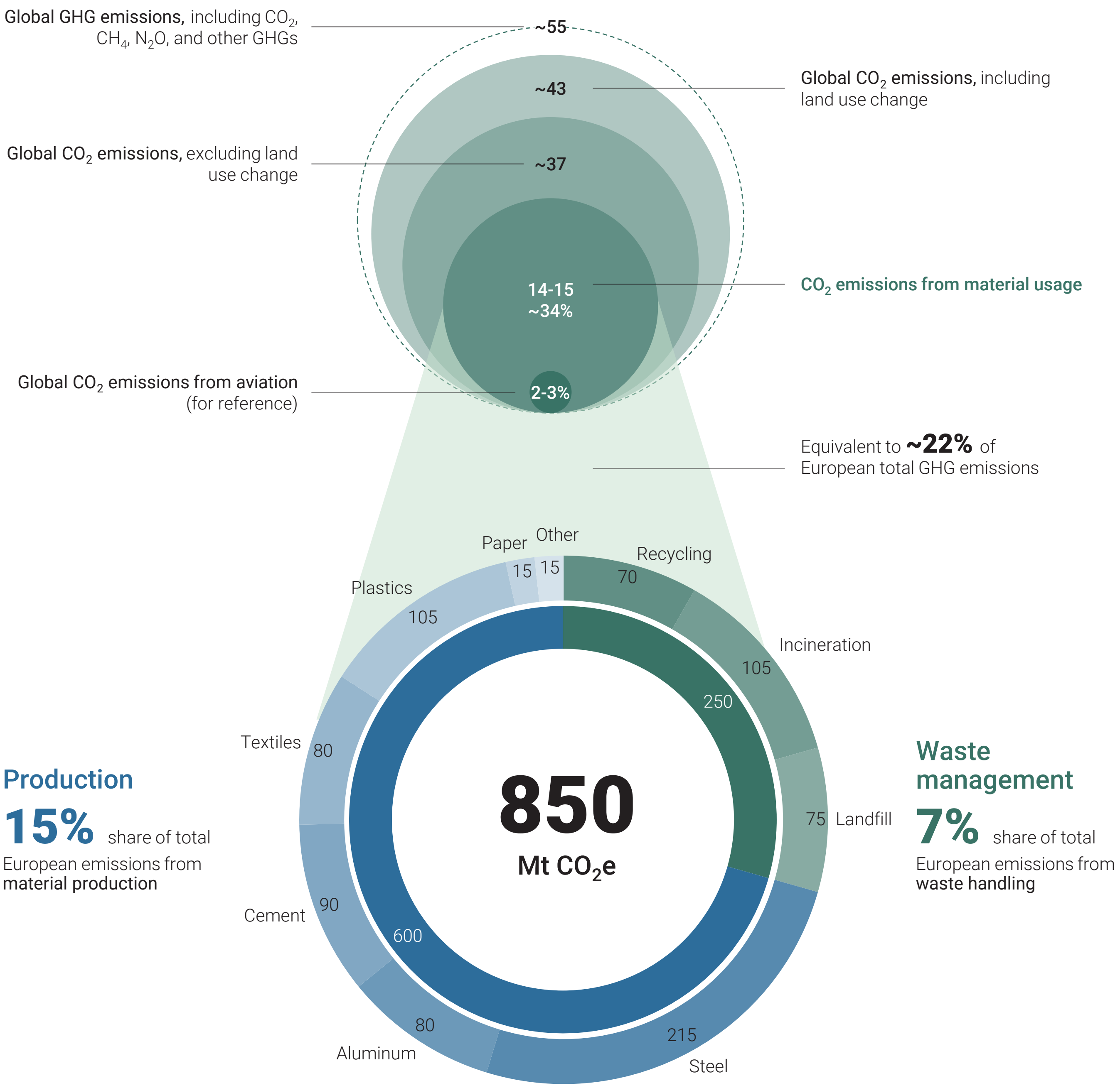
Finally, intensive resource use has many other negative consequences. Overall, the extraction and processing of natural resources account for more than 90% of global biodiversity loss and water stress impacts.[16] The chemical, cement, and steel sectors require the extraction of 680 Mt of primary limestone, coal, gas, oil, and iron ore.[17] Material use and food production also rely on the extraction of some 17 EJ of biomass via forestry and agriculture.[18] These two in turn are among the global top drivers of biodiversity loss. Reducing waste and improving the main associated uses of biomaterials—food, textiles, pulp and paper, and wood—could be significant contributors to reversing the trend of worsening biodiversity in Europe and globally (as these sectors, together with construction, are expected to account for 60% of the species abundance loss by 2050[19]). In fact, by some estimates, transitioning to circularity within these sectors holds one-third of the solution.[20] And of course, halting climate change is itself a major part of reducing biodiversity loss. Likewise, it would reduce pressure on freshwater resources, as some 53 Bt of water used to produce textiles and food is consumed in the EU.

The current patterns of resource use also challenge Europe's strategic autonomy. Europe is currently painfully feeling how concentrated fossil fuel dependency poses major economic and security risks. Similar dependency is now emerging for the critical raw materials that will underpin the new energy system. A more circular economy dilutes risk by making the most of the materials already available in the economy via productive use and recycling. Likewise, a circular economy can help with Europe's energy equation by mobilizing additional domestic energy from waste.

The above adds up to a powerful argument for change. There is potential for more productive use, reuse, recycling, and waste management. Implementing a circular material system often makes economic sense and can help address some of the most pressing societal challenges—from increased productivity to climate objectives, biodiversity, and strategic autonomy. The system is ready for change.

Exhibit 6:
Material accounts for around one-third of global CO_2 emissions

Global GHG emissions[1], 2019 (Gt)



1. Including production emissions generated outside EU27+UK for materials imported to and consumed within the EU27+UK

Source: Global emissions: UNEP Gap Report 2019, CICERO. European emissions: Summa Equity analysis building on multiple sources[21]

The critical decade: Circularity could scale massively in the 2020s

The material system is underpinned by large physical assets, entrenched by consumer norms, and bound in long-standing regulation. Changing it is a “wicked problem” as it requires multiple actors to work in sync while realigning well-established incentives. Yet the stage is set for change, and several forces are helping push the system toward a tipping point for circularity. If Europe chooses, the 2020s could become the pivotal decade in the transition toward a more circular economy.

2

Theory of Change: Six forces driving circularity in Europe

Moving to a circular economy is a "wicked problem" meaning that it is not easy to definitively solve (see Exhibit 7). Several actors need to work in sync and incentives need to be realigned to realize the full potential of circularity. There must be reliable demand for circular solutions (driven by consumers, consumer-facing brands, or regulation), new technologies must be developed and scaled rapidly, enabling infrastructure must be in place, policies and regulation must be rewritten to remove obstacles and tilt incentives away from linearity, and new types of collaborations across value chains must be established. For example, waste companies need to start collecting plastics separately, or sort them from mixed waste, to provide recyclers the feedstock they need, to in turn be able to supply the packaging and consumer goods industry with the material it needs to reach its recycled content targets.

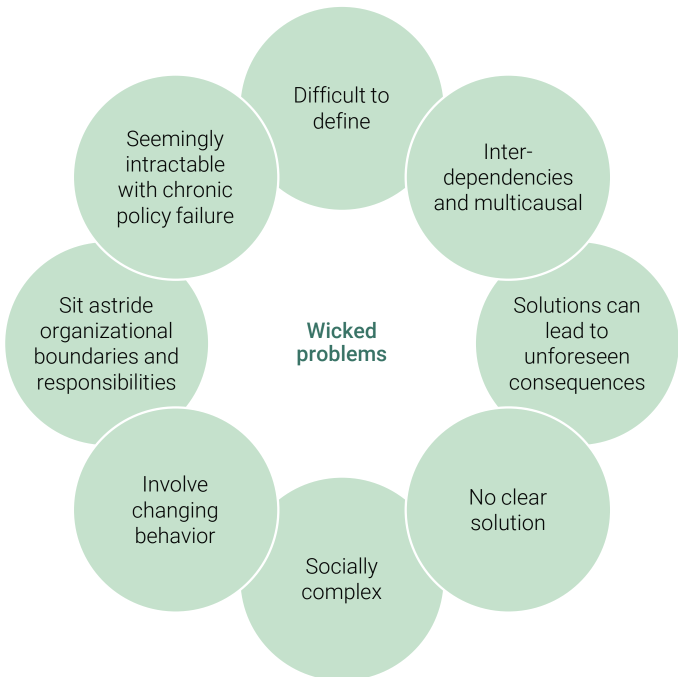
The transition is challenging—but the solutions are mostly here. It is tempting to think of large economic systems as slow-moving, not least when underpinned by large physical assets (material production) and entrenched consumer norms. Yet we have learned over the last decade that valuations in the energy system have shifted fundamentally as conviction was built around the renewables revolution; the same happened in automotive when the scale and speed of the shift to electric vehicles became clear.

The stage is now set for a similar revolution to take place in the material system. It will shift from recycling to reuse to waste management. From our conversations with market participants, we sense a whole new sentiment on the horizon. Several forces are at work within and around the material system, collaborating to create an inflection point in Europe's S-curve toward a more circular economy (Exhibit 8).

Exhibit 7:
Moving to circularity is a wicked problem

A ***wicked problem*** cannot be definitively resolved.

John C. Camillus,
Professor of Strategic Management,
University of Pittsburgh



Source: Camillus, John C., Harvard Business Review (May 2008). Strategy as a Wicked Problem

Exhibit 8:
Multiple forces are pushing the economy toward a circularity tipping point

6 driving forces

1. Policy and regulations

Strong push toward circularity in the EU, for carbon and import dependency reasons. Long range of policy packages, including

- Packaging and packaging waste directive
- Textiles strategy, food strategy
- Carbon Border Adjustment Mechanism and Emission Trading System
- EU Taxonomy for Sustainable Activities

4. Energy and supply security

- Recycled materials require significantly less energy than virgin production, i.e., up to 95% less for steel and 80% less for aluminum
- Recycled materials are locally available; lower geopolitical risk
- Residual waste can be a source of energy (heating, electricity), advanced fuels, and chemicals

2. Cost and CO_2

The business equation for shifting to recycled materials has greatly improved over the last 3-4 years due to

- High and volatile prices for many primary materials
- The increase of CO_2 prices from a EUR 20-30/t, to EUR 80-90/t

Circularity tipping point

From

- Substantial material overuse
- Limited product reuse
- Needless waste generation
- Low-quality recycling and incineration

To

- Efficient material use across the economy
- Material demand and waste generation limited by new reuse models
- High-quality sorting and recycling of materials

5. Technology advancement

Recycling technology is advancing at a fast pace for many materials, e.g.,

- Sorting technology for aluminum
- Reprocessing of textiles
- Digital tracing and marking

3. Value chain pressure

Cooperation between players in the value chain is increasingly important when solving for circularity and addressing the CO_2 targets committed to across sectors. For instance, Scope 3 emission reduction targets in

- Fast-moving consumer goods, 20-100% CO_2 reduction
- Automotive, 40-100% CO_2 reduction
- Construction, 20-50% CO_2 reduction

6. Digital circular business models

- At-scale reuse of durable consumer products, sharing services, and advanced waste prevention
- Digital platforms for reuse markets for clothing, electronics, etc.
- Digital solutions for sharing services such as car sharing
- AI-enabled waste prevention systems (e.g., for food waste)

Source: Summa equity analysis building on multiple sources[22]

1 Circular economy policy is creating tipping points for large markets

The EU is setting hugely ambitious circular targets and implementing policies in this area. Whereas the first Circular Economy Action Plan in 2018 set a direction, the current revision creates a serious platform for change. First, aggregate targets are being ratcheted up to a tipping point where entire systems need to change. Second, these targets will be implemented in the near term via specific sector targets, which are creating massive new markets.

One example is waste handling. The Landfill Directive now requires that landfill waste be limited to under 10% in the 2030s. At the same time, incineration is limited by CO_2 targets and charges (Box 3). The wider energy transition is also driving demand for sustainable energy and fuels, including targets for increased use of nonfossil fuels in aviation and shipping. Together, landfill phaseout, CO_2 reduction and pricing, and demand for sustainable fuels are requiring a fundamental rework of how waste is managed.

Specific sector strategies are also evolving (Exhibit 9), creating large new markets. Circular economy policy is taking a leaf from the climate policy playbook, setting quotas similar to those that have driven the massive scaling and technology development of renewable energy. One example is packaging, where the proposed Packaging and Packaging Waste Directive would require up to 30% recycled content in large packaging categories by 2030 (versus the 2023 level of barely any). This alone is likely set to create a EUR 10 to 15 billion market. Similarly, legislators are eyeing targets for recycled content in textiles (exact percentage to be decided), collection for recycling (61% for batteries), and food waste reduction (50%).

Box 3

Energy recovery: Why massive change is coming

In past decades, European countries have encouraged the incineration of waste as an alternative to landfill. As a result, there are now more than 500 energy recovery plants in Europe,[23] burning some 170 Mt of waste per year.[24] The share of waste handled is growing, having increased from 24% in 2010 to 26% in 2021,[25] with 50 new plants built.[26] The capital invested is significant, with a new-build capex of some EUR 200 billion.

Energy recovery has some advantages over landfilling waste. For example, it can neutralize toxic or hazardous waste, avoid methane emissions and other problems with landfill, concentrate valuable metals, and contribute electricity and heat. However, its critics also point out that the share of energy recovered often is low, that local air pollution can be a problem, that much of the waste that is burnt could have more valuable uses, and that incentives to burn waste can get in the way of recycling.

Moreover, like all combustion, energy recovery produces CO_2. By some estimates, the fossil CO_2 emissions are over 100 Mt per year.[27] European policymakers have woken up to this and recently decided that these emissions should be included in the emissions trading scheme. While these emissions continue, Europe has to find other ways to cut corresponding emissions, at a cost of some EUR 10 bn per year. Resolving these issues is now getting urgent. European policy is to phase out the landfill wholly. Several countries are turning to incineration as the immediate alternative, so the problem will only grow unless a different course is struck.

One strategy is to remove more waste from the fraction burnt, for example, through different treatments of biowaste and through additional sortation to extract plastics and metals. However, while this cuts volumes and CO_2 and enables greater circularity, it does not solve the underlying issue. Likewise, while carbon capture and storage can be viable for large plants near suitable storage facilities, it would be an extremely expensive solution for the more than 500 plants, many of which are small-scale.

Our analysis suggests that other solutions look more promising in the longer term. New technologies are rapidly under development: carbon capture and utilization, gasification of waste, biological conversion routes, and plasma-based technologies. Deploying these, waste can be a valuable source of biomass for SAF, shipping fuel, chemicals feedstock, or high-quality energy supply.

At that point, what today is “waste” will instead be valuable feedstock supporting Europe’s decarbonization and circular economy agenda.

Exhibit 9:
Major EU regulation is already in place and has accelerated in recent years

Category	Description	Selected examples	
Content quotas	Recycled content mandated in products necessitates both high collection and recycling rates and high-quality recycling to ensure usability in new products.	**65%** recycled content in plastic packaging from 2040 *EU Packaging and Packaging Waste Regulation (proposal)*	**85%** recycled lead content in batteries *EU Battery Regulation (proposal)*
CO_2 emissions, costs, and targets	In addition to the benefits of circularity legislation, the EU has enacted several GHG-specific measures to (partly) price in the externality of carbon emissions.	**EUR 97/t** maximum per t CO_2e emissions daily in 2022 *EU Emissions Trading System (ETS)*	**Net zero** target for EU CO_2e emissions by 2050 *EU Climate Law*
Product (design) regulation	Good product design facilitates the recovery and recycling of products and is a cornerstone of increasing the amount of circularity.	**100%** of packaging must be recyclable *EU Packaging and Packaging Waste Regulation (proposal)*	**85%** of materials (by weight) in new vehicles must be recyclable *End-of-Life Vehicles Directive*
Disclosure regulation	Disclosures can help consumers and business make more sustainable decisions. These can include company- or investment-level disclosures of the degree of entity sustainability, as well as informational labelling of individual products.	**50,000** companies in the EU will be covered by new corporate sustainability reporting requirements, with a subset starting in 2024 and 2025 *Corporate Sustainability Reporting Directive*	**100%** of packaging to be marked with a label containing information on its material composition in order to facilitate consumer sorting *EU Packaging and Packaging Waste Regulation (proposal)*
Import/ export regulation	In a globalized economy, imposing restrictions and costs on EU producers can lead to outsourcing of production or waste handling to geographies where regulations are less strict. Managing such dynamics is a key part of maintaining the efficacy of EU sustainability measures.	**6** product categories covered in the 1st phase of the Carbon Border Adjustment Mechnism (CBAM), "carbon tolls"	**33 Mt** of waste exported from the EU in 2020; proposed near-total ban on export of shipments destined for disposal including textiles *Waste shipment Regulation (proposal)*
Waste treatment and handling	Europe is transitioning from landfills to incineration to recycling, to increase the value extracted from waste. Limits and financial incentives are being launched to support this.	**<10%** of municipal waste may be sent to landfill by 2035–with a planned revision to possibly lower this target further	**EUR 400/t** increase to incinerate plastics under revised EU Emission Trading System[1]

1. Assuming an emission factor of ~3 at ~EUR 130/t

2 CO_2 regulation is evolving to strongly support recycled materials and shifts in waste management

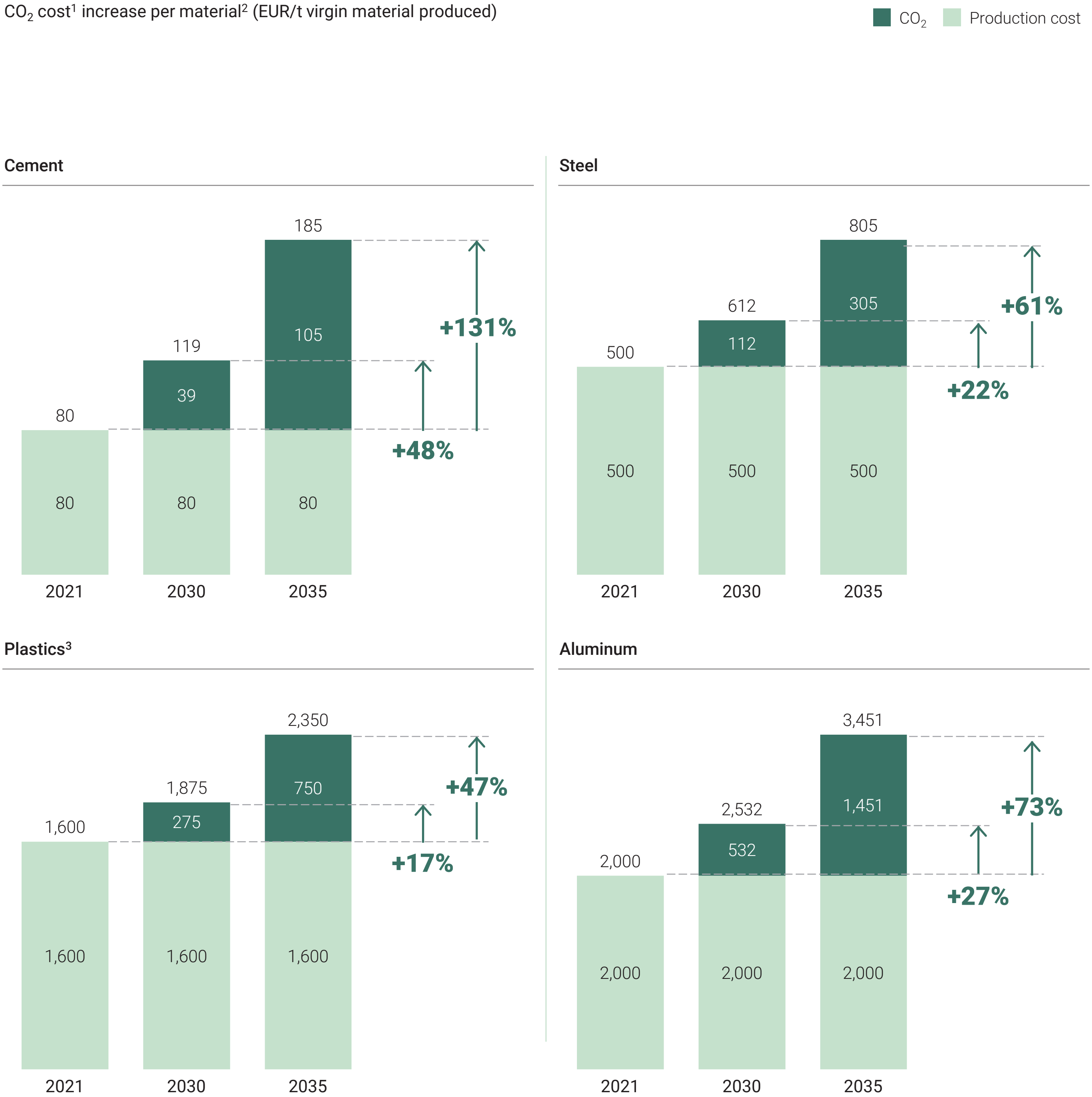
A massive change is also coming to material markets as Europe becomes the first region to see high CO_2 prices directly translated into commodity prices. Two forces are driving major changes in the business case for recycling and other circular economy business models. First, CO_2 prices have more than tripled from their 2015-2018 level of EUR 20/t to EUR 30/t, to a current level of EUR 75/t to EUR 90/t. We estimate it could reach between EUR 100/t to EUR 130/t by 2030.

Second, reforms including import tariffs (the EU's Carbon Border Adjustment Mechanism) mean that prices will directly feed through to product prices for steel, aluminum, fertilizer, cement, chemicals, and several other key materials, starting in 2026 (Exhibit 10). For plastics, for example, this will add around 30% to the life cycle cost, making recycled production a more viable option. Similarly, it will add 40% to the price of primary steel, and close to double the price of cement. For the first time in any region, the CO_2 advantage of recycled materials will thus become fully visible in commodity pricing.

Finally, waste incineration looks set to incur the same CO_2 charges. Much of the fossil CO_2 emissions from waste incineration arise from plastics, which emit around three tons of CO_2 for every ton of plastic burnt. This alone creates incentives of around EUR 300/t to EUR 400/t to divert plastics from incineration or manage the resulting CO_2 so that it is not released into the air.

Exhibit 10:
CO_2 prices will shift the fundamental economics of material markets by 2030

CO_2 cost[1] increase per material[2] (EUR/t virgin material produced)



CO_2 cost increase driven by CBAM[4] and phaseout of free allocations, -55% by 2030, -100% by 2035

1. Assuming CO_2 prices of EUR 80/t CO_2 today, EUR 100/t in 2030, and EUR 150/t in 2035
2. Assuming constant emission factors for materials
3. Based on ETS included for oil, plastic production itself not covered directly, including emissions from incineration of plastics (almost 3 t CO_2/t plastics)
4. Carbon Border Adjustment Mechanism

Source: Summa Equity analysis building on multiple sources[28]

3 Consumer and value chain pressures require a shift to circularity

The strong policy push is mirrored by the pressures created by large companies in major value chains, requiring a whole new level of performance from their supply chains.

One part of this is CO_2 targets, with leading companies in automotive, consumer goods, and construction now targeting net-zero supply chains (Exhibit 11). Analysis suggests only some of these targets can be met via available low-CO_2 steel, plastics, and other materials, which are emerging but will take time to grow to sufficient volumes—and which are still trading at a significant scarcity premium in the meantime. Circular materials, with their generally lower CO_2 footprint, will therefore be indispensable to meet these targets.

Likewise, direct recycled content targets are also having a major impact. The biggest consumer brands are setting ambitious targets for recycled metals, plastics, textiles, and more. For plastics and textiles especially, these require supply sources that do not exist today. This emerging demand is already driving real market impact. For example, recycled PET plastic was traded at a 40% premium on average over the same-quality virgin PET in 2021.

