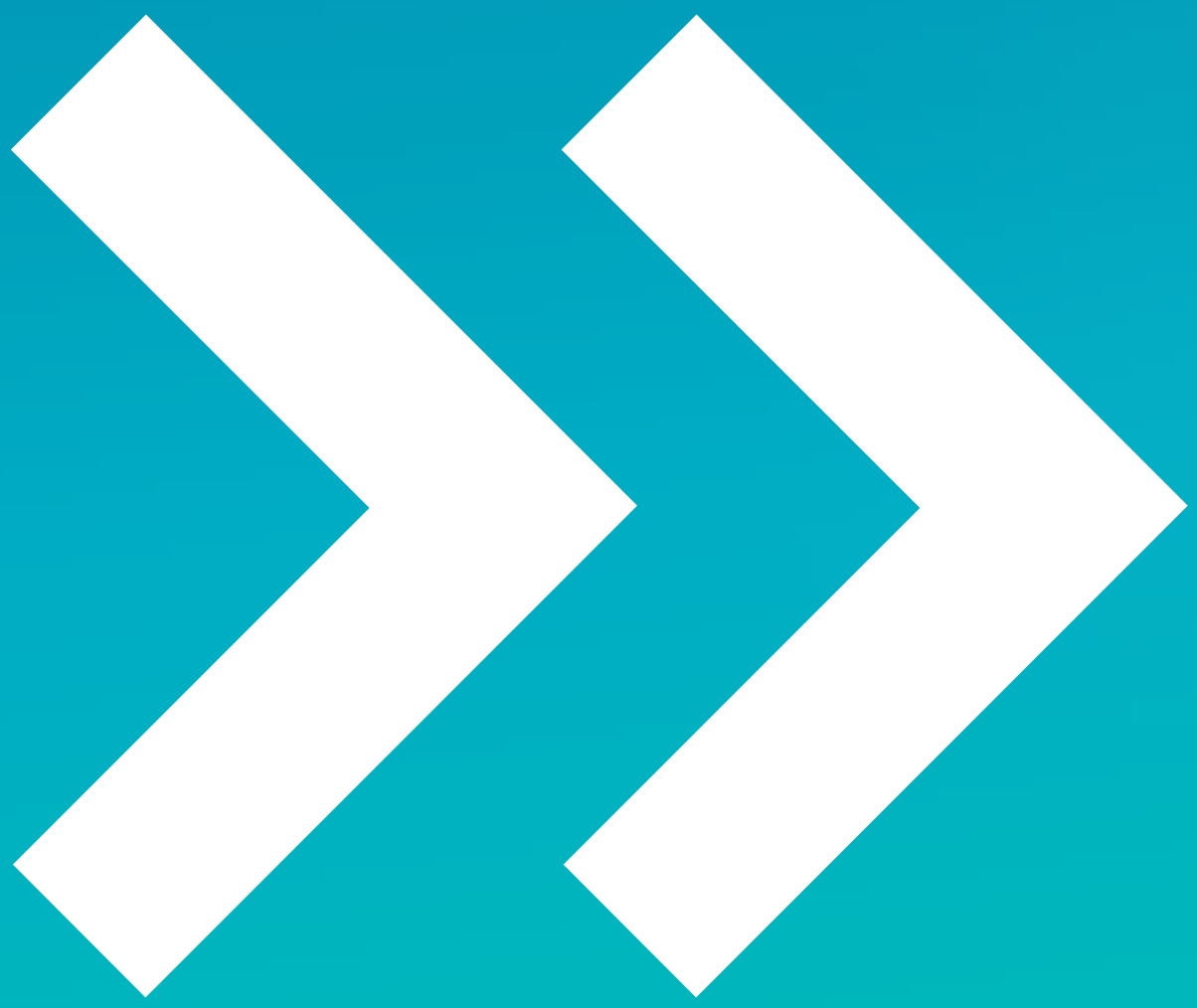
ACHIEVING 'GROWTH WITHIN'

A €320-BILLION CIRCULAR ECONOMY INVESTMENT OPPORTUNITY AVAILABLE TO EUROPE UP TO 2025

SYSTEMIQ

SUN Institute
Environment & Sustainability
Initiated by Deutsche Post Foundation

ELLEN MACARTHUR FOUNDATION



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FOREWORD

The shift from a linear to circular economy in Europe is accelerating by the transitional power of new technology and business models. As the previous report "Growth Within" (2015) pointed out the value chains mobility, building and food- representing 60 percent of the average EU household budget and 80 percent of resource consumption - could contribute significantly to Europe's overall economic performance and welfare by adapting a restorative and regenerative economic system. Circular mobility, building environment and circular food systems offer ground-breaking, attractive innovation and investment opportunities, and the EU is uniquely placed to exploit these. This comes at a time when the EU is in great need of industrial renewal and attractive investment opportunities. Circular economic investments offer resilience and transformation of those assets that otherwise might face being stranded or becoming redundant. However, circular economy investment opportunities have remained unrealized until now.

I am therefore very pleased with the insights that this report "Achieving Growth Within" gives in ten attractive circular innovation and investment themes , totaling €320 billion through to 2025:
- €135 billion in the mobility system
- €70 billion in the food system.
- €115 billion in the built environment

These 'next wave' of priority circular economy investments could realistically be unlocked with modest policy reform or action by industry in the near term.

I endorse the message of this report that increasing investments into the circular economy is a very attractive option for Europe's companies and policymakers. This agenda is hugely synergistic to Europe's social, competitive, regional, environmental and digital agenda. A circular economy system could provide Europe with a new industrial agenda with a clear and positive message.

A European transition would also have impact far beyond its borders: it could create de facto global standards for product design and material choices, and provide other world regions with a much-needed blueprint. This would put Europe's political as well as corporate leaders at the forefront of a major global industrial innovation.

Achieving Growth Within is well-timed and inspiring. I wish you a pleasant reading.

Wiebe Draijer
Chairman Executive Board
Rabobank

IN SUPPORT OF THE REPORT

"The European Commission's circular economy package resulted from a genuine cross-sectoral effort within the Commission, and benefited from fruitful discussions with businesses, NGOs, national authorities and academia. It remains a central political project for Europe, with an enormous potential for renewed competitiveness, innovation and job creation. The circular economy can make a substantial contribution to sustainable development; as well as to some of our major political commitments. We are progressing towards a circular economy; implementing the package and learning with others in the process. Investment is of course a key element here. The environmental community needs to work together with the investment community to ensure that we deliver on the Sustainable Development Goals, the Paris Agreement on climate change, the transition to resource-efficient, circular economies, to halting biodiversity loss and the degradation of our natural capital. This new, inspiring report is a useful and timely contribution to help us focus our efforts and resources on the most promising aspects of the circular economy."

Karmenu Vella, European Commissioner for the Environment, Maritime Affairs and Fisheries

"This report shows clearly how unlocking the significant potential of circular models could be reached within relatively short time. it reminds us policy makers that change doesn't come by itself - but also that major benefits can be realised relatively painlessly with targeted policy moves. Europe needs to be more circular: old, linear ways of thinking, producing and consuming have made us reach the limits of our planet. Once again, this report stands to show that circularity is a win for our environment but even more so, a great win for our economy."

Sirpa Pietikäinen, Member of the European Parliament

IN SUPPORT OF THE REPORT

"The circular economy offers a real opportunity for economic growth and for managing that growth sustainably, making better use of existing assets and space, leveraging technology innovation. We aspire to London becoming the global centre for circular economy leadership by engaging and collaborating with a range of actors in the space. This is becoming an unstoppable movement with a wide range of like-minded organisations coalescing in the city to start demonstrating the impact that circular practice can bring. This report helps to bring focus and clarity to the areas that can have the greatest impact – the potential economic benefits identified to the European economy should make every business leader sit up, take note and join the movement!"

Wayne Hubbard, Chief Operating Officer, London Waste & Recycling Board

"Shifting Europe towards a fully circular economy has been forecasted to provide significant economic, environmental and societal benefits. Achieving this will require investments towards technology and business model innovations. Increasing the capital deployment towards these innovations will require investors, both small and large, to identify these new growth opportunities as well as understand their risks. This report provides new ideas on how to approach this topic for the investment community. PGGM, as founder of a joint working group FinanCE, welcomes this dedicated research very much."

Else Bos, Chief Executive Officer, PGGM

"In a resource constrained environment, Circular economy must become a priority for Europe, and the world. While European investment is still lagging behind since the crisis, banking on the Circular Economy, coupled with the digital transformation, offers a unique opportunity to boost growth, employment and reduce CO2 emissions. Suez believes that the resource revolution will be circular, concrete and collaborative, and has already started to invest in innovative circular water and resource recovery technologies and business models, notably through its corporate venture vehicle. Businesses need to close the loop on resources to become more competitive and protect themselves from resource scarcity and price volatility. This is particularly true in areas such as mobility, food systems, or the built environment. The Achieving Growth Within report provides substantial evidence that Circular Economy is becoming a game changer investment opportunity."

Jean-Louis Chaussade, Chief Executive Officer, Suez Environment

ACKNOWLEDGEMENTS

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SUN Institute Environment & Sustainability (Stiftungsfonds für Umweltökonomie und Nachhaltigkeit GmbH) The Deutsche Post Foundation established SUN as a non-profit organisation in September 2014 in order to strengthen its international activities supporting institutions, programmes, and projects dealing with the challenges and opportunities of globalisation and enhanced cross-border activities. Research funded by SUN aims at developing concepts to reconcile economic needs with ecological reason and social responsibility.

The Ellen MacArthur Foundation
The Ellen MacArthur Foundation was created in 2010 to accelerate the transition to a circular economy. The Foundation works across five areas: insight and analysis, business and government, education and training, systemic initiatives, and communication. With its Knowledge Partners (Arup, IDEO, McKinsey & Co., and SYSTEMIQ), the Foundation works to quantify the economic opportunity of a more circular model and to develop approaches for capturing its value. The Foundation collaborates with its Global Partners (Cisco, Danone, Google, H&M, Intesa Sanpaolo, NIKE, Inc., Philips, Renault, Unilever), and its CE100 network (businesses, universities, emerging innovators, governments, cities and affiliate organisations), to build capacity, explore collaboration opportunities and to develop circular business initiatives. The Foundation has created global teaching, learning and training platforms on the circular economy, encompassing work with leading universities, schools and colleges, and online events such as the Disruptive Innovation Festival. By establishing platforms such as the New Plastics Economy initiative, the Foundation works to transform key material flows, applying a global, cross-sectoral, cross value chain approach that aims to effect systems change. The Foundation promotes the idea of a circular economy via research reports, case studies and books series, using multiple channels, web and social media platforms, including Circulatenews.org which provides a leading online source for circular economy news and insight.

Further information:
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EXECUTIVE SUMMARY

An additional €320 billion of circular economy investment opportunities is available to investors in the European Union (EU) until 2025 that can be unlocked through modest action by policy makers or industry. This investment would put the EU on the path to seize the economic, societal, and environmental benefits of the transition to a circular economy and mitigate the mounting risks that reside in conventional industrial assets in an era of rapid change.

Shifting the EU towards a circular economy that is restorative and regenerative means moving away from today's wasteful use of resources. This transition would bring with it substantial economic, societal, and environmental benefits.[1] The time is ripe as the circular economy has now gained attention within the EU political landscape at the European Commission, Member State, regional, and city level. Additionally, certain corporations and investors are looking to shift towards more circular practices and investments as they realise the enormous business opportunity this presents.

One of the main barriers to fulfilling the true extent of these opportunities is the lack of investment. The circular economy has not yet become a mainstream investment area for the private sector, leaving the transition lacking in funds and therefore risking the realisation of its full benefits. While previous reports[2] have outlined long-term circular economy visions for the EU, this report focuses on identifying the 'next wave' of priority circular economy investments that could realistically be unlocked in the near term, and describes what the EU needs to do to capture them. It has eight key findings:

1 The circular economy offers ground-breaking, attractive innovation and investment opportunities, and the EU is uniquely placed to exploit them. The circular economy enjoys political and business support due to its many benefits for growth, employment, resource dependency, health, and environment. As such, making the transition to it is a key prerequisite in reaching many of the 17 Sustainable Development Goals (SDGs) that the EU officially signed up to in 2015.[3] The circular economy provides a systemic shift in the industrial landscape, including product design, business models, resource flows, and value creation. It offers a different industrial logic that in the future will guide investment in physical and digital products and infrastructures. This shift also points towards the opening up of many attractive innovation opportunities, and will lead to the emergence of novel market segments and companies. It is enabled by, and highly synergistic with, the digital disruption that is now reshaping the industrial landscape, and offering opportunities for sharing, virtualisation, and remanufacturing. Specifically, the EU has the unique combination of scale, integrated markets (notably through the single market), and political and economic institutions that can facilitate an acceleration in the development of the circular economy. If successfully pursued, a transition to the circular economy could become a major source

of innovation and renewal for the EU economy over the next decades, and it could provide the EU with a new joint project to rally around – an important political opportunity for the Union to gain industrial leadership globally in an area that sits at the core of its strengths.

2 This comes at a time when the EU is in need both of industrial renewal and of attractive investment opportunities. The context of circular economy investments is a weakened European economy that has not fully recovered from the financial crisis, with corresponding stagnating industrial investments. Indeed, the role of industrial investments as an economic driver has decreased from on average c.7% of GDP between 2000 and 2009 to 6% of GDP between 2010 and 2015.[4] Post-crisis recovery of EU investments versus other mature markets, such as Japan or the US, is lagging significantly. In addition, since the crisis, returns on capital investments within the EU have recovered only to levels similar to those of 2000. Trying to stimulate demand and investment, central banks have pushed interest rates to record lows, but the 75 largest EU corporates still held 40% more cash in 2016 than in 2010, interpreted by many as a sign of a perceived lack of attractive investment opportunities. This lack of investment seriously hampers the EU's industrial innovation and renewal, its future competitiveness, and it puts Europe's industrial core at risk of slow erosion.

3 Circular economy investment opportunities remain unrealised. There are niches related to the circular economy that enjoy rapid growth in investments, such as R&D for electric vehicles and autonomous cars or space sharing start-ups. However, the majority of circular opportunities, including car remanufacturing, car sharing, anaerobic digestion (AD), organic farming, and building materials reuse, still only constitute <10% of their respective markets, with conventional linear investment making up the remaining 90% to 100%. Waste management, the most 'traditional' circular investment area for which public statistics are available, has seen flat investment levels between 2009 and 2013 (the last year for which statistics are available). Some of the smaller circular opportunities (e.g. sharing of cars and houses) are growing rapidly, and there are also numerous policy successes that could well lead to additional investments (for example, the creation of an organic fertiliser market), but these are exceptions to a general pattern of underinvestment. In many cases, the key reasons seem to be: an uncertainty about which strategic direction the value chain is moving in; a set of policy barriers; transition costs; and, in some cases, a lack of awareness about circular opportunities and their benefits among company executives, who have been raised in a linear economy. The lack of underlying profitability is an issue only in some cases, and therefore does not seem to be the primary barrier.

EXECUTIVE SUMMARY

4 Ten attractive circular innovation and investment themes, totalling €320 billion through to 2025, have been identified and could be unlocked with modest policy reform or action by industry. These themes represent investments in the circular economy that were identified as needing modest intervention to achieve their full potential and to take off at scale. As such, these ten areas are potential innovation and investment 'hot spots' that policymakers and companies should work on jump-starting. They provide a new lens for building high-growth industrial investment portfolios. As can be seen in Figure 1, by 2030, these hot spots could create an additional 7% of GDP growth; reduce raw material consumption by an additional 10%; and reduce annual CO_2 emissions by 17% more than would be achieved within the current development pattern. The ten themes are all in line with the EU's long-term circular economy strategy.[5] They are all fertile ground for innovation: for example, imagine if the EU transitioned its mobility system towards a shared, integrated mobility infrastructure instead of the current single-mode, single-owner system, this would lead to vehicles being designed and built to fit that system; different materials being used and reused; new service and access models; and a data-rich mobility environment in which new apps and systems would emerge to increase efficiency and convenience. The scope of this report encompasses mobility, food, and the built environment, as these value chains represent 60% of consumer spending and 80% of resource use; there are likely to be additional themes and opportunities that lie beyond this scope. However, these areas offer compelling cases:

a. €135 billion in the *mobility* system could be invested in: creating modally integrated shared mobility systems; transitioning to circular car designs; and ramping up the reverse value chain for vehicles through focusing on remanufacturing.
b. €70 billion in the *food* system could be invested in: fully regenerative agricultural practices; closing organic nutrient loops; scaling high-productivity indoor urban farming opportunities; and developing next-wave protein sources.
c. €115 billion in the *built environment* could be invested in: designing and constructing buildings based on circular principles; closing the loop on building construction and demolition materials; and building circular cities.

5 Circular economic investments offer resilience and transformation of those assets that otherwise might face being stranded or becoming redundant. Powerful technology and market trends are underway with the potential to create unprecedented stranded assets across Europe. The shift from a linear to a circular industrial model presents a way to mitigate that risk. Two factors drive the risk of assets and companies being stranded: businesses relying on one-way volume flows (leaving them open to being damaged by higher asset utilisation, materials looping, and the cutting out of intermediaries) and businesses not carrying their environmental costs (this applies to much of the process industry, according to recent estimates). This is particularly the case for capital intensive, long-lived assets such as power plants; the major write-offs in the EU's utility industry over recent years show the

scale of the risk. However, unlike other transitions, the circular transition is more likely to take decades rather than a few years, and if the stranded asset risk is responsibly managed, our belief is that it can largely be avoided. Four principles of 'circular economy-compliant' investment have been developed and are presented in this report. Adopting these or similar principles would provide investors with a more thematic approach to investing not offered by 'modern portfolio theory' (MPT), which is often used to identify a diversified investment portfolio, but typically overlooks risks that run across seemingly uncorrelated assets.[6]

6 Policymakers at the European, national, regional, and city levels should take four roles: setting direction for the transition, removing policy barriers, facilitating cooperation and innovation along the value chain, and shifting public investment towards the ten themes.

a. Setting direction and showing commitment. One of the success factors of the ongoing clean energy revolution is its clarity of direction, something that has been lacking for the majority of the ten circular investment themes. As a result, too many investors take a 'wait-and-see' approach. Therefore, providing such direction is a crucial task for policymakers, be it through targets, strategies, public investments, consistent international trade agreements or industry convening. One implication of setting direction is to strive to level the playing field for circular business models.

b. Removing policy barriers. An inventory of regulatory change requirements to unlock the ten investment themes has been made and is presented in this report. As recent work of the Ellen MacArthur Foundation has highlighted, this includes addressing unintended regulatory consequences that prevent circular economy solutions from taking off, such as the current strict limitations on how food waste may be used or how remanufactured car parts can be utilised.

c. Creating platforms for dialogue, cooperation, and awareness creation. From 2012 to 2014, the European Resource Efficiency Platform (EREP) was widely seen as central to the creation of the European Commission's first circular economy package in June 2014. It acted as an effective mechanism to attract attention, increase knowledge, gather input from relevant stakeholders, develop pragmatic solutions, and build support. Moving forward, we believe similar platforms – ideally separate ones for mobility, food, and the built environment – could serve a comparable purpose. Additionally, creating awareness, in both consumer and producer groups, of the possibilities and benefits of the shift towards a circular economy would be a key enabler.

EXECUTIVE SUMMARY

d. Focus public procurement, public circular economy investments, and existing subsidy regimes towards the ten themes. For example, EU public funding from Horizon 2020 and the European Fund for Strategic Investments (EFSI) currently only partially overlap with the next wave of circular economy investment opportunities. Specifically, directing funds towards the hot spot innovation and investment themes within food and buildings is a major opportunity to increase returns on public investment (whereas there is a better overlap for mobility opportunities). Getting biorefineries, 3D printing of building elements, and urban food farms through the proof-of-commercial-concept phase are good examples of high-return opportunities for public investment. Moreover, providing fiscal incentives for the identified investment opportunities could be an effective way to stimulate investments.

7 Company executives should move early and carve out their role within the ten investment themes, in parallel with scaling back from investments at risk of becoming stranded. Participating in these themes will often require experimentation with new business models and partnerships, as many of the themes require changes from stakeholders along the value chain. Having consulted a wide variety of industrial companies, it is clear that many of them see the promising business opportunities within the ten themes. In the same way that the lean operations lens allowed executives to see a whole new set of improvement options, the circular economy lens most often allows executives to see a new wave of opportunities. Again, generally companies operating within the EU are short on attractive investment opportunities, as their cash build-up signifies. Being a first-mover in this space often allows companies to secure the most attractive opportunities (the so-called 'low-hanging fruit') and as such make the most of profitable business options. In parallel, executives should shift business strategy and investments away from the resource-intensive business models most at risk of getting stranded.

8 The strong synergies between Europe's digital agenda and the circular economy transition should be captured. The digital revolution is a crucial enabler for many parts of the circular economy transition, for example sharing, virtualisation, managing complex reverse logistics chains, and keeping track of valuable assets. At the same time, improving growth and employment – two important effects of a circular economy transition – are the ultimate aims of the EU's digital agenda. Currently, these strong mutual synergies are only partially captured. Specifically, the EU's digital agenda could strengthen three synergy areas, which are further explored in this report: intelligent assets / digital product IDs; open data material platforms; and setting up a measuring and evaluation system to track progress on the circular economy transition.

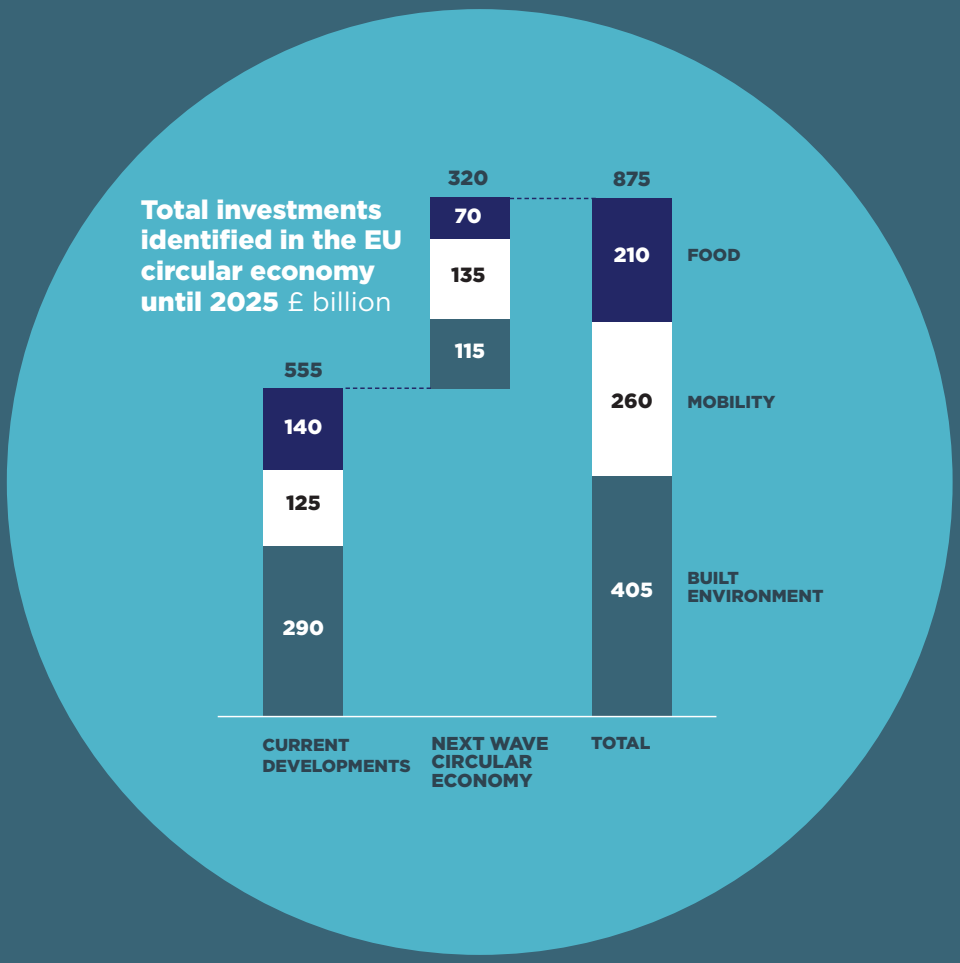
For all these reasons, the conclusion of this report is that increasing investments into the circular economy is a very attractive option for the EU's companies and policymakers, and a very achievable one. This agenda is hugely synergistic with the EU's societal, competitive, regional, environmental, and digital agenda. In terms of size and importance, the opportunity could even compare to the creation of the internal European market, or to a European 'Energiewende' (Germany's revolutionary transition to a low-carbon energy supply). Politically, it could provide the EU with a new industrial agenda that has a clear and positive message.

An EU-wide transition would also have impact far beyond its borders: it could create de facto global standards for product design and material choices, and provide other world regions with a much-needed blueprint. This would put the EU's political, as well as its corporate, leaders at the forefront of a major global industrial innovation.

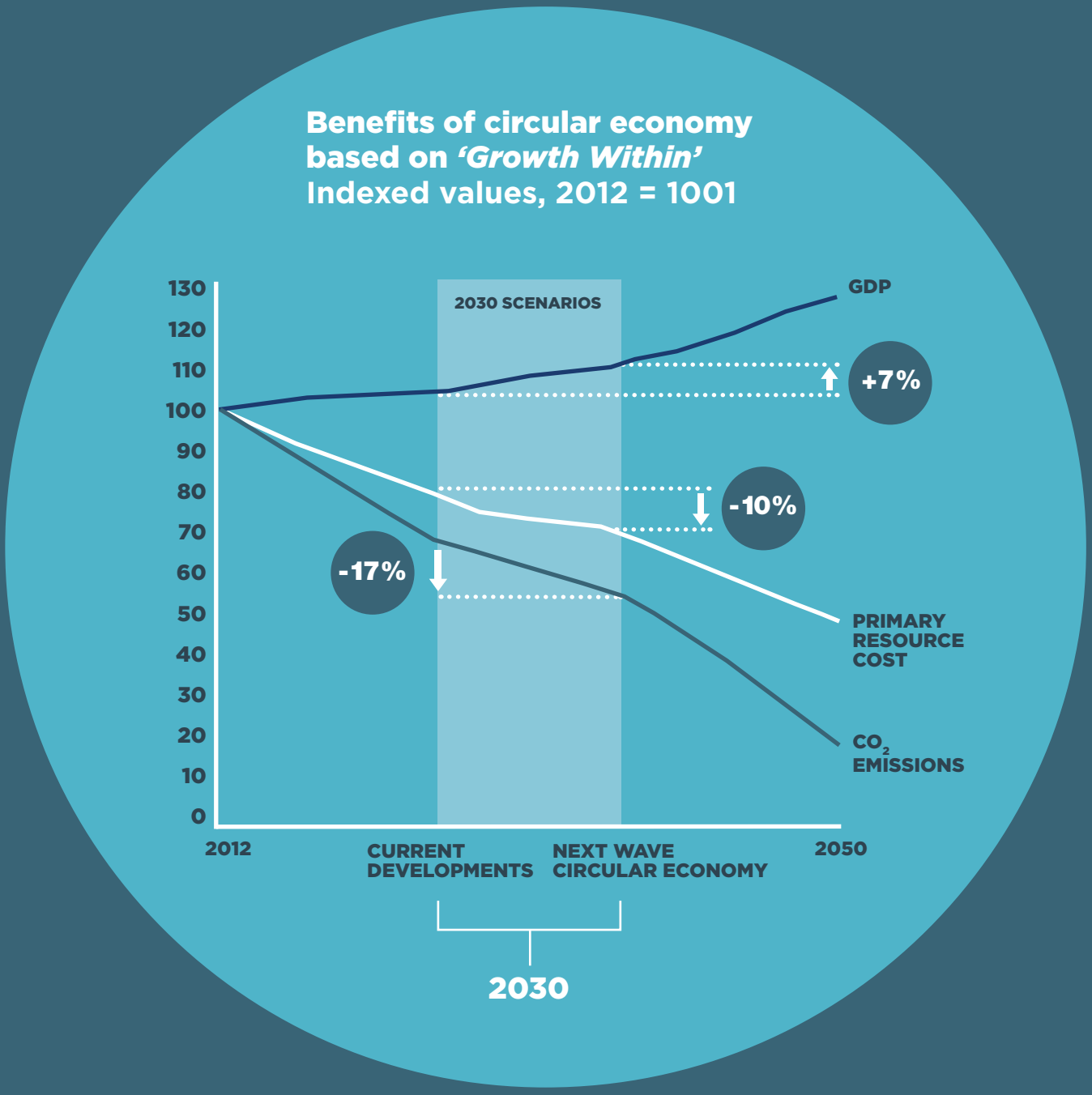
EXECUTIVE SUMMARY

FIGURE 1

INVESTMENTS REQUIRED TO ACHIEVE CIRCULAR ECONOMY BENEFITS



1 Total impact across mobility, food and built environment value chains. 100% of *'Growth Within'* impact assumed to be achieved, even though some levers – most notably dietary shift – are not driven by direct investments.
Sources: *'Growth Within'*; SYSTEMIQ.


Benefits of circular economy based on 'Growth Within'
Indexed values, 2012 = 1001
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2030 SCENARIOS
GDP
+7%
-10%
-17%
PRIMARY RESOURCE COST
CO_2 EMISSIONS
2012
CURRENT DEVELOPMENTS
NEXT WAVE CIRCULAR ECONOMY
2050
2030

MAIN FINDINGS

INDUSTRIAL INVESTMENT WITHIN THE EU: IN SEARCH OF ATTRACTIVE OPPORTUNITIES

The context for circular economy investments in the EU is one where there is a clear need for attractive industrial investment opportunities, and specifically investments that contribute to innovation and renewal, and to the transition towards a more restorative and regenerative economy. In reaching this conclusion, three factors have been considered:

1 Industrial investment in Europe is in a long period of stagnation: investments as a share of GDP are still well below the level seen before the start of the financial crisis in 2008, with absolute EU investment levels only getting back to 2008 levels in 2015 in nominal terms. In comparison, nominal US investment levels were 16% higher and Japanese investments levels 7% higher in 2015 versus 2008. In addition, returns on invested capital have been not recovered to pre-crisis levels at *c.*24% in 2015 compared to *c.*26% on average between 2000 and 2007 (see Figure 2).

The stagnating investments are not due to a lack of available capital: approximately 40% more cash is held on corporate balance sheets across the top 75 largest EU corporates in 2016 than it was in 2010.[7] Despite record-low interest rates, implying record-low returns on holding cash or short-term financial investments, companies seem to increasingly prefer this option compared to making industrial investments within the EU. Industrial executives and investors do not seem to find enough investment opportunities that they consider attractive.[8] They may be right: EU corporates have experienced an average gross profit margin decline of 1.5% over the last ten years,[9] and returns on European equity are projected to decrease from an average of 7.9% return over the last 30 years to 4.5–6.0% return over the next 20 years.[10] The reasons for this vary across industries and countries, but common themes include the EU's weak macro-economic development, high cost of labour, weak demand growth, and high resource prices.

Whatever the reasons, the consequences for the EU economy are serious: the resulting low investment levels significantly hamper the EU's industrial innovation and renewal, and put the EU's industrial core at risk of eroding. This is particularly true in a time of fast change, with ever-shorter product cycles. In the current climate of a slow-growing EU economy, increased investments would also act as a much-needed stimulus.

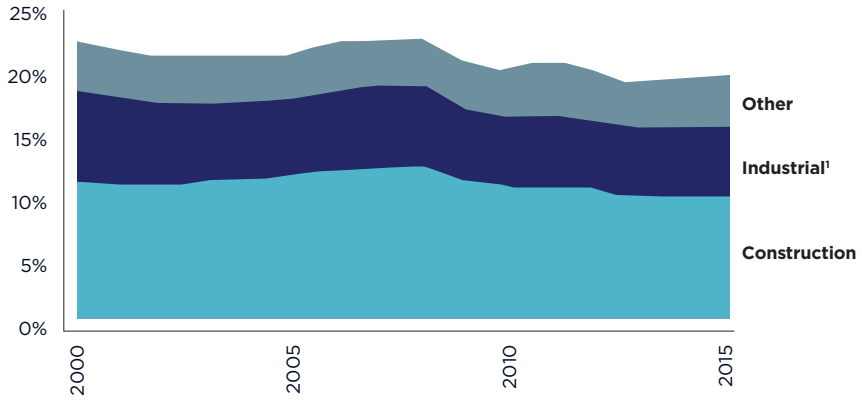
2 Governments in the EU and globally have come to realise that the current direction the economy is heading in is unsustainable, not only in terms of growth but also from an environmental and resource-use perspective. Recent agreements such as the United Nation's (UN) Sustainable Development Goals and the Paris Agreement on climate change have provided objectives, but the strategic direction and associated concrete action plans have yet to be developed, and investments need to shift substantially faster towards sustainable business models and assets than they are doing currently.

3 A digital and broader technology disruption is revolutionising the economy. It has so far primarily transformed information sectors like retail banking, entertainment, and communication, but is now quickly starting to also transform the large physical systems, most importantly food, mobility, and the built environment. Examples include: growing R&D investments in autonomous driving and a shift towards electric vehicles in the mobility sector; increasing use of precision agriculture in the food sector; and 3D printing and modular building techniques in the built environment. The technology disruption will change these value chains quickly and fundamentally, whether the EU wants that or not. Given this, perhaps it is better to use the disruption as a tailwind to transition to a more restorative and regenerative economy?

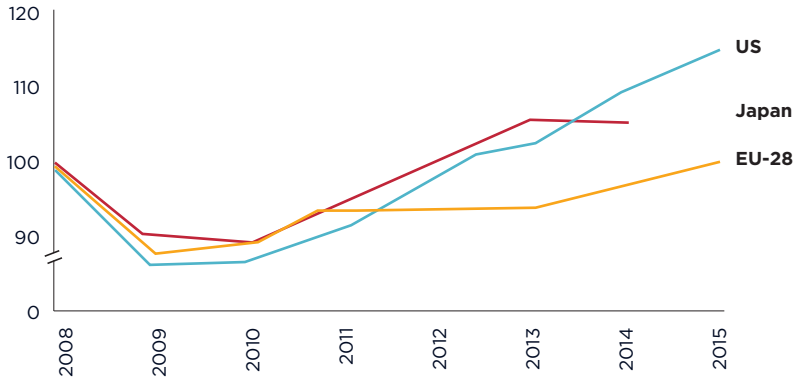
So, in summary, the current context of industrial investment in Europe is one where good sustainable investment opportunities are scarce and urgently needed.

FIGURE 2 **HISTORICAL INVESTMENT LEVELS AND INVESTMENT RETURNS IN THE EU**

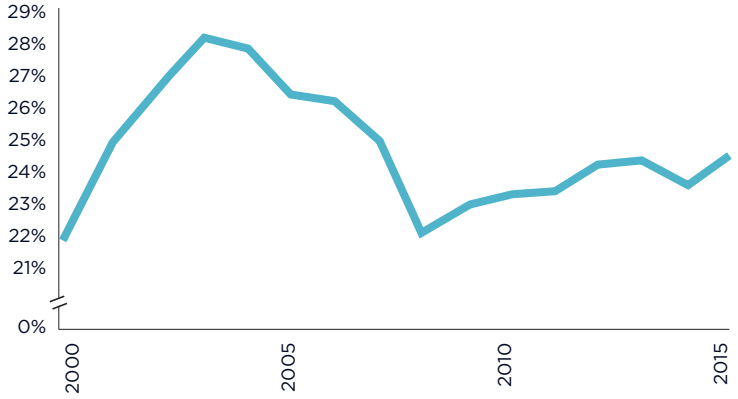
EU-28 investments as share of GDP



EU-28 investments since financial crisis versus Japan and US
2008=100



Euro area return on capital employed before tax[2]



1 Using investments in machinery and equipment as a proxy for industrial investments.
2 Return on capital employed for non-financial corporations; EU-28 data unavailable.
Sources: Eurostat; OECD; SYSTEMIQ.

