ELLEN MACARTHUR FOUNDATION

V1.1

DELIVERING THE CIRCULAR ECONOMY
A TOOLKIT FOR POLICYMAKERS

FOREWORD

Flemming Besenbacher
Chairman of the Supervisory Board of Carlsberg A/S

How can we create prosperity for a growing world population while strengthening the systems that support us? How can we achieve continued economic development while preserving the resource base that is fuelling this economy? The growing interest around these questions suggests it is time to rethink the way we operate. The circular economy holds the promise of reconciling these seemingly opposing objectives and creating long-term value. It is my firm belief that the 'take-make-waste' economy is about to be replaced by a circular, restorative approach where we no longer consider anything to be 'waste'.

The circular economy is of particular interest to Carlsberg because our products depend on well-functioning natural systems and a stable supply of raw materials. We are working in this area through our partnership platform – the Carlsberg Circular Community – to develop innovations and practical solutions optimised for the circular economy.

This toolkit represents a valuable blueprint for policymakers who want to stimulate the progression from a linear to a circular economy. It rightfully positions the circular economy as a unique opportunity for dialogue and collaboration between private and public entities to achieve the common goal of long-term value creation.

I therefore encourage governments across the world to apply this toolkit and work closely with businesses to unleash the circular economy in their country and unlock its true potential. I also urge companies to continue to lead the way to a more resilient operating model, decoupled from resource constraints. Carlsberg is determined to do so.

FLEMMING BESENBACHER
JUNE 2015

"**There is a new movement within cities, regions and governments to accelerate the move towards a circular economy.** This toolkit is a key resource for policymakers to enable them to get to grips with the complexity of this emerging area and develop route maps that will help the transition from linear to circular."

Wayne Hubbard
Chief Operating Officer
LONDON WASTE AND RECYCLING BOARD (LWARB)

"The methodology and insight provided in this toolkit will be invaluable to help mobilise stakeholders in Northern France to develop a shared circular economy strategy. **Most importantly, it provides structure to go beyond a 'nice idea' and move towards implementation**."

Christian Traisnel
Director
CD2E RESPONSIBLE FOR DEVELOPING THE CIRCULAR ECONOMY IN NORTHERN FRANCE

"**This inspiring report is very helpful to us** – I am sure we will apply some of the tools and insights from the Denmark pilot in our program to accelerate the transition to a circular economy."

Kees Veerman
Policy Coordinator
DUTCH MINISTRY OF INFRASTRUCTURE AND THE ENVIRONMENT

"This report provides **a useful methodology that will help move all stakeholders involved** in a circular economy transition **into action.**"

Pere Torres Grau
Secretary for Business and Competitiveness
MINISTRY FOR BUSINESS AND LABOUR, GOVERNMENT OF CATALONIA

"**A well-structured guide to practical policy development** for transitioning to a circular economy."

Steve Creed
Director Business Growth
WRAP

"**We are delighted that this report is dedicated to the role of policymakers in the circular economy.** We would like to, together with businesses and knowledge institutes, contribute to the transition to a circular economy."

John Nederstigt
Deputy Mayor
HAARLEMMERMEER

"The Ellen MacArthur Foundation has once again shown **the way forward in how to move to a circular economy.** This toolkit is an excellent starting point for policymakers."

Caroline Ankarcrona
Project Manager for "Resource efficient business models – increased competitiveness"
ROYAL SWEDISH ACADEMY OF ENGINEERING SCIENCES (IVA)

"This report, exploring the policy tools to help deliver a circular economy, provides lots of food for thought. **Creating a circular economy is an economic, environmental and moral necessity –** it will create jobs in our communities, improve quality of life, and just makes good sense. As the Scottish Government prepares to publish its own circular economy strategy, we are proud to be working with international partners such as the Ellen MacArthur Foundation and the Danish Government towards a more circular economy."

Richard Lochhead
Member of Scottish Parliament,
CABINET SECRETARY FOR RURAL AFFAIRS, FOOD AND ENVIRONMENT

"**This toolkit is a much needed and relevant aid to policymakers globally to assist them in the transition towards a circular economy.** The pilot has been very helpful for Denmark by clearly outlining effective options for Danish policymakers to accelerate the shift towards a circular economy."

Ida Auken
Member of the World Economic Forum Meta-Council
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"Pinpointing economic opportunities through the combination of company-level analysis, macro-economic modelling and barrier assessment provides **a very powerful starting point for our future work on the circular economy.**"

Anders Hoffmann
Deputy Director General
DANISH BUSINESS AUTHORITY

"This project has been a fruitful experience for us. **The systematic approach offered by the toolkit has given us valuable new insights** into the potential of, and barriers to, further transitioning towards a circular economy."

Claus Torp
Deputy Director General
DANISH ENVIRONMENTAL PROTECTION AGENCY

"**The toolkit offers additional evidence on the circular economy opportunity and provides an important key to help the EBRD to focus on investments increasing resilience and competitiveness** in the Bank's region. It provides us with pragmatic arguments and case studies to use in our engagement with commercial clients and governments."

Dr. Nigel Jollands
Senior Policy Manager
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DISCLAIMER

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This report describes a methodology for circular economy policymaking. It also explores a range of policy options that Denmark – the country of the report's pilot study – could choose to pursue. The report does not recommend any specific policy intervention to Denmark or to any other country.

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EXECUTIVE SUMMARY

Business leaders and governments alike are acknowledging that continued long-term value creation requires a new economic model that is less dependent on cheap, easily accessible materials and energy, and that is able to restore and regenerate natural capital. In its research to date, the Ellen MacArthur Foundation has demonstrated that the circular economy is a clear value creation opportunity. As many policymakers become interested in this promising model, they envisage the important role they can play in creating the right enabling conditions and, as appropriate, setting direction to unlock it. This report looks at the circular economy opportunity from a country and policymaker perspective, and aims to provide policymakers with an actionable toolkit to help accelerate the transition towards the circular economy.

Delivering the circular economy – a toolkit for policymakers is the result of a collaboration led by the Ellen MacArthur Foundation, with the Danish Business Authority and the Danish Environmental Protection Agency as key contributors, especially in the Denmark pilot phase. The toolkit was developed in cooperation with Danish and international stakeholders, including leading policymakers, businesses and academics. The McKinsey Center for Business and Environment ("MCBE") provided analytical support. NERA Economic Consulting provided support for the macroeconomic and policy analysis for Parts 2 and 3 of this report. The MAVA Foundation funded the project.

Eight key insights emerged from developing the toolkit and testing it in the Denmark pilot:

1

A transition towards the circular economy can bring about the lasting benefits of a more innovative, resilient and productive economy. Modelling conducted in this study suggests that it could lead, in Denmark, to 0.8–1.4% additional GDP growth, the creation of 7,000–13,000 job equivalents, 3–7% reduction in carbon footprint, and 5–50% reduction in virgin resource consumption for selected materials.

These estimates are for 2035 and only consider producing sectors and hospitals, covering 25% of the Danish economy. They do not take into account a further shift towards renewable energy. While such estimates rely by necessity on a number of assumptions and are associated with uncertainty, they confirm the findings from a growing body of research that the impact of a transition to the circular economy on economic growth, job creation and the environment is likely to be positive.

2

Many circular economy opportunities have a sound underlying profitability, but there are often non-financial barriers limiting further scale-up or holding back development pace. Policymakers can play an important role in helping businesses overcome these barriers.

Barriers include unintended consequences of existing regulations (e.g. definitions of waste that hinder trade and transport of products for remanufacturing), social factors such as a lack of experience among companies and policymakers to detect and capture circular economy opportunities, and market failures such as imperfect information (e.g. for businesses to repair, disassemble and remanufacture products) and unaccounted externalities (e.g. carbon emissions). In addition to creating enabling conditions, policymakers can, as appropriate, set direction for a transition to the circular economy.

3

Sector-by-sector analysis can be a valuable approach to address the variety of opportunities and challenges involved in transitioning towards the circular economy. Within each sector, effective circular economy policymaking requires the combination of many policy interventions, and does not rely on a 'silver bullet' or blanket solutions.

Policymakers can address market and regulatory failures to create the right enabling conditions for circular economy initiatives to reach scale. They can also more actively steer and stimulate market activity by setting targets, implementing circular and total cost of ownership-oriented public procurement, and investing in innovative pilots and R&D.

4

Broader changes to the existing fiscal system and the measurement of economic performance could help enable a systemic transition towards the circular economy.

While many circular economy opportunities already have a sound underlying profitability, a number of international organisations, such as the European Commission, the OECD, the International Monetary Fund (IMF), and the International Labour Organization, have suggested further opportunities could be unlocked by shifting fiscal incentives towards labour from resources. However, any such shift is a sensitive matter and needs to be seen in the light of international competitiveness, administrative issues, tax revenue stability and distributional effects. Complementing today's flow-based metrics such as GDP as a measure of economic success with measures of a country's stock of assets could be an instrument for policymakers to account for the restoration and regeneration of natural capital.

5

Industry involvement and cross-government department collaboration are crucial. As the Denmark pilot has shown, involving businesses intensively throughout the process is especially important, for three reasons: (i) get insights and knowledge to identify the most relevant circular economy opportunities and barriers in each focus sector; (ii) create early alignment on common direction for the country and the focus sectors; (iii) further demonstrate circular economy benefits to businesses and build skills as well as capacity.

As businesses are already starting the transition, the circular economy offers an opportunity for policymakers to collaborate with businesses. Furthermore, there is a need for cooperation between different government departments (including business/industry, finance and environment) so that no new unintended policy barriers are created and – like the business solution – the policy response is designed to maximise system effectiveness. Other society stakeholders, including citizens and consumers, labour unions and environmental organisations, should also be engaged.

6

Even in a country with a starting position as advanced as Denmark, there are significant opportunities to scale up the transition towards the circular economy, and policymakers can play an important enabling role. Opportunities were investigated in five focus sectors, and the economic potential appears to be the largest in Construction & Real Estate and in Food & Beverage.

In Construction & Real Estate, building sharing, switching from low-value recycling to reuse and high-value recycling, and industrial production and 3D printing of building modules could unlock significant value. In Food & Beverage, maximising value from organic by-products and waste streams through cascaded value extraction in bio-refineries could be an important opportunity. The potential identified in Denmark could, with the right enabling conditions and direction, mostly be captured within the next 20 years.

7

In European Union member states, EU-level policy interventions would need to complement national policies, as the value chains of many products extend across borders.

Product policy and promoting the market for secondary raw materials are just two examples that could be coordinated at the European level so as to simplify and reduce the cost of doing (circular) business.

8

The outcomes of applying this toolkit will differ for each country depending on economic and policy starting positions. The process to get to these answers will be similar, with adaptations to local circumstances.

In a first assessment, three factors seem to be the most likely to influence the process itself: (i) level of circularity already achieved and support for circularity; (ii) institutional set-up; and (iii) available resources. While more basic starting positions allow a country to leapfrog to high-performing circular systems, strong starting points provide confidence that circular economy is a viable option to create economic value, and allow a country to move from strength to strength.

These insights are further elaborated in the upcoming sections of this report, which is structured as follows. Part 1 introduces the core concepts of the circular economy and discusses the role of policy within that framework. Part 2 lays out a how-to guide for policymakers who want to design a strategy to accelerate the transition towards the circular economy. Part 3 covers the core findings of the pilot study in Denmark.

READER'S GUIDE

This report is structured in three parts:

Part 1. Why the circular economy matters
This part introduces the core concepts of the circular economy, which provides a positive and viable alternative to the linear 'take, make, dispose' economic model that is pervasive at global scale. It discusses how the circular economy might contribute to important policy objectives such as generating economic growth, creating jobs, reducing virgin resource consumption, and reducing carbon emissions, and why it is important for countries to consider transitioning to the circular economy now. There is also a discussion of the potential role of policymakers in the circular economy, and an overview of selected previous work on circular economy policy.

Part 2. Methodology for policymakers to accelerate the transition
This part is a how-to guide for policymakers who want to design a strategy to accelerate the transition towards the circular economy. It offers a detailed step-by-step methodology to explore and prioritise circular economy opportunities; quantify their impact; identify the barriers limiting these opportunities; and map and prioritise the policy interventions to overcome these barriers. There is also a discussion of when and how to engage relevant stakeholders, and a final section for policymakers considering how to tailor this methodology to their specific circumstances.

Part 3. Case study – Denmark
This part covers the core findings of a pilot study in Denmark. The pilot study was undertaken in order to make this toolkit as concrete and actionable as possible. This part explores circular economy opportunities, barriers and potential policy options for five focus sectors. The findings may be of interest to Danish stakeholders. While they cannot be directly transposed to other countries, they might serve as a source of inspiration for the identification of opportunities, barriers and policy options.

WHY THE CIRCULAR ECONOMY MATTERS

1 WHY THE CIRCULAR ECONOMY MATTERS

The linear 'take, make, dispose' economic model relies on large quantities of cheap, easily accessible materials and energy and is reaching its physical limits. The circular economy is an attractive and viable alternative that businesses are already exploring today.

The circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption. It enables key policy objectives such as generating economic growth, creating jobs, and reducing environmental impacts, including carbon emissions.

A favourable alignment of factors makes the transition possible. Resource-related challenges to businesses and economies are mounting. An unprecedented favourable alignment of technological and social factors enables the transition to the circular economy.

As many circular economy opportunities have a sound underlying profitability, businesses are driving the shift towards the circular economy. Yet there are often non-financial barriers limiting further scale-up or holding back pace. Policymakers therefore can play an important role to help overcome these barriers and to create the right enabling conditions and, as appropriate, set direction for a transition to the circular economy. This toolkit aims to complement existing literature by offering policymakers an actionable step-by-step methodology to design a strategy to accelerate the transition towards the circular economy.

1.1 From linear to circular – Accelerating a proven concept

CIRCULAR ECONOMY – AN INDUSTRIAL SYSTEM THAT IS RESTORATIVE AND REGENERATIVE BY DESIGN

The linear 'take, make, dispose' model, the dominant economic model of our time, relies on large quantities of easily accessible resources and energy, and as such is increasingly unfit for the reality in which it operates. Working towards efficiency – a reduction of resources and fossil energy consumed per unit of economic output – will not alter the finite nature of their stocks but can only delay the inevitable. A deeper change of the operating system is necessary.

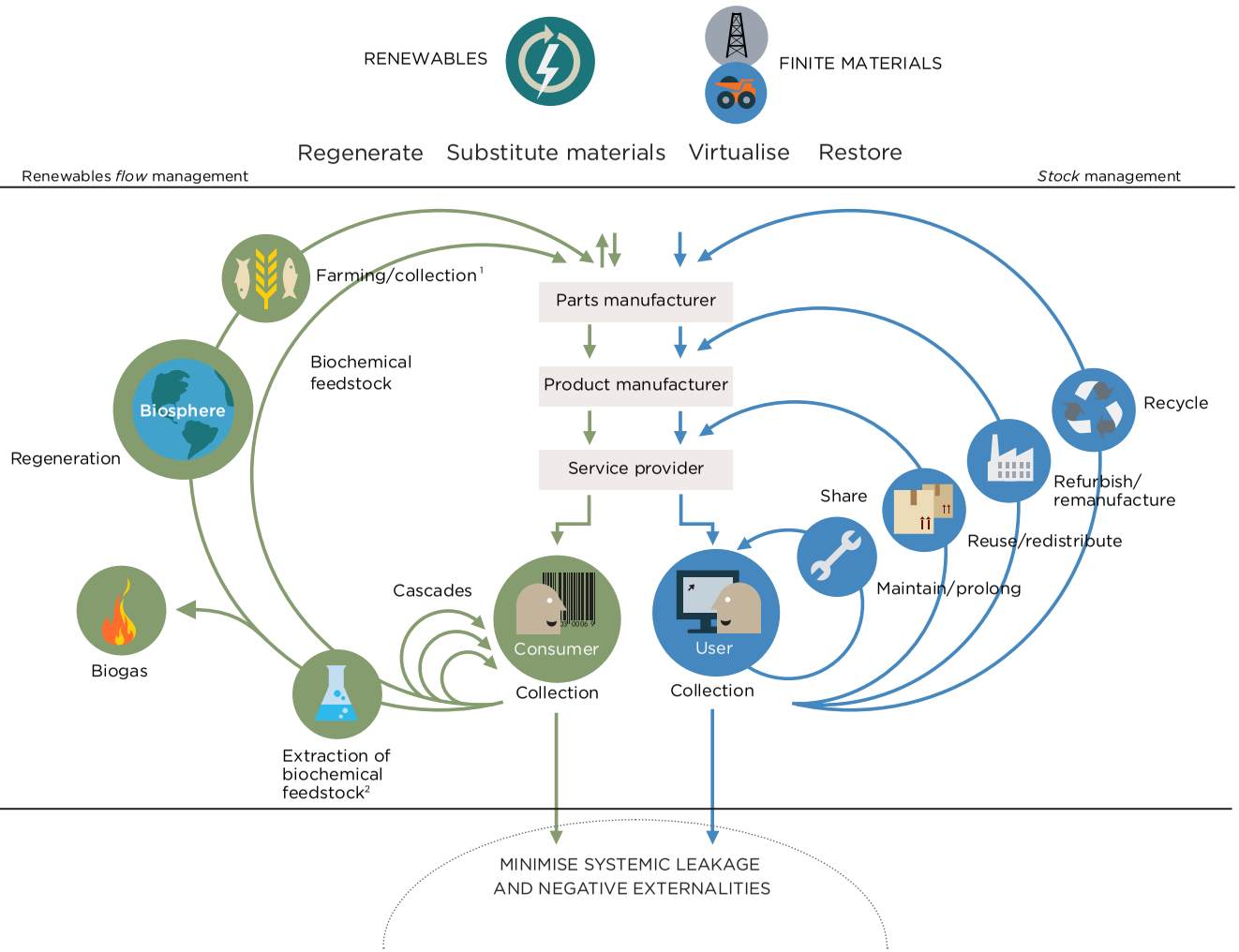
The notion of the circular economy has attracted attention in recent years. The concept is characterised, more than defined, as an economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. It is conceived as a continuous positive development cycle that preserves and enhances natural capital, optimises resource yields, and minimises system risks by managing finite stocks and renewable flows. It works effectively at every scale.

Figure 1: Circular economy – an industrial system that is restorative and regenerative by design

Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows
ReSOLVE levers: regenerate, virtualise, exchange

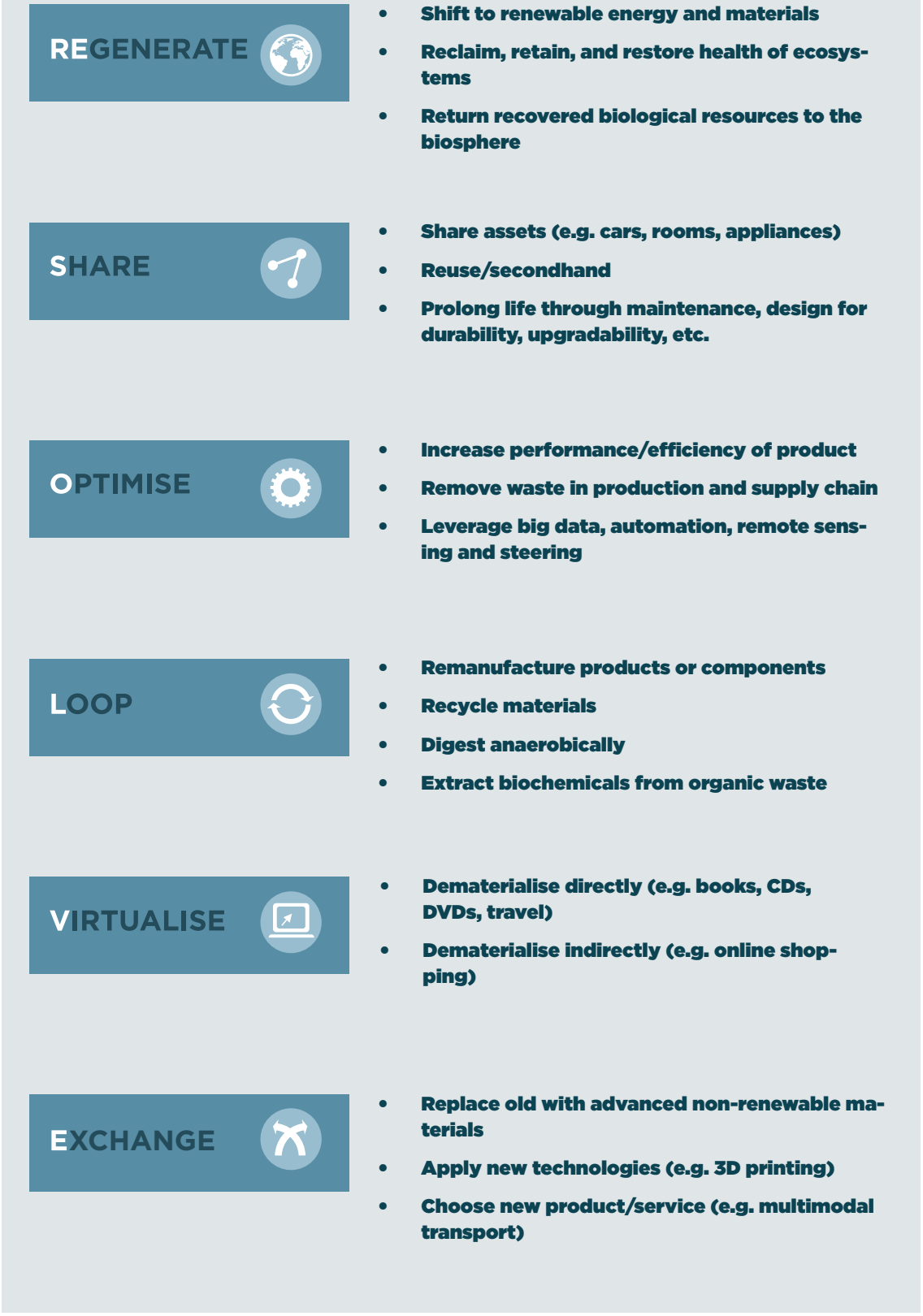
Optimise resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles
ReSOLVE levers: regenerate, share, optimise, loop

Foster system effectiveness by revealing and designing out negative externalities



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
SOURCE: Ellen MacArthur Foundation
Adapted from the Cradle to Cradle Design Protocol by Braungart & McDonough

Figure 2: The ReSOLVE framework: six action areas for businesses and countries wanting to move towards the circular economy



SOURCE: Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015). Based on S. Heck, M. Rogers, P. Carroll, Resource Revolution (2015).

The circular economy provides multiple value creation mechanisms that are decoupled from the consumption of finite resources. Consumption should in a true circular economy only happen in effective bio-cycles; elsewhere use replaces consumption. Resources are regenerated in the bio-cycle or recovered and restored in the technical cycle. In the bio-cycle, life processes regenerate disordered materials, despite or without human intervention. In the technical cycle, circular economy technologies and business models aim to maximise the value extracted from finite stocks of technical assets and materials, and thereby address much of the structural waste in industrial sectors. In the biological cycle, a circular economy encourages flows of biological nutrients to be managed so as not to exceed the carrying capacity of natural systems, and aims to enhance the stock of natural capital by creating the conditions for regeneration of, for example, soil.

In a diverse, vibrant, multi-scale system, restoration increases long-term resilience and innovation.[1] The systems emphasis in circular economy matters, as it can create a series of business and economic opportunities, while generating environmental and social benefits. The circular economy does not just reduce the systemic harm engendered by a linear economy; it creates a positive reinforcing development cycle.

The circular economy rests on three key principles, shown in Figure 1.

- **Preserve and enhance natural capital** by controlling finite stocks and balancing renewable resource flows—for example, replacing fossil fuels with renewable energy or using the maximum sustainable yield method to preserve fish stocks.

- **Optimise resource yields** by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles – for example, sharing or looping products and extending product lifetimes.

- **Foster system effectiveness** by revealing and designing out **negative externalities,** such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use.

These three principles of the circular economy can be translated into a set of six business actions: Regenerate, Share, Optimise, Loop, Virtualise, and Exchange – together, the ReSOLVE framework (see Figure 2).[2] For each action, there are examples of leading companies that are already implementing them.

Each of the six actions represents a major circular business opportunity which, enabled by the technology revolution, looks quite different from what it would have 15 years ago or what it would look like in a framework for growth in the linear economy. In different ways, these actions all increase the utilisation of physical assets, prolong their life, and shift resource use from finite to renewable sources. Each action reinforces and accelerates the performance of the other actions.

The ReSOLVE framework offers businesses and countries a tool for generating circular strategies and growth initiatives. Many global leaders have built their success on innovation in just one of these areas. Most industries already have profitable opportunities in each area.

A short description of these levers, and examples of businesses that are implementing them, follows below.

REgenerate. Shift to renewable energy and materials; reclaim, retain, and regenerate health of ecosystems and return recovered biological resources to the biosphere. Cumulative new investments in European renewable energy represented USD 650 billion

1 John Fullerton, Regenerative Capitalism: How Universal Principles and Patterns Will Shape Our New Economy (Capital Institute, 2015).

2 Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

over the 2004–13 period.[3] The Savory Institute has influenced the regeneration of more than 2.5 million hectares of lands worldwide.

Share. Keep product loop speed low and maximise utilisation of products, by sharing them among different users (peer-to-peer sharing of privately owned products or public sharing of a pool of products), by reusing them through their entire technical lifetime (second hand), and by prolonging their lifetime through maintenance, repair, and design for durability. BlaBlaCar is one famous car example growing at 200% per annum with 20 million registered users in 19 countries. BMW and Sixt's Drive Now offer by-the-minute rental of cars that can be collected and dropped anywhere in a city centre. Lyft matches passengers needing a lift with drivers of their own cars willing to provide one through a smartphone app. In housing, Airbnb has more than one million spaces listed in more than 34,000 cities across more than 190 countries.

Optimise. Increase performance/efficiency of a product; remove waste in production and supply chain (from sourcing and logistics, to production, use phase, end-of-use collection etc.); leverage big data, automation, remote sensing and steering. All these actions are implemented without changes to the actual product or technology. A well-known illustration of this lever is the lean philosophy made famous by Toyota.

Loop. Keep components and materials in closed loops and prioritise inner loops. For finite materials, it means remanufacturing products or components and recycling materials. Caterpillar, Michelin, Rolls Royce, Philips or Renault are just a few companies exploring this direction. For renewable materials, it means anaerobic digestion and extracting biochemicals from organic waste. The Plant is an example of closed loop, zero-waste food production located in Chicago.

Virtualise. Dematerialise resource use by delivering utility virtually: directly, e.g. books or music; or indirectly, e.g. online shopping, autonomous vehicles, virtual offices. Google, Apple, and most OEMs plan to release driverless cars on the market in the next decade.

Exchange. Replace old with advanced non-renewable materials, apply new technologies (e.g. 3D printing or electric engines) and choose new products/services (e.g. multimodal transport). For instance, in 2014 Chinese company WinSun 3D-printed ten houses, each about 195 square metres, in 24 hours.

BENEFITS OF THE CIRCULAR ECONOMY

The transition towards the circular economy can bring about the lasting benefits of a more innovative, resilient and productive economy. The principal benefits to moving to the circular economy are as follows:

- **Substantial net material savings and reduced exposure to price volatility:** based on detailed product-level modelling, the Ellen MacArthur Foundation has estimated that, in the medium-lived complex products industries, the circular economy represents net material cost savings at an EU level for an 'advanced' scenario of up to USD 630 billion annually; in fast-moving consumer goods (FCMG) at the global level net materials savings could reach USD 700 billion annually – see Figure 3.

- **Increased innovation and job creation potential:** circularity as a 'rethinking device' has proved to be a powerful new frame, capable of sparking creative solutions and stimulating innovation. The effects of a more circular industrial model on the structure and vitality of labour markets still need to be further explored, but initial evidence suggests that the impact will be positive (see below).

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3 Angus McCrone, *Global Trends in Renewable Energy Investment 2014* (Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance, the United Nations Environment Programme (UNEP) and Bloomberg New Energy Finance, 2014).

- **Increased resilience in living systems and in the economy:** land degradation costs an estimated USD 40 billion annually worldwide, without taking into account the hidden costs of increased fertiliser use, loss of biodiversity and loss of unique landscapes. Higher land productivity, less waste in the food value chain and the return of nutrients to the soil will enhance the value of land and soil as assets. The circular economy, by moving much more biological material through the anaerobic digestion or composting process and back into the soil, will reduce the need for replenishment with additional nutrients. This is the principle of regeneration at work.

The circular economy can be an important lever to achieve key policymaker objectives such as generating economic growth, creating jobs, and reducing environmental impact. Multiple studies have already demonstrated how the circular economy can contribute at a national, regional and supranational level to objectives such as generating economic growth, creating jobs, and reducing environmental impact. While using different methodologies and performed on different sectoral and geographical scopes, these studies have consistently demonstrated the positive impacts of the circular economy: growing GDP by 0.8–7%, adding 0.2–3.0% jobs, and reducing carbon emissions by 8–70% (see Figure 4 and Table 1).

Table 1: Selected literature on the macroeconomic impact of the circular economy

TNO – The Netherlands Organisation for Applied Scientific Research, *Opportunities for a Circular Economy in the Netherlands* (2013)[4]

This report analyses the opportunities and obstacles that will present themselves as the Netherlands moves towards a more circular economy and makes policy proposals to accelerate the process. It finds that the overall impact of the circular economy in the Netherlands is estimated at EUR 7.3 billion annually, creating 54,000 jobs. The current value of the circular economy for 17 product categories from the metal and electrical sectors is EUR 3.3 billion and that an additional market value of EUR 573 million per year could be achieved. The use of the 34 most important waste streams already represents a value of EUR 3.5 billion. An estimated investment of EUR 4–8 billion in new technologies could create added value of EUR 1 billion per year for the circular economy in the areas of bio-refining, biogas extraction and sorting household waste.

Club of Rome, *The Circular Economy and Benefits for Society: Swedish case study shows jobs and climate as clear winners* (2015)[5]

The central theme of this report is how greatly enhanced resource efficiency is a prerequisite for the global economy to stay within the planetary boundaries. It finds that, if applied in conjunction with efforts to increase energy efficiency and the use of renewable energy, organising manufacturing along the lines of a materially efficient circular/performance-based economy in Sweden would lead to an increase in employment of 100,000 (2–3% of the labour force), an improvement in the trade balance of >3% of GDP and a reduction in CO_2 emissions of 70%. Similar studies for the Netherlands and Spain are underway, but were not published in time to be included in this report.

Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015)

This report aims to contribute to the fact base for the discussion around the circular economy from a European perspective. The report paints a vision of what the circular economy could look like in three of the largest and most resource-intensive European value chains: mobility, food systems and the built environment. It compares its attractiveness with the current linear development path, and models European economic and environmental outcomes in both scenarios. The report finds that the circular economy could bring, by 2030, an increase in GDP by 6.7%, and a reduction in CO_2 emissions by 25%.

4 http://www.government.nl/documents-and-publications/reports/2013/10/04/opportunities-for-a-circular-economy-in-the-netherlands.html

5 www.clubofrome.org/cms/wp-content/uploads/2015/04/Final-version-Swedish-Study-13-04-15-till-tryck-ny.pdf

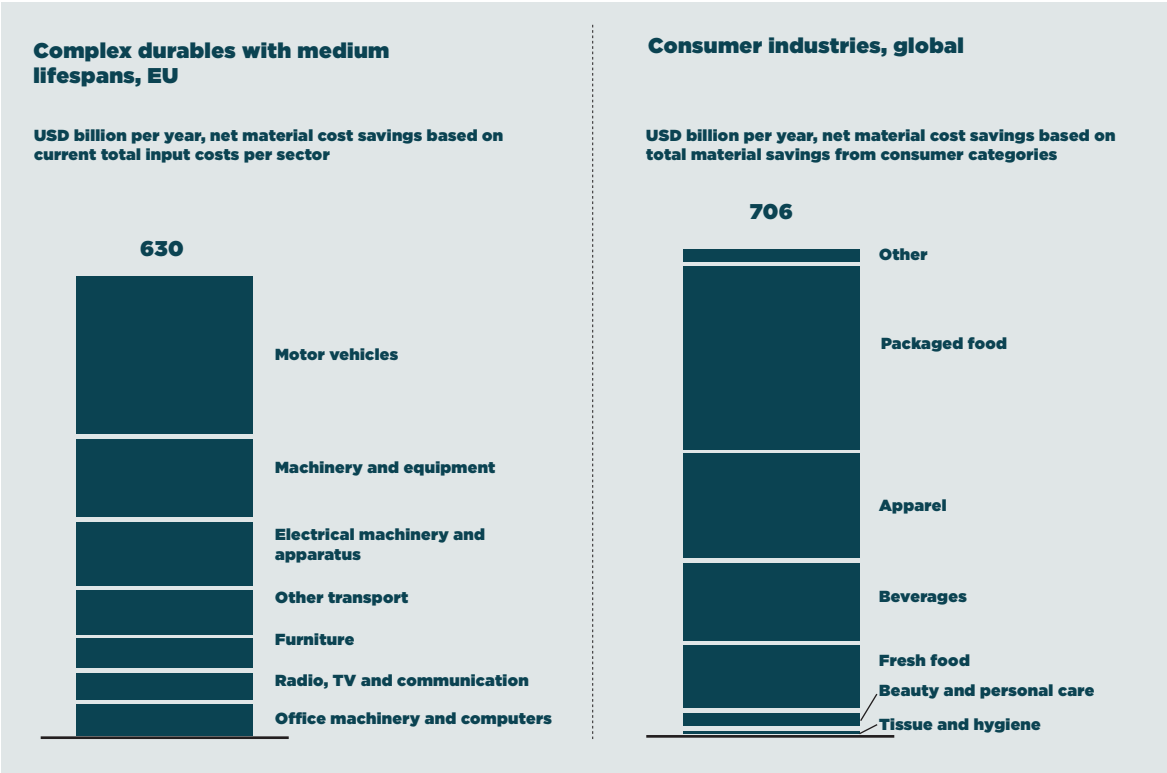
Cambridge Econometrics / Biointelligence Service / European Commission, *Study on modelling of the economic and environmental impacts of raw material consumption* (2014)

This technical report provides a quantitative analysis of different resource productivity targets for the EU using GDP per unit of raw material consumption. The targets range from 1–3% per annum improvement in resource productivity (cumulative 15–30% to 2030). The modelling results suggest that resource productivity improvements of around 2–2.5% per annum can have net positive impacts on EU28 GDP. They also show that with 2% per annum resource productivity improvement around two million additional jobs are created.

WRAP and Green Alliance, *Employment and the circular economy: Job creation in a more resource efficient Britain* (2015)[6]

This report looks at how to address the UK's economic challenges in its use of labour and scarce natural resources. It indicates that in the UK the circular economy could create ~200,000–500,000 gross jobs, reduce unemployment by ~50,000–100,000 and offset ~7–22% of the expected decline in skilled employment to 2022, depending on whether the development of the circular economy follows its current trajectory or takes a more transformative path.

Figure 3: The economic opportunity of the circular economy



NOTE: Rough estimates from advanced scenario
SOURCE: Towards the Circular Economy 1, 2 by the Ellen MacArthur Foundation

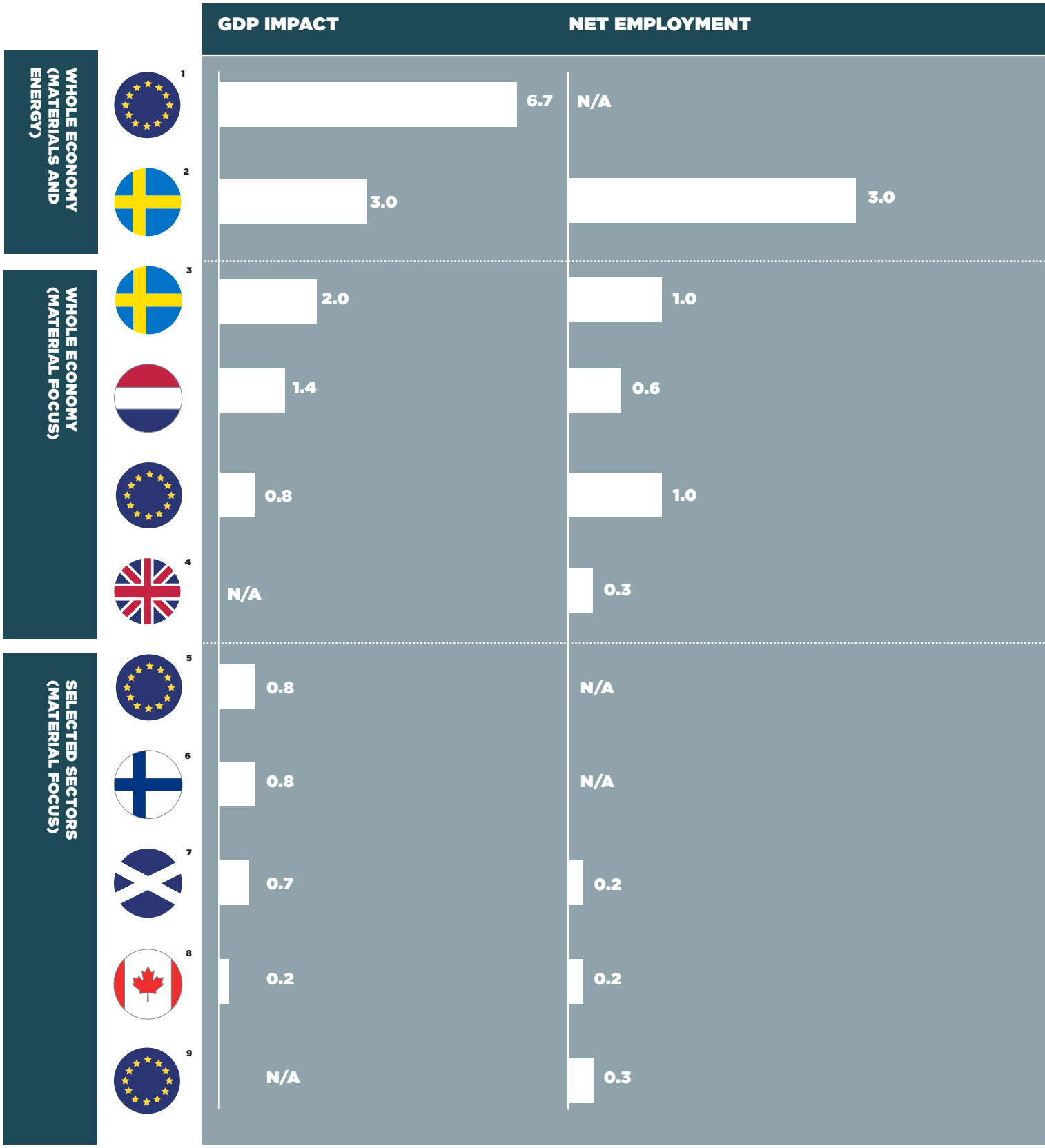
CIRCULAR ECONOMY LITERATURE

The circular economy concept has deep-rooted origins and cannot be traced back to one single date or author. Its practical applications to modern economic systems and industrial processes, however, have gained momentum since the late 1970s as a result of the efforts of a small number of academics, thought-leaders, and businesses. The general concept has been refined and developed by the following schools of thought, which all treat the economy as a complex adaptive system and draw on insights from living systems especially:

- Regenerative design (Prof. John T. Lyle);

6 www.wrap.org.uk/sites/files/wrap/Employment%20and%20the%20circular%20economy%20summary.pdf

Figure 4: Estimated potential contribution of circular economy to economic growth, job creation and reduction of greenhouse gas emissions



1 2030 scenario.
2 Full scenario; GDP impact equal to trade balance effect.
3 'Material efficiency scenario'; GDP impact equal to trade balance effect.
4 Net job creation from increased reuse, remanufacturing, recycling, bio-refining and servitisation.
5 Built environment.
6 Forestry, pulp and paper, machinery, equipment and electronics, built environment, food waste, P2P sharing.
7 Remanufacturing industry.
8 Ontario; Waste management and recycling industry.
9 Waste management and recycling industry; compiled from several reports, see http://ec.europa.eu/environment/circular-economy/index_en.htm, http://ec.europa.eu/smart-regulation/impact/planned_ia/docs/2014_env_005_waste_review_en.pdf

GHG EMISSION REDUCTION	SOURCE
25.0	SUN, Ellen MacArthur Foundation and McKinsey
70.0	Club of Rome
10.0	Club of Rome
8.0	TNO
N/A	Cambridge Econometrics, Biointelligence service
N/A	WRAP
N/A	EC, TNO
N/A	SITRA
N/A	Zero Waste Scotland
N/A	Conference Board of Canada
4.5	Zero Waste Europe

SOURCE: NL: TNO, Opportunities for a circular economy in the Netherlands (2013); EU (1): Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth Within: A Circular Economy Vision for a Competitive Europe (2015); EU (2): Cambridge Econometrics / Biointelligence Service / EC, Study on modelling of the economic and environmental impacts of raw material consumption (2014); SWE: Club of Rome, The circular economy and benefits for Society (2015); UK: WRAP, Employment and the circular economy: job creation in a more resource efficient Britain (2014); FIN: SITRA, Assessing circular economy potential for Finland (2014); EU, built environment: TNO / EC, Assessment of scenarios and options towards a resource efficient Europe: an analysis for the European built environment (2013); SCO: Zero Waste Scotland, Circular economy evidence building programme: Remanufacturing study (2015); EU, waste management: Zero Waste Europe, EU circular economy package: Questioning the reasons for withdrawal (2015); CAN: Conference Board of Canada, Opportunities for Ontario's Waste: Economic Impacts of Waste Diversion in North America (2014)

- Performance economy (Prof. Walter Stahel);
- Cradle to Cradle (Prof. Michael Braungart and William McDonough);
- Industrial ecology (Prof. Roland Clift, Thomas E. Graedel);
- Biomimicry (Janine Benyus);
- Natural capitalism (Amory Lovins);
- Blue Economy (Gunter Pauli).

To learn more about the concepts that lie behind the circular economy framework, a good starting point is Chapter 2 of *Towards the Circular Economy I* by the Ellen MacArthur Foundation (2012). For a broader discussion of the three principles and the ReSOLVE framework, see the report *Growth Within: A Circular Economy Vision for a Competitive Europe.*[7] For a more general discussion of the interplay between the circular economy, employment, education, money and finance, public policy and taxation, see the book *The Circular Economy – A Wealth of Flows* by Ken Webster, Head of Innovation at the Ellen MacArthur Foundation.

1.2 A favourable alignment of factors makes the transition possible

The economic system over the past 200 years has relied on getting cheaply accessible resources out of the ground. This model has its limits, given the finite nature of these resources, the related price volatility and supply risks, and the negative externalitiŝes resulting from the use of these resources. In recent years several factors have combined to offer significant opportunities to overcome this impasse. New technologies such as smartphones are enabling the development of, for example, sharing business models. These are finding a ready market among consumers and are being made easier by the urbanisation of the global population. At the same time there is an increasing amount of capital available to support businesses that not only deliver sound financial returns, but also create social and environmental value.

CURRENT CHALLENGES IN THE LINEAR MODEL

The reliance of many current business models on a ready supply of cheap non-renewable resources exposes businesses and economies to price risks, supply risks, and environmental degradation. Such risks pose a fundamental challenge to long-term economic development. They can also be translated into short-term challenges to businesses if their licence for certain resource-intensive or environmentally damaging operations is revoked or externalities are priced in.

Price risk. The last decade has seen higher price volatility for metals and agricultural output than in any single decade in the 20th century. According to the think tank Chatham House, "[v]olatility of resource prices is the new normal, hitting both consumers and producers".[8] The steep rise in commodity prices between 2002 and 2010 – although partially reversed since then – erased the entire 20th century's worth of real price declines and was a wake-up call to many businesses and economies, forcing them to rethink their buy-process-sell model and come up with value-retaining material management strategies. Higher resource price volatility can dampen economic growth by increasing uncertainty, discouraging businesses from investing and increasing the cost of hedging against resource-related risks.