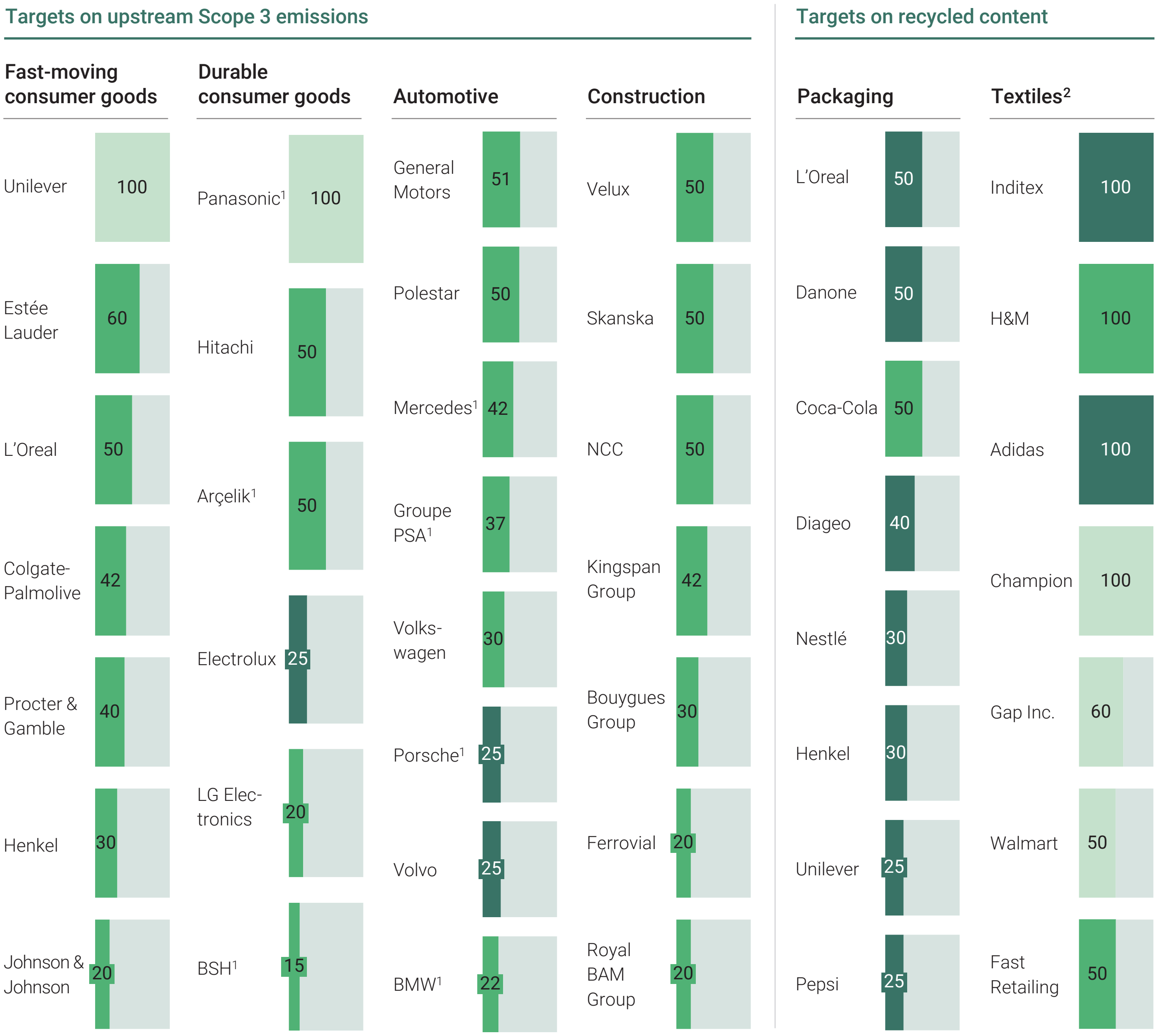
At its root, these commitments and premiums arise because consumers value sustainable products. There is little reason to think they will step away from these, as slightly more expensive materials only minimally impact end use prices. For example, our analysis suggests that even 80% decarbonization of a passenger car would only increase its price by some 0.7%, while using recycled polyester in a shirt would only increase the retail price by 1% to 5%.

Exhibit 11:
Companies across industries have committed to ambitious emission reduction targets

Commitments (percent)

2025 | 2030 | 2040 and beyond

Top players across value chains have set commitments to reduce emissions and increase recycled content in their products. Demand for low-emission and recycled materials has never been higher



1. Only includes emissions from product use
2. Some targets focus on polyester, while some include all fibers. Some targets aim at recycled or sustainably sourced (e.g., bio-based) materials

Source: Company websites, financial reports, and press releases

4 Europe needs to solve a new strategic resource equation

Supply security is already high on Europe's agenda for the 2020s.[29] Access to resources emerged as a key issue in the wake of the supply chain disruptions caused by the COVID-19 pandemic, and the conflict in Ukraine is now impacting trade.

Circular economy strategies can contribute to the solution. The EU's energy strategy response, REPowerEU, set a target of 35 billion cubic meters of biomethane production by 2030 to help offset the loss of natural gas imports.[30] Biowaste will be the crucial feedstock for this. More broadly, waste is a key near-term source of sustainable biomass, with at least 1.5 EJ of unexploited potential (two to three times Germany's total consumption of bioenergy today)—more than can be realistically achieved from other sustainable sources in the near term.[31] Valorizing biomass in residual waste and freeing up flows via improved recycling are thus both key components of the EU's energy strategy for the 2020s.

The concern around energy is now also influencing the EU agenda on raw materials—which are seen as "the new gas and oil" of a low-carbon and digital economy.[32] The European Commission has thus announced its intention for a Raw Materials Act "to ensure an adequate and diversified supply for Europe's digital economy as well as for the green transition—and prioritize reuse and recycling."[33] This priority already requires strict recycling targets for sensitive metals (for example, battery materials). In parallel, the availability of domestic EU circular resources is growing rapidly. For example, the amount of steel available for recycling is poised to grow from around 100 Mt per year today to some 130 Mt by 2040, while as noted above, large amounts of waste plastics remain unexploited as a source of hydrocarbon feedstock. By 2040, Europe could in theory largely drive its economy through end-of-life materials (Exhibit 12).

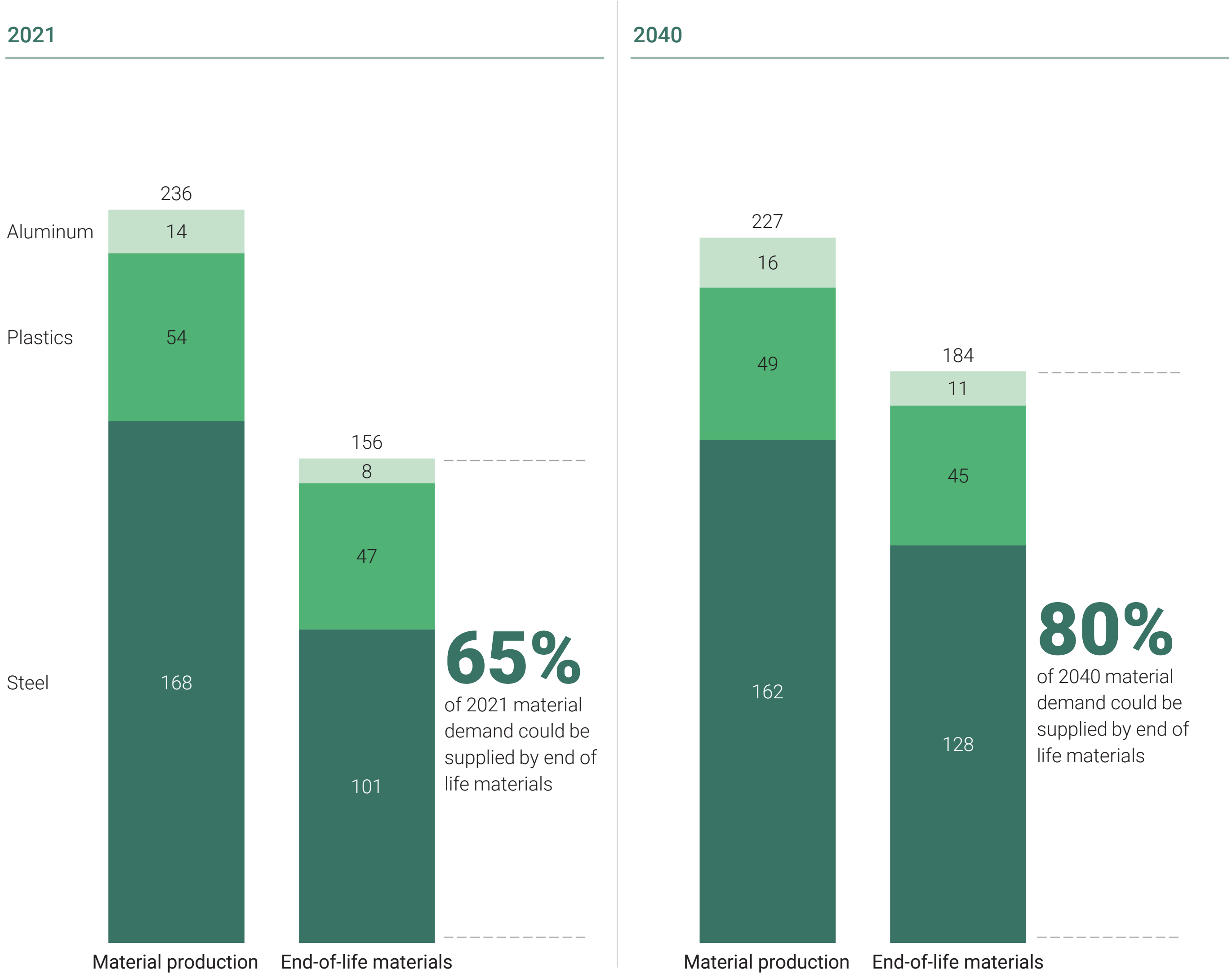
In response, steel, chemicals, and other industries are rebuilding their asset base with a major shift toward recycled feedstock. As much as 60 Mt of new steel capacity capable of being recycled has been announced in just the last three years (compared to around 100 Mt of current primary production).[34]

The European primary aluminum industry shrank by around 30% over the last 15 years as imports from China increased. This trend could be accelerated by the ongoing energy crisis, as aluminum is highly energy intensive. This would result in a net increase in emissions, as the carbon footprint per ton of primary aluminum produced in Europe is only about one-third of the average in China—the world's largest producer. Yet this trend can be turned around through recycling. The amount of aluminum available for recycling is growing fast and could in principle meet all forecasted growth in demand.[35] For context, bauxite—the ore used to produce aluminum—was recently classified as one of the EU's "critical minerals."

In sum, the circular economy is an effective way for the EU to structurally reduce resource needs, build a resilient supply chain, and effectively access new resources (the stock of materials, products, and energy already available in the economy).

Exhibit 12:
A future European economy could largely live off its end-of-life materials

Available end of life materials relative to production (Mt)



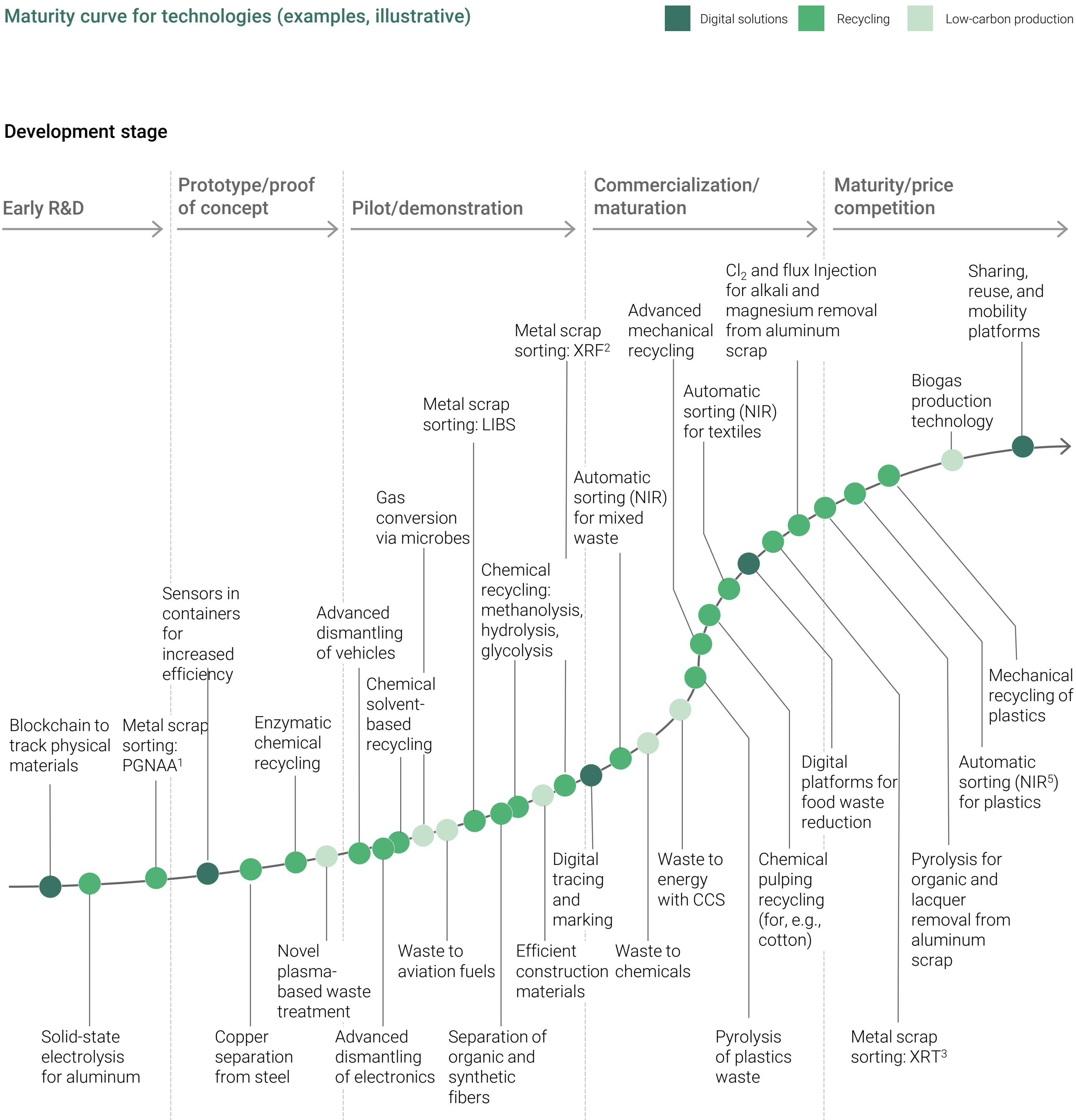
Source: Summa Equity analysis building on multiple sources[36]

5 Recycled material technologies and markets are maturing quickly

The increasing benefits of circular solutions are also attracting significant innovation resources because the circular economy is a new and burgeoning cleantech area. Both entrants and incumbents are racing to hone new technologies to meet the rising demand for high-quality recycled materials and circular business models.

The new cleantech agenda proposes novel solutions in a wide range of sectors and value chains (Exhibit 13). New reprocessing technologies offer the potential to turn large volumes of waste plastics and textiles into valuable raw materials—notably via chemical recycling. In metals, new approaches to purifying steel and aluminum are leaving the pilot stage, promising to make new waste flows available as feedstock. The new, circular raw materials supply chains will be underpinned by a boom in sensor, sorting, and automation technologies, from LIBS-based advanced metal sorting to new NIRS- and UV-VIS-based automated sorting for plastics, textiles, and mixed waste. Product reuse and sharing business models will be increasingly enabled by new digital platforms. Technologies are also emerging that enable the valorization of residual waste, including gasification and CCU technologies to turn waste into sustainable chemicals and fuels—offering a decarbonization pathway for hard-to-abate industries such as aviation. Much of this waste-as-feedstock technology is strongly synergistic with the ongoing advances in hydrogen production technology. This new circular technology innovation system is also creating a set of learning curves. The lesson from the climate technology space is that technologies can quietly improve outside the range of commercial applicability, only to prove enormously disruptive once they improve sufficiently and drop enough in price. Photovoltaics and lithium batteries have both followed this logic in their respective fields. Foreseeing the next disruption is always hard, but the odds are that new technologies will play a major role in reshaping supply chains. For example, chemical recycling for textiles could, with favorable emerging technology, even compete on cost with primary textile production (Exhibit 14).

Exhibit 13:
A wide range of circular technologies are ready to scale

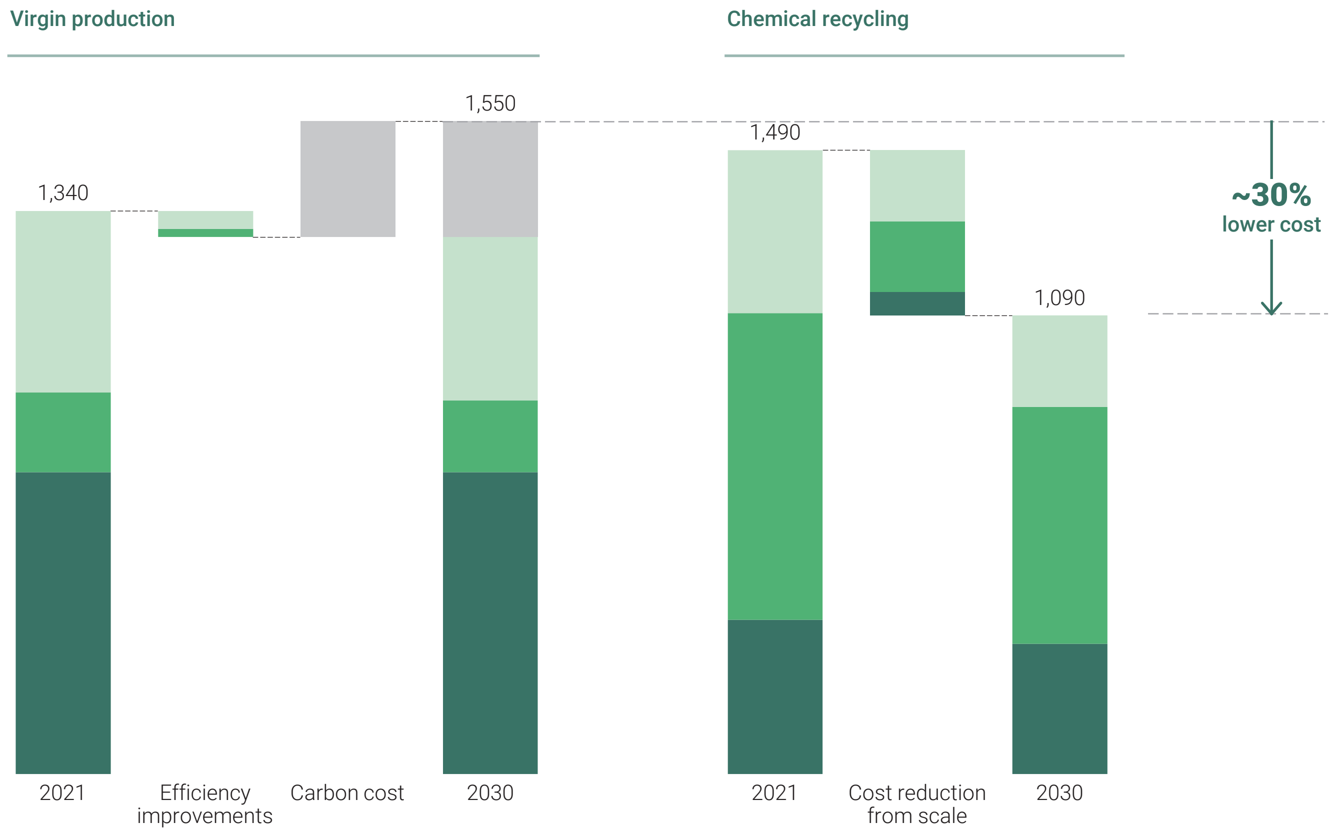


1. Prompt Gamma Neutron Activation Analysis
2. X-Ray Fluorescence
3. X-Ray Transmission

Source: Interviews with experts

Exhibit 14:
New circular solutions in textiles could rival current virgin production in performance

Polyester fiber production cost (EUR/t, indicative)



Cost drivers

Chemical recycling of polyester fiber has the potential to be **30% less expensive** than virgin production when done at scale, driven by cheaper feedstock and no CO_2 cost

Feedstock cost
Feedstock cost is the biggest difference between virgin production (~EUR 800/t PET) and chemical recycling (<EUR 400/t PET).

Operating costs
Expected to decrease significantly for chemical recycling when plant reaches large scale (250 kt p.a.)

Capex charge
Expected to decrease significantly for chemical recycling when plant reaches large scale (250 kt p.a.)

Carbon cost
CO_2 price expected to reach ~EUR 100/tCO_2. Emissions of 5 t CO2/t PET (including incineration). 55% of free allocations phased out

Source: Summa Equity estimates[37]

6 Digital circular business models enable reducing and reusing

In our current system, many products are poorly utilized—cars are stationary 92% of the time on average[38]—resulting in a system that requires a lot of resources for each useful service. Digital circular solutions can help increase utilization, extend product lifetimes, avoid overproduction, and thus reduce the total demand for resources.

Circular business models using new digital platforms and AI-enabled solutions have scaled rapidly over the last decade and are expected to see continued strong growth in the coming years (especially ride-hailing services such as Uber and Bolt). Examples of established circular business models include recommerce platforms for clothing and electronics, sharing platforms for mobility and housing, and apps selling close-to-expiry food. In addition to these businesses continuing to grow, their digital technologies and business models are being applied to other products and applications. There are several early-stage ventures in the field of reducing and reusing: recommerce of furniture, rental of apparel, AI-enabled food waste monitoring and prevention, and many more.

□ □ □

We see enough momentum behind all these forces to believe that change is nigh. This can be the decade that the European material system shifts to circularity if actors continue to move in the current direction. This will result in great improvements to both the European economy and our shared environment.

A circular scenario for 2040: Great change and opportunity

This chapter lays out an ambitious but realistic scenario for a circular transition for the EU. The scenario would require fundamental shifts in several major value chains—resulting in significant environmental benefits, massive expansions of the circular markets, and several promising investment opportunities. We estimate that the circular economy could cut 55% of all emissions from the material system by 2040, reduce water usage by 5 Bt, and improve the EU's resource autonomy. Furthermore, we estimate the size of the circular economy to be EUR 820 billion in revenues per year. In addition, the massive shifts from the circular transition could lead to several promising investment opportunities, including emerging recycling technologies, digital sharing, recommerce platforms, and increased valorization of residual waste.

3

A circular scenario for 2040

With so much at stake, investors and other stakeholders need something to guide them. In this section, we lay out an ambitious but realistic scenario for how Europe's circular economy transition could unfold (Exhibit 15 and 17) given the powerful trends and drivers we identified in the previous section. Our projected scenario sees a massive expansion of value across all four main circular economy strategies (Box 4 and Exhibit 16). Together, they amount to significant change for most European industries dealing with physical materials and products via a major shift from primary to secondary material production, new business models to reduce and reuse materials and products, and different end-of-life treatment practices (Exhibit 15). Circular economy markets could reach EUR 820 billion in annual revenues by 2040 and reduce CO_2e emissions by 650 Mt per year.

The scenario is meant to be ambitious but realistic. It builds on technologies already available or in development and shows a mostly incremental but clear evolution of trends. Together, however, they add up to a dramatically different system, with large new market potential, investments, and improvements in climate and biodiversity performance. Moreover, as we describe below, this is not just a 2040 story because many of the value shifts will take root prior to 2030. On the flip side, this scenario will not materialize automatically. As we discuss in the next chapter, it will require conducive policy support, business model innovation, intensive collaboration along the relevant value chains, and major investment in new infrastructure. Nonetheless, it paints a picture of an attractive future firmly in reach as Europe considers its options ahead.

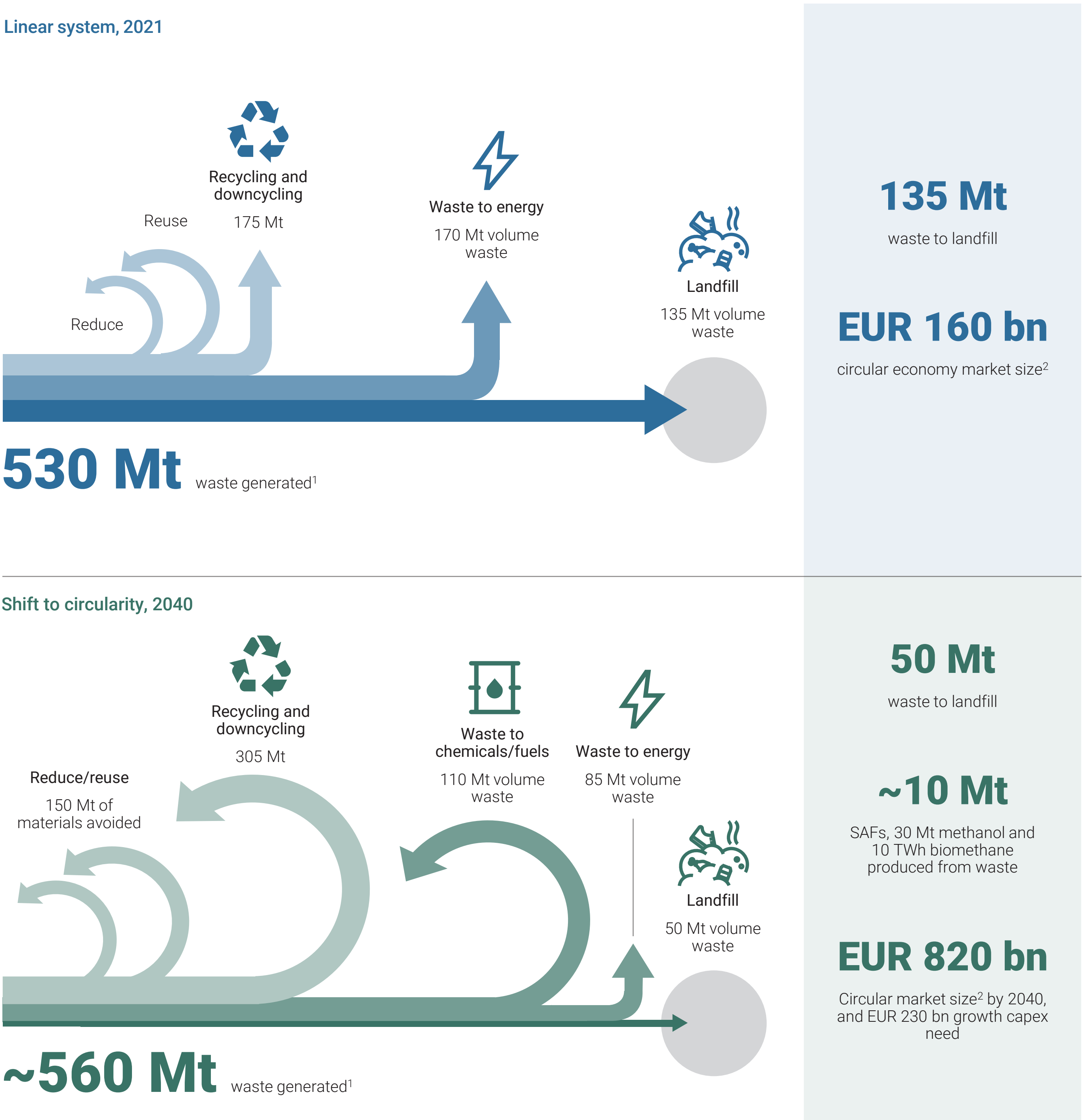
Concretely, whereas today some 230 Mt (39%) of flows are handled via circular economy solutions, by 2040 this will grow to 430 Mt. The linear practices—landfill/disposal and low-value-adding incineration[39]—will in turn shrink substantially, to just 20% to 25% of today's volumes. 150 Mt of materials and food production will be avoided through circular business models and increased material efficiency. The economic value is significant, as this often captures product values that far exceed the value of just the materials (for example, through recommerce of consumer durables). Recycling will grow from 215 Mt to 335 Mt, but this is only part of the story; as described below, the recycled materials will produce higher value, forming the backbone of Europe's industrial system. Finally, residual waste will remain a major feature, but only because its value will increase. Some 100 Mt of largely bio-based flows will be turned into valuable aviation fuel, basic chemicals, or CO_2 removal—while also providing valuable energy production directly (Exhibit 17).