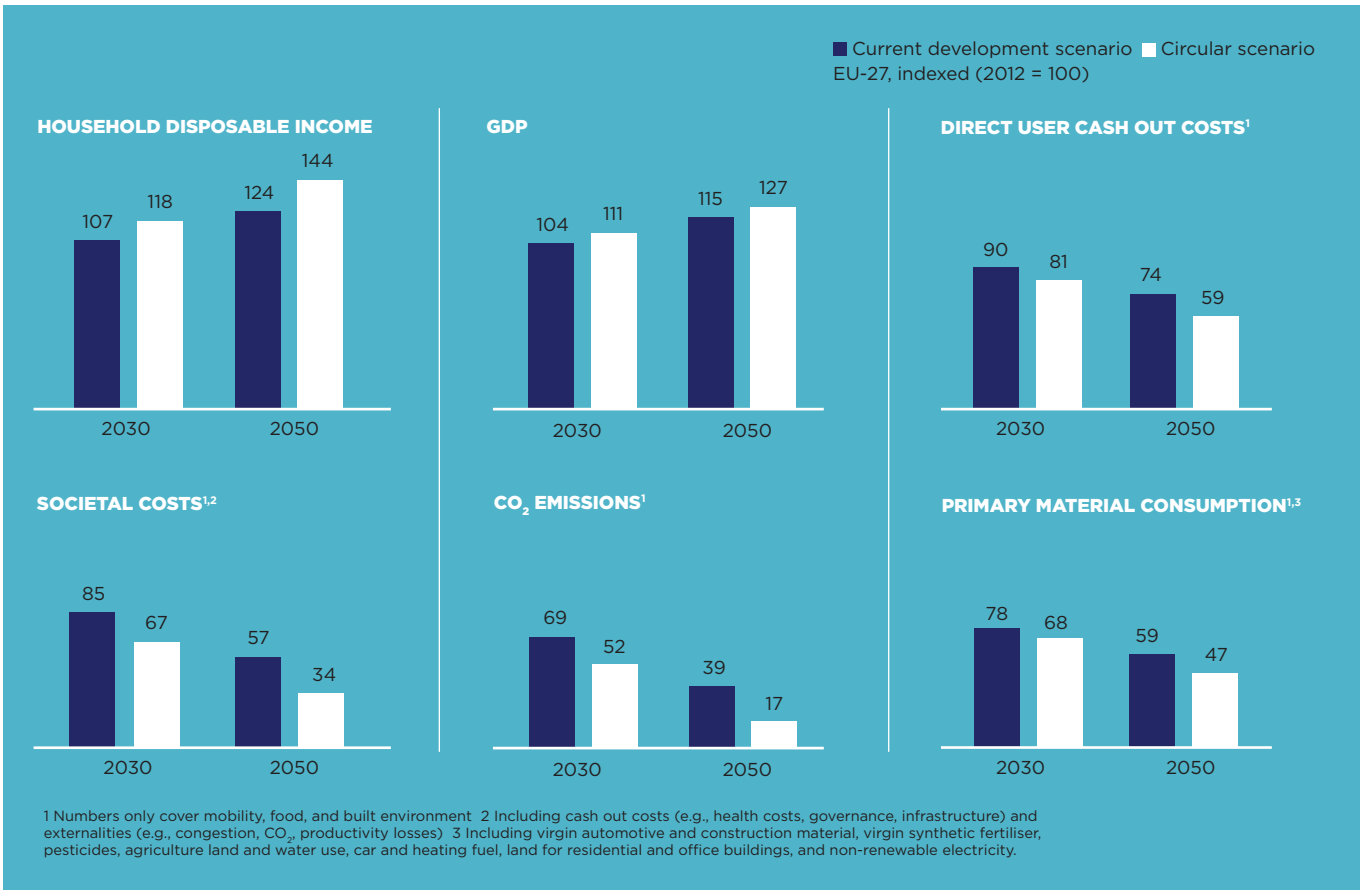
>> MAIN FINDINGS

The circular economy offers a new, sizeable, and attractive area for industrial innovation and investment

In this context, the circular economy offers a new innovation investment theme that, if mobilised across the EU, could arguably become one of the most attractive structural reform opportunities available at this point. A substantial body of research has emerged over recent years, highlighting the benefits of a circular economy for economic growth, reduced greenhouse gas emissions, reduced resource supply risks, improved trade balance, health, and employment. Institutions that have shown this include, but are not limited to: Club of Rome, Cambridge Econometrics & BIO Intelligence Service, the Netherlands Organisation for Applied Scientific Research (TNO), The Waste and Resources Action Programme (WRAP), and the Green Alliance. Specifically, the 2015 *Growth Within: a circular economy vision for a competitive Europe* report delivered by the Ellen MacArthur Foundation, McKinsey&Company, and the SUN Foundation, which is in many ways the precursor to this report, identified a broad set of benefits offered by a circular transition as shown in Figure 3.

In recognition of these benefits, political leaders in the EU, as well as

FIGURE 3 **BENEFITS OF MOVING TOWARD A CIRCULAR ECONOMY ACCORDING TO *'GROWTH WITHIN'***



1 Numbers only cover mobility, food, and built environment 2 Including cash out costs (e.g., health costs, governance, infrastructure) and externalities (e.g., congestion, CO_2, productivity losses) 3 Including virgin automotive and construction material, virgin synthetic fertiliser, pesticides, agriculture land and water use, car and heating fuel, land for residential and office buildings, and non-renewable electricity.

many Member States, are pursuing the circular economy. In June 2014, the European Commission adopted its initial circular economy package with a revised version being adopted in December 2015. The package consists of a circular economy action plan and revised legislative proposals on waste management. The action plan contains measures covering the whole cycle (from production and consumption, through waste management, to markets for secondary raw materials). The revised legislative proposals on waste management provide clear targets for the reduction of waste and improved recycling rates, as well as establishing a long-term path for resource management (e.g. promoting reuse and stimulating industrial symbiosis). The Commission has also put in place financial support mechanisms for circular economy investments, with funding for waste projects coming from the ESIF (€5.5 billion), from the Horizon 2020's 'Industry 2020 in the circular economy' initiative (over €650 million), from the Programme for the Environment and Climate Action (LIFE, €223 million), as well as from supporting programmes such as the European Fund for Strategic Investments (EFSI) and Competitiveness of Enterprises and Small and Medium-Sized Enterprises (COSME). Concurrently, the Commission is progressing on several circular initiatives, such as the creation of a market for organic fertilisers.

In addition, several Member States are moving towards defining their circular economy strategy. For example, the Netherlands has positioned itself through the Netherlands Circular Hotspot campaign during its EU presidency in Spring 2016 and created its 'Circular Economy in the Netherlands by 2050' plan; Finland has published an ambitious roadmap to the circular economy; and Scotland has presented its circular economy strategy through its February 2016 *Making Things Last* report, as well as setting up an investment fund geared towards the circular economy through Zero Waste Scotland. In fact, the circular economy as a topic on the political agenda across the EU seems to have more momentum than the climate change agenda had during the early 2000s. But is it also a sizeable and attractive transformation theme for industry? The conclusion of this report is that it is. Circular business models imply significant shifts for many companies and industries, in everything from R&D to product design, purchasing, customer relationships, marketing, and value proposition. It is relevant to almost all industries that are based on physical products. As such, it is clearly a significant shift and the €320 billion of additional investment opportunity comes on top of a €555 billion investment in circular economy areas that is poised to happen due to current development trends. In total, this makes for an opportunity of €875 billion, or about 33% of the total investments in the studied systems. Moreover, as circular markets scale-up, this share will surely grow.

Alongside offering sizeable investment opportunities, the underlying business opportunities based on circularity principles also provide an estimated market opportunity of €150 billion per annum through to 2025, mainly in markets that typically generate between 10% and 20% Earnings

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Before Interest, Taxes, Depreciation, and Amortisation (EBITDA) margins.[11] Importantly, the circular investment opportunities pass a number of filters applied by executives when making investment decisions, most notably consistency with sustainability goals, digitisation as a driver for growth, following policy direction, and providing access to innovative technologies and business models.

The broader circular economy is currently underinvested

Although there are tangible changes towards a more circular system in specific pockets of the economy, such as electric vehicles and the sharing economy as described above, total investment levels in the circular economy are generally far too low to put the EU onto a circular economy pathway. Investment in the waste sector, typically the most embedded circular sector, have been stable or slightly decreasing between 2009 and 2013, the last year for which EU-wide figures are available.[12] This is despite the large amount of EU funding that has gone into this area.

Looking at broader circular opportunities, such as circular design of cars and buildings, food nutrient recovery or car remanufacturing, the picture that emerges is that circular investments are still less than 10% of linear investments. As can be seen in Figure 4, some niches are growing fast, primarily electric vehicles and the sharing economy: car sharing is growing by 25% per annum[13] and Airbnb recently surpassed the total hotel sector in number of rooms added over the last year. Indeed, these circular growth areas across the mobility, food, and building systems have provided investors with substantial investment opportunities. For example, Airbnb has so far raised US$2.4 billion in equity funding.[14] However, these are fast-growing exceptions against a broader trend of single-digit growth in many of the most obvious circular markets.

So, while there are exciting pioneers in almost every segment as described above, they are so far marginal in size. This is not a problem per se – any transition needs to start somewhere and renewable power technologies, that now correspond to more than 50% of all power generation investments worldwide, were at a similar place 15 years ago. But what is worrying is that the circular investments do not scale very fast, beyond individual niches, and that few industrial companies and financial investors have made circularity a mainstream investment area.

Our interviews and discussions have revealed four major reasons for this:

1 **The systemic nature of the circular transition and associated transition costs.** Typically, ramping up circular business models is different from ramping up a linear business model, in that it is not simply a matter of launching a new product or using a new technology to improve efficiency. It nearly always necessitates redefining roles along the value chain, for suppliers as well as customers. For example, remanufacturing requires securing sufficient supply of end-of-life material at predictable volumes and quality on the one hand, while finding customers willing to take the remanufactured parts or materials on the

FIGURE 4 **CIRCULAR ECONOMY INVESTMENT LEVELS ASSESSMENT**

CATEGORIES	SHARE OF TOTAL MARKET SIZE FOR INDICATOR MARKETS[1]		ANNUAL GROWTH CIRCULAR BUSINESS MODEL[2]	
	LINEAR BUSINESS MODELS	CIRCULAR BUSINESS MODELS		
CAR SHARING	100%	<1%	›››	25%
OFFICE SHARING	100%	<1%	›››››››››	80%
ELECTRIC VEHICLES (EVs)	99%	1%	›››››››››››	100%+
CAR REMANUFACTURING	99%	1%	›	3%
RESIDENTIAL SPACE SHARING	98%	2%	›››››››››››	100%+
ONLINE GROCERY SHOPPING	97%	3%	›››	25%
ORGANIC FARMING	95%	5%	›	5%
ORGANIC WASTE PROCESSING	95%	5%	»»	10%
BUILDINGS RECYCLING	91%	9%	›	6%
ALUMINIUM USAGE IN CARS	90%	10%	›	3%

1 % of total cars for sharing, % of office workers at co-working areas, % of EV registration for total car registration, % of total material for remanufacturing/recycling, % total hotel rooms occupancy for space sharing, % of grocery shopping for online shopping, % of total hectares agricultural land for organic, % of total waste arising for waste processing, % of construction waste recovered, % of total material per car for aluminium.
2 Depending on data availability, based on between 1 and 10 years of historical data.
Sources: ACEA; McKinsey&Company; Oakdene Hollins; Airbnb; Planet Retail; BCG; Wards Auto; Volkswagen; Reuters; European Commission; OWS; Eurostat COFOG and SBS; SYSTEMIQ.

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other. Likewise, shifting to regenerative agricultural practices means not only securing the required inputs, but also ensuring there will be sufficient offtake for the products at the right price point.

Investing in the circular economy is different from other 'new' investment areas, such as clean-tech; the latter has generally been a technology play focused on the speed of cost reduction, whereas investing in circular businesses is mainly a systems play. Although circular opportunities can use innovative technology, in many cases proven technologies can be employed initially with additional technologies being included as and when these reach sufficient maturity. For example, designing and producing circular cars or buildings can be done using materials and technologies available today, while further innovations, such as incorporating autonomous driving could be included in the production process over time. Therefore, the initial investment risk is less a technology risk, but rather a system risk.

2 **Uncertainty about the direction.** While many companies buy into the attractiveness of a circular end state for their value chains, and for the economy at large, they still feel uncertain about if, and when, the transition will happen. Unlike for clean energy, the race is not seen to be on and hence companies are not willing to go 'all in' the way they know they need to for solar PV, batteries or wind technology. Overall, this uncertainty is amplified by the raw material bust. The World Bank's non-energy commodity index increased on average by 7% per annum during the 2000–06 period, to a high of 13% per annum during 2009–11 in the middle of the resource boom, but has since decreased by -8% per annum until 2015. This has reduced the perceived urgency and importance of the overall transition. But also at a local level, if cities convincingly signalled they were fully committed to making local mobility systems integrated and shared, this would do wonders for the local investment appetite. Similar examples could be given for many of the other themes.

3 **Policy barriers.** Although our research has shown that the main barriers for initial scaling of circular business models are typically not policy changes, there are still many complex policies that increase (real or perceived) complexity and cost, and therefore hold back the progress of circular models. This is true for food waste, remanufacturing, sharing models, and many other areas.

4 **Mindsets and lack of awareness.** In many cases, the main players relevant to a specific circular business opportunity lack awareness of the costs and benefits that shifting to a circular business model would bring. Examples include 54% of UK car repair shops not having heard of remanufacturing,[15] many farmers not knowing in detail what the benefits are of shifting to more regenerative practices, and the building construction market generally being conservative when it comes to moving to innovative business models. Often in addition to awareness creation, a lack of the skills and capabilities needed to implement circular business models further hampers the ramp-up of the transition.

Nevertheless, importantly most companies consulted could still identify plenty of circular opportunities with a sound underlying profitability, once the initial transition costs have been amortized. Regenerative farming practices can generate similar, if not higher, profits than conventional practices;[16] designing and producing for prolonging and looping is often profitable, even if in some cases this implies higher production costs, as it opens up potential new revenue streams and some emerging customer segments are likely to be willing to pay a premium because the product has a higher value to them;[17] and the market for producing premium food products continues to grow,[18] providing profitable market segments for produce from indoor vertical farms or next-wave protein sources.

Ten new circular investment themes representing a total of €320 billion up to 2025

Building on the research carried out for the 2015 *Growth Within* report, the research for this report also focused on the three main human needs that together account for 60% of EU household spend and 80% of resource use – mobility, food, and the built environment. Using the trends and projections pinpointed for 'Growth Within' across these three systems, ten circular investment themes were identified using the following three-step approach:

1 Translate the *'Growth Within'* circular economy scenario for each of the three systems to a set of well-defined innovation and investment areas.

2 Prioritise these innovation and investment areas according to the likelihood of realisation by 2025.[19] As is shown in Figure 5 below, three categories were used:

a. Areas that are about to materialise already in a 'current development' scenario, for example a certain growth in car sharing. The project did not focus on these areas as they are expected to happen anyway.

b. Areas that could be unlocked through what we judge as modest policy or industry interventions. We judge these interventions as entirely achievable by 2025, and crucially realistic enough for policymakers and companies to spend time on and invest in. We call these 'next wave' circular economy investments and these are the focus of this report.

c. Areas that are further out in time, requiring multiple policy changes, uncertain technology advancements or fundamentally redesigned value chains. The project did not focus on these areas as they are not expected to happen in a material way within the time horizon analysed.

3 Each of the ten innovation and investment areas that fell into the 'B' category was then explored in depth including quantification of its possible size, a literature review, and multiple interviews with 50+ relevant experts.

The ten investment themes across the mobility, food, and built environment systems can be seen in Figure 6 below. Each of these themes includes one or more investment opportunities, the details of which can be found in the appendix. Taken together, a total capital deployment

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FIGURE 5 **INVESTMENT THEME FEASIBILITY FRAMEWORK**
Increasing level of risk reduction required before opportunity becomes investable at scale

	A	B	C
DESCRIPTION	Businesses and projects that currently receive substantial investments and are the main driver of the CE transition	Businesses and projects that receive limited investments today as these are just outside the private capital investment space These opportunities require 1 – 2 interventions to become investable	Businesses and projects that receive no/very limited investments today as these require substantial risk reductions to become attractive at scale
INTERVENTION REQUIRED TO MAKE INVESTMENT-READY	None	Maximum one additional government support scheme, and/or; Maximum one new value chain collaboration initiative	Multiple government support schemes or; Using unproven technology or; Consumer/ government acceptance deemed highly unlikely in the near-term
RISK/RETURN PROFILE	Low	Medium-High	High; mainly outside of private capital focus
EXAMPLES	Taxi/ car/ ride sharing companies Small-scale urban farming projects Shared office space Organic farming *Opportunities in the current development' scenario in* 'Growth Within'	Integration of vehicle sharing with public transport Transitioning to regenerative farming practices **Next wave circular economy opportunities** *Opportunities in the 'circular' scenario in* 'Growth Within'	Integrating fully autonomous driving vehicles made with highly durable materials Integrated E2E local supply chain leveraging blockchain of IoT/ effective tracking system with almost zero waste **Circular economy transition accelerated**

Source: SYSTEMIQ

FIGURE 6 **DESCRIPTION OF NEXT-WAVE CIRCULAR ECONOMY INVESTMENT THEMES**

		DESCRIPTION	CASE EXAMPLES	INVESTMENTS UP TO 2025[1] € BILLION
MOBILITY	Integrating mobility systems	Fully integrate the public transport system with shared vehicles	DriveNow, switchh, MAAS GLOBAL SOLUTIONS	100
MOBILITY	Designing and producing circular cars	Design and produce zero-emission cars made for looping with durable materials	BMW, UBER	35
MOBILITY	Remanufacturing car parts	Rollout remanufacturing of car parts at scale	RENAULT, AUTOCRAFT, Li BALANCE	1
FOOD	Deploying regenerative agricultural practices	Shifting towards an agricultural system that regenerates the soil and revitalises ecosystems	MilkFlex	15
FOOD	Closing nutrient loops	Scaling nutrient and energy recovery from various waste streams using anaerobic digestion or biorefineries	CONSORZIO ITALIANO COMPOSTATORI, HARVEST POWER STORE, CSS	10
FOOD	Farming through indoor urban farms	Scaling hydroponic, aquaponic, and aeroponic farms in urban areas	AeroFarms, UF, AGRICOOL	45
FOOD	Developing next-wave protein sources	Develop new and efficient sources of protein from vegetables, bacteria, algae or insects	BEYOND MEAT, innovafeed	2
BUILT ENVIRONMENT	Designing and producing circular building	Design and produce multi-usage highly modular and energy positive buildings made of durable non-toxic materials	LIVING BUILDING CHALLENGE, Ministry of Environment and Food of Denmark, PARK 20|20	105
BUILT ENVIRONMENT	Closing building loops	Ramp up recycling and re-manufacturing of building materials	GYPSUM RECYCLING, danogips	2
BUILT ENVIRONMENT	Developing circular cities	Integrate circularity into urban developments through innovative business models	EcoDistricts	10

CROSS-CUTTING OPPORTUNITIES: DIGITAL INNOVATIONS (IOT, APPLICATIONS, ANALYTICS); MATERIAL TRACKING SYSTEM THROUGH SECONDARY MATERIAL MARKET

1 Total investments by system and across systems have been rounded to nearest €5 billion throughout the report.
Source: SYSTEMIQ.

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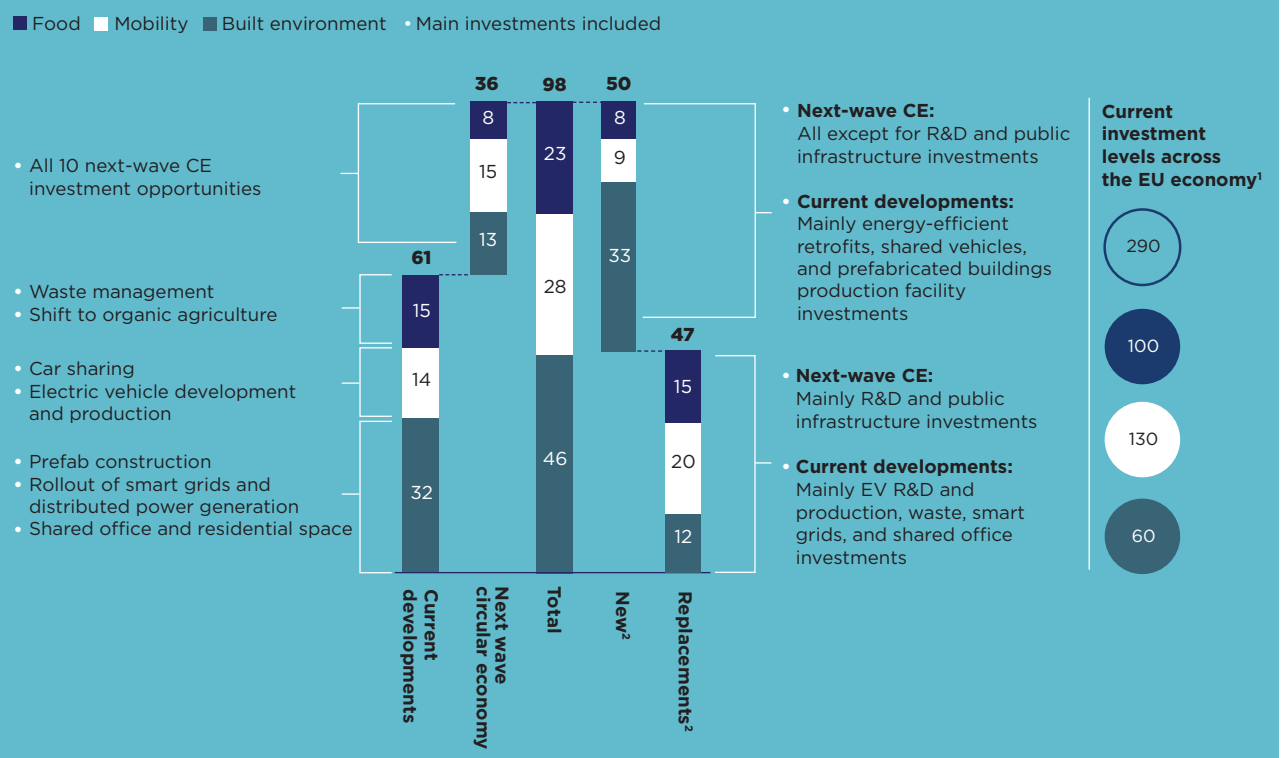
FIGURE 7 **CIRCULAR ECONOMY INVESTMENT IDENTIFIED**
Average annual investment identified until 2025, € billion



1 Defined as 'gross capital formation' for government investments and 'gross investment in tangible goods' for private sector investments.
2 New investments defined as investments in a fully new asset class or investments in new assets that compete directly with existing production facilities. Replacements defined as those investments which will most likely come from existing capex budgets.
Sources: Expert interviews; internet search; Eurostat COFOG and SBS; EC agriculture data; SYSTEMIQ.

potential of up to €320 billion, or €36 billion on average per annum, by 2025 has been identified across these ten themes. This is on top of an estimated €61 billion investments on average per annum in current developments ('category A') as can be seen in Figure 7. If this total of €98 billion per annum until 2025 materialises, the EU will move onto a circular economy transition pathway.

Investing $135 billion until 2025 in a Circular Mobility system[20]

The current trends in electric vehicle rollout, vehicle sharing growth, and R&D in autonomous cars will lead to a more shared, interconnected, and cleaner transport system in the future. Although this would shift the mobility system towards greater circularity, additional potential benefits are left untouched. Setting up modally integrated transport systems with closed-loop cars, based on circular design principles, could further increase vehicle lifetime and utilisation, grow the use of public transport, and reduce the need for virgin materials to produce vehicles. To achieve this, three investment and innovation areas have been identified that the EU can realistically act on before 2025 and that would unlock a total of up to €135 billion in investment.

1 First, the full integration of shared vehicles with urban transport systems would not only make the sharing of (clean) vehicles more attractive, but also spark the development of new journey optimisation apps, payments, and traffic optimisation systems. This would require investments in the adaptation of public transport infrastructure, for example the construction of "modal" drop-off and pick-up points and preferred lanes for shared vehicles. The total capital deployment potential between the vehicle fleet build-up and (digital) infrastructure construction is estimated to be €100 billion by 2025. Some early pilot projects on modal integration exist across the EU, such as the DriveNow partnership with Arriva in Copenhagen. However, to scale this investment theme, city and national governments would need to set the right conditions for shared vehicle companies and other relevant private funders and operators to invest in this integrated model. This could be done by supplying the necessary transport infrastructure based on modal integration principles, as well as providing the private sector with the required incentives, for example through tenders or direct procurement of shared vehicles used for modal integration. Close collaboration between private and public sector organisations would be essential for a fast growth of this investment theme.

2 Second, designing and setting up production lines for remanufacturing of cars using high-value, durable materials is required to prolong the lifetime of cars and allow for end-of-life looping of materials. Currently, innovative materials are used by most car manufacturers but with limited scale; for example, Renault is known to be focusing part of its R&D budget on materials for greater durability, such as high-quality and thinner steel, aluminium chassis and powertrain parts, magnesium body panels, in addition to serial production solutions like plastic fenders.[21] Through the strong growth in shared cars, a new sizeable market segment suitable for more durable cars that sell at a premium is opening up, Ford is moving into this segment as it has recently announced it is developing autonomous cars specifically for sharing.[22] Companies managing a fleet of shared vehicles[23] are likely to value durability more and have longer payback time requirements than individuals. These companies could provide a market for higher priced cars that have enhanced lifetime benefits. For investors to deploy capital in this opportunity of up to €35 billion by 2025, car developers would need to collaborate with car sharing companies to create the commercial conditions required to attract the capital for R&D and setting up of new production lines. A relevant example of this is General Motors investing US$500 million in Lyft in January 2016 to push the development of autonomous, on-demand cars.

3 Third, a ramp-up in remanufacturing capacity and associated investments is needed. The EU currently has an automotive remanufacturing market estimated at €7.4 billion,[24] mainly comprised of small facilities that serve local car manufacturers, with a limited number of Original Equipment Manufacturers (OEMs), such as

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Renault or Bosch, active in this space. Doubling that market by 2025 would put the EU onto a circular transition pathway, which would require up to €1 billion of investments during that time. As remanufactured car parts can be cheaper than newly manufactured parts and can typically provide the same quality level, the main risk for potential investors looking to deploy capital in remanufacturing plants is the deficit of sufficient customers (garages) willing to buy the parts. A combination of lack of awareness of the cost and benefits of remanufactured parts and concerns over reputational risk when using remanufactured parts prevents this market from scaling. Limited availability of efficient markets for secondary automotive parts will also make it difficult to achieve scale. Therefore, for this opportunity to become investable in the next few years, collaboration networks between car manufacturers and remanufacturers are needed in order to agree on quality standards, provide attractive economics for both parties, and set up efficient reverse logistics processes. Also, car insurers could play a role in scaling these activities as quality remanufacturing offers an opportunity to drive down the costs of claims. This would have to be done in parallel with creating markets for end-of-life parts based on standardised quality measures for parts, which should result in an increasing volume of parts becoming available.[25]

Investing €70 billion by 2025 in a circular food system[26]

The food system is being changed through the 'precision agriculture' revolution driven by fast digital developments across Big Data analytics, robotics, and the Internet of Things (IoT), and in parts of the world it is also starting to be changed by policymakers recognising that current agricultural practices are deeply unsustainable (specifically around freshwater use, nitrogen and phosphorous flows, and soil depletion). Although EU governments have focused on shifting away from sending (food) waste to landfill, investments in waste management have been flat over the last five years.[27] A further four investment themes have been identified across the food system all of which could realistically be unlocked in the EU by 2025.

1 First, shifting beyond organic farming to regenerative agricultural practices[28] would attract multiple new funding opportunities. Although the EU's agriculture sector has been transitioning towards organic farming at a rate of on average 0.5 million hectares (ha) per annum, the combination of a faster ramp-up and a stronger shift to fully regenerative practices is needed. There are currently companies active in this space, such as Volterra in Spain or the Balbo Group in Brazil. However, most farmers are unaware of the benefits and costs (such as equipment purchases and obtaining of skills) of moving to these systems and therefore the shift is not happening at scale. Transitioning to these practices may well lead to reduced profitability for the first 2–4 years, depending on the type of agricultural practice used, but after this initial period, profit levels could be up to 200% higher than before.[29] Therefore, the investment of up to €15 billion by 2025 needed to finance the transition

consists not only of investments in specific equipment and machinery, but also of providing bridge finance during those initial years. Redirecting existing support mechanisms for EU agriculture such as the Common Agricultural Policy (CAP) through future revisions to favour regenerative practices and create awareness programmes for farmers would be an efficient way of accelerating the transition. Companies up the food value chain, such as large food retailers, could also actively encourage farmers to switch.

2 Second, substantial infrastructure investments are required to shift away from landfilling or incinerating organic waste, to obtaining higher value from these waste streams through the extraction of nutrients and energy recovery from organic waste. Currently, this is generally carried out via anaerobic digestion, which at a capacity of 7.5 million tonnes per annum (MTPA) feedstocks[30] – mainly across Germany, Switzerland, UK, and the Netherlands – only addresses a fraction of the total estimated organic waste volume of c.150 MTPA.[31] In addition, pilot projects for biorefineries that take organic waste as feedstocks, with the aim of producing high-end chemicals or proteins, are being developed across the EU. For example, in Denmark the SUBLEEM generic biorefining pilot aims to extract high-value products – such as proteins, peptides, oils, soluble fibres, peptides, and saponins – from excess biowaste, e.g. sugar beet leaves, beach cast, and residues from beer production. For these organic waste processing facilities to become investable at up to €10 billion until 2025, it would be key for governments to provide stable, large volumes of organic waste for feedstocks, through the mandating and managing of waste separation and collection. Moreover, government financial support would be needed temporarily to allow for further capital expenditure and operational expenditure reduction in anaerobic digestion plants, as well as to provide proof-of-concept for biorefineries. The European Commission has taken initial steps on the policy front through the creation of an EU-wide organic fertiliser market as part of the implementation of the circular economy package. Further policy support would be required over time, such as allowing complete proteins recovered from organic waste to be used for human consumption.

3 Third, the drive towards more resource-efficient food production will attract agriculture technology investments through the rollout of indoor vertical urban farming, which uses high-tech to produce mainly fruit and vegetables efficiently. Initial commercial success has been shown by US-based AeroFarms who manage over 100,000 square feet of indoor urban farms across Newark, New Jersey and who have raised US$90 million in debt and equity over recent years from venture capital investors, as well as banks.[32] Some initial indoor farm pilot projects are being created in the EU, for example the UrbanFarmers UF002 De Schilde in The Hague, Netherlands. Currently, the economics of indoor urban farms are not sufficiently positive without some form of government support, such as reduced rents, long-term energy price guarantees or direct financial support. However, the AeroFarms example shows that if the right government support is put in place, private investors are willing to

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provide the majority of the required capital.[33] Also as the (digital) technology used matures and operators gain experience, the cost of operating these innovative farms will further decrease, further de-risking the estimated investment opportunity of up to €45 billion by 2025

4 The fourth and final investment theme in the food system is to develop next-wave sustainable protein sources. Investment opportunities in this area of up to €2 billion by 2025 consist of investments in technologies and companies that create complete protein sources, such as animal feed in processed food or as food for direct human consumption. Next-wave protein sources range from seaweed and insects to microalgae and vegetables, all offering higher resource efficiency versus conventional protein sources. As shown by InnovaFeed, a French company focused on producing insect-based farmed fish feed, next-wave protein sources could provide an attractive new investment opportunity to develop its agro-industrial model and scaling production in Europe. The main issue holding back faster growth in this area is the need for proof-of-concept at scale for the underlying technologies – which is why it is currently mainly an area for venture capital investors – while legislative change to allow different protein sources in the human food chain would be required for scale-up.

Investing €115 billion by 2025 in a circular built environment[34]

The built environment is currently being disrupted by a very strong growth in sharing of offices and residential space, and net-zero energy buildings are scaling fast. There are also emerging and potentially disruptive trends around 3D printing of the building exterior, and more modular building techniques. If scaled up sufficiently by attracting the required investments, these trends would shift value from the construction process and energy suppliers, to real estate managers who excel at getting value out of existing buildings and deep retrofits.

1 First, in order to scale up the required circular business models in the built environment, the buildings construction sector would need to see an increase in investments in new production facilities. This would facilitate the ramp-up of the number of new buildings with modular design and adaptable to different uses, and the development of building materials that are designed for end-of-life reuse, as well as technologies aimed at making these buildings energy-positive. A good example of this is Park 2020 in the Netherlands, which is developed by the Delta Group based on cradle-to-cradle principles using designs that bear the reuse of materials in mind.[35] Modular design of buildings is already happening across the EU, but further change to building design is required, such as the removal of toxic materials in order to allow for reuse and the utilising of innovative technologies, e.g. 3D printing for construction. In addition, although new buildings currently are highly energy efficient, driven by the Energy Performance of Buildings Directive, a further shift towards energy-positive buildings is required. This would need combined investments of up to €105 billion by 2025 in R&D, new construction

facilities to produce prefabricated and modularised buildings, and the additional construction costs to make buildings energy-positive. However, two main risks exist that prevent this from happening: the business case for selling circular buildings is typically too risky due to high upfront costs and due to fragmentation in the construction sector. This fragmentation does not provide a solid basis for end-of-life material value extraction due to split incentives, high transaction costs, and lack of the necessary capabilities and skills. This can be mitigated by shifting to performance-based or service-based business models where buildings are rented or leased. However the business case for these models comes with other risks due to new pricing structures and longer investment payback times. A way to overcome this is for design companies, construction companies and other stakeholders to jointly collaborate to set up end-of-use processing of materials, as well as integration of circularity principles within building sector standards. An additional key factor will be awareness creation, specifically among small and medium-sized enterprises (SMEs) active in the construction space, of the need to shift to innovative circular building design and capacity building on the relevant design principles, as well as of (reverse) construction technologies.

FIGURE 8 **MAIN BARRIERS IDENTIFIED FOR THE MOBILITY SYSTEM**

MOBILITY	ECONOMICS	MARKETS	REGULATORY	SOCIETAL
INTEGRATING MOBILITY SYSTEMS	Lack of alignment of structure of business case across different EU countries and cities for clean vehicles focused on modal integration	Required commitment of public sector at city level to create/allow the required market conditions such as clean-technology charging stations, parking spaces or drop-off and pick-up points		Potential resistance from incumbents against car sharing
DESIGNING AND PRODUCING CIRCULAR CARS	Uncertainty of business case related to income beyond the point of car sale linked to end-of-life value recovery	Uncertainty of business case related to size of customer segment willing to pay premium for durable cars Lack of sizeable secondary car material markets		
REMANUFACTURING CAR PARTS		Lack of efficient processes regarding reverse logistics Difficulty combining OEM new and remanufactured spare parts procurement Difficulty in disassembling car parts	Policies preventing use of remanufactured parts; for example the EC Directives related to end-of-life vehicles, electronic equipment, and the disposal of hazardous waste focus primarily on recycling and have mixed effects on remanufacturing activities	The OEMs' perception of reputational risk OEMs' concern over cannibalisation of new spare parts business Lack of awareness among OEMs

Source: Expert interviews; internet search; SYSTEMIQ.

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FIGURE 9 **MAIN BARRIERS IDENTIFIED FOR THE FOOD SYSTEM**

FOOD	ECONOMICS	MARKETS	REGULATORY	SOCIETAL
DEPLOYING REGENERATIVE AGRICULTURAL PRACTICES	Farmers need to overcome temporary volatility in profits during the transition that can vary between 1 to 8 years depending on the starting point and regenerative practices implemented			Lack of awareness and skills required for new practices among farmers (as regenerative practices are more knowledge-intensive) Lack of awareness of benefits among consumers
CLOSING NUTRIENT LOOPS	Anaerobic Digestion plants are typically not profitable at the scale at which these are deployed today without support, given energy prices and feedstock costs Biorefineries for chemicals/ fertiliser production typically still require proof-of-concept at scale	Insufficient stability in volume and quality of organic waste streams can create too high risk to build plants at scale		'Not In My Back Yard' trend for large infrastructure projects dealing with waste streams Lack of skills required to operate plants if rolled out at scale
FARMING THROUGH INDOOR URBAN FARMS	Uncertainty on return on investments required to design and build urban farms due to novelty of production methodology	Uncertainty on demand for urban farms products sold at premium price, if rolled out at scale	Urban permits and zoning laws preventing construction of new indoor farms	Lack of consumer awareness regarding benefits of food from indoor urban farms
DEVELOPING NEXT-WAVE PROTEIN SOURCES	Facilities innovating protein production typically require proof-of-concept at scale		Restrictions currently imposed by human food chain legislation	Lack of awareness of benefits and willingness to shift to next-wave protein sources

Sources: Expert interviews; internet search; SYSTEMIQ.

FIGURE 10 **MAIN BARRIERS IDENTIFIED FOR THE BUILT ENVIRONMENT**

BUILT ENVIRONMENT	ECONOMICS	MARKETS	REGULATORY	SOCIETAL
DESIGNING AND PRODUCING CIRCULAR BUILDINGS	Risks related to longer investment payback times when business models are used that are service-based and/or link the payback over time to the building's performance	The fragmentation of the sector does not provide a solid basis for end-of-life material value extraction Lack of sizeable secondary building material markets		Construction sector fragmented and conservative to circular design technologies and business models
CLOSING BUILDINGS LOOPS		Lack of stable flows of buildings materials Lack of industry standard for secondary materials	Legislation preventing construction players from certifying non-virgin inputs and using some associated machinery	Resistance from businesses due to attachment to current habits, and sometimes defiance towards non-virgin materials
DEVELOPING CIRCULAR CITIES	Lack of track record for structuring of projects that link investments to benefits realised in the context of circular urban developments Lack of pricing of negative externalities at city level	Required commitment of public sector at city level to create the market conditions		Lack of knowledge among city government of different business model possibilities to achieve circular urban planning

Sources: Expert interviews; internet search; SYSTEMIQ.