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7 Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

8 Press release for Chatham House report *Volatile Resource Prices a Menace to Global Stability* (2012).

Supply risk. Many areas of the world possess few natural deposits of non-renewable resources of their own and so must rely on imports. The European Union imports six times as much materials and natural resources as it exports.[9] Japan imports almost all its petroleum and other liquid fuels and its natural gas, and India imports around 80% and 40% respectively.[10] As well as risks to the supply of raw materials themselves, the risk to supply security and safety associated with long, elaborately optimised global supply chains appears to be increasing.[11]

Natural systems degradation. A fundamental challenge to long-term global wealth creation is the set of negative environmental consequences related to the linear model, described in Box 1. While these negative environmental externalities are not new, in recent years, businesses have witnessed an increased effort on the part of regulators to curtail and price them. Since 2009, the number of climate change laws has increased by 66%, from 300 to 500. These climate laws account for almost 90% of global greenhouse gas (GHG) emissions.[12] Carbon pricing, in the form of an emissions trading scheme or a carbon tax, has been implemented or is scheduled to commence in almost 40 countries and over 20 cities, states and regions, covering in total around 12% of global GHG emissions.[13] By 2011 there were globally 205 active watershed payment programmes (incentive or market-based mechanisms used to protect watersheds, including e.g. payments for ecosystem services and water quality trading markets), with transactions worth USD 8 billion a year[14] and a further 76 in development. The price for water itself is rising in some areas: farmers in California's Central Valley, the world's most productive agricultural region, are paying as much as 10 times more for water than they did before supply was cut due to a record-breaking drought – in one district, for example, prices rose to USD 1,100 per acre-foot in 2014 from about USD 140 in 2013.[15] In Europe 20 countries levy landfill taxes, which together raised revenues of EUR 2.1 billion in 2009/2010. Some of these taxes have risen steeply over the last years: in the UK for instance the standard landfill tax rate per tonne increased 260% between 2007 and 2012.[16] According to KPMG '… companies in all sectors are finding that their externalities have increasing implications for their corporate value creation. The disconnect between corporate value and societal value is disappearing'.[17]

The three challenges outlined above are increasingly recognised by capital markets. Several large institutional investors have started to divest from companies with high exposure to fossil fuels, including electrical utilities highly dependent on coal. In May 2015, Norway's USD 900 billion sovereign wealth fund – the largest in the world, holding 1% of the global equities – moved to divest from both coal producers and coal-burning power utilities.[18] In the same month, Axa Group, the largest insurance company in the world,[19] said it would remove EUR 500 million of coal investments from its portfolio and provide investors with more information on the risk to its investments from climate change.

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9 Frans Timmermans, Jyrki Katainen, Karmenu Vella and Elżbieta Bieńkowska in Die Zeit 'Weg mit der Weg-werfmentalität' (28 May 2015).

10 US Energy Information Administration, *Oil and natural gas import reliance of major economies projected to change rapidly* (22 January 2014).

11 Ellen MacArthur Foundation, *Towards a Circular Economy III* (2014).

12 M. Nachmany, S. Fankhauser, T. Townshend, M. Collins, T. Landesman, A. Matthews, C. Pavese, K. Rietig, P. Schleifer and J. Setzer, *The GLOBE Climate Legislation Study: A Review of Climate Change Legislation in 66 Countries. Fourth Edition* (London: GLOBE International and the Grantham Research Institute, London School of Economics, 2014).

13 World Bank and Ecofys, *Carbon pricing watch 2015* (May 2015).

14 Ecosystem Marketplace (Forest Trends), *Charting New Waters: State of Watershed Payments* (2012).

15 Bloomberg, *California Water Prices Soar for Farmers as Drought Grows* (24 July 2014).

16 European Environmental Agency (EEA), *Overview of the use of landfill taxes in Europe* (2012).

17 KPMG, *A New Vision of Value: Connecting corporate and societal value creation* (2014).

18 David Crouch and Pilita Clark in the Financial Times, 'Norway oil fund plans to withdraw from coal-burning utilities' (27 May 2015).

19 www.investopedia.com/articles/personal-finance/010715/worlds-top-10-insurance-companies.asp

Box 1: Natural systems degradation

According to the United Nations Environment Programme (UNEP): "The currently observed changes to the Earth System are unprecedented in human history. Efforts to slow the rate or extent of change – including enhanced resource efficiency and mitigation measures – have resulted in moderate successes but have not succeeded in reversing adverse environmental changes. As human pressures on the Earth System accelerate, several critical global, regional and local thresholds are close or have been exceeded. Once these have been passed, abrupt and possibly irreversible changes to the life-support functions of the planet are likely to occur, with significant adverse implications for human well-being".[20] A selection of four elements contributing to this environmental pressure are:

- **Climate change:** GHG emission reduction plans to 2030 released by the G7 and the EU would leave the world on track for warming of 3–4°C by 2100 compared to pre-industrial levels, well above the 2°C limit agreed by the UNFCCC.[21] Risks of climate change to human livelihoods and health, agricultural productivity, access to freshwater and ecosystems include: increased storm surges, coastal flooding and sea level rise; inland flooding; extreme weather events; extreme heat; and the loss of marine, coastal, terrestrial and inland water ecosystems.[22] The economic cost of these effects could potentially by a reduction in GDP of 20% per annum in 2050.[23]
- **Loss of biodiversity and natural capital:** At a global scale, without any additional policy action, losses in the value of ecosystem services due to biodiversity decline are estimated to reach EUR 14 trillion by 2050, 7% of projected global GDP.[24]
- **Land degradation:** the productivity of over 20% of land globally – on which 1.5 billion people reside – has declined persistently between 1981 and 2003.[25] Land degradation costs an estimated USD 40 billion annually worldwide, without taking into account the hidden costs of increased fertiliser use, loss of biodiversity and loss of unique landscapes. Agricultural productivity growth has been steadily declining, from 2.2% per annum in the 1960s to 0.9% per annum in the 2010s, despite increases in the use of fertilisers, chemicals, fuels and other inputs. Today, more nitrogen is fixed synthetically in fertilisers than naturally in all terrestrial ecosystems combined.[26]
- **Ocean pollution:** An estimated 8 million tonnes (Mt) of plastic waste enter the oceans every year, a figure predicted to rise to 17.5 Mt per annum by 2025. Since they are so long lived in the environment (it is estimated, for example, that PET takes 450 years to decay into unrecognisable fragments in the ocean), the stock is also rising – it is forecast to increase from 130–150 Mt in 2013 to 250 Mt by 2025[27]. While some of these plastics sink, others degrade into micro-particles that are absorbed into marine food chains.

20 United Nations Environment Programme (UNEP), *Global Environment Outlook 5* (2012).

21 Climate Action Tracker, *G7+EU INDCs: some improvement, but a large emissions gap remains* (June 2015).

22 Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2014: Impacts, Adaptation and Vulnerability, Working Group II contribution to the fifth assessment report of the IPCC* (2014).

23 N. Stern, *The Economics of Climate Change: The Stern Review* (Cambridge University Press, 2006). It should be noted that integrating into economic models an appropriate assessment of the impacts of climate risks presents challenges that include continued uncertainty regarding the magnitude and probability of such impacts and difficulties converting them into monetary values. For more detail see The Global Commission on the Economy and Climate, *The New Climate Economy Report* (2014).

24 European Commission, *The Cost of Policy Inaction (COPI): The case of not meeting the 2010 biodiversity target* (2008).

25 Bai, Z., Dent, D., Olsson L., and Schaepman, M. E., Soil Use and Management 24, pp.223–243, '*Proxy global assessment of land degradation*', (September 2008).

26 European Environment Agency *The European environment – state and outlook 2015: synthesis report* (2015).

27 Jambeck et al, Science, Vol. 347 no. 6223, *Plastic waste inputs from land into the ocean,* (13 February 2015).

For example, 66% of seabirds and 100% of sea turtles are affected in some way by marine debris[28]. As well as biodiversity loss, this waste reduces the viability of fisheries, impacts tourism and is a fundamental loss of valuable materials.

OPPORTUNITIES TO GO CIRCULAR

Advances in technology create ever greater opportunities to support circular economy business models. Information and industrial technologies are now coming online or being deployed at scale, which allow the creation of circular economy business approaches which were previously not possible. These advances allow more efficient collaboration and knowledge sharing, better tracking of materials, improved forward and reverse logistics set-ups, i.e. initial product design and material innovation seamlessly joined up with subsequent processing of secondary material streams, and increased use of renewable energy. Examples of emergent technologies in this area are:

- **Smartphones:** mobile smartphone subscriptions have increased globally from 0.5 billion in 2009 to 2.6 billion in 2014 (500% increase), and are expected to more than double again by 2020.[29] This technology has been critical in some on-demand sharing services like Uber and product logging and re-sale platforms like Stuffstr.

- **The 'Internet of things':** ABI Research says there are already more 'things' connected to the Internet than people – over 16 billion devices in 2014, a 20% increase from 2013.[30] According to the same source, this number is expected to grow to more than 40 billion by 2020. Connections today come in the form of home and office IT devices such as PCs and laptops, mobile smart devices and new connected business and manufacturing devices. In the future, everything is likely to be connected, from container ships and buildings to needles, books, cows, pens, trees and shoes. This interconnectedness enables tracking efficiency and predictive maintenance that was previously inconceivable.

- **Advanced manufacturing and processing technologies:** these technologies open up completely new paradigms for adopting circular operations at lower cost. For example, 3D printing substantially reduces waste in the manufacturing process itself, allows the reduction of product inventory by moving to 'make-to-order' systems from what are often 'make-to-stock' systems, and is widely used in the reworking of spare parts.

- **Decreasing costs of renewable energy.** Solar panel costs have fallen 80% since 2008 and wind turbine prices are down nearly a third. This is driving so much clean energy generation that more new renewable capacity has been added each year since 2013 than coal, natural gas and oil combined, according to the Bloomberg New Energy Finance research group.[31]

Consumer acceptance of alternative business models has in some markets been demonstrated. Circular economy business models enabled by new technologies are finding ready customers. For instance Uber, the on-demand taxi service where drivers use their own cars, forecasts net revenue of more than USD 2 billion in 2015, five times as much as in 2014, which was itself about four times as much as in 2013, according to the *Wall Street Journal.*[32] This creates a level of certainty for new businesses extending these models, such as sharing, into other markets. This is important because young consumers' lifestyle choices in this decade have the power to shift the economic model away from

28 Secretariat of the Convention on Biological Diversity, *Impacts of Marine Debris on Biodiversity* (2012)

29 Ericsson, *Mobility Report* (November 2013 and June 2015).

30 ABI Research, *The Internet of Things Will Drive Wireless Connected Devices to 40.9 Billion in 2020* (2014).

31 Pilita Clark in the Financial Times, *'Climate campaign wins over more senior executives'* (27 May 2015).

32 WSJ Technology, *'Uber Expands Funding Round as Revenue Growth Accelerates'* (18 February 2015).

the linear system. How pervasive the shift will become remains to be seen, but a new model of consumption could be emerging, in which consumers embrace services that enable them to access products on demand rather than owning them, thus becoming users.

There is a rapidly growing amount of capital available for businesses that not only delivers sound financial returns, but also creates social and environmental value. Sustainable and Responsible Investment (SRI) overall has increased from just over USD 3 trillion in 2010 to well over USD 6 trillion in 2014 (doubling in four years). Issuance of green bonds has increased from under USD 5 billion in 2010 to nearly USD 40 billion in 2014 (an eight-fold increase in four years). Leading institutional investors are joining the field: AXA Group has committed EUR 150 million of internal capital to an impact investment project; Zurich Insurance Group is developing an impact investment strategy, and hopes to encourage the adoption of responsible investment in the mainstream.

Socio-demographic trends make the benefits easier to capture. For the first time in history, over half of the world's population resides in urban areas. Continued urbanisation and overall population growth is projected to add another 2.5 billion people to the urban population by 2050, bringing the proportion of people living in cities to 66%.[33] With this steady increase in urbanisation, the associated costs of many of the asset-sharing services and the costs for collecting and treating end-of-use materials will all be able to benefit from much higher drop-off and pick-up density, simpler logistics, and greater appeal and scale for service providers. Centralised use should mean that reverse logistics – like the logistics of new product delivery – become more efficient and more cost-effective.

1.3 The role of policymakers and this toolkit

As many circular economy opportunities have a sound underlying profitability, businesses are driving the shift towards the circular economy. Yet there are often non-financial barriers limiting further scale-up or holding back development pace. Policymakers therefore can play an important role in enabling and, as appropriate, setting the direction for a transition to the circular economy.

Policymakers around the globe have already started to provide positive stimulus for the adoption of circular business practices. The Dutch government's Green Deal (see Box 3 for more details) offers a responsive service to companies that ask for help in realising circular economy opportunities and face implementation barriers. Some governments have set up taskforces to remove regulatory barriers, for example the Taskforce on Resource Efficiency in Denmark (see Box 5 in Part 2 for more details), which aims to identify barriers to circular economy practices in existing regulations, and to propose options to overcome them. Until recently, London's housing legislation made the practice of residents letting their homes on a short-term basis through sharing websites such as Airbnb illegal. The legislation was amended in 2015 to legalise the practice. The Scottish government, in setting up the Scottish Material Brokerage Service, aims to aggregate contracts for the 3 million tonnes of secondary materials collected annually across 200+ public bodies into a robust and cost-effective supply chain. China has chosen to stimulate the use of secondary materials in production processes by reducing by 50–100% the VAT on goods produced from them.

There are two broad, complementary policymaking strategies that can help accelerate the circular economy. The first is to focus on fixing market and regulatory failures. The second is to actively stimulate market activity by, for example, setting targets, changing public procurement policy, creating collaboration platforms and providing financial or technical support to businesses. These approaches are complementary and policymakers can determine where to put the emphasis, taking inspiration from the most applicable aspects of both approaches. Moving towards the circular economy offers a unique chance for businesses and policymakers collaboratively to accelerate specific business opportunities while at the same time helping to achieve wider societal goals.

33 United Nations, *World Urbanization Prospects – The 2014 Revision* (2014).

Policy options to support the circular economy have been investigated in a number of studies. Table 2 below lists selected literature on this topic.

Table 2: Selected literature on circular economy policymaking

European Commission, *Scoping study to identify potential circular economy actions, priority sectors, material flows and value chains* (2014)[34]

A study identifying 13 barriers to a transition to the circular economy, ranging from insufficient skills and investment in circular product design to weaknesses in policy coherence. It suggests three types of policy intervention are needed to help overcome the barriers: (i) regulatory instruments, including better implementation and enforcement of related existing legislation, revisions to relevant legislation, and new measures or regulations; (ii) other instruments and approaches, including voluntary agreements, fiscal incentives including taxes, charges and levies, information and advisory services and awareness raising campaigns; and (iii) public investment in e.g. R&D, skills and training and infrastructure, industrial symbiosis and clusters, and green public procurement.

EREP – European Resource Efficiency Platform, *Manifesto & Policy Recommendations* (2012)[35]

A call for a circular, resource-efficient and resilient economy in the EU to be achieved by taking the following actions: encouraging innovation and accelerating public and private investment in resource-efficient technologies, systems and skills; implementing, using and adopting smart regulation, standards and codes of conduct; abolishing environmentally harmful subsidies and tax breaks; creating better market conditions for products and services that have lower impacts across their life cycles, and that are durable, repairable and recyclable; integrating current and future resource scarcities and vulnerabilities more coherently into wider policy areas, at national, European and global level; providing clear signals to all economic actors by adopting policy goals to achieve a resource-efficient economy and society by 2020, setting targets that give a clear direction and indicators to measure progress relating to the use of land, material, water and greenhouse gas emissions, as well as biodiversity.

UK House of Commons Environmental Audit Committee, *Growing a circular economy: Ending the throwaway society* (2014)[36]

A parliamentary enquiry into the circular economy that consulted businesses trying to exploit circular economy business models. The committee recommends that the UK government: (i) reform taxation and producer responsibility regulations to reward companies that design more circular products; (ii) improve information about the location of materials; (iii) give direct guidance to local authorities on what materials are collected and recycled, including separate food waste collections and banning sending food waste to landfill; (iv) set longer warranty periods for consumer products; (v) set new standards for eco-design; (vi) stop businesses using materials that cannot be recycled when better alternatives exist; (vii) use government procurement standards to promote a more circular economy; and (viii) encourage the Green Investment Bank to finance innovative circular economy technologies.

University College London, *'Policy Options for a Resource Efficient Economy' (POLFREE)*[37]

A University College London (UCL)-led research effort to support European Commission policy efforts and initiatives on resource efficiency. It will propose new policy mixes, business models and mechanisms of global governance through which resource-efficient economies may be promoted. Its work areas are: (i) Why resources have been used inefficiently; (ii) New concepts and paradigms for policies for resource efficiency; (iii) Scenarios and modelling of policy implementation for resource efficiency; (iv) Support, dissemination and policy insights. Collaborating institutions are the Wuppertal Institute, TNO, ICIS Maastricht University, Gesellschaft für Wirtschaftliche Strukturforschung (Osnabrück), Sustainable Europe Research Institute (Vienna), Potsdam Institute for Climate Impact Research, and International Synergies

34 www.ieep.eu/assets/1410/Circular_economy_scoping_study_-_Final_report.pdf

35 http://ec.europa.eu/environment/resource_efficiency/documents/erep_manifesto_and_policy_recommendations_31-03-2014.pdf

36 www.publications.parliament.uk/pa/cm201415/cmselect/cmenvaud/214/214.pdf

37 https://www.ucl.ac.uk/polfree

(UK). The project receives funding from the EU's 7th programme of research, 2007–2013.

European Environment Agency, *Resource efficiency in Europe — Policies and approaches in 31 EEA member and cooperating countries (2011)*[38]

An overview of resource efficiency policies and instruments in 31 European countries aiming to analyse national experiences in developing and implementing resource efficiency policies, The country submissions indicate that: (i) there is neither a clear definition nor a common understanding of 'resource efficiency' across countries; (ii) only Austria and Germany (as well as the Flanders Region in Belgium) report having a dedicated strategic policy document for resource efficiency; (iii) the priority resources most commonly reported by countries were energy carriers (22 mentions), waste (18), minerals and raw materials (16) and water (14); (iv) strategic objectives for resource efficiency tend to be fairly general in nature, most often referring to ensuring more efficient use of resources, increasing recycling, increasing the share of renewables, and preventing waste or decoupling its generation from economic growth.

German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), *German Resource Efficiency Programme (ProgRess)* (2012)[39]

The goal of the German Resource Efficiency Programme (ProgRess) is to make the extraction and use of natural resources more sustainable in the belief that improving resource efficiency can limit environmental damage, strengthen the competitiveness of the German economy, create new jobs and secure long-term employment. In 2002, the German government set the goal of doubling raw material productivity by 2020 compared with 1994. ProgRess aims to contribute to reaching it. Strategic approaches are identified and underpinned with measures such as strengthening efficiency advice for SMEs, supporting environmental management systems, taking greater account of resource aspects in standardisation processes, placing greater focus on the use of resource-efficient products and services in public procurement, strengthening voluntary product labelling and certification schemes and enhancing closed-cycle management. Examples of material flows and technologies particularly relevant for the strategic approaches are bulk metals, rare and strategic metals, photovoltaics and electric mobility, sustainable construction, and the closed-cycle management of plastic waste. The government will report every four years on progress.

The Ex'Tax Project, in cooperation with Deloitte, EY, KPMG Meijburg and PwC, *New Era. New Plan: Fiscal reforms for an inclusive, circular economy* (2014)[40]

Identifies viable options for a fundamental shift in taxation from labour to natural resource use and consumption. A case study looks at a (mid- to long-term) tax shift worth more than EUR 30 billion in the Netherlands alone. The report suggests that in the case of international coordination, such a tax shift could potentially create hundreds of thousands of jobs,

This report aims to complement existing circular economy policy literature by:

- **Providing an actionable methodology.** Rather than providing general answers, this toolkit offers a methodology for policymakers to identify policy options, based on country- and sector-specific circumstances. It covers the selection of focus sectors, the identification of sector-specific circular economy opportunities, the impact quantification of these opportunities, the assessment of the barriers preventing the opportunities, and ultimately the analysis of the policy options to overcome the barriers. This process is described in detail in Part 2.

- **Providing insights from the Denmark pilot.** Part 3 of this report shares insights gathered through a six-month pilot study conducted in close collaboration with Danish policymakers and businesses.

This report complements previous research from the Ellen MacArthur Foundation by looking at the circular economy opportunity from a national, policymaker perspective.

38 www.eea.europa.eu/publications/resource-efficiency-in-europe

39 www.bmub.bund.de/en/service/publications/downloads/details/artikel/german-resource-efficiency-programme-progress/?tx_ttnews%5BbackPid%5D=1742

40 www.ex-tax.com/files/4314/1693/7138/The_Extax_Project_New_Era_New_Plan_report.pdf

The toolkit complements the report *Growth Within: A Circular Economy Vision for a Competitive Europe*,[41] by offering an actionable 'how-to' guide for policymakers inspired by the vision of what the circular economy could look like as laid out in the *Growth Within* report. It is an initial exploration of circular economy policymaking by the Ellen MacArthur Foundation, and does not aim to bring the final word on the subject.

Policymakers at all government levels – municipal, regional, national, and supranational can play an important role in the circular economy. The toolkit is aimed primarily at national policymakers, but could be – according to initial conversations with various actors – largely applicable also to municipal, regional and supranational policymakers.

Cities in particular, though not the focus of this report, have a key role to play in the transition to the circular economy, with an excess of both the challenges and opportunities. A high density of businesses (especially retailers) and consumers makes cities concentrators of flows. This requires and allows the creation of reverse operations at scale. As within city boundaries consumption is often higher than the production of goods, setting up local loops and increasing self-sufficiency can be of interest. Cities are also a hotbed of innovation: incubator spaces, maker labs and urban farming are just three examples. City governments can in certain instances move faster than their national counterparts, especially when united in city networks.

41 Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

METHODOLOGY FOR POLICYMAKERS TO ACCELERATE THE TRANSITION

2 METHODOLOGY FOR POLICYMAKERS TO ACCELERATE THE TRANSITION

This toolkit aims to support policymakers who have decided to transition to a circular economy in designing a strategy to accelerate this process. It offers a step-by-step methodology to explore and prioritise circular economy opportunities; quantify their impact; identify the barriers preventing these opportunities; map and prioritise the policy interventions to overcome these barriers; and to engage relevant stakeholders.

The methodology is laid out in Figure 5, and detailed below.

1 **Align on starting point, ambition and focus (Chapter 2.1).** As in any strategic project, relevant stakeholders need to be mapped and engaged early on in the process. Based on an understanding of the national circularity and policy context (Section 2.1.1), a realistic ambition level (Section 2.1.2) and sector scope (Section 2.1.3) needs to be defined.

2 **Assess sector circular economy opportunities (Chapter 2.2).** Once the focus sectors have been selected, the sector-specific assessment can begin. This step can be conducted in parallel sector working groups, and heavily relies on the involvement of businesses. The most relevant circular economy opportunities need to be mapped (Section 2.2.1) and prioritised (Section 2.2.2). For the prioritised opportunities, sector-specific economic impact needs to be assessed (Section 2.2.3), barriers limiting their realisation identified (Section 2.2.4) and policy options to overcome these barriers mapped (Section 2.2.5).

3 **Analyse national implications (Chapter 2.3).** Once the sector-specific circular economy opportunities have been assessed, they can be aggregated and the economy-wide implications analysed. This step will typically be driven by a core group of policymakers, policy and economics experts and with the participation of multiple government agencies. The sector-specific impact assessments could be aggregated in one overarching whole-economy impact assessment to support the mandate for policy intervention (Section 2.3.1). Sector-specific policy options could be complemented by economy-wide policy options (Section 2.3.2). The set of sector-specific and economy-wide policy options needs to be prioritised and assembled into coherent policy packages (Section 2.3.3).

The steps outlined in the methodology have been designed to be implemented consecutively; but policymakers could also pick one or a few of the tools and use them – to a certain extent – standalone or in a different order. Each of the tool sections below contains a 'standalone' description of the tool's context and objectives, a tool description, and a how-to-use guide.

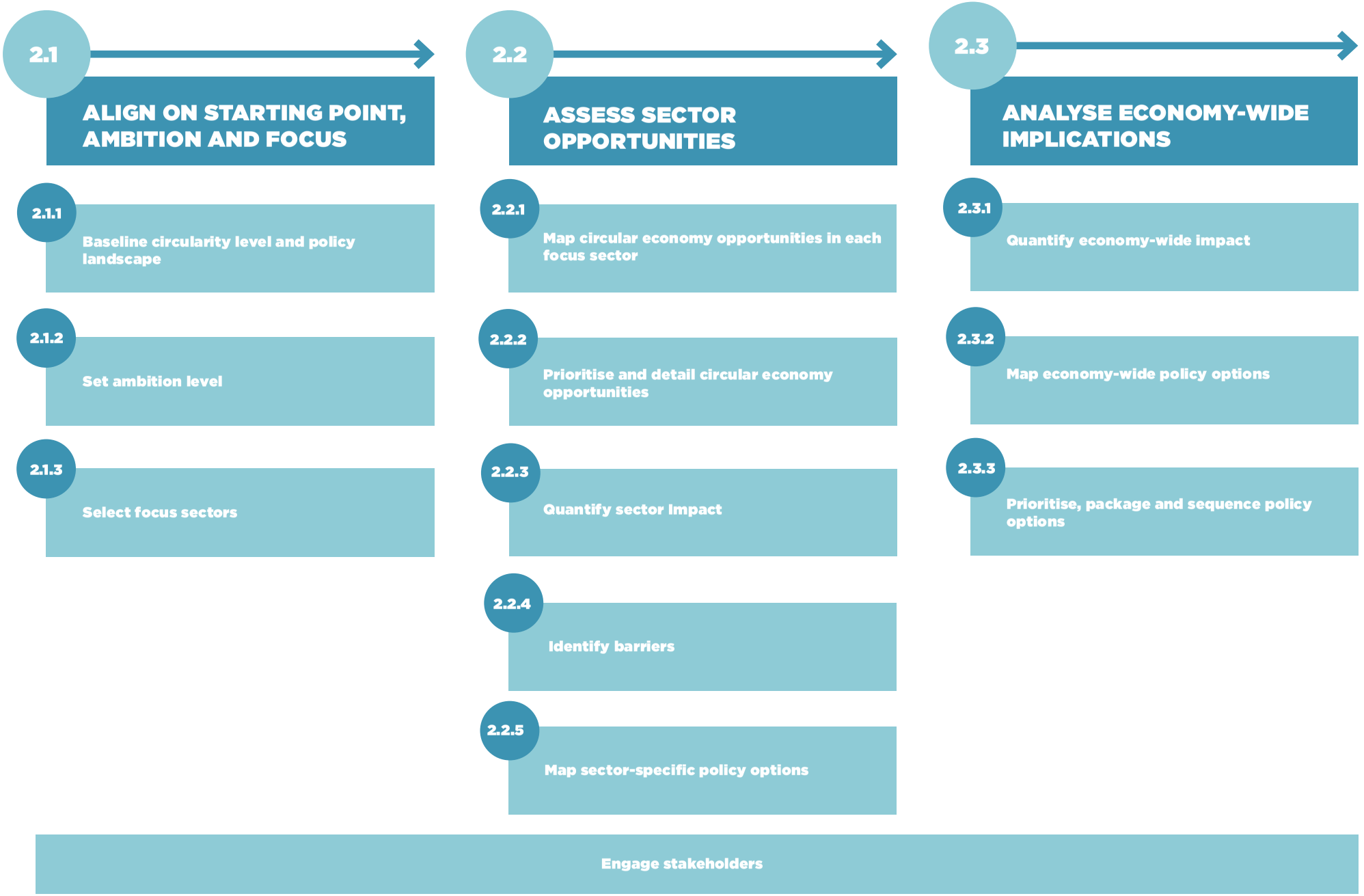
The methodology has been designed to be applicable in any country or region, with different nuances and focal points to accommodate for local circumstances. Chapter 2.4 outlines some of these potential adaptations.

2.1 Align on starting point, ambition and focus

As in any strategic project, relevant stakeholders need to be mapped and engaged early on in the process. Based on an understanding of the national circularity and policy context (Section 2.1.1), a realistic ambition level (Section 2.1.2) and sector scope (Section 2.1.3) needs to be defined.

In this first step, the core team should have at their disposal strong business analysis skills and expertise in the circular economy, including the ability to benchmark circularity metrics, facilitate first discussions with project stakeholders, and make an assessment of the role in the national economy and circularity potential in the sector selection.

Figure 5: Step-by-step methodology



Especially the assessment of the circularity potential in the sector selection would benefit from prior experience in the circular economy. The core project team ideally contains members from different government departments (including business/industry and environment), to ensure broad expertise as well as early buy-in from these key departments. In the Denmark pilot, in total, around five man-months were dedicated to this step.

In the Danish pilot, both the Danish Business Authority (part of the Ministry of Business and Growth) and the Danish Environmental Protection Agency (part of the Ministry of Environment) provided key contributions to the core project team; this resulted in a very strong mix of expertise and access to data and contacts.

As in any strategic project, key stakeholders should be engaged from the very start of the project. Three broad types of stakeholders need to be engaged in the project: businesses, policymakers and other society stakeholders.

Businesses. It is crucial to involve businesses throughout the project in order to: (i) get insights and knowledge to identify the most relevant circular economy opportunities and barriers in each focus sector; (ii) create early alignment on common direction for the country and the focus sectors; (iii) further demonstrate circular economy benefits to businesses and build capabilities. As the circular economy is a new notion to both policymakers and (certain) companies in many countries, business involvement is even more important than in other policy areas. Different from some other policy areas, it is crucial to engage individual businesses and not just industry associations, as the assessment of opportunities and barriers requires a deep technical understanding of specific products and business lines that individual businesses can typically provide better than industry associations. Of course, involving industry associations is important as well to provide a well-rounded picture of opportunities and barriers in the focus sectors. Businesses would need to be involved primarily in the second phase of the project – i.e. to identify the circular economy opportunities and barriers once the focus sectors have been identified. In the Denmark pilot, 25-plus businesses were involved. Most of these companies were Danish, but selected businesses outside Denmark were also interviewed in order to incorporate international best practices.

Policymakers. Aside from a core group of policymakers leading the project, it is important to engage a wider group of policymakers, including representatives from different government departments (for example Finance, Business/Industry, Environment, Food/Agriculture, Energy). They should be involved intensively throughout the project, to leverage their expertise and ensure alignment with the project direction. In the Denmark pilot, senior representatives from six ministries (the Ministry of Business and Growth, the Ministry of Environment, the Ministry of Finance, the Ministry of Foreign Affairs, the Ministry of Climate, Energy and Building, and the Ministry of Food, Agriculture and Fisheries) and policy and economic experts from the Danish Climate Council, Statistics Denmark and DREAM (a macroeconomic modelling organisation) were involved in an 'Observer Group' from the beginning of the project. This 'Observer Group' convened three times over the course of it, and provided crucial input in each step.

Other society stakeholders. These include citizens and consumers, labour and environmental organisations, researchers and academics. They should be involved throughout the project to ensure a rounded picture of national circumstances and ambitions. In the Denmark pilot, a multi-stakeholder 'Danish Society Stakeholder Group' consisted of representatives from, amongst others, different political parties, industry associations, and unions.

2.1.1 Baseline circularity level and policy landscape

Objective:	**Understand country starting point before deciding where to go.**
End product:	**Assessment of the country's level of circularity compared to other countries. A broad understanding of the landscape of existing circular economy related policies.**

Level of circularity

Assessing the current level of circularity provides useful guidance to set an appropriate national ambition level. The circularity baselining gives a first indication of the areas in which a country is more or less advanced compared to its peers, which provides useful input for setting the ambition level. It also provides initial high-level direction on the solution space. If a country performs very well on a certain metric, significant attention has probably been spent on it in the past, and it can be useful to consider whether significant progress is still possible on top of the expected impact from existing initiatives. An example from the Denmark pilot is energy efficiency and the adoption of renewable energy. Denmark is already one of the world leaders in these domains, and has even more ambitious targets in place. Therefore, these areas were deprioritised when assessing circular economy opportunities.

If a country performs below average on a metric, it could be fruitful to use existing success formulas to quickly advance in that area, or to leapfrog the potentially suboptimal solutions that other countries have developed (e.g. a large incineration infrastructure to avoid landfilling).

Existing metrics do not fully cover the circular economy. Some important metrics such as the level of sharing and the level of remanufacturing are simply not yet available at a national level, beyond anecdotal evidence in specific sectors or applications.

To baseline a country's level of circularity within reasonable time and effort, using existing metrics is often however the only option. Figure 6 shows a set of such metrics for Denmark and the European Union.[42] Although this set is neither comprehensive nor a firm recommendation, it covers four key circularity areas, and balances completeness with more pragmatic objectives such as data availability and comparability over time and across countries. The four key areas and corresponding metrics are:

- **Resource productivity.** The resource productivity metric is the lead indicator of the European Commission's Resource Efficiency scoreboard, and consequently has high-quality data availability and transparency. A drawback is that domestic material consumption in the denominator is highly influenced by the industrial structure in each country, and that weight does not necessarily reflect environmental costs.

- **Circular activities.** Ideally, a complete set of indicators including the adoption of remanufacturing and sharing would be measured. As this data is not readily available, recycling rate and eco-innovation indexes were selected as proxy indicators.

- **Waste generation.** The two metrics shown have been selected to reflect that overall waste generation, often driven by industries, could be quite different from waste generated by consumers (a large contributor to municipal waste). As with resource productivity, there are caveats such as the influence of industrial structure on overall waste generation.

- **Energy and greenhouse gas emissions.** Two straightforward metrics of renewable energy use and greenhouse gas emissions per GDP output were selected, recognising that again, industrial structure influences the outcome.

42 The level of circularity in the Denmark pilot primarily used the EU as the benchmark. While this was the natural choice due to data availability and similarities in legal framework, a more comprehensive comparison to international best performers could lead to interesting insights as well.

As part of a strategic circular economy initiative, a wider transparency and circularity measurement effort can be launched. To ensure comparability with other countries, such an effort would ideally happen in an international context, involving, for example the OECD, Eurostat, or the United Nations.

There are currently a number of initiatives in progress to increase data transparency and/or further develop adequate metrics, to give just a few examples:

- In Scotland, a carbon metric was developed to quantify the carbon impact of waste, assessing the emissions generated by producing and recycling materials as well as the emissions from the disposal process itself.[43]

- In Europe, the EU Resource Efficiency scoreboard and the Raw Material Consumption (RMC) indicator illustrate the progress towards increased resource efficiency of individual member states and the European Union as a whole.[44]

- In the UK, Sankey diagrams were developed to visualise and analyse material flows and circularity of the economy.[45]

- In Denmark, Statistics Denmark is implementing a system of physical supply-use tables and physical input-output tables. The system aims at complementing the monetary supply-use and input-output tables with information on the quantities of materials (natural resources, products and residuals) flowing into, through and out of the economy.

- The Ellen MacArthur Foundation and Granta with EU LIFE Funding, have developed Circularity Indicators for companies to assess how well a product or company performs in the context of the circular economy. The main indicator, the Material Circularity Indicator, measures how restorative the material flows of a product or company are, and complementary indicators measure additional impacts and risks[46].

- The German government's goal to double raw material productivity by 2020 compared with 1994 (see Table 2 for more detail) is expressed using the ratio of GDP to Direct Material Input in tonnes of abiotic raw materials. The indicator Domestic Material Consumption in raw material equivalents is also used as it takes into account material flows caused by the production of imports. A third indicator, Total Material Consumption, will also be used in future – if data quality can be sufficiently increased – to cover extracted resources that are unused, such as mining spoils.[47]

For a more detailed discussion of measuring national economic performance taking into account the three principles of the circular economy as laid out in Chapter 1.1, see Section 2.1.2.

Standard setting organisations also have a role to play in providing measurement frameworks. Some examples of work in this area include:

- The Association of German Engineers (VDI) provides a set of technical product standards on resource efficiency and on recycling, including on disposal logistics. It also provides services such as resource checks and regional events for a resource efficiency network to help link entrepreneurs and information and funding

43 www.zerowastescotland.org.uk/category/subject/carbon-metric

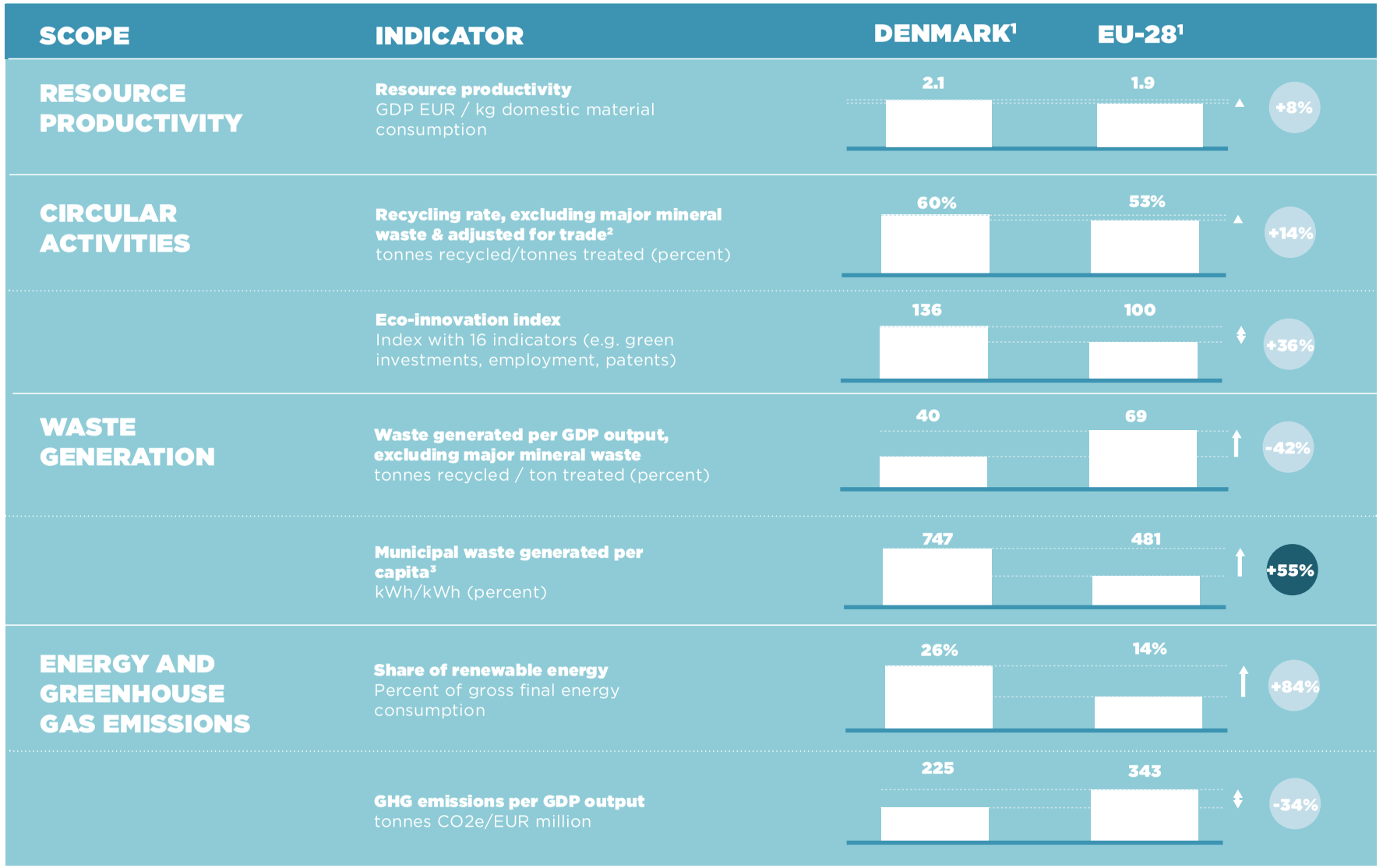
44 http://ec.europa.eu/environment/resource_efficiency/targets_indicators/scoreboard/index_en.htm

45 www.wrap.org.uk/content/material-flows-uk

46 For more information see: www.ellenmacarthurfoundation.org/circular-economy/research-initiatives

47 German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), *German Resource Efficiency Programme (ProgRess)* (2012)

Figure 6: Circularity baselining in the Denmark pilot



1 2012 values if not stated otherwise
2 Recycling of domestically generated waste (incl. exported waste, excl. imported waste)
3 2013 data
SOURCE: Resource Efficiency Scoreboard 2014 Highlights, European commission (2014); Eurostat; Statistics Denmark, Danish EPA

providers.[48]

- In the UK, the British Standards Institute (BSI) has developed a number of standards that support waste prevention, resource efficiency, eco-design and remanufacturing, for example on design for manufacture, assembly, disassembly and end-of-use processing. It is also working on a framework standard for the circular economy, detailing the core principles an organisation should embed to realise its full benefits[49].

- The Cradle to Cradle Institute administers the publicly available Cradle to Cradle Certified Product Standard and is developing an open database of 'preferred' alternative chemicals, materials and processes to help companies reformulate products to make them more circular.

Policy landscape

Understanding, at a high level, the strengths and possible development areas of the current policy landscape allows for more targeted identification of relevant policy interventions later in the project, and to engage stakeholders early on in a discussion on which broad types of policy interventions could make sense for the country. This discussion will of course be refined once specific circular economy opportunities and related barriers have been identified; yet getting a reflection started with key stakeholders as soon as possible is a valuable end in itself. Such a discussion could reveal potential upcoming policy revisions, which are highly relevant to consider when new policy interventions are developed.

An understanding of the policy landscape can be established within six key categories illustrated with examples in Figure 7: education, information and awareness; collaboration platforms; business support schemes; public procurement and infrastructure; regulatory frameworks; and fiscal frameworks. These categories are explained in more detail in Section 2.2.5.

Figure 8 shows the outcome of this analysis for the Denmark pilot. For the 'examples of existing interventions' column the exercise involved consulting government reports and other information sources with assistance from multiple Danish government departments. The 'examples of possible additional interventions' column involved research on circular economy policies other countries are pursuing and on interventions that have been discussed in literature, for example those studies listed in Table 2.

2.1.2 Set ambition level

Objective:	**Align stakeholders on overall direction and focus of later sector deep dives to work towards a common direction.**
End product:	**Clear, quantified ambition level.**

Setting a national ambition level can be a powerful lever to align project stakeholders on the overall direction. An ambition level can for example influence the sector selection (e.g. focus on employment vs. environmental challenges when selecting focus sectors), as well as the prioritisation of circular economy opportunities within the focus sectors.

If adopted (even if non-binding), national targets can send important signals to businesses and investors. Famous examples include the carbon reduction targets adopted by the European Union[50] (20% reduction by 2020 and 80% by 2050, vs 1990 levels), the US[51] (26–28% by 2025, vs. 2005 levels), and China[52] (peaking of CO_2

48 See for example VDI Annual Report 2013/2014.

49 See for example BSI, *Waste prevention and the circular economy: Due diligence research report* (2014)

50 European Commission, *Roadmap for moving to a competitive low-carbon economy in 2050* (2011).

51 The White House, *US-China Joint Announcement on Climate Change* (12 November 2014).

52 The White House *U.S.-China Joint Announcement on Climate Change* (12 November 2014).

emissions around 2030 and increasing the share of non-fossil fuels in primary energy consumption to around 20% by 2030).

Below is a brief outline of three themes that could, individually or in combination, inspire countries in setting their ambition level:

1. **Quantitative circularity targets.** The targets can be set using existing indicators (such as in Figure 6) or by developing new metrics. Targets could also be linked more directly to the three principles of the circular economy as laid out in Part 1. The report *Growth Within*[53] lays out initial ideas of what such metrics could look by providing one primary metric and a set of secondary metrics for each of the three principles (see Figure 9 and the *Growth Within* report for more details).

2. **Quantitative 'common' national policy targets.** Circular economy can contribute to many 'common' policy objectives, such as, for example, the targets related to the EU 2020 agenda (see Figure 10).

3. **Qualitative circular ambitions.** This could mean setting a qualitative goal of being the 'best in Europe' in waste prevention or recycling, or becoming a 'world leader' in remanufacturing.

2.1.3 Select focus sectors

Objective:	**Focus assessment of sector opportunities (Chapter 2.2) on the most relevant parts of the economy.**
End product:	**Set of focus sectors based on a prioritisation matrix that maps sectors on 'role in national economy' and 'circularity potential'.**

The sector selection is a key tool in the methodology, as it determines the focus for the rest of the project, not only in terms of analysis but also in terms of stakeholder engagement. A large part of the analysis is sector-specific, as opportunities, barriers and policy options typically differ significantly by sector. Stakeholders from the selected sectors (and their broader value chains) need to be engaged extensively in the sector-specific analysis, as detailed in Chapter 2.2.

To select focus sectors in a circular economy initiative, both the role in the national economy and the circularity potential can be assessed. Below, a framework to analytically assess both dimensions is laid out. This analytical framework is not an end in itself, but can serve as a facilitator for a structured debate with key stakeholders and experts.

The two natural dimensions to prioritise sectors in a circular economy initiative are the sectors' role in the national economy and their resource profile. These can be divided in a number of sub-dimensions, for example[54]:

i. **Role in the national economy**: size (and growth) measured by share of GVA (gross value added), contribution to employment (and growth), international competitiveness.

ii. **Circularity potential**: material and energy intensity, volume of waste generated, share of waste landfilled/incinerated, high-level estimate of scope for improved circularity.