Significantly improved environmental and resource outcomes. A major reason this scenario is both attractive and plausible is the significant contribution it makes to Europe's environmental and resource/raw materials agenda. Circular economy practices reduce material emissions by around 520 Mt of CO_2 versus a "frozen" baseline scenario where today's practices are used to feed tomorrow's economy (Exhibit 19, page 46). Most of the decrease is achieved by reducing the need for emissions-intensive primary material production (both within Europe and from imports) and by avoiding CO_2 emissions from waste incineration.

In addition to the GHG reductions within the material system, residual waste can be a large and sustainable source of biomass. Biomass is expected to be scarce (we predict supply-demand gap of 5 EJ to 8 EJ by 2050) but an important feedstock for several hard-to-abate sectors such as aviation and chemicals. Residual waste streams in this study's circular scenario could reduce 130 Mt of GHG in other sectors, by avoiding approximately 10 Mts of aviation fuels, almost 30 Mts of fossil methanol, and replacing some 10 TWh of natural gas by biomethane from biowaste—while at the same time avoiding the landfill emissions that biowaste otherwise generates (Exhibit 18, page 45).

Besides GHG, the circular transition also has other environmental benefits: water usage could be reduced by 5 Bt thanks to fewer virgin textiles (especially cotton) and reduced food consumption (as a result of lower food waste). Reduced food waste could furthermore help save 9 to 10 million hectares of agricultural land—an area bigger than Austria.[40]

Exhibit 15:
An ambitious but realistic European circular economy scenario for 2040



1. The 2021 components do not sum to 530 Mt due to exports (25 Mt), processing losses (10 Mt), anaerobic digestion (15 Mt) that is not shown; in 2040, exports and processing loss volumes (10 Mt) are excluded from the image
2. Circular economy defined as the market sizes (annual revenues) of circular business models, recycling, and waste to X

Note: Waste volumes include ferrous and nonferrous metals, plastics, textiles, biowaste (including food waste), cement, paper and cardboard, wood, rubber, and glass. The volumes exclude hazardous waste, moved earth, and aggregates

Source: Summa Equity circularity analysis

Box 4

A pragmatic definition of the circular economy for investors

Summa Equity grounds its approach to the circular economy in three basic observations:

1. Significant environmental, economic, strategic autonomy, and other benefits arise through reduced dependency on primary materials produced from newly extracted resources. This is what creates the pressure for change and where our focus as a society and as investors should lie.

2. The economic and social significance of materials and products is best understood by considering their contribution to essential services and human needs in the economy: thus, the steel in a car contributes to transportation; plastics in packaging contribute to protection or marketing of food, etc. By focusing on useful service, we can find genuine improvements in productivity and social benefits.

3. As long as the economy has significant waste flows, these must be managed, with radically different outcomes depending on how well this is done. A consistent story for waste therefore must be included.

This leads us to the four main circular economy strategies and associated business models. Together, they provide a comprehensive breakdown of the opportunity space (see also Exhibit 16):

A) Circular business models that increase the useful service produced by every product or structure made. This includes business models that avoid waste of products (such as food waste or destruction of unsold goods); "as a service" and other business models that enable more widespread sharing and thus intensive use of products created (more benefit at any one point in time); and, finally, business models that extend the lifetime of products and structures (reuse, repair, etc.).

B) Material efficiency strategies that reduce the amount of material needed to produce a given product or structure. This includes improved design, materials, and processes in construction and manufacturing that reduce yield losses, eliminate waste, and avoid overspecification.

C) Circular materials that replace new primary materials with recycled equivalents. These rely on several strategies, from design for recycling to advanced dismantling, sorting, aggregating, and standardizing. They also require novel reprocessing and recycling technologies. Far from just a volume game, genuine replacement of primary materials also requires a step-change in quality, avoiding downgrading as materials are reused or used as feedstock for new production.

D) Residual waste valorization to extract as much value and useful service as possible out of the remaining unavoidable, nonrecyclable waste. This ranges from the basics of avoiding negative impacts (such as emissions from landfilling) to increasing the value of reprocessing waste into energy, fuels, feedstock, or new materials.

Exhibit 16:
The circularity equation

Levers to increase circularity and reduce virgin materials without reducing value for the user

A. Circular business models | **B. Materials efficiency** | **C. Circular materials**

$$\frac{\text{Product or structure}}{\text{Useful service}} \times \frac{\text{Total material input}}{\text{Product or structure}} \times \frac{\text{Virgin materials}}{\text{Total material input}} = \frac{\text{Virgin materials}}{\text{Useful service}}$$

A. Circular business models

- Reduced unsold goods (e.g., reduced unsold food, fashion, via production on demand, improved demand forecast, etc.)
- Sharing business model with access replacing ownership (e.g., asset-as-a-service such as car sharing, fashion rental companies)—second-hand apparel market expected to reach ~25% of total circular business models market by 2040
- Improved maintenance (e.g., predictive maintenance)

B. Materials efficiency

- New product design to allow for lightweighting (e.g., shift shape of packaging)
- New production methods (e.g., prefabrication of building structures)
- Reduction of process scrap (e.g., by 3D printing or better stamping processes)
- Variation in size to match different user needs (e.g., not all cars will have 5 seats)
- Improved inventory (e.g., avoid overordering of ~15% of all building materials)
- Digital systems for waste production (e.g., food waste where 10 Mt to 20 Mt waste can be avoided)

C. Circular materials

Increased recycled content (e.g., plastics from 13% to 50-60%, textiles go from being almost completely linear (1% closed loop) to having ~50% virgin materials avoided by secondary materials)

- New product design to allow for increased use of materials recycling (i.e., changed product specification), e.g., change in plastic types
- Internal closed loop of production scrap, e.g., steel, aluminum
- Replace virgin materials with renewable/recyclable materials such as chemicals from recycled carbon, fiber-based packaging, etc.

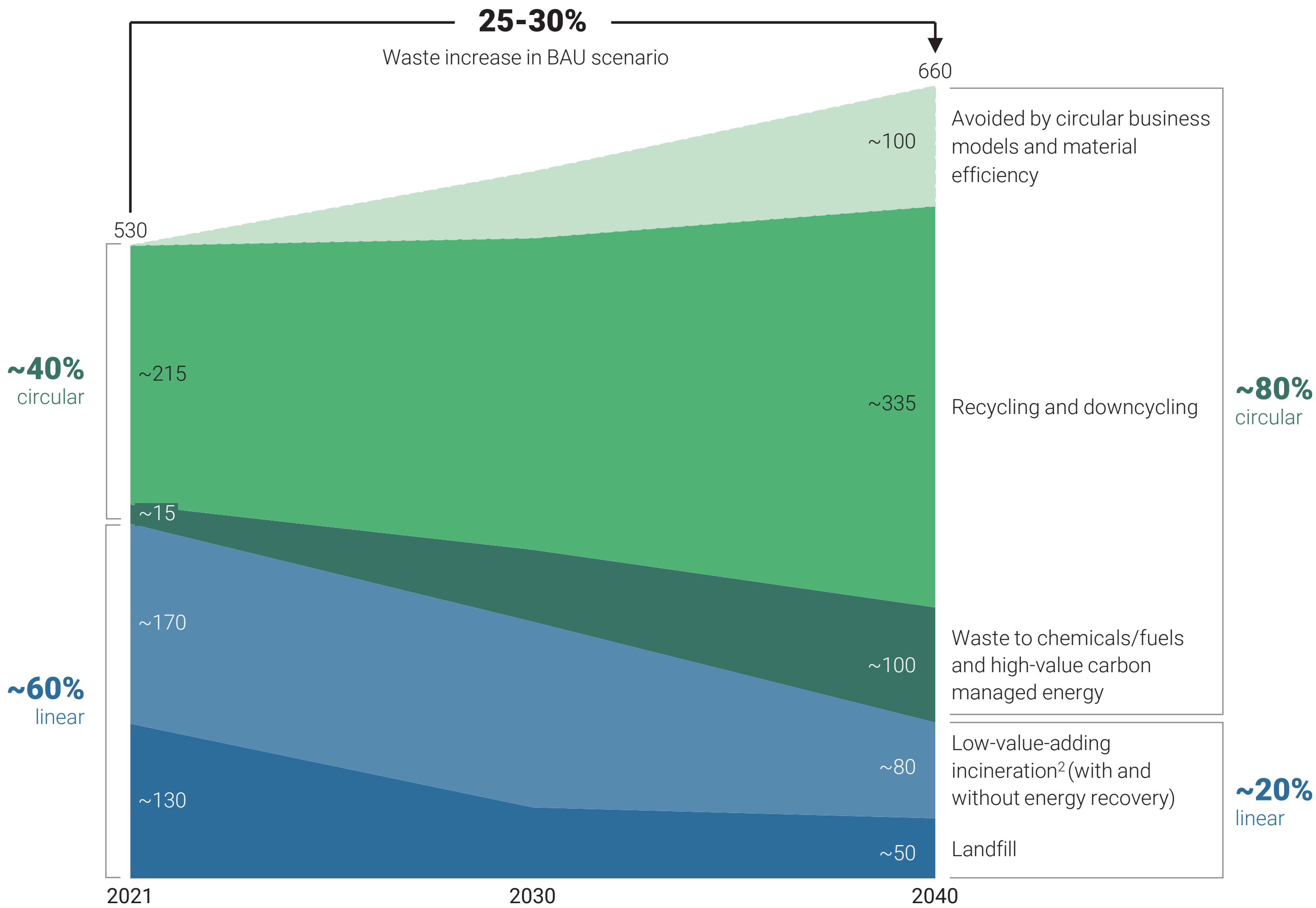
D. Approaches to handle the residual waste

- Emerging technologies (such as gasification of residual waste and CCUS implemented on waste incineration facilities) enable production of chemicals and fuels from residual waste (potential to produce 30 Mt of methanol and 10 Mt of SAFs), market reaching ~EUR 45 bn by 2040
- Produce biomethane from organic waste, ~10 TWh biomethane can be produced from only biowaste, market expected to grow ~10x from EUR 0.5 to EUR 5 bn
- High-efficient carbon-managed energy recovery can provide valuable heat and electricity services

Source: Adapted from Material Economics (2018)[41]

Exhibit 17:
A circular economy scenario for Europe by 2040

Development of end-of-life treatment in a circular scenario, EU27+UK (Mt[1])



~15% **waste avoided** through reduce and reuse initiatives
~100 Mt **waste avoided** through sharing platforms, product design for lightweighting, efficient construction, digital systems for waste reduction

From **~40% to 60%** of waste volumes are **collected for recycling** (including downcycling and exports of secondary material)
120 Mt increased recycling volumes by 2040, mainly driven by steel, and plastics
Plastics and textiles go from almost fully linear system (<12% and <1% closed-loop recycling, respectively) to **40 to 60% recycled content** in new production

From **~3% to ~20% of waste volumes** to other value recovery
Potential to produce **10 Mt SAFs, 30 Mt green methanol,** and **10 TWh** from biomethane

From **~30% to 15%** of waste volumes—a **reduction of ~90 Mt**

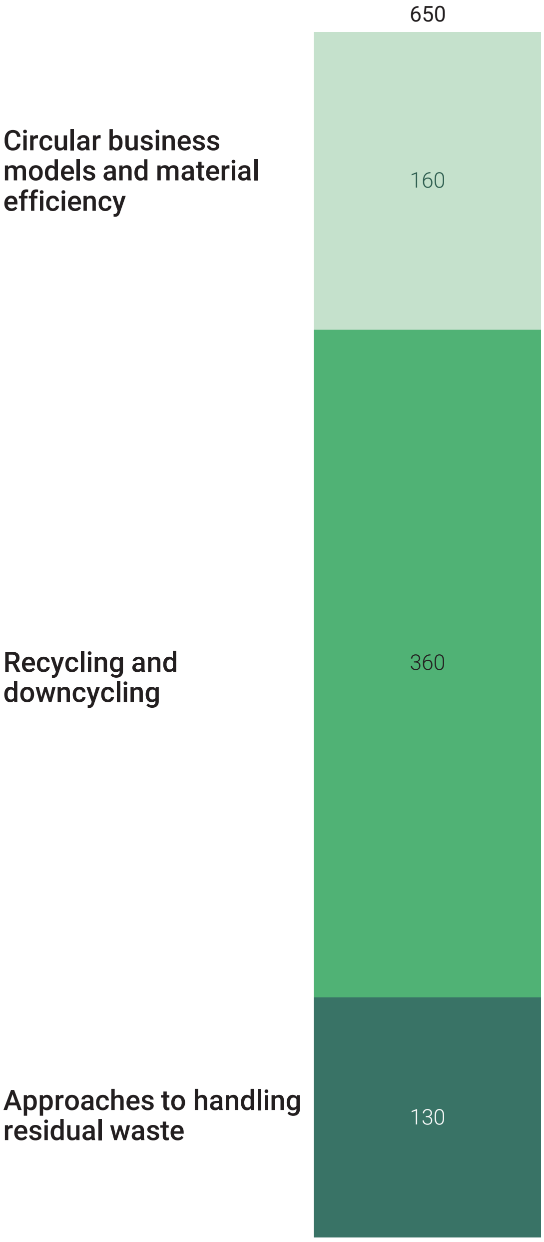
From **~25% to 10%** of waste volumes to landfill—a **reduction of ~80 Mt**

1. Not including hazardous waste, concrete aggregates, WEEE
2. We define low value-add as incineration with low conversion efficiency and/or resulting in substantial fossil CO_2 emissions

Source: Summa Equity circularity analysis

Exhibit 18: The circular economy can reduce CO_2e produced by 650 Mt by 2040

CO_2e emission savings from circularity (Mt CO_2e)



15%
reduction expected in total material demand, e.g., as a result of shared mobility and increased efficiency in buildings

15 Mt
plastics avoided through packaging material efficiency and reuse, increased car sharing, etc.

~140 Mt CO_2e
savings from increased steel recycling, from 63 Mt to 115 Mt recycled steel scrap, avoiding ~50 Mt of primary production

~110 Mt CO_2e
savings from increased plastics recycling, where recycling avoids both production and incineration emissions, together emitting ~5 t CO_2e/t plastics

10 Mt
of SAFs produced, replacing fossil jet fuels

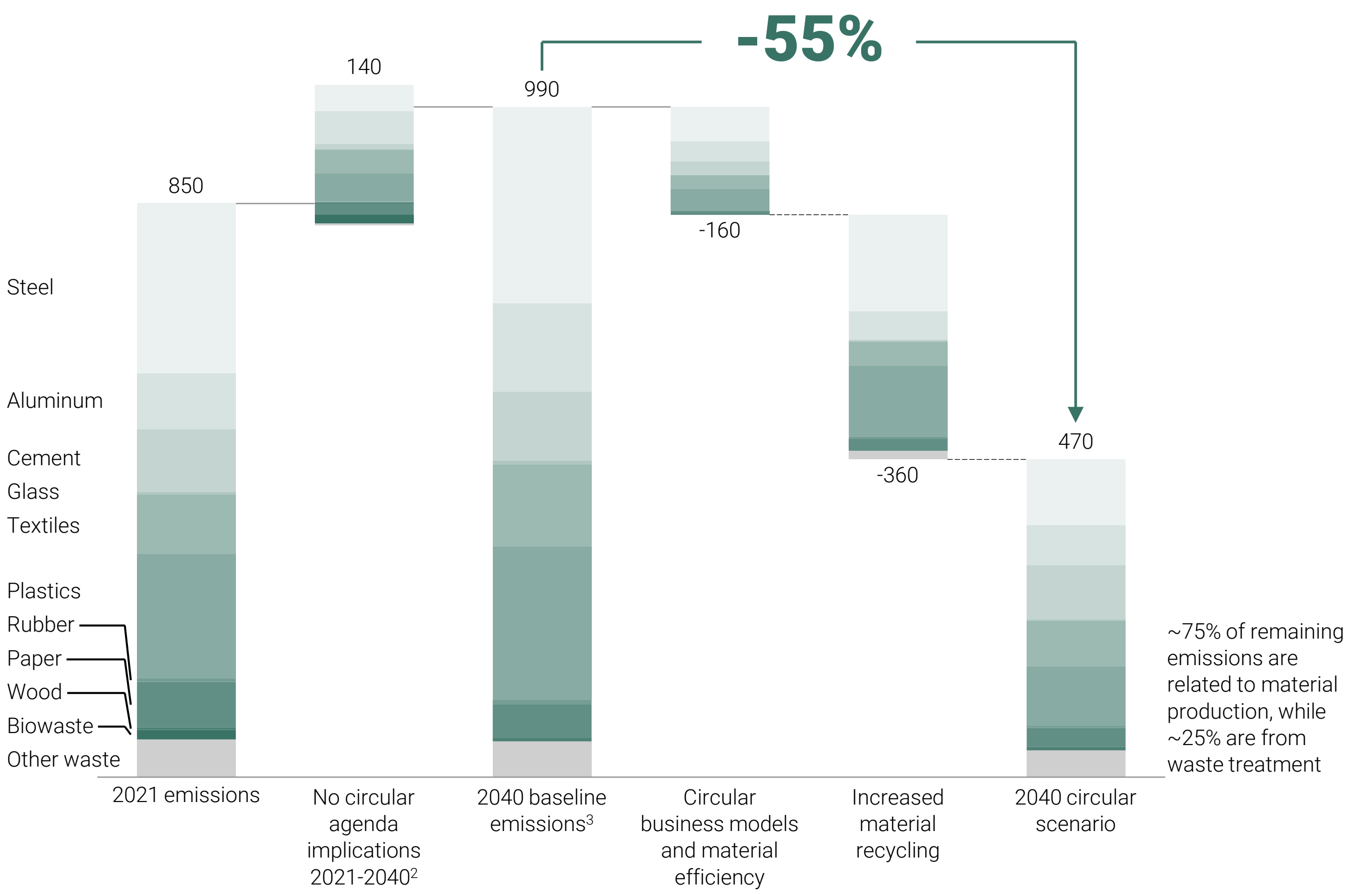
30 Mt
of biomethanol produced, replacing fossil methanol fuels

10 TWh
of biomethane, replacing natural gas and reducing food waste in landfills

Source: Summa Equity circularity analysis

Exhibit 19:
The circular economy can reduce materials emissions by 55% by 2040

European material system CO_2e emissions[1] development, 2021-2040 (Mt CO_2e)



~520 Mt

CO_2e emissions could be avoided by transitioning to a circular material system by 2040

~75%

of remaining emissions can be managed by the energy transition and low-carbon production routes (such as H-DRI-steel)

20 to 30%

remains hard to abate (mostly cement)

1. Covering production and end-of-life treatment emissions
2. EU's phaseout of landfill is included in the "no circular agenda" implications; volumes are reallocated to incineration instead, since the recycling capacity is not assumed to be built out (covered in "Increased material recycling"). Paper and biowaste together account for approximately -30 Mt CO_2e as landfill volumes are shifted to incineration, where methane emissions from landfill is avoided and as these fractions are biogenic, there are no increased emissions from the higher incineration share
3. Does not include energy mix improvements or industrial transformations with new technology (such as H-DRI steel)

Source: Summa Equity circularity analysis

End-of-life materials: A foundation for strategic resource autonomy in the EU

Looking at the parts of the EU economy that end-of-life materials could supply highlights the strategic importance of the circular transition. End-of-life materials could be the EU's new resource base, as shown in Exhibit 20. The 560 Mt of waste generated in 2040 could supply enough secondary steel and aluminum for the entire automotive production industry in the EU, provide enough recycled plastics for all of the EU's plastic packaging, and increase European textile production with 4 Mt recycled textiles—which could generate 30,000 to 60,000 new jobs.[42] Furthermore, this study's scenario assumes that around 75 Mt of bio-based residual waste will be equally distributed between production of SAFs and methanol, and that 23 t of biowaste will be upgraded to biomethane. This residual waste could be used to produce 30 Mt of biomethanol, 15 to 20 TWh of biomethane, and 10 Mt of SAFs—equal to 20% of the EU's total jet fuel consumption.[43]

Efficient use of end-of-life materials as a new resource base would also reduce the EU's import dependency significantly:

- **Petrochemicals.** Whereas today's sector uses almost 90 Mt of largely imported oil and gas feedstock, in the circular scenario some 30 Mt to 40 Mt of waste plastics will be mobilized for the production of new chemicals and plastics. Together with 30 Mt to 70 Mt bio-based feedstock,[44] including from waste and recycled CO_2, much of the fossil feedstock could be replaced.

- **Iron and steel.** Production will pivot from using some 250 Mt of largely imported iron ore and coal[45] to 115 Mt of end-of-life steel. This will make the transition of the remaining primary steel to hydrogen-based production more manageable.

- **Aluminum.** More than half of demand will be met through recycling, reversing the trend of the last 15 years where Europe has turned to highly carbon-intensive imported aluminum (Europe currently imports almost 7 Mt primary aluminum, up from approximately 3 Mt 20 years ago).

- **Bioenergy and bio feedstock.** The waste sector will provide Europe with another 1.5 EJ to 2.0 EJ of biomass resources, making it the single largest source of new biomass resources for materials, fuels, and energy. Getting the same amount of bioenergy would require 8 million hectares to 14 million hectares of agricultural land.[46]

All in all, circular flows will increasingly make up the backbone of the European material system and basic materials sectors. This will be complemented by 1) increased resource efficiency that will reduce the need for resources overall, and 2) clean electricity and hydrogen that will replace fossil fuels and feedstock to propel many of the core processes. For a resource-poor continent, this is a major opportunity.

Moreover, the increased resource efficiency and reuse of materials will make the overall energy transition more manageable. For example, the increase in recycling will save 150 TWh to 200 TWh of electricity that otherwise would be needed to produce hydrogen for decarbonized steel.[47] Likewise, the need to capture and manage around 140 Mt of CO_2 from end-of-life plastics could be avoided. All in all, a more circular economy will reduce pressure on other scarce resources, making Europe's net-zero transition more achievable.