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FIGURE 11 **CIRCULAR ECONOMY INVESTMENTS IMPACT ASSESSMENT ON EUROPE'S PRIORITY AREAS**

++ Very positive
+ Positive
+/- Neutral

		MAIN AREAS OF PRIORITY FOR EUROPE			
		Growth[1]	Jobs	Competitiveness & Innovation	SDG[3] and Climate Goals
MOBILITY	**Integrating mobility systems**	+	Investment opportunities provide new jobs directly; the jobs reduced as a result in sectors with stranded assets most likely shift to service sector which has low labour productivity[2]	+	++
	Designing and producing circular cars	+/-		++	+
	Remanufacturing car parts	+		+/-	+
FOOD	**Deploying regenerative agricultural practices**	+/-		++	++
	Closing nutrient loops	+		+	++
	Farming through indoor urban farms	++		++	+
	Developing next-wave protein sources	+		++	++
BUILT ENVIRONMENT	**Designing and producing circular buildings**	++		++	++
	Closing buildings loops	+		+/-	+
	Developing circular cities	+		+	+

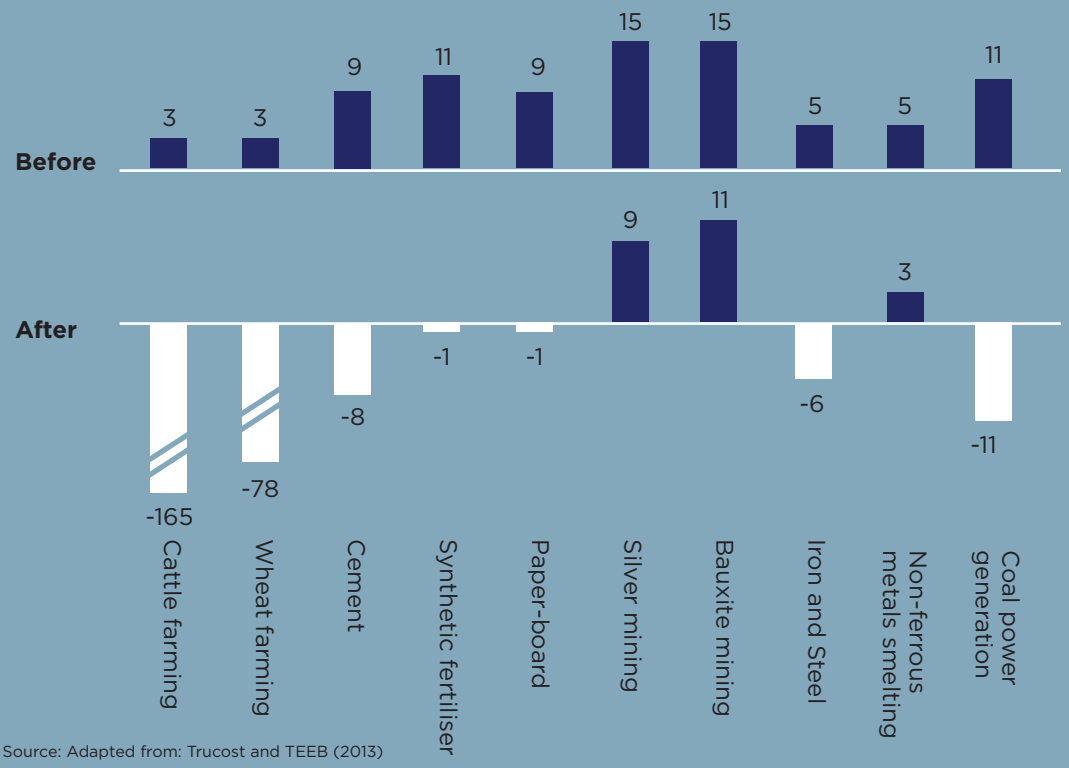
1 Taking into account both short-term and long-term growth impact. 2 Based on analysis done for *Growth Within*
3 Sustainable Development Goals, mainly 2. good health and well-being; 7. affordable and clean energy; 8. Decent work and economic growth; 9. Industry, innovation, and infrastructure; 11. Sustainable cities and infrastructure, and; 12. Responsible consumption and production. Source: SYSTEMIQ.

2 Second, materials from demolished or – preferably – deconstructed buildings should increasingly be recycled or repurposed where possible, requiring sizeable funding for newly built facilities. Currently, on average 54% of demolition materials from buildings are going to landfill, however in some countries this is only 6%,[36] indicating that with the right incentives it is possible to reuse these materials. Ramping up the recycling and remanufacturing facilities could provide an investment opportunity of up to €2 billion by 2025. The main risk reductions required for these investments to happen are, on the one hand, a change in legislation preventing building materials made of non-virgin constituents from being certified, and, on the other, securing sufficient offtake of the processed materials by creating platforms or a collaboration network of construction companies committed to using the materials. Providing a new income stream for these used materials would also alleviate issues related to the longer time it would take to deconstruct rather than demolish buildings.

3 Last, a shift towards fully circular cities implies urban planning that – next to new approaches in mobility and urban living as already mentioned – is based on circularity principles, such as increasing green spaces, grey water systems, and energy-efficient street lighting. The underlying business models for

FIGURE 12 **IMPACT OF NATURAL CAPITAL COSTS ON PROFITABILITY**

Profit margin (EBIT) before and after natural capital costs, based on top two companies in each Morgan Stanley Composite Index category, 2012



Source: Adapted from: Trucost and TEEB (2013)

these separate opportunities are well researched[37] and initial projects have been implemented, for example in the area of energy-efficient street lighting.[38] However, a more comprehensive rollout is required. This could provide an additional investment opportunity over and above current urban planning investments of *c.*€10 billion by 2025. The public sector would need to supply the necessary conditions for private capital to invest. In most circumstances, the underlying business case requires an innovative contractual structure to link the societal savings, such as reduced water or energy use, directly to the investment in order to provide attractive risk-adjusted returns to investors; this would involve a shift towards the total cost of ownership when assessing the underlying business case. In addition to providing an attractive business case to the private sector for individual projects, (local) governments would need to define clear plans for how to base future urban developments on circularity principles in order to provide investors with clarity on the way forwards. The European Commission has taken a step in that direction by including standards for increased water reuse in its circular economy action plan.

A massive stranded asset risk to be avoided

The shift from a linear to a circular industrial model will entail major shifts in the demand for different types of

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goods, shifts in value creation, and hence changes in asset value. If the ten investment themes represent the upside of the circular economy business opportunity, the stranded asset risk represents the downside. It is a substantial and a near-term risk that investors should start to manage. In fact, it is becoming more widely accepted that the main risk-management methodology, the modern portfolio theory, no longer holds. This theory teaches that investing in uncorrelated asset classes provides a diversified investment portfolio. However, the stranded asset risks described below run across seemingly uncorrelated asset classes.

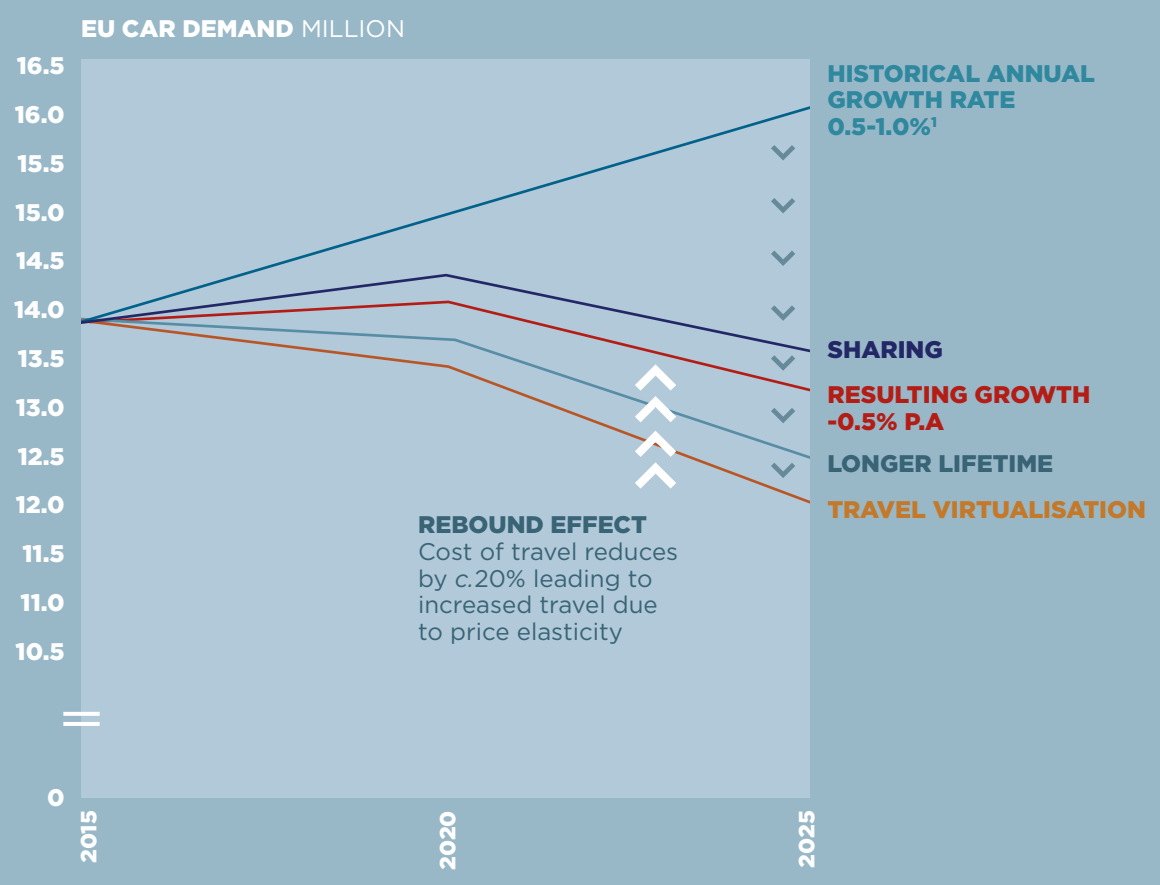
Two main forces are at work, and often both are present for the same type of assets:

1 Business activities not carrying their environmental and societal costs. A mapping[39] of all the major environmental externalities globally estimated that unpriced environmental damages amounted to a staggering 13% of global GDP in 2009. They come in five major forms: greenhouse gas emissions, overuse of water, negative land use effects, air pollution, and waste generation. These environmental damages are disproportionally caused by a relatively small number of resource extraction and primary processing industries. The study estimated what the profitability of these industries would be if they had to carry their environmental cost. The result was startling: almost none of them would be profitable at all, and many of them would be deeply unprofitable (see Figure 12). This represents a major stranded asset risk at the heart of the global economy. Economic history shows that industries can get away with being at odds with their surrounding societies for some years, but not decade after decade. With raising awareness and transparency of these damages, customers, regulators, and investors will increase pressure on these companies to act, and the stranded asset risk will rise. In fact, an increasing number of executives take externalities into account when defining their strategy.[40]

2 Volume-based businesses risking negative growth and a disproportionate negative impact on profitability. Many capital-intensive businesses share the same characteristics: assets are inflexible once built, and profitability crucially depends on high asset utilisation and high market prices, which in turn is explained by a delicate supply versus demand balance. In the EU, many capital-intensive businesses also suffer from low demand growth, often of only 1–2% per annum. Now, such linear business models are coming under greater threat, as new circular models can offer increased customer value and utilisation out of existing products, materials, and infrastructures, instead of building new ones. Take office buildings as an example: the construction market has been growing by *c.*1% per annum over recent years in the EU,[41] and currently, the average European office is occupied only 35–50% of the time even during office hours. There are several strong circular forces now at work to reduce the growth: office sharing, teleworking, and more flexible office layouts. Together, these forces might well make growth negative and shift business to other sectors and companies.

FIGURE 13 **POTENTIAL IMPACT OF CIRCULAR ECONOMY TRANSITION ON CAR PRODUCT DEMAND**

Estimates of the impact of circular economy scenario on EU car demand until 2025, based on *Growth Within*



ASSUMPTIONS

SHARING
1 shared car replaces 8 owned cars

LONGER LIFETIME
Electric vehicles can last up to 50% longer than ICE

Use of durable materials for the main body can further enhance lifetime by c.100%

TRAVEL VIRTUALISATION
Increase in remote working leading to reduction in passenger km of 7%

1 Average pre-crisis annual growth rate between 1990-2007 for EU-15 + EFTA
Sources: *'Growth Within';* ACEA; SYSTEMIQ

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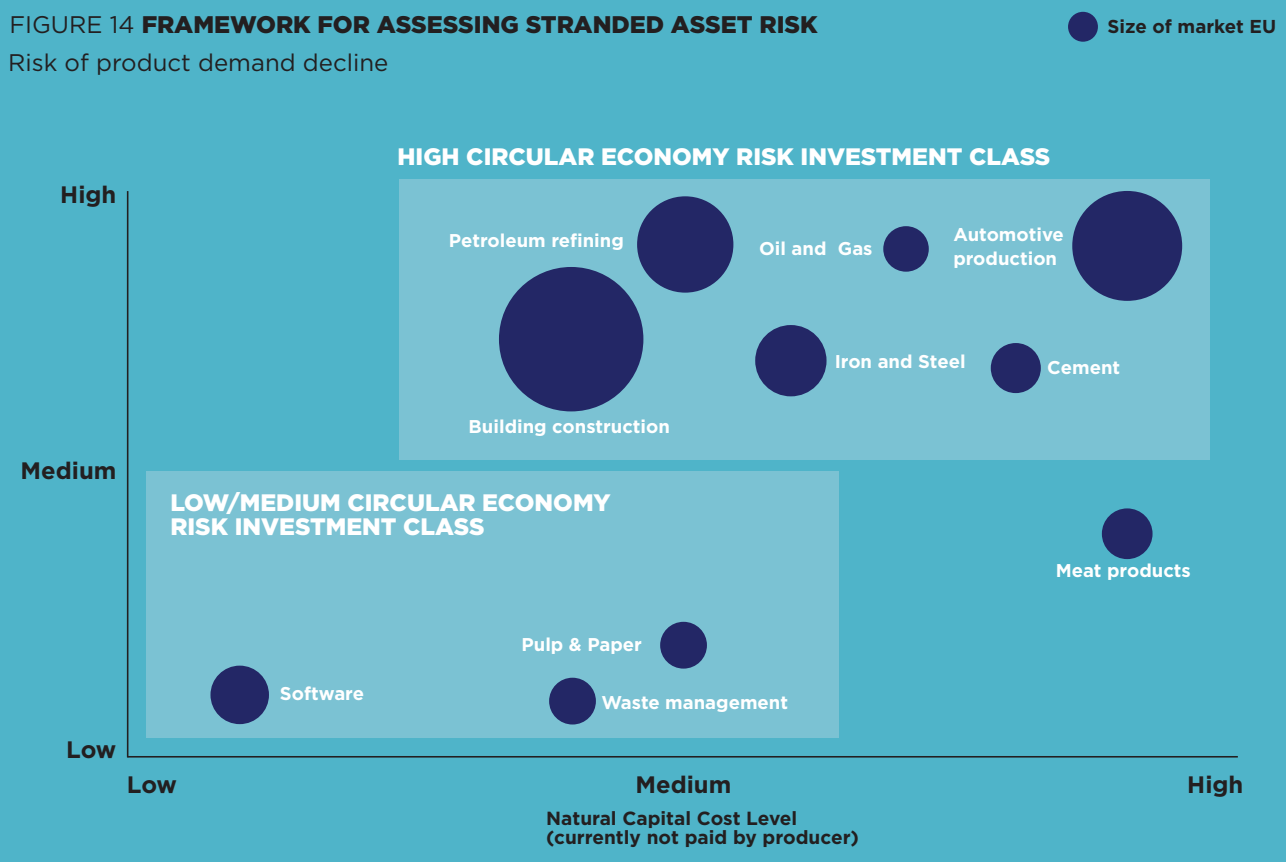
FIGURE 14 **FRAMEWORK FOR ASSESSING STRANDED ASSET RISK**
Risk of product demand decline



Sources: Eurostat, SYSTEMIQ.

Negative growth means a dramatically less attractive business in many industries – and hence a stranded asset risk – since three negative developments combine: lower demand, increased price pressure as competitors try to offload their volumes, and a hit in the stock market as future growth expectations are slashed. As a result, many industries see a 'tipping point' logic when growth turns negative, This risk is tangible, and may materialise much faster than many investors believe. First, growth and profitability is weak in many European primary and processing industries already today. Second, for many of these industries the trends of sharing, virtualisation, reuse and remanufacturing are together strong enough to shave several percentage points off the growth: See Figure 13 for an example in the automotive sector. In total, the *'Growth Within'* report estimated a reduction of European raw material use of 32% by 2030 in an ambitious circular economy transition scenario.

The European electricity industry illustrates many of these effects, and might serve as a warning case: a very slow underlying demand growth combined with a continued quick build-out of renewable power generation created a situation of negative growth for the incumbent coal- and gas-based generation technologies. This, in combination with the risk of future increases in CO_2 prices, caused revenues and growth prospects to all

but collapse, which results in the top 16 utilities across Europe writing off €22.9 billion in 2014.[42]

Examples of asset classes at risk can be seen in Figure 14. They include many of the traditional raw materials industries, but also some of the materials- and capital-intense manufacturing industries. However, there are major differences between various segments of these industries, as well as major company-level differences. For example, in the steel industry, a company such as Ovako Steel uses almost exclusively secondary steel as an input, and by doing so has significantly reduced its risk, compared to those relying on primary steel. So not all assets within these industries are at risk, but still the size and urgency make it crucial for investors to watch these trends, and identify which companies bear the largest risks.

To avoid getting stuck with stranded assets, and their disproportional value loss, this report would like to suggest that companies adopt a more thematic style to investing that looks across the classic silos as defined by the modern portfolio theory, by adopting the following set of investment principles. Of course, these need to be weighed up against other company-specific criteria:

A. Avoid companies that have a low utilisation rate of valuable assets. This is specifically the case in sectors where new technologies and business models (e.g. sharing) now make substantially better utilisation an attractive opportunity. Office buildings, road vehicles, boats, and high-end machinery are good examples.

B. Avoid companies where unpriced environmental damage is large compared to current profitability. Regulators and consumers have many ways of detecting and pressurising such companies. For example, water-intensive industrial activities often get shut down in times of shortage, have production permits withdrawn or expansion curtailed.

C. Avoid companies generating large amounts of waste. Waste is the ultimate indicator of poor design and an undermanaged business, and most circular economy efforts will ultimately result in less waste. Therefore, waste generation itself is often a good acid test of a company's circular economy compliance.

D. Avoid companies without a clear roadmap to circularity. While few businesses have fully adopted all circular economy principles in their strategy and operations, leaders have already come some way towards improving product design and material choices, employing innovative business models, and developing advanced reverse cycle capabilities. Observing what strategies and roadmaps companies have in place is a useful indicator of the stranded asset risk.

The decline in output during the transition towards the circular economy for those industries most at risk from both circular business models and from allocation of natural capital cost is a topic that will need to become part of government agendas across the EU. Planning to deal with stranded assets can minimise the risks of this transition. Identifying early on the industries most likely to be affected and engaging with them on re-training employees for circular business models could increase the likelihood of job retention. Crucially, the earlier industry executives assess the extent of the stranded asset risks facing their current and planned

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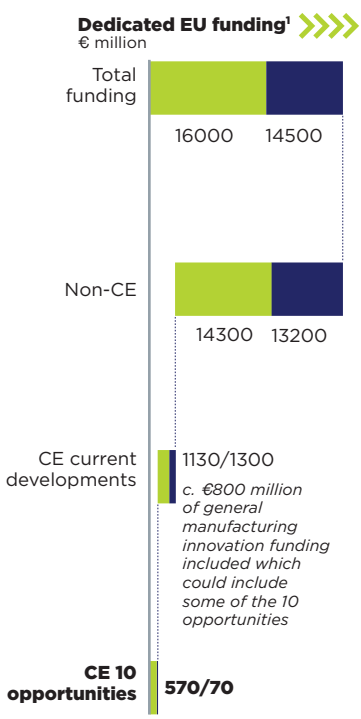
FIGURE 15 **EUROPEAN COMMISSION FUNDING TOWARDS 10 INVESTMENT THEMES**



	Dedicated funding[1] € million	Investment focus	Investments not included
MOBILITY			
Integrating mobility systems	170	• Increase sustainability of public infrastructure and transport hubs	• Implementation of transport optimisation technology • Specific infrastructure required
Designing and producing circular cars	116	• Use of lightweight material • 3D printing • Autonomous cars	• Integration of full circularity in car design and production • Material tracking systems
Remanufacturing car parts		• n/a	• All
FOOD			
Deploying regenerative agricultural practices	82	• Soil planning and management • R&D for appropriate regeneration policies	• Transition cost funding
Closing nutrient loops	67	• Close nutrient loops in the agriculture sector • Nutrient loops from water	• R&D outside of agriculture • AD or biorefining infrastructure investments
Farming through indoor urban farms		• n/a	• All
Developing next-wave protein sources		• n/a	• All
BUILT ENVIRONMENT			
Designing and producing circular buildings	13/70	• Develop reusable construction structures • 3D printing	• Investments in new production facilities • Material tracking systems
Closing buildings loops		• n/a	• All
Developing circular cities	122	• Integration of energy efficient technologies at a district level	• Holistic shift to fully circular districts and cities
TOTAL	**570/70**		

Horizon 2020 '16/'17 EFSI '15/16

1 Horizon 2020 budget for '16/'17 and EFSI funding spent to date for the part of the fund managed by the EIB.
Sources: EIB; European Commission Horizon 2020 website; SYSTEMIQ.

capital investments, the higher are their chances of effectively addressing them.

Policymakers should focus on four areas

Each of the ten opportunities has its own solutions to the barriers identified that are relevant to policymakers, but four overarching themes emerge:

1 **Setting direction and showing commitment.** One of the success factors of the ongoing clean energy revolution is its clarity of direction. Few company executives, researchers or policymakers doubt that the EU and the world are moving towards a clean energy system. Therefore, they invest business development and research resources based on that belief, further reducing cost and increasing attractiveness, and making the clean energy transition a self-fulfilling prophecy. There is no such clarity for the majority of the ten themes. As a result, too many investors take a 'wait-and-see' approach, or they bet on countervailing trends, such as shorter use-cycles, more resource-intensity, and lower product costs. So, providing such direction is a crucial policymaker task, be it through targets, strategies, public investments, consistent international trade agreements or industry convening. One specific case is to constantly strive to level the playing field for circular business models. Again and again when analysing circular business cases, the historic bias for linear business models becomes obvious: primary materials can be easily internationally traded, while substantial hurdles exist to trade secondary ones. Taxi hailing is hindered by incumbents where it should be helped, labour taxes are ten times higher than resource taxes even though labour should be maximised and resource use minimised. Obvious externalities, such as congestion and environmental damages are not priced, to take just a few examples.

2 **Removing policy barriers.** Many of the identified themes require legislative changes to become investable at scale. Most often, these consist of removing policy barriers (so-called unintended consequences) that prevent specific investment themes from taking off, such as the current strict limitations on how remanufactured cars or building components can be used, or how proteins from sources transforming agricultural by-products or food waste may be used. Often these barriers currently exist to manage consumer health and safety risks but in the context of adoption of circular economy business innovation, these risks are manageable. For example, quality and safety standards could be set for remanufactured parts or food proteins. A good analogy is the removal of policy barriers to open up the market for energy efficiency in buildings. Depending on the specific legislation the change may be required at EU or Member State level.[43]

3 **Creating platforms for dialogue, cooperation, and awareness creation.** Successful examples of circular business models clearly show the need for multiple stakeholders along the value chain to change (part of) the way they execute their business model. For example, in the case of looping waste streams, new suppliers would have to be found and contracted to provide required waste streams, while the stakeholders creating the waste would need to be incentivised

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FIGURE 16 **SOLUTIONS TO OVERCOME THE BARRIERS FOR THE MOBILITY SYSTEM**

MOBILITY	POLICY MAKER INTERVENTION OPTIONS			
	SETTING DIRECTION	**POLICY CHANGES**	**STAKEHOLDER PLATFORMS**	**FINANCIAL SUPPORT**
INTEGRATING MOBILITY SYSTEMS	Provide long-term strategic direction towards a fully integrated transport system	Provide market conditions for shared vehicles to shift towards modal integration		Set up public-private partnerships or public procurement to establish integrated shared vehicle schemes and develop required digital infrastructure Develop required public transport infrastructure, such as parking spaces and pick-up and drop-off points
DESIGNING AND PRODUCING CIRCULAR CARS	Set long-term strategic direction towards clean, durable cars	Mandate or provide support to shift towards circular car design	Create consumer awareness of benefits of circular cars Support dialogue between car manufacturers and target customers to determine market needs	Support innovations in circular car design and production Public procurement for circular cars
REMANUFACTURING CAR PARTS	Set a precise definition of circular cars, especially related to remanufacturing and re-use	Mandate or provide support towards the use of remanufactured parts	Create consumer awareness of benefits and quality of remanufactured parts Support dialogue between car manufacturers and remanufacturers	Public procurement for remanufactured parts

Sources: Expert interviews, internet search, SYSTEMIQ.

FIGURE 17 **SOLUTIONS TO OVERCOME THE BARRIERS FOR THE BUILT ENVIRONMENT**

BUILT ENVIRONMENT	POLICY MAKER INTERVENTION OPTIONS			
	SETTING DIRECTION	**POLICY CHANGES**	**STAKEHOLDER PLATFORMS**	**FINANCIAL SUPPORT**
DESIGNING AND PRODUCING CIRCULAR BUILDINGS		Adjust legislation to drive the inclusion of circularity in the buildings sector standards and regulation	Support innovative business models that allows for sharing risks between players to stimulate material looping	Public procurement for circular buildings Provide support for material production technology innovations
CLOSING BUILDINGS LOOPS		Adjust legislation preventing construction players from certifying non-virgin inputs Provide strong incentives, such as mandating of increased use of non-virgin materials to overcome resistance from businesses	Support dialogue between construction companies and material recycling companies to create further market growth	
DEVELOPING CIRCULAR CITIES	Setting direction/ targets on rollout of circular cities		Support setting up of new business models underpinning investments in circular infrastructure	Set up public-private partnerships to mitigate risks Rollout public infrastructure required for circular districts

Sources: Expert interviews, internet search, SYSTEMIQ.

FIGURE 18 **SOLUTIONS TO OVERCOME THE BARRIERS FOR THE FOOD SYSTEM**

FOOD	POLICY MAKER INTERVENTION OPTIONS			
	SETTING DIRECTION	**POLICY CHANGES**	**STAKEHOLDER PLATFORMS**	**FINANCIAL SUPPORT**
DEPLOYING REGENERATIVE AGRICULTURAL PRACTICE			Support awareness, skill-building and demo farming projects delivered by best-practice farmers	Public procurement for food products from regenerative farms Focus agriculture subsidies (e.g. CAP) on transition Provide financial support for pilots or full transition to regenerative practices
CLOSING NUTRIENT LOOPS	Continue to set direction for shift towards greater (organic) waste separation and collection	Further improve organic waste collection processes through simplification and standardisation Pricing in negative externalities	Engage local communities in new infrastructure project development	Scale-up waste collection logistics and infrastructure Provide (financial) support to AD, biorefineries or other organic waste processing facilities
FARMING THROUGH INDOOR URBAN FARMS	Incorporate urban farms in urban planning and development	Support provision of permits and leases to build farms in urban areas	Create consumer awareness of benefits and quality of food from indoor urban farms	Public procurement for food products from indoor urban farms Provide incentives that reduces the risks to investors, such as tax breaks Provide support for technology innovations
DEVELOPING NEXT-WAVE PROTEIN SOURCES		Research a legal framework at the EU level to allow and ease next-wave sustainable protein sources complying with quality and safety standards	Promote public awareness of benefits	Public procurement for food products from next-wave protein sources Support technology innovations

Sources: Expert interviews, internet search, SYSTEMIQ.

to separate and collect the waste in the required volumes and quality. In addition, customers would have to become aware of the benefits in order to shift from only accepting newly created products to adding products made from the end-of-life streams (such as remanufactured cars or building materials). All of this requires awareness creation, dialogue, and negotiations between players varying from producers to consumers to financers. The public sector could play an active role by setting up platforms with the right set of players to facilitate these discussions. A successful example of this was the European Resource Efficiency Platform (EREP) set up during 2012–14, which was generally acknowledged as being vital to the creation of the European Commission's first circular economy package in June 2014. It acted as an effective mechanism to gather input from relevant stakeholders, develop pragmatic solutions, and build support. Therefore, similar platforms should be set up, ideally separate ones for mobility, food, and the built environment. This should not only be done for those themes where the public sector plays a large if not leading role, such as integrating mobility systems or scaling circular urban environment, but also

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for those where the private sector is more likely to lead, such as industrial design based on circular principles or remanufacturing of materials.[44]

4 Focus public procurement, public circular economy investments, and financial support towards the ten themes. Some of the investment themes require technology innovations such as biorefineries, indoor farming or 3D printing. As private capital is not always set up to invest in the perceived risk level of these innovations, focused public financial support would be needed to de-risk these innovations sufficiently for the private sector to provide 100% of the funding required. Investing in pilot projects to get these innovations through the proof-of-commercial-concept phase is a good example of high-return opportunities for public investment. Although the circular economy budget within Horizon 2020 funding is currently already being deployed in this area, it does not yet cover the identified themes and underlying innovation fully. If funds were directed towards the hot spot innovation and investment themes within food and the built environment (there is already a better overlap for mobility opportunities), a major opportunity to increase returns on public investment would be opened up. In addition to innovation funding, the public sector has been supporting lower risk investments at larger scale with a central focus on infrastructure. For example, European Investment Bank (EIB) has been investing *c.*€14.5 billion over the last two years through the EFSI fund mostly in infrastructure projects, however less than 10% of this is going to circular economy-related investments (see Figure 15). As the circular investment themes identified in this report have large infrastructure components, allocating a budget within existing funds for them would shift investments towards circular opportunities while providing new growth opportunities to those funds, but also, at the same time, shifts investments towards circular opportunities. Investment funds at the Member State level could well provide an additional supply of public capital towards the investments themes. Lastly, reforms to existing subsidy frameworks should be considered, mainly in the area of shifting linear agricultural practices towards more circular ones, while fiscal incentives should also be geared towards circular business models.

Company executives should carve out their role within the ten themes

Successful examples of businesses shifting to a circular model show the importance of bringing together relevant players to collectively driving the change needed. Examples of this include working with suppliers to design and build products with looping in mind; working with customers to convince them of the additional value of buying a premium-priced product because of its end-of-life worth; and increasing the appetite for alternative, performance- or service-based business models ('access over ownership'). As such, in order for company executives to start investing in circular opportunities, identification of the most relevant investment theme(s) is needed. Depending on

the current role a company has in the value chain, it could make more sense to invest in looping than investing in prolonging for example, which in its turn would depend on the existing skills and capabilities in the organisation, as well as the required risk/return profile of the available capital.

Furthermore, a mapping of the relevant stakeholders along the value chain is essential, including a strategy that defines the necessary change from each and how to achieve this. For example, in the case of scaling up remanufacturing in the mobility sector, the leading organisation aiming to invest in new remanufacturing facilities would need to decrease the risks sufficiently to deploy capital. This could be done by ensuring the supply of available components with the required specifications, commitment from manufacturers to incorporate the remanufactured parts into their supply chain, as well as making sure experienced staff could be employed in the new remanufacturing facility. Achieving this entails, besides access to the required type of capital, the right network of businesses along the value chain, skills and capabilities to rollout and operate the remanufacturing facility, and a strong senior management commitment to achieve the desired outcome.

Moving towards circular business models will often call for some experimentation with new business models and partnerships. However, the majority of the industrial companies involved in this research could identify promising opportunities within the ten themes. In the same way that the lean operations lens has allowed executives to see a whole new set of improvement opportunities, the circular lens often opens up an undiscovered wave of opportunities. Examples of profitable circular business models, such as DESSO or the Balbo Group,[45] show that typical success factors for implementing and investing in a fully circular business model are:

1. Clear vision of the target business model;
2. Identification of specific market segments where suppliers and consumers could be lined up to provide initial revenue at the right price levels;
3. Executive commitment and leadership in a player in the value chain that can bring together the required stakeholders.

To illustrate how private players can start investing across the ten themes in the near term across the risk/return spectrum, examples of potential opportunities are summarised in Figure 19 below. A number of these are indeed about starting engagement with suppliers, customers or relevant public sector organisations to identify suitable locations across the EU with the most favourable economics where developing investable projects is likely to be easiest.

At the same time, executives should shift business strategy and/or investments away from linear business models most at risk from the circular economy transition. This could be done by adding a 'filter' to the investment- and strategy-setting process that analyses each opportunity in line with the principles of circular investing. Additionally, they should analyse their existing asset portfolio to determine the exposure to these risks. For those assets most at risk, a progress-tracking process should

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FIGURE 19 **EXAMPLE PRIVATE CAPITAL INVESTMENT AREAS ACROSS THE RISK/ RETURN SPECTRUM**

		HIGH	MEDIUM	LOW
MOBILITY	**Integrating mobility systems**	• Developing digital infrastructure for modal integration	• (Clean) vehicle sharing business linked to public transport	• Upgrading public transport infrastructure
	Designing and producing circular cars	• Innovative production technologies such as 3D printing • Developing fully circular cars	• Developing cars with incremental circular features	• n/a
	Remanufacturing car parts	• Digital secondary car part market	• Fully new car remanufacturing supply chains[1]	• Scaling existing remanufacturing in supply chains
FOOD	**Deploying regenerative agricultural practices**	• Precision agriculture technologies for regenerative farming practices	• New ecological/ regenerative farms	• Transition financing to existing farms
	Closing nutrient loops	• Biorefineries	• AD plants	• Organic waste collection businesses
	Farming through indoor urban farms	• New vertical farm technologies and businesses	• Urban farm infrastructure	• Conventional green houses
	Developing next-wave protein sources	• Next-wave protein production technology providers	• Scaling existing vegetable-based production facilities	• n/a
BUILT ENVIRONMENT	**Designing and producing circular buildings**	• Innovative production technologies such as 3D printing • Developing fully circular buildings	• Buildings with new circular features, such as materials with lower toxicity	• Buildings with well-understood circular features, such as prefabrication
	Closing buildings loops	• Digital secondary building material market	• New building material looping supply chains[1]	• Scaling existing building material looping supply chains
	Developing circular cities	• New circular city models without track record[2]	• Replicating existing circular city projects with existing track record[2]	• Green urban infrastructure

1 Including use of new components and materials.
2 New models such as grey water systems; existing projects such as energy-efficient lightning.
Source: SYSTEMIQ.

be implemented that measures the penetration of competing circular business models and progress in natural capital cost allocation for the relevant products. This would size the risk from the circular economy transition on a regular basis and, if done properly, should allow executives to start implementing transition measures when needed.

For example, synthetic fertiliser producers could set 'boundary' penetration levels for organic fertilisers in their respective markets that, when met, would allow them to either find alternative markets for their production facilities or lead to a managed accelerated depreciation of their assets during which time they could decide to enter the organic fertiliser market or find alternative business strategies.

CIRCULARITY CAPITAL

Circularity Capital is a specialist private equity firm founded to provide clients with access to investment opportunities created by the circular economy. The firm has raised £17.6 million to date and plans to start deploying capital in Q1 2017. The creation of this dedicated fund was driven by growing investor appetite for such business models and the recognition that companies in this space have unique growth trajectories and face unique challenges. In particular, its investors were interested in deploying capital in the circular economy because of the catalytic nature of Circularity Capital's proposition and the opportunity to support circular SME growth and innovation, thereby delivering commercial returns in addition to positive environmental and societal impacts.

Circularity Capital uses the circular economy as a framework to identify and assist selected European SMEs to capture the value creation opportunities from their continued adoption of circular economic practices. The firm seeks out businesses that can outperform the market and their linear competitors by applying the circular economy framework. Circularity Capital targets investments of £1–5 million in the growth stage of SMEs operating in the circular economy across the EU. The team leverages its specialist expertise and network in the circular economy to identify, source, and secure proprietary investment opportunities.

EXAMPLES OF PRIVATE SECTOR INVESTING IN THE CIRCULAR ECONOMY

DESSO

An example of a successful transition towards a business based on circularity principles is DESSO, a Dutch carpet tile manufacturer. Led by its CEO Stef Kranendijk, DESSO set out to ensure that all its products would be Cradle to Cradle® certified and that it would run on 100% renewable energy by 2020. In 2008, DESSO started to remove chemicals that did not meet EPEA3 standards and to introduce new purer materials. During the initial phase, between 2008 and 2015, this allowed DESSO not only to double its carpet tile market share (in Europe from 15% to 30%), but also, alongside a restructuring programme, to increase its carpet EBIT margins from 1% in 2007 to 9% in 2011 and an estimated 12–14% in 2015.

After coming in as co-owner and CEO in 2007, Kranendijk set innovation as a core strategic priority to reinvigorate the business. He adopted a strong focus on design and on sustainability with substance. After learning about Michael Braungart's Cradle to Cradle® approach, Kranendijk committed to obtaining this certification for the company's products by focusing on healthy materials, design for easy disassembly, take back and recycling, and switching to renewable energy.

The strategy initially increased risks with key groups of stakeholders, but the team was able to successfully mitigate these through clear target setting and a continuous senior management commitment to the transition.

INTERNAL ORGANISATION

The organisation initially responded with resistance, having changed ownership several times in recent years, but Kranendijk was able to incentivise them through: consistent internal messaging; dedicated presentations and training; concentrating on 'quick wins' that produced tangible results and motivated employees; and aligning Key Performance Indicator (KPI) with the new focus on innovation and sustainability. From the day he communicated the transition internally in 2008, Kranendijk also made speeches and gave interviews in numerous media channels. The transition became known as 'the DESSO Case' and the company gained a reputation for doing good rather than less bad, which had a hugely positive impact on employee satisfaction because, as Kranendijk notes, "it feels great to do good".

SUPPLIERS

The transition to Cradle to Cradle® required obtaining large amounts of information from DESSO's suppliers about the toxicity of their inputs, and placed a burden on them to alter products to comply with more onerous requirements. DESSO focused on getting supplier cooperation through in-person meetings to demonstrate their commitment and making the process as easy as possible. Some of DESSO's suppliers were still hesitant to adopt the new standards, but the ones who were willing to cooperate went further in reconsidering the making of their products and welcomed co-development opportunities. DESSO also

developed a multi-supplier strategy for each key input to ensure sufficient availability and support industry-wide adoption. Two collaborations stand out. The first, with Aquafil, Europe's largest yarn manufacturer, built a $20 million plant to depolymerise old yarn into the original monomer from which new yarn could be made. Before Aquafil built the plant, DESSO committed to become its launch customer. Currently, more than 50% of DESSO's carpet tile volume is made from up to 100% recycled yarn. The second, with chemical giant Dow, led to the development of a 100% pure material (polyolefin) as a replacement for the conventional bitumen tile backing.

CUSTOMERS

DESSO's shift to Cradle to Cradle® led to a greater focus on carpet tiles specified by architects and designers with a commitment to sustainability. This focus led to a significant change in customer profile, towards those willing to pay a premium for high specification tiles. Extensive external presentations by DESSO's CEO and managers to their opposite numbers in many companies directly or via the World Economic Forum, London Business School, IMD Lausanne and the Rotterdam School of Management, led to high awareness of 'the DESSO Case' in the business community and had a tremendously positive effect on all customers. DESSO also shifted to a differentiated selling strategy by providing their products in advance, in accordance with specifications. Additionally, the company set up its own Take Back System to collect used carpet tiles. Once it had separated the yarn from the bitumen backing the company sold the recovered yarn to Aquafil to be made into new yarn, as described above, and the remaining bitumen to companies such as Heijmans in the roadbuilding industry.