This list does not aim to be exhaustive, and can be adapted based on, among others, data availability and national priorities. Other sub-dimensions, such as the environmental

53 Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

54 More details on the sub-dimension and exact quantification methodology can be found in Appendix A.

Figure 7: Six policy intervention types with examples

POLICY INTERVENTION TYPES	EXAMPLES
EDUCATION, INFORMATION & AWARENESS	Integration of circular economy/systems thinking into school and university curricula
	Public communication and information campaigns
COLLABORATION PLATFORMS	Public-private partnerships with businesses at national, regional and city level
	Encouragement of voluntary industry collaboration platforms, encouraging value-chain and cross-sectoral initiatives and information sharing
	R&D programmes in the fields of, for example, material sciences and biosystems
BUSINESS SUPPORT SCHEMES	Financial support to business, for example direct subsidies, provision of capital, financial guarantees
	Technical support, advisory, training and demonstration of best practices to business
PUBLIC PROCUREMENT & INFRASTRUCTURE	Public procurement
	Public investment in infrastructure
REGULATORY FRAMEWORKS	Government (sector) strategy and associated targets on resource productivity and circular economy
	Product regulations, including design, extended warranties and product passports
	Waste regulations, including collection and treatment standards and targets, the definition of waste, extended producer responsibility and take-back systems
	Industry, consumer, competition and trade regulations, for example on food safety
	Accounting, reporting and financial regulations including accounting for natural capital and resources, and the fiduciary duty of investors and managers
FISCAL FRAMEWORKS	VAT or excise duty reductions for circular products and services
	Tax shift from labour to resources

Figure 8: Policy landscape in the Denmark pilot

POLICY INTERVENTION TYPES	EXAMPLES OF EXISTING INTERVENTIONS	EXAMPLES OF POSSIBLE ADDITIONAL INTERVENTIONS (AS OBSERVED AT START OF PROJECT AND NOT TAKING INTO ACCOUNT SUBSEQUENT ANALYSIS)
EDUCATION, INFORMATION & AWARENESS	• Consumer information campaigns, e.g. 'Use more, waste less' and 'Stop Wasting Food'	Systems thinking integrated in curricula Further pilot projects to demonstrate circular economy potential to businesses
COLLABORATION PLATFORMS	• Green Industrial Symbiosis programme • Four new partnerships (food, textile, construction and packaging) as part of the Danish Waste Prevention Strategy • Rethink Resources, an innovation centre to support resource efficiency in companies • 'Genbyg Skive' pilot project to re-use building materials to create business opportunities and reduce waste	-
BUSINESS SUPPORT SCHEMES	• Fund for Green Business Development (EUR 27m 2013–2018) to support innovation and new business models • Maabjerg Energy Concept (MEC) bio-refinery part funded by Innovation Fund Denmark (EUR 40m)	Dutch 'Green Deal' inspired programme to provide on-demand support to companies in implementing circular economy opportunities
PUBLIC PROCUREMENT & INFRASTRUCTURE	• Government Strategy on Intelligent Public Procurement contains initiatives to support circular procurement practices • Strategy on waste prevention also contains an initiative to develop guidelines for circular public procurement	Guidelines on the circularity of materials and products integrated into public procurement policy
REGULATORY FRAMEWORKS	• Ambitious energy efficiency and GHG emissions targets, e.g. 40% GHG reduction by 2020 vs. 20% at EU level, • Ambitious targets for recycling/incineration/landfill, updated every 6 years, e.g. recycle 50% of household waste by 2022 • Taskforce for increased resource efficiency to review existing regulations affecting circular economy practices	New metrics introduced to measure economic performance, e.g. complements to GDP such as natural capital Engagement at EU level to adapt existing or introduce new regulations relevant to the circular economy, e.g. product policy
FISCAL FRAMEWORKS	• Taxes on extraction and import of raw materials, vehicle registration and water supply • High and incrementally increased taxes on incineration / landfill to promote recycling and waste prevention • Highest energy taxes in Europe (70% above EU27) and CO2 taxes • Tax cuts designed to promote use of low-carbon energy	Investigation into effects of tax shift from labour to resources

SOURCE: European Commission, Tax reforms in EU Member States 2013; IEA, Energy Policies of Denmark: 2011 review; Nordic Council of Ministers, The use of economic instruments in Nordic environmental policy 2010-2013; Danish legislative council, Waste management policy in Denmark, 2014; The Ex'Tax project, New era. New plan. Fiscal reforms for an inclusive, circular economy, 2014

Figure 9: Potential contribution of the circular economy to 'common' policymaker ambitions

Direct effect

Indirect effect

EU STRATEGIC POLICY OBJECTIVES FOR 2020	POTENTIAL CONTRIBUTION OF THE CIRCULAR ECONOMY
EMPLOYMENT • 75% of the 20–64 year olds to be employed	• Could create growth[1] and employment[2] • Potential increase in labour-intensive activities such as remanufacturing and regenerative agriculture
RESEARCH AND DEVELOPMENT • 3% of the EU's GDP to be invested in R&D	• Could uncover innovative business opportunities that need new technologies • Likely higher demand for breakthroughs in for instance the materials sciences and bio-sciences
CLIMATE CHANGE AND ENERGY • GHG emissions 20–30% below 1990 • 20% of energy from renewables • 20% increase in energy efficiency	• Shift to renewable energy • Reduced industrial GHG emissions due to lower levels of virgin material extraction, reduced energy intensity (e.g. remanufacturing, increased asset utilisation)
EDUCATION • Reduce rate of early school leaving below 10% • At least 40% of 30–34 year olds completing third-level education	• No demonstrated direct effect on this specific target • Systems thinking could make education more appealing and can prepare students for labour markets that prize creativity
FIGHTING POVERTY AND SOCIAL EXCLUSION • At least 20m fewer people in or at risk of poverty and social exclusion	• No demonstrated direct effect on this specific target • Potential to increase household disposable income[1] • Potential for more local community-based enterprises and increased levels of sharing

1 The Growth Within report finds that in the EU a circular economy scenario in 2030 leads to a reduction in GHG emissions of 25% compared to the baseline, while increasing GDP by 6.7% and household disposable income by 10%. Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).
2 The Study on modelling of the economic and environmental impacts of raw material consumption by Cambridge Econometrics / Biointelligence Service / EC (2014) finds that in the EU resource productivity could generate 2 million jobs by 2030.

impact of resource extraction and use, or the scarcity of required resources, could be taken into account. An additional, pragmatic dimension could be the sectors' relative receptiveness to the circular economy.

A semi-quantitative approach to score these sub-dimensions and aggregate them into overall scores for sectors' role in the national economy and circularity potential was used in the Denmark pilot, and can be useful for other countries. As the availability of quantitative data for sub-dimensions may vary and it might be desired to use sub-dimensions that cannot be evaluated quantitatively, it can be useful to express each dimension as an aggregate, semi-quantitative 'score' of normalised scores from each sub-dimension. Each sub-dimension is thus evaluated quantitatively or semi-quantitatively,[55] based on the nature of the underlying data. The final result of the sector evaluation for the Denmark pilot is visualised in Figure 11 where the top-right quadrant guides the final selection.

A good starting point to conduct the sector selection is to consider the producing sectors[56], as they typically have the largest direct material footprint. This already narrows down the scope of the exercise – the producing sectors in Denmark, for example, represent 24% of the Danish economy.[57] It can also be useful to look at non-producing sectors that are large consumers of resources. As can be seen in Figure 11, the 'hospitals' sector was included in the Denmark pilot since it is an important consumer of resources. In addition, it is mainly public sector owned, which allowed to investigate opportunities in public procurement – important in an economy where the public sector represents

Figure 10: Measuring the circular economy – initial suggestions from *'Growth Within'*

	PRIMARY METRIC	SECONDARY METRICS
Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows	**Degradation-adjusted net value add (NVA)[1]**	• **Annual monetary benefit of ecosystem services, e.g. from biodiversity and soils** • **Annual degradation** • **Overall remaining stock**
Optimise resource yields by circulating products, components and materials at the highest utility at all times in both technical and biological cycles	**GDP generated per unit of net virgin finite material input[2]**	• **Product utilisation** • **Product depreciation/lifetime** • **Material value retention ratio (energy recovery, recycling and remain industry)/value of virgin materials (rolling net average last five years)**
Foster system effectiveness by revealing and designing out negative externalities	**Total cost of externalities and opportunity cost**	• **Cost of land, air, water, and noise pollution** • **Toxic substances in food systems** • **Climate change, congestion, and health impacts**

1 The System of Environmental-Economic Accounting, 2012.
2 Adapted based on the EU's Resource Efficiency Scoreboard (Eurostat, 2014). The adaptation is to deduct recovered materials and only include finite materials.
SOURCE: Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

55 This could for example be a numerical, 'traffic-light'-based ranking, or a product of several numerical rankings.

56 Producing sectors include agriculture, forestry and fishing; mining and quarrying; construction; electricity and gas; manufacturing

57 Statistics Denmark, based on gross value added 2011

26% of the national economy.[58] Another non-producing candidate that could be considered is the transport sector – one of the top energy consumers in any country.

As seen from Figure 11, the food and beverage, construction and real estate, machinery, and hospitals sectors were prioritised based on the assessment of their role in the national economy and the circularity potential. Four key insights resulted from this analysis:

- The economic size of a sector is not the only factor for the 'score' on the 'role in national economy' dimension. Consider construction and real estate versus mining and quarrying. Both sectors have similar contributions to national gross value added and trade, but the construction sector has grown by twice the rate of mining and quarrying over the past 10 years, and employs nearly 30 times more people.

- The 'circularity potential' dimension takes into account not only total resource consumption and waste generation, but also the potential to avoid and/or valorise that waste. For example, mining and quarrying has the lowest score since initial analysis indicated that there is little dependence on other raw materials, little intrinsic value of the materials handled (since mining is generally the first stage in a value chain), limited avoidable waste generated, and a small potential value to valorise the waste. In contrast, the construction sector has a high raw material dependence and handles materials with high intrinsic value, while generating significant volumes of waste that are deemed feasible to further valorise through circular activities.

- The resulting matrix is only a guide to the sector prioritisation – there is always a judgement call involved in the final selection.

- In addition to sectors, it is also possible to consider other important contributors to resource consumption and waste in the economy, especially from a consumer point of view. Packaging was included as a fifth focus sector[59] in the Denmark pilot since it represents a formidable challenge in terms of reducing the resource footprint of consumer and other goods.

While most data needed to assess the role in the national economy can be found in national statistical databases, assessing the 'circularity potential' relies more heavily on expert opinion and judgement. Assessing the 'circularity potential' will require a first round of interviews with sector experts and consultation of previous reports (such as the Denmark findings in this report, and the reports mentioned in Table 1 in Part 1). To structure the assessment of the scope for improved circularity, inspiration can also be taken from the ReSOLVE framework laid out in Chapter 1.1. Figure 12 in Section 2.2.2 provides an indicative overview of which ReSOLVE circularity action areas could be worth further investigation in different sectors.

It is useful to consider the sectors as 'anchor sectors' for their respective value chains. This means that subsequent opportunity analysis would also look at a focus sector's supply chain and customers.[60] For example, in the Denmark pilot, the selection of the anchor sector 'Food & Beverage processing', also involved an analysis of the consumer side to address the issue of avoidable food waste. An alternative to the selection of 'anchor sectors' is the direct selection of full value chains. The Netherlands Organisation for Applied Scientific Research (TNO), Circle Economy and MVO Nederland developed an approach for such a value-chain selection mechanism, and is currently applying it to the Dutch economy.

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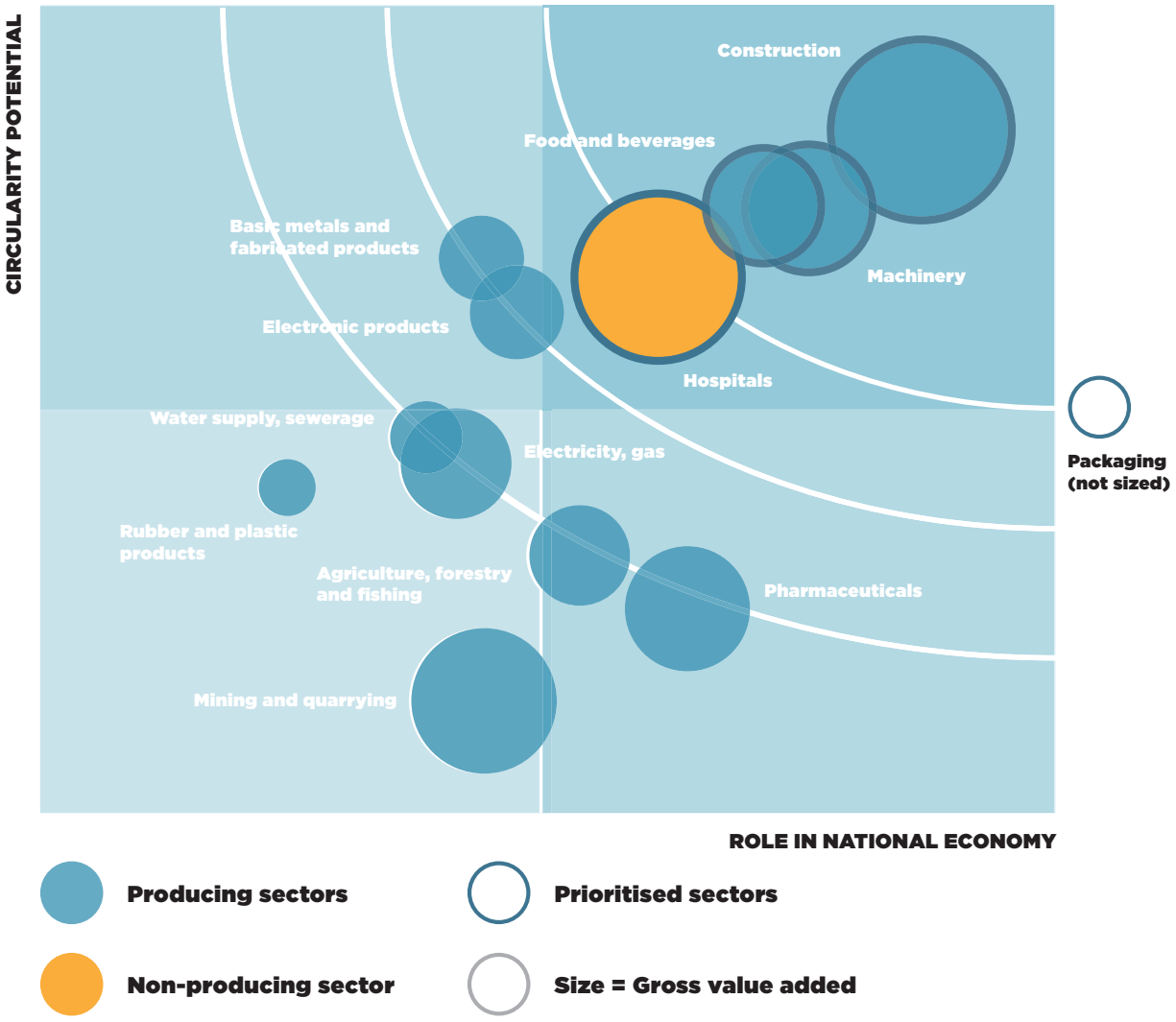
58 Statistics Denmark

59 While not technically a sector, 'packaging' is referred to as a focus sector throughout the rest of the document.

60 This perspective also allows the evaluation of opportunities within 'non-producing' sectors, as part of the anchoring sector's value chain.

Figure 11: Results of sector prioritisation in Denmark pilot



NOTE: Only producing sectors (24% of national GVA) and hospitals (3.5% of national GVA) considered
SOURCE: Statistics Denmark (2011 data); Danish Business Authority; Danish Environmental Protection Agency; Ellen MacArthur Foundation circular economy team

2.2 Assess sector opportunities

Once the focus sectors have been selected, the sector-specific assessment can begin. This step can be conducted in parallel sector working groups, and heavily relies on the involvement of businesses. The most relevant circular economy opportunities need to be mapped (Section 2.2.1) and prioritised (Section 2.2.2). For the prioritised opportunities, sector-specific economic impact needs to be assessed (Section 2.2.3), barriers limiting their realisation identified (Section 2.2.4) and policy options to overcome these barriers mapped (Section 2.2.5).

The different sector deep dives can be conducted in parallel by one central project team, or managed by individual project managers or small teams. The project team(s) in this step should have disposal of strong business analysis skills and circular economy expertise, including the ability to understand value chains, facilitate discussions with businesses and perform sector-specific quantification of economic impact. Prior experience in circular economy is an important success factor especially for the mapping and prioritisation of circular economy opportunities described in Sections 2.2.1 and 2.2.2. Policy analysis skills are required for the mapping of policy options. In the Denmark pilot, in total, around 25 man-months (5 to 10 persons over a period of 4 months) were dedicated to this step.

For this step, it is crucial to intensively engage businesses from the focus sectors and their value chains, in order to:

- Get insights and knowledge to identify the most relevant circular economy opportunities and barriers in each focus sector.
- Create early alignment on a common direction for the country and the focus sectors.
- Further demonstrate circular economy benefits to businesses and build capabilities.

It can be helpful to engage a diverse group of businesses, as perspectives on opportunities and perception of barriers may differ between businesses even within one sector based on the business size, business model, product focus and prior experience with circular business initiatives. Engaging selected businesses from other countries where relevant in addition to the focus domestic businesses can help capture international best practices. Industry associations, academics, consumers and other society stakeholders are also relevant to involve at this point.

Practically, a mix of individual interviews and sector working sessions is likely to be helpful. Individual interviews work well to capture detailed input on opportunities and barriers. Bringing businesses together in sector and value chain (and, to a lesser extent, cross-value chain) working sessions can complement individual interviews by providing a forum to jointly align on the way forward, and to create a strong network of businesses dedicated to accelerate the transition towards the circular economy. Ideally this network does not simply help to identify opportunities and barriers in the project itself, but continues to exist as a standalone network where circular economy frontrunners can exchange best practices and find partners for circular business opportunities.

The Denmark pilot included a series of 90-minute phone interviews with over 25 individual businesses, complemented with an in-person joint working session format that built upon the existing Danish circular economy network ‘Cirkulær økonomi’, led by Ida Auken, Member of Danish Parliament, member of the World Economic Forum Meta-Council on the Circular Economy 2014-2016, and former Danish Minister for the Environment.

2.2.1 Map circular economy opportunities in each focus sector

Objective:	**Create exhaustive overview of possible circular economy opportunities, to be prioritised in Section 2.2.2.**
End product:	**Structured map of potential circular economy opportunities for each focus sector, identified along the ReSOLVE framework.**

The circular economy covers many types of opportunities that can differ significantly by sector and country. It can therefore be helpful to systematically map potential opportunities in each sector before proceeding to prioritise among these opportunities.

The ReSOLVE framework laid out in Chapter 1.1, offers a structure for such a systematic screening of opportunities.[61] Using the ReSOLVE framework to identify and map opportunities involves an iterative exercise that begins with a high-level mapping for each focus sector derived from existing circular economy literature, including the reports listed in Table 1 (in Part 1) and the findings for Denmark listed in Part 3. Thereafter it can be helpful to reach out to sector stakeholders and experts to refine this overview to ensure that the mapping covers all relevant opportunities.

As the purpose of the mapping exercise is to create an overview of opportunities by sector, not to fully detail all these opportunities, the exercise can be conducted relatively quickly.

2.2.2 Prioritise and detail circular economy opportunities

Objective:	**Prioritise and detail opportunities in each focus sector based on potential impact**
End product:	**Set of (one to three) prioritised and detailed opportunities per sector.**

The systematic screening of opportunities described above can result in a large number of possible opportunities for each focus sector. To guide further analysis, these opportunities need to be prioritised. The prioritised opportunities can then in turn be detailed and assessed in terms of sector-specific impact (Section 2.2.3), barriers (Section 2.2.4) and policy options (Section 2.2.5).

Prioritising and detailing the opportunities is, together with the two following analyses (quantifying the value and identifying the barriers in Sections 2.2.3 and 2.2.4), the part of the methodology that probably entails most involvement of businesses. While the project team can make proposals based on literature review and international best practices, only businesses can provide input grounded in local business reality on what the opportunities could exactly look like.

PRIORITISATION

The expected impact is likely the best guide for an initial prioritisation of opportunities. A classical impact-feasibility prioritisation approach could also be used, but it can be easier to only assess potential impact (and not feasibility) at the start of the process, when the understanding of the opportunities is least advanced. In the Denmark pilot, for example, it quickly became clear that 3D printing of building modules could have a significant impact in the construction sector (see Chapter 3.3 for more details). It was however much harder to assess its feasibility without more detailed analysis.

A simple, qualitative scoring mechanism to rank the circular economy opportunities can be used. Figure 12 shows an indicative prioritisation based on economic and resource impact of the different action areas in the ReSOLVE framework for 20 major sectors

61 Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

in Europe. While this table should not be regarded as the final say on where potential can be found, it can give a first indication to guide the effort. The Denmark pilot used a qualitative, five-tiered ranking to prioritise up to three opportunities per sector. Figure 13 shows an example mapping for the Construction & Real Estate sector in the Denmark pilot.

When ranking the opportunities, it is important to not only consider the action areas as individual, decoupled parts, but also to keep in mind their systemic effects. In packaging, for example, focusing on objectives such as light weighting ('optimise') using composite/ multi-layered polymer/fibre/metal materials without consideration of the full life-cycle of the packaging (explicitly at the end of use) can lead to a significantly reduced potential for recyclability ('loop'). Impacts can even extend across sectors – for example, wrapping cucumbers in a plastic film increases the amount of plastic waste, but can increase the cucumbers' shelf life from three to 14 days,[62] which is an important lever in avoiding food waste.

DETAILING THE OPPORTUNITIES

Prioritising and detailing the opportunities happens in an iterative process – understanding the opportunities to a certain extent is required to rank, but prioritisation is required to determine which opportunities need to be fully detailed.

To make the opportunities concrete and tangible, it can be helpful to zoom in on a specific part or a few specific products within a value chain. For example, in the Denmark pilot, analysis in the machinery sector was focused on two of its key products: pumps and wind turbines. It can also be helpful to assess how they can be implemented using the four building blocks of the circular economy, described in the first *Towards the Circular Economy* report and briefly summarised below:

- **Circular design,** i.e. improvements in materials selection and product design (standardisation/ modularisation of components, purer materials flows, and design for easier disassembly), which lie at the heart of the circular economy.
- **Innovative business models,** especially changing from ownership to performance- based payment models, which are instrumental in translating products designed for reuse into attractive value propositions.
- **Core competencies along reverse cycles and cascades,** which involve establishing cost-effective, better-quality collection and treatment systems (either by producers themselves or by third parties).
- **Enablers for improving cross-cycle and cross-sector performance** which are factors that support the required changes at a systems level and include higher transparency for materials flows, alignment of incentives, and the establishment of industry standards for better cross-chain and cross-sector collaboration. Other aspects are access to financing and risk management tools and infrastructure development.

As an example, consider the remanufacturing opportunity identified in the machinery sector in the Denmark pilot. It belongs to the 'Loop' action area of ReSOLVE. It involves at least three circular economy building blocks: design for disassembly and remanufacturing, performance business models that allow the manufacturer to retain ownership over the products, and reverse cycles to return and remanufacture the products.

DEFINING SCENARIOS

To ensure a consistent ambition level when detailing the opportunities, it can be helpful to define the time horizon and the overall scenarios in which these opportunities are

62 According to the Cucumber Growers Association, this requires 1.5 g of packaging. Other studies have found that shrink-wrapped apple trays reduce wastage by 27%, with similar results for potatoes and grapes. See, for example, Levitt, S. D. & Dubner, S. J., *When to Rob a Bank: A Rogue Economist's Guide to the World* (2015).

assessed. A short-term and long-term time horizon can be defined to identify tangible near-term opportunities as well as more ambitious, longer-term potential. Ideally, the selected time horizons align with other strategic national or international targets and initiatives. The scenarios can include a view on how society is expected to have evolved, at the selected time horizons, in terms of technology, customer behaviour, and other frame conditions.

In the Denmark pilot, a short-term scenario of five years (2020) and a long-term scenario of 20 years (2035) were selected. The year 2035 was selected to illustrate as much of the full potential of circular activities as possible, without going so far out that businesses and other stakeholders would find it hard to assess concrete opportunities. The related circular economy scenarios were defined relatively conservatively – for example, only relying on technologies that are today already at late R&D or early commercial stage. See Appendix B for additional details.

2.2.3 Quantify sector impact

Objective:	**Understand the economic (and resource) impact of circular economy opportunities, either as input to an economy-wide assessment (see Section 2.3.1) or as a standalone result.**
End product:	**Quantified impact for each opportunity and circular economy scenario (where applicable).**

To build the case for business action and potential policy interventions, the economic impact of each prioritised circular economy opportunity needs to be assessed. This section describes a tool to conduct this impact quantification for individual opportunities. The ambition level for the quantification exercise needs consideration before the exercise is initiated – while understanding the impact is important to help mobilise business and build the case for policy intervention, the related (potentially high) resource demands needs to be balanced with that of the other steps from the toolkit.

This sector-specific quantification can be a goal in itself, or serve (as was the case in the Denmark pilot) as further input for the economy-wide impact quantification described in Section 2.3.1. In the latter case, calculations should be performed with a sufficient level of detail to be able to convert to the input-output tables needed in the CGE or other type of economy-wide impact assessment model (see Section 2.3.1 for further details).

While economic impact is a natural first choice of metrics to make the case for the circular economy, other metrics such as resource savings and greenhouse gas emissions can also be taken into account. In the Denmark pilot, resource savings were estimated for two key materials (steel and plastics) and the change in CO_2 footprint was modelled in the economy-wide modelling step (see Section 2.3.1).

Figure 14 shows an overview of a possible quantification methodology, illustrated in the form of a driver tree. While the details typically need to be adjusted for each opportunity, the driver tree offers a useful structure for the quantification. The core of this approach is to zoom in on specific sub-sectors or even products (branch A of the driver tree), and consequently *scaling up* the impact found in these sub-sectors or products to the full sector and adjacent sectors (branch B of the driver tree). The advantage of this approach is that it makes the analysis tangible, and allows businesses to provide specific input. Other approaches are possible as well.

Branch A. Net value created in deep dive sub-sector. The net value creation is defined as a product of the overall adoption rate of the circular economy opportunity, the number of 'units' addressed, and the net value created per unit.

- **Adoption rate.** The adoption rate is a quantitative answer to the question 'How widely will this opportunity have been adopted in a circular scenario?' where 100% means full realisation of the potential. In the Denmark pilot, the adoption rates were always expressed as a difference between the circular scenario (2035

Figure 12: Indicative prioritisation of ReSOLVE action areas for 20 sectors in Europe

ECONOMIC ACTIVITIES	REGENERATE	SHARE	OPTIMISE	LOOP	VIRTUALISE	EXCHANGE
Information & communication services, media and telecommunications	MIDDLE	LOW	HIGH	MIDDLE	HIGH	MIDDLE
Scientific R&D, other professional, scientific & technical activities	MIDDLE	LOW	LOW	MIDDLE	HIGH	MIDDLE
Education	MIDDLE	LOW	LOW	MIDDLE	HIGH	MIDDLE
Human health and social work activities	MIDDLE	LOW	LOW	MIDDLE	HIGH	MIDDLE
Administrative & support services	MIDDLE	LOW	LOW	MIDDLE	HIGH	MIDDLE
Arts, entertainment and recreation	MIDDLE	LOW	LOW	MIDDLE	HIGH	MIDDLE
Financial and insurance activities	MIDDLE	LOW	LOW	MIDDLE	HIGH	MIDDLE
Legal & accounting head offices, consulting, architecture & engineering, TIC	MIDDLE	LOW	LOW	MIDDLE	HIGH	MIDDLE
Distributive trades (incl. wholesale and retail trade)	HIGH	HIGH	LOW	LOW	HIGH	LOW
Manufacture of wood and paper products, and printing	HIGH	HIGH	LOW	MIDDLE	HIGH	MIDDLE
Public administration and defence; compulsory social security	MIDDLE	HIGH	LOW	LOW	HIGH	LOW
Real estate activities	MIDDLE	HIGH	LOW	MIDDLE	LOW	MIDDLE
Manufacturing of textiles, apparel, leather and related products	HIGH	HIGH	LOW	MIDDLE	LOW	LOW
Construction	MIDDLE	HIGH	HIGH	HIGH	LOW	LOW
Manufacturing of transport equipment	MIDDLE	HIGH	LOW	HIGH	HIGH	LOW
Manufacturing of furniture	HIGH	HIGH	LOW	LOW	MIDDLE	MIDDLE
Water supply, waste & remediation	HIGH	LOW	LOW	MIDDLE	MIDDLE	LOW
Manufacturing of elec. equipment, computer, electronic and optical products	MIDDLE	LOW	LOW	HIGH	LOW	LOW
Manufacturing of machinery and equipment	MIDDLE	LOW	LOW	HIGH	LOW	LOW
Manufacturing of rubber, plastics, basic and fabricated metal products	LOW	LOW	LOW	HIGH	MIDDLE	HIGH
Transportation and storage	MIDDLE	LOW	LOW	HIGH	MIDDLE	HIGH
Agriculture, forestry and fishing	HIGH	MIDDLE	LOW	MIDDLE	MIDDLE	HIGH
Manufacturing of food, beverages and tobacco products	HIGH	MIDDLE	LOW	HIGH	MIDDLE	HIGH
Mining and quarrying	MIDDLE	MIDDLE	LOW	HIGH	MIDDLE	HIGH
Electricity, gas, steam and air-conditioning supply	HIGH	MIDDLE	LOW	LOW	HIGH	HIGH
Manufacturing of coke, refined petroleum, chemicals products	MIDDLE	MIDDLE	LOW	LOW	MIDDLE	HIGH
Manufacturing of pharmaceuticals, medicinal chemical, botanical products	LOW	MIDDLE	HIGH	LOW	MIDDLE	LOW
Accommodation and food service activities	LOW	HIGH	HIGH	LOW	LOW	MIDDLE

SOURCE: Adapted from Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

Figure 13: Qualitative assessment of potential of opportunities for the Construction & Real Estate sector in the Denmark pilot

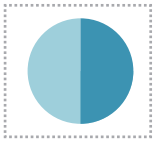
QUALITATIVE ASSESSMENT OF POTENTIAL

REGENERATE		• Use of biological elements in architecture (e.g. 'living roofs' that purify water) • Return of organic construction material to biosphere

SHARE		• Sharing of floor space reducing demand for new buildings
		  • Shared residential floor space (e.g. Airbnb, Couchsurfing, Hoffice)
		  • Shared office space (e.g. Liquidspace) and increase of desk sharing policies
		• Increased use of under-utilised buildings
		  • Multi-purposing of offices and public buildings for better utilisation
		  • Re-purposing of building interiors to increase lifetime of existing buildings

OPTIMISE		• Coordination of all stakeholders along value chain to reduce structural waste • Energy use optimisation through low-energy houses and smart homes

LOOP		• Increased reuse and high-value recycling of building components and materials, enabled by
		  • Designing buildings for disassembly
		  • New business models (e.g. other owner of materials than property owner)
		  • Building passports/signatures and reverse logistics ecosystems

VIRTUALISE		Increased teleworking to reduce need for office floor space
EXCHANGE		Modular production off-site for rapid assembly on-site 3D printing of building components

SOURCE: Ellen MacArthur Foundation circular economy team

and 2020 horizons) and a 'business as usual' scenario (where some adoption rate is typically also greater than zero). This allows the model to take into account that circular economy opportunities will probably be adopted to some extent even in a non-circular scenario.

- **Number of units in deep dive sub-sector.** The number of units is used to denote any quantity used as the basis of the quantification in the subsector. The unit could be (an estimated) number of products, or a volume of material flow (such as tonnes of organic waste). It could also be a monetary unit, such as 'value of purchased goods' or 'output of new buildings'.

- **Net value created per unit.** Circular activities bring two kinds of direct financial benefits to businesses: (i) cost savings from materials, components or labour (for example due to parts recovery or virtualisation), and (ii) increased revenues (from additional sales and/or a higher unit price). Additional costs include increased labour costs, increased material/component costs (for example to design more robust products), and increased energy and capital expenditure, for example to set up bio-refineries or remanufacturing plants. These elements can all be assessed separately (as was done in the Denmark pilot), or, alternatively, for a high-level estimate, in one value (e.g. 5% net cost savings per unit). They can also be assessed for consumers rather than businesses (as in, for example, the reduction of avoidable food waste).

Branch B. Scale-up factor. The scale-up factor is used to bring the net impact estimated for the deep-dive sub-sector to the full sector (and adjacent sectors). The calculation is driven by the relative size of the adjacent sub-sectors compared to the deep dive sub-sector, and a 'scalability' factor introduced to reflect the relative applicability of the circular economy opportunity in different sub-sectors. The final scale-up factor is the sum of each individual scale-up factor for all sub-sectors present.

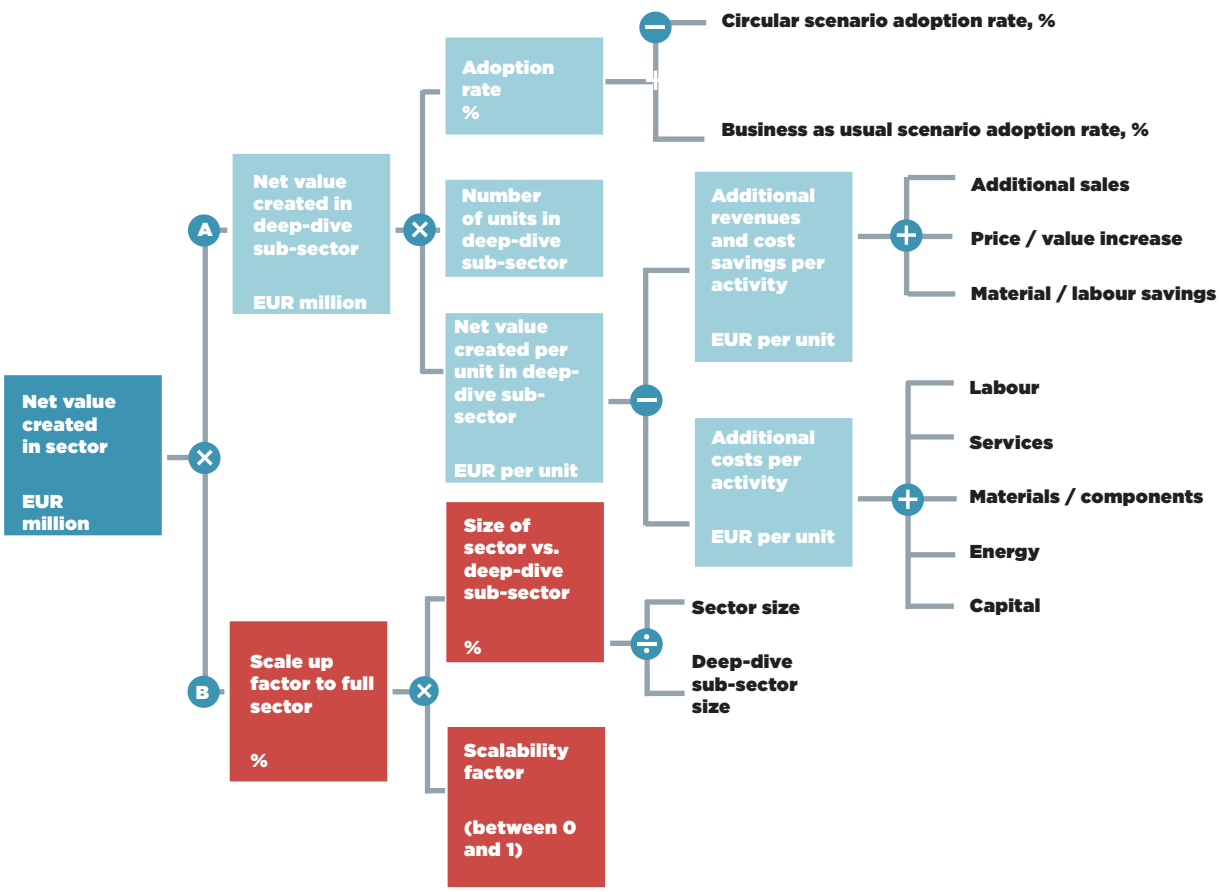
- **Relative size of sub-sector.** This calculation is based on the relative economic size of the individual sub-sectors, for example calculated by comparing output or gross value added.

- **Scalability factor.** This value, set between 0 and 1, is introduced to adjust the scaling based on how applicable an opportunity is to an adjacent sub-sector compared to the deep-dive subsector. For example, a scalability factor of 0.2 means that the impact is estimated to be 20% of the impact estimated for the deep-dive sub-sector.[63]

As in any modelling exercise, the hardest part is not to define the structure of the model, but to find good data to feed into the model. Here it is crucial to engage businesses to provide input on the key quantification assumptions. Practically, in the Denmark pilot, the key quantification assumptions were tested with businesses while detailing out the circular economic opportunities (see previous section). Existing reports such as the reports listed in Part 1 and the results from the Denmark pilot in Part 3 of this report can also be a useful source of information. Industry associations, public bodies and statistical authorities can help complete the picture. Finally, no matter how diligently the data gathering and impact quantification is carried out, predicting the impact of circular economy opportunities on multi-year time frames will always at best be a well-informed estimate that relies on important assumptions.

63 Technically, it is of course possible to set scalability factors to more than 1, if it is assumed that the circular economy opportunities are in fact larger in an adjacent sector. This was not done in the Denmark pilot.

Figure 14: Schematic overview of sector-specific impact quantification



SOURCE: Ellen MacArthur Foundation circular economy team

2.2.4 Identify barriers

Objective:	**Understand the barriers standing in the way of the identified circular economy opportunities, in order to render policy options (Section 2.2.5) more targeted.**
End product:	**Importance and description of barriers for each opportunity, structured by 15 types of barriers in four categories (economic, market failures, regulatory failures, social factors).**

Once the circular economy opportunities have been prioritised, it is time to look at the barriers that stand in their way. The toolkit provides a framework to categorise these barriers and analyse their severity. Careful analysis of barriers forms the basis for the next step of arriving at targeted policy options.

The approach in this toolkit is to combine a standard analysis of market failures and regulatory failures with social factors and the economic concerns of business. The methodology refers to 15 types of barrier in four categories. It starts with the economic concerns of businesses that are assessing these opportunities: profitability, capital and technology. It includes the two 'classic' barrier categories from economic theory, market failures and regulatory failures, split into ten types, drawing heavily on the *EU Impact*

Figure 15: Example of barrier analysis for opportunity 'sharing and multi-purposing of buildings' in Denmark pilot

	BARRIER	IMPORTANCE	DESCRIPTION / COMMENTS
ECONOMICS	Not profitable for businesses[1] even if other barriers are overcome		N/A
	Capital intensive and/or uncertain payback times		N/A
	Technology not yet available at scale at a cost effective level		N/A
MARKET FAILURES	Externalities (true costs) not fully reflected in market prices		N/A
	Insufficient public goods / infrastructure[2] provided by the market or the state		N/A
	Insufficient competition / markets leading to lower quantity and higher prices than is socially desirable		N/A
	Imperfect information, for example asymmetric or high cost information, that negatively affects market decisions		Not always clear to building owners and tenants whether sharing is profitable net of costs (e.g. related to safety)
	Split incentives (agency problem) when two parties to a transaction have different goals and levels of information		N/A
	Transaction costs such as the costs of finding and bargaining with customers or suppliers		It is costly (including in time) for building owners and tenants to find other individuals or organisations to share their building with
REGULATORY FAILURES	Inadequately defined legal frameworks that govern areas such as the use of new technologies		Unclear rules and regulations related to e.g. taxation, creating uncertainty for parties that want to engage in sharing
	Poorly defined targets and objectives which provide either insufficient or skewed direction to industry		N/A
	Implementation and enforcement failures leading to the effects of regulations being diluted or altered		N/A
	Unintended consequences of existing regulations that hamper circular practices		Contractual restrictions exist on tenants sub-letting their houses or flats for less than a year and there is concern that companies such as Airbnb can start to turn residential areas into 'hotel areas'
SOCIAL FACTORS	Capabilities and skills lacking either in-house or in the market at reasonable cost		N/A
	Custom and habit: ingrained patterns of behaviour by consumers and businesses		There is an inherent resistance to change habits around housing, such as sharing/renting out, and there are also deeply rooted norms and traditions around the use of offices

Critical barrier ('make or break')

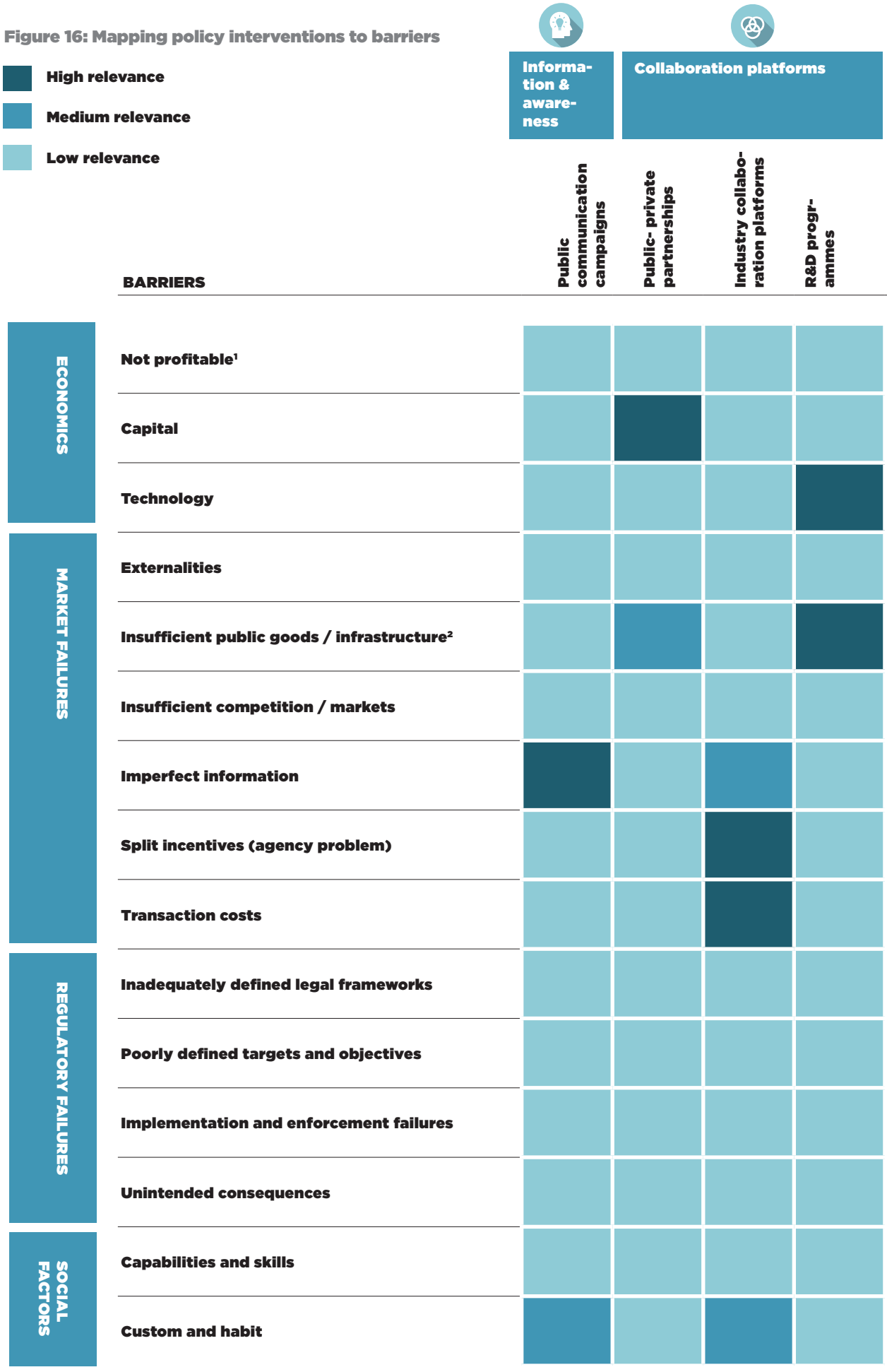
Very important barrier (to scale-up / acceleration of lever)

Important barrier (to scale-up / acceleration of lever)

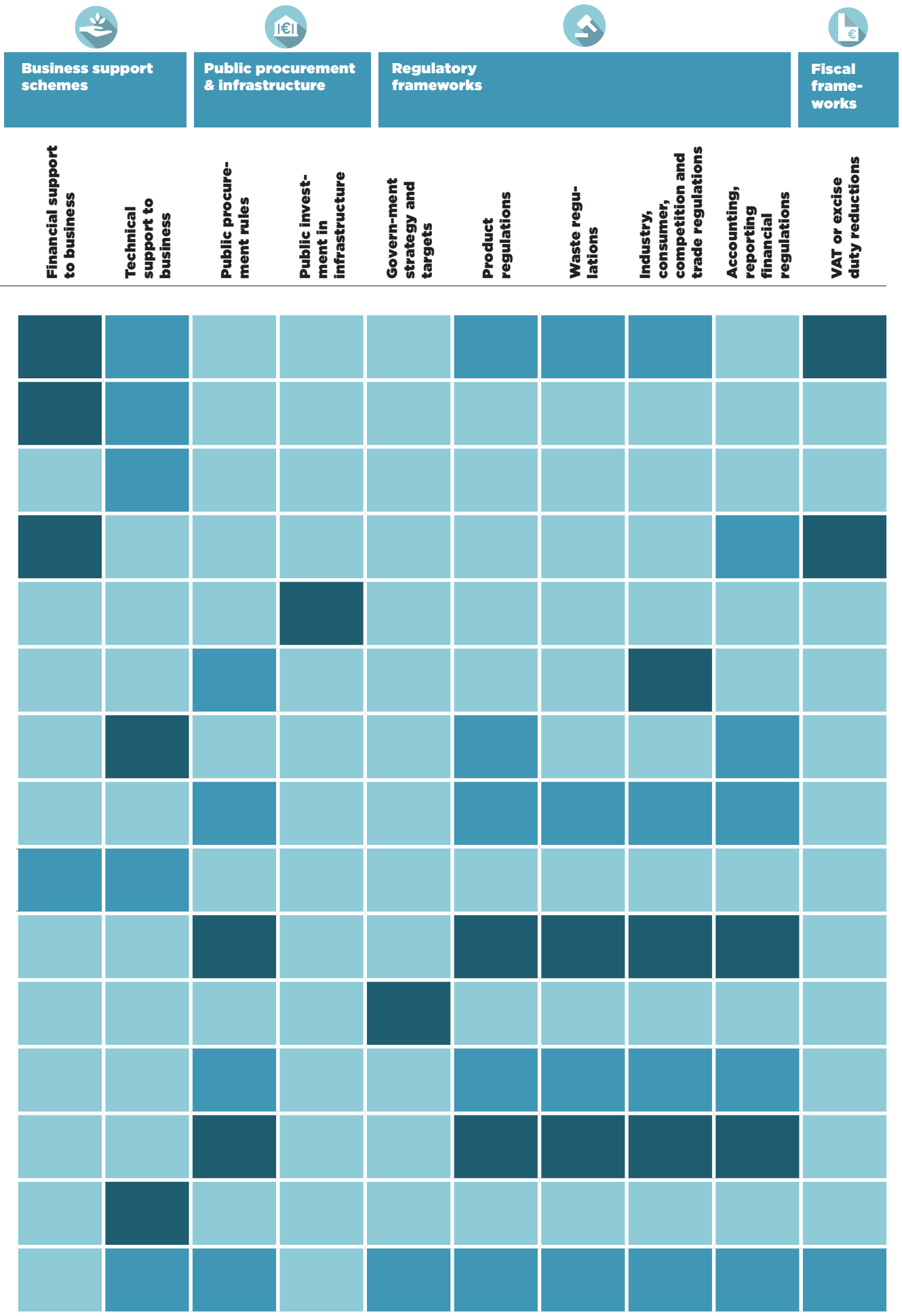
Limited or no barrier

1 At market prices excluding the full pricing of externalities such as greenhouse gas emissions, ecosystem degradation and resource depletion
2 Infrastructure defined as fundamental physical and organizational structures and facilities, such as transportation, communication, water and energy supplies and waste treatment

Figure 16: Mapping policy interventions to barriers



1 At market prices excluding the full pricing of externalities such as greenhouse gas emissions, ecosystem degradation and resource depletion
2 Infrastructure defined as fundamental physical and organizational structures and facilities, such as transportation, communication, water and energy supplies and waste treatment


Business support schemes
Public procurement & infrastructure
Regulatory frameworks
Fiscal frame-works
Financial support to business
Technical support to business
Public procure-ment rules
Public invest-ment in infrastructure
Govern-ment strategy and targets
Product regulations
Waste regu-lations
Industry, consumer, competition and trade regulations
Accounting, reporting financial regulations
VAT or excise duty reductions

Assessment Guidelines.[64] Finally, even in the absence of the first three barrier categories, social factors – the fourth barrier category – can stand in the way, particularly in the case of circular economy opportunities that involve new business models or other far-reaching changes to established practices. The barriers are explained below and an example of the framework in use in the pilot study in Denmark is given in Figure 15.