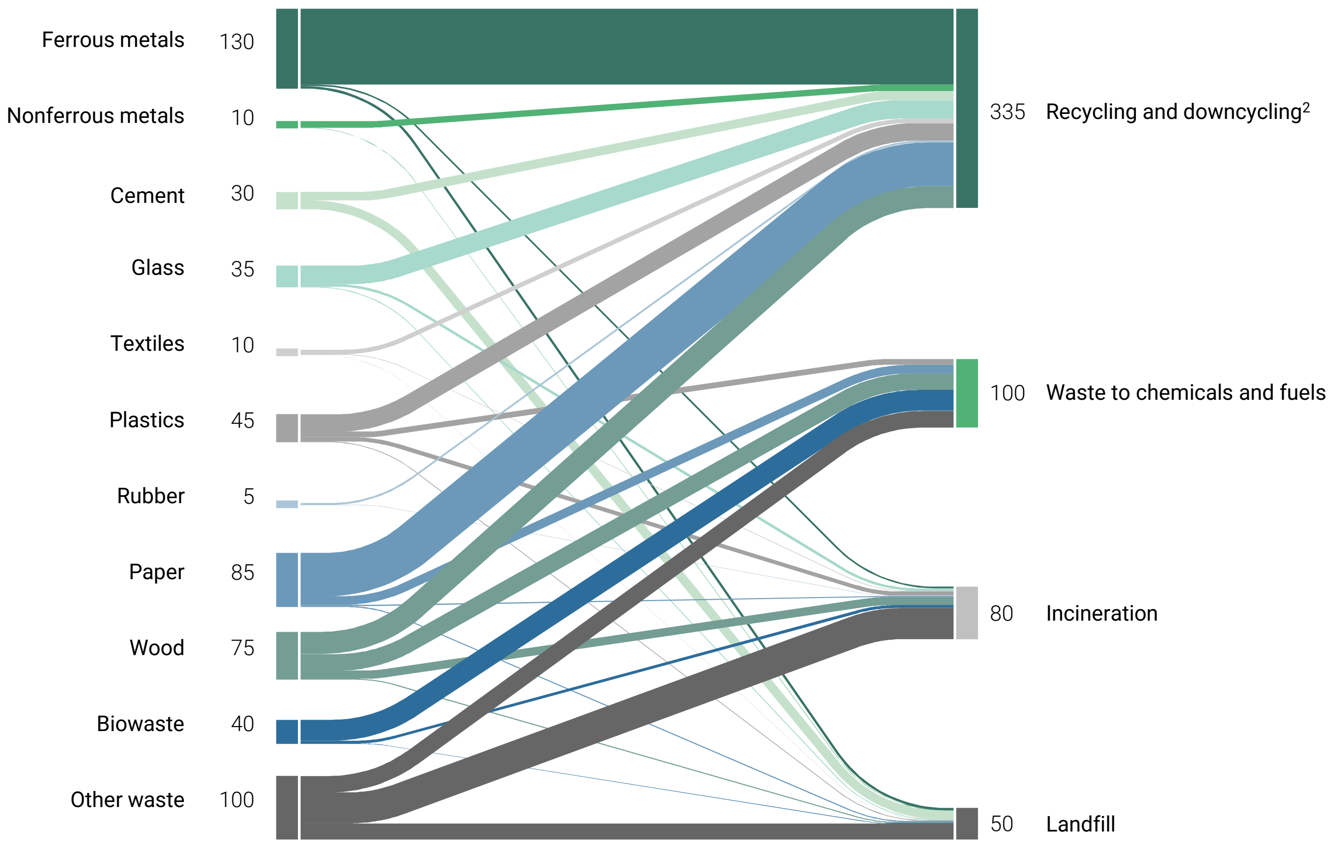
Wider economic benefits in jobs creation and consumer purchasing power. While all major transitions bring uncertainties, all indications are that the circular transition will reinforce efforts for high-skilled jobs rooted in local production systems. It will see Europe substitute resource-intensive primary materials imports and production for data-intensive business models, increased logistics, and in many cases more labor-intensive modes of value creation. Jobs will thus both be created in new businesses and value chains, and be reduced as some of the current, resource-intensive practices and patterns of consumption shrink.

Research suggests that the overall effect is one of net job creation (for example, an estimate found that the net effect of implementing the EU's Circular Economy Action Plan from 2015 would be a net increase of nearly 700 thousand jobs by 2030).[48]

There also is reason to think the circular transition can be net positive for consumer purchasing power. For example, circular business models often increase productivity to reduce the total cost of providing vital goods and services. For example, increased utilization of capital assets (as in the case of car sharing) or extended lifetimes of durables (as in the case of textile rental models) can reduce the total cost of ownership for consumers. Some estimates show that a full circular transition has the potential to result in significant cost savings for households: in an ambitious and visionary transition, annual mobility costs could be reduced by over 60% (mainly driven by shared mobility), food costs by 25 to 40% (from optimized system with less waste), and built environment costs by 25 to 35% (more durable, mixed-use buildings designed in modular ways).[49] Likewise, producing recycled steel, aluminum, glass, and paper will cost less than their carbon-intensive primary counterparts, while upgrading waste is among the cheapest ways to produce SAFs. Even where there are increased costs compared to today's products (for example, in textile or plastics recycling), the impact on end consumers will mostly be small. Thus a 25% green premium on recycled polyester (over primary polyester) would only increase the consumer price of a EUR 15 to EUR 20 dress by 1.4% to 1.6% at maintained profit to the brand.[50] The prices of other products like cars, housing, and packaged goods would also not need to increase by more than 1% to pay for the full added cost of low-CO_2 materials.[51]

Exhibit 20:
End-of-life materials: A foundation for strategic resource autonomy in the EU

560 Mt[1]
End-of-life materials generated, 2040



The recovered material has many uses

Recycling and downcycling[2]

>70+% of steel and **>60%** of aluminum demand–**more than enough to supply the EU's entire automotive production**

25 to 30 Mts of plastics–enough for all EU's plastic packaging

45% of textile demand–**more than doubling the European textile production**

Waste to chemicals and fuels

10 TWh of biomethane–identified as **key to replacing EU natural gas dependency**

30 Mt of biomethanol–enough to cover EU's total methanol demand

10 Mt of SAFs–**20% of total EU jet fuel demand**

1. Fraction figures do not sum to 560 due to rounding
2. Including exports and processing losses of 15 Mt, net recycled and downcycled volumes correspond to 320 Mt

Source: Summa Equity circularity analysis

Creation of a EUR 820 billion circular economy market

Large new markets and business opportunities will be created with the major reconfiguration of EU material value chains, consumer goods categories, and waste management. We estimate a current market size of EUR 160 billion in annual revenues, which will grow more than fourfold to EUR 820 billion by 2040 (Exhibit 21). All parts of the circular economy will expand, with the greatest growth in new circular business models capturing the large value of increased sharing, reuse, and refurbishment of consumer durables and capital-intensive goods. The details of the transition vary significantly between value chains (see Chapter 4 for more details). Specifically:

Scaling of circular business models for valuable consumer and business products. This scenario builds on the significant scaling in the last several years of new digital circular business models for valuable products with low wear and tear. Key segments include transportation, packaging, high-end fashion, IT and telecom equipment for consumers and businesses, and office furniture. More generally, new businesses will tap into the enormous scope for many product categories—from cars to electronics to fashion to industrial machinery—to circulate with longer lifetimes and higher utilization, including via new service-based business models. Lifetime improvements will also be made elsewhere in the economy, such as repurposing buildings instead of demolishing them. In this scenario, such circular business models could create revenues of EUR 265 billion by 2030 and EUR 450 billion by 2040, which would in turn represent some 15% of the physical consumer goods market by 2030.

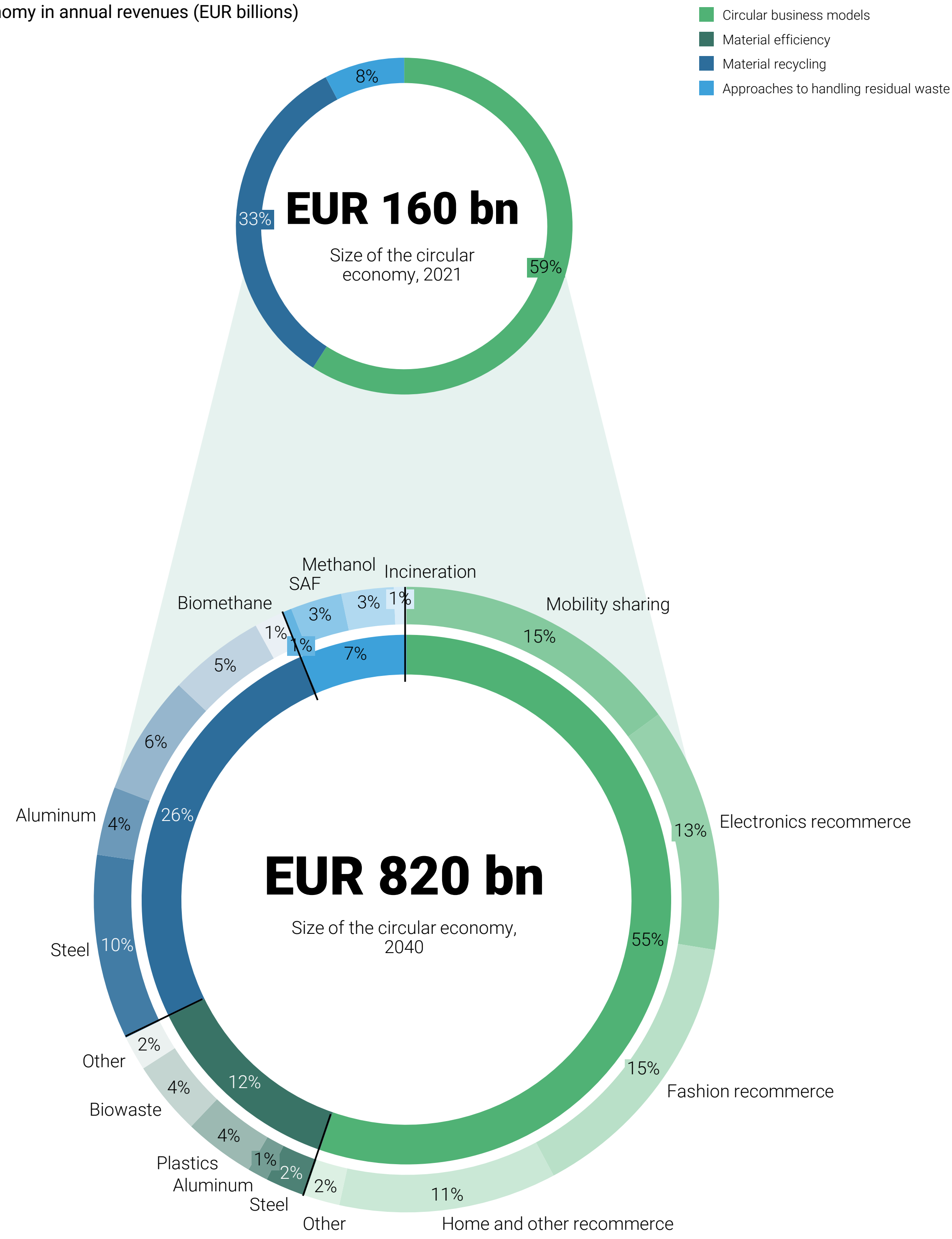
Material efficiency: Reducing waste and overproduction in food and industrial materials. The scenario also sees the deployment of a wide set of strategies to reduce structural overuse in materials and resources to produce the food, products, and structures required by the economy. These range from manufacturing via product-as-a-service models or additive manufacturing; to packaging via new delivery models; to construction via prefabrication, high-strength materials, and more sophisticated design; to food, where food worth more than EUR 130 billion is wasted each year. All told, some 150 Mt of material use can be avoided without compromising service. In the Nordics, for instance, Holdbart is an online retailer that helps wholesalers and retailers sell close-to-expiration food products.

Circular materials: Creation of a circular European materials backbone. No major material flows will be untouched as Europe turns to recycling as a major source of its future raw materials. Another estimated 130 Mt of waste will be diverted from landfilling and incineration, while changes to design, separation, and sorting will make for higher-value material recovery in metals, plastics, and more. In parallel, European chemicals, steel, and other industries will build out a new asset base centered around recycling for input, while key material flows such as plastics and textiles will be recycled at scale for the first time ever. For the waste management industry, this will mean more sophisticated waste sorting and reprocessing into materials that can compete with virgin materials and be turnedn into higher-value energy products such as aviation fuel. This material reprocessing industry could be worth EUR 210 billion to EUR 220 billion by 2040, compared to EUR 60 billion to EUR 70 billion today. This increase in value stems from higher recycled volumes and major growth in value as CO_2 is priced into material markets and as recycling produces higher-value products (Exhibit 22).

Approaches to handling residual waste: Turning residual waste into a valuable feedstock for hard-to-abate sectors. Residual waste will reach a tipping point where it can be transformed from a costly problem to a valuable feedstock. There are three trends that will create this opportunity: 1) residual waste will become increasingly bio-based as fossil-based materials such as plastics and textiles are removed from waste streams, 2) biomass will increase in value as it will become a scarce resource for industries such as the chemical sector, aviation, and niche energy applications, and 3) new emerging technologies (gasification, CCUS, efficient and carbon-managed energy recovery, and more) will use waste and emissions from waste treatment as bio-based feedstocks to create advanced fuels and chemicals, such as SAFs, methanol, and methane. This could substantially increase the valorization of residual waste, creating a market worth approximately EUR 60 billion by 2040, compared to EUR 12 billion today.

Exhibit 21:
The 2040 market size of the circular economy will grow to EUR 820 billion

Size of the circular economy in annual revenues (EUR billions)



Source: Summa Equity circularity analysis

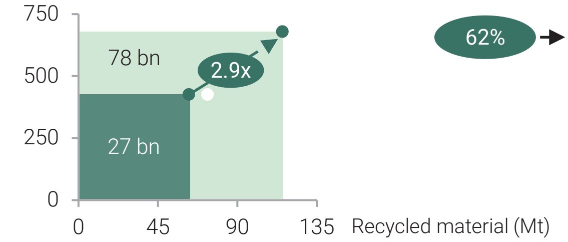
Exhibit 22:
A circular scenario sees massive growth in circular material value by 2040

Value of materials produced from recycled feedstock, EU27+UK (EUR billions)

2021 | 2040

Material recycling | Price of recycled material (EUR/t) | **Recycling rate**

Steel



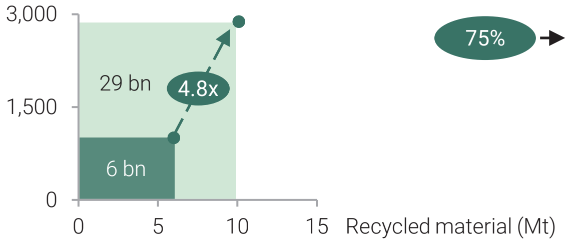
62% → 90%

Growing waste volumes (from 101 Mt today to 130 Mt 2040)

EAF capacity built out to handle all scrap volumes (today the EU exports ~20 Mt)

Price increase of primary steel (from carbon price) allowing a higher price for secondary materials as well

Aluminum



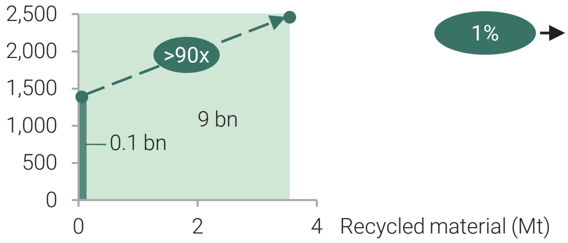
75% → 92%

Scrap volume increases by 100%

Improved sorting upgrades scrap to higher qualities and allows for higher prices (currently, large scrap volumes are trading at 50% of primary aluminum price)

Carbon price adds 50 to 80% of primary aluminum cost, making secondary aluminum even more attractive

Textiles

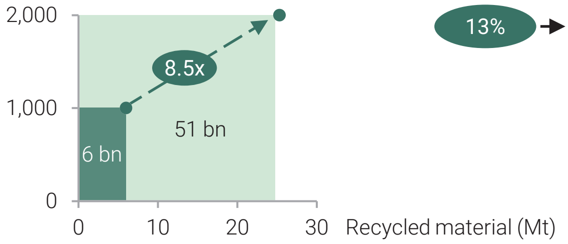


1% → 42%

An entire new value chain created, increasing collection from 35% to 80% and fiber-to-fiber recycling from <1% to ~40%

Chemical recycling enables virgin quality output, with strong possibility for a green premium

Plastics



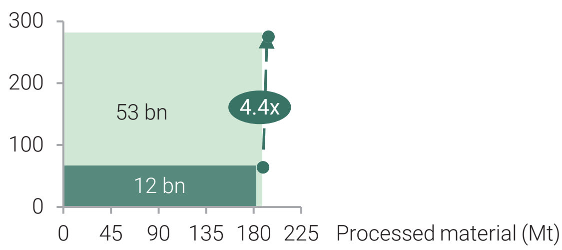
13% → 56%

Chemical recycling scaled to handle ~12 Mt plastics

Green price premium of 30% for recycled plastics vs. virgin price in 2021

Waste to X

Price of output per ton waste input[1] (EUR/ton)



Emerging technologies enable increased valorization of residual waste—from low-value-adding incineration[2] to being a large and sustainable feedstock for hard-to-abate sectors such as aviation and chemicals

1. Price per ton of endproduct (e.g., methanol or SAFs), divided by the number of tons of waste needed to produce one ton of the end product
2. We define low value-add as incineration with low conversion efficiency and/or resulting in substantial fossil CO_2 emissions

Source: Summa Equity circularity analysis

The circular economy as investment opportunity

The above scenario comes with major investment requirements. Summa Equity will lean in and invest heavily in this transition and encourages other companies to do the same.

The circular transition will create major new investment opportunities. The circular scenario involves large-scale investment in major new infrastructure. This is not a cost but rather an opportunity in a space set for disruptions; healthy returns on investments are achievable for a wide range of investors—venture capital can enable the scale-up of new circular technologies, private equity can roll up and professionalize existing value chains and emerging business models, and infrastructure funds can back the new major capital assets required.

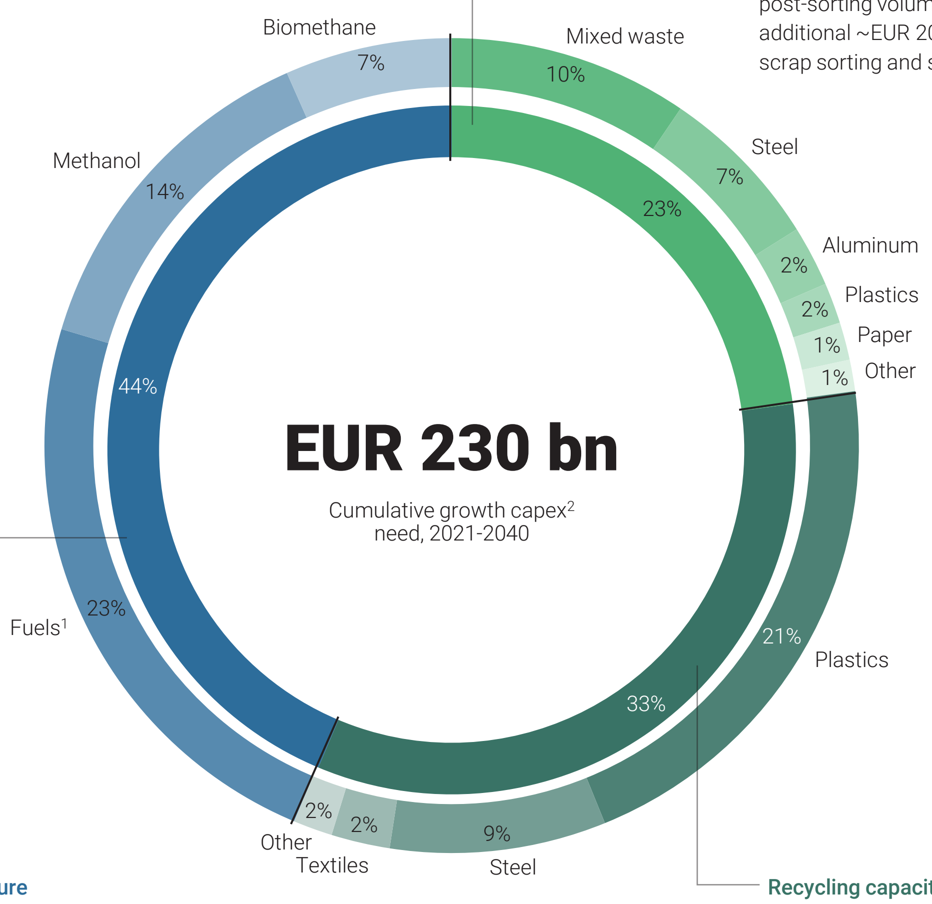
For the infrastructure portion, we estimate an investment need of around EUR 230 billion for physical assets (Exhibit 23). Almost half of this would go toward mobilizing waste as a major resource for the production of materials, fuels, and energy compatible with climate targets. The other half would go toward the new infrastructure of a more circular material system: more sophisticated collection and sortation, as well as higher industrial capacity for reprocessing end-of-life flows into valuable new materials in steel, chemicals, fiber, and more. Our work thus confirms previous findings of the circular economy as a major investment opportunity.[52] The investments can be categorized into three categories:

1. **Increased collection and sorting infrastructure and improved technologies.** As demand for recycled content rises, the demand for high-quality feedstock will grow as well. This in turn will require increasing and improving collection and sorting infrastructure and technologies. We estimate that investments of at least EUR 50 billion will be required to scale the infrastructure needed:
   - Automated sorting of recyclable materials such as plastics, paper, and aluminum from residual waste will require approximately EUR 20 billion to scale. The technology is largely in place, and the next step is large-scale deployment. A few facilities have already been built, such as Stockholm Exergi's Brista plant, but they will need further investment to work on a broader scale. Sorting out recyclable, often fossil-based, materials is also key to enabling further improvements to the systems.
   - Both plastics and textiles need massive expansion of the latest generation of sorting capabilities, which are capable of serving a wide range of emerging chemical recycling routes. Automated sorting technologies, like UV-VIS and NIR, are nascent—and joint initiatives are needed to rapidly deploy them to the first industrialized facilities, especially for textiles.
   - Ferrous and nonferrous metal scrap sorting and separation can meet increasing demand from recycling with investments of around EUR 20 billion. Emerging technologies and systems capable of alloy-level sorting of mixed aluminum scrap are now being deployed and are expected to scale across Europe. We believe prices will begin decreasing, which makes deployment key to kickstarting innovation.
   - In addition, collection infrastructure for several materials and products must be built out: this includes scaling deposit return schemes for plastics across Europe, mandating separate collection for both textiles and food waste with EU regulation, implementing reuse systems for bottles and other packaging, and creating take-back programs for apparel, electronics, and other durable consumer goods.

2. **Recycling capacity scaled across key materials.** To scale recycling capacity enough to meet targets and commitments across materials, investments of some EUR 80 billion are required. These can be grouped into three types of opportunities:
   - Mature technologies that need scaling and further refinement, as well as integration into joint circular and primary production systems. In many cases, such as metals, incumbent companies need to mobilize balance sheet financing. For steel, some EUR 20 billion is needed to build out another 50 Mt yearly capacity. It is important for the business case for the new joint recycling and H-DRI models to work. For aluminum, new remelting capacity linked to existing rolling mills is needed. For conventional mechanical recycling of plastics and textiles, far greater capacity and more advanced processing are necessary.
   - Emerging technologies are in need of massive capital injections to quickly build out new supply chains even as the technology matures, which is often driven by new companies that need the right capitalization. For example, chemical recycling technologies such as pyrolysis are reaching the end of their pilot and demonstration phases and now need several hundred kilotons of rollout. Reaching scale is expected to be key for competitiveness, so massive buildout is expected. At scale, costs can be on par or even below virgin

Exhibit 23:
A circular scenario sees massive growth in circular material value by 2040

Cumulative growth capex need by category, 2021-2040



Sorting infrastructure

Investments of ~EUR 50 bn in collection and sorting infrastructure

Largely driven by ~EUR 20 bn in mixed waste post-sorting capacity, increasing post-sorting volumes with ~45 Mt—an additional ~EUR 20 bn need in metal scrap sorting and separation

Waste-to-X infrastructure

Potential to turn residual waste into a valuable feedstock for hard-to-abate sectors such as aviation and chemical industry

Will require significant investments in gasification technology and CCU capabilities

Recycling capacity

EAF capacity increased from 63 Mt to 115 Mt steel scrap

Investments of EUR 50 bn to EUR 55 bn needed in mechanical and chemical recycling of plastics and textiles

1. Only biowaste-derived investments, not covering the total investment need for all biomethane production
2. Only including the capex need for buildout of additional capacity, excluding maintenance, retrofits, or plants being consolidated

Source: Summa Equity circularity analysis

production—which together with the premium for recycled plastics/textiles (recycled PET traded at 40% premium to virgin PET 2021) offers an interesting opportunity.

- Immature technology that needs de-risking via value chain collaboration and co-investment, continued venture capital, and public support to finance the technology development and piloting—and accelerate the route to market. Examples include solid-state electrolysis for aluminum remelting and novel chemical recycling technologies such as enzymatic recycling of PET.

3. **New technologies and infrastructure for residual waste treatment: A EUR 100 billion opportunity.** New technologies enable a step-change in valorization of residual waste—from landfill, incineration, or at best low-efficient energy recovery—to a valuable feedstock that can be turned into chemicals or advanced fuels such as SAFs. To make this a reality, an entirely new infrastructure around these new technologies is required:

- There is a large existing incineration infrastructure (some 600 incineration facilities in the EU), and investments in incineration are ongoing, partly due to the landfill phaseout. However, these investments might be at risk from the uncertain future of traditional incineration. To continue burning fossil waste is not only unsustainable but would also be increasingly costly when carbon costs from EU Emissions Trading System reaches full effect (this could add around EUR 400/t plastics incinerated by 2035). To put incineration in a more strategic position for the net-zero transition, the carbon emissions will need to be managed.

- However, when residual waste becomes increasingly bio-based—thanks to increased sorting of fossil recyclable materials like plastics, glass, and aluminum—some promising CCU investments will be enabled. These are already starting to happen but need offtakes or support today for the business case to work. The competitiveness of some CCU routes such as power-to-liquid SAFs or e-methanol production are dependent on cheap hydrogen, however—but, with hydrogen reaching below EUR 3/kg, the economics are in favor of the CCU route becoming one of the most cost-efficient ways to produce SAFs.

- Another example of interesting new technologies is gasification of waste to generate syngas, which can be further converted into chemicals and fuels; however, it is capital intensive and dependent on scale (we estimate a total investment need of up to EUR 50 billion to EUR 60 billion). However, at scale and with waste as a feedstock, it offers a cost-competitive route to both SAFs and chemicals such as methanol. There are ongoing projects, for example the Canadian gasification technology provider Enerkem's partnerships with Shell and Port of Rotterdam to produce SAFs from waste, and with Spanish Repsol and a waste company to produce methanol from waste.