SHAREHOLDERS

On joining the company the CEO was under pressure from investors to turn the company around, and the proposed transition plan required high upfront investment. However, the shareholders had sufficient faith in the management team to give them a 'grace period', and DESSO's subsequent ability to show financial results and outperform competitors convinced the shareholders. The first private equity investor in the company, NPM Capital, which in 2007 co-invested with management, got eight times their money back (including loans) in 2011. The subsequent private investor got twice their money back (including loans) in January 2015. These are both remarkable returns on investment in an extremely tough macro-economic period. In 2011, the CEO of Tarkett, came to DESSO headquarters to be convinced that implementing Cradle to Cradle® principles is not only good for people and the planet, but also good for business. As a result of that visit Tarkett decided to become a Cradle to Cradle® certified company, and in 2015 acquired Desso.

>> MAIN FINDINGS

Capturing the synergies between the EU's digital agenda and the circular economy transition

The digital revolution is a crucial enabler for many parts of the circular economy transition, including asset sharing business models, virtualising products, managing complex reverse logistics systems, and keeping track of valuable assets. Vice versa, it is only tangible societal benefits such as those offered by the circular economy transition, that can motivate public spending on a digital agenda. The synergies are strong.

Most spending on digital technology in the next-wave opportunities outlined above will be inherent to those investments and will be done with private sector financing. One example is Google's Waze 'Connected Citizens' initiative, which transmits data between commuters and governments to improve traffic flow. Another is the Quartz Project,[46] an open data platform on building materials that provides information on the environmental and health impact of over 100 building materials.

There are, however, several areas where public intervention is beneficial. The EU is already allocating funding towards the circular economy digital agenda, mainly through its Horizon 2020 programme. Figure 20 shows that this budget only covers some of the ten investment themes identified. For circular economy opportunities, the public role is primarily about setting standards and creating digital platforms to reduce transaction costs and facilitate business models that require cooperation between companies. There are three additional areas that currently do not receive substantial funding and would benefit from it:

1 **Product IDs** There are two key reasons why secondary markets for materials and products show slow growth: first it is hard for buyers to know the content and quality of what they are buying; and second it is hard for sellers, especially consumers, to know how to most profitably sell their products after use. The result is that the market for secondary goods in the EU is a very small fraction of that for new goods. This could all change with new technology. Imagine if products and materials carried suitable IDs, in the form of barcodes, cheap electronic tags or other such labelling technology (the best technical solution will vary by product and material). As an example, suppose barcodes were required to carry relevant information about the contents and exact type of a product, so consumers could scan that barcode with their smartphones whenever they made a purchase of a durable good. This would give consumers, with very little hassle, an inventory system as sophisticated as some companies have today. After some years, when the consumer is ready to get rid of the product, he or she highlights this with the smartphone, getting buy-back offers from remanufacturers, secondary material providers, recyclers, and so on. An early example of such an approach

in the retail sector is Stuffstr, a company that lets consumers find buyers to reuse or recycle their items after-use, and provides access to a large, transparent repair services market during use. Such a service drastically reduces transaction costs and gives used products a real value. If they were widespread, such systems would prompt manufacturers to compete on the secondary value of products and would make designing for easy disassembly and using pure materials valuable business strategies. Creating such standards and systems would be a substantial achievement for the European Commission.

2 Open platforms for secondary materials Although many companies are interested in the notion of ramping up the market for secondary materials, most are not actively pushing this and are looking at others to take the initiative. The main barriers are a lack of market transparency and profitable business cases. As is shown by the relatively low rates of remanufacturing across different sectors, it is difficult to set up a business at scale that has suppliers of a sufficient volume of suitable end-of-use components, and customers willing to buy remanufactured components. Therefore, an open, online secondary marketplace would require public support to take off, as there will be a lead time before its business case becomes positive.

3 Circular economy evaluation and measuring systems As support efforts to shift economies towards circularity pick up across the EU, an increasing need to track progress will arise. Such monitoring is important to assess the effectiveness of initiatives, as well as to determine the best allocation of funding. While robust systems are in place to track greenhouse gas emissions, similar systems to monitor material efficiency at a detailed level are lacking. Examples include: comprehensive data on waste generation and treatment in the construction and demolition industries is virtually non-existen; the EU only requires Member States to provide waste data every two years with 2012 the latest available year; high quality data on the sharing of cars, buildings or other assets is lacking. Therefore, to start tracking material flows as part of a 'circular economy Key Performance Indicator dashboard' would require not only increasing the quality, detail and collection frequency of data, but also improving the interfaces used to report and view it. Similar to how the Carbon Disclosure Project developed its greenhouse gas emission reporting system over time, such as dashboard could be built up from company to industry or city level to create transparency on resource efficiency at a detailed level.

MAIN FINDINGS

Conclusion

Investing in the circular economy is a compelling proposition for EU companies and policymakers alike. The economic and innovation opportunities it provides are sizeable and could influence EU industrial strategy in a positive and powerful way. If such investments prove successful, they could see the EU become a world leader in circular economy, at the forefront of a global shift that could be truly transformative.

FIGURE 20 **HORIZON 2020 FUNDING FOR DIGITAL PROJECTS TOWARDS THE TEN INVESTMENT THEMES**

€ MILLION		HORIZON 2020 FUNDING	DIGITAL ENABLERS INCLUDED IN H2020	DIGITAL ENABLERS NOT INCLUDED IN H2020			
MOBILITY	**Integrating mobility systems**	119	R&D for SMEs Innovation on transport & Smart cities Digital road automation	Integrated app planning optimised multi-modal journey & managing seamless payment	**CE monitoring and evaluation**	**Product passports**	**Secondary material market systems**
	Designing and producing circular cars	100	Autonomous cars 3D printing (through general manufacturing funding)	Car material tracking system			
	Remanufacturing car parts			Automotive open material platforms			
FOOD	**Deploying regenerative agricultural practices**	70	R&D of robotic technology for precision farming and harvesting	Precision agriculture technology for regenerative practices			
	Closing nutrient loops	50	R&D on digital monitoring of water cycles to increase the nutrient recovery				
	Farming through indoor urban farms			Urban farming monitoring and operating technology			
	Developing next-wave protein sources			Production monitoring and operating technology			
BUILT ENVIRONMENT	**Designing and producing circular buildings**			Building material tracking system			
	Closing buildings loops			Buildings open material platforms			
	Developing circular cities	96	R&D on digitalisation for energy optimisation technologies at district level	Digital advanced lighting, power, water and waste sub-metering & management			
	Total	435					

Source: European Commission Horizon 2020 website; SYSTEMIQ.

10 INVESTMENT THEMES

1. INTEGRATING MOBILITY SYSTEMS
2. DESIGNING AND PRODUCING CIRCULAR CARS
3. REMANUFACTURING CAR PARTS
4. DEPLOYING REGENERATIVE AGRICULTURAL PRACTICES
5. CLOSING NUTRIENT LOOPS
6. FARMING THROUGH INDOOR URBAN FARMS
7. DEVELOPING NEW PROTEIN SOURCES
8. DESIGNING AND PRODUCING CIRCULAR BUILDINGS
9. CLOSING BUILDING LOOPS
10. DEVELOPING CIRCULAR CITIES

10 INVESTMENT THEMES

1 INTEGRATING MOBILITY SYSTEMS

Further growing the use of shared vehicles through seamless integration with public transport could be achieved by investing up to €100 billion between now and 2025. This investment could be directed towards the build-up of an integrated fleet of zero-emission shared vehicles, associated public transport infrastructure, and required digital systems. Such an investment could put Europe on a pathway to achieve total societal cost reduction of up to €175[48] billion per annum by 2030 on a number of fronts, e.g. reduced congestion or fewer parking spaces required. Strong public sector commitment to provide the infrastructure and incentivise customers to switch would be needed, while the private sector could move forward concurrently through integrating the necessary digital systems and rolling out the associated vehicle fleet.

Relevance of investment theme

What if journeys combining public transport and zero-emission shared vehicles were to become the norm across most European cities by 2025? At the current rate of development, it is estimated that by 2025 *c.*2% of passenger kilometre travelled could be made in shared cars across the European Union (EU). However, if cities throughout Europe moved towards an integrated transport system with a focus on zero-emission vehicles, this percentage could increase to above 10%.[49]

This shift would see benefits from a variety of perspectives. Transport time would be shortened, as transition from public transport to the final destination becomes easier thanks to the combining of public transport and shared vehicles, and the optimisation of these services through multi-modal journey planning. Indeed, these changes would make it possible to reduce total car fleet size, and thus traffic congestion. Greenhouse gas emissions and air pollution in cities would be significantly decreased as the smaller car fleet would also be more environmentally friendly. This would further lower the cost of mobility for users and allow for a better use of inner-city land – of which currently as much as 50% is devoted to roads and parking spaces.[50]

All these benefits contrast with the current picture of commuting, as a source of significant inefficiency, air pollution, and traffic congestion in large cities. Today's typical European car is owned by an individual and is parked 92% of the time – often on valuable inner-city land – and, when it is used, on average only 1.5 of the 5

available seats are occupied. Even at rush hour, cars cover only 10% of road area taken as average across Europe. Yet, traffic congestion costs verge on 2% of GDP in cities such as Stuttgart and Paris.[51]

To capture the full potential, mobility services would need to be made so attractive that users would be prepared to make a wholesale shift in their current commuting modes. So, the challenge is to make shared journeys flexible, fast, and affordable compared to personal car journeys. This can be achieved by combining as many as possible of the following levers to incentivise users to shift to sharing:

- A fully integrated user app allowing people to plan journeys that minimise commuting time by combining public transport and zero-emission shared vehicles, enabled by optimised fleet management systems.
- Seamlessly integrated payment options embedded in apps.
- A fleet of zero-emission shared vehicles, including bikes and cars/shuttles, run on electricity, hydrogen or other technologies.
- Infrastructure for these zero-emission shared vehicles, such as charging stations and parking spaces.
- Infrastructure for an unbroken transition between public transport and zero-emission shared vehicles (e.g. spaces for seamless pick-ups and drop-offs).
- Optimised public transport infrastructure such as lanes exclusively for buses and shared vehicles or increased metro capacity.
- Additional incentives to shift, such as priority lanes for buses and zero-emission shared vehicles or free parking.

Recent developments

The time is ripe for such a transition: better mobility systems are a key priority for most cities, and new technologies and innovative business models are now available to enable the shift. Indeed, car sharing is growing at a rate of 40% per annum, electric vehicles are becoming competitive with conventional vehicles on price and performance,[52] and software developments allow users to optimise shared vehicle fleets, as well as instantly plan their journeys using a variety of transport options. The new generation of urban citizens seems less attached to car ownership and increasingly seeks on-demand and/or shared mobility.[53]

New journey-planning apps make it easier for consumers to use different transport modes. Most apps do not yet provide full modal integration options, which would allow the user to easily transition from one type of transport to another, but some examples approach this functionality. For example, Uber Ride Request offers passengers convenient first and last mile rides to and from public transport[54] and in September 2016 Uber partnered with public transport apps in Australia to integrate public transport planning.[55] The Xerox Go Los Angeles app comes closest to full modal integration by capturing available public and private transportation options and computes the shortest, cheapest, and most sustainable way to get to the chosen destination.[56] On the other hand, many

10 INVESTMENT THEMES

journey-planning apps remain focused on a subset of options, i.e. only public transport, taxi hailing, bike or car sharing.

Some European cities – such as Helsinki, Copenhagen, and Hamburg – have started the shift towards full modal integration. The Finnish company, MaaS Global, launched in June 2016 the first all-inclusive multi-modal transport service in Helsinki, which is to be rolled out across the city by the end of 2016 and eventually to all Finland's cities and public transport networks.[57] In Hamburg, the city provides incentives such as reserved parking spaces for shared cars, free shared bikes, and charging stations for electric vehicles are provided to encourage users to shift. Hamburg also has the Switchh app that allows users to design the optimal multi-modal journey. In Copenhagen, the mobility system that integrates zero-emission shared cars and public transport was set up by DriveNow, which provides users with a common app and integrated payment options, a fleet of zero-emission shared vehicles, charging stations, and free parking.

These are a few examples of successful ways in which the public and private sectors have come together to grasp the opportunities for integrated mobility systems, but there is much still to be done to achieve the target level of integration across Europe.

Investment opportunities identified

The shift towards integrated urban transport systems provides investors with multiple investment opportunities of up to €100 billion between now and 2025. They include:

- Developing digital infrastructure, most notably:
  - Establishing integrated user apps to plan optimised journeys that combine public transport and zero-emission shared vehicles. These could build on existing initiatives, such as the DriveNow or MaaS projects, or be new apps. To make an app a 'one-stop shop', it will need to include a payment system adding to the total investment requirement.
  - Creating a fleet optimisation platform. Making use of a public transport system integrated with shared vehicles sufficiently attractive for customers will require continuous optimisation of traffic flows to reduce congestion and, in turn, total travel time. New digital innovations, such as Google's Waze, currently provide solutions driven by Big Data analytics that allow planners to optimise traffic flows, but these need to be tied into an overall transport optimisation platform.

- Providing and managing fleets of zero-emission shared vehicles, including associated infrastructure such as charging stations. Investment will have to be made in the vehicles that will be used for sharing, as well as the charging/fuelling stations and possibly some facilities to allow for vehicle maintenance (if this is kept in-house).

- Constructing and upgrading current public infrastructure. To improve the speed and cost of using public transport and zero-emission shared vehicles for consumers, construction of spaces for seamless pick-ups and drop-offs would be needed, while at the same time further improving public transport to allow for increased passenger numbers. This implies a re-allocation of public

infrastructure spending, geared towards an integrated multi-modal transport system with improved public transport infrastructure, and additional incentives to shift towards integration, such as priority lanes for buses and zero-emission shared vehicles.

Current barriers to investments

At the moment, the main barrier preventing integration of zero-emission shared cars and public transport from scaling up is the lack of a clear commitment to such integration from relevant public sector bodies. The private sector by itself could further expand some of the activities that have already been set in motion, such as rolling out combined car sharing and public transport journey-planning apps or creating car sharing parking spaces near public transport stations. However, a step-change in modal integration would require public sector commitment on all fronts, even though this commitment could take various forms and levels of intensity depending on local situations.[58] For example, creating an integrated payment system on top of the journey-planning app involves access to public transport payment platforms; allowing shared car parking spaces near train or metro stations would require public sector approval; and using electric-only shared vehicles would require the rollout of charging stations. Furthermore, without the required infrastructure, such as pick-up and drop-off points, the business case to provide a fleet of zero-emission shared cars specifically for modal integration would likely not be positive, as car utilisation rates would be too low to provide attractive returns on the capital deployed.

Moreover, the risk of opposition from incumbents such as original equipment manufacturers (OEMs) and taxi drivers threatened by car sharing if deployed at scale could provide a barrier to growth. Currently, opposition is mainly focused on ride sharing platforms such as Uber, which are disrupting the taxi industry globally, while car sharing is not under the same degree of scrutiny, probably due to the difference in scale of the disruption to date.[59] However, if car sharing becomes the norm and the transition is not managed properly, incumbent opposition could limit its growth.

Interventions to scale up investments

To put the EU on a path to a fully integrated urban mobility system, a strong push by relevant public bodies would be needed. Many elements would need to ramp up at the same time, such as public transport infrastructure, zero-emission shared vehicle fleets (and their charging networks), and all the relvant digital infrastructure. As these investments are in different asset classes with their own risk and return profiles and associated investor types, risks would have to be properly managed during the growth phase, something the private sector cannot do alone. Nevertheless, there is a clear role the private sector can play in technological and fleet development, as already outlined. Furthermore, by actively engaging with city administrations, as BMW is doing with its DriveNow initiative, private sector companies

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can achieve the required momentum. However, action is needed by all parties:

- **European Commission:** The main role for the European Commission could be to incentivise innovations, as well as providing the infrastructure build-up needed to underpin an integrated mobility system. This is already being done through some of the Horizon 2020 funding geared towards Smart Transport; allocating more funding both towards these (digital) innovations, as well as the public transport infrastructure required, will further support the transition. In addition, initiatives could be rolled out aimed at providing strategic guidance and knowledge sharing to EU city governments about integrating mobility systems, as well as supporting consumer awareness programmes.

- **National, regional, and local governments:** To achieve a fully integrated system national, regional, and local governments would need to play a leading role, and in particular those organisations that deal with urban infrastructure and public transport planning and funding. They would need to provide the near-term vision and associated detailed plans on how to integrate the mobility system in such a way that investors have sufficient confidence to develop the required (digital) infrastructure and zero-emission shared car fleet. This could include setting up incentives for consumers to switch, such as introducing congestion charges, car taxes, zones free of fossil fuel-powered cars or discounted electricity prices for charging stations. In addition, detailed plans regarding the construction and funding of public transport infrastructure would be required. Lastly, clarity would be needed on how the digital infrastructure requiring government collaboration would be developed and scaled.

The most effective way to achieve this is through bold, coordinated action among all relevant public and private sector players. This would be necessary in order to incorporate views on feasibility of not only the technical, but also the economic aspects of the transition, before starting to implement the different elements. For example, building up a shared electric car fleet geared towards modal integration would require a minimum vehicle utilisation rate to achieve the return on investment required by investors. This return would also depend on the pricing strategy, which would have to be competitive with individuals using their own cars. In addition, the utilisation of shared cars would rely on the ease of use of shared vehicles for 'the last mile', i.e. from the public transport station to the desired end location. For this to be successful, many elements would need to come together at the right time, requiring close collaboration between stakeholders.

The risk of incumbent opposition could be mitigated by ensuring a level playing field, for example all potential providers of car sharing services and their users could be plugged into the integrated app and benefit from incentives,

provided they met the conditions required (e.g. using rented or shared zero-emission vehicles). Exclusivity should not be granted to a few players or, if this is the case, only for a limited period of time (e.g. for the first one to two years), after which the system would be open to all players.

- **Private sector:** Despite the onus being on the public sector to achieve a fully integrated (zero-emission) urban transport system, the private sector could continue to push ahead with specific elements. Building on examples that are already being rolled out, this includes the integration of public transport journey planning apps and shared vehicle apps. For example, the public transport journey-planning app Citymapper[60] is already providing the option to order a ride share through Uber directly, however the next step would be to integrate available shared cars into the app. Additionally, focusing car sharing growth on public transport stations by securing parking spaces in those areas would allow consumers to further test using shared cars for 'the last mile'. This, in turn, could show the public sector the way forward and lead to further buy-in. Private players in the space could also advise governments on relevant policies and infrastructure planning.

CASE STUDY >>

MAAS GLOBAL

In June 2016, Finnish company MaaS Global launched the first all-inclusive multi-modal transport service to be rolled out across all of Finland's cities and public transport networks.[61]

To get around the city, commute or escape for the weekend, Helsinki dwellers and tourists can now use a single multi-modal mobility app giving them instant access to bus, train, shared bikes, taxis or hire cars, and multi-modal planning features. The same card is used for public buses, metro, trains, and shared cars. Monthly mobility packages are available but users can also choose the pay-as-you-go option.

The initiative was officially launched in mid-June 2016 together with the beta test, which aims to fine-tune the mobile validation technology. Full rollout across the country began in September 2016, starting with the Helsinki region. Twenty-four organisations put money into the project with eight emerging as shareholders: four Finnish companies and four international companies invested, with international French transport company TransDev and Turkish automotive company Karsan Otomotiv both owning 20%, alongside Finnish company Veho as a majority shareholder.[62]

The launch is the culmination of six years of planning, involving multiple public and private stakeholders, including Finland's rail and city public transport companies, the Finnish company Mobility-as-a-Service Global (which produced the Whim app), and the car hire company Sixt. In particular, the Finnish government has been pushing the initiative, saying that: 'The biggest driver has been jobs and economic growth'. Mobility packages run from less than €100 for public transport access to €1,000 packages that give users unlimited access to a hire car without the hassle of ownership.

Moving forward, upgrading infrastructure such as intermodal transition points may be required to grow the user base even further. Looking beyond Finland, MaaS is already in negotiations with other countries and regions across the globe, and they hope that Estonia will come on board shortly.

CASE STUDY >>

DRIVE NOW

In Copenhagen, DriveNow has set up the largest mobility system in Europe integrating zero-emission shared cars and public transport.

On a business area of 82.8km^2 in Copenhagen, 400 fully electric BMW i3 cars[63] are integrated with the public transport system. Users are thus provided with an easy, flexible, and clean option for their journeys: they can reserve the nearest electric car with only one click on the DriveNow app, and return it promptly anywhere, at any time, within the area. Everything can be found at a glance on the app: from the route of the vehicle, to the charging stations for the free refuelling and the satellite locations where the cars can be parked. The app is also the key to the 400 cars, which can be opened or closed with the DriveNow card or the Rejsekort travel card. The planning and payment system for these shared electric cars is also fully integrated with public transport. Users can park for free almost everywhere[64] and get 20 minutes' bonus parking time when they park and plug in the car at a charging station.[65] The infrastructure will also be expanded as the energy group E.ON plans to build 640 charging points for the benefit of all electric vehicle drivers. Priority lanes for electric vehicles are already in place at Copenhagen's airport.

This easy, flexible and zero-emission mobility service was made possible by a close partnership between a set of public and private players. Indeed, the Arriva-DriveNow partnership[66] is supported by the Danish Energy Agency and the Capital Region of Denmark.

These examples provide clear templates for how this shift can be realised through public and private sector investment and cooperation.

2 DESIGNING AND PRODUCING CIRCULAR CARS

Moving to the design and production of fully circular cars would create a car industry based on more durable vehicles, the looping of component and material flows, and reductions in negative externalities. This transition would leverage innovative technologies for car production (such as robotics and 3D printing), lightweight materials, and end-to-end material tracking. The introduction of such circular cars could be achieved with an investment of up to €35 billion between now and 2025, and could put the EU on a pathway to realise a total cost benefit of €75 billion per annum by 2030, driven mainly by reduced costs of materials, and a smaller total car fleet.

Relevance of investment theme

Multiple features of circularity are already established in specific segments of the European car industry. Remanufacturing has a positive economic case (as shown in Investment Theme 'Remanufacturing car parts'),[67] which could be further enhanced if cars are designed that take into account disassembly. Some companies are exploring and, in some cases, already producing, cars with durable materials,[68] while electric vehicle sales in the EU are growing rapidly.[69] Meanwhile, both manufacturers and non-traditional players, such as technology companies, are dedicating an increasing part of their R&D budgets to autonomous vehicles. Combining all of these elements into a single model of car design could provide a step-change towards the production of fully circular cars.

Such cars would be material banks, from which used or unfashionable parts could be removed and replaced by remanufactured parts ready for another life. They could also be designed to maximise the potential for upgrades in functionality, features, size or performance. If higher-value materials are used that provide increased durability, incentives to remanufacture those would grow in order to avoid losing value.

Indeed, designing and producing such circular cars would shift the transition to an overall circular economy into a higher gear and generate sizeable economic value, notably through increased resource efficiency, as well as reaping significant environmental benefits[70] that would otherwise not be captured. The need for primary materials, the volume of waste, and greenhouse gas emissions would all be reduced due to the combination of longer lifetimes, clean technologies and increased reuse, remanufacturing, and recycling.

The economic benefits are derived from a number of factors: mainly the lower cost of remanufactured parts versus the cost of new parts; energy and water savings; reduced lead times and lowering of costs associated with long supply chains, as well as associated security risks;[71] and decreased costs in the mitigation of risks related to the scarcity and price volatility of material inputs.[72] Designing and producing circular cars makes these benefits even more substantial as circular car parts can, by definition, be looped more systematically, more easily, and more efficiently.

Designing for looping would also allow manufacturers to deal with a faulty unit without recalling all their products. The cost savings involved could be substantial, as shown by a battery pack manufacturer that went into bankruptcy after a faulty unit was discovered post-production: the company tried to recall just the batch from which the faulty unit came, but because the units were not designed for looping, the serial numbers were not accessible, so they were forced to recall all of their products.[73]

In addition, producing cars that are both low emission and made for looping would generate cost synergies. For example, the project ABACUS run by a consortium that includes Jaguar Land Rover, WMG, University of Warwick, Potenza Technology, and G&P Batteries, has investigated the synergies between designing for looping and using lithium ion batteries to power electric and hybrid vehicles. The project has found that adjustments in the design to allow for the looping of battery parts would generate cost savings as recycling costs would be reduced[74] and valuable parts that are subject to supply risks could be recovered. The project has also developed a business model in which the battery might be owned by someone other than the car owner, therefore easing the process of battery collection, and also likely increasing sales of electric cars as it reduces their upfront cost – a key consumer concern.[75]

The benefits captured are even greater when the same player manufactures and owns circular cars. Some manufacturers, such as Rolls Royce, have recognised that by employing leasing models, the selling of a product as a service can incentivise better design and generate mutual benefits, where customers are guaranteed a fixed engine maintenance cost over an extended period of time, and the car manufacturer retains the product and the associated benefits of looping it and its components and materials. Such a business model implies combining the production of circular cars with service offerings such as car leasing or car sharing. Indeed, in this set up the car manufacturers are incentivised to invest even more in higher-value materials and design for looping: they will own the cars throughout their life cycles, and therefore know they can recover the majority of the substantial investments they have put into the cars at some point through looping. Thus, the focus shifts towards producing a car that is both as durable and as easy to loop as possible , which fully phases out planned obsolescence.[76]

10 INVESTMENT THEMES

When driverless car technologies reach the commercialisation phase, they will open up additional investment opportunities for circular cars.

Recent developments

The timing is now opportune to design and produce such cars. Indeed, innovative technologies and business models are available to effectively allow this change to take place:

- The use of higher-value parts and materials is an important step towards the production of cars made for looping. For example, headlamps have a much higher value today (at least €100 each), than they used to.[77] Therefore, it is more profitable to remanufacture headlamps than it is to buy new ones. Specifically, higher-value materials that are also more durable and lightweight, such as aluminium, can make reuse, remanufacturing or recycling more attractive[78] as there is no loss of quality during the process.[79]

- Electric vehicle sales grew by more than 100% in 2015 and many car manufacturers are spending an increasing share of their R&D budgets on this technology.[80]

- Many OEMs, as well as technology and car sharing companies, are devoting an increasing budget to the development of autonomous cars.

- Digital technologies and innovations (such as digital passport IDs) are emerging that allow for the monitoring and tracking of car parts and materials end-to-end, making it easier to collect end-of-life parts.

- Innovative production technologies, including robotics and 3D printing, could be powerful ways to reduce production costs for cars made to be looped and the subsequent remanufacturing costs. Currently, disassembly operations are complex and tend to be mostly manually executed, but the development of more efficient production and remanufacturing processes, which leverage robotic technologies to carry out disassembly in a collaborative fashion between man and machine, or with minimal human intervention, is increasingly the focus of pilot and research projects.[81] Indeed, the stakeholder workshop dialogue 'Supporting Excellence in UK Remanufacturing', which involved industry leaders, top academics, and supporting organisations[82] reached the conclusion that: 'Improvements in automation, decision-support systems, and other technologies are helping to drastically improve the efficiency of remanufacturing processes and reduce costs. Other technologies such as 3D printing or laser cladding are also improving the cost and quality of remanufacturing.'[83]

- Car sharing shifts the focus from car purchase price to total cost of ownership, as car ownership transfers from consumers to car sharing companies. Businesses typically take into account the full cost of owning cars, including depreciation and maintenance, therefore more durable cars with lower maintenance requirements – and possibly with lower fuel costs because they are lighter – that can be easily upgraded are likely on balance to be favoured over more traditional cars. Additionally, if a car

has a higher market value at the end of its life, it should also improve the economics of the industry.

• Service-based business models, such as car sharing, provide car manufacturers with more opportunities to create and foster direct interface with clients. Indeed, such integrated service offerings could be a way for car manufacturers to be seen as providers of value-added services,[84] rather than pure hardware suppliers. The world-leading manufacturer Caterpillar Inc. demonstrates that service-based offerings, such as leasing or servicing, are a powerful lever to building and maintaining a long-term client relationship.

• As the new generation of car users is willing to extend their increasingly connected lifestyle to more day-to-day activities, there is an opportunity to design a circular car that would provide features specifically created to enhance car sharing, such as innovative in-transit services (e.g. desktops for passengers allowing them to work and make video calls during their journey).

Investment opportunities identified

Three main areas of investment have been identified: circular car design and development; establishing production lines; and rolling out digital tracking systems for car materials:

• The first investments would have to be made in the design and development of circular cars. Initial designs would have to show how far the key elements of circular cars (durability, optimisation for looping, low-emission technology) could be integrated. Based on the potential designs, market testing would have to demonstrate which designs would be most commercial. This testing could lead to adjustments in elements of the car's design and further testing would have to be carried out in order to move towards the setting up of a new production line. This investment opportunity consists of different sub-parts, such as design, prototype building, and market testing, and would likely require a range of specialist companies to be involved. As the design of a new car model can typically cost between €1–3 billion, investments in the design and testing of a fully circular car would potentially need to come from a large (corporate) investor.

• If the testing phase of the newly designed circular car showed positive results, a new production line would have to be established, with a variety of component production facilities supplying the assembly plant. Depending on how different the production process is from existing production lines, this could either imply upgrades or completely new production facilities. As production of the BMW i-series has shown, with its material production plant in the US and assembly plant in Germany, the whole investment does not necessarily have to be made in the EU.

• Investment in material tracking system innovation could be made concurrently to that in the design and manufacturing processes. This would enable manufacturers to track materials and components throughout their lifetimes and to identify – when

they approach their end-of-life stage – where they are in the system, what condition they are in, and what the best looping option (reuse, remanufacture or recycle) would be. This system could be embedded into both the new circular car designs and also in other new car models. Such a system could include:[86]

- Product information (i.e. a 'product passport') to enable traceability and understanding of what conditions products and parts have been subjected to during their lifetime, and how/whether they can be remanufactured;

- Labelling for products that are designed for disassembly. This would enable dismantlers or component brokers to easily determine how to channel products collected at the end-of-life stage.

- Support systems to determine whether products are fit for reuse, remanufacture or recycling.

Current barriers to investments

If an OEM perceives a sufficiently attractive market for a new car model, its design and production investments will naturally increase. As indicated above, car manufacturers have already been designing cars with some elements of circular cars in mind but so far have not integrated all elements into one model. A fully circular car design has not yet taken off at scale largely due to a combination of high upfront costs and a lack of certainty regarding capturing value at end-of-use. As a result, the business case is too risky for the typical business model which is based on car manufacturers selling cars to customers.

The higher costs of circular cars are driven both by the use of more expensive materials to generate increased durability, as well as the use of low-emission technologies such as batteries. However, it is proposed that both of these elements have scope for cost reduction.[87]

In order to make a positive business case for cars designed for durability and looping, the value recovery mechanism at the end-of-life stage needs to be clear. This clarity would have to be such that customers of the new circular car could take this value into account when assessing the attractiveness of the circular car versus its competition. Consequently, car buyers (companies or consumers) would also have to shift from valuing a car based on its purchase price only to total cost of ownership.

A ramping up of remanufacturing would be required to make circular car design and production attractive. This investment theme is therefore closely linked to the investment theme on remanufacturing car parts. It would not be able to scale fully unless barriers to car remanufacturing outlined in that theme are lifted in the near term.

Interventions to scale up investments

The main solutions to increasing the design and production of circular cars lie in reducing the market risk. Explicitly, this means providing car designers

and manufacturers with sufficient certainty on market potential to start deploying capital towards the initial design process. Achieving this will require collaborative efforts between car designers, manufacturers, and potential customers, which could include car sharing or leasing companies and potentially public sector bodies. Further efforts to set up innovative business models would also be required: for car manufacturers such models could focus on providing clarity on end-of-life value recovery, but also on shifting to service offerings such as car leasing or car sharing.

• **Governments at EU, national, regional, and local level:** Although the main work around car design, development, and production would have to be led by the private sector, the public sector could play a facilitating role by further bringing together the required stakeholders, such as manufacturers and circular car customers. Additionally, financial support through schemes, including direct funding or tax support, along the full car value chain could be provided, such as:

- Pilots for car design technology innovations. Horizon 2020 is already providing funding in the area of electric vehicles and the use of lightweight materials[88] and this could be broadened to include design for remanufacturing and integrated designs taking all these factors into account;
- Investments in circular car production facilities;
- Innovations in digital material tracking systems and secondary material markets;
- Support for circular cars similar to support schemes for electric vehicles;
- Public procurement of circular cars.

Moreover, the public sector could support the creation of secondary materials and component markets similar to the efforts around the organic fertiliser markets;[89] by aligning standards and definitions across borders, it should become easier for car (re)manufacturers to source predictable volumes of parts and materials if such a market exists at scale. Creating consumer awareness of the benefits of circular cars would also support demand for such vehicles.

In parallel, both the public and private sectors should provide support to ramping up remanufacturing, notably through collaboration across the value chain (such as Intellectual Property sharing models); the rollout of more efficient reverse logistics systems; awareness building among consumers and governments; and the promotion of procurement policies that make decisions based on total cost of ownership.

• **Private sector:** One key step forward would be for the private sector to bring together car designers, manufacturers, remanufacturers, and customers in order to determine more specifically which circular car designs would likely lead to greatest market penetration. Probable primary market segments are car sharing and leasing companies like commercial fleet managers, but taxi drivers could also be considered. All potential market segments have in common that they own highly utilised cars[90] and would therefore

>> 10 INVESTMENT THEMES

DRIVERLESS CARS

Significant investment has already started into R&D for driverless car technologies. Examples of OEMs operating in this area include General Motors investing $500 million in Lyft during the early part of 2016; Ford announcing its move into this sector by developing autonomous cars specifically for sharing;[93] and Tesla developing its own driverless electric model. Additionally, non-OEMs, such as Google and Uber, are developing their own driverless vehicle technologies, and new entrants have appeared such as Zoox, which has raised $290 million to date[94] and has developed a completely new car model designed without a steering wheel.

According to expert views, driverless vehicles could be available commercially within five years,[95] with a launch by a first mover most probable in a medium-sized city. This rollout is unlikely to be very fast as the driverless technology needs to be adapted city by city, with an estimated initial rollout of a maximum of 1,000 to 2,000 driverless vehicles.[96] Driverless cars are not likely to be a cost-effective technology in the next few years, and legislation for driverless cars will not be widespread for some time.

benefit from longer vehicle lifetimes, lower maintenance and fuel costs, and retained value at end-of-use. Other market segments could be customers who procure cars based on a whole life valuation[91] or those who are willing to pay a premium for the resource efficiency and environmental benefits generated by circular cars made for looping, e.g. customers looking to build an environmentally friendly reputation or attract and retain talented workers.

Although these market segments are likely to be willing to pay a premium price for circular cars, further efforts to set up innovative business models would be required to derive the full value from circular cars.[92] These innovative business models could focus on providing clarity on end-of-life value recovery, but also on shifting to service offerings such as car leasing or car sharing, as this has the advantage of lifting the two key barriers: high cost and lack of certainty regarding capturing value at the vehicle's end-of-life stage.

Lastly, car designers, manufacturers, and remanufacturers could set up an open automotive material backbone centralising standardised data on durable easy-to-loop materials. This would allow designers, manufacturers, and remanufacturers to get an overview of materials' performance but also its durability and easiness to loop, and thus foster design of circular cars.

CASE STUDY >>

VOLVO

A car designed for disassembly by Volvo dispenses the myth that remanufacturing and a reputation as a supplier of safe, solid, and high-quality cars do not mix well.

Volvo has adopted a market-leading approach to integrating circularity into its business strategy. Disassembly and opportunities for remanufacturing have played a central role in the design process of its flagship twin-engine plug-in hybrid XC90 t8. For example, it uses screws instead of glue or welded joints when sealing the casing of certain components such as the high-voltage battery casing, all of which allows for easier disassembly. Also, in August 2016, Uber and Volvo announced a partnership in which both companies will jointly invest $300 million to develop a fully autonomous, self-driving car. Both companies will use the same base vehicle, the XC90, for the next stage of their respective developmental processes. The partnership highlights the systemic change underscoring the automotive industry, and the opportunities for investment into new frontiers of technology.

Specifically, designing for disassembly is attractive for Volvo as it already has a remanufacturing process in place that remanufactures parts to its original specification, called the Exchange System. Newly designed components – such as the high-voltage battery, rear axle drive, and integrated starter generator – can be included in the Exchange System. The economic case for this system is strong for Volvo – a remanufactured part uses up to 85% less raw materials and 80% less energy than a new product. In 2015, Volvo saved over 780 tonnes of steel and 300 tonnes of aluminium. In total, Volvo's Exchange System accounts for 15% of its spare part sales, which is therefore expected to increase through its newly designed car model. The drive to mainstream disassembly throughout its design process demonstrates Volvo's confidence in its business case and commitment to integrating a circular approach to its manufacturing process.

3 REMANUFACTURING CAR PARTS

Remanufacturing is defined as 'a series of manufacturing steps acting on an end-of-life part or product in order to return it to like-new or better performance, with warranty to match'.[97] The used product typically goes through a number of stages: after being disassembled, its useable parts or components are cleaned, restored, and tested, before being reassembled to obtain a product that matches or is superior to the original product when it comes to performance, warranty, and all other specifications including design and safety. There is a clear investment opportunity to ramp up car remanufacturing for the current car fleet (i.e. cars not designed for looping). It is estimated that by investing up to €1 billion between today and 2025 in car remanufacturing, could move the EU onto a pathway to achieve a €30 billion benefit by 2030, largely through a reduction in the costs of manufacturing new car parts.