Economic

- **Not profitable** for businesses even if other barriers are overcome.
- **Capital** intensive and/or uncertain payback times.
- **Technology** not yet available at scale.

Market failures

- **Externalities** (full costs to society) not fully reflected in market prices.
- **Insufficient public goods/infrastructure**[65] provided by the market or the state.
- **Insufficient competition/markets** leading to lower quantity and higher prices than is socially desirable.
- **Imperfect information** that negatively affects quality of market decisions, such as asymmetric information.
- **Split incentives (agency problem)** when two parties to a transaction have different goals.
- **Transaction costs** such as the costs of finding and bargaining with customers or suppliers.

Regulatory failures

- **Inadequately defined legal frameworks** that govern areas such as the use of new technologies.
- **Poorly defined targets and objectives** which provide either insufficient or skewed direction to industry.
- **Implementation and enforcement failures** leading to the effects of regulations being diluted or altered.
- **Unintended consequences** of existing regulations that hamper circular practices.

Social factors

- **Capabilities and skills** lacking either in-house or in the market at reasonable cost.
- **Custom and habit:** ingrained patterns of behaviour displayed by consumers and businesses.

Though many of these barriers can be attributed to individual opportunities, some can apply across opportunities in one sector or even across several sectors. An example of such a cross-cutting barrier is unpriced negative externalities, e.g. carbon emissions, that applies to most circular economy opportunities regardless of sector – albeit to

64 European Commission, Impact Assessment Guidelines (and Annexes) (2009).

65 Infrastructure defined as fundamental physical and organisational structures and facilities, such as transportation, communication, water and energy supplies and waste treatment.

a different extent. The regulatory failure of inadequately defined targets also applies across the economy, which is measured primarily by flow metrics such as GDP without taking into account, for example, stocks of natural capital.

Making an assessment such as that illustrated in Figure 15 ideally entails discussions with a wide range of relevant businesses and their representative associations, along with think tanks and academics. Each business will perceive the barriers particular to its line of business, product focus and position in the value chain. To get a rounded picture it is advisable to consult multiple businesses for the focus sector as well as selected businesses along the focus sector's value chains. Industry associations are also important to consult as they have a higher-level perspective on the general barriers and pressures reported by firms across the sector. Barriers relating to the unintended consequence of existing regulations will likely require the most detailed work – the devil is in the details here.

In undertaking the exercise for Denmark it became clear that while many circular economy opportunities have sound underlying profitability, there are often non-financial barriers limiting further scale-up or holding back their development pace. An overview of the barriers to each of the opportunities in the Denmark pilot is provided in Chapter 3.1.

2.2.5 Map sector-specific policy options

Objective:	**Lay out all relevant available policy options to address the barriers identified in Section 2.2.4.**
End product:	**List of policy options for each barrier to each opportunity.**

Once the barriers have been identified for each circular economy opportunity, policymakers can systematically map policy options to overcome them. The sector-specific policy options that are the focus of this Section can be complemented by economy-wide interventions (discussed in Section 2.3.2). Mapping policy options is just a first step and needs to be followed by cost-benefit analysis and prioritisation, packaging and sequencing (detailed in Section 2.3.3), and building the necessary political consensus and momentum for change.

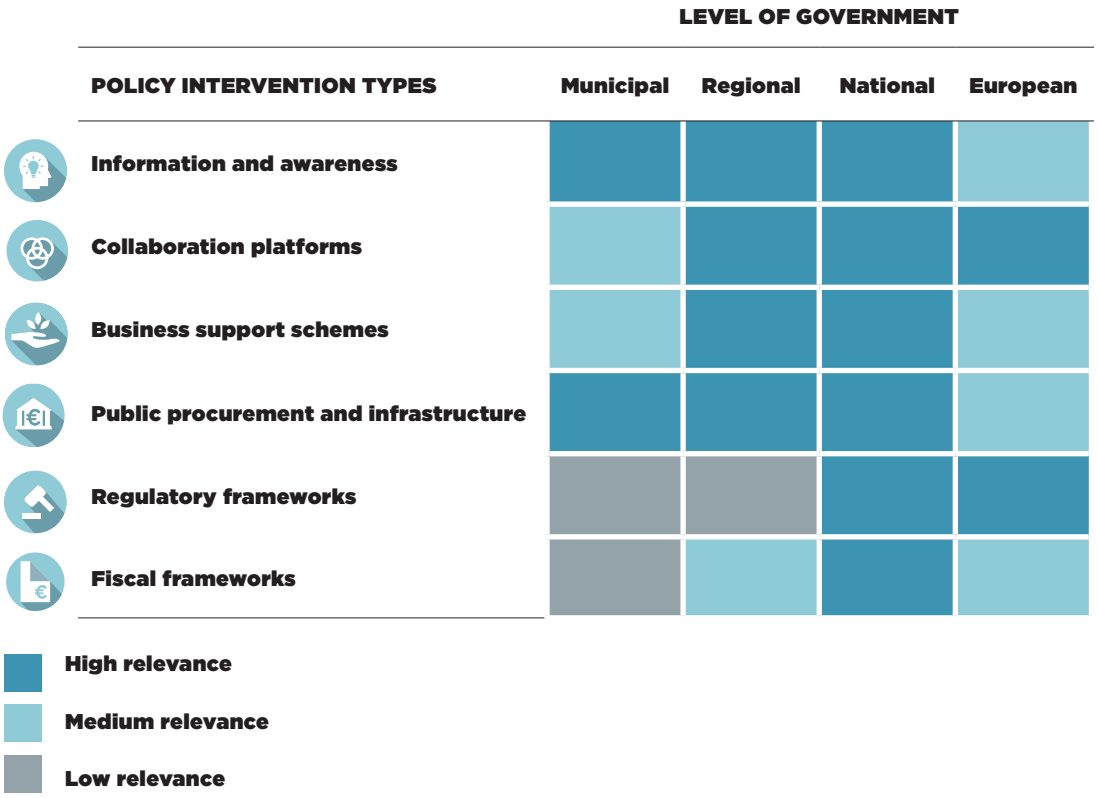
Six types of policy can be useful to enable the circular economy. An overview of these types, with examples of each, is shown in Figure 7. Figure 16 gives a broad, illustrative indication of how these policy interventions could address the barriers – though variations will exist depending on regional and sector specifics.

A first source of inspiration for mapping sector-specific policy options can be found in existing reports about circular economy policy, such as those listed in Table 2 in Part 1, or the policy options listed for the different opportunities for Denmark in Part 3 of this report. Interviewing policymakers who have already implemented circular economy policy in other countries would also be a valuable exercise at this stage, as would another round of interviews with industry stakeholders to gauge their perspective on different policy approaches for specific opportunities. Inspiration could also come from experience in other policy areas: for instance the innovative public-sector-supported financing mechanisms applied to overcome the split incentives barrier to increasing energy efficiency might be applicable. The application of behavioural economics techniques could be useful in taking an experimental, iterative route to finding the right interventions.

While national policymakers have a broad set of policy instruments at their disposal, some interventions require international coordination, especially in a European context.

The regional and municipal level can also play an important role. Figure 17 gives an example indication for the Denmark pilot of how the relevance of the six policy intervention types is broadly distributed among the different government levels.

Figure 17: Policy intervention relevance by level of government in Denmark



DESCRIPTION OF POLICY INTERVENTION TYPES

Information and awareness

Since the concept of the circular economy is still not widely known among the public or in the business community, policy interventions aimed at increasing information and awareness play an important role. These policies aim to change ingrained patterns of behaviour and ways of thinking that companies and individuals have developed over long periods of time. They also seek to plug gaps in information that prevent or restrict circular economy opportunities.

A related barrier is that of imperfect information. Since the circular economy requires business to cooperate across traditional sectoral and functional silos, an understanding of the economic potential and the practicalities is important, and often lacking. An example of targeted information delivery by the public sector is Denmark's Esbjerg municipality where officials inform farmers about agricultural plastics waste during farm inspections as part of the municipal waste management plan.[66] Information and awareness campaigns can be broadcast to the general public, for example the food waste prevention campaign in Catalonia, or provided to consumers through product labelling: South Korea's Eco-label indicates not only the emissions of pollutants associated with the product, but also the conservation of resources through the product's life cycle relative to other products of the same category.[67]

Collaboration platforms

When pursuing circular economy opportunities, businesses incur transaction costs finding, and interacting with, suitable collaboration partners along and across value chains. Similarly, circular economy opportunities can be held back by a lack of

66 Nordic Council, *Economic Policy Instruments for Plastic Waste* (2014).

67 Korea Environmental Industry and Technology Institute (KEITI), *Policy Handbook for Sustainable Consumption and Production of Korea* (2014).

commercially viable technology. In both cases there is a case for policy support to facilitate partnerships either between businesses or across business and academia. Collaboration platforms can take various forms, including industrial symbiosis, public-private agreements, R&D clusters and voluntary industry initiatives.

Companies that look for collaboration partners for circular business ventures, but are challenged by a lack of information or find the transaction costs involved high, can benefit from industry collaboration platforms. These include industrial symbiosis programmes, examples of which include the Green Industrial Symbiosis programme in Denmark, the UK's National Industrial Symbiosis Programme,[68] the Western Cape Industrial Symbiosis Programme (WISP) in South Africa[69] and eco-industrial parks in China.[70] Similar platforms include the Textiles Recycling Valley initiative in Northern France, where the local government is directly fostering collaboration around textiles flows in four clusters to develop innovation in recycled textiles. Cooperation can be centred on an association or an institution with government involvement, for example the Chinese Circular Economy Association (CCEA) and the Circular Economy Institute in France. Voluntary industry initiatives can work where a circular economy opportunity requires change along the value chain: the Australian Packaging Covenant (APC) is an agreement between government, industry and community groups to improve packaging sustainability; and EcoProFabrics is a joint project, part-funded by the EU Eco-Innovation Initiative, of six companies in the Netherlands that closes a clothing production loop.[71]

When the barrier to the viability of a circular economy opportunity is a lack of cost-effective technology, R&D collaboration can be effective. Rethink Resources[72] is an innovation centre in Denmark for resource-efficient production and product design. It is a partnership between universities, technology centres, manufacturing companies and the Danish Ministry of Environment and aims to support resource efficiency in companies. It provides new knowledge about product design, manufacturing processes, closed-loop, life-extension and new business models. The German government has provided funding to foster a leading-edge cluster for lignocellulose bio-refining, and the UK government is funding research clubs on integrated bio-refineries and bio-based processing.[73] In Scotland there is a public-private partnership arrangement funding the Institute for Remanufacture at Strathclyde University (see Box 2).

Box 2: Policy case example – The Scottish Institute for Remanufacture

'As an SME business, we need to keep up with innovation in the design and manufacture of transmissions and the technologies involved in their assessment and repair. The creation of the Scottish Institute for Remanufacture will enable us to utilise the sizeable expertise in academic institutions to address issues and to network with other remanufacturers to share information and transfer best practice.'

John Mackie, Managing Director, Mackie Automatic & Manual Transmissions

The Scottish Institute for Remanufacture was launched in 2015 to engage in remanufacturing research and private sector collaboration. The institute is hosted by the University of Strathclyde in Glasgow and supported by Heriot-Watt University in Edinburgh. It will receive GBP 1.3 million government funding over three years, GBP 1 million from the Scottish Funding Council and GBP 0.3 million from Zero Waste Scotland. Companies based in Scotland have already pledged GBP 0.8 million of funding or in-kind support for potential research projects for

68 For further details see www.nispnetwork.com

69 For further details see greencape.co.za/what-we-do/projects/wisp/

70 See Europe's World, *China's policies and instruments for developing the circular economy* (15 June 2014).

71 De Groene Zaak, *Governments going circular* (2015).

72 For further details see rethinkresources.dk

73 German Bioeconomy Council, *Bioeconomy Policy: Synopsis and Analysis of Strategies in the G7* (2012).

the institute, which it offers to PhD students and researchers on secondment to companies in Scotland through a bidding process. Companies are starting to benefit from their involvement with the institute by meeting other companies to learn from and collaborate with. The centre has identified 60 companies active in remanufacture and continues to find others, including those not yet active but interested in the potential.

The idea for the institute stemmed from the Scottish government's consultation process on *'Safeguarding Scotland's Resources – Blueprint for a More Resource Efficient and Circular Economy'*; which also meets its Waste Prevention obligations under the EU Waste Framework Directive. Strathclyde University identified the need for increased capabilities and skills in industry regarding remanufacturing, an issue which could be addressed by a centre of expertise on the subject, and approached the Scottish government with a proposal. A benefit of the discussions involved in setting up the institute was to uncover potential barriers to remanufacturing, which the institute can help address, including the lack of clear standards to distinguish true remanufactured products from those that have been refurbished or repaired; the difficulty that third-party remanufacturers experience when trying to access technical information from original equipment manufacturers; and the need for more R&D in the sector.

Remanufacturing is now part of Scotland's Economy Strategy published in 2015.[74]

Business support schemes

In seeking out circular economy opportunities, companies can face economic barriers such as lack of access to technology, capital and in some cases challenges to profitability, and market failures such as insufficient competition, split incentives and transaction costs. Policy interventions in this area can take the form of financial support, such as grants and subsidies, and capital injections and financial guarantees, but also importantly technical support, advice, training, demonstration of best practices and development of new business models. A particular focus of these support schemes will likely be SMEs, which can lack the internal capacity, capabilities and financial resources to take advantage of these new opportunities.

Examples on the ground are often instruments that offer a mixture of both financial and non-financial support. Denmark's Fund for Green Business Development is an example that provides grants, advice, support for partnerships and pilot projects, and an acceleration programme for new green business models.[75] In South Korea the 'Green Up' offers environmental management consultations with SMEs aimed at enhancing competitiveness, reducing resource costs and improving environmental performance; and the Eco-Design programme provides technical and financial assistance to SMEs commercialising eco-innovation initiatives for their products and services.[76] REBus, an EU Life+ funded collaborative project in the UK and Netherlands, provides technical expertise to businesses to develop resource-efficient business models in textiles and electricals (in the UK the focus is on building the financial case for a transition to a circular business model; in the Netherlands it is through public procurement).[77] Finally, an example of tailored, on-demand business support around circular economy opportunities is the Green Deal in The Netherlands (see Box 3).

Box 3: Policy case example – Dutch Green Deal

'These initiatives are driven by those who say they want to do something and as a

74 The Scottish Government, *Scotland's Economic Strategy* (2015).

75 For further details see groenomstilling.erhvervsstyrelsen.dk/greenbusinessfund

76 Korea Environmental Industry and Technology Institute (KEITI), *Policy Handbook for Sustainable Consumption and Production of Korea* (2014).

77 See www.rebus.eu.com

government we try to support it'

Kees Veerman, Ministry for Infrastructure and the Environment

The Green Deal programme was launched in October 2011 by the Netherlands Ministry of Economic Affairs with the joint aims of saving energy, materials and water and stimulating economic activity from the ground up. It gives a different role to government — providing a responsive service to organisations that ask for help to realise (circular economy) opportunities that align with those aims and that face implementation barriers.

Process and governance

The applicant outlines their (circular economy business) idea, the barriers that stand in its way and potential solutions to them. The proposed initiative must be in line with the mentioned aims, profitable or have the potential to become profitable, be able to demonstrate results preferably within three years, should lead to new economic activity or generate costs savings for business and individuals. Once the government selects an idea it enters into a voluntary agreement (Green Deal) with the initiating organisations to work with them for two to three years. Barriers can include lack of clarity on obtaining relevant permits or navigating applicable regulations or problems finding business partners. The government can take action by sharing knowledge on relevant legislation; modifying legislation; providing access to relevant networks; or supporting the market for a new product or service. No specific financial incentives are provided; rather the government can point out existing relevant subsidy schemes. The Green Deal Board is responsible for monitoring and evaluating progress and results of the Green Deals in place and stimulating new initiatives. Its nine members are drawn from business, non-governmental organisations (NGOs), and government. By June 2015, more than 160 Green Deals have been concluded.

Policymaker experience

Policymakers involved in the development and execution of the Green Deal programme report a surprising level of appetite to sign deals both on the part of the companies that drive the process and also from the government. They also note that one of the unexpected benefits of the programme has been to give companies certainty about their business model, in having been selected by the government as being promising and received guaranteed support for two to three years. Companies have reported finding beneficial the simple act of opening up a line of communication with the government, and with other companies.

The government for its part has become comfortable with the evolutionary approach of reviewing each deal after two to three years and stopping those that are not running as successfully as hoped. It has also found that the help needed by companies is often not financial and also not in the area of fixing the unexpected consequences of existing regulations. When discussions go deeper it becomes clear that even if a regulatory hurdle has already been knocked down, the perception that it still stands remains in people's minds for a long time; therefore simply clarifying relevant legislation is useful.

Successful example project – Dutch Phosphate Value Chain Agreement

In 2011, the government brought together 20 water, chemical and food industry and agricultural stakeholders through the 'Nutrient Platform' to sign the 'Phosphate Value Chain Agreement'. This was a Green Deal that aimed to turn the Netherlands into a net exporter of secondary phosphate. The Ministry of Infrastructure and Environment appointed a full-time value-chain director as director of the network for two years to work closely with the Nutrient Platform to execute the agreement.

The deal brought together stakeholders in the value chain that do not normally

work together and generated trust even when certain parties stood to benefit more than others. The government set new rules for the use of recovered phosphates as fertiliser in the Netherlands, to overcome the barrier of legislation hindering the use of recovered materials, in particular if they contain heavy metals or other pollutants. The Nutrient Platform also involved the financial sector to make a closer connection between innovahhtive companies and financial institutions to accelerate sustainable secondary phosphate innovations being brought to market. This action was needed to overcome the barrier of high price volatility in the secondary phosphate market discouraging investment.[78] No government incentives such as subsidies needed to be offered.

Public procurement and infrastructure

When businesses face the barrier of entrenched customs and habits or a lack of markets for a circular economy opportunity, the public sector can step in to provide purchasing power. A circular public procurement approach is achieved when public organisations meet their needs for goods and services in a way that achieves value for money throughout the life cycle, for the organisation and for wider society, while minimising materials losses and environmental impacts. To this end circular economy standards can be incorporated into procurement law or guidelines, lists of preferred suppliers or materials can be drawn up, and capabilities and skills in concepts such as total cost of ownership (TCO) and measures of material circularity can be built in procuring departments. Examples include Denmark's Government Strategy on Intelligent Public Procurement, which contains initiatives to support circular procurement practices and puts in place dissemination activities and partnerships on green public procurement.[79] In Flanders the government has created a market for high-quality recycled aggregates through their own procurement.[80] Box 4 shows how the US has integrated circular economy thinking into several levels of its public procurement policy.

If the barrier holding back circular business practices is insufficient public infrastructure – such as waste collection systems and treatment facilities – public sector budgets can provide investment that enables private sector circular economy activity and potentially investment. An example is the South Korean government's construction of secondary infrastructure in order to boost car sharing as part of the Seoul Sharing City programme. Governments can also help by opening up access to the sharing of their own assets such as buildings and vehicles on platforms to be used by individuals or organisations such as in Flanders where the government is considering expanding a programme to share with the public its cars when they are not in use, for example at weekends.[81]

Box 4: Policy case example – Circular public procurement in the US

Federal level

The US EPA (Environmental Protection Agency) implemented its Comprehensive Procurement Guidelines (CPG) programme in 1995. It designates products that are or can be made with recovered materials, and recommends practices for procuring them. Once a product is designated, state and federal procuring agencies are required to purchase it with the highest recovered material content level practicable. In 2004, the EPA designated seven additional products, including remanufactured vehicular parts.[82]

Covering the repair and maintenance of vehicles, the 'Federal Vehicle Repair

78 For example, the price of phosphate rock rose from USD 50 to USD 450 in 2007/2008 as a result of supply issues in China and then fell to USD 100 in late 2009.

79 See www.ellenmacarthurfoundation.org/case_studies/public-procurement-in-denmark

80 De Groene Zaak, *Governments going circular* (2015).

81 See www.flanderstoday.eu/politics/government-flanders-looks-car-sharing-public

82 See www.epa.gov/epawaste/conserve/tools/cpg/index.htm

Cost Savings Act', introduced in the House in February 2015 and now on the Senate legislative calendar, aims to reduce the bill for repair and maintenance of government vehicles, which approaches USD 1 billion a year. If it passes it would require the head of each federal agency to encourage the purchase of remanufactured vehicle components, such as engines, transmissions, alternators, and starters, if they reduce the cost of vehicle maintenance while not lowering its quality.[83]

State level

In 1998 New York State passed a remanufacturing law mandating that purchase requests from the commissioner and state agencies for durable equipment consider remanufactured goods first. The law also provides that 'products purchased by the commissioner or other state agencies shall be recycled or remanufactured products … provided the cost … does not exceed a cost premium of 10%'. The law also prohibits state agencies from purchasing commodities from OEMs that place restrictions on remanufacturing. Texas, Connecticut and California have subsequently passed similar laws.[84]

Regulatory frameworks

Regulatory policy interventions can address barriers of several types, including profitability and split incentives, and are of course critical to address regulatory failures. In cases where circular economy activity is hampered by the unintended consequences of existing regulations, it can be helpful to form a taskforce on circular economy or resource efficiency. Examples include Denmark's Taskforce on Resource Efficiency (see Box 5), Finland's working group on National Material Efficiency Programme[85] and the UK's Circular Economy Task Force.[86]

Where the barrier is that of inadequately defined legal frameworks, new or adapted product, waste, industry, consumer, competition and trade regulations may be needed. These could come in the form of restrictions on, or requirements relating to, existing activities. Examples include New York City's ban of Styrofoam cups;[87] France's requirements for manufacturers to display on product labels for how long spare parts will be available and to offer free repair or replacement for the first two years after purchase;[88] California's amendments to its rigid plastic packaging container regulations to more effectively require plastic resin manufacturers to use at least 25% of recycled resins in their products;[89] and France's proposal to ban large supermarkets from throwing away unsold food, instead either donating it to charity or sending it for composting or for use as animal feed.[90]

Such interventions can equally come in the form of lifting existing restrictions or setting a positive legal framework for circular economy activities. Examples include Japan's policy to give food waste to pigs under highly sanitary conditions; Nevada's legislation to permit the licensing and operation of autonomous vehicles;[91] the US's Good Samaritan Law that limits the liability of food companies and retailers for products they donate to charities; and the Basel Convention's new guidelines that could also allow countries to classify products and parts as destined for reuse or extended use, or for repair and refurbishment, to exempt them from the convention's requirements on the export of

83 US Congress, *S.565 - Federal Vehicle Repair Cost Savings Act of 2015.*

84 EEF, *Materials for Manufacturing: Safeguarding Supply* (2014).

85 Finnish Ministry of Employment and the Economy, *Working group proposal for a National material efficiency programme,* (2014).

86 See www.green-alliance.org.uk/CETF.php

87 Scientific American, *NYC Bans Expanded Polystyrene Food Containers, Opens Market to Alternatives* (2015).

88 Fast Company, *This New French Law Is Designed To Make Products Easier To Repair, So They Stay Out Of The Trash* (March 2015).

89 See www.calrecycle.ca.gov/laws/regulations/title14/ch4a3a.htm

90 Süddeutsche Zeitung, *Supermärkte müssen nicht verkaufte Lebensmittel spenden* (22 May 2015).

91 See www.dmvnv.com/autonomous.htm

hazardous waste.[92]

Box 5: Policy case example – Danish Taskforce for Resource Efficiency

'The Taskforce will identify regulatory barriers and underlying conflicting interests that prevent businesses from utilising their input of materials and water more efficiently. The work of the Taskforce is an iterative process that alternates between business studies, other analysis, and development of solutions in dialogue with companies and relevant authorities.' – Anders Hoffmann, Danish Business Authority

The Danish Taskforce for Resource Efficiency was set up with aim of increasing the competitiveness of the Danish economy and was part of the national growth strategy of the Danish Government, published by the Ministry of Finance in 2014. Its aim is to review existing regulations affecting resource productivity and circular economy practices, identify barriers and work to find solutions. It will use explorative studies of the experiences and daily work of companies to understand how barriers appear and affect the behaviour of the companies, covering the rules themselves, how they are administered and the help businesses receive to navigate them. In 2015 the taskforce will identify barriers blocking potential increases in resource efficiency. In its second and third years (2016–2017) it will establish solution teams for each selected barrier to find the most effective way to overcome them.

Though in its early stages of work, the taskforce has made some preliminary findings of potential regulatory barriers reported from companies, consultants and business associations in Denmark and abroad. However it should be stressed that the full mapping and analysis of barriers will be undertaken during the rest of 2015 and these are only initial leads on where the focus might lie:

- Import/export of waste: high barriers to start trading secondary raw materials
- Take-back of products: regulation is onerous when more than one product is collected
- Definition of waste: identical products can be subject to two different regulations if one is made from virgin materials and the other is made from recycled materials
- Product design: eco-design regulations do not sufficiently address resource efficiency and circular economy ambitions

Fiscal frameworks

The main barriers to circular economy opportunities that fiscal instruments could address are those of profitability for companies and unpriced externalities. Similar to regulations, fiscal instruments can be applied either to discourage non-circular activities on the one hand or explicitly support circular economy opportunities on the other. An example of a fiscal instrument applied to a product difficult to incorporate into a circular system is Ireland's levy on disposable plastic carrier bags.[93] Examples of pricing more fully the negative externalities of waste (management) through fiscal interventions are Denmark's high and incrementally increasing taxes on landfilled or incinerated waste and Finland's levy and deposit system on disposable drink containers. Examples of tax breaks for circular economy products and processes include New York's tax credit in favour of remanufacturing firms and China's reduced or eliminated VAT on goods

92 Basel Convention of the United Nations Environment Programme on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

93 See www.environ.ie/en/Environment/Waste/PlasticBags/

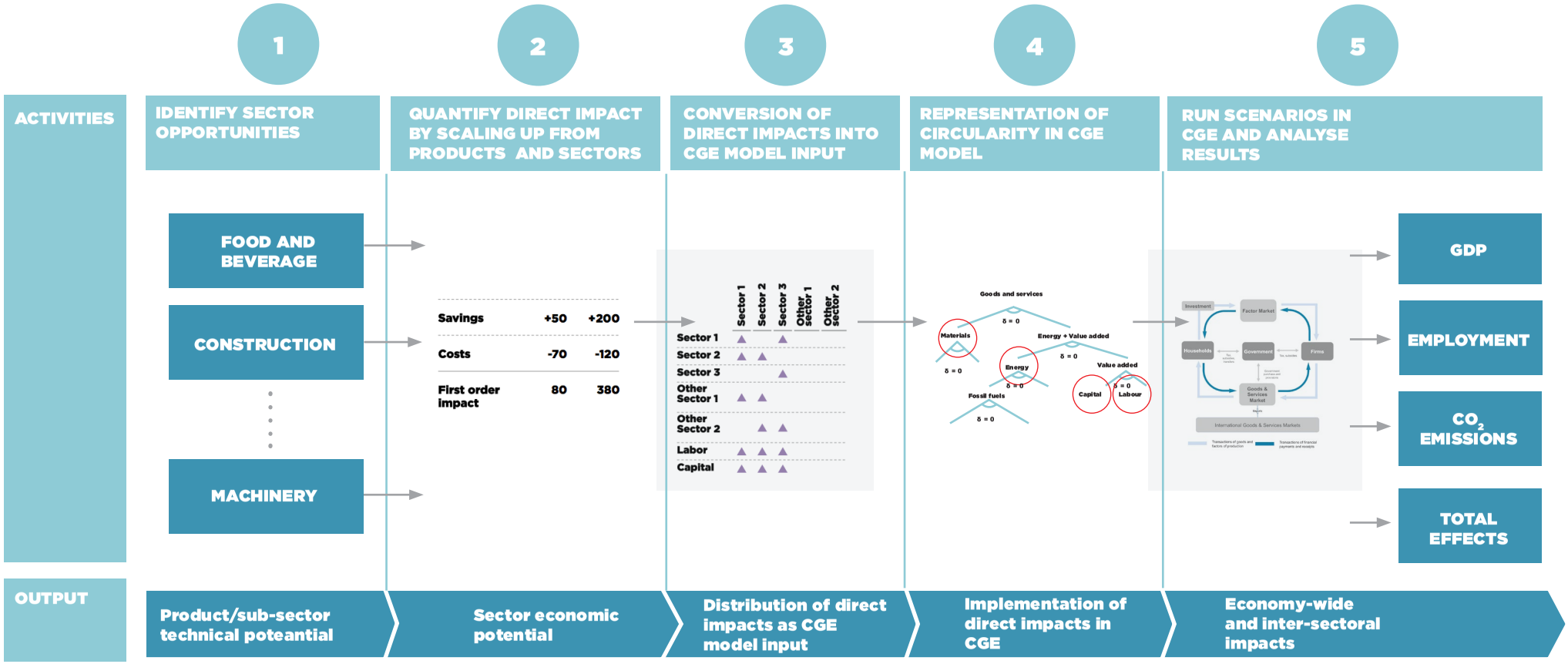
Figure 18: Methodological options for economic impact assessment modelling

	PARTIAL EQUILIBRIUM MODELLING	MACRO-ECONOMETRIC MODELLING	INPUT-OUTPUT (SOCIAL ACCOUNTING MATRIX) MODELLING	STATIC AND DYNAMIC CGE MODELLING	AGENT-BASED MODELLING
DESCRIPTION OF MODELLING APPROACH	Supply-and-demand models representing in high detail a specific sector, market or groups of markets	Statistical model representing evolution of a sector or groups of sectors based on historical relationships	Static representation of all inputs and outputs for all agents in the economy	Static or dynamically optimised representation of economic flows across all agents in the economy	Integrated and dynamic representation of decision making of all economic agents
REPRESENTS THE WHOLE ECONOMY	✗	✓	✓	✓	✓
INCLUDES ECONOMY-WIDE PRICE EFFECTS	✗	✓	✗	✓	✓
CAN SIMULATE STRUCTURAL CHANGE	✓	✗	✗	✓	✗
MODELING AND ANALYSIS COMPLEXITY	Low to High	Medium to High	Low to Medium	Medium to High	Medium to High
WHEN TO USE THIS APPROACH FOR CIRCULARITY IMPACT ASSESSMENTS	When assessment is for a single sector or a low number of sectors and whole economy and/ or indirect impact is not required	When an economy-wide view is required, with a focus on short-term forecasting (scenario changes are within historical variations)	When a quick assessment of economy-wide impact is required (excluding time, price and associated indirect effects)	When a comprehensive assessment of economy-wide impacts is required, (including time, price and associated indirect effects)	When an economy-wide view is required, and it is important to explicitly model (irrational and other) behavioral aspects of agents such as consumers, producers, and governments
APPLICATION IN RECENT CIRCULAR ECONOMY/RESOURCE PRODUCTIVITY IMPACT ASSESSMENT STUDIES	Employment and the Circular Economy – Job creation in a more resource efficient Britain (2015) Opportunities for a circular economy in the Netherlands (2013)	None identified	The Circular Economy and Benefits for Society: Swedish Case Study (2015)	Assessment of Scenarios and Options towards a Resource Efficient Europe (2014) Growth Within: A Circular Economy Vision for a Competitive Europe (2015)	None identified

SOURCE: NERA Economic Consulting, Ellen MacArthur Foundation circular economy team

Selected for the Denmark pilot study (Dynamic CGE)

Figure 19: Overview of a 'hybrid' CGE approach



SOURCE: NERA Economic Consulting, Ellen MacArthur Foundation circular economy team

produced from recycled materials.[94]

2.3 Analyse economy-wide implications

Once the sector-specific circular economy opportunities have been assessed, they can all be put together and the national implications analysed. This step will typically be driven by a core group of policymakers, policy and economics experts and with the participation of multiple government agencies. The sector-specific impact assessments could be put together in one overarching whole-economy impact assessment to support the mandate for policy intervention (Section 2.3.1). Sector-specific policy options could be complemented by economy-wide policy options (Section 2.3.2). The set of sector-specific and economy-wide policy options needs to be prioritised and assembled into coherent policy packages (Section 2.3.3).

Demonstrating the economic potential of the circular economy compared to alternative pathways is in many cases required in order to advance the circular economy. Assessing the direct economic impacts within the focus sectors, as presented in the previous section, is a fundamental component of that process. However, some stakeholders, such as finance ministries, might also want to appraise the broader economic impacts of such transformations, requiring the use of tools and methodologies that can quantify the potential macroeconomic, economy-wide impacts of delivering the circular economy opportunities.

Once the economic and broader societal rationale for policy intervention has been developed, and a set of potential policy options has been identified in each of the focus sectors, policymakers might reflect on complementing these with economy-wide policy options. They can conduct a structured cost-benefit assessment process to prioritise the different policy options and put these together in structured policy packages, including the development of provisions to address any important distributional consequences that could otherwise hinder societal acceptance of the overall policy change.

This step will typically be driven by a core group of policymakers, policy and economics experts and with the participation of multiple government agencies. The project team needs to have at its disposal strong macroeconomic modelling skills (if a macroeconomic modelling effort as laid out in Section 2.3.1 is performed) and policy analysis expertise. In the Denmark pilot, in total, around ten man-months were dedicated to this step.

2.3.1 Quantify economy-wide impact

Objective:	**Support the case for economy-wide and broad sectoral policy interventions.**
End product:	**Estimate of expected impact of circular economy opportunities on national macroeconomic indicators such as GDP, employment, net exports, and carbon emissions.**

There is – to the best of our knowledge – no methodological approach available that fully captures the impact of transitioning towards the circular economy. The main underlying issue is that current economic models are built relying heavily (although not necessarily exclusively) on historic correlations (in a linear economy) between different sectors. This approach has inherent limitations when modelling the circular economy with – by nature – very different relationships between sectors.

There are however several 'standard' approaches available to quantify macroeconomic impact. Among these, while there is no 'one size fits all' approach, computable general

94 See www.china-briefing.com/news/2011/11/28/china-expands-tax-incentives-to-promote-circular-economy.html

equilibrium (CGE) models might be a good choice as they have multiple desirable attributes. The diversity and specificity of circular economy opportunities means that hybrid CGE approaches – which combine the strengths of high granularity sector-specific impact modelling with the aggregated economy-wide impact assessment capability of a CGE framework – are among the best suited, existing impact modelling approaches for this task.

APPROACHES FOR MODELLING ECONOMY-WIDE IMPACTS OF THE CIRCULAR ECONOMY

Multiple methodological options are available to quantify the economy-wide impact of a circular economy transition, each with its own advantages and limitations. Of course, any approach needs to follow applicable impact assessment guidelines and requirements.[95] The choice of the most appropriate economy-wide modelling approach will depend, among other things, on the desired attributes of the economic model and the availability of resources. Figure 18 below presents a high-level description and comparison of some of the most widely used methodological approaches for economic impact quantification.

Computable general equilibrium (CGE) models are among the most widely used types of models for assessing economy-wide impacts of structural changes in the economy and are a strong option to model the expected effects of a transition towards the circular economy. A dynamic CGE model was selected in the Denmark pilot study, and the rationale for selecting a CGE framework might be applicable to other policymakers looking to conduct economy-wide impact assessments of the circular economy.

Whether it is with CGEs or other modelling approaches, economic impact assessment of the circular economy is in its early stages and, as will be discussed later in this section, multiple areas for methodological development remain.

'HYBRID' CGE APPROACHES FOR MODELLING CIRCULAR ECONOMY IMPACT

To assess the economy-wide impact of greater circularity in certain economic sectors as accurately as possible, it is necessary to simultaneously model a large number of products, technologies, and/or sectoral detail, as well as their interaction with the broader economy. For such cases, 'hybrid' modelling approaches can be adopted. These approaches combine the detail of product and sector-specific economic impact modelling (e.g. the cost savings in the machinery sector as a result of increased remanufacturing), with the aggregated, inter-sectoral features of an economy-wide modelling framework (e.g. to assess the effects of greater productivity in the machinery sector on growth and employment in the broader economy). CGE frameworks are well suited to be used in conjunction with sector-specific models. Such 'hybrid' CGEs have been used for impact assessment in many economic sectors and activities including energy, transport or postal services and, recently, resource productivity.[96]

A hybrid approach was developed and applied in the Denmark pilot, and might be useful in other countries as well. The approach consists of a five-step process, as illustrated in Figure 19.

1. Identify circular economy opportunities in each focus sector: as laid out in Sections 2.2.1 and 2.2.2.

2. Perform 'bottom-up' sector-specific impact quantification: as laid out in Section 2.2.3. Define the 'business as usual' or reference scenario, as well as the circularity scenarios and sensitivities.

3. Conversion and scaling: this is a crucial 'interface' between sector-specific impact quantification and economy-wide CGE. Departing from a reference

95 See for example European Commission, Impact Assessment Guidelines (2009).

96 A hybrid bottom-up CGE approach was recently used in a European Commission study that quantified the economic impacts of greater resource productivity in the built environment in the EU. See *European Commission, Assessment of Scenarios and Options towards a Resource Efficient Europe* (2014)

input-output (I/O) table, distribute sector-specific revenue and cost impacts over the relevant supplying and consuming sectors. The end product of this step is a 'delta' (meaning change from the baseline) input-output (I/O) table that is balanced.[97] The delta I/O tables are then used as inputs to the CGE model.

4. Implementation in the CGE: The balanced delta I/O tables for the selected circularity scenarios are 'implemented' into the CGE model. There are several options to do this and these are discussed in greater detail in Appendix C.

5. Model runs and output: Scenario impacts are compared to the 'business as usual' levels to quantify the changes in key macroeconomic indicators such as GDP, employment, industrial output, trade and CO_2 emissions.

Hybrid approaches are relatively time and resource intensive processes. Not all policymakers may therefore opt for an economy-wide impact quantification on top of the detailed sector-specific impact quantification.

AREAS FOR FUTURE METHODOLOGICAL DEVELOPMENT

While hybrid CGE models are among the best suited methodological options today, they still have important shortcomings in terms of fully representing the circular economy. As yet, many of the CGE models that have been used to assess structural change, and including the one applied in the Denmark pilot study, are unable to fully represent the economic structure, relationships between agents, materials and economic flows, and other details of the circular economy. CGEs (and other economy-wide impact models) have significant scope for development across several areas including:

- *Comprehensive representation of materials and products flows*: Many impact assessment models represent energy, emissions, water or any other focus commodity, but seldom represent together a broad spectrum of materials and products flows (e.g. raw commodities; intermediate products; reusable by-products; unusable waste, emissions and effluents; final goods). Explicit and comprehensive representation of material and product flows would enable a much more precise quantification of supply, demand, price and externality impacts from the circular economy.

- *Representation of new or expanding circularity sectors and economic relations*: The representation of such activities is often highly aggregated or lacking altogether. These often include emerging or new value-adding activities that will play an increasingly important role in the circular economy. An explicit representation of emerging circularity activities would allow a precise quantification of the size, price impacts, and added-value creation of circularity within the economy. Examples of future developments in this area could include:

    - *New production methods*: the representation of production technologies that can substitute raw or virginal materials with usable waste or by-products from other sectors as production inputs, and technologies that reduce the intensity of materials inputs in production. The alternative potential production inputs will need to be incorporated into the data for the social accounting matrix.

    - *Expanded natural resource representation*: Representation of natural resources as inputs to production is often limited to important depletable resource supplies in current models. To better capture the value of reuse, representation of renewable natural capital stocks and how those stocks are affected over time by alternative production processes may be a valuable future development.

    - *Product services vs. products: A*s consumers move towards greater

97 A 'balanced' I/O table means one where the total changes (i.e. 'delta') in inputs or supply in the circularity scenario equal the total demand or output delta.

'share, use and return' behaviors, representation of consumer welfare will require more emphasis on consumption of product services than of the products themselves. For example, consumption of transportation services will become more important to represent than numbers of vehicles purchased.