- Upgrading biowaste to biomethane is a mature technology used at commercial scale, especially in the Nordics. Full rollout across the EU is the next step, which could require another EUR 15 billion in investments. Despite a short-term supply shortage and high prices from the energy crisis, the long-term perspective of waste-derived biomethane looks promising. As part of the initiative REPowerEU, the EU aims to produce 35 billion m^3 biomethane per year by 2030—a tenfold increase in demand, higher than what could be supplied only by biowaste (for example, food and garden waste). However, biowaste combined with wastewater and animal manure will be an important feedstock, as it is cheaper and more sustainable than many alternatives (such as dedicated energy crops).

The examples above are three of several interesting technologies in the field of residual waste treatment; others include emerging efficient low-carbon energy recovery, nutrient looping of food waste, and more.

The way forward: An agenda for change

The scenario outlined in the previous chapter offers an attractive vision for European businesses and society. While there is now real momentum behind the change, it is still far from assured that Europe will achieve the many benefits a more circular economy could bring, highlighting the need for an agenda for change. To start this conversation, Summa Equity has outlined several broad topics that European industry, policymakers, and investors should pursue.

4

Industry action

We have identified four themes for action across European industries (summarized in Exhibit 24):

1. **New supply chains and collaborations.** Circularity requires doing things differently. Instead of throwing away and burning plastic, it should be collected, aggregated, carefully sorted, and sent to the right reprocessing or recycling facility. This will require new supply chains and collaborations.

2. **New technologies and asset base.** Though some technology is already in place, more innovation is still needed. As previously outlined, we estimate that around EUR 230 billion need to be invested in new physical assets. A large part of this investment will be best handled by incumbent industrial leaders.

3. **Design and innovations for circularity.** Almost without exception, all industries need to improve their product (and sometimes process) design to enable circularity.

4. **New business models.** To be sustainable, the transition must also be profitable. This will require additional innovation in business models and established incumbents being open to experimenting and engaging with new ways of doing business, such as rental models or take-back programs.

Below we outline a way forward for each industry.

Basic materials industries

The competitive position on the cost curve for basic materials players has been closely linked to process expertise and efficiency, asset age and reinvestment needs, and access to integrated margins. Going forward, performance in the reprocessing of circular raw materials is set to become another major driver of competitive cost curve position and margins. In this chapter, we take a closer look at three major basic materials industries—steel, aluminum, and plastics—and outline their starting point and way forward.

Exhibit 24:
Four themes across which to drive the circular agenda

Industry	Why change is needed	New supply chains and collaborations	New technologies and asset base	Design and innovations for circularity	New business models
Steel	Recycling is at the heart of the massive sustainability transition. However, with increasing requirements and scale, the industry and its supply need to change.	Closed-loop partnerships to avoid scrap downgrading BMW, SALZGITTER AG Stahl und Technologie Consolidations and forward integration	Expansion of EAF capacity by ~50 Mt by 2040 H2 green steel		
Aluminum	Circularity offers the potential for a new foundation for the EU aluminum industry. However, major change is required to avoid mixed and downgraded scrap.	Sortation, separation, and upcycling Closed-loop partnerships to avoid scrap downgrading Volvo, Novelis	Remelting capacity linked to existing rolling mills Sortation technologies (LIBS, XRF, etc.) Hydro		
Plastic	After decades of efforts, only 13% of plastics are recycled. Regulation and brand commitments to recycled content is creating huge demand for recycled plastics that the industry needs to provide.	Cross-border feedstock aggregation agilyx Partnership between waste management and recycling tech companies EASTMAN interzero zero waste solutions	Scaling of mechanical recycling capacity Investment in new chemical recycling technologies (e.g., pyrolysis, hydrothermal treatment, solvolysis) Enablement of tracing and sorting through digital watermarks	Shift from hard-to-recycle plastics to recyclable options (e.g., PET, PP, PE, or new materials) Avoidance of multi-layered plastics	

Industry	Why change is needed	New supply chains and collaborations	New technologies and asset base	Design and innovations for circularity	New business models
Construction	Largest material user of all industries. Increased efficiency possible with improved building design and industry digitization.	Improved control of material flows at construction sites	Investment in innovative materials and recycling tech	Reduction of structural material overuse Build-to-last concept Industry standards for modularity and easier renovation	
Management of residual waste	Management of residual waste can turn from a costly, polluting, logistics-focused business into a provider of valuable feedstocks for hard-to-abate sectors. However, this will require entirely new assets and technologies.	Partnership with technology provider	Post-sorting at waste to energy plants Carbon capture capacity CCUS, gasification, emerging low-CO_2 tech, etc.		Taking on larger role as feedstock aggregator/provider Entry into bio-based markets (biochemicals, biofuels, etc.)
Fashion	Material system is almost entirely linear (<1% fiber-to-fiber recycling). Ambitious targets and regulations have been set. To reach them, an entirely new end-of-life value chain and infrastructure need to be built.	Closed-loop partnerships or offtake agreements between brands and recyclers Infrastructure for separate collection Feedstock aggregation	Chemical recycling (solvolysis, pulping, etc.) Automated sorting (NIR, VIS, etc.) Traceability/transparency tech (e.g., digital watermarks)	Pure fibers, easy to disassemble	Rental, refurbishments, resell
FMCG	To reach the industry's many ambitious targets will be challenging—and large changes are needed.	Industry-wide collaboration for end-of-life infrastructure Offtake agreements with recyclers	Traceability/transparency tech (e.g., digital watermarks)	Shift to easy-to-recycle packaging materials and away from multi-materials	Rollout of new delivery models, such as refillable/returnable packaging or package-free deliveries
Durables	Today, durables are typically used for one cycle—but this is changing. We see huge growth in resell, rental, and refurbishment markets.	Development take-back programs Industry-wide collaborations for collection	Traceability tech (e.g., digital watermarks)	Design for disassembly and repair	Rental, resell, and refurbishment of business models
Food production and retail	16-17% of food is wasted. The EU is committed to halving food waste per capita by 2030, yet limited progress has been made. The UK may provide inspiration.	Industry-wide collaboration on measures and targets (like WRAP in the UK) Infrastructure for separate collection	Digital solutions for food waste monitoring and reduction		Digital platforms or subscription models for, e.g., sales of imperfect or surplus food
Automotive	As EVs take off, vehicles' environmental impact will shift to the materials. Circularity is key to reaching the industry's targets but will require significant efforts.	Closed-loop partnerships between OEMs and materials recyclers Collaborations for refurbishing and reselling spare parts	Production technologies reducing scrap: additive manufacturing, laser cutting, etc.	Lightweighting, easy to dismantle	Car sharing, leasing, etc. Refurbishment/resell of spare parts

Source: Expert interviews and company websites

Steel

The European steel industry is undergoing massive change. To cut CO_2 emissions, around 30 projects have been announced to deploy new hydrogen-based steelmaking and/or build electric furnaces with 60 Mt of annual capacity per year.[53] This places recycling at the heart of the sector's net-zero transition. End-of-life steel will become a vital input to nearly all steelmaking. By mobilizing scrap, industry will be able to turn to carbon-neutral production faster and relieve an upcoming bottleneck in the supply of green hydrogen. The resources are available: Europe already exports 20 Mt of scrap that it cannot process, and the end-of-life steel available is set to grow by almost 30% over the next decades.

This means that steel recycling will need to change in multiple ways. It is already a major business, supplying some 63 Mt of materials to the EU industry with a value of EUR 25 billion to EUR 30 billion. However, with new, more demanding production turning to recycling and scale increasing, industry and supply chains will need to change. For companies in the steel value chain, three actions stand out:

1. **Build the new recycling capacity.** Approximately 50 Mt of new capacity to remelt steel will be needed in a future EU steel sector. As noted, this is now starting to happen, with around two dozen projects already announced. However, few of these projects have reached a final investment decision. Policy, steel companies, and customers need to put in place the conditions required to make this reality.

2. **Secure access to high-quality scrap via partnerships and vertical integration.** Our analysis is that there is enough scrap available for the EU transition, but high-quality scrap will become increasingly scarce. EU steel companies need to proactively build the new supply chain. Vertical integration is one option; for example, steel company ArcelorMittal recently acquired four steel recyclers, increasing recycling capacity by 1.4 Mt per year.[54] With consolidation underway, valuations of steel scrap companies have also increased sharply.

   Closed-loop partnerships involving manufacturers, steel producers, and recyclers are another key route. For example, BMW has, in addition to partnerships around low-carbon-produced steel, closed-loop agreements with Salzgitter AG and H2 Green Steel to send back steel scrap from production. Likewise, Salzgitter AG and Ørsted are arranging for Salzgitter to supply green steel to Ørsted's wind farms, while Ørsted supplies green power and steel scrap.

3. **Coordinate value chain efforts to avoid scrap downgrading.** There is a need to build out capacity to sort, track, separate, and make available high-quality scrap in tandem. Today, scrap is often needlessly downgraded as dismantling and handling results in contamination by copper and other elements. This is a long-term threat to steel circularity,[55] and addressing this will require a concerted push:

- Product design is one place to start; for example, Toyota recently replaced some of the copper wiring in its cars with aluminum, which does not adversely affect steel quality when recycled.
- Dismantling practices also need to change; the current practice of shredding mixed metal could be replaced with more disassembly.
- Scrap handling can be improved if scrap collectors and sorters use technology such as LIBS or XRF sorting and ensure best-practice material handling to satisfy growing demand.
- Finally, removal of impurities may be possible. One steel company we talked to is seeking patents on removing impurities from molten steel—a real breakthrough if it can be scaled commercially.

Exhibit 25/1: The steel industry is accelerating to run almost completely on secondary material by 2040

Current state

Highly emitting system

~170 Mt
yearly consumption

215 Mt CO_2e
emissions from steel production

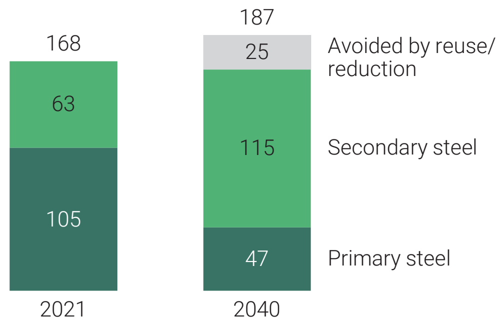
37%
recycled of total consumption[1]

20 Mt
scrap exported

Material system, 2021 and 2040

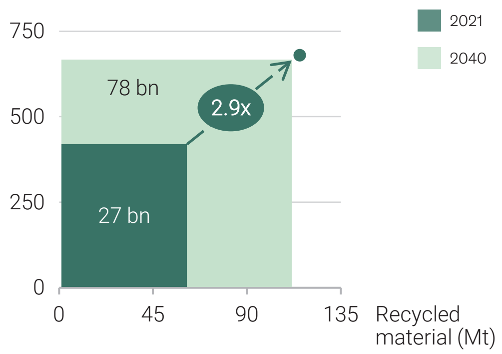
EU steel demand

Consumption in EU27+UK (Mt)



Market size for secondary steel

Price of recycled material (EUR/t)



Post-consumer scrap volumes increase by 100%

Improved sorting upgrades scrap to higher qualities and allows for higher prices

Carbon price adds 50-80% of primary aluminum cost, making secondary aluminum even more attractive

Impact of shifts

Close to fully circular system

25 Mt
avoided by reuse and reduction models

190 Mt CO_2e
saved compared to noncircular scenario 2040

78 bn
market size for recycled steel by 2040

20 bn
capex opportunity for recycling capacity increase

1. ~60% end-of-life waste volumes recycled

Source: Summa Equity circularity analysis

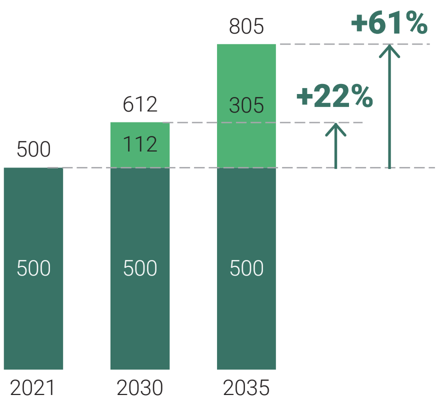
Exhibit 25/2:
The steel industry is accelerating to run almost completely on secondary material by 2040

3 shifts will drive the change toward circularity

CO_2 pricing and changing asset base

CO_2 cost increase of steel
(EUR/t virgin material produced)

CO_2
Production



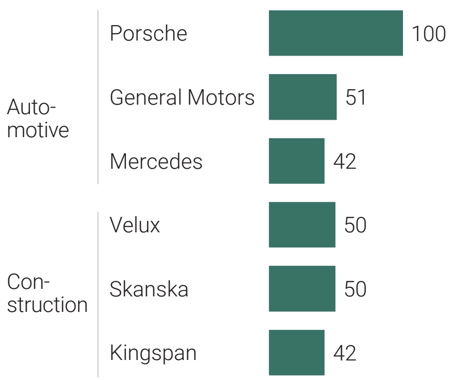
Decarbonization regulations and carbon pricing regimes (EU ETS Phase IV and CBAM) will increase primary steel price with EUR 250-300/t (+60-70%) compared to virgin steel today

Shift to electric furnaces enables industry to run on larger volumes of scrap, ~80% of emissions per ton of steel avoided

61 Mt electric furnace capacity announced in Europe to be online by 2032

Demand for low-CO_2 steel with recycling as cheapest lever

Scope 3 emission reduction target by 2030 (percent)



Commitment from major players in largest steel-consuming industries to reduce CO_2 emissions with 50-100% and ~75% of cars made globally are by car manufacturers by Scope 3 targets

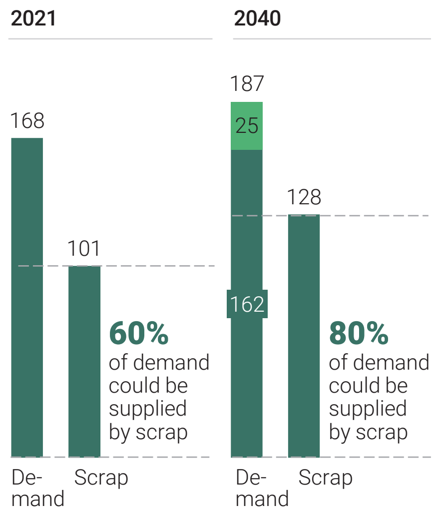
Recycling is cheapest and quickest way to reduce emissions from steelmaking

Both automotive and construction sector are setting increasingly ambitious targets–together, these sectors represent over 50% of all EU steel demand

Amount of available scrap increasing

Available end-of-life materials relative to production (Mt)

Avoided through circular business models and material efficiency[1]



European scrap availability will grow from 101 Mt to 128 Mt by 2040

Today Europe exports 20 Mt of steel scrap each year–re-routing these volumes to the domestic market would increase Europe's level of self-sufficiency

1. E.g., car sharing, reducing material overspecification in construction, material-efficient production processes (additive manufacturing, laser cutting, etc.)

Source: Summa Equity circularity analysis

Aluminum

Circularity offers the potential for a new foundation of the EU aluminum industry. The current trend is one of closures of primary production and increased import dependency: around 30% of European primary production capacity has been lost since 2008, 45% to 50% of aluminum is imported, and there is risk of further closures caused by the energy crisis.[56] At the same time, there is an opportunity to reverse the trend. Aluminum scrap availability is growing, so recycled metal could supply around 60% to 70% of the need in Europe (versus only 5% to 40% today). Not only would this diversify the European industry's access to metal and overcome European energy disadvantages, but the CO_2 gains of recycling aluminum are enormous. Aluminum imported to Europe is almost 20 times as emissions intensive as recycled metal.[57] All in all, circularity can serve as a foundation for the future European industry.

To build the future sector on recycling, a major course correction is needed. To date, end-of-life scrap has been mixed and downgraded to the point where it can be used only for a small share of the market (cast products), but not for the majority of applications that need rolled or extruded products. This system is already starting to break down, leaving Europe unable to recycle its own scrap and forcing it to export—often with a large discount on primary metal—instead. The task at hand is to fix this for a circular system to be possible. Three tasks stand out:

1. **Develop and deploy significant new sorting and remelting infrastructure.** Aluminum scrap processing is changing fundamentally due to new technologies for sorting, separation, and upcycling. The incentive to upgrade mixed scrap streams to higher qualities (for example upgrading Zorba to separate alloys) will increase, and we expect around EUR 5 billion will be needed over the next two decades to develop and scale new sorting systems. Scrap processing will therefore become significantly more capital intensive, and new financing and business models may well be needed. Vertical integration offers one way to achieve this. For example, Norsk Hydro has significantly expanded its own recycling capacity. Consolidation could further enable this more capital-intensive processing.

2. **Create new value chain partnerships.** Like the steel industry, closed-loop partnerships between manufacturers and aluminum players can also ensure availability of scrap volumes in the right qualities. One example is the partnership between Novelis and Volvo Cars, which gives manufacturers access to lower-cost and lower-carbon materials while aluminum recyclers receive clean scrap with known specifications. Such partnerships are now spreading in automotive but also have potential in other industries, for example the cable industry—avoiding the need for sorting by closing loops by design.

3. **Steer materials choice, design, and dismantling to circular principles.** A perpetual question is how to reduce the number of alloys by switching to functional rather than chemical specifications. Relatedly, "recycling friendly" alloys need to be further adopted. Recycling could also increase further by considering more fundamental changes to product design, such as constructing aluminum cans from a single alloy instead of mixing two different types together as is done today. Dismantling of products will also need to change. Perhaps the most pressing need is in vehicles, where current shredders are optimized for extracting steel but not for recycling aluminum in a high-value way. Taking these types of steps requires extensive collaboration between beverage companies, can manufacturers, and can sheet providers; between automotive manufacturers, metal recyclers, and car recyclers; and between manufacturer users of aluminum and aluminum companies; etc.

Exhibit 26/1:
The market for secondary aluminum will increase fivefold, and emissions decrease by 70 Mt CO_2e

Current state

Import-dependent and polluting system

14 Mt
yearly consumption

80 Mt CO_2e
emissions from aluminum production

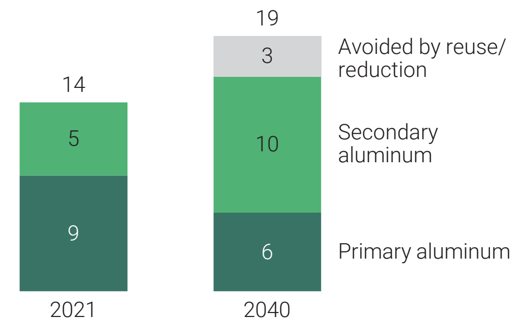
7 Mt
Net import of primary aluminum

~2 Mt
potential oversupply of low-quality scrap in BAU case

Material system, 2021 and 2040

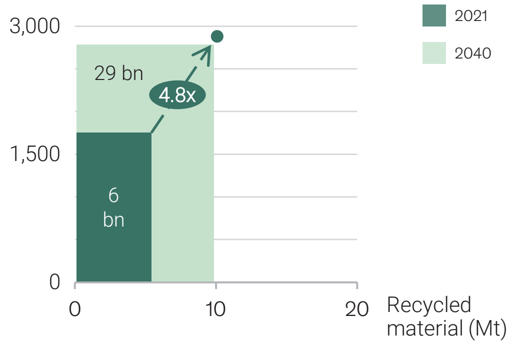
EU aluminum demand

Consumption in EU27+UK (Mt)



Market size for secondary aluminum

Price of recycled material (EUR/t)



Post-consumer scrap volumes increase by 100%

Improved sorting upgrades scrap to higher qualities and allows for higher prices

Carbon price adds 50-80% of primary aluminum cost, making secondary aluminum even more attractive

Impact of shifts

Large European circular industry

70 Mt CO_2e
saved by circularity

~92%
of waste recycled

63%
recycled content

29 bn
market size for secondary aluminum 2040

5-8 Mt
net import avoided by circularity

1. Decrease in attributed volumes of materials extracted globally–including fossil fuels, biomass, and metallic and non-metallic minerals–to final demand of EU countries

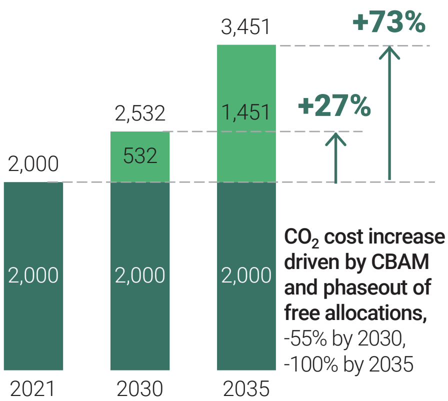
Source: Summa Equity circularity analysis

Exhibit 26/2: The market for secondary aluminum will increase fivefold, and emissions decrease by 70 Mt CO_2e

3 shifts will drive the change toward circularity

Carbon prices add significant cost on primary aluminum

Production cost of primary aluminum (EUR/t virgin material produced)



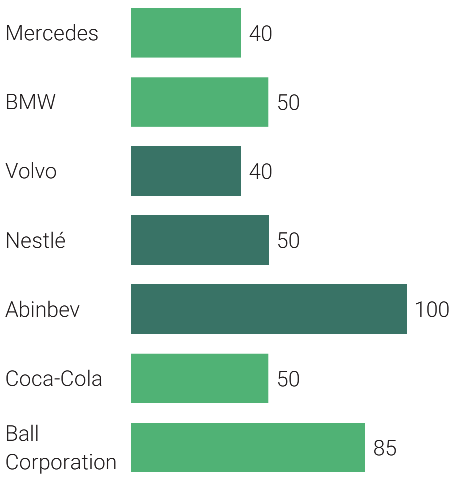
EU Emissions Trading System and other regulations will increase incentives for secondary aluminum production

EU ETS/CBAM can increase cost of primary aluminum by EUR 500-1500/t

EU Taxonomy on Circularity (2022 proposal) targets 25% recycled content and 70% recycled packaging by 2030

Key customer segments set increasingly ambitious targets

Recycled content targets (percent)



Large packaging producers and consumers are targeting 50-100% recycled content by 2025-2030

Automotive OEMs are targeting 40-50% recycled content by 2025-2030

Together, packaging and transportation sectors represent almost 50% of aluminum consumption

New sorting technologies enable scrap upgrading

Commercial · Pilot · R&D

"LIBS will soon be everywhere in Europe"
Employee at leading aluminum producer

	Technology	Techn. maturity
Sorting and dismantling	Vehicle dismantling system	Commercial
	Automotive design to recycle	Commercial
Separation	XRT: X-ray transmission	Commercial
	XRF: X-ray fluorescence	Pilot
	PGNAA: Prompt gamma neutron activation analysis	R&D
	LIBS: Laser-induced breakdown spectrometry	Pilot
Pre-processing	Pyrolysis for organic and lacquer removal	Commercial
	Cl2 and flux injection for alkali and Mg removal	Commercial
Metal refining	Fractional crystallization	R&D
	Vacuum distillation	R&D
	Solid-state electrolysis	R&D
Remelting	Automated furnace sampling and OES analysis	Commercial
	AI-based prediction and optimization of furnace blend	Commercial

Emerging sorting technologies like LIBS and XRF technologies are expected to reach commercial applications in 1-2 years, enabling avoided downgrading from mixed scrap alloys

In addition, metal refining technologies such as solid-state electrolysis are being developed

Source: Summa Equity circularity analysis

Plastics

The EU plastics industry is facing a pivotal decade. Despite decades of effort, only 13% of plastics are recycled today, while more and more plastics are burnt at end of life, releasing fossil CO_2. Even the best-managed plastic loops (such as PET bottles) suffer from significant downcycling quality losses, which means recycled plastics often fail to replace primary production.

A multitude of factors are now necessitating major change. Consumer companies have committed to a step change not just in recycling but in the use of recycled materials in their products and packaging. Regulators have also set a clear course; for example, the EU Packaging and Packaging Waste Directive (PPWR) porposes 65% recycled content in plastics packaging by 2040. Carbon charges, meanwhile, will make burning plastics increasingly expensive—around EUR 300/t by 2030 according to current predictions. These company com mitments and regulations will create a new market for recycled plastics of EUR 25 billion to 30 EUR billion by 2030, increasing to just above EUR 50 billion by 2040. Getting there will require large changes affecting all major value chains using plastics, including packaging (39% of plastics use), building and construction (21%), and automotive (9%).[58] Several initiatives would be needed to achieve the targeted levels:

1. **Invest in advanced mechanical and chemical recycling capacity at scale.** Deployment of new recycling technologies has been sluggish and stuck at 20 kt to 40 kt demonstration-size units. An expansion to industrial scale is set to happen, promising both cost reductions and larger supply. Examples include Mura Technology and Dow partnership for a 120 kt facility in Böhlen, Germany,59 and Eastman's announcement of a USD 1 billion 160 kt polyester recycling facility in Normandy, France.60 Making recycling happen depends not only on such technology partnerships but also on wider value chain collaboration. The Eastman investment is supported by letters of intent from many consumer goods companies as well as a collaboration with Interzero, a large German plastic reprocessing and sorting company. We believe this model of value chain integration will be widely needed. Consumer goods companies need to actively foster the new market or risk fostering a market incapable of supplying the recycled plastics they have committed to buying.