Relevance of investment theme

Car remanufacturing has been in place for decades, with examples of remanufacturing operations found in a range of automotive parts, including but not limited to: engines, transmission and drivetrain parts, rotating electrics and ignition parts, as well as air conditioning.[98] Car parts commonly remanufactured today are engines, gearboxes, transfer boxes, and power take-off systems.[99] Remanufactured parts are typically supplied to vehicle manufacturers or directly to the third-party aftermarket,[100] thus ensuring that these parts do not end their life in landfill or an incinerator generating a significant value loss for players,[101] as well as adding to greenhouse gas emissions. Most remanufactured parts are sold via the aftermarket[102] and dealer network, the automotive aftermarket being one of the most profitable markets for OEM and original equipment suppliers (OES).

Indeed, car remanufacturing activities present a strong economic case for companies in the space mainly due to the lower cost of remanufactured versus new parts. Remanufacturing allows the industry to recover the total value of the materials,[103] with minimal additional input of raw material. In contrast, recycling – which reduces the product into raw materials, which can then be used again[104] – only allows players to recover the materials but not their value-added potential. Remanufacturing could offer savings of 88% in material costs.[105] Remanufacturing also typically uses 85% less energy than manufacturing,[106] as well as lower water consumption. Conservative estimates show that with reduced input costs and increased labour spend there can

still be up to a 50% increase in gross profit.[107] By keeping products 'whole', remanufacturing also reduces lead times and costs of long supply chains and their associated security risks.[108] Companies could also mitigate the impact of a scarcity of new material inputs and price volatility by retaining or reclaiming ownership of products and parts at their end-of-first-life.[109]

Renault's remanufacturing plant at Choisy le Roi is testament to the benefits of car remanufacturing: it is the group's most profitable industrial site – it reuses 43% of carcasses and recycles 48% of materials in foundries to produce new parts.[110] Remanufacturing could also provide a competitive advantage for car manufacturers, increasing customer loyalty and boosting market share. According to Ben Walsh, former manager of the Centre for Remanufacturing and Reuse: 'For businesses remanufacturing is about retaining both the value of products and a client base.' For example, Caterpillar Inc. shows that this can be achieved by keeping the price low for clients and leveraging service-based business models (e.g. leasing and servicing) to build and maintain long-term client relationships. In fact, remanufacturing could open up new market segments for car manufacturers. Given that lower price points can be achieved with remanufactured products, one option could be to offer remanufactured parts to clients who are more price-sensitive, creating brand equity and loyalty with these new customers.[111] A basic remanufacturing process using longer-life products could even be established for these client segments, as research has shown that they typically do not seek the latest product features.[112]

In order to further grow car remanufacturing profitably, a few key elements need to come together:

- A stable flow of end-of-life car parts of similar types to provide remanufacturers with the input needed to run their facilities without having to manage large fluctuations in volume, type, and quality of parts;
- The building of additional remanufacturing facilities and the training of qualified staff to operate them;
- A growing demand for remanufactured parts from car manufacturers, willing to commit to buying them at pre-specified quality standards.

Recent developments

The European car remanufacturing market is estimated at €7.4 billion and could continue growing at a relatively slow rate of 3% a year, following the trajectory of current developments.[113]

However, the time is ripe for growth. The 2015 European Remanufacturing Network Study for EU Horizon 2020[114] estimated that the European automotive remanufacturing sector has the potential to increase its annual growth to up to 18% by 2030, which would unlock sizeable economic, environmental, and societal benefits. This accelerated ramp-up could generate an additional turnover of up to €11.5 billion, create up to 18,600 net jobs, and avoid up to 5 million tonnes of carbon dioxide emissions. These additional benefits brought by an accelerated scenario, would not be realised in the current development

course of events.[115] [116] According to experts in automotive remanufacturing, a huge opportunity to increase car remanufacturing exists even without changing the way cars are designed, and OEMs as well as external players are now taking this opportunity more seriously.[117] Beyond growing the current volumes of remanufactured mechanical car parts, additional opportunities exist to remanufacture higher-value parts including electric motors. According to the Society of Motor Manufacturers and Traders, turbochargers, engine control units, instrument clusters, clutches, and steering pumps and gears will be among the fastest-growing product lines for remanufacturers.[118] Batteries for electric vehicles and hybrids may not be viably remanufactured as such, but the electrochemical elements inside them could be.[119] Indeed, some companies, such as LiTHIUM BALANCE, are exploring the possibility of remanufacturing batteries from electric vehicles and using them for alternative purposes, such as storage for photovoltaic systems.[120]

Investment opportunities identified

The accelerated growth of the car fleet remanufacturing market mainly requires investments in new remanufacturing facilities, estimated to be worth up to €1 billion between now and 2025. Although typical investments per remanufacturing facility are smaller than a new car production facility, the returns could be attractive due to the combination of a profitable underlying business case, the untapped growth opportunity, the associated opportunities to enhance customer reach and loyalty, and the increasing momentum behind the shift towards circularity. Indeed, several experts see remanufacturing as an interesting area for private equity players to consider investing in.[121]

Current barriers to investments

The main barriers that prevent the European car remanufacturing industry from growing faster in the near term are resistance and lack of awareness among car manufacturers, as well as policy barriers. Some of these barriers include: the need for adapted procurement systems[122] to coordinate supply from remanufactured parts and new parts, lack of an efficient market for end-of-life parts, and the difficulty in disassembling parts, particularly when they are glued, riveted or welded.

The resistance among car manufacturers to ramp up remanufacturing volumes stems partly from concerns over reputational risk, and partly from concerns about the cannibalisation of their new spare part market. Concerns around reputational risk relate mainly to the potential damage to a brand known to provide robust, safe vehicles. However, this view varies in adjacent sectors. For example, in the heavy-duty vehicle sector, Caterpillar Inc. explicitly markets its remanufacturing activities as enabling the group to keep prices low for its clients while maintaining its quality.[123] Remanufacturing in other sectors is common practice: for example, 12% of parts used in the European aviation industry are remanufactured, for instance.[124] DLL, a European financial

institution, recently concluded that remanufactured second-life assets may enhance financial performance[125] due to benefits such as protection of brand image from third-party brand dilution and customer demand for second-life assets. Alongside resistance to car remanufacturing in some parts of the industry, other car manufacturers are unaware of its potential.

Currently, EU policies are not always designed to encourage remanufacturing. Even though the European Commission has issued several directives that encourage reuse, recycling, and recovery – such as those relating to end-of-life vehicles, electronic equipment, and the disposal of hazardous waste[126] – these policies focus primarily on recycling and have mixed effects on remanufacturing activities.[127] For example, the EU's Restriction of the Use of Certain Hazardous Substances (RoHS) Directive has reportedly driven up costs and/or reduced the recovery of parts for some EU remanufacturers by prohibiting the reuse of electric and electronic parts containing certain substances such as lead, cadmium, and mercury.

Interventions to scale up investments

To achieve a step-change in the growth in sales of remanufactured automotive parts across Europe of up to 18% per annum and unlock the significant investment opportunities, car manufacturers and remanufacturers would have to jointly set up clear quality standards, establish efficient reverse logistic processes, and ensure proper value-sharing and Intellectual Property (IP) protection. In addition, policies designed to incentivise car remanufacturing and stimulate the market for end-of-use car parts are needed to speed up the shift. The public sector could provide further stimulus by requiring public procurement of remanufactured parts.

- **Governments at EU, national, regional, and local level:** The three main areas where the European Commission as well as governments in Member States could provide support to stimulate car remanufacturing are: increasing demand for remanufactured cars through public procurement; increasing consumer awareness of the benefits and supporting the creation of an EU-wide market for remanufactured parts similar to the creation of the market for organic fertilisers; and providing policies that incentivise the use of remanufactured parts. The latter could be done through financial incentives, legislative changes or direct mandating. For example:

- Providing funding for innovations and pilot schemes to improve car remanufacturing processes;[128]
- Implementing tax breaks for remanufacturers, so encouraging the uptake of remanufacturing;
- Implementing procurement policies that favour remanufactured cars (e.g. by adopting whole-life costing[129] and other procurement measures). For example, the US Senate passed the Federal Vehicle Repair Cost Savings Act in October 2015 which requires all federal agencies to consider using remanufactured parts when maintaining the federal vehicle fleet – a similar policy change could be implemented across Europe;[130]

10 INVESTMENT THEMES

- Adopting a common definition of remanufacturing across Europe to provide clarity to businesses when distinguishing between it and other circular economy concepts, such as refurbishment and reuse;[131]
- Amending legislation to distinguish products that can be remanufactured from those that cannot to ensure that products that can be remanufactured do not fall under the remit of waste regulations (all equipment could be classified as a product before it is fully assessed and only then could it be deemed waste[132]). Indeed, since remanufacturing occurs during the use-phase of the vehicle, remanufacturing should be addressed by a use-phase policy instrument;[133]
- Legislating for access to product specifications (e.g. set the requirement that a designer is compelled to state, upon request from a manufacturer or remanufacturer, the components of a product to enable easier remanufacturing);
- Revising ISO 9001 to include remanufacturing[134] and re-examining Waste Electrical and Electronic Equipment (WEEE) targets to place more importance on reuse/remanufacture over recycling;[135]
- Considering the potential of a certified mark for remanufactured products to demonstrate that they have been tested and comply fully with the standards of a new product;
- Setting targets that push remanufacturing and focus on the value retained in the economy, rather than the volume of waste shredded,[136] such as minimum remanufactured content in new cars;
- Accounting for the environmental benefits from remanufactured parts in the product's whole life cycle. This may mean doing a lifecycle cost analysis and developing an environmental balance sheet that can bring to the fore the gains that are made as a result of remanufacturing;[137]
- Requiring garages to offer clients remanufactured parts as well as new parts for the repair and maintenance of their vehicles (a similar law was passed in France in January 2016);[138]
- Collaborating to incorporate recommendations in remanufacturing from private sector players such as the business standards company, BSI.[139]

• **Private sector:** A good way to accelerate market development is to set up collaboration schemes between manufacturers and remanufacturers to increase remanufacturing volumes in a controlled way that reduces risks sufficiently for (re)manufacturers to invest in new facilities.[140]
The following elements should be considered in these collaborations:[141]
- Certification schemes for remanufactured products to meet defined standards;
- Integrated reverse logistics or services to reclaim end-of-life parts;
- Fair sharing of economic value between manufacturers and remanufacturers that incentivises close collaboration and high availability of parts (e.g. through royalties from remanufactured products);
- IP-sharing models that enable manufacturers to maintain control over IP, while providing remanufacturers with access to critical data, such as materials and process requirements, or disassembly sequences.

Additionally, private sector organisations looking to drive the growth in remanufacturing markets could support the rollout of a more efficient reverse logistics system and the creation of a market for remanufactured parts. Ways in which this could be done include:

- Incentivising users to return cars and/or parts, so they can be remanufactured. This could work in a similar way to Xerox, which operates a reverse logistics process to get back all their end-of-life products so they can be remanufactured. In order to incentivise consumers to do so, the company buys back each product at a given rate, based on demand;[142]
- Promoting a whole-life costing approach in procurement;[143]
- Considering setting up digital marketplaces for automotive parts;
- Developing quality marks for remanufactured products, which could reassure customers;
- Running pilot schemes that demonstrate cost-effectiveness for innovative business and operation models, which incorporate re-manufacturing (e.g. for end-of-life car parts collection systems).

Insurance companies in particular could play a role in accelerating the growth of car remanufacturing, as they take ownership of large volumes of cars when they are written off. Indeed, insurance companies have been invited to promote the use of remanufactured parts and have been generally positive about doing so.[144]

More widely, the private sector can help create awareness among consumers and governments by:
- Advising governments on the relevant incentives and legislative changes required to make remanufacturing business models work. An example of this is the new business-led Council for Remanufacturing, which has been created by Oakdene Hollins in Brussels to lobby for change;[145]
- Establishing joint training and capacity building programmes;[146]
- Supporting joint consumer awareness programmes.

CASE STUDY >>

MCT ReMAN LTD

Driven by the recent growth of interest in remanufacturing from new players, the English car contract remanufacturer MCT ReMan Ltd is exploring opportunities to expand remanufacturing to more car parts and components, including in the electric vehicle drivetrain.

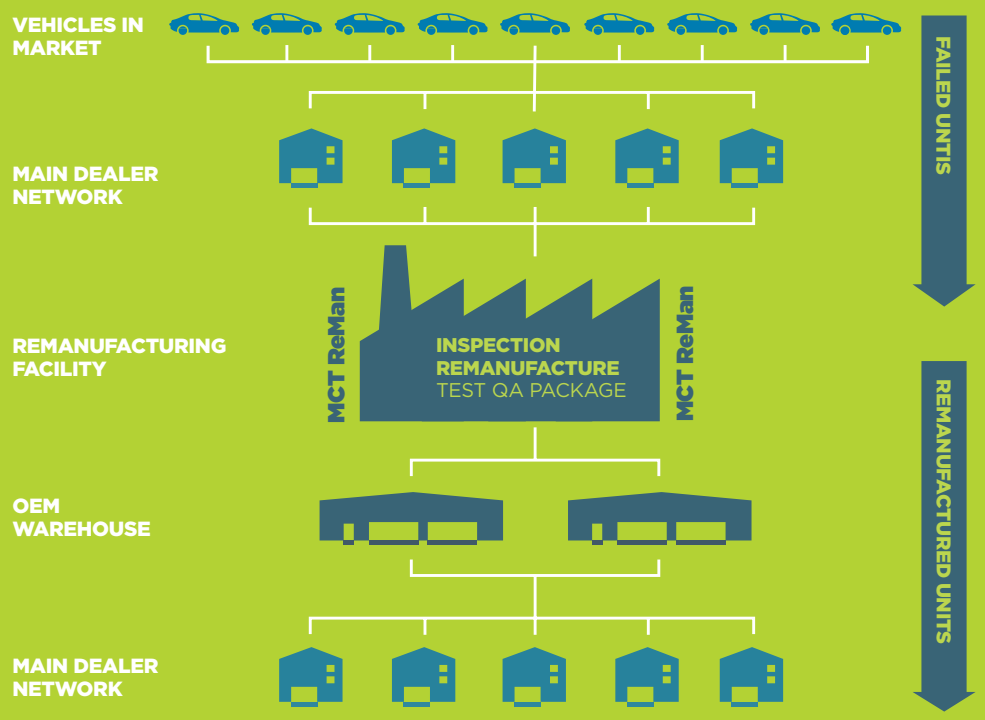
MCT ReMan Ltd, based in Weston-Super-Mare, England, is a remanufacturer of automotive engines and gearboxes. Emerging from the manufacture of industrial fans in the 1960s, it moved into remanufacturing in the mid-1970s to respond to demand from its customer, Ford. With a turnover of £7 million and 68 employees, MCT remains focused on this key facet of the circular economy, remanufacturing a broad range of high-volume engines and gearboxes for a variety of OEMs.

Although OEMs could (and do) carry out remanufacturing themselves, they often find it beneficial to outsource to smaller specialists due to their unfamiliarity with some of the processes involved (e.g. disassembly, cleaning, and the procurement of small volumes of components) and their characteristics, such as variability, risk, and relatively small throughput.

To provide OEMs with car parts in the most optimal and cost-effective manner, MCT's business model is based on taking ownership of the product and warranty before returning them to the end user via the OEM and their dealer network. The company primarily remanufactures engines and gearboxes that are still in warranty but have failed. At this point, the logistics of collection and return is straightforward, and the value returned (relating to what will still be a current specification engine or gearbox) is clear. The OEMs collect failed units (referred to as 'cores'), via their dealer network, and transfer them to MCT. Ownership of the core transfers to MCT, although it is 'free issued' (free of any payment either way). MCT carries out its remanufacturing processes, including the procurement of genuine OEM components and testing. MCT's remanufacturing process takes an average of ten hours for a typical engine, from receipt of the core to dispatch. MCT gets paid upon receipt of the remanufactured unit back at the OEM's warehouse. From there, the units are distributed and installed in the end user's vehicle via the OEM's main dealer network (see Figure 21). Liability relating to the warranty on the remanufactured unit is owned by MCT. The duration of this warranty is the same as for a brand-new unit. However, the unit the end user receives is unlikely to be the very same unit that failed. Instead, MCT, working with the OEM, keeps an appropriate level of cores in stock, which reduces lead time and risks.

Recognising the quality and value of MCT's services, a variety of OEMs make use of them, including: Ford, Jaguar LandRover, Volvo, Mitsubishi, GM, Opel, and the London Taxi Company. MCT remanufactures a total of approximately 14,000 units per year. MCT works closely in partnership with OEMs to understand their particular balance of needs and drivers. It does compete with other similar contract remanufacturers, but there is room for several players in the marketplace, which keeps their costs and risks manageable.

FIGURE 21 **MCT REMAN LTD'S PLACE IN THE VALUE CHAIN**



While MCT has all the paperwork (accreditations, processes, and management and ownership of risk) and sophisticated testing equipment that one would expect, remanufacturing by contract remanufacturers like MCT ultimately relies upon reputations and trusted relationships. This trust manifests itself in the additional services that MCT is asked to provide, including problem solving and support for new product development.

The company is now exploring opportunities to expand remanufacturing to more parts and components. Beyond automotive engines and gearboxes, MCT is also increasingly remanufacturing other products, such as compressors and hydraulic components. To expand its remanufacturing operations to other products, it is considering mostly electric and hybrid vehicle components and renewable energy technology. It is also looking to new technology (such as data gathering/tracking, metrology, automation, and additive manufacturing) as an enabler of its work. Working with sister company Tecforce, it is deploying its expertise for the benefit of the rail industry.

"MCT have been remanufacturing for over 40 years. We have recently seen a growth of interest in the industry from external sources and new players, which is very positive. A major enabler of future growth will be increased collaboration with the manufacturers."
Ian Briggs, MCT ReMan Ltd, 2016

MCT ReMan Ltd is an exemplar of the way remanufacturing can flourish and support the whole automotive industry. It also clearly demonstrates the opportunities for growth and investment in this crucial part of the circular economy.

4 DEPLOYING REGENERATIVE AGRICULTURAL PRACTICES

Regenerative agriculture could be broadly defined as the synergistic combination of as many practices as possible, including permaculture, organic, no till,[147] holistic grazing, and keyline land preparation.

Shifting towards an agricultural model that regenerates the soil and revitalises ecosystems through farming management practices and technologies could bring Europe onto a pathway to achieve overall economic benefits of up to €35 billion per annum by 2030, against an estimated investment of €15 billion between now and 2025. The primary areas of potential investment are in providing funding to farmers to bridge the transition towards regenerative practices, as well as investments in specific technologies and machinery enabling these practices. This transition would see economic rewards based largely on a reduced dependency on fertiliser and pesticides throughout the agricultural industry, alongside an overall reduction in agriculture-related greenhouse gas emissions.

Relevance of investment theme

It is becoming increasingly evident how deeply harmful conventional agricultural practices can be.[148] Our current farming model has resulted in 30%–85% of EU agricultural land being affected by soil degradation[149] and productivity gains for major crops starting to decline around the world.[150] The annual cost of soil degradation in Europe amounts to €38 billion.[151] Indeed, gains in European agricultural productivity have fallen steadily from 2.5% per annum in the 1970s to 1.3% per annum in the 2000s and 0.9% in 2010. This slowing of productivity gains has continued despite significant increases in the use of fertilisers, chemicals (such as pesticides, herbicides, fungicides, and insecticides), fuels, and other inputs designed to increase yields.[152] Currently, 73km^3 of water is poured into the European agricultural system each year (of which only 40% actually reaches the plants),[153] alongside 16 million tonnes of synthetic fertiliser (of which only 5% actually goes into nutrients absorbed by humans). Excessive application of chemical fertilisers creates dependency on imports[154] and heightens risk within the system. For example, nitrogen fixation and phosphorus have already exceeded the safe operating limits of the planet by a factor of two.[155] At the same time, conventional agriculture does not always produce healthy outcomes. In a recent report, the nutritional content of several types of fruits and vegetables, including cucumbers and tomatoes, was shown to have fallen significantly during the second half of the twentieth century.[156] Some foods also often contains traces of toxic chemicals and plastics.[157]

However, emerging practices and technologies are providing increasing evidence that one does not have to choose between preserving the soil and using it for agriculture. In fact, profitable agricultural practices exist that not only preserve the soil, but regenerate it. These practices revitalise the farm's entire ecosystem, resulting in many benefits, including:

- The removal of greenhouse gas emissions from the atmosphere to be stored in the ground in the form of carbon;
- Greater yield stability due to a reduced reliance on fertilisers (crops will eventually become more resistant to viruses and weather changes because healthy soils cope better with droughts and floods);[158]
- Decreased water usage;
- Production of healthier food with a higher-quality nutrient profile than that produced with the help of synthetic fertilisers and other chemicals;
- Giving farmers greater control over their cost base, as inputs such as fertiliser are generated by the farm itself.

The idea at the core of these 'regenerative agricultural' practices and technologies is that everything in the farm should be reinvented to mimic nature: in the words of agri-pioneer, Leontino Balbo: 'If we can restore soil to natural ecosystems conditions, nature will do the rest'.[159] This shift goes far beyond resource efficiency, which focuses on using water and other inputs more economically. Pioneer farmers, landowners, and scientists are starting to think outside the box on many levels, such as in the choice of crops and livestock on farms, the harvesting methods and equipment, and the management techniques for water, waste, energy, and above all, land. A shift in all these factors could mean

FIGURE 22 **OVERVIEW OF AGRICULTURAL PRACTICES**

INDUSTRIAL AGRICULTURE

- Monoculture
- Use of turning plough
- Use of chemical fertilisers

CONSERVATION AGRICULTURE

- Crop rotation
- No till
- Heavy use of herbicides
- Use of chemical fertilisers

REGENERATIVE AGRICULTURE

The combination of as many practices as possible

Permaculture
- Introduction of trees and bushes
- Swales for water retention

Organic agriculture
- Crop rotation
- No use of chemicals and genetically modified organism
- Mechanical weed control

No till polyculture
- Mix of different crops (only for grazing)
- No use of chemicals

Holistic grazing
- Short time and limited space grazing plans
- Soil regeneration thanks to manure

Key line land preparation
- Cultivation along contour lines
- Optimised water retention

Sources: Volterra Ecosystems; Rodale Inst., Gabe Brown (No till polyculture); Allan Savory (Holistic grazing); P.A. Yeomans (Key line land preparation);[160] http://ec.europa.eu/eurostat/statistics-explained/index.php/Organic_farming_statistics; http://www.sciencedirect.com/science/article/pii/S209563391530016

that nature is able to revive the entire ecosystem, generating strong levels of natural capital on which to build highly productive agricultural businesses.

Current organic agricultural practices can be considered as regenerative to some extent, as it implies stopping the use of pesticides and conventional fertilisers, and allowing the soil to start regenerating once these inputs have been removed. However, organic agriculture is just one step towards the soil regeneration and ecosystem revitalisation that are essential to regenerative agriculture. Also, existing organic agricultural practices fail to capture most of the potential economic and environmental benefits if they are not combined with other regenerative practices. As shown in Figure 22, combining several regenerative practices (rather than implementing one) unlocks tremendous economic value for farmers. For example, a 50% higher profitability could be achieved by shifting to organic vegetable monoculture (i.e. by stopping using conventional inputs).[161] But a 200% higher profitability could be achieved by shifting to regenerative vegetable multi-culture (i.e. by introducing a mix of annual and perennial plants, and implementing holistic ecosystem management in a way that mimics nature).[162]

Recent developments

Multiple transitions to regenerative agricultural practices have started in Europe, specifically over the last years. Advanced regenerative agricultural practices with a positive business case and successful proof-of-concept are:

- Regenerative fruit/vegetable/cash crops multi-culture;
- Holistic-planned grazing for bovine, ovine, porcine, and poultry farming;
- Agroforestry systems with alley cropping;[163]
- Low-input pasture-based dairy systems.[164]

Figure 23 gives an overview of the business case for three examples of regenerative practices[165] implemented by Volterra Ecosystems. This Spanish company focuses on integrating various practices into coherent management systems aimed at regenerating farmland within profitable enterprises. The profitability results assessed in Figure 23 are based on initiatives that have already achieved such profitability levels in Europe.[166]

Another player in this space, SLM Partners, scales up profitable regenerative practices by acquiring and managing land on behalf of institutional investors. Direct investment in corporate vehicles gives investors the security of land ownership, but also maximum control over how the land is managed, and full equity exposure to the returns from regenerative farming. SLM Partners has identified a number of proven regenerative agricultural systems that are applicable at commercial scale and provide economic returns that are as good, or better than, industrial production models.[167] They are currently investing in one of these systems (holistic-planned grazing for beef cattle and sheep) and are exploring others for further investment opportunities. These examples demonstrate not only viability, but also a willingness to start embracing these methods in key parts

of the industry, making now a conducive time for investment.

Investment opportunities identified

Although a set of regenerative agricultural practices are profitable, leveraging innovative technologies designed to mimic nature – such as Big Data and robotics – has good potential to further enhance profitability and substantially reduce the payback time as shown by the Balbo Group's innovations, detailed in the case study below. The opening up of this regenerative agricultural market offers four key investment opportunities:

- Investment by farmers or farming companies and landowners in machinery, tools, technologies, proprietary agricultural practices, trees or livestock to shift to regenerative agriculture.
- Provision of finance solutions to farmers during the transition phase to bridge the temporary cash flow reduction they face when shifting to specific regenerative practices and/or meeting their needs for capital to invest in machinery or other assets when required.[168]
- Development and dissemination of innovative technologies and services designed to drive the transition, such as Big Data, robotics, apps, and farm management methods aimed at enhancing current agricultural practices (e.g the Agros Fortis model in the case example).
- Creation of cooperative, not-for-profit or public bodies to develop and deploy programmes to increase farmer awareness of and capabilities in regenerative agricultural practices.

Current barriers to investment

The present-day barriers that prevent farmers from shifting towards regenerative practices at scale can be broken down as follows:

- Most farmers are not familiar with regenerative practices and may be risk-averse or resistant towards them, as the shift to organic farming has been challenging on some farms. In addition, incumbent suppliers, such as agrichemical and heavy land equipment companies have vested interests that prevent them from proactively supporting the move to regenerative practices.
- New skills are required to manage innovative regenerative farms, as the practices involved are more knowledge-intensive and need to be tailored to local conditions.
- Consumer awareness of regenerative practices is very low overall, even though it is increasing in regard to organic practices as shown by the growing sales of organic products.
- The shift towards regenerative practices is challenging for farmers or farm owners, as income is more unstable during the transition period and investment payback times are medium to long term, especially for tree crop models.

Interventions to scale up investments

To escalate the shift towards regenerative practices would require the farms to be incentivised to switch at scale. This could be achieved by increasing the demand/pull for products

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FIGURE 23 **OVERVIEW OF THE BUSINESS CASE FOR THREE REGENERATIVE PRACTICES DEVELOPED BY VOLTERRA ECOSYSTEMS**

STEP 1

STATUS QUO	STEP 1 TOWARDS REGENERATIVE AGRICULTURE			
STARTING POINT	**SHORT DEFINITION**	**INVESTMENT NEEDED**	**NUMBER OF YEARS BEFORE SIMILAR/ BETTER PROFITABILITY ACHIEVED**	**PROFITABILITY ACHIEVED AFTER THIS DELAY**
1. Fruit/vegetable/cash crops conventional, modern monoculture (defined by the use of chemical inputs, such as pesticides or fertilisers, and the likely presence of genetically modified organisms (GMOs)); irrigated with excess of water	Organic fruit/ vegetable/cash crops monoculture (defined by no use of chemical inputs and absence of GMOs); use of chemicals can be reduced gradually	€500 euro per hectare (ha) to introduce the right micro- organisms and other elements	Two to three years, depending on how contaminated and depleted the soil is; the organic certifier decides on the number of years for conversion	50% higher than profitability at starting point, but losses in the first two years have to be taken into account
2. Traditional agroforestry (defined by presence of trees on land that is not used anymore/ unproductive, but in principle is suitable for producing feed and/or livestock)	Remove underwood and use biomass in production of energy, compost, animal feed, charcoal, etc Promote natural regeneration, and diversify tree, bush, and grass species	€400,000 to provide a French state-of the-art mobile biomass harvesting and processing machine for at least 2,000 ha per annum (pa)	One to two years, depending on the type of trees	Profitability dependent on type and application of biomass and time needed to (re)introduce livestock into the system
3. Unproductive (bare), rain-fed land destroyed by agrichemicals and monoculture (mainly cereals) OR Unproductive (bare), irrigated land destroyed by agrichemicals and monoculture (mainly corn and sugar beet)	Activate soil with cover crop and micro-organisms (mycorrhizae) in first year and crop rotation and associated crops in years thereafter Decompaction, if required	€300–500 per ha	Two to three years for the land to become productive again (defined by the presence of weeds, fertility, pests, etc) without chemical products Yield per ha on irrigated land is about two or three times that from rain-fed land	50% higher than profitability at starting point, but possible loss of crop in first two years for corn/sugar beet has to be taken into account

STEP 2

STEP 2 TOWARDS REGENERATIVE AGRICULTURE			
SHORT DEFINITION	**INVESTMENT NEEDED**	**NUMBER OF YEARS BEFORE SIMILAR/ BETTER PROFITABILITY ACHIEVED**	**PROFITABILITY ACHIEVED AFTER THIS DELAY**
Regenerative fruit/ vegetable/cash crops multi-culture (defined by a mix of annual and perennial plants and holistic ecosystem management in a way that mimics nature, including the management of the land, soil, air, water, biodiversity, etc)	€200,000–€500,000 for GPS on a 50–100 ha farm, special weeding equipment, and cold storage of product	Three to five years, depending on the type of crops and trees (for example, three years for almonds and five for pistachios)	200% higher than profitability at starting point, with requirement to be organically certified
Introduction of bovine, ovine, porcine, and poultry livestock (defined by a mix of one to two cows per ha and three to six sheep per ha, plus one to two pigs per ha, alongside poultry, such as chickens and/or turkeys) Introduction of rotational grazing (holistic approach)	Dependent on livestock prices, which will vary widely based on type of animals and number	One to three years, depending on the type of animals and the potential of the land	Higher than profitability at starting point for best practices (several projects to demonstrate and quantify the profitability are ongoing[169])
Agroforestry[170] with or without irrigation	Dependent on trees: €500 (almonds, chestnuts, hazelnut, walnuts, wood trees) Up to €2,000 (pistachios)	Three to four years, depending on the type of trees (for example, three years for almonds, five for pistachios, and 25 to 30 years for wood (50 if the starting point was cereals))	200% higher profitability against a starting point of cereals and 300% higher profitability against a starting point of corn/sugar beet (with requirement to be organically certified)

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from transitioned farms by large players up the food supply chain. A push by governments through the provision of financial incentives to switch would also accelerate the shift.

- **European Commission:** The European Commission could leverage existing policy and funding frameworks, such as the Common Agricultural Policy (CAP), the European Innovation Partnership for Agricultural Productivity and Sustainability or Horizon 2020 to provide incentives for farmers to shift. This could be achieved by supporting innovations[171] and pilots that are improving regenerative practices or providing specific funding solutions to farmers for the transition phase. Additionally, support could be given to the rollout of farmer and consumer awareness programmes, as well as the building up of skills and knowledge.

These initiatives could build on existing European Commission initiatives, for example the creation of an EU market for organic and waste-based fertilisers aimed at stimulating agroforestry and crops diversification.[172]

Using the CAP could also be an effective mechanism. Some adjustments in current policy could include: the adoption of an accurate definition of regenerative practices, including the concept of a two-tiered transition; the identification of the CAP pillar that applies for each tier; and a clear definition of key performance indicators to measure the level of transition needed to qualify for certain subsidy allocations.[173] As the CAP aims to provide guidance on supported practices, partnerships could be set up with cooperative/not-for-profit training bodies deploying capability-building and awareness programmes delivered by farmers for farmers.

- **National, regional, and local governments:** Concurrently with the European Commission, the public sector in Member States could support the deployment of capability-building and awareness programmes, both for farmers and consumers. The public sector could also provide direct support to the transition phase or towards innovations and pilots related to regenerative practices. Moreover, it could provide markets for food products from regenerative agriculture through public procurement and procurement guarantees. A good example of Member State action towards regenerative practices is the 4‰ or '4 per 1,000' initiative driven by the French government that aims to increase the soil carbon stock at a rate of 0.4% per annum, thereby halting the current increase in atmospheric CO_2. The initiative helps contributors in the public and private sectors to commit to a voluntary action plan to implement farming practices that maintain or enhance soil carbon stock. Financial support mechanisms and favourable policies and tools are in

place for farmers innovating to this end.[174] Projects, practical action, and results relating to regenerative practices could also be shared on a blog, enabling all participants to benefit from pooled experience.

- **Private sector:** Retail companies in particular can have a significant impact on farming practices, as has been shown in the past.[175] Impact can be achieved by retailers either changing their requirements for the food products they purchase, or by supporting farmers by providing volume and price guarantees. Recent digital developments[176] are providing retailers with additional tools to measure the benefits of switching to buying food from regenerative agricultural systems. These developments are also enabling retailers to explore the possibility of launching a collaborative effort to shift to regenerative models in their extended supply chain. Digital technologies could be further used to increase the reach of regenerative products in the market and establish customer loyalty to them.

In addition, farmer awareness, capability-building, and technology-transfer programmes would need to be designed and financed. These would most likely require involvement from cooperatives, NGOs or private companies. The lessons from existing programmes should be taken into account during this process. Indeed, existing programmes have shown that the most powerful enabler of driving change among farmers is simplicity. The shift should follow a step-by-step approach, starting with the practices that are the easiest to implement and the most relevant based on the farmer's own experience, expectations, scale, and climate area. For example, Volterra Ecosystems' experts support farmers and landowners to identify which regenerative practices they should start implementing, and tailor these practices to local conditions. Farmers are also supported on the ground throughout the transition period to review benefits achieved, train staff, fulfil the conditions for the land to be certified as organic, and prepare for the future commercialisation of the produce.[177]

Lastly, finance providers could structure specific products geared towards transition finance, such as the MilkFlex loan fund. This fund provides a financial solution designed to match the cash flow generated during the transition to regenerative farming. This provides the affordable and flexible capital farmers need to shift, with no repayments during times of low prices and increased repayments at times of high prices, as well as inbuilt 'flex triggers'. Glanbia Co-operative Society, the Ireland Strategic Investment Fund, Rabobank, and Finance Ireland have announced the planned creation of a new €100-million 'Glanbia MilkFlex Fund' in March 2016.[178]

CASE STUDY >>

THE BALBO GROUP

How Brazil's largest organic sugarcane grower reinvented farming practices and leveraged robotics to revitalise ecosystems and attain higher yields than conventional agricultural systems.[179]

The executive vice-president of the Balbo Group, Leontino Balbo, made the bet that reinventing traditional practices and machines in order to regenerate the ecosystem could revive ailing crops and land, as well as boost profitability.

Balbo joined the family business after his graduation as an Agronomist Engineer in 1986. He soon realised the common ground manual harvesting method used at the time – which depended on burning sugarcane straw before harvesting – was incompatible with the modern tropical agricultural techniques he had just learned and which promoted the benefits of mulch. He decided to pursue new and more sustainable methods for harvesting green cane, and ended up developing the first mechanical harvester in partnership with a local manufacturer. The new harvesting system proved viable and – combined with other agro-ecological techniques such as green manure cropping, biological pest control, reforestation, and soil compaction avoidance – made it possible for Balbo to build a comprehensive new production system that he named Ecosystem Revitalization Agriculture (ERA). After many years of iterative implementation projects, the sugarcanes grew stronger and ERA started to prove its worth.

As Balbo explained in 2012: 'At Native [the Balbo Group's agricultural brand], our production system now achieves 20% higher productivity than conventional sugarcane production, with genuine concern for environmental, social, and economic factors. It is the first time that an organic, large-scale initiative has produced a higher yield than conventional agriculture!' [180] His business is thriving, producing 75,000 tonnes of organic sugar – 34% of the world market and a figure he is planning to increase in line with demand – and 55,000m^3 of organic ethanol each year from a crop of approximately 1.2 million tonnes of cane. His sugar is sold on five continents and used in about 120 high profile products. The Balbo Group produces 100% of the energy it needs to process around 6 million tonnes of sugarcane per year in thermoelectric power plants running on sugarcane bagasse (the pulpy residue left after the juice of the sugarcane has been extracted). Beyond that, thanks to its investment in cutting-edge technology, Balbo has generated enough extra power to supply a city of 540,000 inhabitants. Indicators of Sustainability have been defined with leading universities and research centres to assess the health of the soil on the farm, including its fertility and levels of water, air, and biodiversity, and they provide clear evidence that the agricultural activity is regenerative (the indicators can be accessed at www.nativealimentos.com.br).[181]

These benefits were achieved through reinventing a set of farming practices and robotics that help replicate the self-sustaining ecosystem of uncultivated land:

- The group developed the first Brazilian cane harvester, a machine that cuts cane into pieces and feeds them into a hopper where opposing currents of air strip off the leaves and spray them onto the ground, thereby returning 20 tonnes of previously unused cane per hectare to the soil each year. This restores nutrients and forms a mulch that helps keep weeds down and prevents water evaporation.

- The workers were trained and earned qualifications to take more highly skilled positions in the new production programme.

- Chemical fertilisers were replaced by a unique Integrated Organic Fertilisation Programme.

- Pesticides were exchanged for an integrated, natural pest and disease management system, which leverages naturally resistant crop varieties, a biological control programme, and cultural agricultural practices.

- To address the problem of soil compression by conventional equipment, high flotation tyres were adopted, which are partially deflated before vehicles are driven into the fields.[182]

- A system to recycle organic by-products was put in place. The solid residue from juice filtration, the ash from the boilers, and the liquid residue left over after ethanol distillation, were all collected, applied back to the fields, and dry matter was fed directly into a furnace, producing 200 tonnes of steam per hour.

- Beyond agricultural practices and technologies, consumer awareness was raised through demos in supermarkets with animators showing customers the benefits of ERA.