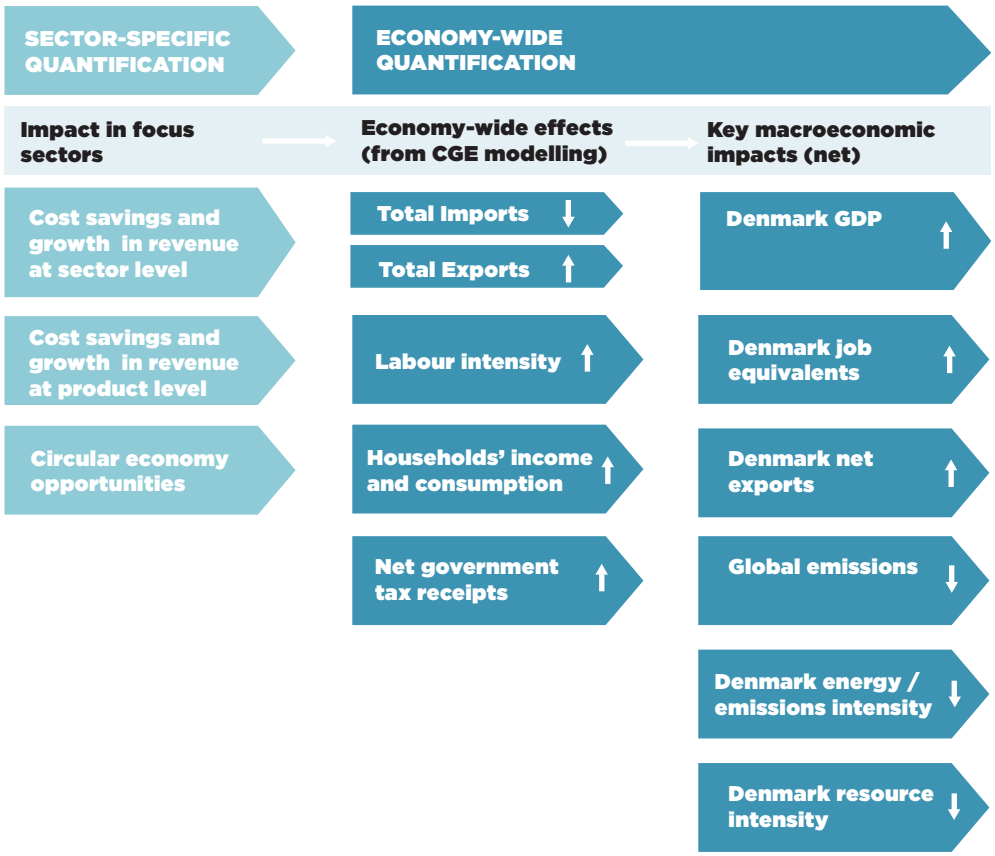
- *Representation of investment and finance*: in most CGEs, capital is accumulated through savings and investment. Capital stock in any time period is the sum of depreciated capital from the prior period plus new net investment. The interaction of capital accumulation and future capital requirements determines the investment pathway. A more granular representation, allowing for the distinction between old (fixed use) and new (malleable use) capital along with sector-specific depreciation rates would allow for better representation of the cost of transition.

- *More comprehensive and integrated representation of flow and stock externalities:* economic impact assessment models are typically used to represent the impact of certain negative flow externalities such as greenhouse gas emissions or other types of harmful effluents; or to represent the impact of consumption of certain materials on their supply and availability. However, impact assessment models seldom have a comprehensive representation of flow and stock externalities, nor are they jointly assessed. In order to measure the true economic value of circularity, impact assessment models need to be able to core comprehensively capture flow and stock externalities generated from resource consumption and depletion in an integrated manner, and how the aggregate effect impacts production and consumption choices.

Interpretation and presentation of results

For CGE models, given their complexity, it can be helpful to complement a classical overview of results on key macroeconomic indicators with a description of the direct and indirect effects that underlie them. An example of such a 'narrative' of the modelling results from the Denmark pilot study is presented in Figure 20.

Figure 20: Overview of direct and indirect effects in pilot CGE modelling



SOURCE: NERA Economic Consulting, Ellen MacArthur Foundation circular economy team

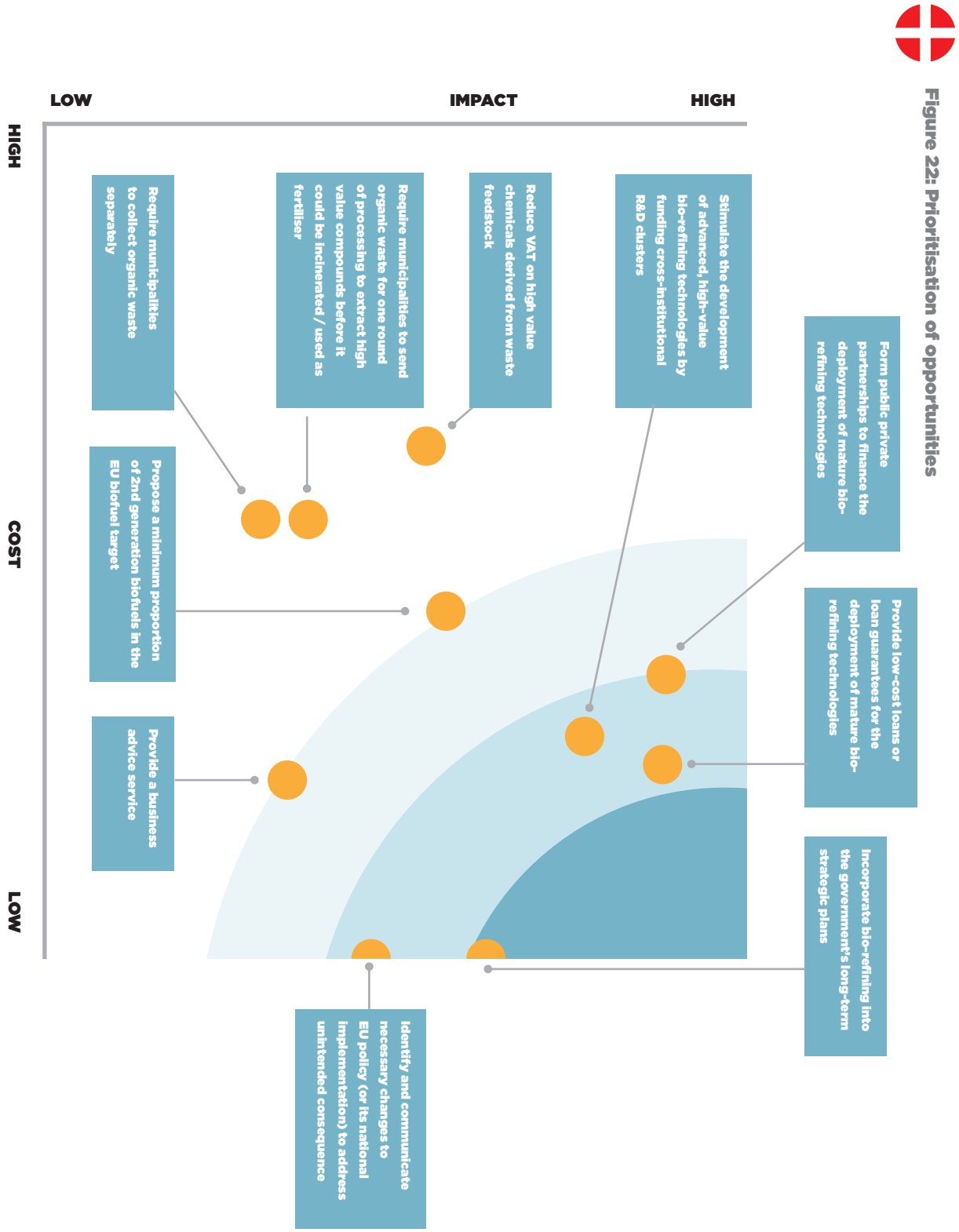
2.3.2 Map economy-wide policy options

Objective:	**Complement sector-specific policy options identified in Section 2.2.5 with economy-wide policy options to enable a broad transition to the circular economy.**
End product:	**List of economy-wide policy options.**

To enable a systemic transition towards the circular economy, policymakers could, in addition to the sector-specific policy analysis, reflect on broader, economy-wide policy interventions.

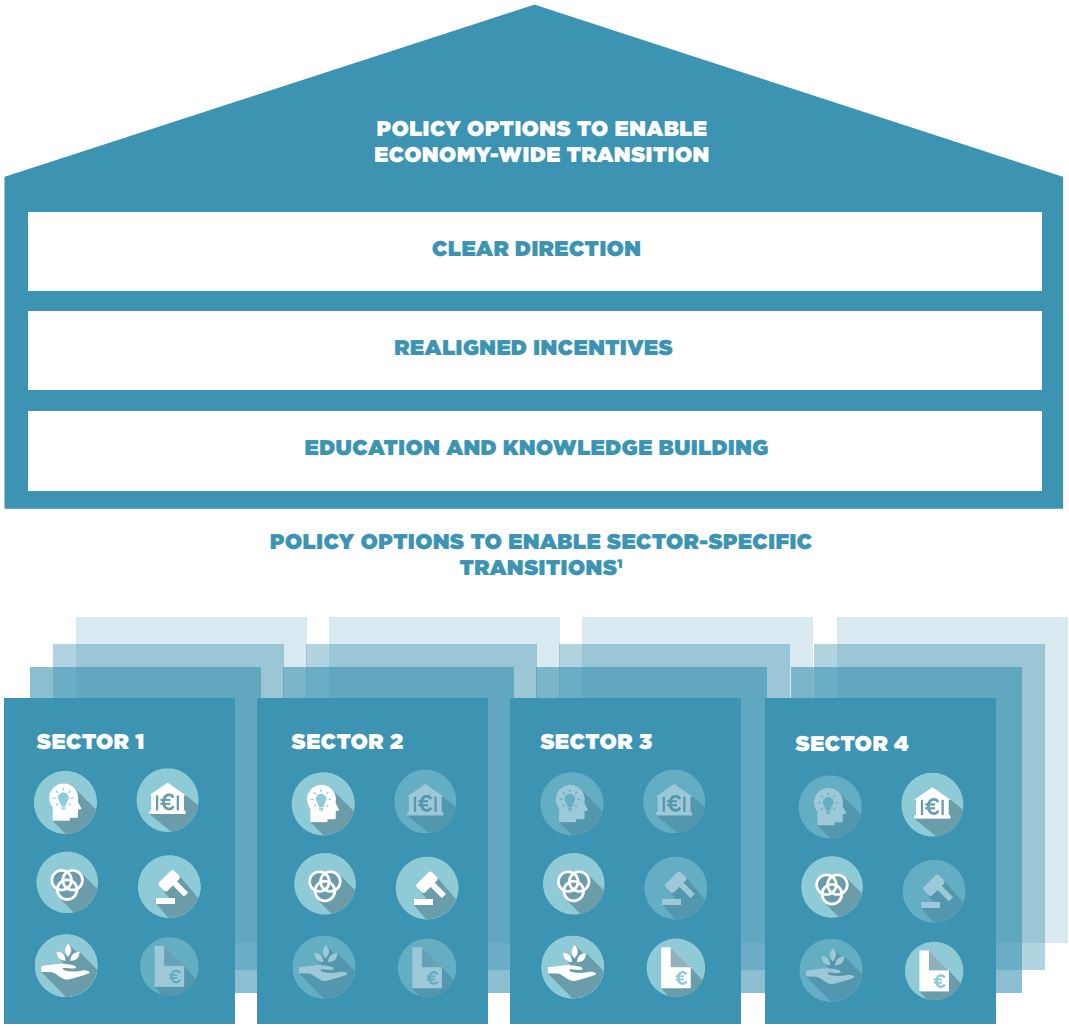
Figure 21 illustrates how such economy-wide policy and sector-specific policy interventions might work together. Three possible elements of economy-wide policy interventions are: setting a clear direction using metrics that reflect a broad definition of economic success, investigating the opportunities and challenges associated with adapting the fiscal system to realign incentives, and building knowledge by embedding systems thinking in education and launching broad circular economy research programmes.

Figure 22: Prioritisation of opportunities



SOURCE: Ellen MacArthur Foundation circular economy team; NERA Economic Consulting

Figure 21: How economy-wide circular economy policy might complement sector-specific policy



1 One policy package per circular economy opportunity
SOURCE: Ellen MacArthur Foundation circular economy team. Adapted from Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

Setting clear direction

As set out in Section 2.1.2, adopting a national ambition level using appropriate targets – based on, for example, the three circular economy principles, as described in Section 2.1.2 – might send a powerful signal to businesses and investors. Setting out a clear economy-wide strategy on circular economy and resource productivity might do so as well, and governments have already begun to do so. Existing national circular economy or resource productivity strategies include China's Circular Economy Promotion Law, Japan's Law for the Promotion of Effective Utilization of Resources, the UK Resource Security Action Plan: Making the most of valuable materials, Germany's Resource Efficiency Programme (ProgRess) – see Table 2 for details – and the Netherlands' Waste to Resource strategy. In Scotland's Economic Strategy 2015 remanufacturing was identified as a strategically important innovation sector.

Realigned incentives

While many circular economy opportunities already have a sound underlying profitability, realigning incentives from resources to labour could potentially unlock further opportunities. Such shifts are sensitive and need to be seen in the light of issues such as international competitiveness, stability of tax revenues, administrative complexity and potential distributional effects. They are, however, an option to explore

since there is some evidence that they could bring economic and societal benefits (see below).

A number of international organisations, such as the European Commission, the OECD, the IMF, and the International Labour Organization, have suggested shifting taxation from labour to resources.[98] They propose that such a shift could increase incentives to minimise waste, maximise resource productivity and increase the feasibility of more labour-intensive circular business practices. Ex'Tax has done detailed analysis on the practicalities and implications of such a shift. Its report presents a case study that finds that a (mid- to long-term) tax shift could shift more than EUR 30 billion in tax revenues from labour to resources and consumption in the Netherlands alone and, if internationally coordinated, could potentially create hundreds of thousands of jobs[99]. As, in Europe, 6% of total tax revenues originate from environmental taxes (including taxes levied on energy, transport, pollution and resource extraction), and 51% from labour taxes and social contributions[100], there might be – at least in theory – significant scope to shift taxes from labour to resources.

The IEA, the World Bank and the IMF, among others, have studied fossil fuel subsidies and their economic and environmental implications[101]. An IMF working paper from May 2015[102] estimates global fossil fuel subsidies in 2014 to have been USD 5.6 trillion (7% of global GDP). The report states that "[eliminating] post-tax subsidies in 2015 could raise government revenue by USD 2.9 trillion (3.6% of global GDP), cut global CO_2 emissions by more than 20%, and cut premature air pollution deaths by more than half. After allowing for the higher energy costs faced by consumers, this action would raise global economic welfare by USD 1.8 trillion (2.2% of global GDP)."

There are however significant concerns about shifting taxation, most notably about distributional effects, the volatility of the tax base after the transformation and the potential for weakened competitiveness of primary materials and heavy industry. Policymakers that are considering tax shifts would need to investigate avenues to alleviate such concerns, which might include but are not limited to: mitigating distributional effects by increasing personal tax-free allowances and providing compensatory subsidies to those on fixed incomes and/or outside the labour market. To implement such a shift, policymakers would have to find widespread consensus on what would be a fundamental change in the approach to taxation among citizens, political parties, employers, unions and industry, and would need to address the significant concerns mentioned above.

Finally, bringing transparency on full costs, and enabling asset managers and corporate executives to maximise long-term value could also help realign incentives. Accounting and reporting standards could bring transparency on externalities. Rethinking the fiduciary duty of asset managers and corporate executives might enable them to maximise long-term value creation for all stakeholders over short-term shareholder value. In the US, and increasingly in other countries, companies can establish themselves as so-called B-Corps and in doing so specify that they '*give legal protection to directors and officers to consider the interests of all stakeholders, not just shareholders, when making decisions'*.[103] Some of these changes – such as changes to international accounting standards regarding natural capital and resources – would need broad international agreement. Others might be introduced by national governments.

Education and knowledge building

While the circular economy can have broad appeal as a value creation opportunity,

98 Stahel, W. R., Palgrave Macmillan, *The Performance Economy* (2006).

99 The Ex'Tax Project, in cooperation with Deloitte, EY, KPMG Meijburg and PwC*, New Era. New Plan: Fiscal reforms for an inclusive, circular economy* (2014)

100 Eurostat, Taxation Trends in the EU (2014).

101 See for example www.worldbank.org/en/news/feature/2012/05/09/real-costs-fossil-fuel-subsidies and www.worldenergyoutlook.org/resources/energysubsidies/

102 IMF Working Paper, *How Large Are Global Energy Subsidies* (2014).

103 B Lab. www.bcorporation.net

knowledge of what the circular model would mean for companies, industries, cities, and countries in the short and medium term is still relatively limited. This knowledge might be helpful to making policy and business decisions. Also important are potential changes to the way the education system teaches children and students, and engages in academic research. This would involve re-imagining curricula and ways of teaching, and conducting research across traditional subject silos to develop new technologies and business practices that work at the systems level. Action areas could include:

- **Education** curricula could inspire new generations of creative problem solvers used to thinking in systems and well-versed in the principles of the circular economy. At primary and secondary level this could be achieved by re-imagining curricula, breaking down subject silos and changing the manner of teaching to emphasise systems thinking and creative education. Students at all levels, school and university, could develop agility between the micro and the macro, i.e. be able to apply content knowledge at a systems level. The education system could respond to the pull demand from circular economy businesses for systems thinking school leavers and graduates. An early example of transformation in both the curriculum and manner of teaching is the International Baccalaureate, which offers to 3-19 year olds programmes of interdisciplinary learning – from several educational frameworks and curricula – that encourage critical thinking, intercultural understanding and environmental awareness. A few examples of the changing landscape at higher education are Bradford University's circular economy MBA, Cranfield University's inter-disciplinary MSc on circular economy, and Stanford University's electives in circular economy in its engineering faculty. Professional training programmes on the circular economy could ensure continued learning throughout a professional career. The extent to which national policymakers can influence these different aspects of education differs by country.

- **Academic research** on for example materials, bio-sciences, economics and policy could be important to generate the fundamental scientific knowledge on which to build circular economic practices. Applying the science is of course critical. Rochester University's Golisano Institute for Sustainability, a centre of excellence in remanufacturing, engages in applied research with industry, as does the newly formed Scottish Institute of Remanufacturing at Strathclyde University (see Box 2 in section 2.2.5). University College London's research lab in its Design Centre demonstrates examples of circular design, and the RECODE project at Cranfield University explores the 'internet of things' and asset tracking. Another strand of research is on circular economics, where many crucial topics about how circularity would change the way the economy works, for example trade patterns, resource flows, employment, GDP generation, and sector composition, could be further investigated. Academics might develop ways to model and measure the circular economy and perspectives on the competitive implications and transition challenges facing different sectors.

- **Sector working groups** could be set up to locate circular opportunities for businesses and consumers. Industry associations could contribute greatly by investigating profitable opportunities and sharing knowledge of circular business models in their industry. They could also explore opportunities to collaborate on things like material specifications and recycling systems to improve volume, quality and cost in secondary resource markets. Government might play a facilitating role.

2.3.3 Prioritise, package and sequence policy options

Objective:	**Prioritise the sector-specific policy options identified in Section 2.2.5; bring them together as required in coherent policy packages; and sequence over time the potential implementation of these policy packages as well as the economy-wide policy options identified in Section 2.3.2**

End product:	A set of policy packages (typically one per circular economy opportunity); an implementation roadmap for both potential sector-specific policy packages and economy-wide policy options

The outcome a policymaker can expect by working through the steps of this toolkit is a set of potential policy options to address the barriers in the identified sector-specific circular economy opportunities, as well as a set of potential economy-wide policy options. This section aims to provide overarching thoughts on next steps regarding prioritisation, packaging and sequencing of policy options. It does not attempt to provide a detailed overview, as these next steps are already laid out in other publications such as, for example, the European Commission's impact assessment guidelines.[104]

Prioritising

An initial mapping of policy interventions to barriers (see Section 2.2.5) can result in a large number of policy options. It can be useful as a first step to apply a high-level policy impact and cost assessment. Other factors such as time to implementation, time to achieve outcome, and distributional effects can also be taken into account. Such a high-level qualitative prioritisation can provide input for the subsequent due diligence and impact assessment/cost-benefit analysis in the policymaking process.

An example of such a prioritisation exercise for the 'Value capture in cascading bio-refineries' opportunity in the Danish pilot is found in Figure 22. Such a matrix can be the result of an analytical exercise or can be made more directly based on expert input. To structure this initial prioritisation, it is worthwhile breaking down impact and cost into their component parts:

- The **impact** of a policy option
    - Importance of the barrier it aims to overcome (as assessed in Section 2.2.4), assigning a weight to each of the barrier 'colours' (critical/very important/important)
    - Effectiveness of the identified policy options at overcoming the barriers
- The **cost** of a policy option
    - Administrative and transaction costs
    - Wider economic costs

The value potential of the opportunity can also play a role in assessing and ranking the impact of a policy option (see Section 2.2.3).

Policy packaging

Once a prioritised set of potential policy options is determined, the next step is to structure them into potential packages. When creating a policy package, a policymaker will naturally consider, in addition to the individual cost-effectiveness and distributional effects of the policy options, their interrelationships and coherence. The interplay of their effects needs to be taken into account.

A national 'programme' could consist of a coordinated set of such packages to enable sector-specific opportunities alongside economy-wide initiatives (see Section 2.3.2). A similar balance needs to be stuck here between policies that enable quick wins and those that lay the foundations for long term, systemic transition.

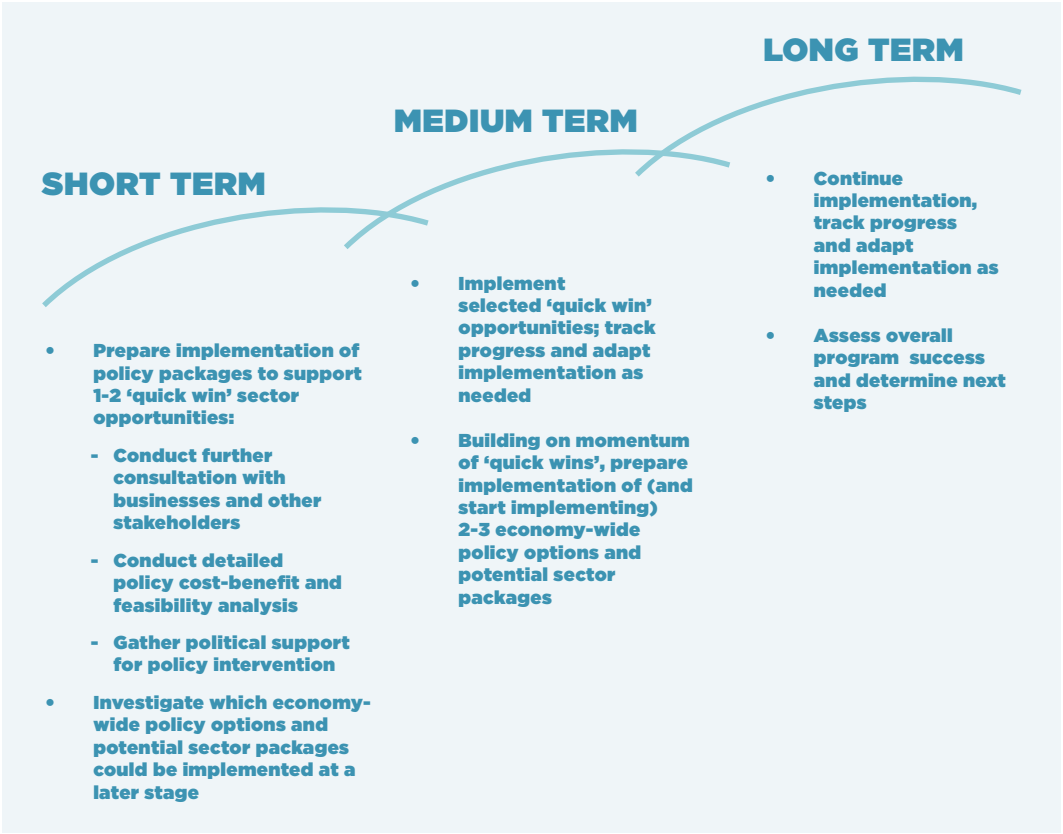
Sequencing

Figure 23 shows an illustrative way to sequence policy options and packages. While this is just one possible way of sequencing policy options, a few general principles stand out:

104 European Commission, Impact Assessment Guidelines (and Annexes) (2009).

- Starting with quick wins can help create momentum for some of the more far-reaching and long-term policy interventions
- It needs to be considered if some policy options serve as the foundation for other options – for example, regulatory issues related to real estate sharing need to be addressed before promoting it through, for example, pilots or partnerships
- In the policy design, sufficient flexibility in policy and policymaking process needs to be built in to be able to re-steer if needed (e.g. if unintended consequences or disruptive technology developments arise)
- Sufficient effort should be dedicated to tracking implementation progress over time and tweaking the policy interventions to ensure initial objectives are met

Figure 23: Example roadmap



2.4 How regional differences could impact the methodology

The step-by-step methodology in this report has been designed to be applicable in countries around the world. While the outcomes will be different depending on macroeconomic and circularity starting positions, the process will be similar – albeit with some variations. Below are some considerations that may be of use to policymakers while tailoring the proposed methodology to fit the situation in their country.

Any country going through the process of moving towards a more circular economy could use the step-by-step methodology outlined in this report as a tool and it is our hope that all governments can extract useful guidance from it. Policymakers will likely have considered how the methodology might be adapted to work in their country while reading the earlier sections of Part 2 but, acknowledging the wide variety of circumstances policymakers face, below are some thoughts and observations on how the different aspects of an economy, a society, and the bodies that govern them, might influence the use and adaptation of this methodology.

2.4.1 Level of circularity already achieved and support for circularity

When an enthusiastic team is about to start developing a circular economy vision and road map for the country, it is crucial to have knowledge of the level of *political support* it is likely to receive. Ideally the effort would receive broad and high-level support, but given that the circular economy framing is relatively new and it too often is still seen as belonging solely to the realm of the environmental agenda, support might be lacking in depth or breadth. In this case building alliances, narrowing the scope, and gathering early evidence are a few strategies that could help to improve the viability of the effort as well as its strength.

Where initial interest from certain departments is lacking, collaborating with the corresponding agencies on specific data requests or subsets of the analytics could offer an opportunity to gradually scale up the attention within the ministries themselves. Understanding how the circular economy could help meet the specific needs and agendas of these potential allies would not only be useful in building alliances, but should also strengthen the recommendations.

Narrowing the scope of the exercise and developing a reference pilot project for one specific product or sector could be a helpful initial stage. The starting point could be informed by different characteristics, such as the sector with the biggest need, one with demonstrated openness towards innovation and disruption, or a sector that has already achieved a certain degree of circularity (albeit with sufficient potential left). The key is to select a sector that brings a high chance of success for the effort (and even better, its subsequent implementation), without compromising too much on its relevance to the economy – marginal or niche success stories may well not prove an influential example with most businesses. There is some disadvantage to a sector-by-sector approach in that system-level or cross-sectoral challenges and opportunities may be missed, e.g. broad public awareness building, capacity building among public procurement officers, or creating attractive investment conditions. This can be mitigated by making a conscious effort to think across sector borders during sector-specific analysis and solution development, e.g. by engaging a diverse group of stakeholders and experts.

In a situation where broad and deep support is lacking, the earliest results – the findings of the baselining exercise – could be leveraged to garner further support. Keep in mind that positive evidence, such as working business models and proven business cases developed by local companies, are as important as assembling the evidence of the necessity for change, such as evidence of certain industries' exposure to commodity risk because of high material imports.

Certain sectors might already have obtained a certain level of circularity – it is important to take this into account as the solution space is defined and explored. Conversely, a less advanced starting point means improvement potential might be identified in additional places. In the food supply chain for example, countries with less efficient agricultural production could adopt a stronger focus on food wasted between field and customer. Overall, lower levels of circularity not only offer the opportunity to 'copy-paste' solutions adopted by countries farther ahead on the curve, but in addition enables leapfrogging – skipping a lot of the trial and error experienced by other countries and potentially avoiding transitional solutions that can lock countries in a suboptimal state (e.g. investments in incineration to avoid landfill).

There is one more point of relevance to understanding the degree of circularity in the country. In an economy already moving towards circularity, local businesses can play an important role in providing expert input in the early stages of the process. But in countries at the beginning of their circular journey, local businesses are less likely to contribute substantially to this debate. The dialogue with the local business community could instead focus on creating understanding of and buy-in for the potential of the circular economy in their respective sectors. The expertise on identifying circular economy opportunities and previous experience with barriers will come to a larger extent from formal (existing) studies and international businesses. It may that both situations occur within a single country, for example if one sector is already more advanced on the circular pathway than another.

2.4.2 Institutional set-up

The strength of institutions should be taken into account when considering solutions: approaches that rely heavily on actions toward public procurement or investment, or complicated administrative policy interventions such as extended producer responsibility schemes at the core of the policy package, are not likely to be successful when institutions in a country are weak. Alternative approaches could include a steer towards voluntary agreements in, for example, the packaging industry or food retailing, potentially working up the value chain, and educating the private sector on alternative models such as performance models for durable goods.

In addition, a note regarding the prevalence of grey markets in a country. A strong informal market does not preclude a rigorous analytical effort to establish circular policies, although more creativity might be required to gather workable data. From an implementation perspective such a workforce could be a strength for labour-intense secondary markets. Rather than risk destroying the livelihood of such workers, proposed policies could leverage this workforce – which usually has a 'granular' access to waste streams that can only be envied by formalised waste management systems. In addition to stimulating local authorities to improve their efficiency (better tools, better coordination with city services etc.) national policies could seek to develop higher effectiveness: grow repair and reuse markets for existing secondary product flows, create such markets for new types of products and services, and potentially improve informal labour participation by equipping them with the right type of information.

2.4.3 Available resources

The Denmark pilot was characterised by a very intense analytical effort with significant data requirements. The analysis relied heavily on data from various government agencies, including the Danish Statistical Agency, the Danish Business Authority and the Danish Environmental Agency, along with qualitative insights from interviews with 25+ businesses, industry bodies and other relevant organisations. In term of manpower, it took a commitment of approximately five to ten full-time employees (FTE) over six months, for a total of about 40 man-months: about 5 for Step 1 (Chapter 2.1), about 25 for Step 2 (Chapter 2.2), and about 10 for Step 3 (Chapter 2.3). This included full- and part-time contributions from a team of analysts from several organisations. The skills of the personnel involved in the project included:

- Business analytics, including ability to understand value chains, facilitate discussions with companies and perform sector-specific quantification of economic impact
- Macroeconomic modelling, for the economy-wide impact quantification
- Policy analysis
- Circular economy
- Environmental and resource issues
- Country-specific understanding of policy and circularity context

There might be other reasons for policymakers to limit analytical effort or organise it differently at one or more stages of the process, such as a lack of relevant data, time and/or resource constraints, lack of political buy-in to the idea of the circular economy, or different, previously established policy analysis methods. At each stage of the methodology it is possible to limit the analytical effort to match available expertise and local constraints:

- *Step 1: Align on starting point, ambition and focus*

- A simplified baselining exercise could eliminate quantitative benchmarking of resource efficiency and/or circularity metrics. It could also limit the policy surveying effort – especially where very few policies are known or suspected to be in place.

- Sector selection could be achieved without quantitative economic analysis, instead taking the country's *priority sectors*, regardless of their resource and/or GDP impact – it being unlikely that the GDP impact of a priority sector would be negligible. A qualitative review of the resource profile might be included, but such a profile matters less if, for instance, the aim is to use circular economy principles to render sectors more competitive in other ways than limiting raw material imports (e.g. by shifting to larger share of services), or if the proposed outcome is to create more employment.

- *Step 2: Assess sector circular economy opportunities*

  - Mapping and prioritising circular economy opportunities in each sector could be simplified by referring to existing inventories and reports (such as this report or the reports mentioned in Table 1 in Part 1) to get a quick overview of relevant possibilities.

  - One of the biggest analytical tasks, assessing the various impacts of the selected levers, could be reduced by relying more on standard impact assessment figures taken from other studies (again such as this one or other studies mentioned in Table 1 in Part 1). At least a minimum of localisation is necessary, i.e. to consider whether the inventoried levers would be similarly attractive and feasible in the country under study. Local factors to take into account when considering the inventoried levers include different starting points (e.g. organics recovery may be an important part of an otherwise underdeveloped waste management system), different industry structures and different access to (export) markets.

- *Step 3: Analyse national and policy implications*

  - Instead of quantifying national economy-wide impact through macroeconomic computational general equilibrium modelling, policymakers could choose to use partial equilibrium sector-level modelling and/or rely on existing studies assessing the national economy-wide impact.

  - Policymakers could decide to rely on informal assessments of policy impact, cost and political feasibility, such as stakeholder consulting methods – or use assessment methods more commonly deployed in their territory.

CASE STUDY
DENMARK

3 CASE STUDY – DENMARK

To make this toolkit as concrete and actionable as possible, it was tested in a pilot country – Denmark. The pilot focused on five sectors: construction & real estate, machinery, plastic packaging and hospitals. This part covers the core findings for these sectors, as well as an integrated national perspective. While these findings cannot be directly transposed to other countries, they might serve as a source of inspiration for the identification of opportunities, barriers and policy options.

The findings for Denmark resulted from an intense analytical phase, going through all steps of the methodology as laid out in Part 2, and including consultations with more than 25 businesses, a group of senior policymakers, and a series of international experts. The findings therefore give a good directional view on circular economy opportunities for Denmark. However, being the result of a pilot phase covering five major sectors in just a few months, the findings below do not aim to be as detailed as a typical impact assessment for one opportunity or policy. Similarly, the set of identified barriers would likely need to be analysed further. The set of opportunities is not exhaustive – significant opportunities may exist in addition to those identified here.

Each of the deep dives below covers the current state of the circular economy, the key circular economy opportunities and related barriers, and potential policy options to overcome these barriers.

3.1 National perspective

Even in a country with a starting position as advanced as Denmark, there are significant opportunities to further transition towards the circular economy. Ten circular economy opportunities in five focus sectors were identified as most promising for Denmark. Modelling conducted in this study suggests that, by 2035, these could unlock, relative to a 'business as usual' scenario:

- **an increase in GDP by 0.8–1.4%;**
- **between 7,000 and 13,000 additional job equivalents;[105]**
- **a reduction of the country's carbon footprint by 3–7%;[106]**
- **a reduction of consumption of selected resources107 by 5–50%;**
- **an increase in net exports by 3–6%.**

Each of these opportunities is limited, to varying degrees, by a number of barriers. Potential policy options to overcome these barriers have been identified. To enable a systemic transition towards the circular economy, Danish policymakers might also consider setting economy-wide direction for the circular economy, broader changes to the fiscal system, and a wider knowledge-building and education effort. These potential policy options should not be considered as recommendations; Danish policymakers would need to assess in the necessary detail their expected costs, benefits and feasibility.

105 Employment impact modelled through conversion of labour bill to job equivalents via a wage curve approach (elasticity = 0.2). Percentage change is computed vs. 2013 total full-time employment.

106 Measured as change in global carbon emissions divided by 'business as usual' Denmark carbon emissions.

107 For steel and plastic, in selected sectors in Denmark. Includes resources embedded in imported products/components.

DENMARK TODAY

Leading Danish companies, including large multinationals as well as SMEs, are pioneering circular economy solutions. Shipping company Maersk has introduced product passports for their container ships, actively working with the Korean shipyard DSME and approximately 75 suppliers of parts. The passport, which will be updated throughout the life of the ship, is a database listing the material composition of the main parts of the ship, and documents approximately 95% (by weight) of the materials used to build the ships. It will enable better recovery of parts and materials used in the construction and maintenance of the vessels.[108] Brewing company Carlsberg is using the Cradle-to-Cradle® (C2C) design framework[109] to develop C2C-certified packaging, and has set up the Carlsberg Circular Community, aiming to rethink the design and production of traditional packaging material and develop materials which can be recycled and reused indefinitely while keeping quality and value.[110] Baby clothing company Vigga offers a circular subscription model for baby clothes. The baby clothes, made from organic fabrics, are returned to Vigga once outgrown, where they are dry cleaned in an environmentally friendly way and made ready for another baby to optimise the use during the lifetime of the baby clothes.[111] These are just three out of many inspiring examples.

Denmark has a long and rich tradition of innovating policies that stimulate the circular economy. It introduced the very first deposit-refund scheme for beverage containers in the 1980s. It has incrementally increased landfill taxes since they were introduced in 1987.[112] In 2011, it set the target to be fully independent from fossil fuels by 2050. More recently, Denmark has laid out a comprehensive waste management strategy in 'Denmark Without Waste I/II', focused on moving from incineration to recycling and waste prevention, respectively. It has established the Task Force for Resource Efficiency, the National Bioeconomy Panel, the Green Industrial Symbiosis programme, and the Rethink Resources innovation centre. Denmark participates in international initiatives such as the Ellen MacArthur Foundation's CE100 programme.

Selected KPIs reveal that Denmark has indeed an advanced starting position compared to other European countries:

- Waste generated per unit GDP: 40 tonnes/EUR million vs. 69 for EU28.
- Waste diverted from landfill: 93% vs. 59% for EU28.
- Recycling rate[113]: 60% vs. 53% for EU28.
- GHG emission per unit of GDP: 225 tonnes CO_2e per EUR million vs. 343 for EU28.
- Share of renewable energy: 26% of gross final energy consumption vs. 14% for EU28.

Denmark is internationally recognised as a front runner in the circular economy. A case in point is the Danish Business Authority winning the 2015 'Ecolab Award for Circular Economy Cities/Regions' at the World Economic Forum in Davos.[114]

Yet even Denmark has significant opportunities to further transition towards circularity. Across the economy, significant material value is left on the table as most waste

108 Maersk. www.maersk.com/en/hardware/triple-e/the-hard-facts/cradle-to-cradle

109 Created by William McDonough and Professor Michael Braungart. www.c2ccertified.org

110 Carlsberg. www.carlsberggroup.com/csr/ReportingonProgress/SustainablePackaging/Pages/default.aspx

111 www.vigga.us

112 Danish Environmental Protection Agency, *From land filling to recovery – Danish waste management from the 1970s until today* (2013).

113 Excluding major mineral waste. Scope: recycling of domestically generated waste (including exported waste, excluding imported waste).

114 https://thecirculars.org

streams and by-products are used for relatively low-value applications. Of the 93% waste diverted from landfill, only two thirds is recycled – the rest is incinerated.[115] In the construction sector, 87% of materials is recycled, but mainly for low-quality applications,[116] and there is only an estimated <1% reuse of building components and materials. In the machinery sector, >95% of its most important material (steel) is recycled, yet there is an estimated <1% remanufacturing.[117] Nearly 100% of industrial organic waste is being valorised, but mainly in low-value applications such as incineration, direct fertilisation, or animal feed, while only ~3% of waste is used in biogas production and there is <1% cascading bio-refining.[118]

In addition, the headline figures quoted above hide pockets of opportunities. Municipal waste per capita is the highest in the EU (~750 kg/capita vs. ~480 kg/capita EU28 average).[119] There is an estimated 80-90 kg annual avoidable food waste per household.[120] Only ~15% plastic packaging is collected for recycling from households, of which only half actually gets recycled in new resin.[121]

CIRCULAR ECONOMY OPPORTUNITIES AND THEIR POTENTIAL IMPACT

Five focus sectors were selected for the Denmark pilot, using the approach described in Section 2.1.3. The focus sectors are:

- Food & beverage, a *producing* sector. The analysis in this sector focused on the pork and dairy processing industry, but also included a deep dive on the consumer side.
- Construction & real estate, a *producing* sector. The analysis in this sector focused on the construction and renovation of buildings, but also included a deep dive on real estate utilisation (sharing).
- Machinery, a *producing* sector. The analysis in this sector focused on pumps and wind turbines.
- Plastic packaging, a *cross-cutting* sector spanning consumer goods companies, wholesalers, retailers, and consumers.
- Hospitals, a *consuming* sector. The analysis in this sector focused on public procurement.

The energy sector, while critical for the transition to the circular economy, has not been selected as a focus sector in this study, as Denmark is already working towards a target to base all energy consumption, including the transport sector, on renewables by 2050.[122]

Using the approach described in Chapter 2.2, ten circular economy opportunities were identified across these five focus sectors. These opportunities are shown in Figure 24, and are detailed in Chapters 3.2–3.6, which each cover one sector.

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115 Eurostat.

116 Statistics Denmark; interviews with the Danish Environmental Protection Agency and sector experts.

117 Statistics Denmark; interviews with sector experts.

118 L. Lange, A. Remmen, *Bioeconomy scoping analysis* (Aalborg University, 2014); interviews with sector experts; Danish Government, *Denmark Without Waste I. Recycle more – incinerate less* (2013); Danish Energy Agency, *Biogas i Danmark – status, barrierer og perspektiver* (2014).

119 Eurostat. There are some discrepancies in how this metric is calculated in different member states.

120 Danish Environmental Protection Agency, *Kortlægning af dagsrenovation i Danmark – Med fokus på etageboliger og madspild* (2014).

121 Danish EPA; Statistics Denmark.

122 The Danish Government, *The Danish Climate Policy Plan* (2013).

Figure 24: Ten circular economy opportunities in five focus sectors

SOURCE: Ellen MacArthur circular economy team

These ten identified opportunities are already being pursued to some extent today, inside or outside Denmark. There is however significant potential to scale up. Doing so could bring Denmark from the – dependent on the sector – early or advanced transitioning economy it is today to an advanced transitioning and in some areas almost fully circular economy by 2035 (see Figure 25).

For the impact assessment, two scenarios were defined – 'conservative' and 'ambitious' – to differentiate assumptions on the scalability of the focus products to the wider focus sectors, and of the five focus sectors to adjacent producing sectors. The impact estimated for pumps and windmills, for example, is scaled up to the full machinery sector. The impact for the machinery sector is then, in turn, scaled up to the adjacent electronics sector. In the conservative scenario, such scale-up is heavily discounted – for example, when scaling up the results from the construction of buildings to infrastructure construction, these results are reduced by 80%. In the ambitious scenario, higher scale-up rates are used. A detailed overview of the scale-up used in the two scenarios can be found in Appendix B.

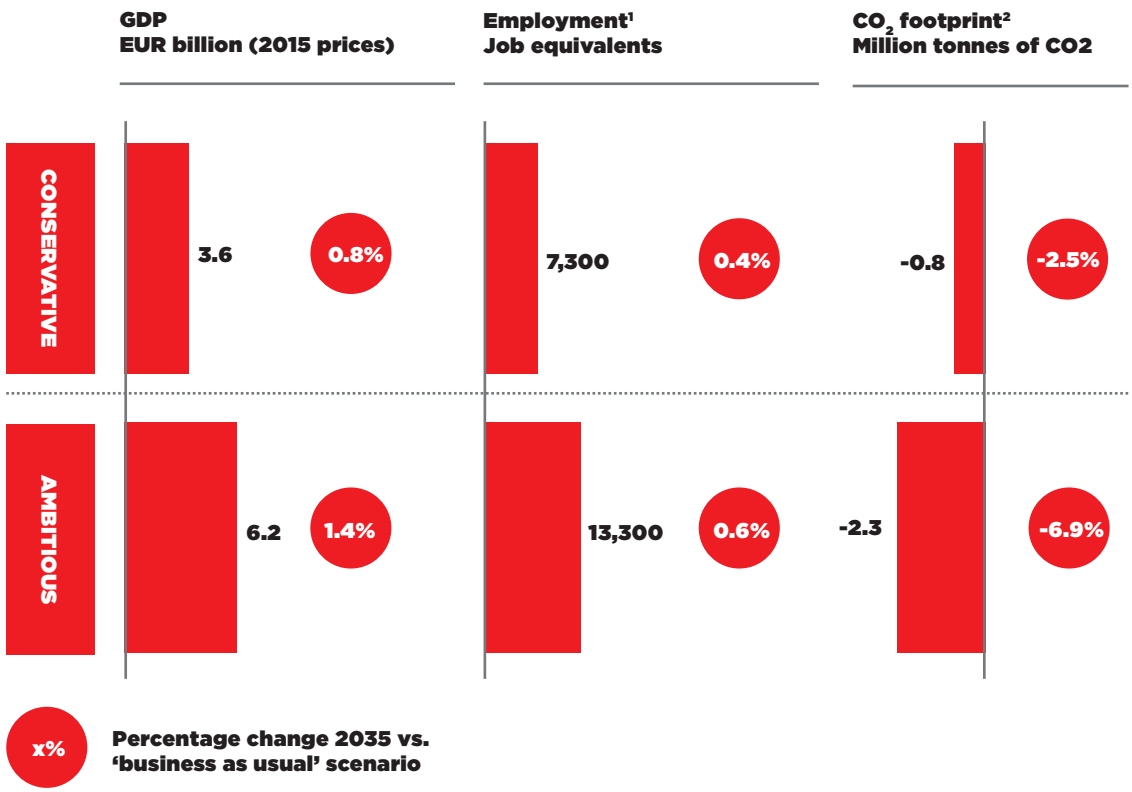
Overall, the underlying assumptions for both scenarios can be considered relatively conservative. The scenarios rely, for example, only on technologies currently at commercial stage or late R&D. In addition, the analysis focused on the producing sectors

and hospitals only, representing, in total, 25% of the Danish economy[123]. No direct circularity effects have been modelled for the service sector (except hospitals), which represents (excluding hospitals) over 70% of the Danish economy. The Danish energy mix was assumed to be the same in the 'business as usual' and circularity scenarios – which limits the size of the potential CO_2 reduction. More details on key model assumptions and data sources can be found in Appendix C.