2. **Build new value chains to secure feed- stock.** High-quality, well-sorted feedstock is set to quickly become a con straining factor on recycling. For recycling to expand at scale, today's small-scale, fragmented, and often municipal waste management needs to be aggregated to the size of industrial feedstock. There are several inter esting developments in this space. Waste managers are taking steps to create access to new sources of waste plastics. For example, several players in the Netherlands, Norway, and Sweden are now looking to sort residual waste to remove up to 75% of plastics for recycling. New business models and value chain roles are also emerging. One example is Agilyx, which is listed on the Oslo Stock Exchange. It is pioneering the new role of feedstock aggregator, i.e., capable of collecting and sorting recycled feedstock in line with exact specifications for different recyclers' processes. Similarly, numerous companies aim to provide end-to-end solutions to customers seeking recycled plastics.

3. **Improve recyclability of plastic products.** This includes implementing better product design—shifting from hard-to-recycle plastics to PET, PP, PE—and avoiding multilayered plastics where possible. Additionally, increased transparency of the plastics content in pack- aging, for example, digital watermarks, could help sorters correctly sort plastic waste, thereby increasing recycling throughput and quality. One example of collaboration in this space is the HolyGrail 2.0 initiative driven by AIM (European Brands Association) and powered by the Alliance to End Plastic Waste, which aims to prove the viability of digital watermark technologies. The initiative connects over 160 organizations from the packaging industry as well as machine vendor TOMRA, for instance.61

Exhibit 27/1:
"True" circularity in plastics is currently limited to PET bottles, but recycling is poised to increase

Current state

PP and PE

Only downgrading

~22 Mt
yearly consumption

20%
Recycled, no "same-cycling"– only downgrading

~81 Mt CO_2e
emissions per year

PET

Only beverage bottles closed-loop recycled

5.1 Mt
yearly consumption

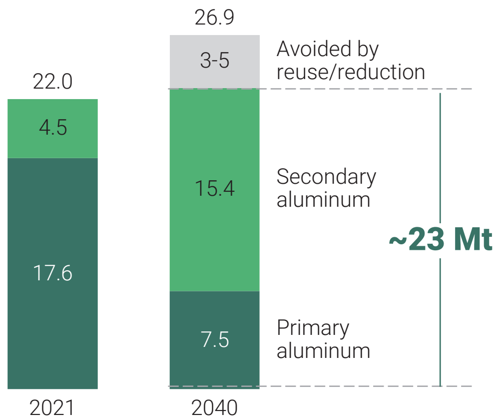
~13 Mt CO_2e
from production and incineration

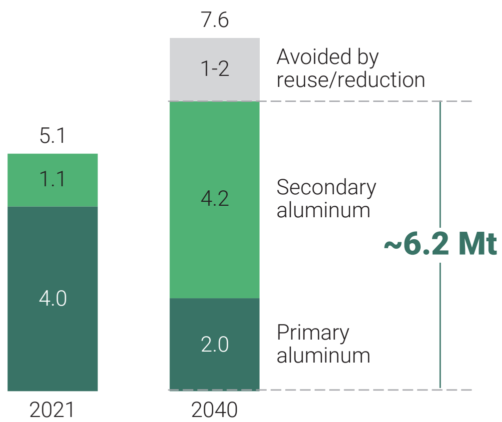
~22%
open-loop recycling[1]

~8%
closed-loop recycling, and only for beverage bottles

Material system, 2021 and 2040

Consumption in EU27+UK (Mt)





Impact of shifts

PP and PE

Huge shift to recycled content

~23 Mt
yearly consumption

~40%
"fully circular" (same-cycled)

~40 Mt CO_2e
saved vs. BAU development

PET

Closed-loop recycling beyond beverage bottles

6.2 Mt
yearly consumption

1-2 Mt
plastics avoided by reuse and reduction models

~6% CO_2e
saved from increased recycling

~55%
closed-loop recycling

1. Excluding PET downcycled to polyester fiber (used in clothing)

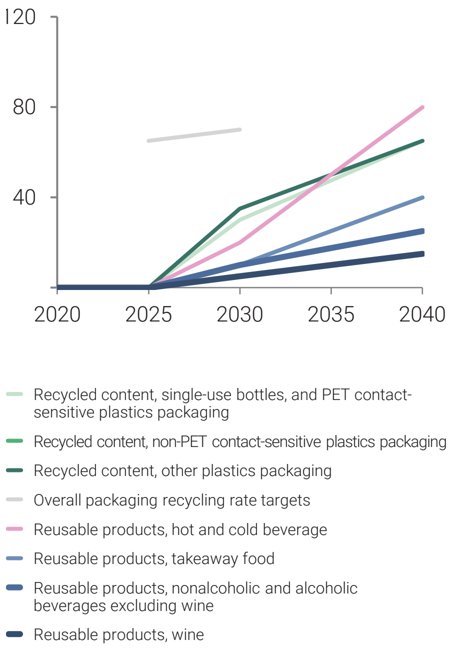
Source: Summa Equity circularity analysis

Exhibit 27/2: “True” circularity in plastics is currently limited to PET bottles, but recycling is poised to increase

3 shifts will drive the change toward circularity

Regulation requiring recycled plastics, driving demand

Regulatory targets on recycled content, recycling rates, and reuse (percent)



Plastic packaging: 65% recycled content required by 2040 (PPWR)

Mandatory deposit return schemes across Europe (PPWR)

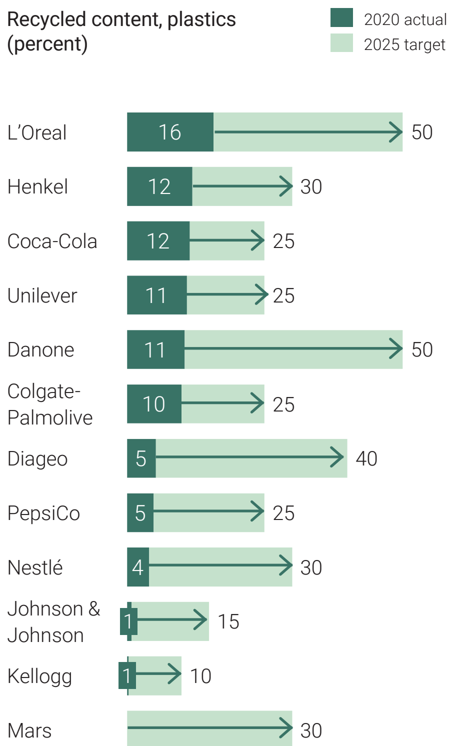
EPRs to be instituted across additional materials

CO_2 costs increasing, e.g., recent EU ETS price increase; CBAM to take effect

Phaseout of landfill coming in Europe

Strong brand commitments on recycled plastics content

Recycled content, plastics (percent)



Many large brands have committed to high recycled content targets but have a long way to go to meet these targets. If serious about reaching them, the willingness to pay for recycled plastics will continue to support a green premium (for recycled plastics prices vs. virgin plastics prices), creating an attractive market for plastics recyclers

New chemical recycling technologies

Key chemical recycling technologies, capacity, and example players

Pyrolysis

Converts plastic waste to energy, e.g., oil that can replace naphtha

Technology with most momentum in EU, several plants already running with more than 1.1 Mt announced capacity 2030[1]

Glycolysis

Converts plastic waste to monomers using ethylene glycol, which is used for new plastics production

Commercial scale exists for PET bottles, other industries (e.g., textiles) are piloting

Methanolysis

Converts plastic waste to monomers using methanol, which is used for new plastics production

Several additional technologies of varying maturity currently being developed and scaled

1. As per early 2022

Source: Summa Equity circularity analysis

Management of residual waste

The waste management industry has been on a long journey to increase sustainability. It first aimed to reduce residual waste and then began minimizing the negative effects of landfilling. It subsequently moved toward incineration to eliminate waste, concentrate valuable materials, neutralize toxins, and—to some degree—recover some of the energy content.

However, these approaches are now reaching their limits. Regulations aim to almost phase out landfilling completely in Europe by the 2030s. Meanwhile, incineration has a growing CO_2 problem. At the same time, Europe is facing an energy crisis and scarcity of biomass for energy and feedstock use. These pressures mean that waste management is set to change fundamentally. Waste management companies now have the opportunity to play offense, transforming from a largely logistics business to an industry of significant infrastructure assets capable of turning residual waste into valuable feedstocks for hard-to-abate sectors such as chemicals and fuels while managing carbon in waste flows. We see two emerging opportunities for waste companies:

1. **Establish partnerships to increase valorization of residual waste.** There are several partnerships that can significantly increase the valorization of residual waste. Technology partnerships, such as in post-sorting technologies, can significantly increase recovery of recyclable materials like metals and plastics. Other types of partnerships include full end-of-life solutions for products. Norsk Gjenvinning has partnered with Novo Nordisk to recycle end-of-life insulin pens into plastic granules. Waste management companies also have a natural position to aggregate flows and process them further toward the more sophisticated feedstock needed in increasingly circular materials industries. Another example is converting wood waste to biochar, which can be used for steel manufacturing and other metallurgy as replacement for coal, thereby helping decarbonize heavy industry.

2. **Enter new bio-based markets.** Sustainable biomass is expected to be a scarce resource in a decarbonizing Europe, with a potential supply-demand gap of 4 EJ to 7 EJ by 2050. Waste could supply 2 EJ or more of the emerging gap. Moreover, once waste is largely biomass, technologies including gasification, biological pathways, or carbon capture and utilization (CCU) can be used to convert waste into chemicals or advanced fuels. One example is the conversion of waste wood to biochar that, in turn, helps decarbonize metals production. Other examples include the partnership with Enerkem (a gasification technology provider), Repsol, and a Spanish waste company to build a waste-to-chemical plant in Tarragona—aiming to convert 400 kt of waste into 220 kt of methanol. In addition, capturing and storing biogenic emissions (BECCS) to create and potentially sell negative emissions is also an option that is being investigated by companies incinerating biomass (for example, Fortum is looking to implement carbon capture at their Oslo waste incineration plant).

Exhibit 28/1:
Residual waste can be turned into a valuable feedstock for hard-to-abate sectors

Current state

Costly problem with significant emissions

135 Mt

waste ending up in landfill

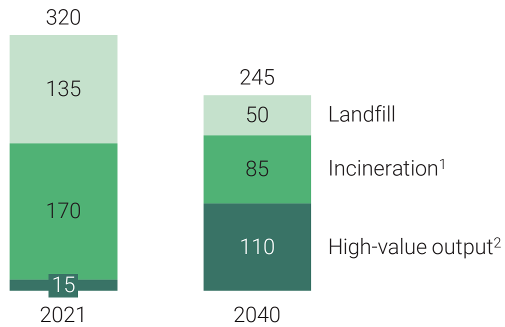
180 Mt CO_2e

emissions from landfill and incineration

Material system, 2021 and 2040

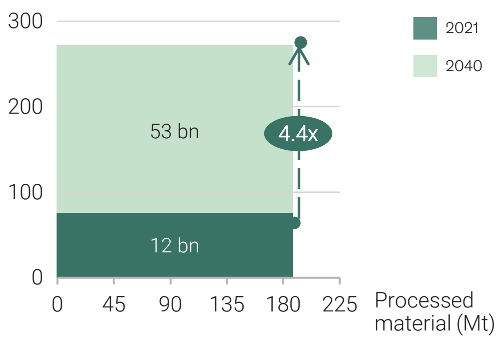
EU residual waste volumes

Treatment in EU27+UK (Mt)



Waste to X

Price of output/t waste input (EUR/t)



Emerging technologies enable increased valorization of residual waste–from low value-added incineration[3] to being a large and sustainable feedstock for hard-to-abate sectors such as aviation and chemicals

Impact of shifts

Valuable source of feedstock for hard-to-abate sectors

125 Mt CO_2e

saved in other sectors, such as aviation, chemicals, and energy

10 Mt SAF

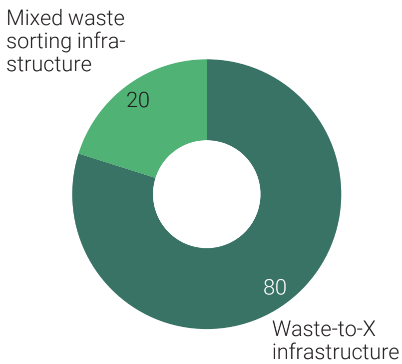
produced, 30 Mt methanol and 10 TWh biomethane

EUR 55 bn

Market size for waste to X by 2040

Cumulate growth capex need, 2021-2040

(percent, 100% = EUR 110 bn)



1. With or without energy recovery
2. Waste to X, including SAF, methanol, biomethane, and biogas production
3. We define low value-added as incineration with low conversion efficiency and/or resulting in substantial CO_2 emissions

Source: Summa Equity circularity analysis

Exhibit 28/2:
Residual waste can be turned into a valuable feedstock for hard-to-abate sectors

3 shifts will drive the change toward circularity

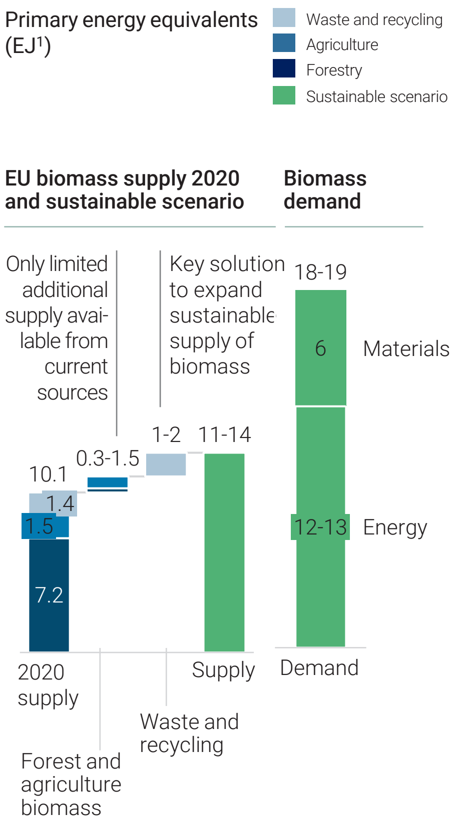
Residual waste increasingly bio-based and regulated

Majority of fossil waste (plastics, aluminum, textiles, etc.) collected separately or sorted out for recycling, leaving remaining waste increasingly bio-based

The EU will limit waste to landfill to <10% by 2030, consequently increasing volumes to incineration and other treatments

REPowerEU has set a target of producing 35 bn m^3 biomethane by 2030—a >10x demand increase compared to today, and biowaste can be an important feedstock

Supply-demand gap for biomass



Many industries rely on biomass for decarbonization. Demand from materials and energy expected to increase, and several scenarios project growth to 18-19 EJ (compared to 10 EJ today)

Potential supply-demand gap of 4-7 EJ by 2050

Waste is a large, cheap, and sustainable way to increase biomass supply

Emerging gasification and CCUS technologies

Emerging gasification and CCUS technologies can transform residual waste into chemicals like methanol and advanced fuels like SAFs—scaled to handle 40-50 Mt waste each

Furthermore, high-efficiency carbon-managed energy recovery can provide valuable heat and electricity, and carbon-managed energy recovery from bio-based sources (with biogenic emissions) could create negative emissions

Biowaste upgrading to biomethane is already applied commercially, mainly in the Nordics, but will need to scale significantly to meet the targets by REPowerEU

1. Excludes large-scale expansion of energy crops

Source: Summa Equity circularity analysis

Consumer goods

We estimated the consumer goods market in Europe at approximately EUR 1.2 trillion in 2021 and expect it to grow to around EUR 1.7 trillion to EUR 1.8 trillion by 2030, and up to EUR 2.5 billion by 2040.[62] This market is mostly linear today. As much as 87% of all plastics here end up as waste within a year, and fast fashion has significantly reduced the life span of clothing—or at least how many times an article of clothing is worn before being thrown away.

Yet nowhere is the push for circularity as strong as here, from regulators (for example, the EU's Packaging and Packaging Waste Directive), brands (for example, H&M's and Inditex's commitments to recycled fibers), and start-ups innovating new business models (for example solutions for refurbished smartphones or reusable food packaging).

As such, this could be the industry where change happens fastest. Each subsector of the consumer goods industry faces its own challenges. Below, we detail the broad strokes of the way forward for textiles and fashion, fast-moving consumer goods and packaging, durables consumer goods, and food production and retail.

Textiles and fashion. Although the fashion industry already has an established second-hand market, the system for its foundational raw materials—textile fibers—is almost entirely linear. Less than 1% of textiles come from fiber-to-fiber recycling, causing significant emissions as the EU consumes and wastes more than 7 Mt of textiles per year.

Several of the biggest brands have now made strong commitments—for example, Adidas has a target of using 100% recycled polyester by 2024, while Inditex (parent company of Zara and others) aims to use 100% organic, sustainable, or recycled fibers by 2025. However, targets themselves are not enough. The supply of the fibers these companies have committed to using does not exist today. The brands will have to actively participate in creating the investment environment in which a new end-of-life industry and supply chain can be built by doing the following:

1. **Proactively create the new circular supply chain.** This includes real investments into the required collection infrastructure, such as in-store collection of textile waste, or industry-wide collaborations to build up extended producer responsibility strategies and public collection infrastructure (similar to what the packaging and retail industry has done with bottles and cans[63]). By doing this, textile collection rates could reach 60% to 80% by 2030, instead of today's 30% to 35%.[64] Brands might also find they need to forward-integrate into fiber recycling—for example, through joint ventures with chemicals players or by acquiring recycling companies. In addition, closed-loop partnerships could be beneficial for brands, since they could a) fuel total feedstock availability (there is a real risk of feedstock shortages beyond 2030), b) secure recycled content at a lower price, and c) enable powerful stories around circularity efforts.

2. **Create demand and enable the next investments.** Textiles need to rapidly overcome the "chicken and egg" problem that has beset plastics recycling for decades. Brands can de-risk investments and secure access to feedstock, for example through offtake agreements with emerging recycling technology providers. One example is H&M's partnership with Renewcell—an agreement where H&M sources recycled textiles from Renewcell and will ramp up volumes over a five-year period. Another partnership example is Zara's collaboration with LanzaTech to produce fiber from captured CO_2.

3. **Design for circularity.** Major technology advances are required to successfully recycle textiles. The hurdle can be lowered by already considering end-of-life treatment of garments during the design stage. Examples of factors to consider are repairability, durability, disassembly, and fiber mix. A current problem for the emerging recycling technologies are mixed fibers—complicating recycling both technically and economically. By increasing the fiber purity (for example, using 100% cotton or polyester), brands can improve the economics of the entire end-of-life value chain.

Exhibit 29/1:
The textile end-of-life value chain will undergo a major transformation in the coming 10-20 years

Current state

Completely linear system

~8 Mt
yearly consumption

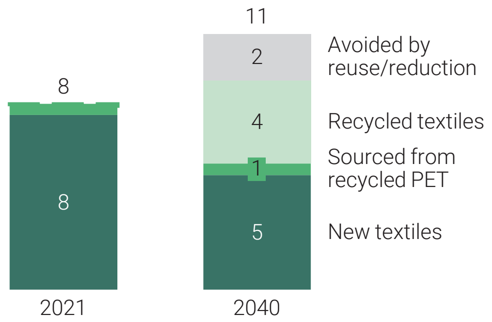
30-35%
collection rate for textile waste

<1%
fiber-to-fiber recycling

Material system, 2021 and 2040

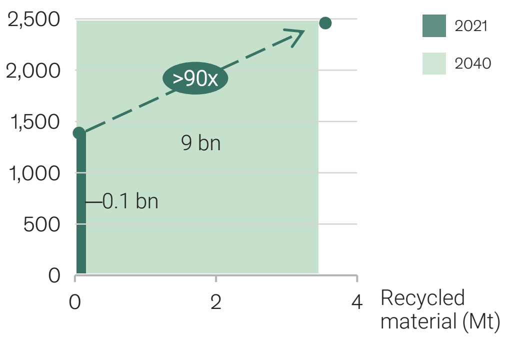
EU aluminum demand

Consumption in EU27+UK (Mt)



Market size for recycled fibers

Price of recycled textiles (EUR/t)



An entire new value chain is being created, increasing collection from 35% to 80% and fiber-to-fiber recycling from less than 1% to more than 40%

Chemical recycling enables virgin quality output, with strong possibility for a green premium (rPET traded at 40% premium compared to virgin PET in 2021)

Impact of shifts

Huge shift to recycled content

~80%
collection rate for textile waste

~45%
fiber-to-fiber recycling

~6.5 Mt
virgin fibers avoided by circularity

EUR 11-13 bn
yearly revenues for recycled fibers by 2040

EUR 8-12 bn
growth capex opportunity 2021-2040

Source: Summa Equity circularity analysis

Exhibit 29/2:
The textile end-of-life value chain will undergo a major transformation in the coming 10-20 years

3 shifts will drive the change toward circularity

Carbon prices add significant cost on primary aluminum

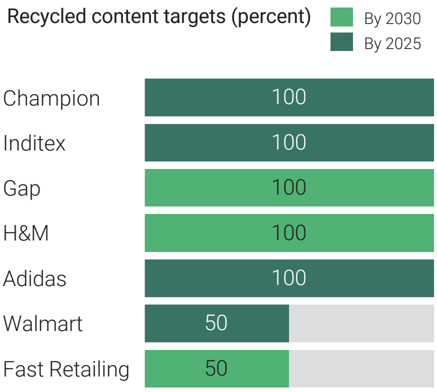
EU Strategy for Sustainable and Circular Textiles, including new design requirements (e.g., setting mandatory minimum for inclusion of recycled fibers)

EU Waste Management Law states that all EU countries must have separate textile collection by 2025

Several EU members working on regulation on EPR (extended producer responsibility)

Possible EU border carbon tax increasing fiber prices for imports from countries with high CO_2 electricity mix

Key customer segments set increasingly ambitious targets



Champion: 100% recycled cotton and polyester
Inditex: 100% of cotton, linen, and polyester will be organic, sustainable, or recycled
Gap: 100% regenerative, organic, or recycled cotton by 2030; 100% recycled polyester
H&M: Only use 100% recycled or other sustainably sourced materials
Adidas: 100% recycled polyester
Walmart: 50% recycled polyester
Fast Retailing: 50% recycled materials

Many large brands have committed to high recycled content targets but have a long way to go to meet these targets. If serious about reaching them, the willingness to pay for recycled textile fibers will continue to support a green premium, creating an attractive market for recyclers

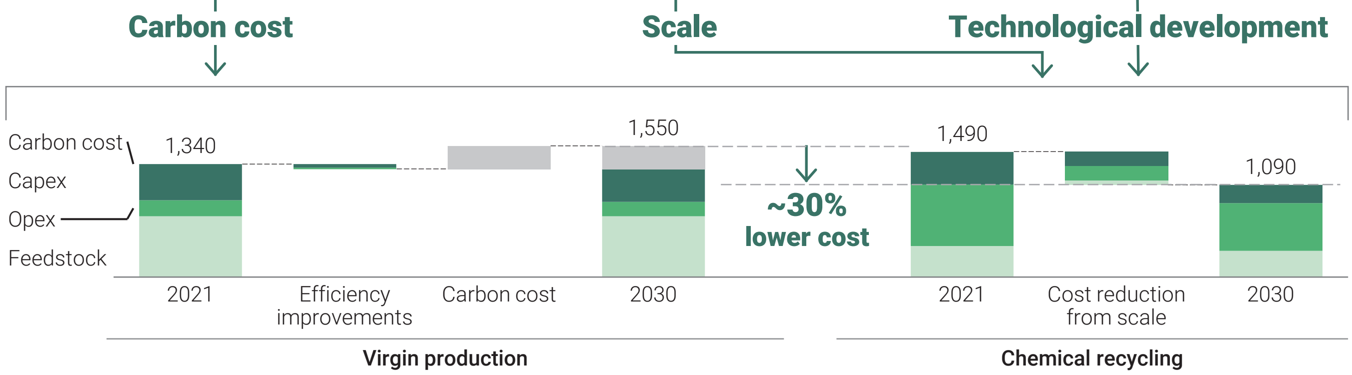
New sorting technologies enable scrap upgrading

◆ Commercial ◆ Pilot

	Technology	Techn. maturity	Fiber type
Mechanical	Closed-loop traditional	◆ Commercial	Textile waste
	Closed-loop soft	◆ Pilot	Fibers and blends
Thermo-mechanical		◆ Pilot	Polyester/ polymide
Chemical polymer	Pulping	◆ Commercial	Polyester
	Solvent-based	◆ Pilot	Polyester/ polycotton
Chemical monomer	Methanolysis	◇	Polyester
	Glycolysis	◇	Polyester
	Hydrolysis	◇	Polyester

Soft closed-loop mechanical recyclings return virgin quality

Automated sorting (e.g., NIR and VIS technologies) at scale—important enabler for improved recycling (both chemical and mechanical)



Source: Summa Equity circularity analysis

Fast-moving consumer goods and packaging

Companies in fast-moving consumer goods (home care, personal care, food and beverages, etc.) have every reason to consider how circularity fits into their broader business model and strategy. For a start, many have set science-based targets to sharply reduce GHG emissions, often including emissions from their value chains and packaging, as well as goals for increasing recycled content in packaging. However, many have not yet translated these into a action plan. As they do so, they will discover that large changes are needed, with circular economy at the heart of the agenda:

1. **Reduce packaging with new delivery models.** For many, reducing the environmental impact of packaging must include considering where total packaging use can be reduced. This is now also enshrined in European policy, with hard targets for total packaging volumes put on the market. In response, companies are starting to roll out refillable or returnable packaging or package-free deliveries. Examples include Miele's cartridge systems for detergent, bundled with washing machines and dishwashers; concentrated delivery for home care products or beverages, such as PepsiCo's acquisition of SodaStream; product format changes such powdered soap and bodywash products; refill systems such as Dial's collaboration with Plastic Bank on packaging for hand soap; and Germany's bottle deposit program—where bottles are returned, cleaned, refilled, and delivered back to stores.