The Balbo Group continues to take innovative action. Aiming to find a solution which can be widely used in agriculture, it has launched a project to construct a prototype of a 100% autonomous weed control robot. Balbo explains that: 'This can avoid the use of pesticides not just in organic agriculture. The benefit for humankind and the planet can be enormous'.

To disseminate ERA practices and technologies, a technology-transfer company, Agros Fortis, has been created. Farmers will be charged a certain amount per hectare of land to apply ERA practices and technologies, as well as a share of the additional revenue generated. According to Balbo: 'I feel it is my duty to disclose this expertise, and I hope it will help apply our findings to other fields, other crops. I hope Native will be seen as an example of what can be achieved for the future, as living proof that anything is possible.'[183]

>> 5 CLOSING NUTRIENT LOOPS

Currently, 44% of municipal organic waste produced across Europe is collected separately and composted or recycled,[184] the other 56% is usually deposited in landfill or incinerated. Getting rid of this organic waste rather than capturing its embedded nutrients and energy potential is a typical feature of a linear system. Shifting towards a system that captures as much of the nutrients and energy potential as possible would reduce chemical inputs to the agricultural sector, and thereby decrease reliance on fossil fuels for energy and chemicals. A total investment of €10 billion could see a benefit of €2 billion across Europe, mainly due to a 5% reduction in CO_2 emissions and value creation from extracted nutrients.

Relevance of investment theme

There is a growing recognition of the economic value being lost in organic waste, particularly as key nutrients still have to be manufactured or imported; e.g. more than 95% of the consumed phosphorus in Europe is currently imported. Also, the current open nutrient loops lead to huge environmental problems. Nitrogen fixation and phosphorus flows into the ocean have exceeded the safe operating limits of the planet by a factor of two, while the run-off of fertilisers from the soil into rivers, lakes, and oceans creates a breeding ground for algae leading to eutrophication (an unhealthy overgrowth of plant life), as well as the depletion fish stocks and other species.[185]

One of the significant shifts towards a more circular system in the food value chain could be through gasification of organic waste such as food waste. This is commonly achieved through anaerobic digestion (AD), whereby naturally occurring bacteria break down the organic materials in the absence of oxygen. This process produces biogas, which can be used to generate power or fuel vehicles. For example, AD for processing organic municipal waste is currently used in many countries, generally in northwest Europe, with a total installed capacity to process up to 7.8 million tonnes of biowaste feedstocks a year, equivalent to around 5% of the total organic municipal waste generated in Europe.[186] However, it has taken Europe more than 20 years to achieve this capacity, with an average annual growth rate of approximately 10%,[187] which is substantially lower than for other renewable energy sources. For example, solar PV systems have seen annual growth rates of at least 60% over the last ten years.[188]

Using AD plants provides multiple benefits, a key one being that they can process a relatively diverse mix of organic feedstocks (including waste water and sewage sludge) making them

suitable for municipal waste, while both methane and CO_2 emissions are avoided. Additionally, the production of biogas can be used to power inner-city buses, offering advantages such as reduced air pollution from particulates, lower noise levels, and decreased volatility in fuel costs. The process of AD also produces a solid digestate that can be used as a fertiliser.

Biorefining as a technology includes a variety of biochemical processes that all have one thing in common: the feedstocks consists of biomass (typically a relatively homogenous flow of biowaste) and, through the refining process, organic chemicals are produced that can be used for further processing. Most of these outputs can continue in the food value chain (e.g. proteins), as agricultural inputs (e.g. fertilisers) or in the chemical industry (e.g. polyethylene).

To transition from current linear waste disposal models to circular biowaste solutions would require a substantial increase in organic waste separation, collection, and treatment. This change would provide clear benefits of up to 5% CO_2 reduction and a 10% decrease in synthetic fertiliser use by 2030.[189] However, the infrastructure needed to treat organic waste, such as AD plants and biorefineries, is relatively capital intensive. Current estimates indicate an investment opportunity of up to €10 billion between now and 2025, if Europe can increase the growth in organic municipal waste treatment capacity from the 10% per annum[190] seen over the last decade to approximately 40% per annum in the years leading up to 2025.

Recent developments

It is an opportune moment for such investments: substantial capital has been deployed in AD in recent years mainly in northwest Europe, indeed the UK saw an estimated €1.1 billion of investments between 2014-15.[191] However this scale-up could benefit from a broader EU rollout. Pilot biorefineries have also been developed recently to test new practices: an example is the Danish SUBLEEM project that focuses on chemicals production. Biorefineries on the other hand are not yet rolled out at scale, but many pilot projects are running across Europe and there is a commonly held belief that biorefining could contribute substantially to the looping of organic waste.[192]

Through the proposed escalation of organic waste processing, AD plants would likely take on a different role from biorefineries. AD plants can handle mixed organic feedstocks and can be deployed at scale, which means they would be well suited to municipal organic waste treatment. On the other hand, biorefineries rely on specific organic material feedstocks to produce the targeted nutrient or chemical, which makes them less suitable for processing municipal waste, but more suitable for treating specific industrial organic waste streams, or as an add-on to existing production facilities with a biological waste product.

Undoubtedly, the shift towards processing biowaste through both methods would reap rewards economically and environmentally.

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Investment opportunities identified

As outlined above, two key investment opportunities exist to treat organic waste: the development, construction, and operation of AD plants and of biorefineries.

As mainstream investment funds have put substantial capital into AD facilities over the last years, the business case and associated risks are well understood by investors. Although many AD plants have recently been constructed on farms, to make a significant shift in waste treatment city-scale AD plants would be required and these present a clear investment opportunity.[193]

Biorefineries focused on using organic waste for the production of high-end chemicals and nutrients have not yet seen substantial investment, as in some cases the technologies and processes involved still require proof-of-concept in order to bring them to commercial scale. This means that typical investments in these assets have mainly been through high-risk capital with government backing or grant funding.[194] Broadly speaking, there are two types of biorefineries that can be considered for investment, each with a different risk profile. The first type of plant uses fermentation to produce chemicals for plastics. The process to create these chemicals is usually tolerant of multiple and varied feedstocks and is able to produce multiple and varied outputs. This type of refinery is therefore resilient to feedstocks and market risks. The second type of plant relies on the extraction of specialist chemicals from separated feedstocks. This enables higher value products to be extracted, but with greater technology, feedstock, and market risks.

Current barriers to investments

The key issues that currently prevent these two investment opportunities from taking off in the near term are: the lack of stable volumes and sufficient quality of feedstocks; the lack of stable financial support for AD; and the lack of proof of viability at scale for biorefineries.

In order to provide attractive risk-adjusted returns for both AD and biorefinery investments, not only would strong offtake contracts be needed (for the gas, energy, digestate, and chemicals produced), but also sufficient certainty of feedstocks supply. As the typical payback times for these infrastructure-type investments are relatively long, a multi-year outlook for feedstocks sourcing would be required, detailing tonnage as well as quality. Currently, to mitigate the feedstocks supply risk, the majority of AD (as well as biorefinery) plants are located close to their feedstocks source, for example on a farm or industrial site. In order to increase the scale of the plants, these locations might no longer be viable, leading to an increased feedstocks supply risk, which would have to be resolved. Adding to the complexity of this picture is that, unlike for example biomass from wood, organic waste cannot be stockpiled in a cost-effective way as it will start to decay. Therefore, the turnaround time between delivery to other sites and processing would have to be relatively short.
In the absence of any financial

incentive, such as waste gate fees or feed-in-tariffs, AD plants are typically not yet profitable enough to provide attractive returns to investors. Although the levelised cost of electricity production has decreased by 50% over the last 10 years,[195] it is still more expensive than alternative electricity generation technologies, while the risks remain higher in comparison. Financial incentives to support AD plants would therefore be needed to mitigate this investment risk. Biorefineries that produce chemicals are typically still at the pilot project rather than full commercial plant stage. Although the technologies are not considered nascent, a need for proof of viability at scale exists before these become a greater investment opportunity.

Finally, some additional barriers exist that might prevent scaling of these opportunities. The first is the common 'not in my back yard' (NIMBY) response by residents to proposals for large infrastructure projects near residential areas, particularly in this case due to the perception that they would produce gases or strong odours. These potential planning concerns could delay or prevent such projects. Second, issues could arise related to a shortage of skilled operators needed to run AD plants. Operating an AD plant demands the skills needed to manage the gasification process carefully. If AD plants are being rolled out at scale, specific training of operators would be required. Third, outputs from biorefineries that serve as feedstocks to highly specialised chemical processes could have a slightly different composition from feedstocks derived from traditional sources such as crude oil and could therefore meet some resistance from chemical companies. Furthermore, regulatory restrictions exist that may prevent proteins recovered from organic waste being used in animal and human food chains.

Interventions to scale up investments

In the near term, the first priorities for scaling up AD plants in urban areas is the securing of a stable feedstocks supply and clear offtake agreements. Concurrently, the business case for such investments needs to be made sufficiently attractive. This could be achieved either through the pricing in of negative externalities, in the form of waste gate fees or a carbon tax, or through fiscal incentives such as tariffs or tax breaks.

Bringing biorefineries producing chemicals to commercial scale would necessitate the running of multiple successful pilot projects testing different technologies, organic waste feedstocks, and chemical outputs. This work would have to be done in close collaboration with the purchaser of the outputs to ensure they are of the right quality and composition. The outcomes of these pilot projects would be used to determine the best way to roll out biorefineries at scale.

- **European Commission:**
The European Commission, in implementing its Circular Economy Package, has started to set up a market for organic fertilisers that will provide a strong platform to expand production facilities for these products. In order

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to also ensure sufficient feedstocks for these products – and for chemical products and biogas – the European Commission would need to lend more support to the mandating of organic waste separation and collection. Within the circularity space, waste has been a one of the main areas of focus for the Commission, through its Waste Framework Directive. This framework could be used to further increase the supply of organic waste across Member States. Additionally, it could provide direct funding for either biorefining projects or AD plants.

Finally, a shift towards allowing the use of recovered nutrients in food value chains would be needed to ensure overall success. Currently, the use of recovered nutrients is regulated by two European Commission directives,[196] as well as Member State legislation (e.g. environmental codes).[197] In order to support the growth of biorefineries producing proteins, adjusting or removing such legislative barriers would be necessary.

- **National, regional, and local governments:** Alongside the European Commission, national and local governments could further push for organic waste separation and collection. This could be achieved through a variety of means, for example through mandates or economic incentives such as waste gate fees. In order to ensure that the additional waste volumes are indeed treated by AD plants or biorefineries, collaboration would be needed with developers and operators of these plants to confirm that sufficient infrastructure would be built to treat the waste. This support would also need to help determine a sufficiently positive business case for investors and facilitate collaboration to reduce the risks involved to manageable levels. As this report has explored, some of the ways this could be done include: ensuring that the required permits are provided; offering offtake agreements for biogas to be used in city buses; and providing sufficient financial incentives. Alongside these measures, it would be important to raise consumer awareness about both the benefits of, and need for, waste separation, as well as the importance of building organic waste treatment plants.

The city of Milan offers a successful example of strong government intervention to significantly improve organic waste collection, separation, and processing. In 2012, the city introduced the collection of separated household food waste to be sent – among other destinations – to AD plants to create biogas. Waste collection company Amsa was granted full government support in rolling out the new scheme and it benefitted from a large consumer awareness programme, distribution of dedicated bins, and the use of biodegradable bags. Organic waste recovery rose from around 53kg per capita in 2013 to around 92kg per capita in 2015, one of the highest rates in Europe.[198]

In order to support the construction of new biorefineries, national and local governments could not only provide funding for new pilot projects, but also broker agreements between feedstocks suppliers and biorefinery developers. For example, the Green Alliance analysed biorefining opportunities for the food and drink sector in Scotland and found that due to the high number

of relatively small companies involved, support would be required to access high-value recovery opportunities in the form of a matchmaking service. Examples of potential areas of collaboration included: recovering fishmeal and oils from fallen stock on salmon farms; recovery of protein and platform chemicals from the higher-volume whisky distilleries; and lignin-based biorefining from forestry by-products.[199]

- **Private sector:** For the development of new city-level AD plants, project developers and investors could work with local governments to identify the most important barriers and the best ways to overcome them, whether they be in feedstocks supply, offtake of gas, energy and digestate, permitting processes, or community engagement. One of the key factors in moving into the construction and operation of biorefineries would be to create the links between the supplier of the right type of feedstocks, the biorefinery operator, and the buyer of the final products. This would need to happen at the same time as identifying other relevant stakeholders such as investors and specialised construction companies.

As we have seen, initially most biorefineries would likely be located near their feedstocks source to minimise the risks related to stability of supply. A good example of this is California Safe Soil (CSS). The company uses food that supermarkets cannot sell and turns it into Harvest-to-Harvest liquid fertiliser that can be applied in conventional ways. The supermarkets, that are paying CSS to take away the food, are about 12 miles from the processing site. This example shows that no government intervention may be needed for specific organic waste treatment technologies, as long as there are sufficient feedstocks nearby (ensuring low transport costs) and a ready market for its products. The company is currently still in its seed investment phase and recently raised $5.9 million through Keiretsu Forum Northwest.

Harvest Power is also showing how private capital can be unlocked for scaling AD. The US-based company develops and operates mainly AD plants that produce fertilisers and energy through biogas. It manages the end-to-end process of collecting waste, operating the plants, and delivering fertilisers. Its operation comprises three AD plants with a total waste capacity of 160,000 tonnes, and total investment from 2009 to 2016 is $193 million.[200]

CASE STUDY >>

SUBLEEM BIOREFINERY

Biorefining pilot supported by the Danish Business Authority[201]

The SUBLEEM generic biorefining pilot was launched by a partnership led by the Danish Technological Institute (a Danish research and technology organisation involving the Municipality of Guldborgsund) with involvement from companies such as Nordic Seaweed, Nordic Sugar, HedeDanmark, and SEGES, as well as research institutions[202] and the cluster and management organisation Agro Business Park. The purpose of the pilot is to assess the business potential of establishing full-scale biorefining facilities extracting high-value products (e.g. proteins, peptides, oils, soluble fibres, and saponins) from excess bio-resources, such as sugar beet leaves, and residues from beer production. After the facility is up and running, the partnership will be planning an event for companies to come and see how they could potentially create value from their excess resources, and to discuss future business opportunities.

This pilot approach is very different from the classic approach to biofuels, the main focus of which in recent years has been on profitability involving large industrial partners. By contrast, the focus at SUBLEEM is on designing innovative business models and production plants that are profitable as well as scaleable. This is done by identifying the most interesting types of biomass and residues, and finding the optimal equipment and processing technologies to recover nutrients from them. The pilot project manager Dr Anne Christine Steenkjær Hastrup, explains: 'We want for the companies setting up these facilities [to have] business models and plants [that are] successful even when using low volumes of local waste supply, so that we can manage better the risk of insufficient or unstable volumes of organic waste'.

The team estimates that such a model could achieve a total profit 200% higher than that of a typical biofuel-based biorefinery, that three to five plants could come online in the next five years in Denmark, and that they could then be rolled out to other European countries. In general, it makes sense for such biorefining operations to be launched first in countries such as Denmark where existing infrastructure can be leveraged.

Building the processing infrastructure to make such a scheme work would require private investment of €5 million to €20 million depending on scale (for a range of 1,000 tonnes to hundreds of thousands of tonnes of waste processed per year). Public or semi-public investments would likely be needed to build or upgrade the collection infrastructure in order to secure stable feedstocks supply. Nevertheless, this example demonstrates what could be achieved through innovation and collaboration.

6 FARMING THROUGH INDOOR URBAN FARMS

The agricultural sector is being changed through technological innovations, where a novel way of producing food is emerging: indoor vertical farms. By harnessing agricultural technology, fruit and vegetables can be grown without soil, indoors in closed environments that are fully independent of the weather fluctuations. This allows these farms to be located in urban areas, near the target markets for their produce. These indoor urban farms use systems such as aeroponics, aquaponics, and hydroponics in multi-layered crop beds, to produce high-quality healthy vegetables, fruit, herbs, and fish right inside or on top of city buildings. A total investment of €45 billion in this shift towards urban agriculture over the next years leading up to 2025 could reap an economic reward across Europe of up to €50 billion, with the key benefits being the freeing up of much-needed land space and reducing the reliance on fertilisers and pesticides.

Relevance of investment theme

By 2050, the world's urban population is projected to grow by 3 billion.[203] At current trends, caloric demand will increase by 70% and crop demand for human consumption and animal feed will rise by 100% in the same period.[204] Using current practices, feeding the expanding population would require dedicating 1 billion hectares of new land to farming[205] – more than the area of Brazil and Indonesia combined. Moreover, as the effects of climate change are realised through extreme weather patterns, devastating crop yields and increasing food prices, and consumers become more conscious of their carbon footprint, the demand for sustainable farming continues to grow.

Over the last five years, vertical farms have emerged as one of the potential solutions to overcoming the environmental challenges affecting traditional farming. Vertical farms maximise the use of urban land, providing high-quality produce within the built environment, using 70%–98% less water than traditional farming methods. Led by Japan, Singapore and the US, the rest of the world needs to wake up to the potential of disrupting the $5 trillion food and agribusiness industry.[206]

Vertical farms are essentially multi-storey greenhouses using innovative aquaponics or hydroponics systems. Hydroponic farming is a method of growing produce without soil. Seeds are planted in a soil substitute, then grown in nutrient-rich water. The water is then recirculated. Water temperature, salinity, humidity, and air temperature are controlled to induce maximum yield.[207] Aquaponic farming combines hydroponics with aquaculture (fish farming) to create a closed loop system. The nutrient-rich water containing fish waste is pumped to the roots of plants, where microbacteria convert the nutrients into natural fertilisers. The plants in turn purify the water, which is pumped back into the fish tanks.[208]

>> 10 INVESTMENT THEMES

Growing crops in urban farms provides multiple societal benefits:

- A reduction in food waste along the supply chain;
- Reduced land use and soil degradation;
- Up to a 98% decrease in water usage through looped systems;[209]
- Reductions of up to 70% in fertiliser usage;[210]
- Complete alleviation of the need for pesticides and herbicides;[211]
- Production of healthier food unpolluted by chemicals;
- Significant decreases in transport costs and related emissions;
- More stable year-round production, as crops are protected from the volatility of weather and overall changes in the climate.

Vertical farming also makes efficient use of land restraints: crops are grown in high-rises in multiple levels that vastly reduce land footprint requirements. An American start-up from Nashville in the US, Greener Roots Farm, claims to produce pesticide and GMO-free produce that travels no more than ten miles to its end destination. It also claims to use 90% less land and water than conventional farming, and boasts a tenfold increase in production per square foot.[212] Further, vertical farms have started to demonstrate potential viability as a profitable enterprises as was shown for example by Spread's Kameoka plant in Japan.

However, one issue related to these practices is the high-energy usage required, mainly to power the necessary indoor lighting. Although this is certainly a considerable share of the total cost of running these farms, increased use of specialised highly efficient LED technology is mitigating this problem. LED technology is not only aiding this shift through directly lowering energy usage, but also through creating better insulated buildings as it is no longer necessary to ventilate the heat generated from the lights. As technology advances, LED lighting will become increasingly efficient, and energy costs will continue to fall. Between 2012 and 2014, LED lighting efficiency increased by 50% and between 2008 and 2014, the price of LEDs fell by 85%.[213]

With current technologies aiding production, there is a clear opportunity to invest in an agro-industry that could bring such obvious economic, environmental, and societal benefits.

Recent developments

Indoor urban vertical farming as an investment theme is taking off globally. In 2015, start-ups producing technologies in and around the indoor agriculture space raised slightly more than $107 million in funding globally, which was just over 2% of the $4.6 billion total invested in agricultural technology across the year.[214] There are currently around 230 vertical farms globally, the majority of which are based in Japan. However, the segment is gathering pace in other markets, especially in areas where food production has structural problems, particularly around water resources, for example in the US.[215] In 2013, FarmedHere opened North America's largest indoor farm, a space of around 8,400m^2 in Bedford Park, Illinois, yielding a fifteen-fold increase in the number of crop cycles yielded by traditional farming.[216] In 2014, Green Sense Farms constructed a vertical farm of around 2,000m^2 in Portage, Indiana. In 2015, it partnered with Star Global Agriculture to build a network of farms in China, the first of which, in Shenzen, became operational earlier this

year. It currently has ten additional farms in its developmental pipeline across the US, Canada, China, and Scandinavia.[217] Also, in August 2016, Kimbal Musk launched a vertical farm incubator in Brooklyn, New York.[218]

In Japan, the majority of vertical farms are owned by electronics companies, such as Toshiba, Panasonic, and Fujitsu. The exceptions to the rule are its two largest vertical farms, owned by Mirai and Spread respectively. Mirai's farm is located in the Miyagi Prefecture, the region affected by the earthquake and tsunami in 2011. According to Shinji Inada, Spread's CEO, momentum for vertical farming in Japan grew rapidly in the aftermath of the Fukushima nuclear disaster in 2011, after which Japanese consumers took greater interest in the content of its produce.[219]

In the rest of Asia, vertical farming continues to grow. China's government has engaged Green Sense Farms to roll out twenty sites across China.[220] Given its climate vulnerabilities, with temperatures falling as low as -55°C, China has begun to embrace vertical farming. In 2013, there were 75 commercial plants in China, of which 25 used artificial light.[221] In 2011, Sky Greens, the world's first low-carbon, hydraulic-driven vertical farm was launched in Singapore, delivering produce to national supermarkets.[222] It uses rainwater to power a water-pulley system rotating growing troughs around an aluminium tower. The same rainwater used to power the pulley system nourishes the plants.[223] Vertical farms in Europe have been slower to spread.[224] Earlier this year, Urban Crops opened Europe's largest automated plant factory in Waregem, Belgium.[225] Infarm, a vertical farming start-up in Berlin, Germany, is running a pilot project with the Metro Group supermarket chain, growing produce in store. [226] Despite these examples, vertical farming in Europe has yet to scale to the same extent as it has in Asia and the US.

Vertical farm experts generally agree that the timing is right to start scaling up the indoor vertical farming capacity as a few key trends have all sufficiently progressed to enable success. These include:

- The evolution of high-efficiency LED lighting technology specifically made for indoor farming;
- Cost reductions in the sensing and data collection technologies needed;
- Growth in the knowledge base for producing food through the use of hydroponics technology.

The combination of these developments has effectively moved indoor vertical farming out of the R&D phase and into the proof-of-concept stage.[227]

Investment opportunities identified

The current number of installed indoor urban farms in Europe is considered to be relatively low. Nevertheless, the EU is seeing some initial indoor farm pilot projects, such as the Urban Farming De Schilde in The Hague. Therefore, an opportunity exists to support the scale-up of indoor vertical farms in Europe, through providing the investments required to establish the necessary infrastructure (including the associated technology).

At the moment, the food products from indoor vertical farms are mainly targeted at consumer segments that are looking for healthy, homegrown food and that are generally willing to pay a premium for such produce. Typical customers are

restaurants, organic and health-focussed food retailers or direct sales to consumers through local farmers' markets. This consumer segment is relatively large and has been growing substantially over recent years. For example, the European market for organic food was estimated to be worth a total of €26 billion (around 2% of the total food market[228]) and showing a growth of approximately 8% per annum in 2014.[229]

In addition to these identified consumer segments for the sale of the produce from indoor farms, there is also an opportunity for players in the space to sell entire indoor farms to countries or companies that would operate these. Due to the likely decreases in the cost of production for indoor urban farms as operators gain experience and the technology continues to be optimised, in the future, urban farms should be able to compete with conventional food production outputs.

The potential benefits from this opportunity have convinced multiple investors over the last year to deploy capital. For example, US-based Aerofarms, which manages over 9,000m^2 of indoor urban farms in Newark, New Jersey, has raised $20 million, while another US-based operator, Bright Farms, has raised $14 million. Both deals were the companies' Series B financing, raised in 2015, mainly from venture capital investors.[230]

Alongside investment in set-up and infrastructure, additional investments would be required to further develop and scale up the production for the required technology. Such opportunities include further support for the development of LED lighting technology specifically for farming or development of data-driven farm management systems.

Current barriers to investments

Although the global market for indoor vertical farms is projected to grow up to 30% per annum between 2015 and 2020,[231] the main driver for growth is considered to be the Asia–Pacific (APAC) region, in particular Japan and China. The main barriers holding back growth in Europe are: perceived risk regarding the technology used; uncertainty about profitability due to the novelty of using these technologies at scale; and issues with securing permits and leases.

A key problem with setting up a new indoor vertical farm is the high level of upfront capital investment and high perceived risk of new technology. For example, the Sky Greens project in Singapore required $1 million to launch, while the farm's total costs at completion totalled $28 million.[232] The perception of risk is driven by uncertainty on production stability having not used these technologies at scale coupled with the possible need for premium pricing, and, in turn, the associated issues of a limited market size versus that for conventional production outputs. Given that the industry is so young, there has been little opportunity to observe existing market players making significant profit. Although Spread's Kameoka plant has been declared profitable, many vertical farms are yet to make profit.[233] Profitability is especially elusive for aquaponic farms; a 2015 US Department of Agriculture study on the economics of aquaponics found indoor fish rearing to be two to three times more expensive than raising fish in open ponds.[234] A 2013 study found fewer than one-third of aquaponics farms to be profitable.[235]

Another factor is that, if these indoor farms are to be scaled up across urban areas, issues with obtaining the required permits and leases could arise, as real estate in urban areas is scarce across many countries in Europe and so these farms would be competing with other organisations requiring commercial property.

Relatively low consumer awareness regarding the benefits of buying products from urban farms might pose an additional barrier to growth, as well as the availability of a sufficiently able workforce as operating these farms requires a specialist skillset.

Interventions to scale up investments

Europe could see an increase in the scale-up of these farms, if sufficient support is provided to achieve proof-of-concept at scale and if the required real estate is made available at a reasonable price. Playing an active role in increasing consumer awareness and specific training would be important areas for stakeholder contributions.

- **European Commission:** Further funding for urban farming R&D and pilot projects could be considered.[236] Concurrently, existing agriculture frameworks, such as the Common Agricultural Policy (CAP), could stimulate urban farming as a recognised practice which would create more of a level playing field versus traditional agricultural practices. Additional support could be provided by linking project developers, technology providers, and investors for indoor urban farms across the EU, enabling them to share their learning and experiences.

- **National, regional, and local governments:** The public sector could provide direct support for indoor urban farming pilots and projects in a variety of ways, e.g. through long-term guaranteed energy prices, specific funding instruments or tax breaks. The AeroFarms project was awarded $9 million in city and state money via tax breaks and grants.[237] Additionally, local support towards obtaining permits and leases could be provided, possibly through the designation of specific areas for urban farming. Generally urban farms can find suitable locations in old industrial sites or abandoned buildings or even underground [238] so not only in prime real estate areas. As a result, creative thinking and co-operation with planners could open up potential sites for development. Finally, public procurement of food could support further growth in market size. Once these farming practices start to take off in specific cities, additional consumer awareness and training programmes could be rolled out to offer more support to the scale-up.

- **Private sector:** Initial efforts to develop new projects could focus on identifying the most suitable areas for urban farms projects, specifically honing in on cities where the market for premium priced fruit and vegetables is large and growing, and where backing for these innovative practices exists within local government. Using the model of the Urban Farmers project in The Hague, a support structure could be agreed with local government in order to make these initial projects financially viable, while at the same time securing offtake contracts from local food retailers and restaurants. Once the concept is proven sufficiently, scaling of production could potentially be achieved without further government support.

CASE STUDY >>

AEROFARMS

US-based AeroFarms demonstrates how the right level of government support can help to make the risks manageable for institutional capital.

AeroFarms builds and operates aeroponic indoor urban farms within the US. Their anchor project is a 6,500m² farm in Newark, New Jersey, which saw its first seeding in September 2016. This new farm is set to become their global headquarters and will be one of the largest indoor farming projects in the world. They also operate a number of other facilities in Newark: a 5,000m² R&D farm (first seeding November 2013), a 2,750m² 'Newark Farm' (first seeding August 2015), and a 5m² School Farm (first seeding September 2011) in a local academy where students can harvest their own produce for their lunches. All of these sites are based in Newark, New Jersey, and (apart from the School Farm) have reused old industrial buildings, including a steel mill, nightclub, and paintball arena to create indoor agriculture spaces.[239]

They use a combination of a patented aeroponic system and proven technology to achieve a 50% reduced growth time for their crops, stable yields, and healthy produce with minimal environmental impact. Their aeroponic system is a closed loop model that uses 95% less water and 40% less hydroponics than conventional farming methods. They do not use fertilisers at all, but instead use a pest-resistant design to ensure pests cannot get access to their crops. They deploy LED lights throughout their crop beds to allow for maximum productivity and control. They have also developed a smart, patented substrate cloth made from recycled plastic. These methods give them 75% more productivity per square metre than a conventional field farm and enable scaling to suit a range of sites and needs.[240]

The AeroFarms model is testament to how local government support, coupled with private sector funding, can make urban farms viable and profitable at scale. In 2009, AeroFarms were granted $0.5 million seed funding and in 2015 they received up to $39 million of venture capital funding from multiple investors, with Wheatsheaf being the leading investor. They also secured a $30 million debt package from Goldman Sachs and received an additional $9 million in state funding, tax credits, and grants. They have recently raised a further $20 million in equity funding.
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CASE STUDY »

SPREAD

Japan-based Spread delivers profitability then turns its eye to the world's first robot-run farm.

In 2007, Spread constructed the Kameoka plant in Kyoto, with the stated mission of 'continually work[ing] towards the realisation of a sustainable society while protecting the environment through the use of food technology for the comfort and safety of our children and of future generations.'[241] The plant has the capacity to produce 21,000 heads of lettuce, and at opening, it was the world's largest indoor farm in terms of production. After six years of operation, it declared the Kameoka plant to be profitable in 2013. Spread is currently constructing a new farm, designed to be almost entirely robot-run. Although humans will remain responsible for the initial planting of seeds, robots will take on all other tasks, including re-seeding, watering, trimming, and harvesting crops.[242] Spread's automated model will increase lettuce yields by an additional 30,000 heads of lettuce a day to 51,000 between its two farms. It is also projected to reduce labour costs by 50%, cut energy use by 30%, and recycle 98% of water needed to grow the crops.[243] Furthermore, it is slated to host an integrated research and development centre. The total cost of the second farm is estimated between ¥1.6 and ¥2.0 billion ($15–$19 million) with an estimated payback time of between seven and nine years.

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>> 7 DEVELOPING NEXT-WAVE PROTEIN SOURCES

Bringing to market sustainable complete protein sources[244] would alleviate the looming crisis of demand for meat and fish outstripping supply. This would unleash significant rewards, both societally and in investment return for any potential investor. Supporting the development and escalation of the market for these protein sources ranging from insects to seaweed and microalgae, through investments of up to €2 billion over the next ten years, could result in a total benefit across Europe of up to €40 billion by 2030, mainly through reduction of reliance on fertilisers and pesticides, reduced water usage, as well as contributing to a decrease in greenhouse gas emissions.

Relevance of investment theme

As a result of continuous worldwide population growth and an increasing requirement for meat and fish, the market for complete proteins[245] is expanding rapidly. Indeed, it is expected that by 2030 protein demand for human consumption and animal feed will have grown worldwide by 40%.[246] This exponential growth is more than the conventional production systems can supply.

Indeed, while growth in demand for complete proteins has been met primarily through significant productivity gain in the past, agricultural productivity gain is now dropping in Europe and around the world. For example, agricultural productivity gain has fallen steadily from 2.5% per annum in the 1970s to 1.3% in the 2000s, decreasing further to 0.9% in 2010. This is despite significant increases in inputs and technologies aimed at supporting or boosting productivity, such as fertilisers, chemicals, and fuels.

Moreover, the further expansion of conventional production systems to meet demand growth would also be challenging in a variety of ways. Expansion is already constrained by severe pressures on land assets and fish stocks, and poses high environmental and societal risks. For example, more than 30% of soils are already classed as moderately to highly degraded worldwide;[247] and 61% of commercialised fish populations are fully fished, with another 29% being fished at a level that prevents regeneration of the ocean's stock. In addition, expansion of conventional livestock production is already the main driver of agricultural greenhouse gas emissions[248] and demands high water input.[249] Yet, regardless of this massive use of resources, conventional production systems do not provide safe, healthy outputs, as complete protein food often contain traces of antibiotics, toxic chemicals or plastics.[250]

In this context, the EU's food supply chain is especially at risk. The EU is already highly dependent on imports for such strategic products, with 70% of its complete proteins being sourced externally.[251] In fact, the EU runs the risk of competing with China – the largest importer of complete proteins – notably for the supply of key animal feed products, such as soybean. The Waste and Resources Action Programme (WRAP) estimates that traditional feed prices will fluctuate in the lead up to 2025 (as has already been witnessed in the fishmeal market), causing a direct knock-on effect on food prices.[252]

One of the ways to meet the growing demand for complete proteins in Europe could be to increase the consumption of products that require less land and resources than red meat, such as chicken, fish or vegetable-based products, alongside the development of sustainable aquaculture and land agricultural systems.

Another key way to meet the demand could be through the use of next-wave sustainable complete protein sources. On a positive note, there are sustainable complete protein sources that are not being tapped into currently, and the production of which could scaled in the near term. For example, insects are surprisingly efficient protein converters and can turn low-grade inputs into high-grade nutritional products. The focus of this theme is on the commercialisation of a set protein sources for specific uses, as it is becoming increasingly apparent that these opportunities could be particularly promising over the next ten years.[253] Insects and bacteria for animal feed, seaweed and micro-algae for animal feed and human consumption, and vegetable-based protein sources for human consumption. Additional opportunities are also emerging (e.g. commercialising insects or lab-grown meat as food for direct human consumption) that have not been included here, as they are considered less likely to be scaleable within the next decade due to barriers in consumer acceptance, legislation or cost-effective technology.[254]

The next-wave complete protein sources in our focus offer sizeable advantages from a variety of perspectives, which would otherwise not be captured in conventional systems. Complete protein production represents a major reservoir of growth for the European economy, accounting for €20–35 billion in GDP globally in 2015. Next-wave protein sources would also open up new market segments, such as the high-value sustainable fish market, as insect-based fish feed could allow producers to control inputs to make sure these are sustainable, something that is currently not possible. Economic growth in this area could also be driven by valuable by-products with potential for sale into further food or fuel applications, such as high-value molecules with antimicrobial properties for insects, or triglyceride oils and ingredients for microalgae.[255] Such changes would ensure the EU's dependency on foreign high-protein sources would be reduced.[256]

Next-wave protein sources are typically environmentally friendly, causing fewer greenhouse gas emissions and requiring few resources, thereby alleviating pressure on land, energy, and water (microalgae can produce 50 times more oil than corn per hectare; insects require ten times less land at the most, far less

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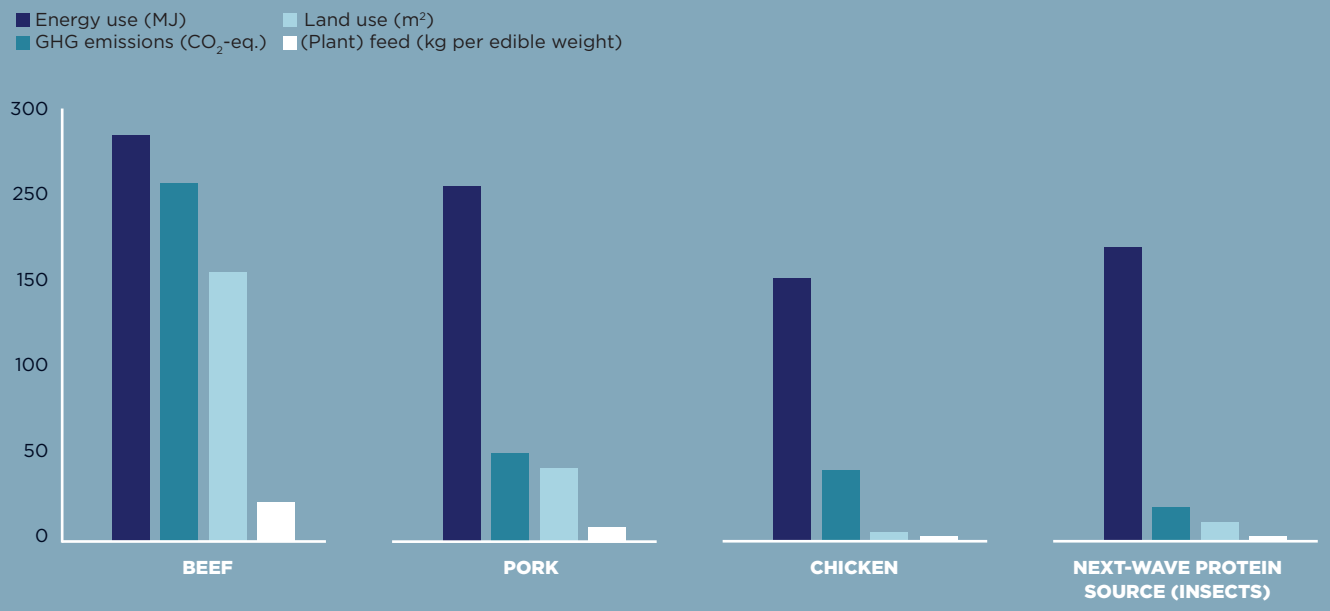
FIGURE 24 **TYPICAL INPUT FOR THE PRODUCTION OF 1KG OF PROTEIN FROM BEEF, PORK, CHICKEN, AND INSECTS**[261]



Source: http://www.fao.org/docrep/018/i3253e/i3253e05.pdf[262]

plant feed,[257] and produce significantly fewer greenhouse gas emissions than beef, as shown by Figure 24). Societal benefits would also be generated through local job creation, e.g. within local insect production units and the revitalisation of the farming industry. Indeed, the purchase of production inputs that are not used currently, such as agricultural by-products or waste, would provide new sources of revenue for farmers.[258] Human health and animal health would also benefit from next-wave protein sources, due to their healthy and nutrient-rich content, alongside a more easily digested amino acid mix[259] (90% digestibility levels for insects) that could likely help to reduce the use of antibiotics in the food chain.[260] For example, the potential nutrient and health benefits of next-wave protein sources include:

- 55–70% protein content in insects;
- Up to 47% for seaweed, of which most types contain all the essential amino acids that may help increase body condition and wool production in sheep and milk production in cows ;
- High lipid (oil) content in microalgae;
- Up to 60% protein levels in bacteria.