Relative to a 'business as usual' scenario, the identified circularity opportunities, along with their potential knock-on effects on other sectors of the Danish economy, could produce significantly positive economic and environmental results (see Figure 26). While such estimates by necessity rely on a number of assumptions and recognising that the methodology used to estimate them will continue to be developed, these findings support conclusions from a growing body of research (see Figure 4 in Chapter 1.1) that the impact of a circular economy transition on economic growth, job creation and carbon emissions is likely positive.

Figure 26: Estimated potential impact of further transitioning to the circular economy in Denmark

Economy-wide impact by 2035. Absolute and percentage change relative to the 'business as usual' scenario.



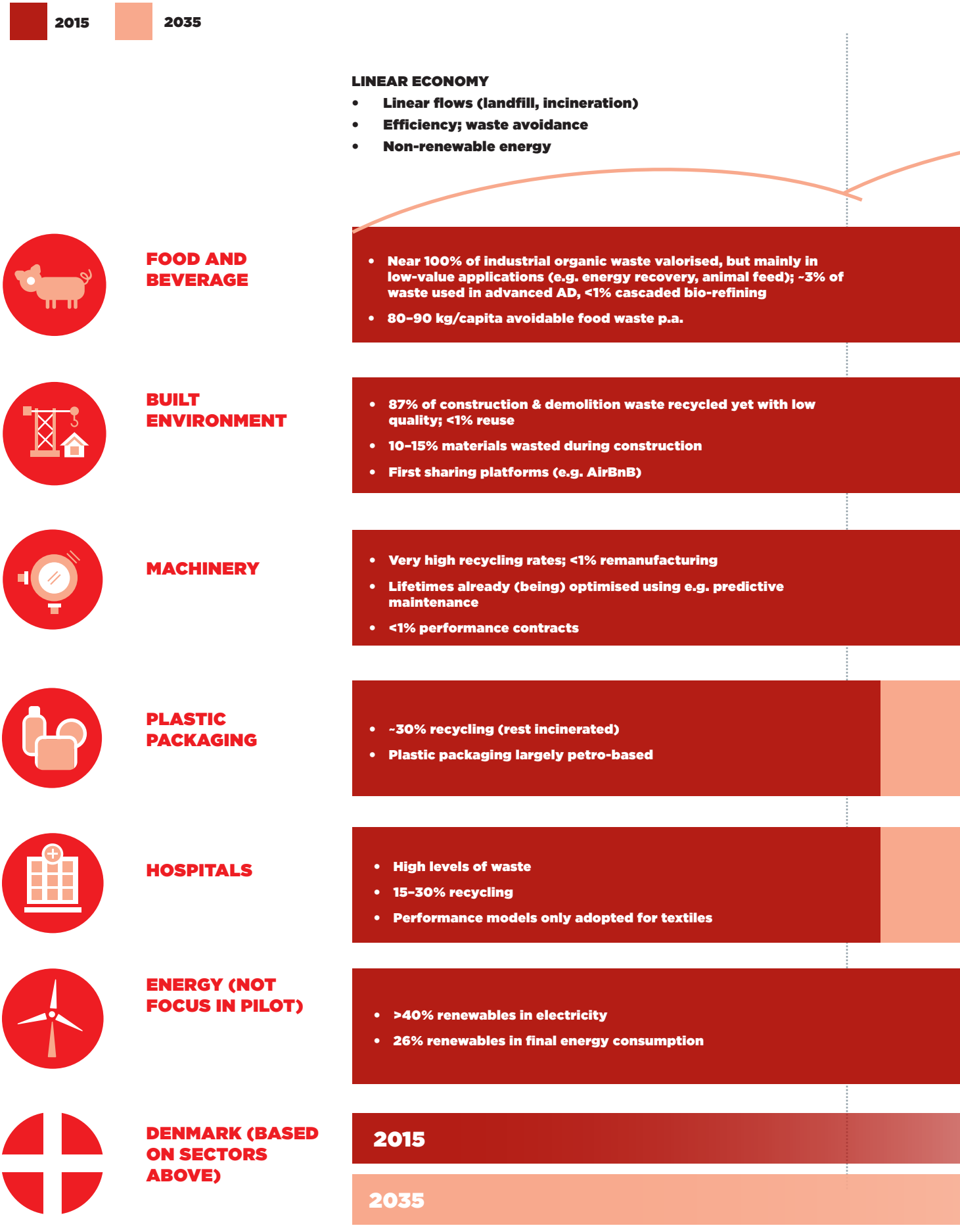
1 Employment impact modelled through conversion of labour bill to job equivalents via a wage curve approach (elasticity = 0.2). Percentage change is vs. 2013 total full-time employment (Source: Statistics Denmark)
2 Change in Global CO2 emissions vs. Denmark baseline 2035 emissions; other GHG emissions are not included.
SOURCE: Ellen MacArthur Foundation circular economy team; NERA Economic Consulting

The economy-wide impact assessment of the conservative and ambitious scenarios of circularity opportunities produced positive results for Denmark. Positive changes relative to the 'business as usual' scenario were identified in five key areas:

Economic growth (measured as change in Gross Domestic Product): Economic modelling suggests that the identified circularity opportunities could expand Denmark's

123 Based on 2011 gross value added provided by Statistics Denmark.

Figure 25: Illustrative status of circular economy in Denmark today and potential by 2035



SOURCE: Statistics Denmark; Eurostat; Danish Climate Policy Plan; expert interviews; Ellen MacArthur Foundation circular economy team

TRANSITION ECONOMY

- **Low-value circular flows (e.g. recycling, AD)**
- **Mix of renewable and non-renewable energy**

CIRCULAR ECONOMY

- **High-value circular flows (e.g. reuse, reman, cascaded value extraction for organics)**
- **Circular business models (e.g. sharing, leasing)**
- **Renewable energy**

- **~90% of organic waste in advanced AD and cascaded bio-refining**
- **40–50 kg/capita avoidable food waste p.a.**

- **15% of building materials and components reused; recycling with higher quality**
- **<1% waste in construction process**
- **Widespread building sharing**

- **15–35% remanufacturing**
- **10–15% performance contracts**

- **~75% recycling**
- **Bio-based materials replacing petro-based plastics in selected products**

- **Avoidable waste designed out**
- **>80% recycling (of non-toxic waste)**
- **40% performance models adoption for addressable equipment**

- **100% renewables in electricity and heating**
- **Oil for heating and coal phased out**
- **Fossil fuels remain in e.g. transport**

GDP by between +0.8% (in the conservative scenario) and +1.4% (in the ambitious scenario) by 2035. This increase in national economic growth would be achieved mainly through a combination of increased revenues from emerging circular activities and lower cost of production through more productive utilisation of inputs. These changes in input and output of economic production activities affect economy-wide supply, demand and prices, rippling through the other sectors of the Danish economy and resulting in a series of indirect effects that add to the overall growth. Such effects include changed activity levels in the supply chains, and greater consumption and savings resulting from an increase in household income, in turn resulting from greater remuneration to labour. Together, these effects add up to a positive change in GDP (and contribute to other macro impacts described below).

Employment (measured as job equivalents estimated via a wage curve approach): Total remuneration to labour increases both as a result of general expansion of economic activity, and as a result of the increased labour intensity resulting from certain circular economy opportunities (e.g. remanufacturing). Although the impact assessment model used in the Denmark pilot does not explicitly calculate how this higher remuneration is distributed between wage increases and new jobs, it is possible to estimate this distribution using a 'wage curve' approach and an assumption on long-run labour supply elasticity (elasticity = 0.2). Through such a calculation, it is estimated that the direct and indirect effects of circularity could bring positive impacts to employment by adding between 7,000 (in the conservative scenario) and 13,000 (in the ambitious scenario) full-time job equivalents to the economy by 2035.[124]

Carbon footprint (measured as change in global emissions as a result of Denmark's more circular economy): Increased circularity and the associated reduction in resource consumption would lower the carbon intensity of Denmark's own producing sectors, reduce Denmark's imports of high-carbon-embodied goods, and increase Denmark's exports of lower-carbon-embodied goods. These changes would directly affect the carbon emissions of Denmark and its trading partners, and indirectly also those of its non-trading partners. This could reduce global carbon emissions in a magnitude equal to between 3% (in the conservative scenario) and 7% (in the ambitious scenario) of Denmark's 'business as usual' carbon emissions by 2035. This reduction excludes the effects resulting from a shift to renewable energy.

Resource use: By 2035, increased remanufacturing in the machinery sector could reduce demand for 60,000–90,000 tons of iron/steel annually (6–10% of total consumption in that sector).[125] In plastic packaging, demand for virgin plastic could be reduced by 80,000–100,000 tons annually due to increased recycling (40–50% of total in that sector[126]).

International trade balance: In a circular economy, Denmark's use of goods and services would be more productive than it would be otherwise. That is, Denmark would be able to produce goods and services, primarily those in the focus sectors, at a lower cost. This cost advantage from greater circularity would improve cost-competitiveness internationally, which would result in higher exports and erode the attractiveness of imports, reducing their volume. Such trade effects could ripple across to other countries, resulting in a shift in Denmark's trading patterns with the rest of the world. By 2035, net exports (i.e. exports minus imports) could expand, relative to the 'business as usual' scenario, by 3% (in the conservative scenario) and 6% (in the ambitious scenario).

For a detailed description of the impact assessment methodology, see Sections 2.2.3 and 2.3.1, and Appendix B.

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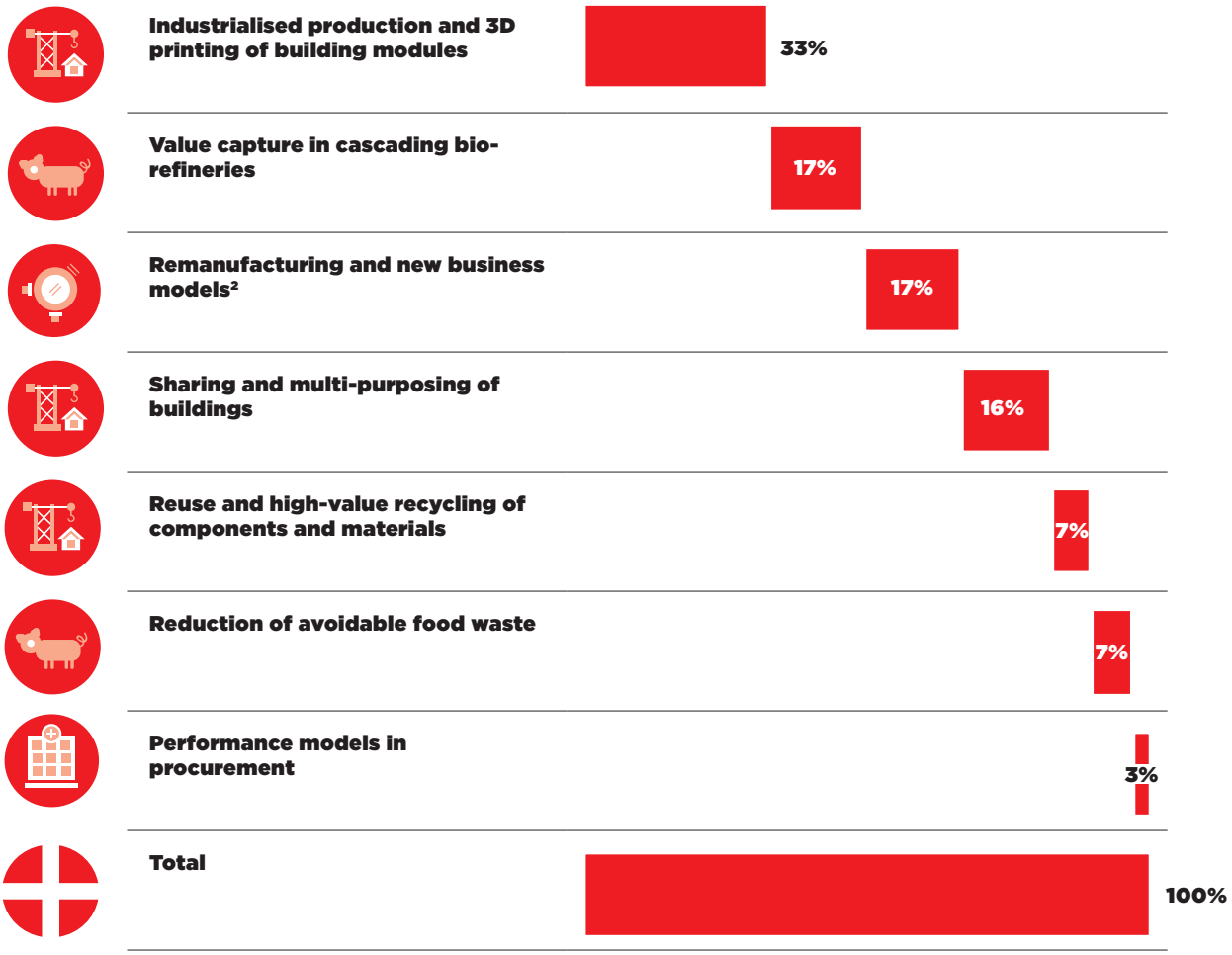
124 Employment impacts are computed assuming a wage curve and a long-run labour supply elasticity of 0.2. This methodology is similar to the approach adopted by the Danish Economic Council (DØRS) when interpreting employment impacts within a CGE with full employment assumption. The chosen elasticity value is an average for European countries.

125 Total steel demand provided by Statistics Denmark. Steel savings estimated based on the adoption rate of component remanufacturing in the machinery sector (Chapter 3.4), informed by material composition provided by industry reports and sector experts.

126 Measured by annual plastic packaging waste generated. Danish Environmental Protection Agency, *Statistik for emballageforsyning og indsamling af emballageaffald 2012* (2015 rev.).

Figure 27 shows a breakdown of these results along the seven quantified circular economy opportunities. Three circular economy opportunities have not been quantified. The economic impacts of the two packaging opportunities and the opportunity related to waste reduction and recycling in hospitals have not been quantified as it is expected that their magnitude would be limited when compared to the full Danish economy.

Figure 27: Breakdown of potential economic impact by quantified opportunity



1 Average between conservative and ambitious scenario. This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling.
2 Including scaling from machinery sector (including pumps, wind turbines and other machinery products) to adjacent manufacturing sectors (electronic products, basic metals and fabricated products, other manufacturing, mining and quarrying)
SOURCE: Ellen MacArthur Foundation circular economy team

BARRIERS AND POTENTIAL POLICY OPTIONS

While most circular economy opportunities identified in Denmark have sound underlying profitability, there are often non-financial barriers limiting further scale-up or reducing their pace. An overview of the barriers to each of the opportunities in the Denmark pilot is provided in Figure 28.

The social factor barriers of capabilities and skills and custom and habit are widespread, as the behavioural changes needed to realise many of the opportunities go against ingrained patterns of behaviour and skill-sets on the part both of consumers and businesses. Imperfect information was also often found to be a barrier: businesses can be unaware of potentially profitable new opportunities, or the information necessary to realise them is unevenly distributed.

Technology can be a critical barrier as well, especially for the more technology-

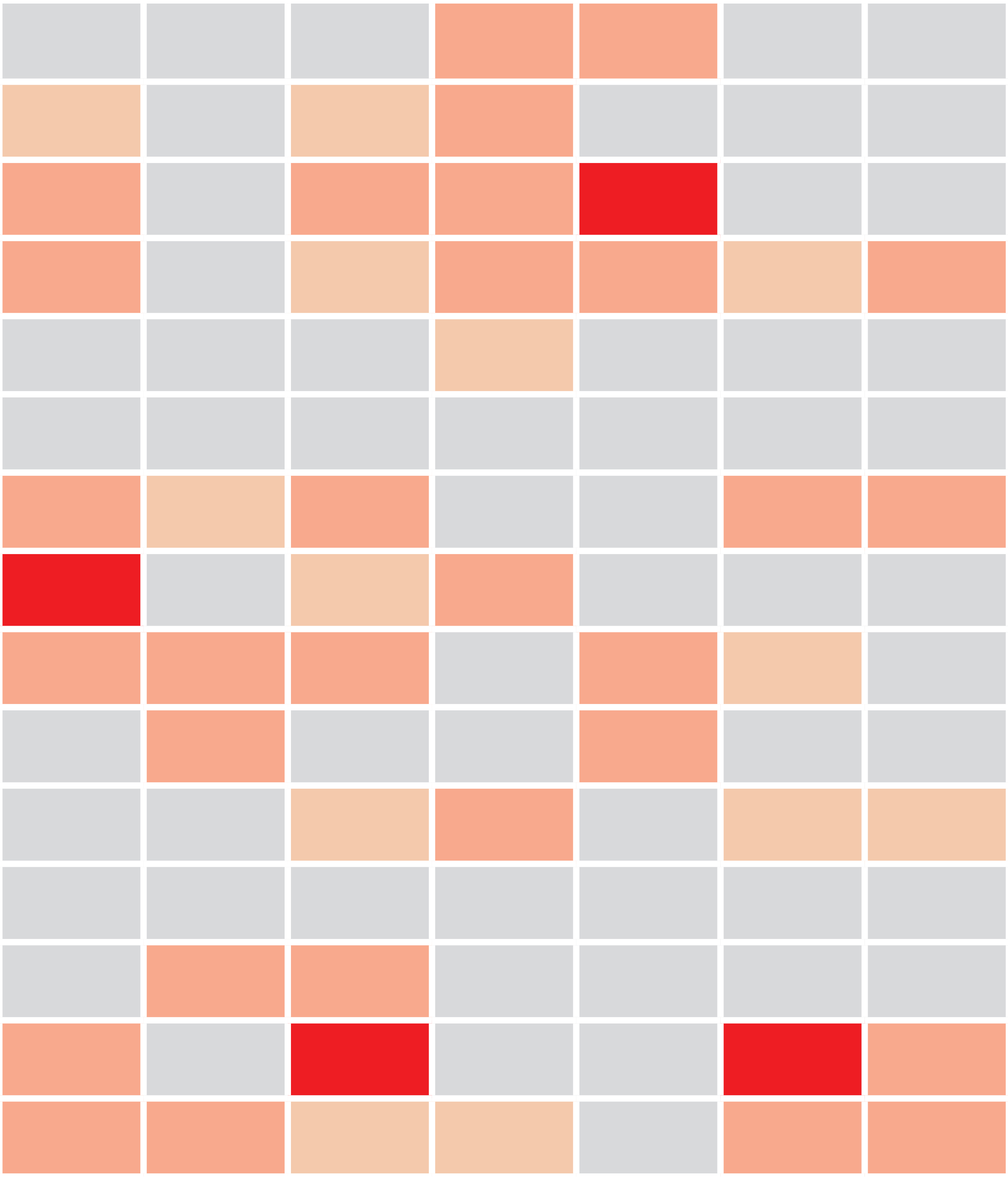
Figure 28: Barrier matrix for the ten prioritised opportunities in Denmark

- Critical barrier ('make or break')
- Very important barrier (to scale-up / acceleration of lever)
- Important barrier (to scale-up / acceleration of lever)
- Limited or no barrier

	BARRIERS	CIRCULAR ECONOMY OPPORTUNITIES: Value capture in cascading bio-refineries	Reduction of avoidable food waste	Industrialised production and 3D printing of building modules
ECONOMICS	Not profitable for businesses[1] even if other barriers are overcome			
	Capital intensive and/or uncertain payback times			
	Technology not yet fully available at scale			
MARKET FAILURES	Externalities (true costs) not fully refletcted in market prices			
	Insufficient public goods / infrastructure[2] provided by the market or the state			
	Insufficient competition / markets leading to lower quantity and higher prices than is socially desirable			
	Imperfect information that negatively affects market decisions, such as asymmetric information			
	Split incentives (agency problem) when two parties to a transaction have different goals			
	Transaction costs such as the costs of finding and bargaining with customers or suppliers			
REGULATORY FAILURES	Inadequately defined legal frameworks that govern areas such as the use of new technologies			
	Poorly defined targets and objectives which provide either insufficient or skewed direction to industry			
	Implementation and enforcement failures leading to the effects of regulations being diluted or altered			
	Unintended consequences of existing regulations that hamper circular practices			
SOCIAL FACTORS	Capabilities and skills lacking either in-house or in the market at reasonable cost			
	Custom and habit: ingrained patterns of behaviour by consumers and businesses			

1 At market prices excluding the full pricing of externalities such as greenhouse gas emissions, ecosystem degradation and resource depletion
2 Infrastructure defined as fundamental physical and organisational structures and facilities, such as transportation, communication, water and energy supplies and waste treatment

Reuse and high value recycling of components and materials	Sharing and multi-purposing of buildings	Remanufacturing and new business models	Increased recycling of plastic packaging	Bio-based packaging where beneficial	Performance models in procurement	Waste reduction and recycling in hospitals



dependent opportunities such as cascading bio-refineries, 3D printing of building components, and bio-based packaging.

Externalities feature as a barrier to many opportunities, though they do not threaten the fundamental profitability of most, with the exception of packaging. In this sector, without the additional factoring in of externalities, the profitability of both recycling and bio-based packaging is highly dependent on the price of the alternative – petro-based plastic, which is in turn determined by global oil prices. A similar reasoning applies to bio-refineries, although cascading bio-refineries could alleviate this concern by diversifying revenue streams beyond alternatives to petro-based fuels, chemicals and plastics.

The barrier of unintended consequences from existing legislation limiting circular economy opportunities is present for example in bio-refining where food safety regulations prevent the use of certain animal products as feedstock. Such barriers can be in the complexity and cost of adhering to regulations as well as in actual prohibition of certain activities. The devil is in the detail here, and more detailed analysis of unintended consequences would be required to determine the exact magnitude of this barrier for the different opportunities in Denmark.

Potential policy options that could overcome the barriers for each of these opportunities have been identified. These options cover a broad range of policy intervention types, and are detailed in the sector deep dive chapters below. They should not be considered as recommendations, rather as an input to Danish policymakers' discussions about if and how to shift to a circular economy. Policymakers would need to assess in detail their expected costs, benefits and feasibility.

To enable a systemic transition towards the circular economy, Danish policymakers could also reflect on setting an economy-wide direction for the circular economy, broader changes to the fiscal system, and a wider knowledge-building and education effort. While many circular economy opportunities already have a sound underlying profitability, a number of international organisations, such as the European Commission, the OECD, the IMF, and the International Labour Organization, have suggested further opportunities could be unlocked by shifting fiscal incentives towards labour from resources. However, the effects of such a shift would need to be carefully analysed, especially considering Denmark is a small and export-oriented country. Complementing today's flow-based metrics such as GDP as a measure of economic success with measures of a country's stock of assets could be an instrument for policymakers to account for the restoration and regeneration of natural capital.

3.2 Food & Beverage

The Danish food and beverage industry has developed a track record of minimising processing waste and finding productive use for its by-products and remaining waste streams – but mostly in relatively low-value applications. It therefore has a significant opportunity to increase the value extraction from its by-products and waste streams by using cascading bio-refineries. While anaerobic digestion and other basic bio-refining technologies exist today, the technology to derive – in cascaded applications – high-value compounds is still an estimated five years away. If technological development continues and plant capacity is built up, modelling suggest that these cascading bio-refineries could yield, by 2035, a potential net value of EUR 300–500 million annually. In parallel, reducing the levels of avoidable food waste from 80–90 kg/capita to 40–50 kg/capita, enabled through building awareness and capabilities among households and businesses and improving technologies across the value chain, could save Danish households and businesses an estimated EUR 150–200 million annually by 2035.

Operating in a highly competitive international context, the Danish food and beverage industry has developed a track record of minimising processing waste and finding productive use for its by-products and remaining waste streams. However, most of these

applications are relatively low-value, such as the production of animal feed or energy extraction. The Danish food and beverage processing industry therefore has a significant opportunity to increase the value extraction from its by-products and waste streams in cascading bio-refineries.

The retail and hospitality sectors and households, on the other hand, generate large quantities of avoidable food waste. Considering that Danish households spent over EUR 23 billion on food and beverages in 2013, or 20% of their total consumption,[127] significant value could be captured by reducing avoidable food waste.

3.2.1 Value capture in cascading bio-refineries

Opportunity:	**Develop cascading bio-refineries that capture the full value of by-product and waste streams by extracting several different products.**
2035 economic potential:	**EUR 300–500 million p.a.**
Key barriers:	**Capital to build and scale up capacity; technology; unintended consequences of existing regulation.**
Sample policy options:	**Long-term strategic targets for bio-refineries; support capacity for current technologies and create markets; support technological development.**

Home to international players such as Carlsberg, Danish Crown, and Arla, the Danish food and beverage sector is a cornerstone of Danish industry, representing 25% of the total product exports, and 7.7% of the gross value added by the Danish producing sectors.[128]

The Danish food-processing industry is already a leader in resource productivity, both in terms of minimising waste and valorising by-products:

- At Carlsberg, ~95% of brewery by-products are sold as fodder supplements, and the company is currently looking into biogas generation for additional value extraction.
- Danish Crown 'does not think in terms of waste at all' according to environmental manager Charlotte Thy. 'It's in our DNA to find applications for all our by-products'. Slaughterhouses today have a multitude of ways to valorise all parts of the animal. For example, bones, trotters and excess blood can be sold as animal feed, and even manure left in the intestines is collected and used for biogas generation.
- Arla has used whey, a by-product of cheese making, to produce high-protein products since the 1980s.

Other organic waste, such as wastewater from industries and households, and food waste, is used to extract energy using anaerobic digestion (biogas), combined heat and power, or direct district heating. Denmark had an estimated 1.2 GWh biogas capacity in 2012. The biogas plants treat 3% of Denmark's organic waste as well as wastewater and manure. Most of the capacity was built before 2000, but in 2012 Denmark adopted a new support model and subsidy scheme for the production and use of biogas. The Danish Energy Agency now estimates that biogas capacity will increase to 2.8 GWh by 2020.[129]

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127 Eurostat, *Final consumption expenditure of households by consumption purpose* (2013).

128 Based on gross value added in 2011, reported by Statistics Denmark. Producing sectors include agriculture, forestry and fishing; mining and quarrying; construction; electricity and gas; manufacturing

129 Danish Energy Agency, *Biogas i Danmark – status, barrierer og perspektiver* (2014).

THE OPPORTUNITY FOR DENMARK

There is still a large opportunity to capture as most of the abovementioned applications extract only a fraction of the value residing in the various organic by-products and waste streams. According to an Aalborg University report, Denmark has a strong position in bioeconomy R&D, but it is insufficiently leveraged since new valorisation technologies have not yet been piloted to the extent required to accelerate them to commercial scale.[130]

It has been argued for some years that advanced, cascading 'bio-refineries'[131] could unlock this value by deriving valuable products from organic waste and by-products, in many ways emulating the conventional petroleum refinery.[132] The core principle is to cascade waste/by-product streams through a series of value-creating steps. The cascade could consecutively produce, for example, high-value biochemicals and nutraceuticals, followed by bulk biochemicals, and still be able to produce biofuels and/or biogas with the remaining biomass. The extraction of nitrogen, phosphorus and potassium (NPK)[133] and the return of digestate to soils (restoration) ensures that the process also helps preserve natural capital.

To ensure viability of full value capture through a set of cascaded operations, development of the more advanced technologies that extract complementary products from the by-products or waste needs to accelerate. There are many promising examples of this group of technologies developed today. The following are selected examples; see also Notes 130 and 132):

- Use newly engineered enzymes to convert keratin-rich parts such as hairs, bristles or feathers to high-protein feed ingredients.
- Extract proteins and other food ingredients from under-utilised residues from plants (press cake from oil seed, potato peelings, brewers' spent grain) or animals (by-catch and side streams from fisheries).
- Extract or synthesise nutraceuticals from pig blood and similar chemically rich by-products.
- Use microbes to synthesise bioplastics from sewage sludge or wastewater, such as in the Danish multi-stakeholder project at special ingredient manufacturer KMC's water treatment plant.[134]

Aside from developing the technologies needed, it is challenging to make them all come together in an integrated way, and also make them work in concert with more basic technologies like anaerobic digestion. One of the few plants today operating in line with the definition of an advanced, cascading bio-refinery (see Note 131) is the Borregaard plant in Norway.[135] The plant, which used to make paper and cellulose, now produces a variety of fine chemicals for both food and chemical industries, cellulose-derived materials and biofuels, mostly based on feedstock from the forest industry. While Borregaard is not directly comparable to a bio-refinery based on organic waste, such developments are underway: for example, Veolia has launched a project in collaboration with UK-based Bakkavor Group to transform a wastewater treatment plant in Belgium to a fully cascading bio-refinery that produces pharma-grade chemicals, bioplastics,

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130 Lange, L., Remmen, A., Aalborg University, *Bioeconomy scoping analysis* (2014).

131 A bio-refinery can be defined as a plant that is designed to convert an organic feedstock into several value streams by cascading the material through a series of extraction and/or conversion operations. This is not to be confused with pure-play biofuel or combined heat and power plants that also use an organic feedstock.

132 For more details, please see Ellen MacArthur Foundation, *Towards the Circular Economy I* (2012), p.52.

133 For example, the EU-led P-REX project seeks to demonstrate phosphorous recovery from municipal wastewater at scale. www.p-rex.eu

134 State of Green, *Producing more with less. Danish strongholds in bioeconomy & resource-efficient production* (2015).

135 www.borregaard.com

fertilisers, energy and clean water.[136]

With the necessary investments in technology and capacity available, Denmark could become a leader in cascading bio-refining:

- By 2020, Danish businesses could have set up the first new bio-refineries to maximise the valorisation of existing waste streams using mature technologies (e.g. enzymatic protein extraction from animal by-products and chemical extraction from wastewater). Continuing extension of biogas and biofuel capacity could serve as platforms for emerging, more advanced technologies. Recognising that such technologies take time to develop at scale, it is estimated that 20% of the organic waste and by-products are available for additional value creation in the short term, and that 60% of the added value would come from extending and improving biofuel and biogas production with 40% provided by extracting bio(chemicals).

- By 2035, Danish businesses could become technology frontrunners in by-product (waste) valorisation in cascading bio-refineries, using by then mature advanced technologies for high-value extraction of biochemicals and nutraceuticals. By this time an estimated 90% of the waste streams could be processed in new applications, and 60% of the total value added could come from extracting bio(chemicals), with 40% coming from producing biofuel and biogas (either directly or by the cascading of material streams from higher-value applications).

By assuming a relatively conservative estimate of additional value extraction from existing waste and by-product streams, the impact assessment suggests that cascading bio-refineries could create an annual value of EUR 300–500 million[137] in Denmark by 2035. This estimate builds on the work of The Netherlands Organisation for Applied Scientific Research (TNO), which has mapped the potential value increase of 34 organic waste and by-product streams that could be achieved by up-cycling to higher-value applications, and estimated that up to 25–30% additional value.[138] These estimates have been applied to the Danish context with input from industry experts and Denmark-specific data. The findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, the most important of which are detailed in Appendix B.

DENMARK IS WELL POSITIONED TO CAPTURE THE OPPORTUNITY

Denmark would be well positioned to develop and expand to such next-generation cascading bio-refineries. With a large agriculture and food processing industry, it has significant access to feedstock. Denmark has a leading position in biotechnological research and innovation, both in academia and in companies such as Novozymes, Chr. Hansen and Daka. It was pointed out in interviews with academics and industry representatives that the biochemical technologies needed to unlock significantly larger value are only about five years from maturity, but investments are needed to take them from the lab to the market: numerous technologies are also already available, but due to a fragmented market nobody has yet connected the dots to create more integrated bio-refining systems.

There is already a focus on this new 'bioeconomy' in Denmark, and the government has appointed The National Bioeconomy Panel, which consists of experts from academia, industry and public bodies, to evaluate strategic options. In March 2015, the panel published a recommendation to support second-generation biofuel generation by introducing a 2.5% mixing requirement in petrol, and to support the use of yellow

136 Veolia and Bakkavor presentation at The Water Event, 2013. www.thewaterevent.com/files/collaboration_and_partnership_delivering_sustainable_solutions_to_water.pdf

137 This *sector-specific* impact does not include indirect effects, e.g. on supply chains, captured in the economy-wide CGE modelling.

138 The Netherlands Organisation for Applied Research, *Opportunities for a circular economy in the Netherlands* (2013). It was estimated that new valorisation technologies could generate an additional EUR 1 billion annually in the Netherlands, compared to the current value of waste streams of EUR 3.5 billion.

biomass[139] to produce biochemicals, biomaterials and biofuels through public procurement, increased research funding or other economic support.[140] The construction of a second-generation bioethanol plant in Maabjerg (The 'Maabjerg Energy Concept' or MEC plant), projected to come online in January 2016, further illustrates that there is a willingness to invest from both private and public stakeholders.[141]

While the increased valorisation of existing waste and by-products is the focus of this analysis, there are several other ways to derive additional value in the bioeconomy. As highlighted during an interview by Mads Helleberg Dorff Christiansen from the Danish Agriculture & Food Council, there is large potential to continue the optimisation of input factors, such as crops with higher resilience and yield, improved livestock breeding, elimination of fertiliser leakage, and better feed. Another option is to deliberately modify plants to produce more auxiliary biomass to be used in bio-refineries. According to a study from the University of Copenhagen, it would be possible to produce an additional 10 million tonnes of biomass without significantly altering regular land use or output from agriculture and forestry sectors.[142] The report claims that products worth between EUR 1.9 and 3.5 billion could be generated from processing this biomass (mainly for fuel), while generating 12,000 to 21,000 new jobs.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'value capture in cascading bio-refineries' opportunity (see Section 2.2.4 for the barriers framework). Although there were some variations in emphasis from the sector experts interviewed in the course of this study, the central message was clear: the largest barriers preventing an acceleration of next-generation bio-refineries are technology and capital. The full value of organic waste and by-products cannot be extracted unless emerging technologies are supported to reach beyond R&D stage to commercial deployment. This study did not encounter any bio-refineries that use microbial or enzymatic processes to produce bio-based materials such as plastics at industrial scale, indicating that such technology is still at the development stage. Building an efficient bio-refinery operation is also capital intensive. The financing of the MEC plant at EUR 300 million would – if they were to take it on alone – represent 9–12% of the balance sheet of leading companies in the sector. Payback depends partially on the ability to use current technologies (such as bioethanol and biogas) as platforms, and then add to the biochemical cascade more advanced technologies when they become commercially viable. While the revenue streams from the high-value, low-volume products such as nutraceuticals combined with bulk biofuels or other chemicals could ensure profitability, the competitiveness of the products would be increased if the prices of alternatives derived from petro-based resources reflected their true costs (externalities).

Unintended consequences of existing regulations also stand in the way of the bio-refinery opportunity. It is important to keep in mind the complex and internationalised regulatory landscape for the food & beverage sector. Denmark, like other European member states, has only limited control over legislation governing raw material and product handling, as well as waste treatment, which is set at EU level. The most prominent example is the more extensive restrictions on animal by-products being rendered into animal feed, following the breakout of bovine spongiform encephalopathy (BSE) in the 1990s. This animal by-product legislation restricts some animal parts from being used in bio-refining. Several sector experts indicate that sometimes Denmark has chosen to implement this legislation more strictly than its peers.

While parts of the legislation governing food safety and waste treatment may have the

139 Yellow biomass includes straw, haulm and dry crop residues.

140 The National Bioeconomy Panel, *Anbefalinger: Det gule guld – halmressourcens uudnyttede potentiale* (2015).

141 Adding to the existing 800,000–900,000 tonnes capacity to convert biomass into biogas, the new plant is expected to convert 300,000 tonnes of yellow biomass to 80 million litres of bioethanol. The total investment of ~EUR 300 million comes from key industrial stakeholders such as DONG and Novozymes, but also from the EU (EUR 39 million) and Innovation Fund Denmark (EUR 40 million).

142 Gylling, M. et al., Department of Food and Resource Economics, University of Copenhagen, *The + 10 million tonnes study: increasing the sustainable production of biomass for biorefineries* (2013). The potential also includes better collection of biomass from farmland, road verges, waterweed and cover crops.

unintended consequence of preventing advancement of new bio-refining operations, interviews indicate that in many cases it is more the complexity of the regulatory framework than the restrictions themselves that act as a barrier. The complexity creates uncertainty and imposes the significant administrative costs of understanding how to comply and going through the process of acquiring the required permits. It should therefore be noted that the regulatory situation in the case of each potential bio-refining value-generation opportunity needs to be investigated closely.

To address these barriers, the following policy options could be further investigated. They are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **As a starting point, including bio-refineries in the government's long term strategic plans**. This could guide and reassure investors—even more so if accompanied by a policy package to deliver the strategy.[143]

- **In the short term, providing capital to deploy commercial-scale versions of *mature* bio-refinery technologies**. Promising policies include providing low-cost loans or loan guarantees for the deployment of mature bio-refining technologies for example through existing Danish business support schemes, and financing at market rates that is better tailored to investors' needs (as provided for example by the UK Green Investment Bank in municipal energy efficiency). Public-private partnerships to finance the deployment of mature bio-refining technologies also hold promise. An interesting example is the Closed Looped Fund NY that provides zero- or low-interest loans to municipalities or companies, albeit more active in developing recycling infrastructure.[144]

- **In addition, creating markets** for bio-refinery output. Pricing externalities, setting targets (e.g. a minimum target for second-generation fuels within the EU's biofuels target) could contribute to such market development.

- **In the longer term, stimulating development of advanced, high-value bio-refining technologies.** The government could set up or fund cross-institutional R&D clusters to accelerate the move into high-value chemicals, nutraceuticals, pharmaceuticals etc. These could take on various forms, like the UK Catapults, a powerful example of public private partnerships in R&D, or the German Fraunhofer Institute, which plays an important role in European innovation with its long-term perspective and clearly defined mission to support application oriented research [145]

- **Complementing these measures with a business advice service.** The primary goal would be to help bio-refinery entrepreneurs navigate a relatively complex regulatory and policy environment, but it might also help the bio-refinery community shape this environment.

- **Identifying and communicating necessary changes to EU policy** (or its national implementation) to address the unintended consequences of some safety-focused regulations that unnecessarily restrict the trade in bio-refinery feedstock or products.

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143 In the G7 Germany, the USA and Japan have specific national bioeconomy strategies with targets. While France, the UK, Italy and Canada do not have a dedicated strategies they provide support for the biobased economy on the ground. Though some of these strategies and other programmes provide specific support to biorefineries, none places cascading bio-refining at their core. For more detail, see German Bioeconomy Council, Bioeconomy Policy: Synopsis and Analysis of Strategies in the G7 (2012)

144 www.closedloopfund.com/about/

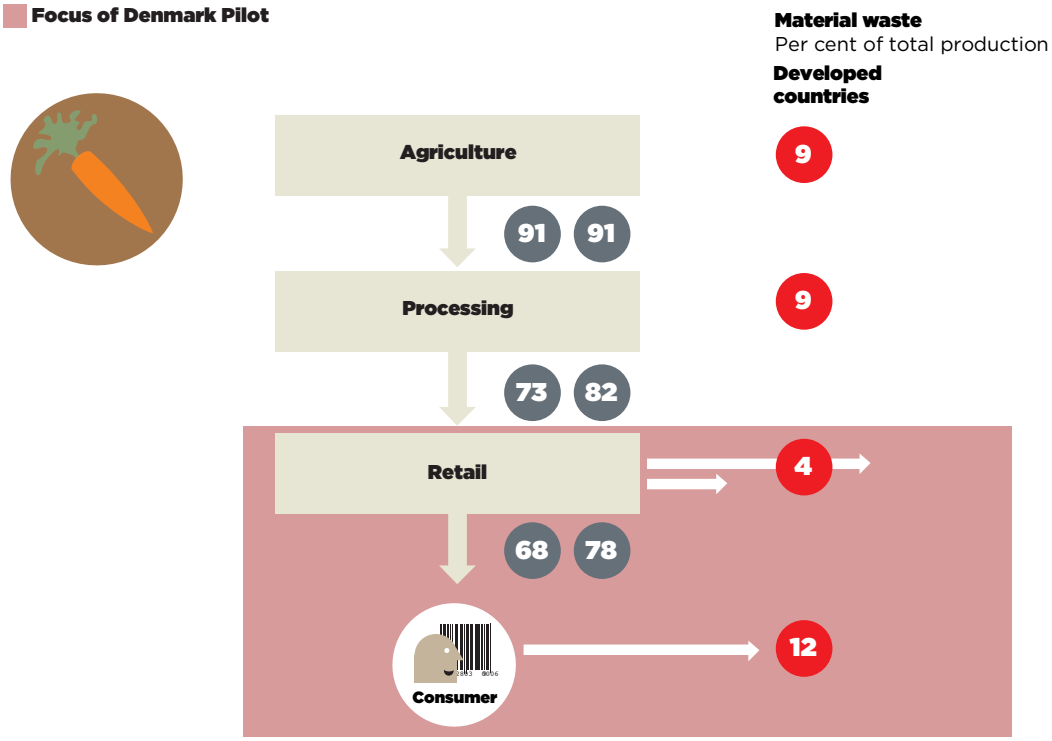
145 UK Catapults: See e.g. www.catapult.org.uk/; Fraunhofer Institute: See e.g. www.fraunhofer.de/en/publications/fraunhofer-annual-report.html

3.2.2 Reduction of avoidable food waste

Opportunity:	**Reduce avoidable food waste by building awareness and knowledge for consumers, leveraging technology and best practices for businesses, and creating markets for second-tier (refused) food.**
2035 economic potential:	**EUR 150-250 million p.a.**
Key barriers:	**Consumer custom and habit; business capabilities and skills; imperfect information; split incentives.**
Sample policy options:	**Consumer information and education; quantitative food waste targets; capability building; fiscal incentives.**

A significant opportunity lies in preventing the very generation of organic waste.[146] On average, 35% of food output is wasted along the value chain, and while developed economies like Denmark are comparatively good at reducing waste in food processing, there is a high waste volume generated by end consumers (see Figure 29). Denmark generates an estimated 80–90 kg/capita of avoidable food waste per year.[147]

Figure 29: Main sources of food waste in global food value chain – production and consumption



SOURCE: FAO 'Global Food Losses and Food Waste – Extent, causes and prevention', Rome 2011; adapted from Ellen MacArthur Foundation, Towards the circular economy II (2013)

For this reason, the opportunity assessment for avoiding waste in the food and beverage sector focuses on the end-consumer-facing part of the value chain (including retail

146 Known as the 'Lansink's ladder', the principle – to avoid waste over reuse, reuse over recycle, recycle over energy recovery, and energy recovery over disposal – has been part of the European Waste Framework Directive since 2008.

147 Danish Environmental Protection Agency, *Kortlægning af dagsrenovation i Danmark – Med fokus på etageboliger og madspild* (2014).

and hospitality).[148] The awareness of this issue has increased rapidly over the past five years, and waste minimisation is now an integral part of the government's 'Denmark Without Waste' strategy.[149] There have already been multiple information and awareness campaigns to reduce food waste among consumers, but much remains to be done.

The Danish EPA has estimated that 56% of the food waste generated by households, and 79% on average in the retail and hospitality sectors, is avoidable.[150] Danish households generate approximately 55% of the avoidable food waste,[151] and even if the value lost from discarded food is significant,[152] customers have a tendency to choose convenient solutions. While businesses have spent a long time minimising food waste, there is still large potential for improvement.