2. **Design products for circularity.** Many traditional packaging formats are built on principles that make recycling difficult. The need to phase out multimaterials, achieve additional lightweighting, or switch to more recyclable polymers and bio-based substrates while retaining function will require deep rethinking and redesign of packaging and sometimes even products. One example is Tesco, which classified substrates as green, amber, or red, with red substrates not allowed in packaging sold in the store and amber substrates to be phased out. Another example is Danone, which is changing the material of its yogurt cups and juice cartons to PET.

3. **Source low-CO_2 and recycled materials.** Companies also need to consider the CO_2 footprint and recycled content of the materials they source. Low-CO_2 primary materials are emerging, but those with low CO_2 footprints are still scarce. Turning to materials with recycled content will therefore be an important complement to this, again with strong regulatory requirements in the pipeline. New approaches will be needed to secure access to such materials. For example, Lush offers to take back its containers in store, while also arranging closed-loop recycling of the materials.

Durable consumer goods

The durable consumer goods industry (furniture, white goods, tools, electronics, apparel, etc.) will also have to act for improved circularity.

First, sustainability and circularity may become elements of "social licenses to operate" in a growing share of the consumer base—so that companies need to demonstrate not just their products' responsible provenance at the point of sale but also sustainability throughout their lifetime of use and responsible solutions for their eventual disposal. For example, furniture giant IKEA aims to be fully circular by 2030, believing that this will be a key business differentiator as well as an opportunity to have positive societal and environmental impact.[65] Added to this, the EU is gradually launching a regulatory regime pushing in this direction, requiring companies to grant a "right to repair" and other policies geared toward conserving resources.

Second, as a result, the value pools associated with circular business models in durable consumer goods are now growing quickly. By 2030, we estimate that 25% to 35% of the total durable consumer goods market could be circular, worth approximately EUR 180 billion. To participate in these new markets, companies will need to move from a "one-time sale and spare parts" business model to end-to-end models including rental, take-back programs with repair, refurbishment, and reselling, and end-of-life recycling solutions. The consumer goods industry can pull three levers to enable that shift:

1. **Align strategy to capture the circular opportunity.** This will look different for each sector. For example, in consumer electronics, the growth comes primarily in refurbishment, extending the lifetime of products, primarily smartphones. In sports apparel, rental models are growing. If circular models are not made an explicit part of the strategy, companies risk creating a blind spot for new competitors to enter.

2. **Design products with a view to high-value take-back programs.** In principle, no company should be better placed for high-value refurbishment than the original manufacturer. For example, Apple has gone a long way toward automated disassembly via its Daisy robot.[66] The market for second-life or end-of-life value capture is growing rapidly, and to maximize of take-back programs, brands need to design their products to enable cost-efficient refurbishment. Again, IKEA is a good example, stating on its website that it has "set product development roadmaps outlining the actions required to make sure all products are circular by 2030."[67]

3. **Collaborate on collection and digital watermarking.** The "reverse logistics" of products remains one of the greatest hurdles for companies. For example, many personal electronics companies have take-back initiatives, but find that only small volumes are returned. One approach is to establish collaborations with retailers or even waste handling companies. Digital watermarking, as developed in the HolyGrail 2.0 project for packaging,[68] may be extended to various products to enable precise sorting of collected goods.

Food production and retail

Food waste is a massive economic and environmental burden. As much as 65 Mt of food, one-sixth of the total produced, becomes waste in the EU27+UK each year. Globally, the GHG emissions associated with food waste are as much as 10%, more than the CO_2 released in the production of steel or cement worldwide.[70] Reducing overproduction of food and the resulting food waste is a key lever to reducing emissions, and the EU is now setting mandatory targets to do so.

Experience shows that major reductions in food waste are possible with concerted effort. Although there are good examples from many countries, the UK has led the way with a holistic approach. The key has been industry collaboration and coordination via the Waste and Resources Action Programme (WRAP), an independent charity established in 2000 to promote sustainable resource use and reduce waste. Under this initiative, a broad group of stakeholders have pooled efforts behind a target to reduce per-capita food waste by 50% of 2007 levels by 2030.[71] Progress is being made: a 17% reduction in retail food waste was achieved by 2017, with a further 8% reduction achieved between 2018 and 2021.[72] Key lessons from WRAP that could be replicated include the following:

1. **Industry-wide collaboration with targets, roadmaps, and subsector guidance.** More than 350 organizations have committed to WRAP, including all major grocery retailers operating in the UK, and are pushing to meet the 50% target. All relevant stakeholders have thus been involved, spanning not just food production, distribution, and retail, but also trade bodies, waste management companies, and consumers. In addition to an overall target, WRAP is working actively with sector-specific guidance, tool kits, and resources for each different set of actors.

2. **A structured program with annual follow-up.** WRAP's "Target, Measure, Act" principles include detailed monitoring of food waste, with tools and templates available for any organization to use. Progress toward the target is reported annually in a "roadmap progress report."

3. **Creative, digitally enabled solutions.** This broad-based work has been fertile ground for new business models aimed at reducing the food waste problem. There are numerous creative examples, ranging from unusually shaped or surplus vegetables and fruits given to customers on a subscription model to avoid imperfect but perfectly edible food being thrown away; to AI-enabled solutions to track, monitor, and reduce food waste; and data analysis solutions to prevent overstocking of food in the first place.

Across Europe, there are many more such solutions emerging, such as Oda and Holdbart out of Norway, and Too Good To Go from Denmark. These companies are developing diverse new business models, from reducing food waste by saving imperfect products and selling surplus food at a discount, to digital solutions that streamline the food supply chain to prevent oversupply.

Automotive

As electric vehicles take an ever-larger share of new car sales, the environmental impact of vehicles is shifting away from fuel use during driving and toward the materials used in their production. The automotive industry is a significant consumer of materials: almost 30% of global aluminum consumption, 20% of steel consumption, and 10% of plastic consumption. Automotive companies now see that a responsibly sourced supply chain is key to their brand and customer offering. Some two-thirds of cars sold globally are made by companies that now have targets for net-zero GHG emissions from the materials they use.

Circularity will be key to achieving these reductions. Genuinely low-CO_2 materials are emerging but will be scarce for some time. The industry has a long way to go: the average car contains less than 20% recycled materials, and the materials that are recycled from cars are typically significantly downgraded. To make their ambitious targets a reality, automotive companies can pull several levers:

1. Adapt design and operations for circularity and material efficiency. With long lead times from design to first sale to phase-out of the vehicle model, it is important to consider long-term sustainability targets (such as emission reduction and recycled content) in the design phase. Material sourcing, lightweight design, and how easy the vehicle is to dismantle are all examples of choices that should be made here. Another area that automotive companies can control is their own production process, where there are often significant yield losses—for example, stamping has a 15-percentage-point difference between leaders and laggards. Implementing best practices or new technologies such as laser cutting and additive manufacturing could reduce yield losses significantly.

2. Build new supply chains for circular materials and components. The automotive sector has been at the forefront of securing access to low-CO_2 materials—including high-profile purchasing commitments that in turn have enabled investment in low-CO_2 steel and battery materials. Vehicle manufacturers can do the same with circular materials, thus establishing a second track toward reducing their environmental impact. The true low-hanging fruit is to maximize the value of their own production scrap. As noted in Exhibit 24, many automotive OEMs are doing this via closed-loop arrangements with their aluminum and steel suppliers. Another is the value to be captured from remanufacturing and parts recovery, where Renault's Refactory is a well-known trailblazer. The need to recycled batteries from electric vehicles also will be at the heart of the industry's future circularity efforts, with large new capacity as well as partnerships needed between miners, recyclers, and OEMs.

The industry also needs to work toward different dismantling practices that preserve more of the material's value, with OEMs perhaps eventually integrating forward into the dismantling and recycling businesses. We are already seeing examples of this across Europe: Encory, specialized in aftersales and reverse logistics of end-of-life parts, is a joint venture between the recycling company Alba Group and BMW. Another example is Gaia, an automotive end-of-life company that is a subsidiary of Renault.

3. Step into new circular business models. Finally, the automotive industry must not lose sight of how vehicles are used. Car-sharing business models have had a fitful start, and the basic fact remains that cars have stunningly low utilization—they are stationary some 94% of the time. Even modest increases in utilization—for example, via sharing models—could drastically reduce both the cost and the environmental footprint of transportation.

Construction

The construction industry is the largest in terms of material usage. Every year, around 180 Mt cement is used in Europe, resulting in around 1,200 Mt of concrete[73] utilized in construction and infrastructure. Construction also uses approximately 40% of the 168 Mt steel utilized each year as well as major quantities of aggregates, wood, plastics, aluminum, gypsum, and glass: all in all, some 1.6 Bt of materials are used for buildings each year. Construction and demolition waste dwarf other waste flows at more than half a billion tons per year in Europe.

However, the industry can greatly improve its material efficiency. According to some estimates, the construction industry uses up to 35% to 45% more steel and concrete than required to ensure structural integrity.[74] Furthermore, 15% or more of materials ordered to site are often wasted rather than used in construction. When buildings are demolished, it is rarely because they are structurally unsound—but reuse or repurposing of structures is nonetheless rare. Although official statistics state that 47% of EU construction and demolition waste is reused or recycled, this stretches any meaningful definition of recycling: mostly, materials with high embodied energy and CO_2 are turned into bulk aggregates or backfill, sometimes at no net CO_2 benefit. In addition, construction waste has significant impact on biodiversity (construction sector is among the top drivers of biodiversity loss). All in all, there is massive potential to improve the productivity in construction material use, with three aspects standing out:

1. **Reduce structural material overspecification, and design for circularity.** Reduced overuse boils down to deploying more complex construction techniques, including managing more complex inventories. The overuse of materials in construction is deep and structural, tied in with how contracts are written, projects specified, and on-site processes managed. To change this, companies will need to directly and deliberately measure and target material efficiency from initial design through execution. They will also need tools to increase digitization of the construction process and track their material usage. For example, Infobric provides access control and telemetric solutions to construction sites. This can help contractors reduce theft, accidental loss, and needless waste through strengthened controls. Contracting and setting the right reward structure for suppliers can also help, and prefabrication can increase efficiency.

2. **Turn to innovative materials solutions.** Construction companies are increasingly turning to innovative materials to reduce the resource footprint of construction. The use of cross-laminated timber can substantially reduce the amount of cement and steel, which are the main sources of CO_2 in construction. The use of high-strength steels can reduce the materials needed for the steel frames supporting many building types by 20%. Further, development is, for example, taking place to reduce the amount of clinker (a CO_2-intensive constituent) in cement by one-third through the use of fillers, plasticizers, and low water content techniques.

3. **Improve end-of-life handling.** Large additional flows of demolition waste can be recycled if industry initiatives are set up to enable them. For example, PVC recycling takes place in several European countries but is missing in others. Pooling flows to achieve sufficient scale often helps. For example, Norsk Gjenvinning, a Norwegian waste management company, partnered with several major construction companies and New West Gypsum Recycling to develop a new gypsum recycling solution.[75] Norsk Hydro has developed solutions to reprocess aluminum from demolition waste into new, recycled equivalent products (instead of downgrading, which is the industry norm). Even cement can be recycled to some extent. One start-up used 15% cement clinker recovered from end-of-life concrete, whereas another permanently mineralized 440 kg of CO_2 into aggregates used in construction.

Policy

In addition to industry and investors, policymakers are critical actors shaping the future of a circular Europe. Their legislation must help set the direction of travel for the entire system while leveling the playing field for circular versus linear solutions and business. They must also help put enablers for new supply chains in place, support innovation, and mobilize action in the public and private sectors. Exhibit 30 outlines a summary of priorities further detailed in this chapter.

Exhibit 30:
Four priorities for policymakers to further the circular agenda

Set the direction

- Articulate a vision for the future circular economy
- Define and monitor concrete targets to track progress
- Support early lead markets to supercharge the transition in the 2020s

Level the playing field

- Introduce effective carbon prices for materials and waste management
- Consider complementary measures to capture biodiversity and other benefits
- Use energy-efficiency-type interventions to overcome nonfinancial barriers

Put enablers in place

- Mobilize new supply chains for a circular economy at scale
- Create an effective innovation system and set an EU circular cleantech agenda
- Adjust regulations to remove barriers to the new circular value chains

Mobilize action

- Use public procurement to stimulate new markets
- Create advance market commitments for circular markets
- Integrate circularity with an industrial agenda

1. Set the direction via a joint vision and concrete targets

The circular economy has real momentum, and conviction about its potential is growing. Nonetheless, material circularity is still a nascent topic. Policymakers play an important role in bringing clarity of vision and ensuring focus on the right priorities, in part through setting tangible targets.

Articulate a vision for the future circular economy. While most senior decision-makers in policy and business now know that the energy system is headed for major change and recognize at least the contours of the unfolding energy transition, there is little awareness of the ongoing transition of the materials system. There is clear work ahead for policymakers to define what a circular economy will mean in practice and to articulate an inspiring vision for the whole economy. The Circular Economy Action Plan, one of the main building blocks of the European Green Deal, is a good starting point to build upon and refine.

Define and set concrete targets to monitor progress. Hand in hand with a long-term vision, there is a need to define and measure "circularity," both for the economy as a whole and at the individual company level. This should take many aspects into consideration, such as: How long should products last and be in circulation? What level of food waste is acceptable in different value chains? What share of inputs should come from recycled materials?

Climate targets can offer inspiration. Here, policymakers have long set a frame for action via targets—first for aggregate emissions and then for important strategies such as the deployment of renewable energy or improvement of energy efficiency. This long-term commitment has also been a significant catalyst in changing expectations about the direction of the energy system.

Similar targets for a more circular economy could have a similar catalyzing effect, synchronizing the many stakeholders—national policymakers, waste management companies, industrial and consumer goods companies, and investors—who need to move in tandem to get there. The circular scenario presented in the previous chapter should be seen in this light not as a prediction but as an attempt to provide a concrete description of what a circular transition could bring.

Support early lead markets to supercharge the transition in the 2020s. There is an immediate opportunity to build momentum for specific markets. Developing up new circular economy areas—whether in plastics recycling, recommerce models for consumer durables, or new ways to valorize residual waste—requires getting over the initial hurdles. In some areas, policymakers have taken inspiration from the success with renewable energy, where commitments to certain lead markets helped provide a basis for investment, learning by doing, and a continuing journey along the technology learning curve.

For example, the hope is that policy mandates and company commitments for the use of recycled plastics will provide the basis for new value chains and commercialization of new recycling technology—overcoming the "chicken and egg" problem and reaping the benefits of scale. Similar agendas are emerging for batteries and textiles and could be used more widely to accelerate new lead markets for additional areas such as novel waste management technologies, business models that minimize food waste, or initiatives that give a second life to durable goods.

2. Level the playing field for the circular business case

To a significant extent, today's markets are tilted in favor of waste and against material efficiency and reuse. Financial incentives will have to change to enable the circular economy transition, starting by correcting for the many externalities of linear business practices.

Introduce effective carbon prices for material and waste management. To date, most material production and waste management processes have been exempt from fees on the CO_2 or other GHG they generate. As noted in the previous chapter, this is now changing. There are now policy moves in Europe to ensure effective CO_2 charges, by including waste incineration in the EU Emissions Trading System, phasing out free allocation of allowances for industrial production, and introducing a border tariff for the import of CO_2-intensive goods.

Together, these moves could have a major impact on leveling the playing field for circular business models. However, there is still a long road to full implementation, which is now planned for the early 2030s. Staying the course on their introduction—or ideally accelerating them—is necessary for achieving circular business models.

Consider complementary measures to capture biodiversity and other benefits. Moreover, as this report has already pointed out, there are many other benefits of the circular economy beyond CO_2 abatement. These include contributions to local jobs, strategic autonomy, industrial competitiveness, and additional environmental benefits such as biodiversity. These do not show up in the business case and have no analogue to fees on CO_2 to drive them. Companies and policymakers will therefore need to be creative and attentive in ensuring that other, complementary benefits are rewarded, too.

Use energy efficiency interventions to overcome nonfinancial barriers. It may be that price mechanisms will only go so far. For example, despite "extended producer responsibility" legislation, manufacturers often have little incentive to account for the impact of materials and design choices on component and material values at a product's end of life. Many circular value chains and business models depend on similar coordination puzzles.

Energy efficiency offers a fruitful comparison to draw on for a circular economy agenda. Here, policymakers have often noted the difficult coordination exercise involved as well as the many nonfinancial barriers that hold back progress: a lack of information, split incentives, incomplete contracts, asymmetric risks, etc. In response, they have introduced a range of carefully tailored policy mechanisms, including aggregate targets, quota systems, financing mechanisms, subsidies, detailed product-level standards, and labeling initiatives. Similarly, multifaceted approaches could benefit the circular economy, complementing pure pricing instruments for CO_2 and other emissions.

3. Put the enablers of circular economy businesses in place

Mobilize new supply chains for a circular economy at scale. Today's circular supply chains are often fragmented, but they must soon be operating at scale. For example, Europe has approximately 500 waste incinerators, often operating on a small scale.[76] In contrast, future solutions for reducing waste, such as carbon management via CCU or CCS or upgrading to advanced fuels, will typically require operation on a larger scale. For example, providing the chemicals industry with a serious supply chain for plastics recycling requires matching millions of household-sized waste flows to large chemicals production sites that often produce more than 1 Mt of plastic waste per year.

There is thus a major task ahead to build the aggregation, specification, standardization, and infrastructure of future supply chains. Policymakers can act as conveners, bringing industry associations and leaders, nongovernmental organizations, investors, and government agencies together to address the creation of new supply chains, as well as allocate funds and simplify regulations to enable these collaborations.

Create an effective innovation system and set a circular EU cleantech agenda. The circular transition is part of the EU's cleantech agenda. Several of the new business models and technologies for material reprocessing or waste valorization are still at an early stage. For the transition to succeed, these early-stage business models and immature technologies must lead to large-scale commercialization. Yet Europe's track record for such mobilization is mixed.

On the one hand, the EU's ambitious climate and environment targets have given Europe an outsized share of early-stage cleantech entrepreneurs in several areas. Early-stage cleantech investment has grown 7.5 times over the last decade. Likewise, there are potential emerging success stories, such as the renewed push to reestablish Europe as a major player in the global battery market.

On the other hand, Europe often falls behind at the scale-up stage. Compared to the US, the EU lacks access to growth equity and exit routes to equity markets and has fragmented national markets. Promising early-stage innovation therefore frequently moves to the US or other places at the critical growth stage.

Europe has genuine potential for first-mover advantage in the circular transition. If successful, the benefits could extend to future European champions in what will be large global markets in the decades to come. To tap into this economic opportunity, the EU needs to boost the capacity of its financial system to support nascent circular businesses. This has worked best (such as in the case of batteries) where it was done through a highly coordinated push including aggregate targets, technology roadmaps, robust demand signals, direct public investment support, and public-private partnerships. Similar initiatives could help unclog scale-up financing for circularity.

Adjust regulations to remove barriers to new circular value chains. Europe also needs to take a hard look at where regulation is directly hampering industrial change. This is a case-by-case agenda, but several themes are well known. For example, regulations still make it difficult to trade some end-of-life products such as waste plastics across borders—treating them as hazardous waste rather than as valuable resources. Likewise, for waste management practices to change quickly, Europe needs to avoid stifling innovation through overly strict permitting regimes.

4. Mobilize coalitions for action

Governments and companies can also have an impact as direct actors in the transition by pledging to use their procurement muscle in support of new circular economy solutions.

Use public procurement to stimulate new circular markets. The public sector is a major player in several significant value chains. For example, it is a major provider and user of mobility services, an owner or operator of much of the built environment, and a buyer of a range of material-intensive products. This means that governments are well positioned to push the market toward a more circular economy through their own investments and purchases.

The discussion about public procurement is now picking up speed, often with a focus on the climate (for example, procuring electric vehicles, renewable power, or low-CO_2 products). The same agenda could also be used to promote the emerging circular economy (for example, supporting business models to reduce food waste, buying used equipment, or requiring the use of recycled content in public projects). Moreover, much of waste management is directly under public control. Given the urgency to find new solutions, this is an area where the public sector can play a major role in supporting the emergence of new solutions.

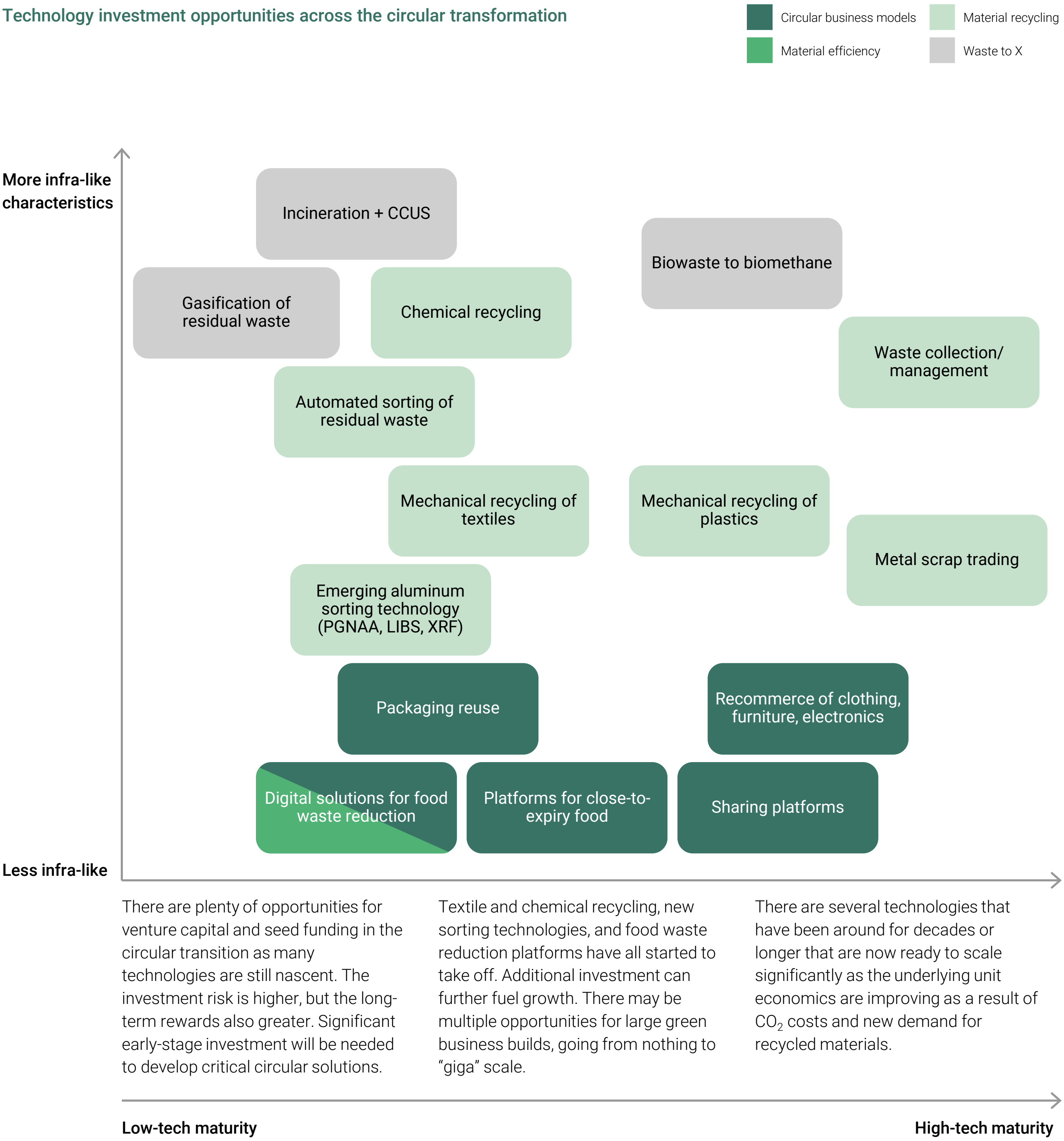
Create advance market commitments for circular markets. The circular economy transition can also be supported via private sector commitments. Initiatives such as the First Movers Coalition are increasingly important for clean production of industrial materials such as steel and concrete.[77] They could be extended to circular solutions to provide an advance market commitment.

More generally, there is a need to make sure that circular materials earn a place alongside clean primary production in emerging standards and initiatives. Companies need to be assured that when they choose recycled solutions with a low CO_2 footprint, they are treated the same way as their primary low-CO_2 equivalents.

Integrate circularity within an industrial agenda. The EU's industrial strategy aims to strengthen the global competitiveness of European industries while contributing to a sustainable and equitable Europe. The circular agenda is already part of the industrial agenda to some extent—yet we believe it would be beneficial to strengthen these ties and make it clear that the circular transition and the energy transition are of equal importance. To achieve this, the circular action plan needs to be further integrated into the overall industrial agenda.

☐ ☐ ☐

Exhibit 31:
Numerous companies are emerging, ranging across all levels of maturity and investment styles



Source: Expert interviews[78]

Investors

In addition to industry and policymakers, investors have a unique and important role to play in guiding the allocation of societal resources to the right ventures with the greatest short- and long-term returns.