Recent developments

Promising solutions are currently being developed for the most attractive of these next-wave protein sources. A few examples are provided below, but this is not an exhaustive overview of the players emerging in this space.

A new insect-rearing industry is being shaped, using insects to transform low-value by-products (such as olive pulp or brewery waste,[263] pre-consumer food waste left over from production, transformation or distribution or post-

consumer food waste) or organic waste from local agro-businesses into high-quality products. This is subsequently used as feed, mainly for farmed animals including chicken, pigs, and fish, as well as for pet food, fish oil, and non-feed products.[264] Numerous companies have entered this market in Europe and abroad. For example, the French company Innovafeed is leveraging agricultural by-products and insects to produce insect-based fish feed and aims to launch a 300-tonne capacity unit in 2017 and deploy a 25,000-tonne capacity by 2020. The South African-based company AgriProtein is using waste food and flies to produce 7 metric tonnes of animal feed mainly for fish, chicken, and pigs,[265] as well as 3 metric tonnes of fish oil and 8 metric tonnes of fertiliser per day. The company raised $11 million from the Bill and Melinda Gates Foundation and private investors in 2012 to build its first commercial farms.[266] Other companies, such as Ynsect, are focusing on pet food; their small industrial-scale production in France will have a 20,000-tonne per year capacity, with further plans to build a large-scale plant in 2017.[267] Ynsect has raised €7.3 million in two investment rounds, with two French venture capital funds and one Singaporean investment company, together with public support, in particular from the French investment bank Bpifrance.[268]

The production of next-wave animal feed is also driven by current developments in bacterial science. For example, the US-based company Nutrinsic manufactures meals for chicken, pigs, and fish from a culture of bacteria that is fed with waste provided by food and beverage processors and biofuel manufacturers. A production facility is already operational with an estimated capacity of 13 tonnes per day. The company plans to reach its target of 80 tonnes per day capacity within 18 months.[269]

Concurrently, players are also tapping into the opportunity to use seaweed and microalgae for animal feed, food for human consumption, and biofuel. A new study even shows that microalgae may be a viable option to replace corn in cattle feed, and algae could potentially replace up to 30% of soybean meal in diets for pigs and chickens. The US-based company Solazyme manufactures a food additive by fermenting, growing, harvesting, concentrating, and drying algae. After the launch of large-scale production in 2014, the company operates two production units in the US and a large site in Brazil with a capacity of 100,000 metric tonnes per year. In the future, capacity may expand to 100,000 metric tonnes per year in Iowa.[270]

Commercialisation of various next-wave protein food and meals for human consumption has already started and is being rolled out in some territories, especially in the US. Currently, 22,000 tonnes of mycoprotein products are manufactured per annum and sold in 16 countries by Quorn. The US-based company derives its mycoprotein from fungi and wheat-derived glucose syrup, which are then mixed with egg albumen and water to obtain Meat-Free Mince, Chicken Style Pieces or Fillets that are steam-cooked and rapidly frozen to enhance texture. With 3 billion meals being prepared across the world and a growing demand (+30% in the US 2014–2015), the company launched operations in Germany, Italy, and Spain in 2015. There have been £30 million

investments made to double the UK plant capacity to 40,000 tonnes, with a view to meeting growing demand in the UK, the US, and European markets.[271] Vegetable-based meat and meals are also gaining ground, as shown by Beyond Meat whose 100% plant-based products are sold in the meat section of grocery stores across the US. The company provides heat-and-eat meals, such as beef crumbles or chicken strips, made mostly with non-GMO pea protein. The veggie burgers are said to taste, sizzle, and smell like meat burgers when cooked, and sold out in one hour when they went on sale in one Whole Foods store in Colorado.

Investment opportunities identified

Investors who are looking to deploy capital in the area of next-wave protein sources have to determine which protein sources and which offtake market is the most attractive for them: insect, bacteria, seaweed, micro-algae or other vegetable-based proteins, with some aimed at animal feed only, others for human consumption only, and some for both. All of these opportunities have the potential to play a substantial role in the EU's food market and have already received multiple investments indicating investors' interest. However, as yet it is unclear which of these sectors will eventually provide the best returns.

Once an investment decision has been made, capital deployed will likely be needed to further research and develop the production process, including the setting up of pilot plants. Depending on the exact investment opportunity, commercial-scale production facilities would need to be built to expand the production of proteins, which would also require further capital.

Current barriers to investments

Two key barriers need to be lifted for all of the next-wave protein sources to become viable at scale.

The first is the need for high upfront investments which as yet have uncertain returns. These are required to complete R&D, develop an agro-industrial model, and scale production in the EU. Indeed, bringing to the market and scaling next-wave protein sources would require such high initial investments, while no significant track record exists to provide a good basis to project likely return on these investments. For some next-wave protein sources such as insects, the focus would possibly be on the establishment of commercial production at a cost-effective level and scaling,[272] whereas for other protein sources the focus would also need to be on R&D to develop the necessary engineering solutions.[273] In all cases, the level of mechanisation and automation involved would be a key driver to achieve cost effectiveness at scale.[274]

The second barrier is the restriction currently imposed by human food chain legislation, e.g. in regulations related to the use of insects to feed animals destined for the human food chain as outlined below (no such restrictions exist for pet food[275]). Besides these two key common issues, an additional barrier exists for protein sources destined for direct human consumption – that of consumer acceptance.[276]

However, the 'yuck factor' is likely to be very limited for the selected near-term opportunities, as the protein sources identified as destined for human consumption tend not to trigger negative consumer attitudes (vegetables, seaweed, and microalgae) compared to lab-grown meat or insects.[277] In contrast, protein sources selected for animal feed tend to spark positive consumer attitudes[278] and are bringing strong benefits that can incentivise consumers and food retailers to shift. For example, the recent uptake of insect protein flour in North America has been in response to its nutritional benefits,[279] and it has also been shown that environmental concerns can play a part in changing attitudes.[280] Leading European food retailers have already expressed a willingness to pay a premium for some of these next-wave protein sources, such as insects, as it would enable them to present their fish and meat products as locally grown, free of antibiotics, and more respectful of the environment.

Interventions to scale up these investments

To lift these barriers and unlock the investment opportunities, the primary role of players is to make the case for next-wave protein sources through pilots that reflect conditions of scaling, as well as providing a clear commitment that legislation will become neutral/favourable in the short term and guarantees of short-term demand. Specifically for each stakeholder group, potential actions include:

- **European Commission:** For the innovations in the space to be fully deployed, the current EU legislation would need to recognise next-wave protein sources[281] and allow them to be used where food safety can be secured.[282] One illustration is the use of insect meal in livestock feed which is regulated by two European directives,[283] as well as government legislation (e.g. the environmental codes[284]). In the EU, the use of insects to feed livestock is currently not authorised, although in many cases it is what these animals would eat in the wild. However, the regulation is starting to change. The European Parliament has adopted a resolution to address the EU's protein deficit, stating that urgent action is needed to replace imported protein crops with alternative European sources. In October 2015, the European Food Safety Authority (EFSA) published an initial positive view, which was confirmed on 27 April 2016 by the PROteINSECT research programme.[285] The European Commission is expected to authorise insect meals for aquaculture during 2017[286] (this will apply only to insects fed with agricultural vegetal co-products[287]). Insect meals are already authorised in Switzerland,[288] Japan, Korea, Africa, and certain states of the US. The legal framework to allow broader insect-based proteins into the human food chain should also be researched as this is currently creating a significant barrier to growth.

- **National, regional, and local governments:** Main areas of action in government at all levels are supporting the necessary legal framework adjustments (as outlined above), providing innovation funding, opening up markets, and raising consumer awareness of the benefits of insect-

CASE STUDY >>

INNOVAFEED

InnovaFeed is developing a new insect-rearing agricultural industry for competitive, sustainable, and natural animal feed.

InnovaFeed was created by the coming together of an innovative technology for large-scale insect rearing, developed over more than 30 years in the labs of IPC (Insect Pest Control, a joint IAEA/FAO research unit), and the critical need for sustainable sources of complete protein.

The need for next-wave protein sources is especially strong for aquaculture feed. Aquaculture is one of the most dynamic agro-food sectors (+8% per annum). Currently, farmed fish feed is a mix of wild fish meal, such as anchovies and sardines, and of plant proteins,[291] such as soybean (that account respectively for around 30% and around 70% of farmed fish feed[292]). Neither of these products can meet the need for more complete proteins as feed for farmed fish: the former – known as wild fish meal – is available in limited quantities and is already not sustainable, as it is emptying the oceans;[293] and the latter – plant proteins – cannot account for more than an average of 70% of fish feed as a higher proportion of plant proteins would be unsatisfactory from a nutritional perspective.[294]

Insect meal stands out as a relevant solution to address this problem and drive the development of sustainable aquaculture. InnovaFeed's aims are threefold:

- Provide an environmentally sustainable, health-friendly, high-quality, and safe feed source for aquaculture in order to realise the sector's growth potential.
- Recycle agricultural by-products as part of the shift to a circular economy and improve the European commercial balance.

The global addressable market for insect meal in aquaculture only is estimated at €5 billion in revenue and could grow to reach €30 billion by 2030.

- Make the ecological revolution a lever of growth and employment for the EU as a whole.

The global addressable market for insect meal in aquaculture only is estimated at €5 billion in revenue and could grow to reach €30 billion by 2030.

InnovaFeed has developed technologies enabling the production of high-quality insect meal at industrial scale and competitive costs. InnovaFeed has set up a profitable model enabling the industrial development of the insect industry. The model, developed and implemented at scale, provides a high EBITDA margin of 35% to 45%. This performance is supported by three main technological developments:

- Product quality optimisation: InnovaFeed has optimised the value of its products by improving the lipid profile of the insect oil and by identifying and valorising highly valuable bio-actives.
- Substrate formulation: InnovaFeed has developed a diet composed of agricultural by-products currently not valorised. The fine-tuning of the formulation has allowed it to improve by 40% the feed conversion ratio[295] of the black soldier fly (Hermetia illucens) and to reduce substrate sourcing

cost by 55% (substrate being the main production cost).
• Automation: InnovaFeed has leveraged and adapted the industrial knowhow of its technical partners to define fully automated processes that reduce capital expenditure and operational costs.

Having matured these technological developments, InnovaFeed is now in an industrial phase and is preparing the launch of a 300-tonne insect meal capacity unit in the first half of 2017. This unit will be scaled up to 1,000 tonnes by the end of 2017. This industrial development is also driven by very strong commercial prospects. InnovaFeed has received firm commercial commitments from clients in target market segments (aquaculture in Europe and Africa) and from clients in high-value market segments (pet food in the EU).

All developments to date have been performed with non-dilutive funding (€1.4 million). InnovaFeed is now planning to involve a financial partner (by Q1 2017) to accelerate its industrial development. The priorities of this phase will be to:
• Scale up production to reach target capacity for 2017;
• Prepare the industrial development phase (25,000-tonne capacity by 2020);
• Recruit key talent to move R&D and industrial development to the next level (e.g. optimise biotechnology production processes and identify new bio-actives).

based feed, for example through public procurement, providing innovation funding (possibly through the Horizon 2020 programme), and opening up markets and raising consumer awareness of the benefits of insect-based feed, for example through public procurement.

• **Private sector:** Food production companies, as well as retailers, could play a significant role in the growth of next-wave protein sources. Retailers could source part of their protein supply from these new producers, provide volume and price guarantees, and dedicate shelf space to create visibility of these goods, as Jumbo did in the Netherlands in 2014,[289] thereby enhancing consumer awareness. Food production companies could also dedicate R&D funding to these new production methodologies or directly invest in emerging businesses in this space. Collaboration between traditional food producers, retailers, and start-ups could further ensure buy-in along the value chain. Private players could have a role to play in creating the best conditions for favourable legislation changes, through demonstrating that risks to human health are very limited or could be fully controlled throughout the human food supply chain.

8 DESIGNING AND PRODUCING CIRCULAR BUILDINGS

Shifting to circular buildings would involve designing and producing buildings made for looping, using renewable/recyclable healthy materials, tracking end-to-end, planning for modularity and possibly adaptability,[296] and ensuring that the finished construction is energy-positive. The investment opportunity within this sector is significant, amounting to €105 billion between now and 2025, which could lead to a total economic benefit of up to €135 billion by 2030 in reduced repair and maintenance cost, as well as utility costs.

Relevance of investment theme

Even though looping today's building stock is a sizeable opportunity, designing and producing buildings for looping from the start would open up far greater opportunities on all fronts: economic, environmental, and societal.

Such circular buildings would become material banks, from which companies could remove used or unwanted parts and materials, to replace them with recovered ones that are ready for another life. Materials used would generally be renewable or recyclable, produced to ensure that high quality is retained over time, life cycle after life cycle. They could be adaptable to suit various uses, with convenient arrangements allowing for changes or upgrades in layout, size or functionality. Also, they could typically generate the energy needed to operate them or produce extra energy to be sold on the grid.[297]

Multiple benefits could be generated by these truly circular buildings that would otherwise not be captured. Advantages include: a decrease in virgin material consumption and mitigation of fluctuating material prices; land savings; and minimised waste, greenhouse gas emissions, and energy consumption, not only during the lifetime of the buildings, but also during their construction and demolition phases. Faster construction would also be achieved through shortened drying times and optimised workflow, as well as optimised maintenance through simple connection logic and detailed information at component level.[298] A study by Arup estimated that designing steel for reuse could generate high potential value for building owners, with likely savings of 6–27% for a warehouse, 9–43% for an office, and 2–10% for a whole building, as well as up to 25% savings on material costs.[299] Benefits would also be felt by those living or working inside these buildings, such as greater flexibility and customisation, as well as better indoor air quality and improved health and well-being due to the use of non-toxic materials. All this contributes to

increasing employee productivity and reducing absenteeism as shown by Delta Park2020 buildings.[300]

In contrast, today's mainstream building methods are unsustainable, produce large amounts of waste and greenhouse gas emissions during construction and throughout a building's lifespan, as well as through the disposal of demolition waste. In fact, buildings account for 36%[301] of total CO_2 emissions and 40% of energy demand in Europe, while construction and demolition projects generate 25–30% of the total waste in Europe.[302] More than half of demolition materials are landfilled, although some countries manage to landfill only 6%.[303] In particular, a number of small-sized building firms operate without any form of consideration for materials leakage. Despite the significant amount of waste and emissions generated to construct them, conventional buildings end up being under-occupied. Even during working hours, only 35–40% of European offices are used, despite high prices for space on expensive inner-city land,[304] while 49% of owner-occupied homes are under-occupied in the UK.[305] Because conventional building materials often contain toxic elements, they can be harmful to occupants' health throughout the building's life. For the same reason, most building materials are hard to separate and reuse or recover at the end of the building's life.[306]

A total life cycle assessment for a 42,000m^2 office space done by 3XN, a Danish architect, has shown that designing and constructing this building in a fully circular manner has a positive business case versus using the traditional design over the building's lifetime.[307]

Clearly, those engaging in the design and production of circular buildings would be pushing the limits of sustainability, flexibility, customisation, and well-being. As such, they would be unlocking benefits for the environment and society, as well as differentiation strategies and revenue potential for construction companies and investors.

Recent developments

Timing is now opportune to make this shift to circular building design and construction, due to a number of recent innovations, including:

- Innovative industrial processes, such as modular-building[308] and 3D printing. These make it simpler to produce easy-to-loop buildings. Indeed, these processes consist of slotting together various elements of the building, which can also ease disassembly and reassembly of parts and materials. These processes are already revolutionising construction, demonstrating: 50% (in some cases higher) faster construction rates,[309] costs lowered by as much as 30%,[310] and possibilities for increased flexibility and accuracy in design. For example, in 2014 ten houses were built in 24 hours by the 3D printing company WinSun at a cost of €5,000 per house, using 30–60% fewer materials than conventional building companies.[311]

- Innovative renewable/recyclable materials are coming to life, some of them literally. For example, the bioMASON plant in Durham, North Carolina, grows '500 biological cement

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bricks a week with sand and natural bacteria'.[312] Nutrients and minerals required in the process are obtained from natural, renewable sources, but may also be extracted from industrial waste streams. Accoya wood offers another example of innovation in the field. Manufactured by Accsys using its propriety acetylation technology, Accoya wood delivers outstanding levels of performance and durability, but also boasts: zero trace of toxic chemicals within the product, sustainable wood sourcing, the use of more than 50% renewable energy in the manufacturing process, and a material reutilisation score of 89%.[313] At the end of (one) life, Accoya can be reused in applications with the same or even higher added value (known as upcycling), such as the manufacturing of Tricoya.[314] If upcycling is not possible, Accoya wood may be used for energy production through incineration, releasing only the CO_2 absorbed during growth, and no additional toxic substances, unlike wood chemically impregnated with metal salts.[315]

- Innovative digital technologies that make it possible for end-to-end monitoring and tracking building parts and materials end-to-end, e.g. by adding digital passport IDs on parts and materials. This technology allows for easy recalling of parts that have reached the end of their (first) life or are to be removed to allow for more flexibility/upgrades. The EU-funded Buildings as Material Banks (BAMB) project launched in September 2015, is developing Material Passports and Reversible Building Design tools that will enable the shift to buildings functioning as banks of valuable materials.[316] Google is also developing, together with other partners, an open database of composition, health hazard, and environmental impact data for building products. This could drive the shift towards less toxic and more environmentally friendly buildings.[317]

- Technologies are also available that allow buildings to generate the energy needed to operate them, or even extra energy to be sold on the grid. These technologies include power-use sub-metering, rooftop photovoltaic systems, solar water heating, and battery storage or low-impact fit-out components (e.g. LED lights), as well as closed-loop systems such as anaerobic digestion (AD) or bio-reactive façades. For example, the SolarLeaf's building façade generates renewable energy from algal biomass and solar thermal heat. These outputs are then transferred by a closed-loop system to the building's energy management centre, where the biomass is harvested through flotation and the heat is captured by a heat exchanger. Thanks to full integration with the building's services, the excess heat can be stored or used to heat water throughout the building.[318]

- Innovative service-based business models are emerging that further incentivise companies to invest in designing and producing more circular buildings. These models work especially well for the building's services layer[319] (i.e. the pipes, wires, energy, and heating systems) and stuff layer, which includes the furniture and lighting. They typically allow building owners and users to pay only for their actual use through the leasing or renting of services or stuff, with

a guarantee of high performance over time. Through this set-up, the providers know that they will recover most of the investments made in these more circular building elements at some point. So, their focus shifts to designing building elements that are as circular as possible, by making them perform well over time, requiring little ongoing maintenance, and easy to loop and upgrade. DESSO has been innovating in the space by leasing its carpet tiles, implementing take-back programmes, and developing products that can be separated from the backing and used over and over again. Philips is now renting lighting to clients through quarterly payments and is responsible for maintenance, performance, and disposal.

The modular and digital technologies mentioned above could also make it easier to design buildings that are adaptable (i.e. that could match various purposes), for example workplace or residential space, various uses such as different sizing or layouts, or even various locations (e.g. through relocating the building to another place). Clients would get the option to adapt the size, layout or performance of the rooms to the needs of the moment through smooth arrangements or upgrades. Do It Right This Time (DIRTT) provides an insight into how these possibilities could be realised. The Canadian company produces innovative prefabricated modules so interiors are customised to suit the space dimensionally, functionally, and aesthetically. To achieve this, they rely on their proprietary Institute of Civil Engineers (ICE) 3D design, configuration, and manufacturing software with integrated in-house manufacturing.[320] The prefabricated modules are provided at a cost that is 50% lower than on-site construction[321] and some of them leverage looping (e.g. recycled cotton denim is used to produce the 100% renewable cotton fibre wall insulation).

The Belgian company, Beddeleem has also tapped into the great potential of combining circular design principles and modular technologies for building interiors. The construction company specialises in the manufacture of relocatable partition walls, glazed partitions, suspended ceilings, and door systems.[322] It has leveraged these principles in its glazed partition products, which are made of healthy materials[323] that take advantage of looping[324] and are easily relocatable thanks to a smart linking system.

All of these examples clearly show that there is already substantial activity and innovation within this sector and demonstrate the potential opportunities for growth.

Investment opportunities identified

Players keen to get ahead of this shift towards circular buildings could tap into three main investment opportunities:

- R&D and production facility investments to design and produce buildings made for looping. These investments could comprise of funding design and construction companies or separate projects for new production facilities.
- Funding the additional construction costs needed for circular buildings compared to those for conventional

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buildings. This could be done through traditional mortgage-style financing, but also through more innovative structures whereby the payback is linked to the benefits realised. This model is already being tested by some companies in order to lower the upfront cost to the potential customers, while sharing the risk of realising the benefits – effectively putting some skin in the game for the construction company or other stakeholders involved.[325]

- Investments to secure digital enablement through the development of end-to-end material tracking systems, which optimise the use and recovery of materials. Such digital systems could include:[326]
  - Product information (e.g. product passports) to enable traceability and understanding of what conditions products and parts have been subjected to during their lifetime, and how/whether they can be remanufactured.
  - Labelling (e.g. product codes) to indicate products that are designed for disassembly. This would enable dismantlers/core brokers to easily determine how to channel products collected at their end-of-first-life phase.
  - Open built-environment material database, to centralise standardised information on the properties of building materials and their potential for durability, looping, and adaptability. This could also develop into digital marketplaces for built-environment materials and parts.

Current barriers to investments

Two key barriers need to be lifted in order to achieve scaleability and broad applicability of circular building design and production across the fragmented construction industry: uncertain market size for newly designed buildings and longer payback times for investments required.

The first is the fragmentation of the construction sector. This does not provide a solid basis for end-of-life material value extraction due to split incentives, high transaction costs, and lack of the necessary capabilities and skills. If a construction company opts for selling the circular building entirely at the time of construction, it would likely have to sell it at a higher price than that of conventional buildings to cover both the investments made to develop the new building as well as the (potentially) higher costs of production, depending on the materials and technologies chosen. This price premium can be (partially) offset only if the end-of-life value can be priced in, which is difficult given the current sector fragmentation.

In addition, investment payback times can be longer if business models are used that are service-based and/or link the payback over time to the buildings performance. Although these business models could lower the demand uncertainty barrier for circular buildings (by spreading payments over time instead of requiring a high initial payment or by providing strong performance guarantees), they also come with risks for the players involved in the building design and production. For example, those involved face a risk of lower revenues than forecast, as these may vary depending on the performance generated by the

building over time.[327] They also face complexity regarding the funding of the building, as they could end up having more limited revenues during the construction phase and significant assets on their balance sheet.

Alongside these key barriers, other issues that could slow down scaling, include: the need to enthuse new attitudes and habits into the fragmented and conservative construction sector, as well as the current low awareness about the benefits of circular buildings among construction players and clients. In fact, the poor integration of the construction sector leads to limited information sharing and transparency, transaction costs, and split incentives, as each player naturally focuses on improving its own profit.[328] Whereas, the design and production of circular buildings requires collaboration and aligned incentives across the value chain, including between investors, architects, developers, engineers, (sub)contractors, owners, and tenants. In addition, current valuation and accounting practices are not yet tailored to sufficiently price in end-of-first-life value. Legislation could also be a barrier to scaling, although the situation varies across European countries.[329]

Interventions required to scale up investments

The key levers to achieve a substantial ramp-up of circular buildings are: collaboration schemes, allowing for broad applicability of service-based circular business models across the industry; integration of circularity within building sector standards; and additional incentives for construction players to switch, such as guarantees of future demand and favourable legislation.

- **European Commission:** Although the main work around building design, development, and production will have to be led by the private sector, the European Commission could facilitate the shift in the following ways:
  - Research legal framework at EU level to incentivise players to shift to circular buildings in the short term (e.g. tax breaks/subsidies/discounted electricity pricing).
  - Use the expansion of the existing Ecodesign Directive as a way to extend producer responsibility schemes to promote durable, repairable, recyclable, and upgradeable products.
  - Change the definition of construction and demolition (C&D) waste and associated recycling targets to facilitate the shift towards reuse, thereby providing long-term certainty to investors.
  - Provide funding for technology innovation related to multi-usage, highly modular buildings that are constructed from durable non-toxic materials.
  - Support the creation of a European market for secondary building materials, in a similar way to the European Commission's creation of a market for organic fertilisers. This could potentially start with specific materials, such as concrete, wood or metals. The Waste Directive already pushes waste away from landfill, but barriers remain to reuse these materials rather than deploying them for backfilling.
  - Provide energy efficiency standards, not only for the building envelope but also the building interior.

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National, regional, and local governments: Working alongside the European Commission, the public sector in Member States could offer further direct and indirect support towards the transition, including:
- Directly provide demand for circular buildings (e.g. through public procurement);[330]
- Offer funding for technology innovation related to multi-usage, highly modular buildings that are made of durable non-toxic materials;
- Roll out capability building and awareness programmes that could be delivered by industry players to highlight the benefits of such buildings;
- Support sharing of building space for both residential and commercial purposes, in order to increase utilisation of the building stock;
- Facilitate the creation of advocacy platforms to push the circular design and production agenda.

Private sector: Beyond further increasing collaborative/open design and co-development of prototypes and projects with partners across the value chain, the private sector could play a leading role in setting up innovative, collaborative schemes that mitigate risks for players wanting to shift, building and scaling construction standards that take circularity into account, and providing business-to-business guarantees of future demand for circular buildings. More specifically, further efforts would be required to set up innovative, collaborative schemes to effectively address the complexity and risk associated with circular buildings. For example, to mitigate the risks associated with the service-based and/or performance-based business models described above, collaborative responsibility structures[331] could be developed to allow multiple players to share and mitigate risks. The players involved might include: investors, architects, developers, engineers, (sub)contractors, service providers, remanufacturers, recyclers, and demolition companies, as well as possibly banks, insurance companies, owners, and tenants. They could typically align on a long-term outlook for building performance, and link this to revenue using Key Performance Indicators (KPIs) based on a contract that allows sharing of risks and revenues between players. Multiple pilot projects are being launched in this area across the EU by organisations such as DELTA and Arup. An intermediary company could also facilitate collaborative projects by helping players achieve contractual arrangements between them. There is a specific opportunity for financial players to provide new forms of capital flows or alternative earnings models that incentivise these circular building business models, and for legal players to effectively update contracts for the ownership and use of assets. For example, the R50 Baugruppen co-housing project in Berlin uses innovative financing models where a collective construction funding package is structured by the bank and project manager through pooling the future residents' mortgages, and architect-led participatory design involving the future residents to explore a new way to collaboratively fund and create buildings.[332]

- Industry standards will play a role in accelerating the shift to circular

buildings. Players in the space could agree on construction standards taking circularity into account and/or update existing standards, and ensure the integration of these construction standards. For example, this could be achieved by adjusting the criteria for quality certifications, such as the Building Research Establishment Environmental Assessment Method (BREEAM) or the Leadership in Energy and Environmental Design (LEED).

- Commercial buyers of new buildings could change their selection process for construction companies based on the long-term costs and performance of the building rather than just the construction costs. This shift has been made by the Danish government for the construction of the office hub for four Danish government agencies; a Private–Public Partnership (PPP) was set up that required the contractors to compete on the operation and maintenance costs of the project over a 30-year period[333] (see case example for more details).

• In addition, architects, developers, engineers, (sub)contractors, service providers, remanufacturers, recyclers, and demolition companies keen to drive the transition could also engage in the following:

- Design, deliver, and/or fund industry-wide training programmes, focused on players from architects to sub-contractors working on the ground.
- Support and advise the European Commission and/or governments on relevant incentives, urban planning, and potential legal issues.
- Create and update an open built-environment material database to centralise standardised data on durable and easy-to-loop building materials. This would allow players across the value chain to get an overview of not only the materials' performance, but also its durability and easiness to loop, thereby fostering the design of circular buildings.
- Create awareness about the benefits of circular buildings among users at all levels.

CASE STUDY >>

FIRE STYRELSER, DENMARK

Fire Styrelser is an office hub for four Danish government agencies that will house: the Transport Authority, Banedanmark, the Energy Authority, and the Danish Road Directorate. The building is located on Kalvebod Brygge in the centre of Copenhagen.[334]

The vision for Fire Styrelser is to create a flexible and future-proof office building with an inspiring and healthy environment. The workplace framework allows for movement, social interaction, and sharing of knowledge. It aims to create a working environment with great visual experiences, where individual users can work more or less privately, according to their needs, and have influence on the indoor climate. The project is among the largest and most complex headquarters built in Denmark and lends itself to a case study, as the principles developed for such a complicated building would be easy to use for smaller and less complicated buildings.

The project is also interesting because it is a Private–Public Partnership (PPP) that requires the contractors (and their architects) not only to compete on the design, functionality, and price of the project, but also on the operation and maintenance costs over a 30-year period. The costs of operation and maintenance over a 30-year period for such a project are approximately 50% of the value of the contract with the client. Consequently, this kind of competition forces the competing contractors to focus on the Life Cycle Costs (LCC) of the project and not just on the construction costs. Such an approach will always result in better and more robust buildings of higher quality, and, as such, more sustainable. This provides optimal flexibility for unimpeded rebuilding and reprogramming. By allowing the wall elements to contribute to the stability of the structure, it is possible to create a building with a minimal number of inner bearings. From an overall economic perspective, the façade solution is also optimal in terms of construction and operation. The window frames are a combination of: wood, which is a renewable material; aluminium, which is maintenance-free; and an intermediate composite profile, which efficiently insulates and prevents condensation.

9 CLOSING BUILDING LOOPS

Increasing building materials recycling and reuse, as opposed to landfilling the waste generated by construction and demolition (C&D) activities requires an investment of up to €2 billion between now and 2025 to scale up the number of C&D waste recovery plants. This could lead to societal cost savings of up to €15 billion due to reduced material cost and waste, including decreased greenhouse gas emissions. To accelerate this shift, the public sector could work with industry to standardise quality requirements, and so boost the general confidence of the main players of the construction sector in non-virgin materials.

Relevance of investment theme

The EU currently generates approximately 3 billion tonnes of waste each year.[335] Of this, around one-third (i.e. 1 billion tonnes) comes from the construction and demolition of buildings. Although it is undeniable that waste management has improved in recent years, the European economy is losing a significant amount of potential in secondary raw materials, such as wood, glass, plastics, and metals; for example, on average 38%[336] of demolition material went to landfill in 2012. Already a substantial waste volume is created throughout the construction process, 20–25% of building materials deployed to construction sites are wasted due to unnecessarily high volumes of materials being sourced in the first place.[337] This situation is generally being driven by the high cost of labour compared to the cost of material, therefore meaning the procurement process is optimised to keep the labour productive.

Turning building C&D waste into a high-value resource is one of the main ways to accelerate the shift towards a circular built environment. The EU Waste Directive[338] stipulates that Member States should take all the necessary measures designed to achieve a minimum of 70% recycling rate of non-hazardous and demolition waste by 2020. According to the European Commission, while nine countries already fulfil the directive's target or are close to achieving it, eight countries report recycling rates below 20%.[339] However, some caution is needed in interpreting this data, as many Member States have different definitions for, and ways of measuring, waste recycling. Indeed, most of what is accounted as recycling is actually backfilling (using waste materials to strengthen a new structure's foundation), which is a low-value way to recycle. In order to further shift towards waste reduction, the European Commission has introduced a new protocol on C&D waste management on the 9 November, 2016.

Yet, there are a variety of ways to shift towards reuse of materials such as bricks, cement, wood or glass in new buildings. Examples exist of companies currently reusing materials, such as Danish company Gamle Mursten, which has patented a cleaning technology that ensures building waste materials can be recycled more easily. Old bricks are cleaned, sorted manually, after which these are stacked by robots; next, they are sold to new building projects where clients want to minimise environmental impact. Untreated wood can be repurposed as it maintains its material features, especially the older wood used in many buildings being demolished currently. Multiple projects have shown the potential for concrete recycling over the last years; for example, Danish Lendager Up (part of Lendager Group) is investing in innovative building materials such as upcycled concrete.[340]

Indeed, recycling and reusing building materials could have a positive economic case for companies. Currently, companies often have to pay a gate fee to send their waste to landfill, which can be costly, e.g. in the UK fees can be as high as £80–100 per tonne.[341] In addition to fees, there are transportation costs to move the waste to the landfill site. However, if companies manage to source sufficient volume of materials that can be recycled and reused to the standards required by construction companies, this could turn what is currently a cost into an income stream.

It is clear from examples such as Balfour Beatty – who managed to close the loop on building materials, with up to 25% of total new building materials coming from recycled content, and up to 60% of steel and concrete products[342] – that closing the loop at scale is not only viable, but also beneficial for society and for the economy.

Recent developments

The timing is ripe for such a shift towards recycling and reuse, as new technology developments have improved the economics of the recycling process. These improvements have enabled the C&D recycler to increase its recycling rates by separating non-recyclable granular materials from recyclable granular materials in aggregates, such as mixed concrete (80% aggregate),[343] instead of mixing them or using them for backfilling.[344]

In fact, shifts towards higher looping of building materials are happening in other pockets of the recycling and reusing of C&D waste sector. A good example of how to achieve maximum recycling potential is within the gypsum market. Gypsum is a mineral used for plasterboard that maintains its materials quality and therefore could be 100% recycled. However, of the 2.4 million tonnes per annum of estimated total waste generated that is recycled, only between 5–7% comes from production and construction waste and below 1% from demolition waste.[345] In order to push these recycling rates up, in 2010 the gypsum industry developed, with the European Commission, the green public procurement criteria for wall panels, which effectively requires a minimum share of recycled gypsum to be used in public buildings. The gypsum to

gypsum (GtoG) project, which is a platform run by demolition, recycling, and gypsum manufacturing companies is pushing this increase further through research and pilot projects. The Danish company Gypsum Recycling International (GRI), which is active in northwest Europe, has developed innovative, moveable gypsum recycling facilities that allow it to even remove gypsum from landfill. This is probably one of the reasons why 80% of Denmark's gypsum is now recycled,[346] which is the highest rate in the world.

There are also a number of non-EU examples of recent innovations in the C&D recycling space. For example, the Japanese Taisei Corporation has created a new demolition crane that attaches to a building and demolishes it floor by floor, from the roof to the foundations. This inside out demolition crane increases the recycling rate of the building materials, captures and reuses kinetic energy, saves fuel, and achieves a 90% dust reduction during demolition.[347] In China, a 3D printing construction company, WinSun, is also using a mixture of dry cement and construction waste to build its 3D printed full-sized apartments. WinSun is currently opening 100 recycling facilities in China to transform waste into cost-efficient ink[348] for future buildings.

Additionally, an example of using recycled building materials to construct new buildings has emerged recently in Denmark. The Lendager Group has led the construction of the Copenhagen Towers II using upcycled materials; acoustic ceiling panels are made from PET plastic bottles, 90m high wall panels are made from waste wood, translucent walls are made from discarded racing sails, and a floor is made of upcycled concrete. In fact, versus the conventional alternative, the wall panels were 10% lower cost, the concrete up to 60% lower cost, and the sail frames 35% lower cost.[349]

With so much innovation taking place, there are obvious opportunities for investors to add value, reap rewards, and accelerate the shift to circularity in this space.

Investment opportunities identified

The main investment opportunity in this sector is the deployment of capital into innovative recycling businesses and facilities for building materials. The examples provided above show that innovations are already happening at a low level, but to escalate the growth in C&D material recycling and reusing would require further investment. As building materials consist of many different waste streams, each with its own characteristics and specifications on how to recycle or reuse, different investment opportunities will likely emerge.

Concurrently, there are investment opportunities in the development of (digital) material tracking systems based on material standards. At the moment, recycling companies have to source their own materials, but if there is sufficient growth in the market then this could open new matchmaking-style services, bringing together suitable materials and appropriate facilities.

10 INVESTMENT THEMES

Current barriers to investments

Some materials, such as wood or gypsum, have relatively low technical barriers to their recyclability, whereas others, for example concrete, are considered to be more challenging. Therefore, the investment opportunities in facilities treating these varying streams will throw up different barriers. For example, these could be: the availability of volume of waste (e.g. in the UK, plasterboard is estimated to represent 1% of demolition waste, while concrete is 59%[350]) or the technological development needed to treat the specific waste stream.

There are three other key barriers to scaling up the looping of building materials. The first being the lack of industry standards for recycled materials. Illustrative of this problem is StoneCycling, a Dutch company that creates bricks from ceramic, glass, and other insulation material. However, StoneCycling has found that construction companies are reluctant to purchase its bricks, as these companies have to assume end-responsibility for the building's quality and because there are no official certifications or standards for recycled bricks, they are hesitant in case there are any issues further down the line.[351]

Secondly, legislation prevents the main construction players from using non-virgin inputs and some associated machinery. For example, using recycled concrete could increase reporting and permitting requirements, as it is classified as waste.[352] An example of this problem in action is in the Netherlands where only virgin concrete is directly certified, whereas recycled concrete has to be certified based on an integrated test of its capabilities, which increases the cost.[353] A lack of legislative harmonisation among Member States is certainly preventing the scaling up of the recycled materials market and the use of required associated machinery. Each European country has different minimum quality standards for insulation, varying waste and recycling regulations or product requirements, which makes the re-collection of materials more difficult.

Finally, construction companies themselves can be the barrier, as they often are wedded to their current habits and resistant to change, as well as sometimes being reluctant to use non-virgin materials. This is partly due to the stigmatisation that inconsistent and confusing recycling legislation has created, as well as the lack of standardised recycling processes. It is also partly due to a fragmented value chain, with different incentives for the architects, engineers, constructors, and demolition companies. This means there is no transparent approach to circular products and practices, such as reconstruction rather than demolition, which prevents them from being implemented.