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Consumers and businesses could save significant value by minimising avoidable food waste. A study by SITRA in Finland found that the savings from reducing food waste would be in the range of EUR 150–200 million annually.[153] Translated to the size of the Danish economy, this corresponds to a prevention of roughly 30–50% (30–40 kg/capita) of total avoidable food waste,[154] and an estimated saving of EUR 150–250 million annually by 2035.[155] These findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, the most important of which are detailed in Appendix B. The savings would be achieved by a number of activities, including:

- **Right-sizing the shopping basket.** Consumers could prevent waste by purchasing less unnecessary 'big packs' or '3 for 2' deals, which would seem to save money upfront but could create more waste. A related issue is the practice of paying per unit for fresh produce (the current practice in Denmark, as opposed to paying by weight), which incentivises the consumer to buy the largest item – generating waste both on the consumer side (consumers buy a larger item than they need), and further back in the value chain, as smaller items could get deselected or even wasted without being sold[156]. Restaurants could avoid excess purchases by relentless data tracking and planning, which would require investing in capability building but would not necessarily make procurement more time consuming.

- **Better knowledge about food preservation.** Despite not seeing themselves as 'food wasters'[157], consumers often throw away useful food, either because they prepare too much for a meal, or because they believe the food is spoiled. Date labelling is required on packaged food to protect consumers, but many people throw away food that has passed the date even though it has been well refrigerated or appropriately stored and remains fresh, due to lack of knowledge of what the labelling actually means. This behaviour also affects food retailers, as they

148 While Danish food processing companies are generally regarded as proficient in preventing waste, the Danish Environmental Protection Agency notes that there are still losses from agriculture. Waste prevention in the agricultural sector was not however in the scope of the Denmark pilot.

149 Danish Government, *Danmark uden affald II. Strategi for affaldsforebygglese* (2015)

150 Danish Environmental Protection Agency, Kortlægning af dagsrenovation i Danmark – *Med fokus på etage-bol- iger og madspild (2014); Danish Environmental Protection Agency, Kortlægning af madaffald i servicesektor- en: Detaljhandel, restauranter og storkøkkener* (2014).

151 Around 25% is generated by the retail sector and around 20% from the hospitality sector, based on data from Note 150.

152 A UK study estimated that the value of unconsumed food and drink amounted to USD 770 per household a year. WRAP, *Waste arising in the supply of food and drink to households* (2011).

153 SITRA, *Assessing the circular economy potential for Finland* (2015).

154 In comparison, WRAP has estimated that directed efforts in the UK have reduced consumer food waste by 15–80%. WRAP, *Strategies to achieve economic and environmental gains by reducing food waste* (2015).

155 This *sector-specific* impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling.

156 Halloran, A. et al., Food Policy 49, *Addressing food waste reduction in Denmark* (2014).

157 Beck C. et al., FDB, Vallensbæk, *Forbrugere: Vi smider ikke mad ud!* (2011).

are forced to remove products approaching the 'best before' date. The EU has encouraged the discounted sale of such products since 2012 but market acceptance is low. Better knowledge about the preservation of food and when it can be safely used could lead to significant waste volumes being avoided.

- **Leveraging best practices.** A range of methods exists to reduce the significant volume of food waste occurring in the grocery store and along the value chain. Best practices include using data-driven optimisation of ordering and pricing,[158] and increasing shelf life by improving packaging techniques.[159] In the hospitality sector, preventing leftover waste could be achieved by using data to optimise the size of servings and avoiding unnecessary volumes on buffets.

- **Smart technology.** 'Intelligent packaging', able to transmit information about the food contained within, is a packaging improvement that has been anticipated for some time, and is now beginning to enter the market. In 2012 TetraPak launched a milk carton able to record the time spent at room temperature and change colour when too much exposure has been recorded. While indicators of time and temperature are only a proxy for real identification of changes in the content, packaging manufacturers are increasing by using chemical indicators for oxygen or carbon dioxide levels, as well as microbial activity.[160]

- **Create markets for second-tier food.** Grocers in developed economies such as Denmark are expected to present produce that is always fresh, plentiful and attractive, when in reality the size and appearance of produce always varies within a production batch. Although it is only a second-tier solution, supporting a market for this food, rather than discarding it, could significantly reduce waste produced along the value chain. In addition, products going off the shelf when they approach their 'best before' date could be sold at a discount, donated, or used to produce cheap, ready-made meals.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'reduction in avoidable food waste' opportunity (see Section 2.2.4 for the barriers framework). Custom and habit is the largest barrier limiting the reduction of avoidable food waste in Denmark. Interviews with retail store managers confirm that consumers often reject food in stores with shorter use dates if longer dates are available, often reject 'odd-looking' produce, and are usually unaware of the level and impact/consequences of the food waste they generate. Food waste experts at the Danish Environmental Protection Agency indicate that a lack of capabilities and skills is also very important; there is insufficient knowledge and experience among the general public about how to buy, store, evaluate the freshness of, and prepare food in such a way that minimise waste and left-overs.

There are also market failures: consumers face imperfect information on the true freshness of food since they are often unaware of the difference between 'best before' and 'use by' dates and also underestimate the tolerances that producers/retailers put around these dates. There are also split incentives: retailers have an incentive to sell more food and use, for example, '3 for 2' offers on fresh produce. Producers have an incentive to shorten 'best before' dates to reduce liability and encourage the consumption or disposal of their product as early as possible to increase turnover. The final market failure is of externalities: if the full environmental cost of agriculture and food production was reflected in food prices, the incentive to reduce waste would

158 International retailers like Tesco and CO-OP are already using big data to forecast local demand and adapt replenishment of fresh food. Planet Retail, *The Challenge of Food Waste: Retailers step up to the next level of inventory management* (September 2011).

159 For a more extensive analysis of waste prevention technologies in the food value chain, see Ellen MacArthur Foundation, *Towards the Circular Economy II* (2013). These activities have not been central to the circular economy opportunities assessed for Denmark as they are already advanced and assumed to continue developing even without policy interventions.

160 Swedish National Food Agency, www.livsmedelsverket.se

increase.[161] Any potential solution to this barrier would of course need to take into account distributional effects. There is finally the regulatory failure of poorly defined targets and objectives; for example, the 'Denmark Without Waste' strategy covers avoidable food waste, but does not contain quantified targets to reduce it.[162]

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Informing and educating consumers** using information campaigns on the importance of avoiding food waste; a communication campaign to educate consumers about best-before and use-by labelling: augmenting the national school curriculum with knowledge about food, nutrition, preservation, judging the freshness of food, seasonality, and appropriate ingredient and portion sizing.

- **Creating the right framing conditions to avoid food waste in retail.** This could include adjusting regulations so as not to discourage the donation of food due to liability concerns; encouraging such donations, as was recently voted into law in France or by setting up brokering platforms to facilitate matching donors and beneficiaries, and clarifying the information on best before dates for food and beverages to further facilitate such donations (as has happened in Belgium[163])

- **Stimulating the capability building through training programmes** to ensure that procurement, retail and kitchen staff possesses the necessary skills and tools to minimize food waste.

- **Introducing fiscal incentives** such as variable charging schemes for household waste. A small number of small- and mid-size Danish municipalities have implemented weight-based charging. Experiences in other countries show that fee-differentiated collection schemes are also feasible in larger cities with more multi-family buildings, and Switzerland has made such schemes mandatory in all municipalities.[164]

- **Setting national or EU-level quantitative food waste targets**. This would provide overarching guidance to consumers and businesses on the government's objectives, and would likely be a very useful complement to some of the other policies.

- **Influencing other levels of policy-making, such as**

    - Informing and shaping EU marketing standards to avoid food waste arising as an unintended consequence of such regulations.

    - Motivating supermarkets to reduce waste (e.g. shifting more fresh produce sales to weight-based models). League tables at local authority level have proven their value in shifting practices regarding other environmental/social challenges and could work here as long as it does not require sharing confidential data.

3.3 Construction & Real Estate

Identified as one of the sectors with the highest potential for circular

161 See for example, Nordic Council, *Initiatives on prevention of food waste in the retail and wholesale trades* (2011).

162 Danish Government, *Denmark Without Waste I. Recycle more – incinerate less* (2013), p.12.

163 Agence fédérale pour la Sécurité de la Chaîne alimentaire, *Circulaire relative aux dispositions applicables aux banques alimentaires et associations caritatives* (2013)

164 Ecotec, *Financing and Incentive Schemes for Municipal Waste Management Case Studies – Final Report to Directorate General Environment, European Commission* (2002).

economy at an early stage of the Denmark pilot, there are three main opportunities for the construction and real estate sector to become more circular. Industrialised production processes, modularisation and 3D printing could reduce both building times and structural waste if technology development continues and traditional industry habits are overcome. Reuse and high-quality recycling of building components and materials could reduce the need for new materials and decrease construction and demolition waste, if the split incentives created by a fragmented market are addressed. Sharing, multi-purposing and repurposing of buildings furthermore could reduce the demand for new buildings through better utilisation of existing floor space. Modelling suggests that the annual potential value unlocked by 2035 if these three opportunities are realised could amount to EUR 450–600 million, 100–150 million, and 300–450 million, respectively.

The European construction sector is fragmented, with many small firms, low labour productivity, and limited vertical integration along the value chain – especially in Denmark. There are different incentive structures for different players, and no systematic application of operational best practices, significant material waste and limited reuse of building components and materials.[165] In addition, utilisation of existing floor space is low; only 35–40% of office space is utilised during working hours in Europe.[166] The Danish construction sector has experienced slower productivity growth than leading peers (1% p.a. vs. 2% p.a. for e.g. Belgium and Austria between 1993 and 2007), and is also very fragmented.[167] The Danish Productivity Commission has pointed out that there is a need to increase productivity, especially in the construction sector, in order to maintain competitiveness.[168] The Danish government highlighted similar points in their building policy strategy, announced in November 2014.[169]

While none of these issues can be fixed with one silver bullet, the Danish construction and real estate industries could apply a few different approaches that together could transform the built environment:[170]

- Applying **industrial production** processes to reduce waste during construction and renovation, including **modular** construction of building components or, going even one step further, **3D printing** building modules.
- Expanding the **reuse and high-quality recycling of building components and materials** by applying design for disassembly techniques, material passports, innovative business models, and setting up a reverse logistics ecosystem.
- Increasing the utility of existing assets by unleashing the **sharing economy** (peer-to-peer renting, better urban planning), **multi-purposing** buildings such as schools, and **repurposing** buildings through the modular design of interior building components.

There are several other circular economy opportunities that could both unlock value and save resources in the construction sector. They were deprioritised in the present study primarily because in Denmark they are already the way to being realised (as for energy use optimisation), or because the level of detail required for a meaningful analysis was

165 P.-E. Josephson & L. Saukkoriipi, *Waste in construction projects: call for a new approach* (Chalmers University of Technology, 2007).

166 Josephson, P.-E. & Saukkoriipi, L., Chalmers University of Technology, *Waste in construction projects: call for a new approach* (2007).

167 According to Statistics Denmark, there were more than 2,000 enterprises with <50 employees in the construction sector in 2012, and fewer than 200 enterprises with 50+ employees.

168 Danish Productivity Commission, *Slutrapport: Det handler om velstand og velfærd* (2014).

169 Danish Ministry of Climate, Energy and Building, *Towards a stronger construction sector in Denmark* (2014).

170 The opportunity assessment builds on the 'built environment' deep dive in Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).

beyond the scope of this study (as for substitution of materials[171]). Below follows a (non-exhaustive) overview:

- **Energy use optimisation.** New buildings could be designed and constructed as low-energy houses that consume up to 90% less energy than existing building stock.[172] Retrofitting old buildings could reduce their energy consumption by 20–30%.[173] This opportunity has gained high priority in the EU: the European Energy Performance of Buildings Directive (EPBD) requires new buildings to be 'nearly zero-energy' by 2020. Denmark is even more ambitious: it is the government's strategy to make houses net energy positive after 2020.[174] The Danish Energy Agency recently released a tool to calculate the total cost of buildings including their energy use, creating transparency and a clearer incentive for construction companies to build for optimisation of total cost of ownership (TCO) across the whole life cycle, not only construction costs.[175]

- **Substituting materials**, or facilitated separation of hazardous components. Substituting materials that are difficult to reuse and recycle, or make it difficult to reuse or recycle other materials, with non-toxic, renewable alternatives is an important part of making buildings more circular. Buildings traditionally contain a complex mixture of compounds that are often difficult to separate, making material reuse and recycling difficult. Working to reduce hazardous materials or additives, for example toxic additives in PVC[176] – or at least making them easier to separate – is therefore crucial to enable better material recovery at a building's end of use. Furthermore it would improve indoor air quality with improved productivity and health benefits for the users of the building.

3.3.1 Industrialised production and 3D printing of building modules

Opportunity:	**Use industrial manufacturing methods, modularisation and 3D printing to reduce time and cost of construction and renovation.**
2035 economic potential:	**EUR 450-600 million p.a.**
Key barriers:	**Inadequately defined legal frameworks; immature technology; custom and habit and capabilities and skills in the industry.**
Sample policy options:	**Augmented building codes; support for module production facilities; legal framework for 3D printing materials.**

171 Countries with high-performing material science or engineering programs may of course choose to draw upon relevant insights around material substitution into its visioning or assessment work.

172 The houses are low energy consumers because they use, for example, natural air circulation, better exposition, and reinforced insulation to reduce energy requirements for space heating or cooling. Note that, from an LCA perspective, so called 'passive houses' could be more energy intense than conventional low-energy houses, and that the total embedded energy should be taken into account when optimising the energy use during construction and usage. See for example www.passivehouseacademy.com/index.php/news-blogs/what-is-passive-house; www.ecobuildingpulse.com/awards/ehda-grand-award-volkshouse_o

173 A case that has received much attention is the retrofit of the Empire State Building in New York. The project, guided by the Rocky Mountain Institute, saved the Empire State Building USD 17.3 million and reduced energy consumption by 38%. See www.rmi.org/retrofit_depot_get_connected_true_retrofit_stories##empire

174 Danish Enterprise and Construction Authority, *Danish government strategy for reduction of energy consumption in buildings: Energy efficient buildings in Denmark* (2008); Danish Government, *Strategy for energy renovation of buildings: The route to energy-efficient buildings in tomorrow's Denmark* (2014).

175 Ulrik Andersen, Ingeniøren, *Ny vejledning kan dræbe den faste anlægspris* (14 April 2015).

176 See for example www.vinylplus.eu/; www.naturalstep.org/en/pvc#PVC:_An_Evaluation_using_The_Natural_Step_Framework

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Almost 75% of the average cost of a new house comes from the construction process.[177] Importantly from a circularity perspective, fragmented construction, maintenance and renovation processes – with multiple stakeholders, lack of full project oversight, and use of traditional on-site techniques – also lead to two sizable types of resource inefficiency:

- Large reliance on virgin, finite materials that are assembled manually on-site.
- 10–15% of materials are wasted on-site[178] (through e.g. over-ordering, inadequate storage, theft and poor coordination between stakeholders).

There is an increasing number of cases to show that industrial, off-site production of modules for on-site assembly, coupled with increased coordination of all stakeholders in the construction value chain, might greatly reduce today's construction waste and speed up the construction process considerably. As an example of this new approach, the Chinese builder Broad Group took only 6.5 months to build a 30-story hotel, of which only 15 days were spent actually erecting the building on-site. This was enabled by building each floor in 16x4 m modules, which were then assembled by ~200 workers. Total savings amounted to 10–30% vs. conventional construction.[179] Building interiors could also be modularised at high net savings, as shown by Canadian manufacturer DIRTT ('Doing It Right This Time'). DIRTT provides customisable, modular architectural interiors with standardised dimensions, which can be fitted in new buildings or within the envelopes of old buildings.[180] Players with similar offerings in Europe are Alho, Huf Haus, Baühu, and Caledonian Modular.

A more extreme, but according to many industry experts viable, approach to industrialising and modularising building component manufacturing is 3D printing. Given its exponential technological growth curve over the past years, it is likely that 3D printing of building components will be technically and economically feasible in the near future. Chinese construction company WinSun has demonstrated the revolution 3D printing could bring to the construction sector by building full-size houses made out of only 3D-printed components. WinSun has claimed 80% labour savings and 30–60% material savings.[181] Obviously, the material choice for 3D printing needs to be managed well to ensure positive environmental impact. WinSun has taken a promising approach by using a mixture of dry cement and construction waste, but it still needs to be verified that the long-term indoor quality of using this mixture can be secured, and that the construction waste does not contain hazardous materials that could leak into the environment. Before 3D printing of entire buildings is feasible at scale, the viability of producing smaller 3D construction modules for interior and exterior use is rapidly increasing. In a similar vein, Danish innovator Eentileen's automated process cuts sustainably sourced plywood based on a digital blueprint and significantly reduces waste and emissions.[182]

By being an early adopter of these new building practices and techniques, Denmark could become a leader in making a step change in construction material productivity:

- **By 2020**, the construction sector could have adopted industrialised production processes for up to 5% of new buildings and major renovations, reducing waste and generating up to 10% net material savings. While 3D printing is likely to re-

177 Josephson, P.-E. & Saukkoriipi, L., Chalmers University of Technology, *Waste in construction projects: call for a new approach* (2007).

178 Estimate, compiled from interviews with sector experts.

179 Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015). See also www.archdaily.com/289496/

180 www.dirtt.net/

181 Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit (SUN) and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015). See also www.yhbm.com/index.php?m=content&c=index&a=lists&catid=67

182 eentileen.dk/print

main at a conceptual stage, it is reasonable to assume that approximately 2% of new building components could be 3D printed, for which around 25% material and 40% labour savings could be achieved.[183]

- **By 2035**, industrialised (non-3D printing) production of modular building components could have taken as much as 50% of the total market, leading to 15% material savings. 3D printing could grow to a sizable share of the market, addressing up to 25% of all building components.

If these opportunities are captured, modelling suggests that industrialised production and 3D printing of modules could create an estimated annual value of EUR 450–600 (40–60) million by 2035 (2020).[184] These findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, the most important of which are detailed in Appendix B.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'industrialised production and 3D printing of building modules' opportunity (see Section 2.2.4 for the barriers framework). The critical barriers to unlocking this opportunity lie in the technology and legal framework around 3D printing. As discussed above, while the application of 3D-printing technology in construction has progressed significantly in recent years, it is still at the early commercial stage and would need further development to be economic at large scale, able to compete with more standard methods. The WinSun 3D-printed houses referred to above were completed in spring 2014 (ten individual houses) and in early 2015 (a five-storey house and a villa).[185] Equally important is the lack of a strong legal framework to ensure that the technology has a positive impact, both in terms of environmental and technical performance and the health of occupants. According to industry and policy experts, it cannot become a widely trusted approach while it is still open to the use of any material, however non-circular or hazardous to the health of building occupants.

Experts in the industry were also of the opinion that important social barriers exist for both industrial production of modules and 3D printing. Many players in the construction industry are unwilling to change long-established operational practices, such as rigid business models and extensive subcontracting, resulting in fragmented (over-specialised) knowledge and capabilities. While this factor will to some extent be relevant in any industry, consultation with experts indicated that the construction industry is particularly bound by more traditional practices. On the consumer side homebuyers may also be unwilling to trust non-traditional building approaches. The capital intensity of the industrial facilities in which to produce modules would be a challenge for the industry in Denmark, as it is made up by a large number of SMEs.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Complementing building codes with circularity ratings and targets**:
    - Ratings indicating the circularity potential of materials and construction techniques.
    - Circular economy targets that set minimum requirements using a scoring mechanism. Denmark and the UK have already introduced energy efficiency and carbon ratings. This could be deployed to

183 Estimated by taking half of WinSun's reported savings, since there is still very little data to exemplify cost savings. Actual savings will vary on a case-by-case basis and be dependent on the size and complexity of components being 3D printed.

184 This *sector-specific* impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling.

185 Michelle Starr in CNET, *World's first 3D-printed apartment building constructed in China* (20 January 2015).

stimulate circularity, for example with energy standards that incorporate carbon/kWh scores for both the energy embedded in the materials and that used during operations—with recycled materials scoring considerably better than virgin ones.

- If targets are set, it is important that technology neutrality is maintained and the government is not prescribing the technologies, materials, or techniques to be used. In general, interventions along these lines would be expected to be most effective if introduced gradually, for example with gradually increasing standards as has been the case for energy efficiency within the Danish building regulations. In addition, these interventions would likely have impact across the three circular economy opportunities in the sector.

- **Supporting module production facilities**. The government might choose to play a role in motivating the financial industry to move into this area as such production facilities can yield good returns. If this is not an option or does not yield results at the desired scale or speed, low-cost government loans could also start addressing the access to capital barrier. If concessionary financing is undesirable, government agencies might provide loans at market rates that have been designed to meet the complex financing needs of nascent industries. For example, the UK Green Investment Bank has recently developed innovative loan products that are tailored to the specific needs of companies and local authorities wishing to make investment in energy efficiency improvements, which is a similarly immature market.

- **Creating legal framework for 3D printing materials**. Regulating input materials for 3D printing is necessary to realise the full potential of the technology. The timing is right to work on this, as the 3D printing industry is still young and supply chains are not yet mature and locked in. Given its complexity, developing this internationally—at the EU level or beyond—would make most sense. Along with material policies there is also a need for safety, quality, and environmental standards for the processes and technologies themselves.

- **Bringing together all stakeholders** in the construction value chain to work on systemic solutions to address the lack of skills and established norms that stand in the way of industrialising production. This could take the form of an industry-wide partnership focused on knowledge sharing and collaboration, a project with specific short-term objectives, or a private public partnership.

- **Supporting R&D**. Funding programmes to develop and bring to commercial scale new techniques in the 3D printing of building components and explore technological synergies between component printing and the on-going digitisation of construction. A technology challenge prize (as for example promoted by Nesta in the UK[186]) could also be considered.

- **Launching public procurement pilots.** Such pilots could serve a triple purpose: demonstrate the viability and benefits of existing circular materials and construction techniques, stimulate the development of new materials and techniques (design competitions offer an alternative), and develop the necessary guidance and procedures for procurement teams to be able to accommodate such new or unfamiliar elements (e.g. adjustments to the typical pre-construction dialogues).

- **Funding for industry training programmes** tailored to the various actors along the construction value chain (architects, engineers, entrepreneurs, construction workers, etc.) covering off-site production and on-site assembly of components as well as 3D printing techniques.

186 www.nesta.org.uk/project/big-green-challenge

3.3.2 Reuse and high-value recycling of components and materials

Opportunity:	**Tighter 'looping' of building components through either reuse or high-quality recycling, enabled by, e.g. design for disassembly and new business models.**
2035 economic potential:	**EUR 100-150 million p.a.**
Key barriers:	**Split incentives and lack of information across the construction value chain; custom and habit; capabilities and skills.**
Sample policy options:	**Augmented building codes; industry-wide training programmes; support for material inventory software.**

THE OPPORTUNITY FOR DENMARK

As in other Danish industrial sectors, the construction industry has achieved very high industrial recycling rates, especially of valuable materials such as steel and other metals. The overall recycling rate is 87%, but like in most markets the reuse of building components (such as wall or floor segments) and lower-value materials (such as bricks) is very limited. Three characteristics of the construction sector could help explain this situation:

- Strong safety concerns and a tightly regulated sector, leading to uncertainties about both performance and health issues of reused or recycled materials and components.
- A fragmented value chain, with different incentives for initial investors, architects/engineers, (sub)contractors, owners and tenants, leading to limited uptake of circular design. The fragmentation also makes it hard for new practices to gain traction, such as deconstruction rather than demolition, which would salvage more useful components and materials for reuse and high-value recycling.
- Long-lived construction objects, meaning that those facing demolition or renovation today were not designed with reuse of materials or components in mind.

Fortunately, there are a number of innovative design and operations examples on how to enable increased looping of components:

- **Design for disassembly and reuse of components and materials.** The 'tightest' loop for building components would be to design for non-destructive disassembly and full reuse of building components in new projects.[187] Although not a new idea – the British Pavilion in the 1992 Seville Expo being one example[188] – there are still few buildings designed for disassembly (and reuse). Turntoo, the Dutch company founded by architect Thomas Rau, has led the work of retrofitting the Brummen Town Hall in the Netherlands, where the architects worked together with the material suppliers to establish performance contracts where the suppliers retained ownership of the materials.[189] The renovated town hall, completed in 2013, is designed for disassembly and has an attached materials passport to fully track the building's material assets. In the same vein, the C2C-designed Park 20/20 office complex, developed in the Netherlands by Delta Development, is being built for disassembly and incorporates asset tracking for future reuse.[190] Design for disassembly could also include design regular review

187 Cl:aire, Subr:im Bulletin 05, *Avoiding Future Brownfield Sites through Design for Deconstruction and the Reuse of Building Components* (November 2007).

188 www.steelconstruction.info/Recycling_and_reuse#What_is_recycling_and_reuse.3F

189 turntoo.com/en/projecten/town-hall-brummen/

190 See www.park2020.com/; urbanland.uli.org/sustainability/park-2020-amsterdam-born-recycled/. The office park is expected to be completed by 2017.

and upgrade, which would enable the use of some materials with a lower environmental footprint, e.g. glulam beams as load-bearing construction elements.

- **Use of recycled materials.** Even though few buildings today have been constructed with deconstruction and reuse in mind, it is possible to recover significant quantities construction materials and use them for new buildings. The US EPA's buildings One and Two Potomac Yard in Arlington, VA, were built using 27% recycled content – including slag concrete aggregate, fly ash, and gypsum wallboard.[191] Examples of companies including recycled industrial materials in their products are insulation manufacturer Rockwool[192] as well as DIRTT[193] (see above). A relevant case example from Denmark is the 'Upcycle house', built using processed recycled materials and reducing the overall CO_2 emissions by 86% compared to the building of a benchmark house.[194] As the reuse of components and recycling of materials proliferates and a new reverse cycle ecosystem emerges, a market will emerge for material 'brokers' connecting suppliers with buyers, as with the Scottish Material Brokeage Service [195] There are two challenges to be overcome when reusing/recycling materials from existing buildings: the challenge of hazardous chemicals (including those no longer permitted in building materials today); and the technical performance of components/materials not designed for reuse/recycling.[196]

- **New business models.** The examples above introduce the concept of performance contracts in the real estate sector: the property owner does not necessarily own all materials and systems in the building and might instead buy utility (e.g. lux-hours instead of light fixtures).

- **Deconstruction.** In Japan, Taisei Corporation has demonstrated that deconstruction is possible even for tall buildings such as The Grand Prince Hotel Akasaka. A Taisei-developed approach deconstructed the 141-meter building from the top down, reducing carbon emissions of the deconstruction process by 85%.[197]

Employing these best practices in the construction and real estate sector, Denmark could increasingly use recovered building components and materials in more valuable cycles than downgrading recycling. Examples of value retention already exist; Skive municipality runs a project to improve the reuse of old construction components by incorporating new targets in the municipality's 2015–24 waste management strategy and creating an environment for new business models centred on material looping,[198] and The Fund for Green Business Development has funded a partnership where innovative public procurement is used to increase the reuse of building components and materials in new public building projects.[199] In addition, the Danish Eco-Innovation Program funds a number of project around, among others, using more reusable and recyclable materials in buildings.[200]

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191 US Environmental Protection Agency, *Using Recycled Industrial Materials in Buildings* (2008).

192 sustainability.rockwool.com/environment/recycling/

193 www.dirtt.net/leed/_docs/DIRTT-MaterialsAndProduction_v1-2.pdf. DIRTT pledges to add more recycled content into their materials every year.

194 The Upcycle House was built In collaboration between Realdania Byg and Lendager Architects. www.archdaily.com/458245/upcycle-house-lendager-arkitekter/

195 The Scottish Material Brokerage Service began operating in January 2015. Its aims are twofold: (i) to deliver collaborative contracts for waste and recyclable materials from Scottish local authorities and other public bodies of sufficient scale to help them achieve better value for money, and reduce risk from price volatility; (ii) to create the business conditions for investment in domestic reprocessing by providing certainty in the volume and duration of supply of valuable materials. See www.zerowastescotland.org.uk/brokerage

196 These challenges are currently investigated under the Danish Government's strategy for construction. Danish Ministry of Climate, Energy and Building, *Towards a stronger construction sector in Denmark* (2014).

197 See for example www.wired.co.uk/news/archive/2013-01/15/japan-eco-demolition; www.taisei.co.jp/english/csr/hinsitu/jirei_hinsitu.html. No information was found on the potential for reuse of the deconstructed building components.

198 Skive municipality, *Afslutningsrapport Projekt Genbyg Skive* (2015).

199 groenomstilling.erhvervsstyrelsen.dk/cases/962460

200 ecoinnovation.dk/mudp-indsats-og-tilskud/miljoetemaer-udfordringer-og-teknologiske-muligheder/%C3%B8kologisk-og-baeredygtigt-byggeri/tilskudsprojekter/

Designing for disassembly could be enabled by better coordination and alignment of incentives across the value chain. Digital material passports (already introduced in Denmark by Maersk as described in Section 3.1) and leasing could become the new norm, driven by a change in business models and emergence of material brokers who link material supply and demand in the reverse supply chain. By 2035 (2020), looping of materials could be increased to 15% (5%) by weight, resulting in 30% material cost savings (adding 5% additional labour cost). At this adoption rate, modelling suggests the construction sector could save EUR 100–130 million annually.[201] These findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, the most important of which are detailed in Appendix B.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 're-use and high-value recycling of components and materials' opportunity (see Section 2.2.4 for the barriers framework). A wide range of barriers prevent increasing rates of component and material reuse in the construction sector. Chief among them is the structure of the industry itself, which leads to split incentives along the value chain. There is limited vertical integration and each player – including the investor, architect, developer, engineer, (sub)contractor, owner and tenant – naturally maximizes their own profits at the expense of the others. Since designing for circularity requires some alignment of incentives to close the loop in the value chain, not having such incentives makes the economic case for reuse difficult to make. The fragmentation of the industry also leads to the barriers of transaction costs and imperfect information: the flow of information and resources necessary to provide a system of design for disassembly and reverse logistics is difficult to achieve. Digital information on the materials used in component production that would be very helpful at the point of refurbishment or demolition is lacking or unevenly distributed: while Building Information Modelling approaches are developing, they are not yet in widespread use.[202]

While buildings can already be designed for disassembly, additional technological progress in the production of circular, separable materials and components could accelerate the concept's applicability. Acceptance of such technological advances in the industry could be aided by demonstration that new materials/components meet required technical specifications and are as practical to work with as those that they replace. It would also be helpful if the true environmental costs of using virgin, finite materials were reflected in their market prices. Finally there are inertia factors – pointed out by a range of industry experts – in the construction industry in the form of customs and habits and a lack of the requisite capabilities and skills that make reuse difficult to implement.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Complementing building codes with ratings and targets** as laid out in Section 3.3.1.
- **Funding industry-wide training programmes** how to develop loops in construction, such as minimising and sorting construction waste targeting actors along the entire value chain (i.e. everybody from architects to sub-contractors working on the ground).
- **Supporting the creation of material inventory software** to keep track of the materials used in construction, maintenance, and renovation projects from start to finish and provide information on their lifetime impacts and opportunities for

201 This *sector-specific* impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling.

202 UK Government, Building Information Modelling (2012).

looping. Such support could come in the form of a publicly funded design competition.

- **Creating a 'positive materials list'.** A comprehensive database of construction materials that are favourable for circular design could help inform, educate, and inspire developers, architects, and clients alike. The initiative could define the criteria a material has to meet to get on the list and create an initial set of materials. It could also be expanded with commercially available branded products – it would require the initiative to define a simple application process through which companies can submit their products, and set up a review board. Such a list could then be taken over at the EU level, so as to inform other member states and create more consistency for companies in the industry.

- **Adjusting public procurement practices**. This would allow for more public construction projects with higher resource efficiency by encouraging technological standards that facilitate later repair, remanufacturing, or reuse (e.g. in lighting or heating, ventilation and air conditioning); use of recycled or reused materials and components; procurement of decommissioning services that focus on value preservation; or mandating the inclusion of performance models or Total Cost of Ownership (TCO) metrics. As a first step, an advisory mechanism on circular public procurement practices could be set up. This could be complemented with training programmes for public procurement teams. At a later stage the actual procurement rules themselves might be adjusted.

3.3.3 Sharing and multi-purposing of buildings

Opportunity:	**Increase utility of existing buildings through sharing, multi-purposing and repurposing.**
2035 economic potential:	**EUR 300-450 million p.a.**
Key barriers:	**Inadequately defined legal frameworks; unintended consequences of existing regulations.**
Sample policy options:	**Clarifying the legislation; financial incentives or support; municipal access portals.**

THE OPPORTUNITY FOR DENMARK

There is an increasing awareness that most buildings are under-utilised – 60–65% of European office space is under-utilised even during working hours. Similarly, roughly half of owner-occupied homes are 'under-occupied', with at least two bedrooms more than needed.[203] These figures suggest a massive structural waste that could be reduced by increasing the 'utility' of the floor space.

Airbnb has done just that. Launching its peer-to-peer platform for housing space in 2008, Airbnb's booking rates has grown by 80–90% in the last few years and is expected to overtake worldwide hotel listings in four to five years.[204] In May 2015, Airbnb had approximately 15,000 listings in Denmark. Meanwhile, a number of not-for-profit communities for sharing living space are growing rapidly, such as Hoffice[205] and Couchsurfing.[206]

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203 No data available for Denmark; UK survey taken as proxy. UK Department for Communities and Local Governments, *English Housing study. Headline report 2012–13* (2014).

204 www.airbnb.com; www.venturebeat.com

205 www.bloomberg.com/news/articles/2015-02-19/hoffice-co-working-puts-freelancers-in-each-other-s-homes; hoffice.nu/en/. The concept can be seen as a hybrid in floor-space sharing, where higher utilisation of living space leads to a reduced demand for office space.

206 www.couchsurfing.com/.

In a time of rapid digitisation, it is not difficult to imagine a more virtualised and shared office environment. Since office spaces are already under-utilised, business could rethink the role of the office as central but temporary place for colleagues to meet while spending a significant share of their time working remotely. This would entail increased desk sharing and reduced need for floor space. Another option is to temporarily rent out unused space, an idea Liquidspace capitalises on by connecting people in need of desks or conference rooms with nearby suppliers, much like an Airbnb for office space.[207]

Businesses are very aware of the potential cost savings from reducing office space. In a 2012 survey, over 70% of 500 corporate executives indicated that the gross square foot per person in their organisations would drop to a point that is more than 55% below the current industry average.[208] Two major technology companies, IBM and Cisco, have gradually increased the staff-to-desk ratio by encouraging teleworking, saving EUR 100–250 million a year.[209] A Scandinavian example is Microsoft Sweden, who reduced their office space by 27%, while still adding 1,500 additional seats.[210]

Increased repurposing of existing floor space would make it possible to better utilise old buildings and change the use of freed-up office space to, e.g. residential housing, in a cost-efficient way and reduce the need for demolition and renovation. This is particularly relevant since ~80% of Europeans live in buildings that are at least 30 years old, which risk slipping into costly obsolescence as changing lifestyles and shifting demographics and age distribution drive construction of new buildings.[211] The repurposing concept of companies like DIRTT – with interior building components that are modular and standardised – allows for maximum efficiency in changing the use of a building.

Complementary to repurposing, which changes the *sequential* use of a building, public buildings could be multi-purposed for *parallel* use of the floor space, meaning that different activities can take place during a short and repetitive time cycle. Making better use of schools or libraries for evening activities (e.g. classes and cultural events) is probably the most accessible example – such multi-purposing is indeed extensively implemented in Denmark. A more advanced practice would be to design more multi-purposed buildings. This is already common practice for sports, cultural and conference venues, but could in principle be implemented for smaller buildings as well. Public spaces could be designed for both multi-purpose use *and* gradual repurposing to optimise their economic value; an interesting example is the Boston Convention & Exhibition Center whose parking structure has been designed to be gradually transformed into retail and residential space.[212] So could office spaces; an example is the Park 20/20 mentioned in Section 3.3.2, designed with shared and multi-purposed spaces for meetings, videoconference and other functions.

By 2035, Danish companies could be expected to reduce their need for office space due to shared desk policies and increased teleworking, which together with multi-purposing of public buildings, repurposing of old buildings and freed-up office space, and the accelerating sharing of residential floor space could increase the overall utilisation of buildings by 60% (20%) by 2035 (2020). This could lead to a reduced demand for new buildings by 9–10% (3–4%) by 2035 (2020), saving the Danish economy an estimated EUR 300–450 million.[213] These findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, the most important of which are detailed in Appendix B.

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207 liquidspace.com/. Liquidspace has also partnered with Marriott to provide conference rooms and other functions, thereby increasing traffic to the hotels.

208 Cushman & Wakefield, *Office space across the world* (2013).

209 GSA Office of Government-wide Policy, *Workspace utilisation and allocation benchmark* (2011).

210 vasakronan.se/artikel/det-digitala-arbetslivet-ar-har

211 architecturemps.com/seville

212 Franconi, E. & Bridgeland, B. Rocky Mountain Institute, presentation at Re:Thinking progress conference, *Circular Business Opportunities for the Built Environment* (14 April 2015).

213 This *sector-specific* impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'sharing and multi-purposing of buildings' opportunity (see Section 2.2.4 for the barriers framework). The principal barriers to increasing the sharing and multi-purposing of buildings are regulatory. There are the inadequately defined legal frameworks, as well as unintended consequences of existing regulations, for example:

- Contractual restrictions on tenants/owners to their sub-letting of houses or flats for short periods; for example in New York State it is illegal to rent out an apartment for a period shorter than 30 days if a permanent resident of the apartment is not present.[214]

- Uncertain compliance with other regulations; for example in Chicago, Airbnb has begun to collect city hotel taxes from its hosts, but hotel associations still claim they are not paying all taxes that hotels are obliged to pay.[215]

- When sharing is allowed it might be under-regulated; there is for example concern in Los Angeles that Airbnb is starting to turn residential areas into 'hotel areas', potentially competing with local residents for accommodation.[216]

Denmark has partially addressed the lack of clear legal frameworks – it is currently possible to sub-let apartments on Airbnb or similar sites for six weeks per year before asking the local municipality for a permit. There are however several uncertainties to address; a sector expert notes that the housing and office rental sector is highly regulated, but that this existing legislation has not yet been fully adapted to account for the concepts of sharing.

When it comes to market failures it is often not cost effective for building owners and tenants to spend the time finding other individuals or organisations with which to share their buildings. Factors exacerbating these transaction costs are the efforts and costs involved in changing building insurance, handling security issues and the need for changes to the building (e.g. locks). Furthermore, while some sharing platforms have been successful, there might still be an inherent resistance in the public to changing habits around the sharing of their own homes, and some businesses have deeply rooted norms and traditions around the use of offices. Recent research[217] has confirmed the results of a study made by The Industrial Society's research from 2002[218]: that there are limits to the attractiveness of shared office space to employees and that individual space such as a desk or a workstation is still highly valued.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Clarifying the legislation** governing (participants in) sub-letting residential and office space, and sharing business platforms (like Airbnb and Liquidspace) by defining unambiguously who is entitled to practice it (private tenants, commercial players) and which regulation they need to follow. Doing so could lower the risks perceived by individuals and companies wanting to engage in such transactions.

- **Creating financial incentives or financial support** to local, regional and national public-sector entities such as schools and other public infrastructure could help overcome hesitance towards renting out their properties when not in use (without distorting competition), and possibly remove some practical barriers such as locks that need to be added or changed. This could also have demon-

214 James Surowiecki in The New Yorker, *Airbnb's New York Problem* (8 October 2013).

215 Crain's Chicago Business, *Hotels to Airbnb hosts: Pay up* (14 February 2015).

216 www.latimes.com/business/realestate/la-fi-Airbnb-housing-market-20150311-story.html#page=1

217 Naomi Shragai, 'Why building psychological walls has become a key skill at work', *Financial Times*, (29 April 2015).

218 The Industrial Society, *The state of the office: The politics and geography of working space* (2002).

stration effects for private owners, facility managers in industrial and commercial real estate, and landlords.

- **Setting up municipal access portals** that provide information on public building availability and matches users with providers. This could start out with public buildings; private spaces could be added later, for instance in case a territory is too small or not sufficiently densely populated to warrant a commercial intermediary.

3.4 Machinery

The potential for Danish businesses to engage in remanufacturing and refurbishment is significant. Since this opportunity requires the development of new capabilities, business models and technologies, capturing it could take time, but by 2035, modelling suggests these practices could create an estimated potential net value of EUR 150–250 million annually.

Opportunity:	**Remanufacturing of components and new business models based on performance contracts and reverse logistics.**
2035 economic potential:	**EUR 150-250 million p.a. (plus additional potential in adjacent sectors).**
Key barriers:	**Imperfect information of existing opportunities; technological progress; unintended consequences of existing regulations.**
Sample policy options:	**Remanufacturing pilots and information campaigns; amendment of existing regulatory frameworks; adoption of an overarching government strategy.**

The Danish machinery sector is characterised by the presence of several large manufacturers of long-lived industrial products, such as Grundfos (pumps), Vestas (wind turbines), and Danfoss (thermostats, heating and power solutions) and >1,000 parts manufacturers and service providers supporting these industries.[219] Across the board, these companies have adopted the most common efficiency measures, such as waste reduction in production processes, light-weighting components and products, and waste reduction and energy efficiency in production processes.

Danish machine manufacturers are also proficient in recycling and are increasingly looking into designing for recyclability. Grundfos, for example, notes that around 90% of the components inside pumps are recyclable. In the wind turbine industry, almost all parts are recycled. The last remaining challenge is the rotor blades, which consist of epoxy-covered composites. A number of possible uses for old blades are currently being pursued, guided for example by the Genvind project.[220]

By contrast, discussions with sector experts revealed that there is only a limited number of remanufacturing or refurbishment activities. Remanufacturing and refurbishment (Box 6) leads to higher value retention than materials recycling since a large part of the added value of a product or component is maintained, and more steps along the value chain are bypassed (c.f. Figure 1 in Part 1). Danish companies could thus exploit the largely untapped potential in remanufacturing and refurbishment. In parallel, recycling and efficiency optimisation is likely to continue to improve in the sector, as part of the trajectory Denmark is already on.

219 According to Statistics Denmark, there were 26 companies with 250-plus employees in the machinery sector in 2012, and just over 1,000 with fewer than 250 employees, of which half had 0–9 employees.

220 www.genvind.net

Box 6: Remanufacturing and refurbishment[221]

Component remanufacturing is defined as a process of disassembly and recovery at the subassembly or component level. Functioning, reusable parts are taken out of a used product and rebuilt into another. This process includes quality assurance and potential enhancements or changes to the components. By definition, the performance of the remanufactured component is equal to or better than 'as new'. [222]

Product refurbishment involves returning a product to good working condition by replacing or repairing major components that are faulty or close to failure – and making 'cosmetic changes' to update the appearance of a product. The replacement components could themselves be remanufactured. Any subsequent warranty is generally less than issued for a new or remanufactured product, but the warranty is likely to cover the whole product. Accordingly, the performance may be less than 'as new'.

REMANUFACTURING IS ALREADY A VIABLE BUSINESS CASE

There are numerous examples to show that there is a strong business case for remanufacturing. The consultancy Levery-Pennell has calculated that for a case with remanufactured items selling for 20% less than new items, and increased labour costs for the remanufacturing process, the gross profit could still be up to 50% higher due to the large reduction in input costs, and that the earnings could be even higher with a performance-based business model.[223] Indeed, several large companies have already run successful remanufacturing operations for quite some time:

- Renault's remanufacturing plant in Choisy-le-Roi , France, re-engineers different mechanical sub-assemblies, from water pumps to engines, to be sold at 50% to 70% of their original price with a one-year warranty. The remanufacturing operation generates revenues of USD 270 million annually. Renault also redesigns components (such as gearboxes) to increase the reuse ratio and make sorting easier by standardising components. While more labour is required for remanufacturing than making new parts, there is still a net profit because no capital expenses are required for machinery, and much less cutting and machining to remanufacture the components, resulting in waste minimisation and a better materials yield. Renault has achieved reductions of 80% for energy, 88% for water and 77% for waste from remanufacturing rather than making new components.[224]

- Caterpillar founded its CatReman business line in 1973. It now has global operations with over 4,200 employees, and fully remanufactures a large range of heavy-duty equipment to as-new state, including long-term warranties. Caterpillar has reported that remanufactured components reduce resource consumption by 60–85%.[225]

- Ricoh's 'comet circle' is a well-known and established business model, including remanufacturing and refurbishment of components, and recycling of materials.[226]

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221 For more details, see for example Ellen MacArthur Foundation, *Towards the circular economy I* (2012).

222 Nasr, N., Rochester Institute of Technology, presentation at Re:Thinking progress conference, *Circular Economy and Remanufacturing* (14 April 2015).

223 Dr G. Lavery, Nick Pennell, Simon Brown, Prof. Steve Evans, *The Next Manufacturing Revolution: Non-Labour Resource Productivity and its Potential for UK Manufacturing* (Lavery Pennell, 2degrees, IfM, 2013)

224 group.renault.com/en/commitments/environment/competitive-circular-economy/; Ellen MacArthur Foundation, *The Circular Economy Applied to the Automotive Industry* (2013).