Learn about the circular transition and how it can transform the European economy for the better. Invest time and resources in studying the circular material transition and understand the value it can create. Summa Equity is publishing this report to help build a knowledge network in the investor community that can benefit both investors and portfolio companies.

Engage with portfolio companies to explore their role in circularity. In 2021, private equity firms invested EUR 138 billion into nearly 9,000 companies across almost 2,000 funds.[79] Together, these companies are present in every part of the economy. As outlined in this report, there is opportunity—and necessity—in almost every sector to participate in the circular economy. Engaging with your portfolio companies on the topics raised in this report may reveal exciting opportunities that are otherwise overlooked.

Place your bets—there is room for everyone, and the time is now. As illustrated in Exhibit 31, there are different types of investment opportunities. Several of the most exciting circular technologies are still nascent. The technology risk is great, but the long-term returns are highly promising. For example, chemical recycling of plastics and textiles has the potential to become cost competitive with virgin production at scale—but it's uncertain which technology will win. Equally, digital businesses aimed at reducing food waste take many different approaches and, in the end, not all may pull through. This is a suitable space for venture capital firms to place their bets, as we are certain there will be winners—and some may win big.

Other technologies have been around for decades but haven't had a "level playing field" compared to fossil-emitting or noncircular competition. This is now changing, and growth equity has a golden opportunity to identify the most promising players and help shape their growth plans. We believe the time is right to be bold. As previously shown, the overall market is set to grow fivefold in the coming 20 years, and, in the case of textile recycling, it could be 90 times larger—and we estimate that much of this growth is due to come in the next ten years.

As has proved to be a success in other parts of the green transition, the circular transition also offers the opportunity for green business building at scale, skipping the incremental growth journey of traditional businesses. Similar to how Northvolt or H2 Green Steel have raised capital to build gigafactories, there is an opportunity to invest in scaled recycling plants, mixed-waste post-sortation sites, or waste-to-chemical plants with CCU to sustainable aviation fuel, methanol, or ethylene.

□ □ □

Abbreviations

AI	Artificial intelligence
BAU	Business as usual
Bt	Billion tons
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CCUS	Carbon capture and utilization or storage
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EAF	Electric arc furnace (for steel production)
EJ	Exajoule (10^{18} joule)
EU	European Union
EUR	Euro, €
H-DRI	Hydrogen direct reduced iron
GDP	Gross domestic product
GHG	Greenhouse gas
IT	Information technology
LIBS	Laser-induced breakdown spectroscopy
NIR	Near-infrared spectroscopy
PET	Polyethylene terephthalate
PPWR	Packaging and Packaging Waste Regulation
PV	Photovoltaics
SAF	Sustainable aviation fuel
TWh	Terawatt-hour (1012 watt-hours)
UK	United Kingdom
US	United States
VIS	Visible spectroscopy
WEEE	Waste from electrical and electronic equipment

End notes

1. The valuation of circular markets in 2040 are made by assuming a profitability and EV/EBITDA multiple for each market subsegment. By multiplying the market subsegment revenue estimate with an EBITDA profitability estimate, we derive an estimated EBITDA generated per year in 2040. By multiplying this with the EV/EBITDA ratio, we arrive at an estimate of the market valuation of the businesses present in the market subsegment.

   For example: If we for a certain market segment have estimated a future market size of EUR 100 billion, and EBITDA margins of 10-20% based on current industry ranges, with compa- nies currently trading, publicly, at 7-8x EV/EBITDA, the valuation of this market segment would be EUR 100 billion x 10-20% x 7-8 = EUR 70-160 billion.

   Future EBITDA margins and multiples cannot be known with any certainty. Assumptions are based on benchmarking with currently established companies and expert estimates about future costs and prices.

   For capex estimates, see Exhibit 20 and associated end notes.

   .

   For market size estimates, see Exhibit 18 and associated end notes.

   For CO_2e emission savings, see Exhibits 14 and 16 and associated end notes.

2. Modeling based on multiple publications from Plastics Europe including Plastics Europe (2006). “Plastics–the Facts 2006” https://plasticseurope.org/knowledge-hub/plastics-the-facts-2006/.

3. This refers to the total steel stock, and not to the yearly consumption. Source: “The Circular Economy–A Powerful Force for Climate Mitigation.” https://materialeconomics.com/publications.

4. We exclude construction and mining waste as it is composed of aggregates, stones, sand, and soil, with limited relevance for circularity. Chemical and medical waste are also excluded as they are typically handled separately from other waste streams, and recycling of relevant medical waste such as plastics is covered in the plastics waste stream. It should also be noted that waste data is of mixed quality and that it is not possible to exactly determine the composition of all waste. Around 22% of total waste comprises mixed waste like sludges and materials difficult to separate and of unknown composition. See FEAD, CE Delft, and Prognos (2022). CO_2 reduction potential in European waste management (available online: https://cedelft.eu/wp-con-tent/uploads/sites/2/2022/01/CE_Delft_Prognos_CO2_reduction_potential_European_waste_mngt_FINAL.pdf).

5. The material consumption and usage across industry has been estimated based on various sources.

   — Steel: EUROFER (2022), EUROPEAN STEEL IN FIGURES 2022
   — Aluminum: European Aluminum Association
   — Glass: Glass for Europe and Glass Alliance Europe
   — Plastics: Material Economics (2022), Europe's Missing Plastics–Taking Stock of EU Plastics Circularity
   — Food: Food and Agriculture Association of the United Nations, FAO
   — Paper: CEPI, European pulp & paper industry (2021)
   — Cement: CEMBUREAU (2021), 2021 Activity Report
   — Textiles: McKinsey & Company (2022), Scaling Textile Recycling in Europe
   — Wood: assuming a 50/50 split between construction and consumer goods (i.e., furniture), due to lack of better data
   — Rubber: assuming 95% in transportation (i.e., tires), 5% in consumer goods.
   The waste volumes estimated in this report are based on Eurostat data, combined with additional insights from the above-mentioned sources and: FEAD, CE Delft, and Prognos (2022). CO_2 reduction potential in European waste management.

6. Source for value of food being wasted: European Commission (2023). Food Safety, Food Waste. https://food.ec.europa.eu/safety/food-waste_en#:~:text=In%20the%20EU%2C%20nearly%2057,and%20households)%20may%20be%20wasted.

   Source for value of electronics and clothing discarded: Ökopol. 2021. Policy Brief on Prohibiting the Destruction of Unsold Goods. European Environmental Bureau. https://eeb.org/wp-content/uploads/2021/10/Prohibiting-the-destruction-of-unsold-goods-Policy-brief-2021.pdf.

7. Material Economics (2018). “The Circular Economy–A Powerful Force for Climate Mitigation.” https://materialeconomics.com/publications.

8. Cullen, Jonathan M., and J. Allwood (2013). "Mapping the global flow of aluminum: from liquid aluminum to end-use goods." Environmental science & technology 47 (7) 3057-64.

9. Team analysis based on several sources, including:

   Cars: Material Economics (2018). The Circular Economy–A Powerful Force for Climate Mitigation (available online: https://materialeconomics.com/publications).

   Food waste: European Commission. 2023. Food Safety, Food Waste (available online: https://food.ec.europa.eu/safety/food-waste_en).

   Electronics: Ökopol (2021). Policy Brief on Prohibiting the Destruction of Unsold Goods. European Environmental Bureau (available online: https://eeb.org/wp-content/uploads/2021/10/Prohibiting-the-destruction-of-unsold-goods-Policy-brief-2021.pdf).

Construction: Material Economics. 2018. "The Circular Economy–A Powerful Force for Climate Mitigation." (available online: https://materialeconomics.com/publications/the-circular-economy).

Office space: Ellen McArthur Foundation, SUN, and McKinsey Center for Business and Environment (2015). Growth Within: a Circular Economy Vision for a Competitive Europe (available online: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf).

Recycling rates and emissions: Summa Equity circularity modeling.

10. Summa Equity modeling of material flows, building primarily on the data sources as outlined in the end note to Exhibit 2. Materials included in the flow model are: steel, aluminum, glass, plastics, food, paper, cement, textiles, wood, and rubber. See also Box 1.

11. Eurostat European waste data (ENV_WASGEN) (available online: https://ec.europa.eu/eurostat/databrowser/view/env_wasgen/default/table?lang=en).

Approximately 2,400 Mt waste generated annually, of which 530 Mt are from in-scope materials (22%), 80 Mt chemical and medical waste (4%), and 1,790 Mt construction waste (excluding in-scope materials), mining waste, stones, minerals, aggregates, soil, sand, and similar.

12. Material Economics (2019). Industrial Transformation 2050–Pathways to Net-Zero Emissions from EU Heavy Industry.

13. Material Economics (2020). Preserving value in EU industrial materials–A value perspective on the use of steel, plastics, and aluminum. Exhibit 2, page 9.

14. See: Material Economics (2018), The Circular Economy–A Powerful Resource for Climate Mitigation.

15. See: Material Economics (2019). Industrial Transformation 2050–Pathways to Net-Zero Emissions from EU Heavy Industry, Exhibit 1.3 on page 21.

16. See: IRP (2019). Global Resources Outlook 2019: Natural Resources for the Future We Want.

17. Material Economics. 2022. "Scaling up Europe–Bringing Low-CO_2 Materials from Demonstration to Industrial Scale." https://materialeconomics.com/publications.

18. ~4 EJ used for materials (pulp production and wood products) and ~13 EJ used for food and feed. Source: Material Economics (2021). EU Biomass Use In A Net-Zero Economy–A Course Correction for EU Biomass.

19. Sitra (2021). The Circular Economy Can Turn the Tide on Biodiversity Loss. https://www.sitra.fi/en/articles/the-circular-economy-can-turn-the-tide-on-biodiversity-loss/.

20. Sitra (2022). "Tackling Root Causes–Halting biodiversity loss through the circular economy" https://www.sitra.fi/app/uploads/2022/05/sitra-tackling-root-causes.pdf.

21. For material and waste volumes, see Exhibit 2 and associated end notes. To calculate the related emissions, we have used the 100-year emissions factors (for both production and waste management) from FEAD, CE Delft, and Prognos (2022). CO_2 reduction potential in European waste management (available online: https://cedelft.eu/wp-con-tent/uploads/sites/2/2022/01/CE_Delft_Prognos_CO2_reduction_potential_European_waste_mngt_FINAL.pdf). For cement (not covered by the above study) emission factors of 0.66 tCO_2e/t are taken from CEMBUREAU (available online: https://lowcarboneconomy.cembureau.eu/our-emissions/where-was-the-cement-sector-in-2013/).

Using the above, we estimate the current CO_2e emissions of the production and waste management (including incineration, landfill, recycling, anaerobic digestion, and gasification) to be approximately 850 Mt.

According to Eurostat, total European GHG emissions are 3,871 Mt CO_2e (available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Quarterly_greenhouse_gas_emissions_in_the_EU).

It is worth noting here that the above estimated 850 Mt CO_2e emissions from the material system are not fully included in the Eurostat emissions figures, as these are the emissions from processes within the EU27+UK. However, a significant share of the material emissions is incurred outside of Europe. In particular textiles and aluminum have significant production and emissions outside of Europe. It is thus still correct that the 850 Mt CO_2e emissions are equivalent to 22% of the European CO_2e emissions, but not that they comprise 22% of the same emissions.

22. Put together by analysis team, based on EU regulations, company commitments, analyses of current and emerging technologies, EU ETS projections, etc.

23. CEWEP reports 504 plants in 2020 in Western and Central Europe (https://www.cewep.eu/waste-to-energy-plants-in-europe-in-2020/9.

24. CEWEP estimates the 504 plants tracked by them handle ~101 Mt of waste. The 170 Mt figure refers to the total waste estimated to go to energy recovery or incineration across Europe, including countries not covered by CEWEP (i.e., Eastern Europe).

25. Eurostat waste data, ENV_WASMUN (available online: https://ec.europa.eu/eurostat/databrowser/view/env_wasmun/).

26. CEWEP map of waste-to-energy plants from 2010 reports 450 plants, and the map for 2020 reports 504 plants, and increase of 54 units (see CEWEP website: https://www.cewep.eu/waste-to-energy-plants-in-europe-in-2020/).

27. Using waste volumes to incineration, and incineration emission factors, from FEAD, CE Delft, and Prognos (2022). CO_2 reduction potential in European waste management (available online: https://cedelft.eu/wp-content/uploads/sites/2/2022/01/CE_Delft_Prognos_CO2_reduction_potential_European_waste_mngt_FINAL.pdf).

Material	Incineration volumes, Mt	Emission factor, kg CO_2e/t	Emissions, Mt CO_2e
Ferrous metals	6	-	-
Glass	4	-	-
Textiles	3	1,668	4
Plastics	26	2,780	72
Rubber	1	1,848	2
Paper	15	-	-
Wood	39	-	-
Biowaste	26	-	-
Other waste	53	489	26
Total	**173**		**104**

Note that emission factors for incineration of ferrous metals, glass, paper, wood, and biowaste are negligeable (or zero) and excluded from the calculations.

The emission factor for textile has been adjusted compared to FEAD based on estimates of the polyester content as provided in McKinsey (2022). Scaling textile recycling in Europe–turning waste into value. Approximately 60% polyester or polyamide.

28. 55% of the free allocations are to be phased out by 2030, and by 2035 all free allocations are phased out. We are assuming EU ETS prices of EUR 100/t CO_2 by 2030, and EUR 150/t by 2035. We are using emission factors (ton CO_2 per ton material) of 0.7 for cement, ~2 t for steel, 5 t for plastics (including incineration), and ~9 t for aluminum.

29. In her *2022 State of the Union Address,* on September 14, 2022, European Commission President von der Leyen announced a coming "European Critical Raw Materials Act" with the purpose of securing raw material supply in Europe and reducing dependency on imports (mentioning in particular rare earth metals from China). Available online: https://ec.europa.eu/commission/presscorner/detail/en/speech_22_5493 (Accessed on January 23, 2023).

30. https://ec.europa.eu/commission/presscorner/detail/e%20n/ip_22_3131.

31. Material Economics (2021). EU Biomass Use in a Net-Zero Economy–A course correction for EU biomass.

BP. 2021. Statistical Review of World Energy–Germany's energy market in 2020 (available online: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-germany-insights.pdf).

32. https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_22_5523.

33. https://ec.europa.eu/commission/presscorner/detail/ov/SPEECH_22_5493.

34. Based on announced investments of companies such as Tata Steel, Salzgitter AG, H2 green steel SSAB, ArcelorMittal, etc.

35. European Aluminum (2020). Circularity Aluminum Action Plan. PDF. https://european-aluminium.eu/wp-content/uploads/2022/08/european-aluminium-circular-aluminium-action-plan.pdf.

36. For both the 2021 and 2040 figures, the comparison made is between end-of-life materials and material production. This does not mean that all end-of-life material could be 100% recycled to replace virgin production. Even in the most circular scenario, collection and sorting will be imperfect, there will be waste contamination making recycling difficult (e.g., copper contamination of steel, or chemicals contaminating plastics, and aluminum lost as zorba). Further, plastics recycling today has a significant processing loss, as high as 30%. The scenario laid out in Chapter 3 is our view of a highly ambitious yet plausible circularity scenario.

For material volumes, please see end notes to Exhibit 2.

37. Cost estimates for chemical recycling based on averages from 5 chemical recycling companies. Today's costs for chemical recycling is based on small-scale plants (5 kt to 50 kt per year). 2030 cost based on larger scale plants (250 kt per year).

Assumptions on virgin production development: opex (excluding feedstock) and capex reduction of 10% for virgin production by 2030 through incremental improvements. CO_2 price of 100 EUR/t and emissions of ~5 t CO_2/t for PET, including incineration at end of life, and 55% of free allocations phased out.

38. Pasaoglu, G., Fiorello, D., Martino, A., Scarcella, G., Alemanno, A., et al. (2012). Driving and Parking Patterns of European Car Drivers: A Mobility Survey. Publications Office, Luxembourg.

39. We define low value-add as incineration with low conversion efficiency and/or resulting in substantial fossil CO_2 emissions.

40. Sitra (2022). "Tackling Root Causes–Halting biodiversity loss through the circular economy" https://www.sitra.fi/app/uploads/2022/05/sitra-tackling-root-causes.pdf.

41. Adapted from Exhibit 1.8, page 24, in Material Economics (2018), The Circular Economy–a Powerful Force for Climate Mitigation (available

online: https://materialeconomics.com/publications/the-circular-economy-a-powerful-force-for-climate-mitigation-1).

42. Lower range for jobs per Mt fiber recycled from McKinsey report and higher range from analysis based on Summa Equity modeling, Friends of Earth (2010), and PSIRU (2012).

Friends of the Earth. 2010. "More jobs, less waste: Potential for job creation through higher rates of recycling in the UK and EU"

Hall, David, and Tue Anh (Jenny) Nguyen. 2012. Waste Management in Europe: Companies, structure and employment. PSIRU.

McKinsey & Company. 2022. Scaling textile recycling in Europe—turning waste into value. July 14. https://www.mckinsey.com/industries/retail/our-insights/scaling-textile-recycling-in-europe-turning-waste-into-value.

43. In 2022, transport and environment estimated total jet fuel demand to be about 50 Mt. https://www.transportenvironment.org/wp-content/uploads/2022/06/20220602_E-kerosene-tracker-briefing_SB-1-1.pdf.

44. Some 0.7 EJ to 1.3 EJ bio-based feedstock could be allocated to chemicals, according to Material Economics (2021). EU Biomass Use in a Net-Zero Economy–A course correction for EU biomass.

45. 105 Mt primary steel, requiring 1.5 t iron ore and 0.8 t to 0.9 t coal per ton of steel. Source: https://www.steelonthenet.com/cost-bof.html.

46. Material Economics (2021). "EU Biomass Use in a Net-Zero Economy–A course correction for EU biomass." https://materialeconomics.com/publications.

47. ~0.5 MWh/t recycled steel compared to 3.5-4 MWh/t H-DRI steel, and we are increasing the volume recycled steel by ~50 Mt per year (from 63 Mt to 115 Mt).

48. European Commission, Directorate-General for Environment, (2018). Impacts of circular economy policies on the labour market: final report and annexes, Publications Office. https://data.europa.eu/doi/10.2779/574719.

49. Ellen MacArthur Foundation (2015). Growth Within: a circular economy vision for a competitive Europe.

50. McKinsey (2022). Scaling textile recycling in Europe–turning waste into value.

51. Material Economics (2019). Industrial Transformation 2050–Pathways to Net-Zero Emissions from EU Heavy Industry.

52. For example, in 2017, the Ellen MacArthur Foundation estimated that EUR 320 billion in investments would be needed to fully integrate circularity in mobility (modally integrated transport systems, new car designs, reverse value chains such as remanufacturing); food (regenerative agriculture, nutrient loops, urban farming, next-wave protein production); and buildings (circular city design, circular building designs). See Ellen MacArthur Foundation (2017). Achieving "Growth Within" (available online: https://ellenmacarthurfoundation.org/achieving-growth-within).

53. Based on announced investments of companies such as Tata Steel, Salzgitter AG, H2GreenSteel, SSAB, and ArcelorMittal.

54. Through the acquisitions of John Lawrie, Riwald, Zlomex, and ALBA Group.

55. Daehn, K. E., A. Serrenho Cabrera, and J. Allwood. 2017. "How Will Copper Contamination Constrain Future Global Steel Recycling?" Environmental Science & Technology 51 (11) 6599-6606.

Material Economics (2018). "The Circular Economy–A Powerful Force for Climate Mitigation" https://materialeconomics.com/publications.

56. European Aluminium (2022). Strategic: the new critical in shaping the raw materials strategy. November 15. https://european-aluminium.eu/blog/strategic-the-new-critical-in-shaping-the-raw-materials-strategy/.

Material Economics (2020). "Preserving Value in EU Industrial Materials–A value perspective on the use of steel, plastics and aluminium" https://materialeconomics.com/publications.

57. Imported aluminum has an average CO_2 footprint of 8.2 t CO_2 per ton, while the global average is 16.6 t CO_2. Recycled aluminum, in contrast, has a footprint of half a ton CO_2 or less. See international aluminum statistics (available online: https://international-aluminium.org/statistics/greenhouse-gas-emissions-intensity-primary-aluminium/) and the European Roundtable on Climate Change and Sustainable Transition (available online: https://ercst.org/wp-content/uploads/2021/08/The-aluminium-value-chain-and-implications-for-CBAM-design.pdf).

58. Plastics Europe (2022). Plastics–the Facts 2022 (available online: https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/).

59. Mura Technology press release, September 14, 2022 (available online: https://muratechnology.com/news/mura-technology-and-dow-plan-to-locate-europes-largest-advanced-recycling-facility-at-dows-site-in-bohlen-germany-2/).

60. Eastman press release, March 29, 2022 (available online: https://www.eastman.com/en/media-center/news-stories/2022/eastman-exclusive-negotiation-site-normandy).

61. See official website at https://www.digitalwatermarks.eu/.

62. EU27+UK GDP of about USD 19.7 trillion or EUR 18.1 trillion. Estimates from the World Bank for 2021. Spending on consumer goods estimated at approximately 6% to 7% of GDP and growing at around 4% per year.

    Included in these figures are fashion and luxury, consumer electronics and home appliances, furniture and decorations, sports apparel and equipment, fast-moving consumer goods (packaging), entertainment, outdoor equipment, DIY and tools, and mobility (bikes and similar).

63. In countries where deposit return systems are deployed, such as in the Nordic countries and Germany, various parts of industry or retail (for example, in Sweden, the Swedish Brewers Association, the Swedish Food Retailers Federation, and Livsmedelshandlarna) have jointly invested in establishing the system.

64. McKinsey & Company (2022). Scaling Textile Recycling in Europe.

65. IKEA website. "Our ambition is to be circular and climate positive by 2030, and to inspire and enable the many people to live a better everyday life within the boundaries of the planet" (available online: https://about.ikea.com/en/sustainability/a-world-without-waste).

66. Apple press release (2018). Apple adds Earth Day donations to trade-in and recycling program (available online: https://www.apple.com/newsroom/2018/04/apple-adds-earth-day-donations-to-trade-in-and-recycling-program/).

67. IKEA website (available online: https://about.ikea.com/en/sustainability/a-world-without-waste).

68. While the technology developed in the HolyGrail 2.0 project is primarily intended for packaging, it can be applied to many kinds of products, as the markings are not visible to the naked eye. See https://www.digitalwatermarks.eu/.

69. Eurostat estimates 127 kg of food waste per person, per year, equivalent to 16% to 17% of total food made available for consumption. "Households generated 55% of food waste, accounting for 70 kg per inhabitant. The remaining 45% was waste generated upwards in the food supply chain" (available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220925-2) (Source dataset: env_wasfw).

70. "Ca. 25-30% of total GHG emissions are attributable to the food system. These are from agriculture and land use, storage, transport, packaging, processing, retail, and consumption." Intergovernmental Panel on Climate Change (2019). Chapter 5: Food Security (available online: https://www.ipcc.ch/site/assets/uploads/2019/08/2f.-Chapter-5_FINAL.pdf).

71. "For food waste: To deliver against UN SDG 12.3: a 50% per capita reduction in food waste by 2030 vs the UK 2007 baseline (covering manufacture, retail, hospitality and food service, and household)" (available online: https://wrap.org.uk/taking-action/food-drink/initiatives/courtauld-commitment).

72. WRAP (2022). The Food Waste Reduction Roadmap Progress Report 2022 (available offline: https://wrap.org.uk/sites/default/files/2022-12/WRAP_Food_Waste_Reduction_Roadmap_Progress_Report_2022.pdf).

73. CEMBUREAU estimates 172 Mt cement production in EU27 in 2020 and 182 Mt in 2019 for EU28. We approximate cement production for EU27+UK in 2022 to be around 180 Mt (https://www.cembureau.eu/media/ejohhq5c/global-cement-production-table.png).

    Cement typically makes up ~15% of concrete. Assuming all cement is used for concrete production within the EU27+UK, 180 Mt cement results in ~1,200 Mt concrete.

74. See for example Material Economics (2019). Industrial Transformation 2050–Pathways to Net-Zero Emissions from EU Heavy Industry, p. 170, and end notes 29 and 30 in Chapter 4.

75. Press release from New West Gypsum Recycling, September 1, 2018 (available online: https://www.globalgypsum.com/magazine/articles/762-new-west-gypsum-recycling-commissions-norwegian-plant).

76. The Confederation of European Waste to energy Plants reports that there were 504 waste-to-energy plants in Europe in 2020, excluding hazardous waste incineration plants, jointly thermally treating 101 Mt of waste (available online: https://www.cewep.eu/waste-to-energy-plants-in-europe-in-2020/).

77. The First Movers Coalition is a global initiative led by the World Economic Forum "harnessing the purchasing power of companies to decarbonize seven 'hard to abate' industrial sectors." By "sending a powerful market signal," the initiative members hope to create lead markets for decarbonization solutions, encouraging investors to take risks by investing in emerging technologies (available offline: https://www.weforum.org/first-movers-coalition).

78. Placement of opportunities is indicative and for illustration only, and made based on qualitative statements from industry experts, supported with high level quantitative capex intensity estimates where available.

79. Invest Europe (2022). Investing in Europe: Private Equity activity 2021 (available online: https://www.investeurope.eu/media/5184/invest-europe-activity-data-report-2021.pdf.