Interventions to scale up investments

The main risk reductions that would enable investment and growth in this sector are: changes in the legislation that currently prevents non-virgin materials from being certified as well as securing sufficient market size for the

recycled materials by creating a platform or collaborative network of demolition, recycling, and construction companies.

- **European Commission:** The European Commission could redefine its recycling targets to encourage high-value recycling rather than allowing the continuation of low-value recycling, such as backfilling. Although the EU has set high recycling rate targets of 70% by 2020, the definition of recycling is very broad, leading to many Member States meeting this target even though the majority of their C&D waste is being used for backfilling rather than high-value reuse. It could also provide funding for technological innovations in specific waste stream recycling techniques. Meanwhile, a harmonisation of material standards could open a cross-border market over time if growth takes off.

- **National, regional, and local governments:** A focus for national governments could be to remove legislative barriers impeding the use of recycled materials where possible. Additionally, national or local governments could play a role in facilitating collaborative schemes between the relevant value chain players who could push the building materials looping agenda. Finally, public procurement that requires the use of recycled building materials could also be considered as an effective way to incentivise looping.

- **Private sector:** As shown by GRI, specific waste streams can be recycled profitably by deploying technological innovations. So, private sector players could further research the development of technologies for recycling specific waste streams. In order to further grow the market for recycled materials, industrial collaborations could be established (similar to GtoG, see Case Study below) that set standards and certifications for recycled material flows. The private sector could also work with the public sector to alleviate regulatory barriers. Specifically, the larger construction, demolition, and recycling companies could lead the way, as they provide or buy the volumes needed to make a step-change in setting these standards.

Additionally, digital platforms could be developed to create markets for used building materials. Creating transparency on the availability of specific materials, volumes, and quality would greatly lessen the risk of sourcing sufficient materials for recycling companies. Early examples of such platforms already exist, such as Globechain – an app that shares available ready-for-use items from construction and demolition sectors (among other items). Growing these platforms at commercial scale and targeting them at recycling and construction companies would further enhance building materials looping.

>> 10 INVESTMENT THEMES

CASE STUDY >>

GtoG

The gypsum-to-gypsum (GtoG) project is a good example of value chain collaboration in order to increase recycling rates in the construction and demolition waste stream of gypsum (a material used to make plasterboard). The platform involved key stakeholders along the value chain: demolition companies,[354] recycling companies,[355] and production companies. [356]

The ultimate objective of the project was to transform the European gypsum demolition waste market and to achieve at least 30% reincorporation of recycled gypsum in the manufacturing process. This would result in a closure of the loop on gypsum waste recycling, increasing recycling rates from the current status of on average below 7%, ranging between zero in Spain, Greece or Poland, up to 19% in the Benelux, UK, and France.[357]

The initial objective was to set up standardised procedures for the industry. The procedures started by implementing an audit prior to the deconstruction of the buildings. The audit includes the composition of the building, the identification of the different waste streams, transport costs, and risks (i.e. the possibility of hazardous waste). The next step was to implement new deconstruction techniques during demolition, by providing the demolition companies with the best practices.[358] The document describes the most common types that may be encountered on a deconstruction project, waste acceptance criteria of recyclers, as well as best practices and techniques for each gypsum type. The third procedure to be standardised was in regard to Waste Acceptance Criteria (WAC), to increase the level of gypsum waste recycling and consequently reduce potential risks to the environment due to bad management of gypsum waste, which was driven by analysing the procedures of three leading gypsum recyclers.[359]

The second phase of the project was to implement the new standards and procedures, and compare them to the business-as-usual procedures. The results demonstrated that the implementation of proper deconstruction practices could save money for each player in the value chain and would also maximise the availability of suitable gypsum-based waste for recycling.

Finally, the platform executed five pilot projects across Belgium, France, the UK, and Germany, with the aim of implementing its identified deconstruction techniques, recycling processes, and reusing of recycled gypsum in the manufacturing process. Through these projects, it was shown that in two out of its five schemes, the 30% recycling rates were met, while the cost of the newly produced gypsum from recycled materials was on a par with gypsum coming from primary sources, given current market conditions. In addition, potential bottlenecks for future scaling of gypsum production were highlighted and a transition cost assessment was provided.

The project started in January 2013 and lasted until January 2016, with a total budget of €3.4 million to fund research, of which €1.7 million came from the European Commission's Life+ programme. The project was coordinated by Eurogypsum (the European association of plaster and plasterboard manufacturers).

10 DEVELOPING CIRCULAR CITIES

To really escalate the shift to the next-wave circular economy and underpin the value of all the opportunities addressed throughout this report, it is vital that circular principles are incorporated into urban planning in a holistic way. In order to fully reap the benefits of circular cities, it will not be sufficient to shift to circular transport, food or buildings sectors individually; additional investments will be needed to make all resource flows circular such as water or local energy generation. Additionally, investments will be needed to handle freed up public spaces while preventing continued urban sprawl. For a relatively small total investment of €10 billion across the EU between now and 2025, the total benefit could be as great as €160 billion, mainly in reduced government operating costs for urban development as well as transport costs.

Relevance of the investment theme

Although the other themes capture investments in circular mobility, food, and buildings systems, implementing these will leave some of the benefits of fully circular cities untapped. Water usage can shift towards more efficient processes through a closed-looped system or power can be generated locally while using the heat generated through a Combined Heat and Power system (CHP). Additionally, on the one hand municipalities will need to plan for the impact of circular systems through the opening up of urban spaces due to reduced need for transport infrastructure, while on the other hand prevent continued urban sprawl due to lower household costs.

Indeed, if no clear plans exist for how to manage the potential space that could become available due to reduced buildings and transport infrastructure needs, a risk exists that these new spaces will be used for suboptimal purposes. They could be used as additional green areas or to construct fully circular infrastructure or buildings. The decommissioning of old, inefficient infrastructure could occur earlier in the planning cycle in order to accelerate the shift to circularity.

Additionally, if a shift towards circular systems leads to lower household costs, this could result in an unwanted rebound effect that might lead to a continuation of urban sprawl; basically, if household costs fall by as much as 30–35%, demand for floor space could increase by as much as 30%.[360] The continuation of urban sprawl (currently around 1,000km^2 per annum across the EU), could lead to negative effects such as increased commuting time, additional

greenhouse gas emissions, reduced air quality, accelerated soil erosion, and loss of arable land.[361]

As such, there is a clear need to incorporate circular principles holistically into urban planning. This implies not only planning for the shift to circular mobility, food and buildings systems, and for decommissioning of infrastructure or buildings because of individual sector shifts towards circularity (i.e. resulting from developments outlined in this report), but also identifying additional areas where circular principles can be applied. This includes planning elements such as circular street design (e.g. pedestrian-only streets, permeable pavements) waste and water management systems (e.g. closed grey water systems or waste collection systems that allow for the complete looping of different waste streams) or urban greening.[362]

Implementing circularity into urban planning could require additional upfront cost compared to the linear alternative. Although this cost is typically offset by annual operating savings, the benefits do not necessarily fall to the same stakeholder as the one providing the investment. For example, deploying energy-efficient lighting generally requires higher investments versus alternatives, but could lead to annual savings of 30–50%.[363] A study by McKinsey&Company carried out in 2015 shows that the average payback time of these additional costs ranges from three to five years,[364] assuming the optimal design elements and technologies used are chosen (e.g. savings for street lighting will be higher in northern Europe, as it has longer dark periods throughout the year), thereby maximising the savings.

Recent developments

Urban developments based on circularity principles have emerged over the last few years, either deploying specific design elements or technologies, or focused on districts rather than whole cities.

Some city governments have focused on specific elements of design or technologies in order to reduce emissions, save on energy or decrease waste. Barcelona provides a good example, as it is taking the lead on the implementation of new forms of urbanisation. The city is reclaiming land from roads to expand pedestrian zones, increase urban forestry, and reopen covered rivers as part of its superblock rollout. These developments incentivise the concentration of urban areas and reduce greenhouse gas transport emissions while providing more attractive liveable urban areas. Another example is the rollout of energy-efficient street lighting by third-party operators. Many street lighting systems across Europe are outdated and therefore highly inefficient, resulting in street lighting representing up to 50% of the total power consumption in some municipalities. Shifting to efficient street lighting could provide substantial energy savings.[365] Therefore, the business case to switch is highly positive. In order to reap these economic benefits, multiple municipalities across the UK and Germany have been setting up

Public–Private Partnerships (PPPs) mainly with energy service companies (ESCOs). These ESCOs have taken on the construction, operation, and maintenance risk over a multi-year period, against a return on their capital deployed that is sufficiently attractive for them to accept this risk.

In other cases, specific circular districts are being developed, such as in Hammarby Sjöstad, near Stockholm's city centre. This project aims to develop a district that will incorporate integrated systems, such as a sustainable energy supply, and water and waste management cycles. It will encompass 11,000 apartments and accommodate approximately 35,000 residents.[366] Elsewhere, Amsterdam has stated its ambition to become one of the first European circular capital cities. In order to achieve that goal, the city is trying to reduce food and phosphate dependency and close loops in waste, electricity, and heat systems with innovative measures. [367]

Although the described examples are moving in the right direction, they are typically not yet taking a complete city perspective on circular developments; either only specific design elements are deployed or circular districts are being developed as standalone projects. Other ambitious initiatives touched on in this report target many different systems (urban farming, construction looping, etc), but if a holistic approach is lacking, then they will fail to connect the dots and unleash the integral benefits associated with urban built environment.

Investment opportunities identified

There are multiple investment opportunities within the circular city theme, as all the technologies and design options described above require some form of investment. There is an estimated total investment potential over and above standard urban investments of up to €10 billion between now and 2025. However, the specific conditions in each city will influence which of these options could be deployed and at what scale, leading to total investment need varying across cities.

Generally, for most of these capital investment opportunities in the circular economy to provide sufficient return, a revenue stream will need to be coupled directly to the investment. For example, investments in more efficient (closed) water systems would need to be linked to the savings in the cost of clean water usage. Likewise, the investment in decentralised combined heat and power systems would need to be linked to the associated reduced cost of using the energy. In many cases, this would require developing specific new project structures, as often the owner/investor and operator of these projects are not the same entity, but the model of using PPPs to set up energy-efficient street lighting projects offers a way to achieve this.

10 INVESTMENT THEMES

Current barriers to investments

Without a clear commitment from city and local governments to drive the transition towards fully circular urban developments, it could be difficult for capital to be deployed at the scale needed. Lack of a clear vision and plan of what this transition would look like, including where return-generating investment opportunities may arise, could deter investors from funding circular investment projects at the speed and scale required. Individual projects could still receive funding, but this will likely not be enough to transition towards a fully circular city.

Secondly, the agent issue between investor/owner and operator needs to be overcome. This issue is well understood in the buildings' energy-efficiency space, where a large part of the buildings' stock area is leased out and therefore the energy savings benefit the tenants but not the homeowner. As such, the homeowner has no incentive to invest in energy efficiency, even though the economic benefits of doing so are highly positive from a societal cost perspective. In the case of circular urban developments, these agents are different entities depending on the investment opportunity, which makes it even more difficult to scale. For example, energy savings in buildings benefit the occupiers, water savings could benefit national governments in the case of subsidised water, reduction in waste benefits the municipality, while lower pollution reduction benefits urban residents overall. Also, the benefits are not always easy to capture; especially if benefits are environmental or societal, rather than financial, it could be difficult to provide investors with clarity about their expected returns.

Finally, a lack of knowledge of the potential alongside a paucity of funding models further hampers rollout. City governments typically do not have significant project development and financing experience in general or for circular projects specifically. Executing the required urban planning across multiple and varied stakeholders, such as city departments, residents, and investors makes the project development difficult to achieve. Concurrently, it is vital that the costs and benefits of circular investment projects and setting-up structures are assessed properly and linked through innovative contractual structures, so that they can attract the necessary private funding. This requires specific expertise that many city governments lack.[368]

Interventions to scale up investments

To establish and scale up the circular urban built environment in the EU would require a strong commitment across European, national, and municipal institutions, including the provision of clear transition plans. Additionally, the public sector could work with the private sector to develop projects that are investable by linking income streams directly to the investor, while providing financial support where needed.

- **European Commission:** The European Commission could provide infrastructure funding to support the rollout of circular urban infrastructure. This could be done through existing vehicles, such as the European Fund for Strategic Investments (EFSI) which has been directing limited funding towards circular urban developments, or structural funds.

Additionally, the European Commission could support best-practice knowledge sharing across EU cities, specifically collaborating over ideas on how to make circular city investment projects financeable. This could be put into practice either by linking up cities directly or providing knowledge and expertise from infrastructure-funding projects where EU funding institutions were involved.

- **National, regional, and local governments:** The public sector across governments could have a leading role in supporting and incentivising the transition from linear to circular cities. The systemic nature of the transition towards circular cities is complex as it requires rolling out multiple circular design elements and technologies simultaneously, while planning for the impact of circular business models (e.g. the reduction in demand for building space or cars). Therefore, the relevant urban planning institutions would need to provide a clear roadmap on how to transition urban centres towards fully circular cities. In addition, incentives and support towards specific project investment would be required in order for these to become financeable. Multiple examples exist of PPPs that deliver energy-efficient street lighting through setting up of joint ESCOs,[369] showing how the public sector can provide incentives for the private sector to deploy capital. In addition to PPPs, national or local governments could also de-risk investments through direct investing, i.e. owning and operating investment projects until the investment has been fully recovered, after which they could sell them on to private owners/operators.

In order to overcome the agent issues and lack of experience in financing the required infrastructure, governments can set up specific project teams to build up the required technical and financial capabilities, or they can work with third-party experts and finance institutions. These could become centres of excellence in delivering innovative financing structures taking into account whole life economics, while also identifying new investment opportunities to further speed up the transition. Maintaining and building out knowledge on how to deliver and operate investment projects will be key to achieving the overall shift towards a circular economy. Lastly, building out networks of these centres of knowledge across cities, regions, and countries would further speed up the rollout of new urban planning practices and associated infrastructure investments.

- **Private sector:** Despite the leading role of the public sector, the private sector will be a key contributor in the transition to circular cities. In addition to providing the capital required through well-structured investment (mainly infrastructure) projects, the private sector would need to provide the operator skills to run the circular infrastructure throughout its lifetime. Therefore, investors with knowledge in infrastructure project structuring could provide their expertise to work with the public sector to develop scaleable investment projects. Additionally, private sector players could investigate how to set themselves up to become owners/operators of these projects in order to receive the income linked to the investment. To further support governments in rolling out circular urban developments, private players with relevant experience could share their knowledge and expertise with city governments in the area of infrastructure project development and investments.

CASE STUDY >>

BARCELONA

Barcelona's superblocks: an example of the implementation of partial circular urban planning to facilitate the urban built environment.

Barcelona is a complex and compact Mediterranean city where public spaces are meeting points for its citizens. In a city with those characteristics, having a sustainable environment is crucial for the citizens and the millions of tourists who visit the city every year. In 2014, Barcelona and its 35 surrounding municipalities consistently failed to meet the EU's air quality targets. Moreover, studies were showing that air pollution in the region was causing 3,500 premature deaths per annum. To mitigate this, the city developed an urban mobility plan to reduce pollution. The most innovative part of that plan was the creation of *superilles* (translated as 'superblocks'). These are an urban design concept intended to minimise the presence of cars in city centres. Superblocks are road traffic free spaces in the middle of the city, larger than a block but smaller than a district.

Superblocks consist in aggregate nine city blocks and close off the inside of the block to through traffic. Therefore, any vehicle trying to get from one part of town to the next must drive around the perimeter. Inside the superblock, the speed limit is kept to 10km per hour (in comparison to the average minimum city speed limit of 50km per hour). Curbside parking is replaced by underground parking with priority spaces for residents.

The concept could be scaled to up to 120 possible intersections. The grid structure of Barcelona facilitates the implementation of superblocks, but superblock designers insist that cities do not need a simple grid structure to implement this kind of plan.[370] In order to offset the reduced accessibility by car, an additional 300km of cycle lanes will be built as well as increased bus travel capacity.

The results of this initiative can be inferred from similar initiatives that have been tested in other parts of Spain. In Basque Country, the small city of Vitoria has implemented superblocks since 2008. In the main superblock at the city centre, pedestrian space increased from 45% of the total surface area to 74%.[371] There was a 42% reduction in nitrogen oxide emissions and a 38% reduction in particle pollution in that area.[372]

These superblock initiatives incentivise the implementation of pneumatic waste collection systems and facilitate the implantation of urban forestry, making cities more sustainable and circular.

FIGURE 25 **ROAD HIERARCHY IN A SUPERBLOCK MODEL**

CURRENT HIERARCHY

Basic network 50km/h

Sole right displacement.
Highest aim: Pedestrian

SUPERBLOCK

Local network 10km/h

Exercise of all rights
that the city offers.
Highest aim: Citizen

**Passing vehicles
do not go through**

CASE STUDY >>

SURREY, UK

Smart lighting in Surrey, UK: an example of making circular urban infrastructure investable.

Surrey is a county located in the southeast of England. With a population of 1.1 million people, it is one of England's most densely populated areas. Over recent years, the county of Surrey has carried out a series of projects and policies in order to optimise its street lighting and make it more efficient, saving energy, cutting costs, and reducing greenhouse gas emissions derived from street lighting.

The main objective of this project was to increase the energy efficiency and durability of Surrey's lighting assets over the long term. The key component consisted of the renovation and upgrading of Surrey's street lights. The project was carried out by a consortium between Skanska Plc and John Laing Group Plc. Both companies invested £4.6 million each to replace 69,000 and refurbish 19,000 street lights over the period from 2010 to 2015.[373] Skanska installed white lights to replace the orange glow street lamps across the county. The new lights communicate via low power, very high frequency (VHF) to local nodes and via mobile phone technology to a central hub/computer. Individual lighting columns are remotely accessed from a control centre, giving Surrey's local authority the ability to dim the street lights by 50% in residential roads and 20% on main roads between the hours of 10pm and 5.30am. This reduced energy consumption and, in turn, decreased overall energy bills for the county.[374] In addition, broken and faulty lights can be automatically reported via a remote control system, so enabling a quicker and more efficient reparation of street lights. This ensures the provision of consistent and reliable lighting for residents.

Liability and benefits for the street lights has been transferred from the authority to Skanska for the duration of the contract. The PPP led by Skanska received a construction and operations contract worth a total of £83 million over a 25-year period.[375] This project will lead to environmental savings of 60,000 tonnes of carbon and 150 million kilowatt hours of electricity over the 25-year contract, with a potential saving of £12 million to the taxpayer during the life of the contract.[376] Other measures have been approved in 2016 to underpin the smart lighting project. In October 2016, Surrey County Council approved an energy-efficiency bid that switches off more than 40,000 street lights overnight in residential areas, reducing energy costs and environmental impact. This measure could help the council to save around £210,000 per annum.[377]

APPENDIX – ANALYTICAL METHODOLOGY

Investment theme identification

The investment themes have been identified based on the analytical work in the 2015 *Growth Within* report. Taking this work as a starting point, a detailed overview of all changes required within each of the three systems (mobility, food, and built environment) was created. Based on this, a mapping process was carried out to determine which of these changes are already happening and are likely to grow sufficiently fast ('current developments'), which are not yet taking off but will require modest intervention to do so ('next-wave circular economy investments'), and which ones will take at least five to ten years to take off ('CE transition accelerated').

This assessment was tested by experts, including the project's steering committee, in order to arrive at a final list of key changes in the next-wave circular economy investments. These were subsequently formulated in terms of investments required and mapped into main themes. Through this process, the ten themes in the report were established. Figure 26 below shows the example of this mapping method for the *mobility* system:

FIGURE 26 **MOBILITY - IDENTIFIED INVESTMENT THEMES**
Investment feasibility

TRENDS IDENTIFIED IN *GROWTH WITHIN*	CURRENT DEVELOPMENTS	NEXT-WAVE CIRCULAR ECONOMY	CIRCULAR ECONOMY TRANSITION ACCELERATED
System-level integration of transport modes	Pilot projects integrating electric vehicles (EV) with public transport	**Integrate clean urban transport modes:** public transport, electric shared cars, shared bicycles, and others	Creation of an urban mobility system fully open to all existing car sharing businesses, including provision of access to infrastructure across the EU Large urban mobility infra-structure upgrades across the EU
Sharing	Continued investment in car sharing companies	**Circular car design and production facilities** for EVs produced for sharing while also optimising for either autonomous driving or high-value lightweight materials	New car design and production facilities, fully integrating all design requirements for circular economy transition EU open automotive materials database to enable assessing properties and likely conditions of parts/material
Electrification	Car manufacturers continue to invest in EV development		
Autonomous driving	Continued investments to advance R&D to design autonomous cars; commercial production facilities limited before 2020		
Materials evolution & remanufacturing	Investments into upgrading/new recycling production facilities Investments in remanufacturing facilities post-2020	**Remanufacturing** ramp-up to close the loop for car parts	Recycling/ remanufacturing capacity ramp-up empowered by blockchain of Internet of Things tracking system and digital market places for materials

Source: SYSTEMIQ.

APPENDIX

Determining the barriers and solutions to each of the investment themes was achieved by interviewing 50+ experts across the ten themes, with some experts being interviewed multiple times, as well as through desktop research. This resulted in detailed descriptions of each theme.

Investment sizing

The main quantitative analysis carried out for this project was to size the total investment potential until 2025 in the EU across the ten identified investment themes across the 'current developments' and 'next-wave circular economy' scenarios. The basis for this analysis was the analytical work done for the *Growth Within* report. This work identified one scenario that follows current developments as assumed across all potential circular levers as well as one that would lead the EU towards a fully circular economy by 2050, with detailed quantification of the penetration rates of all the changes required across the three systems during the intermediate years. As the Growth Within report looked at a relatively long time horizon until 2050, in specific cases the short term penetration rates until 2025 were refined for individual opportunities. Specifically, the penetration rates for the 'current developments' scenario were reduced for those levers that were considered to not to take off in a significant way over the next years in that scenario. For example, investments in car part remanufacturing facilities or production of new protein sources were considered to be <€1 billion and therefore not included in the 'current developments' investments until 2025.

The resulting penetration rates were subsequently used as the main drivers for investments for this research. For example, the rollout of shared electric vehicles was used to calculate investments in the shared vehicle fleet. Often, additional assumptions had to be made to get to an investment driver that could be used for this purpose. This is in evidence in the *Growth Within* analyses which only provided the number of shared vehicles, whereas for this research the number of new car models was needed to assess investment in new car model R&D, as these investments are typically made for a new model. Therefore, an assumption had to be made about the average number of cars produced per car model, which then led to a quantification of new car models.
In addition to the investment drivers, an investment metric had to be identified for each opportunity. This was arrived at based on a combination of desktop research and expert interviews. For example, the cost of a new electric vehicle for sharing had to be determined in order to multiply it by the number of cars for sharing to arrive at a final investment number.

In order to establish what investment opportunities were included in each theme and, therefore, what was inside and outside of the analytical scope, a clear overview was created for each theme separately. Based on the sources and data found for those opportunities included in the scope, decisions were made whether these had to be each calculated separately or whether groupings of opportunities could be used to calculate the investment size.

The two figures below provide detailed information on what investment drivers were used based on the *Growth Within* work and what additional investment metric was used to arrive at an investment total, and how the investment scope was defined for each investment theme:

FIGURE 27 **Methodology for assessing size of investment opportunity in next-wave circular economy opportunities**

		Investment driver based on *Growth Within*	Assumption by 2025	Investment metric	Assumption by 2025	Source of investment metric
MOBILITY	**Integrating mobility systems**	• New electric vehicles (EV) in shared fleet	1.6 mln	• Cost of new EV for sharing	€25,000	• *Growth Within*
		• New EV charging stations	1.0 mln	• Cost of new EV charging station	€11,600	• Autolib charging station costs
		• Number of cities adopting multi-model transport	50 cities	• (Digital) infrastructure investment per city	€0.2 bn	• Similar investments, London, Stockholm, Copenhagen, last 5 years
		• Increase in public transport passenger km[1]	100 bn km	• Investment per passenger kilometre	€0.07	• EU transport booklet 2014
	Designing and producing circular cars	• Number of circular car models developed	10 models	• Development cost for complete new circular car model	€2.5 bn	• Expert interviews
		• Production capacity in number of cars per annum for new circular cars	0.5 mln	• Investment per car production per annum	€ 22,000	• Nissan Leaf and Tesla Gigafactory investments
	Remanufacturing car parts	• Growth in EU remanufacturing market size versus today[2]	€10 bn	• Investment growth versus market growth	10x	• Re-manufacturing Goods Overview of the US, US international trade commission 2012[3]
FOOD	**Deploying regenerative agricultural practices**	• Area of land in hectare converted to regenerative practices	30 mln	• Conversion cost per hectare	€600	• Expert interviews
		• Area of land in hectare using precision agriculture	7 mln	• Equipment cost per hectare	€100	• EC DG internal policies precision farming study 2013
	Closing nutrient loops	• Tonnes of waste processed through anaerobic digestion and biorefining	45 mln	• Investment in AD plants per tonne of waste	€240	• Green Investment Bank AD report, 2015
				• Investment in new bio-refining plants per tonne of waste	€230	• Expert interviews
	Farming through indoor urban farms	• Area of fruit and vegetables production from indoor urban farms (square metre)	11 mln	• Investment in new indoor urban farms per square meter of fruit and vegetable production	€3,750	• Aerofarms • Gotham Greens • Macrothink vertical farm economic analysis
	Developing next-wave protein sources	• Tonnes of next-wave protein sources production	1.5 mln	• Investment per tonne of protein (using insect-based as a proxy)	€1,500	• Expert interviews • Innovafeed
BUILT ENVIRONMENT	**Designing and producing circular buildings**	• New circular buildings production capacity (no. buildings p.a.)	0.8 mln	• Investment per building production capacity	€17,000	• Laing O' Rourke and L&G modular building plants
				• Development cost per new building	€300	• Eurostat
		• Number of new circular buildings produced	4 mln	• Investment per building to make energy positive	€23,000	• Fraunhofer Institute for Buildings
	Closing buildings loops	• Tonnes of additional building material re-used	20 mln	• Investment per tonne of recycling capacity	€80	• Material recycling plant investment examples and research by Technical University of Lisbon on C&D plants[3]
	Developing circular cities	• Number of cities adopting green urban planning	30 cities	• Additional cost per average city transitioning to green urban planning	€650 mln	• The state of the city climate finance, CCFLA, 2015. (low end of range used)

1 Assumed to represent investments in public transport upgrades across all modes, as well as shift to cleaner modes such as electric buses.
2 Estimated based on data external from *'Growth Within'*.
3 Triangulated with individual case examples, most notable GE train remanufacturing plant investment and C&D recycling plant investment in Dane County, WI, US.
Source: SYSTEMIQ.

APPENDIX

FIGURE 28 **NEXT-WAVE CE INVESTMENT OPPORTUNITY SIZING SCOPING**

		WHAT INVESTMENTS ARE ASSUMED TO BE INCLUDED?	WHAT INVESTMENTS ARE NOT INCLUDED?
MOBILITY	**Integrating mobility systems**	• Shared (electric) vehicles for modal integration, including parking and charging infrastructure • Public transport infrastructure upgrades and shift to clean public transport modes • Transport optimisation hardware, software; consumer app and payment system	
	Designing and producing circular cars	• End-to-end R&D for new car models, including material tracking system • Production facilities investments (for components production and assembly) for zero-emission cars made of durable material and suitable for disassembl	• Production facilities outside of the EU
	Remanufacturing car parts	• Remanufacturing facilities for all possible car parts	• Infrastructure for car part disassembly, collection, and transport
FOOD	**Deploying regenerative agricultural practices**	• New equipment and machinery required for transition to regenerative practices • Precision agricultural equipment	• Land purchase
	Closing nutrient loops	• New anaerobic digestion and biorefinery infrastructure	• Organic waste separation, collection and transportation infrastructure • Anaerobic digestion and biorefinery R&D
	Farming through indoor urban farms	• Building to house indoor farms • Cost to set up new high-tech vertical indoor farms	• Produce transportation • Technology providers
	Developing next-wave protein sources	• R&D for new technology • New protein production facilities from insects, bacteria, seaweed micro-algea and vegetables	
BUILT ENVIRONMENT	**Designing and producing circular buildings**	• R&D for new design, including material tracking systems • New production facilities for modular, pre-fab residential buildings using durable, renewable materials • Additional cost to construct energy-positive buildings	• Rolling out material tracking system
	Closing buildings loops	• Building materials recycling/remanufacturing facilities for main building materials (wood, concrete, metal, glass)	• Building deconstruction • Waste material collection and transportation
	Developing circular cities	• Additional cost to create green district;, e.g. grey water systems, energy-efficient lighting, combined heat and power	

Not included across all opportunities are (consumer) awareness and capacity/skill building programs; marketing costs; operations and maintenance capex; supply chain investments linked to direct investment opportunity

Source: SYSTEMIQ.

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163 Alley cropping means that cereals, pulses, and oilseeds are grown in rotation, and that rows of trees are planted on the same land. By mixing annual and perennial plants, a regenerative ecosystem is created. The root systems work at different levels in the soil and improve water and nutrient retention: 'Agroforestry systems are defined as land use systems in which trees are grown in combination with agriculture on the same land.' (EU: Article 23 of the New Rural Development Regulation, 1305/201). 'Agroforestry is the intentional growing of trees and shrubs in combination with crops or forage. Agroforestry also includes tree and shrub plantings on the farm or ranch that improve habitat value or access by humans and wildlife, or that provide woody plant products in addition to agricultural crops or forage. Agroforestry is distinguished from traditional forestry by having the additional aspect of a closely associated agricultural or forage crop.' Source: US Department of Agriculture (USDA)

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165 Volterra Ecosystems also intends to include in management plans (depending on each area's possibilities): mushroom production, regulated hunting, beekeeping, eco-tourism and education (local farm visits), regional products and farm shops, and other activities. Volterra Ecosystems: http://www.volterra.bio

166 Initiatives implemented by Volterra Ecosystems in Spain; by Luis Ballesteros (Spain) within the LIFE Crops for Better Soil project (organic chick peas and durum wheat in 70 hectares of rain-fed land with crop rotation and soil decompaction); by Jack de Lozzo (Le Chalet, France) for agroforestry systems; by Natuurboeren (the Netherlands) grazing systems, organic meat, and dairy; by Natuurakkers (the Netherlands) cereals, legumes, and vegetables

167 Holistic-planned grazing for beef cattle and sheep; no-till cropping with diverse cover crops and mob grazing; low input pasture-based dairy; certified organic agriculture; and agroforestry. Ibid, *The Investment Case for Ecological Farming*, 2016, p18

168 For example, for shifts to holistic-planned grazing

169 'The traditional silvopasture systems in Spain and Portugal are hardly profitable nowadays; they depend on EU subsidies to overcome the losses. If the land and the animals are managed through smart planning of the grazing, and regeneration of soils and permanent plants is monitored, we think these ecosystems can become profitable without EU subsidies.' Source: Volterra Ecosystems

170 'Agroforestry systems are defined as land use systems in which trees are grown in combination with agriculture on the same land.' Source: EU: Article 23 of the New Rural Development Regulation 1305/201. 'Agroforestry is the intentional growing of trees and shrubs in combination with crops or forage. Agroforestry also includes tree and shrub plantings on the farm or ranch that improve habitat value or access by humans and wildlife, or that provide woody plant products in addition to agricultural crops or forage. Agroforestry is distinguished from traditional forestry by having the additional aspect of a closely associated agricultural or forage crop.' Source: USDA

171 One way to achieve this is by setting up think tanks to develop innovative technologies and tools to be leveraged across the EU (for example, robotics) involving farmers and experts from research and innovation institutes

172 EU Press Release: 'Circular economy: New Regulation to boost the use of organic and waste-based fertilisers', 17 March 2016, http://europa.eu/rapid/press-release_IP-16-827_en.htm

173 For example, further leveraging the Common Agricultural Policy (CAP) could involve the following:

- Adopt a precise definition of regenerative practices at the EU level, including the description of first-step practices and second-step practices;
- Define which CAP pillar applies for each first-step and second-step regenerative practice;
- Define the criteria to be used for the allocation of each subsidy. These criteria could be a combination of Key Performance Indicators (KPIs), that would be measured to assess whethe obligation of results is met, and of agricultural practices, that would be observed to assess whether obligation of means is met. A relevant KPI could be soil organic carbon stock, as it is easily measurable and a key attribute in assessing soil health, generally correlating positively with crop yield (Bennett *et al*., 2010), and interacts with chemical, physical, and biological soil properties, such as the storage of nutrients, water holding capacity, stability of aggregates, and microbial activity. A systemic approach based on various indicators covering physical, chemical, and biological soil properties could also be relevant. In all cases, attention must be paid to create systems that do not require excessive administration and control;
- To fulfil the CAP's obligation to provide guidance on supported practices, partnerships could be set up with cooperative/not-for-profit training bodies deploying capability-building and awareness programs delivered by farmers for farmers;

174 For example, public capital is mobilised under the framework of the Lima–Paris Action Agenda, which is a joint undertaking of the Peruvian and French Conference of Parties (COP) Presidencies, the Executive Office of the Secretary-General of the United Nations and the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat

175 Examples in the UK poultry sector show how the retail industry can ban practices due to benefits to its customers. See for example: https://corporate.marksandspencer.com/documents/reports-results-and-publications/casestudy.pdf

176 For example, highly predictive decision support tools, such as Cibo's dashboards, could provide retailers with accurate estimates of the benefits they could achieve if the farms provisioning their suppliers were implementing regenerative practices. These decisions support tools could be implemented very swiftly, as they rely primarily on satellite imagery. Driving a collaborative effort to shift their extended supply chain to regenerative practices could be beneficial to retailers in many ways. Increased profit could be achieved (driven by increased yield and improved resource-efficiency) while the risk of lower returns in the transition period could be mitigated through coordinated rollout waves. Not to mention that environmental benefits and improvement in food quality could lead to price premiums, greater market shares, and increased customer loyalty. Data on regenerative agriculture sourcing could be made publicly available to increase product reach and customer loyalty even further.

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182 Ibid, 'Post-organic', Wired, 2013

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185 Ibid, *Growth Within*, 2015

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194 For example, see the Danish Business Authority bio-refining pilot

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244 Complete proteins sources are defined as protein sources that provide a good balance of the amino acids matching the body's needs. While animal proteins tend to contain a good balance of all the amino acids that we need, some plant proteins are low in certain amino acids

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251 Europe imports 70% of the proteins (16.3mt) that are consumed directly or indirectly via animal feed. ABAgri Associated British Agriculture, *Alternative Proteins Market Study*, 2013

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254 Lab-grown meat for direct human consumption was not included in the focus of the theme as it was considered to be less likely to be scaled in Europe in the next ten years due to the consumer acceptance barrier and because developments towards cost-effective mass production are less advanced. Insect-based food for direct human consumption was not included as it was considered to be less likely to be scaled in Europe in the next ten years due to the consumer acceptance barrier and legislative barriers that will likely require proven traceability across the human food supply chain, as well as the need for further research on potential health impacts. However, outside the EU, companies such as Eat Grub and Entotech are already selling edible insects. Insects could also be leveraged directly by farmers/households, for example feeding larvae with farm waste and then feeding them to farm animals (pigs and chicken). The world's first desktop hive for edible insects for consumers is expected to be launched in 2016. Livin farms.com: http://www.livinfarms.com/

255 Valuable by-products from the production of next-wave protein sources have been identified, such as high-value molecules with antimicrobial properties for insects; clean water from food and beverage waste streams for bacteria; triglyceride oils and ingredients for microalgae that can be used as the foundation for industrial products and fuels as well as foods. Ibid, *Food Futures: from business as usual to business unusual*

256 Next-wave protein sources could be produced in Europe, which would reduce dependency on foreign high-protein sources and improve Europe's commercial balance

257 This is partly due to the greater share of edible bodyweight, for example up to 80% of insects' bodyweight is edible and digestible, compared to 55% for chicken and 40% for cattle

258 For business models based on the use of agricultural bio-products/waste, not business models based on the use of organic waste

259 This is not clinically proven yet, just observed. A project is being driven by PROteINSECT, notably to determine the optimal design of insect-based animal feed production systems utilising the results of a comprehensive life cycle analysis. PROteINSECT: http://www.proteinsect.eu/

260 This is not clinically proven yet, just observed. A project is being driven by PROteINSECT, notably to determine the optimal design of insect-based animal feed production systems utilising the results of a comprehensive life cycle analysis. PROteINSECT: http://www.proteinsect.eu/

261 Pimentel and Pimentel (2003) calculated that for 1kg of high-quality animal protein, livestock are fed about 6kg of plant protein. Feed-to-meat conversion rates (how much feed is needed to produce a 1kg increase in weight) vary widely depending on the class of the animal and the production practices used. Typically, 1kg of live animal weight in a US production system requires the following amount of feed: 2.5kg for chicken, 5kg for pork, and 10kg for beef (Smil, 2002). Insects require far less feed. For example, the production of 1kg of live animal weight of crickets requires as little as 1.7kg of feed (Collavo *et al*., 2005). When these figures are adjusted for edible weight (usually the entire animal cannot be eaten), the advantage of eating insects becomes even greater (van Huis, 2013). Nakagaki and DeFoliart (1991) estimated that up to 80% of a cricket is edible and digestible compared with 55% for chicken and pigs, and 40% for cattle. This means that crickets are twice as efficient in converting feed to meat as chicken, at least four times more efficient than pigs, and 12 times more efficient than cattle. Food Agriculture Organization of the United Nations, 'Environmental Opportunities for Insect Rearing for Food and Feed' in *Edible Insects: Future Prospects for Food and Feed Security*, 2013, http://www.fao.org/docrep/018/i3253e/i3253e05.pdf

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328 Ibid, *Delivering the Circular Economy: A toolkit for a policymakers*, 2015

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