225 Caterpillar Sustainability Report (2006).

226 https://www.ricoh.com/environment/management/concept.html

As ~70% of components in a printer or copier can be remanufactured,[227] these products are well placed to be provided on an access-based contract. Ricoh already sells 60% of their products through service contracts, and remanufacturing is an important lever to reach its ambitious target of reducing resource consumption by 2050 to 12.5% of the 2000 levels.

Remanufacturing and refurbishment have been predicted to have a net positive effect on GDP and employment, as well as boosting innovation.[228] The UK All-Party Parliamentary Sustainable Resource Group has reported that remanufacturing could contribute GBP 2.4 billion to the UK economy and create thousands of skilled jobs.[229] Zero Waste Scotland estimates that increased remanufacturing alone could add 0.1–0.4% to Scotland's GDP and provide up to 5,700 new jobs by 2020.[230] However, remanufacturing does pose a significant challenge to product design and is especially difficult for manufacturers of long-lived products and/or in industries where the largest efficiency gains are still driven by hardware improvements. Manufacturers often design for optimised in-use efficiency rather than designing for remanufacturing.[231] Products from companies like Grundfos and Vestas have anticipated lifetimes of 20 years or more, during which time hardware technology can improve significantly. Few would want to remanufacture equipment put on the market 20 years ago, as performance of the hardware has increased manifold since then, and in the case of wind turbines the size has increased significantly. Another consideration is that the content of hazardous substances that have been phased out in new products could make a component or product unwanted for remanufacturing.

But even when the hardware development is still significant, remanufactured or refurbished equipment could be sold to secondary markets. There is already a growing market for used and refurbished wind turbines,[232] and pump manufacturer KSB is looking at selling refurbished products to secondary markets. As hardware technology matures and efficiency improvements become increasingly driven by software it will become increasingly viable to integrate remanufactured components into the next generation of products. An industry expert notes that efforts to increase pump efficiency are likely to shift gradually towards software upgrades over the next five years.

THE OPPORTUNITY FOR DENMARK

In brief, this analysis suggests a large potential for Danish businesses. Even if not all machinery components are addressable for remanufacturing or refurbishment today, applying these practices to a selection of durable components becomes increasingly feasible but requires adaptations in the business model, product design, and the reverse supply chain. Done right, remanufacturing or refurbishment could unlock significant value.

As described in Section 2.2.1 there are four principal building blocks that a business can adopt to pursue a circular economy opportunity: product design (and technology), business models, reverse cycle skills, and cross-sectoral collaborations.[233] Figure 30 summarises the main transitions in the first three dimensions to enable remanufacturing for liquid pumps, a hallmark product in the Danish machinery sector. In the same vein as

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227 N. Nasr, Rochester Institute of Technology, *Circular Economy and Remanufacturing*, presentation at Re:Thinking progress conference (14 April 2015).

228 See Ellen MacArthur Foundation, *Towards the Circular Economy I–III*.

229 All-Party Parliamentary Sustainable Resource Group, *Remanufacturing. Towards a resource efficient economy* (2015).

230 Zero Waste Scotland, *Circular Economy Evidence Building Programme: Remanufacturing study* (2015).

231 It could indeed be more rational to design primarily to increase in-use energy efficiency. At the same time, a life cycle assessment report by PE International on a Vestas V112 3.0 MW turbine showed that the major life-cycle impact comes from the manufacturing stage, indicating significant potential to capture value through remanufacturing. PE International, *Life Cycle Assessment of Electricity Production from a V112 Turbine Wind Plant* (2011).

232 See for example hitwind.com/; www.windforprosperity.com/

233 Ellen MacArthur Foundation *Towards a Circular Economy I* (2012); p.61. Note that the need for cross-sectoral collaborations, such as focus on circularity in education and R&D, and wider acceptance for alternative ownership models, is also highly relevant to capture the remanufacturing opportunity.

reverse logistics for remanufacturing, Grundfos is currently piloting a take-back program for circulator pumps in Denmark, in order to support the recyclability of components and materials. For wind turbines, it was pointed out by a sector expert that there are typically over 2,000 parts that are already fairly standardised, not subject to steep performance improvements and need replacement before the end-of-use of the turbine itself; there are thus interesting opportunities to shape both business model and product for gradually replacing and remanufacturing such components.

Figure 30: Examples of what remanufacturing and new business models could look like for pumps in Denmark

	FROM	TO
PRODUCT DESIGN (AND TECHNOLOGY)	• **Design focused on performance in one lifecycle** • **Most product improvements through hardware upgrades**	• **Standardised and modular design to simplify disassembly, remanufacturing and lifetime extension** • **Most product improvements through software upgrades**
BUSINESS MODEL	• **Traditional product sales with service warranties**	• **More focus on complete solutions including system optimisation[1]** • **Sales of 'pumping as a service' with repair and product upgrade scheme included** • **Manufacturer ownership retention drive increased efficiency improvement during lifecycle**
REVERSE CYCLE SKILLS	• **Difficulty to return dispersed products** • **Lack of remanufacturing skills and facilities**	• **Third-party installers incentivised to return old products for commission** • **Large-scale remanufacturing facilities with high degree of automation**

1 As for example in Grundfos collaboration with Heerlev University Hospital water-cleaning facility, http://www.theguardian.com/sustainable-business/grundfos-partner-zone/2014/nov/11/new-water-treatment-technology-reduces-risks-from-hospital-wastewater
SOURCE: Industry expert interviews; Ellen MacArthur Foundation circular economy team

There are two categories of remanufacturing opportunities for Danish companies.

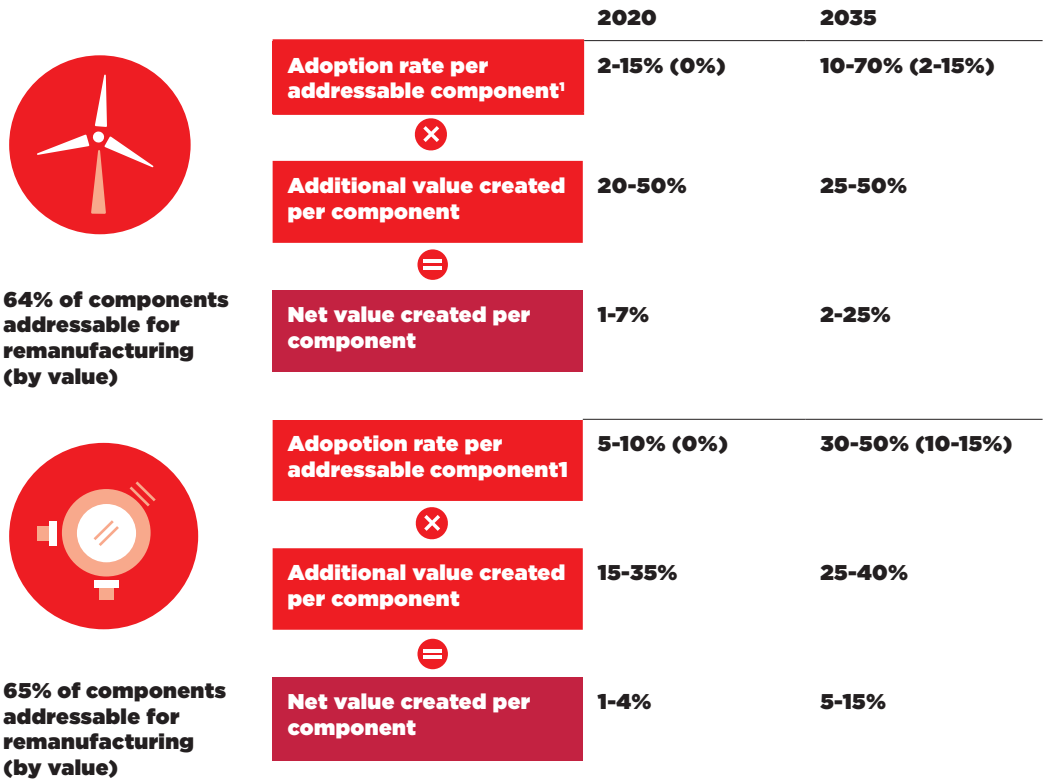
- **Remanufacture or refurbish components or whole products and sell to secondary markets**. This could be a developing market but might also be a local secondary market. Remanufactured equipment could become new product line, as in the case of CatReman.
- **Remanufacture components and use them in new products.** Since remanu-

facturing by definition restores a component to an 'as new' condition, it would be viable to use components again in new products, provided the dimensionality and design is consistent over product generations. This would save significant costs as both the raw material value and most value added from manufacturing the components are retained. This opportunity resembles Ricoh's business model for office printers.

By leveraging the circular economy building blocks and utilising both these opportunities, the Danish machinery sector could gradually adopt remanufacturing and refurbishment. A conservative estimate is that half of all product components could be addressed for remanufacturing. Until 2020, they would likely focus on sales to secondary markets, while by 2035, 15–50% of remanufactured components could be used in new products rather than sold to a secondary market. Figure 31 gives an overview of the estimated potential adoption rates and value creation estimated on a component level for two machinery products, wind turbines and pumps. Overall, this would contribute to net value creations of 1–3% as share of overall product costs by 2020, increasing to 4–9% by 2035. These findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, the most important of which are detailed in Appendix B. It should be emphasised that the estimates take into account the significant challenges of remanufacturing and refurbishment of long-lived equipment, such as liquid pumps and wind turbines.

Figure 31: Estimated potential adoption rates and value creation in wind turbines and pumps

Ranges, adoption rates and value estimated on a per component basis



1 Adoption rates in brackets indicate 'business as usual' scenario

SOURCE: Expert interviews; Ellen MacArthur Foundation circular economy team

Scaling up this value creation to the full machinery sector including pumps, wind turbine and other machinery, it is estimated that businesses could create a net value of EUR 150–

250 million annually[234] by increased adoption of remanufacturing and/or refurbishment and new business models. But they need to be prepared to challenge their perception of both their business models and design to capture the opportunity. For example, the product design requires taking into account resource use and costs over several life cycles, and identifying sub-components that could be more standardised and modularised. There are also large logistical challenges to bring widely dispersed, large products back to a remanufacturing facility, and to bring heavily worn parts back to an 'as new' state.

Finding solutions to overcome all these challenges will require further investigation, but it can be noted that there are a number of methods to restore worn metal components to 'as new' condition, for example cold spraying and other additive processes.[235] The US defence industry performs significant remanufacturing of aircraft, ships and ground systems, of which many have been over 20 years in operation. It is also widely anticipated that increased digitisation is an important enabler, both to drive the continued efficiency improvement and to automate the remanufacturing process, for example through fault detection software.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'remanufacturing and new business models' opportunity (see Section 2.2.4 for the barriers framework). The critical barrier limiting the industry from taking the remanufacturing opportunity is a lack of capabilities and skills: industrial designers and engineers in the machinery sector often lack the knowledge and experience necessary to run successful remanufacturing operations, which require the ability to design for disassembly and set up reverse logistics systems. An industry player highlighted the challenge to establish efficient and effective partnerships along the value chain in order to ensure a reversed flow of products and components. While getting the products into the market is a capability that has been developed for decades, the capabilities for getting the products back are still in an immature state and also highly dependent on the national market conditions.

The most important market failures are the transaction costs related to finding and negotiating with new suppliers, since remanufacturing could significantly disrupt material flows across the value chain; and the uneven distribution of knowledge among manufacturers about the economic potential of remanufacturing and new business models.

There is a steep technological development of hardware in many machinery categories, which makes remanufacturing unfeasible in the short term, e.g. the size of wind turbines is increasing rapidly, making the remanufacture of old parts for use in new products unfeasible.

Even when they are fundamentally economic, some international remanufacturing operations face a high administrative burden to comply with the regulations relevant to being able to move remanufactured components across borders. The exact impact in Denmark of such regulatory barriers would need to be further investigated for each product type.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Stimulating remanufacturing pilots** that allow businesses (in particular SMEs) to gain experience with remanufacturing and make the benefits more tangible to them. In this context, it is worth investigating the scope for funding such pilots

234 This *sector-specific* impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling.

235 For example, the Golisano Institute for Sustainability at the Rochester Institute of Technology develops methods such as cold spraying and collaborates with companies to improve these technologies.

through the Danish Fund for Green Business Development.

- **Using these pilots in industry information campaigns** that highlight best practices in remanufacturing and refurbishing and also draw on international case studies (such as Caterpillar's CatReman business unit). The aim would be to build business awareness of the benefits of remanufacturing (especially among SMEs) and to accelerate the transition to performance models.

- **Encouraging the establishment of a training programme** to ensure that manufacturing and procurement staff in key industries possesses the necessary skills for businesses to fully benefit from the potential of remanufacturing.

- **Create a level playing field** between remanufactured and new products by identifying unintended consequences of national, European and international regulation that put remanufactured products at a disadvantage.[236] Potential examples are health and safety regulations and regulation prohibiting the sale of remanufactured products as 'new'.

- In addition to reviewing existing regulation, **informing the development of new tools at the EU level** that help to provide detailed information on the composition of products and how to dismantle them. Examples include guidance on how to develop product passports and bills of material, product standards (e.g. expansion of existing eco-design rules), or quality-standards and labels on the reliability of remanufactured products.

- **Adopting an overarching government strategy for remanufacturing** and by giving it a clear space in the overall industry/manufacturing strategy (and hence with associated targets and milestones), to galvanise the industry and give it clarity on the direction of future policy development.

- **Supporting the development of remanufacturing technology and design** through strategic funding and investigate the scope for further leveraging the Eco-Innovation Program administered by the Danish Ministry of the Environment for this purpose. The new Scottish Institute of Remanufacture is an example, which is funded by the Scottish Funding Council, Zero Waste Scotland and a range of business interests. Its focus is on delivering industry led research and development projects in collaboration with academia.

3.5 Packaging

Plastic packaging is a central challenge to the circular economy. Although some of the potential solutions require multi-stakeholder alignment at international level, two opportunities stand out in Denmark at the national level: increased recycling and introduction of bio-based materials. By addressing the need for improved collection systems and working together with stakeholders on ways to increase standardisation, Denmark could increase the recycling of packaging to 75% by 2035, saving both embedded energy and carbon. In addition, Danish companies could develop a competitive advantage in bio-based materials, if the need for accelerated technological development and creating functional end-of-use pathways is addressed.

In terms of value, consumer packaging is forecasted to have an annual growth of ~3–5% globally for the next few years.[237] The use of plastics for packaging applications is

236 In May 2015, the Basel convention adopted new technical guidelines on an interim basis to amend its regulation on transboundary shipment of hazardous waste. While the main focus is on EEE, formulations such as exempting materials 'destined for failure analysis, and for repair and refurbishment' from being classified as waste signals an ambition to address unintended consequences.

237 Annual growth over the 2013–2018 period, with constant 2012 prices and exchange rates. Forecast compiled from Freedonia, Euromonitor, and Smithers PIRA.

forecasted to continue to grow at the expense of other materials.[238] Because of their short period of use, packaging materials become waste relatively quickly after they have entered the market. Recirculating plastic packaging is particularly challenging since it is not only very dispersed and therefore relatively hard to collect – which is generally the case for consumer packaging – but it also has a diverse make-up in comparison to, for instance, board-based packaging; plastics also have low material value compared with aluminium or tin-plated steel.

The plastic packaging value chain comprises firstly the design and production of plastic material and packaging, and secondly the after-use phase of collection, waste segregation, and reprocessing. The challenge with influencing the production elements is that they are typically international, so potential regulations or standardisations concerning materials or additives must be decided on an international level. The after-use phase is more localised, and so is an easier area of direct influence for an individual national policymaker. But after-use measures cannot be optimised in isolation; they need to be made in concert with design and production standards. While the outcome of applying this toolkit provides a set of options for national or regional policymakers, another project - the Global Plastic Packaging Roadmap (GPPR, see Box 7) addresses the systemic issues of the current linear plastics economy at a global level, by bringing together international stakeholders involved in plastics and packaging design as well as national stakeholders responsible for collection and recovery systems.

Thus, the Denmark pilot takes a national perspective on opportunities to increase recycling by focusing on improving the after-use treatment (Section 3.5.1). The opportunity to develop bio-based packaging (Section 3.5.2) should meanwhile be seen in the context of driving technology and innovation rather than setting national regulations for bio-based materials.

Box 7: The Global Plastic Packaging Roadmap

Mobilized in 2014, as part of the MainStream Project, the Global Plastic Packaging Roadmap (GPPR) initiative leverages the convening power of the World Economic Forum, the analytical capabilities of McKinsey & Company, and the circular economy innovation capabilities of the Ellen MacArthur Foundation. The vision of the Global Plastic Packaging Roadmap (GPPR) is of an economy where plastic packaging never becomes waste but re-enters the economy as defined, valuable, biological or technical nutrients – a 'new plastics economy'.

The GPPR provides an action plan towards this new plastics economy as an economically and environmentally attractive alternative to the linear model. The project is driven by a steering committee composed of nine global leading company CEOs and more than 30 participant organizations across the entire plastics value chain ranging from plastics manufacturers to brand owners and retailers in FMCG to municipal waste collection and after-use treatment systems. This integrative project setup allows for accelerating systemic change through innovation and collaboration. The GPPR works collaboratively with a number of existing initiatives focused on ocean plastics waste including the Global Oceans Commission, Ocean Conservancy, the Prince's Trust International Sustainability Unit, governmental institutions and policymakers. The project's unique focus on systemic change will complement and inform these other initiatives.

Besides fostering innovation and collaboration across the value chain, the GPPR project will also inform and influence policy on a corporate and governmental level, by highlighting interventions that either hinder or accelerate the transition towards the new plastics economy. First results from the GPPR will be published in January 2016 at the World Economic Forum in Davos.

238 Smithers PIRA (2014).

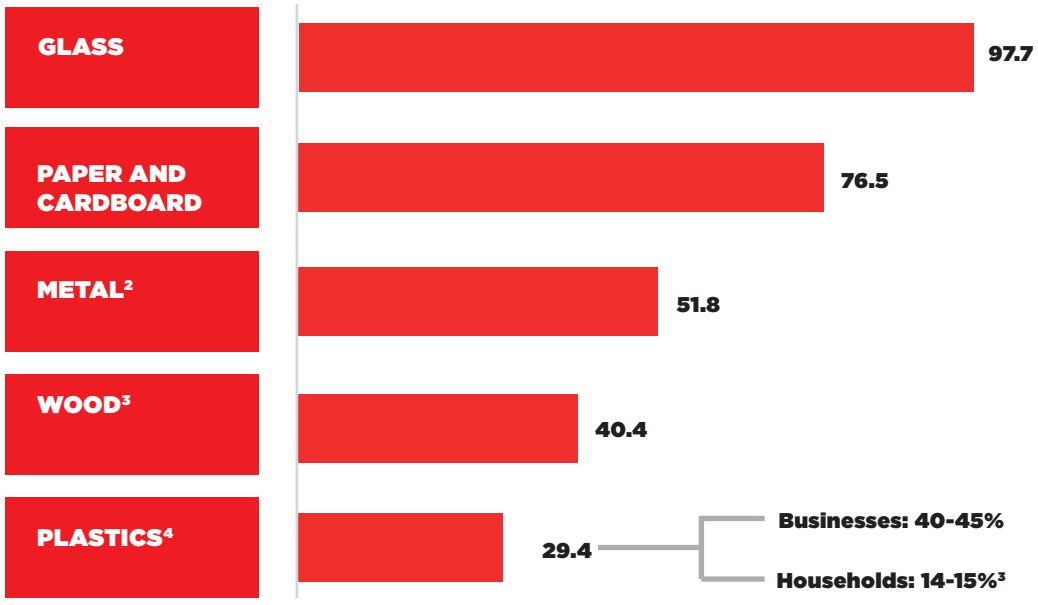
3.5.1 Increased recycling of plastic packaging

Opportunity:	**Increased recycling of plastic packaging driven by better packaging design, higher collection rates, and improved separation technology.**
2035 economic potential:	**Not quantified.**
Key barriers:	**Profitability, driven by unpriced externalities and price volatility; collection and separation technology; split incentives.**
Sample policy options:	**Mandated improvement of collection infrastructure; increased national recycling targets; standardised collection / separation systems; increased incineration taxes.**

In Denmark, the volume of plastic packaging waste grew 2% p.a. over 10 years, to 184,000 tonnes in 2012, while the volume of other packaging waste, such as glass and paper, declined at a rate of 1.3% p.a. over the same period.[239] While Denmark has spearheaded many recycling initiatives, such as one of the first successful deposit-refund systems for bottles, recycling rates are still low for plastic packaging (Figure 32). One root cause may be the large waste incineration capacity in Denmark, using combined heat and power plants to generate electricity and provide district heating. Since low utilisation undermines incinerator economics, the incentive to switch packaging volumes over to recycling has been limited. In the 'Denmark Without Waste' resource strategy, the Danish government expresses a goal to gradually move from incinerating valuable materials – such as plastics – to recycling. Consequently, the estimated projected incinerator capacity is flat.[240]

Figure 32: Share of plastic packaging collected for recycling in Denmark

Percent, 2012[1]



1 Indicates share of waste collected for recycling – actual recycling rates vary depending on material quality.
2 Danish EPA estimates that this is on the low side. Volumes are based on sales of beer and soft drinks, and main uncertainty comes from extensive border trade with Germany. Main leakage point from households is mixed garbage, which gets incinerated. Metal salvaged from incineration ashes is not included in this number.
3 Large share of wood incinerated in incinerators and some parts in household stoves.
4 Including PET bottle recycling in deposit-refund scheme.
SOURCE: Danish EPA; Statistics Denmark; Ellen MacArthur Foundation circular economy team

239 By tonne. Danish Environmental Protection Agency, *Statistik for emballageforsyning og indsamling af emballageaffald 2012* (2015 rev.).

240 Danish Government, *Denmark Without Waste I. Recycle more – incinerate less* (2013); Danish Environmental Protection Agency, *Danmark uden affald. Vejledning fra Miljøstyrelsen nr. 4* (2014).

THE OPPORTUNITY FOR DENMARK

Given this starting point, there is significant potential for Denmark to increase recycling of plastic packaging.

- By **2020**, Denmark could increase the amount of plastic packaging collected for recycling to up to 40% (20% for households and 60% for businesses). This means an overall improvement with 10 percentage points compared to current recycling rate (5 percentage points for households and 20 percentage points for businesses).

- By **2035**, a ~75% recycling rate (65% for households and 85% for businesses) and improved valorisation of the collected plastic waste could become feasible.

A transition towards increased recycling would centre on three key levers – design, collection and sorting – each with a few different enabling mechanisms:

- **Higher collection rates for recycling.** This could mean more convenient collection schemes such as the kerbside collection of plastics or mixed recycling instead of requiring drop-off at recycling centres, or finding better ways to collect plastics that have been in contact with food.[241] Much could be achieved through better incentives for households to sort recyclables from mixed waste. Deposit schemes could be applied for a larger number of container types – if made cost-efficient and associated with carefully implemented reverse vending supply chains. On a regional level, higher collection rates could be achieved through standardised collection systems that provide scale effects.

- **Improved sorting technology**. Better combinations of existing technologies (mid- and near-range IR, colour, x-rays, electrostatic, and visual spectrometry) lead to larger resin volumes extracted from the mixed waste or mixed recyclables stream, at higher qualities.[242] In the absence of such equipment the burden rests fully on households and businesses to deliver such volume and quality through their own choices and actions (for example, carefully separating resins).

- **Design for recycling.** Plastics and packaging manufacturers could use purer materials, for example without unnecessary coloration, to enable production of recycled plastics with qualities comparable to those of virgin sources.[243] Well-considered chemical compositions may also facilitate the sorting of materials. For example, black-coloured trays, popular for ready-made meals and other food applications, have been difficult to sort: the carbon black typically used to provide the black colour cannot be detected by commonly used near-range IR sensors.[244] A multi-stakeholder effort led by WRAP and including Danish Faerch Plast has now identified alternative, detectable colorants for PET and polypropylene food trays. In a wider perspective, standardisation is instrumental for being able to create broad alignment on elimination of structural plastic waste (such as too many compounds or contamination of additives; also see Note 243).

By 2020, increased recycling could reduce demand of virgin plastic material by 20,000—25,000 tonnes; by 2035 this could be 80,000–100,000 tonnes.[245] Compared to using the same amount of virgin plastic material, recycled plastics require approximately 70% less

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241 One waste management expert notes that consumers typically dispose of plastic packaging that is 'sticky' from contact with food since there is no convenient, hygienic way of storing it with recyclables, and that collecting this 'sticky' packaging is essential to increase collection rates significantly above current levels.

242 See for example the pilot study conducted by the Plastic ZERO project. *Plastic ZERO. Public private collaborations for avoiding plastic as a waste* (2014). www.plastic-zero.com/publications/publications-of-plastic-zero-(1).aspx

243 As noted above, this enabler is difficult to drive solely on a national level, and is best addressed through an integrative approach engaging stakeholders at a multi-national level and across the entire value chain, such as in the GPPR project..

244 WRAP, *Development of NIR Detectable Black Plastic Packaging* (2011).

245 Acknowledging that the recycling business is international, this assumes that the corresponding volume of recycled plastic material replaces virgin plastic material in Denmark.

energy to produce: One tonne of recycled plastics saves roughly 10,000–12,000 kWh of energy. By 2035, Denmark could therefore also save as much as 800–1,200 GWh of energy p.a.[246] These findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, of the most important of which are detailed in Appendix B. In addition to energy savings, Denmark's carbon footprint would be reduced – but by how much would depend on what source of energy is used to replace the heat and electricity generated from incineration.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'increased recycling of plastics packaging' opportunity (see Section 2.2.4 for the barriers framework). The main barrier to increased plastic packaging recycling is the price pressure the relatively small plastics recycling industry faces from producers of virgin or primary plastics whose large market share grants them bargaining power. While the barrier at its core is one of unpriced negative externalities of petro-based packaging, this market failure manifests itself in a lack of profitability and capital. Plastics recyclers face volatile profit margins due to a largely fixed cost structure and revenues that are highly dependent on oil prices. This makes raising capital more difficult due to uncertain payback periods. A recent example of this economic pressure is Closed Loop Recycling, Britain's biggest recycler of plastic milk bottles with 80% market share, which in March 2015 warned of potential bankruptcy citing the slump in global oil prices as a major reason. Since the price of recycled plastics shadows that of petro-based plastics, the slump has caused prices for recycled plastics to fall nearly 40% in the second half of 2014 and first quarter of 2015 (another contributing factor is that milk is one of the main battlegrounds in the price war currently being fought between major supermarkets, leaving no margin to pay slightly more for recycled plastics).[247]

Compounding these economic challenges is the lack of rollout in Denmark of two types of technology: packaging designs that reduce the cost of recycling, and plastics separation technologies at the recycling plant. Improving design (such as the detectable colorant mentioned above) and deploying more advanced separation technology would allow recyclers to separate plastics fractions more cost efficiently. Split incentives are also present: producers of plastics lack the incentive to design for recycling since third parties capture the value; and there is a well-documented overcapacity of municipal incinerators in Denmark that reduces municipalities' incentive to recycle plastics.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Mandating the improvement of the collection infrastructure for household plastic waste in municipalities**. Nordic country experience suggests that kerbside collection generates less contamination than the 'bring' approach.
- **Increasing the national target for the plastics recycling rate from 22.5% to up to 60%.** This would move Denmark from the minimum level under current EU law to the levels envisaged in the 2014 EC review of waste policy and legislation presented as part of the EC's circular economy proposals. This could also help insure targets and objectives are well defined.
- **Standardising collection and separation systems across municipalities** to pave the way for economies of scale and stronger sorting and treatment capabilities at the national level. This could lead to a higher profitability of domestic recycling operations.
- **Reviewing fiscal incentives around incineration of plastics**. This could both tackle the externality barrier and accelerate the shift towards the complete recy-

246 www.factsonpet.com/

247 www.theguardian.com/environment/2015/mar/26/uks-biggest-plastic-milk-bottle-recycler-on-brink-of-collapse

cling of plastic waste. In Denmark the taxation rate is already high in comparison with other European countries,[248] so policymakers might consider differentiating the tax rate based on whether or not plastics are separated out before incineration. Catalonia has such a differentiated incineration tax rate for organics collection programmes.[249]

- **Bringing together all stakeholders** in the plastics supply chain to work on systemic solutions to address split incentives that affect plastic recycling. This could take the form of a project with specific short term objectives, or a network, or a private public partnership.

- **Working towards EU-wide rules and standards**

    - on the plastics used in retail packaging solutions to better ensure recyclability. Ultimately this could result in a EU-wide positive list of material/format combinations for which recycling performance is superior.

    - for waste recovery and management procedures so as to create more standardized outputs and allow better trade opportunities for the waste processors.

    - on minimum shares of recycled material in plastic products (as in California) in order to increase and stabilise market revenues for plastic recycling.

- **Setting up league tables ranking neighbourhoods based on their recycling performance.** In the UK for example the Department for Environment, Food and Rural Affairs maintains such a league table and provides information to households on how their communities' recycling rates compare to others. A study made by the University of Guildford concluded that this type of feedback encouraged households to recycle more.[250]

3.5.2 Bio-based packaging where beneficial

Opportunity:	**Innovation-driven shift to bio-based alternatives for selected plastic packaging applications.**
2035 economic potential:	**Not quantified.**
Key barriers:	**Technology; profitability driven by unpriced externalities; inadequately defined legal frameworks.**
Sample policy options:	**Funding of innovation and B2B collaboration; investment in improved end-of-use pathways; working to clarify the EU regulatory framework.**

Bioplastics could potentially replace many applications of petroleum-based plastics. Broadly they may meet one or both of the following definitions: (i) bio-based[251] materials, which have a biological source (in a renewable and sustainable form) and (ii)

248 D. Hogg, DG Environment , European Commission, *Incineration taxes : Green certificates—Seminar on use of economic instruments and waste management* (2011)

249 Ibid.

250 See, for example www.letsrecycle.com/news/latest-news/localised-feedback-boosts-recycling-participation/

251 'Bio-based' is defined here as any fibre or polymeric material derived from organic feedstock, e.g. paper or polymers from cellulose, plastics such as PHBV, polyesters or PLA.

biodegradable[252] materials, which have a biological fate, returning to the biosphere as nutrients. In the context of the Denmark pilot, discussion centres mainly on bio-based materials that could replace petro-based plastics. If they are used in applications most likely to end up as uncontrolled waste in the environment – such as films, bags, or closures – these materials should preferably be biodegradable.

The prevalence of bio-based plastics is still limited,[253] but growing. Nova-Institute determined the tonnage-based share of bio-based structural polymers at 2% in 2013, up from 1.5% a year earlier.[254] European Bioplastics, a trade association, even expects global capacity to quadruple by 2018, mainly driven by rigid packaging applications.[255]

There are two principal pathways for companies and regions to shift from a petro-based plastic to a bio-based material, both facing a set of critical challenges.

- Using a bio-based feedstock to make 'drop-in' monomers to produce the same polymers as from a petroleum source, using the existing plastic value chain – this is the market segment that is globally seeing the strongest growth, spearheaded by partly bio-based PET which is forecasted to grow from ~600 000 tonnes in 2013 to ~7 million tonnes in 2020.[256] Drop-in bio-based resins or resin-precursors (for example ethylene glycol monomers for PET) are functionally indistinguishable from their petro-based counterpart, but are difficult to produce cost-competitively compared to petro-based counterparts at current prices (similar to the challenges for biofuels).

- Replacing the material altogether, either with a new plastic or an alternative material with the same or similar properties. These materials face difficulties matching the performance of petro-based plastics and have been largely limited to very specific applications where new characteristics are desired, such as with Ecovative's mycelium-based and compostable packaging materials,[257] or disposable tableware (which can both be composted or anaerobically digested).

Another challenge for bio-based alternatives is the considerable apparatus that is already in place to produce and use petroleum-based plastic packaging. Accelerating a switchover beyond the conventional investment cycle is therefore expensive and complex. Consider, for example, one large fast-moving consumer goods (FMCG) company that noted that it might take five to eight years to get a new product from concept to shelf – a large share of which is packaging design.

There are nevertheless two strong arguments for making the shift towards bio-based materials.

- **Responding to increasing material demand and price volatility.** The anticipated addition of 1.8 billion more middle-class consumers worldwide between 2010 and 2025 would lead to a 47% increase in demand for packaging. As long as the plastic is sourced from a fossil feedstock, there will eventually be issues of supply and cost unless resource extraction increases at the same pace – leading to increasing risk from price volatility.[258] Bio-based materials would be less sensitive to price volatility and contribute to securing the rising demand from con-

252 According to the EU packaging directive it is only allowed to market/state that a packaging is biodegradable if it complies with the CEN-standard EN 13432. For the purposes of this report, it is assumed that the material can be readily decomposed under composting or anaerobic digester conditions in a short, defined period of time.

253 According to analysis based on SRI, FO Licht, Frost and Sullivan, and press clippings (2011), in 2010-11 less than 2% of the chemical industry's sales worldwide consisted of biopolymers and other bulk biomaterials such as natural rubber and bio-based polyols.

254 Nova-Institute, *Bio-based Building Blocks and Polymers in the World* (2015).

255 European Bioplastics, *Bioplastics – facts and figures* (2013).

256 Nova-Institute, *Bio-based Building Blocks and Polymers in the World* (2015).

257 www.ecovativedesign.com/mushroom-materials/. Also see Ellen MacArthur Foundation, *Towards the Circular Economy II* (2013), p.71.

258 World Bank; Ellen MacArthur Foundation, *Towards the Circular Economy III* (2014), p.25.

sumers.

- **Ensuring unavoidable leakage is bio-sourced.** The highly dispersed nature of plastic packaging means that leakage to the biosphere is always likely – even with excellent recycling – and leakage of petro-based plastic creates either a net addition of CO_2 to the atmosphere or slow degrading waste in the landfill or oceans. In Denmark, 10-11% of plastic bottles do not end up in the deposit-refund system, while this number is 0–2% for refillable glass bottles.[259] But even low leakage rates are problematic for a high turnover item like food and beverage packaging.[260] Another example is the large variety of plastic packaging that is disposed of as mixed garbage, thus having near 100% leakage. If there is (unavoidable) leakage, it is preferable that this material comes from a bio-based feedstock so that the net carbon addition to the atmosphere is minimised upon incineration, or is biodegradable if it is likely to leak into the biosphere without incineration.

THE OPPORTUNITY FOR DENMARK

Denmark businesses could leverage both the drop-in and replacement pathways described above to shift from petro-based plastics to bio-based materials. Some international companies have shown that there are business cases for both options:

- The Coca Cola Company launched its PlantBottle™concept in 2012, where up to 30% of the plastic is made from drop-in, bio-based chemicals. Coca Cola now also collaborates with, among others, renewable chemicals producer Gevo, which intends to supply bio-based paraxylene for making PET. Going further, Coca Cola aims at producing bottles from 100% residual biomass.[261]

- DSM has a number of bio-based plastics for non-packaging applications on the market, for example Arnitel®, partially made using rapeseed oil and used for making temperature-resistant pan liners; and EcoPaXX®, an engineering plastic made from 70% biological feedstock, used for engine covers in cars.[262]

- In Denmark, ecoXpac produces a cellulose fibre-based material that can be moulded like plastics and is biodegradable. In a partnership with Carlsberg, The Carlsberg Foundation and the Technical University of Denmark, and using Cradle2Cradle® design principles, they are developing the first bio-based, biodegradable beer bottle.[263]

Bio-based materials have been controversial because of their potential impact on land use and waste recovery systems, and indeed should be introduced where they are beneficial from a *system perspective*, and aligned with design criteria that include:

1. **Minimise overall waste**: New materials should not increase other waste streams (i.e. reduced gas/liquid barriers of bio-based materials may lead to higher food spillage, biodegradable materials may cause reduced recycling rates and be too slow to decompose).

2. **Do not increase land use**: bio-based packaging materials should, where possible, be derived from secondary organic material streams (e.g. fibre from residual biomass, microorganisms growing on organic waste) in order not to compete with food supply or further increase land use (although the biomass need for plastics substitution is small – currently at 0.01% of the area globally under agricultural

259 Danish Return System.

260 Take aluminium beverage cans for example, which have a 60-day life from can to (recycled) can. Even at a 70% recycling rate, all the original material would disappear from the economy after only one year.

261 www.coca-cola.com/content-store/en_US/SC/PlantBottle/; www.gevo.com/?post_type=casestudy

262 www.dsm.com/products/arnitel/en_US/home.html; www.dsm.com/products/ecopaxx/en_US/home.html

263 www.ecoxpac.com

cultivation;[264] given the current share of biopolymer at ~2% of total polymer volume (see above), even a fully bio-sourced supply would occupy around 2%).

3. **Do not leak nutrients from the bio-cycle to the technical cycle**. Since bio-based materials are essentially taken from the bio-cycle to be used in the technical cycle, it is important to avoid leakage of essential biological nutrients. This is typically avoided by ensuring that produced materials are pure,[265] and that they are returned to the biosphere either directly through composting or digestion, or indirectly through incineration.

4. **Consider existing end-of-use infrastructure**: If a new bio-based material is introduced, it should not disrupt existing end-of-use treatment systems so that overall costs increase. If a biodegradable alternative is introduced, there should already be an end-of-use pathway for it, such as an operational collection system for organic waste.

5. **Avoid leakage of non-circular materials**: Product-by-product evaluation is necessary to assess best end-of-use option. There is a fundamental question around whether the packaging material should be looped within the technical cycle or returned to the biological cycle (c.f. Figure 1).

    - **Technical cycle.** Beverage containers that are relatively clean and easy to recognise and could participate in deposit refund schemes with high recycling rates may benefit from further focusing on recyclability, which could mean a petroleum feedstock is still preferable even if there is the option to use bio-based drop-in chemicals.

    - **Biolocial cycle.** Packaging typically incinerated as mixed waste (such as film and sticky food containers) may benefit from being bio-based – or potentially also biodegradable such that it can be disposed of together with food waste in the organics bin (and be recovered in composters or anaerobic digesters).

Based on these design criteria, Denmark could start the shift to bio-based alternatives, first for selected disposable packaging with high tendency of being incinerated as mixed waste, and subsequently start introducing bio-based feedstock for plastic packaging applications with high degree of recycling. The materials could be sourced from non-food organic feedstock, for example residual wood fibre or plant biomass, or organic waste. Apart from making Denmark more resource resilient, this innovation-driven development could create a competitive advantage and opportunities to export new products and technologies.

- By **2020**, Denmark might seek to launch the first successful at-scale examples of replacing petro-based plastics by new, advanced bio-based materials (as already conceptualised by Carlsberg/ecoXpac). While little replacement of plastics protecting food is anticipated, Denmark could investigate pockets of opportunity where petro-based plastics properties are overspecified and replace these with a bio-based material with lower barriers. Due to the lead time required to build capacity for production of drop-in monomers, e.g. in bio-refineries (see Section 3.2.1), the estimated increase in bio-based feedstock for existing plastic materials is limited.

- By **2035**, Denmark might seek to introduce bio-based drop-in chemicals at scale for the production of recyclable plastic packaging (e.g. PET), leveraging an anticipated bio-refining capacity (see Section 3.2.1). At the same time, Denmark could introduce biodegradable alternatives to replace, in particular, petro-based food packaging with low recycling rates, as well as creating a differentiated packaging offering for exported FMCGs to prioritise biodegradable versions for developing

264 Food and Agriculture Organization of the United Nations (FAO); Institute for Bioplastics and Biocomposites (IfBB), University of Applied Sciences and Arts, Hannover.

265 Polymers typically contain only carbon, hydrogen, oxygen and nitrogen.

markets with low recycling rates.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'bio-based packaging where beneficial' opportunity (see Section 2.2.4 for the barriers framework). To enable bio-based materials to successfully contribute to the new plastics economy (see Box 7), it is critical to ensure that working pathways exist for them to be produced, to fulfil their role, to be accurately separated, and to reach their intended fate at end-of-use. At this point there is still a large need for technological innovation in all segments of such pathways. For example, advanced bio-based materials with the right properties[266] to replace petro-based plastic packaging and with limited negative effects, e.g. without competition with food crops, are still mostly at the advanced R&D or early commercial stage.

The incentive to innovate further is lowered by the actual and potential low cost of petro-based plastics, which are determined by global oil prices. Low prices of petro-based plastics neither reflect the true environmental costs of their production[267] nor the cost of recycling them. This suppresses the potential prices that competing bio-based alternatives can command, meaning that margins remain low except in cases of high-price, low-volume products for specific applications. It gives rise to challenges to the profitability of producing bio-based plastics, which is highly dependent on the oil price. In addition, several stakeholders in the packaging value chain point out that moving towards using bio-based materials could complicate the supply chain from the point of view of packaging users because it adds more suppliers and types of material, thereby increasing transaction costs.

Finally, many stakeholders suggest that legal frameworks need to be better defined. For instance, ecoXpac indicated the benefits of a more transparent and speedy approval process for innovative new materials for food packaging. In another example, the field of bio-based materials could benefit from a Danish Act on excise duties that distinguishes better between petro-based and bio-based materials, in line with its aim of promoting environmentally benign types of packaging.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Fund collaboration in the R&D and design phases.** With sufficient budget available this could take the form of funding R&D platforms—the further development of bio-based materials in collaboration with large CPG companies could follow international best-practice models for public-private innovation (for example the Fraunhofer Institute in Germany and UK's Catapults). More modest collaboration support could bring together designers and engineers in formats that draw inspiration from the packaging eco-design advisory services that Eco-Emballages offers in France.[268]

- **Investing in improving end-of-use pathways** for bio-based and biodegradable materials (including plastics and food waste) in the collection/separation systems.

- **Working to clarify the EU regulatory framework for approving new materials** for food packaging so as to minimise unintended consequences that could hamper innovation and growth in the bioplastics industry.

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266 For example, good gas and liquid barrier properties are crucial for food packaging.

267 Whereas the emissions from producing ethylene from Brazilian sugarcane amount to 0.1 tonnes CO_2e/tonne of product (assuming no forest was cleared to cultivate the sugarcane), this rises to 2.1 tonnes for the same product derived from Chinese naphtha.

268 See, for example www.ecoemballages.fr/; ec.europa.eu/environment/waste/prevention/pdf/Eco_Emballages_Factsheet.pdf

Figure 33: Share of purchased goods in Danish hospitals that could be covered by performance models

	COST BREAKDOWN OF PURCHASED GOODS PERCENT	ADDRESSABLE FOR ACCESS OVER OWNERSHIP MODELS
Diagnostic imaging and radiation equipment	12	✓
Surgical equipment	9	✓[1]
Patient care and wound treatment	9	–
Medical apparel and textiles	4	✓[2]
Other medical equipment	26	–[3]
Medical equipment and accessories	60	
Laboratory, observation and test equipment	13	✓
Food and beverage	7	–
IT equipment	4	✓
Other	15	–[3]
Total	100	
Addressable for access over ownership models	38 / 62	100 ✓

✓ **Readily addressable / high potential**

✓ **Addressable long-term/low-mid potential**

– **Not addressable**

1 Semi-durable equipment (e.g. scalpels, cuffs, sterile drapes) addressable in the longer term
2 Clothing and linen already widely addressed in Denmark
3 Not assessed; long tail of small product categories, although access over ownership models should be feasible in many cases

SOURCE: Statistics Denmark, Danish Regions

- **Considering contributing to an EU-wide debate on taxation** of petroleum-derived materials.

3.6 Hospitals

Hospitals constitute a large, public service in Denmark and as such procure and consume large amounts of resources. The two key circular economy opportunities identified are to adopt performance models in procurement, and to become leaders in recycling and waste reduction. Modelling suggests that performance models in procurement could save hospitals EUR 70-90 million by 2035. With a systematic effort Danish hospitals could become leaders in recycling and minimisation of avoidable waste. For these opportunities to be realised, it is important that necessary capabilities are developed and existing custom and habits are addressed, for example by supporting pilots and training programmes, and by creating national guidelines and/or targets.

The healthcare sector in developed economies face a tremendous challenge over the next decades. Healthcare costs are increasing, for example driven by an ageing population, technological development and increased expectations from patients. Although Denmark is the country with the lowest projected cost increase, its public spend on healthcare is expected to rise from ~7% of GDP in 2008 to ~10% GDP by 2050.[269] Such projections obviously motivate investigations for cost reductions and productivity improvement.

Hospitals are different from the 'producing' sectors discussed in Chapters 3.2–3.4 in that their output is a service. Hospitals do, however, procure, use, and discard vast quantities of goods and materials. For this sector this report therefore focuses on how hospitals could use their scale and centralised management to maximise resource efficiency through performance models, and minimise their waste through best practices in prevention and recycling.

In 2013, Danish hospitals spent EUR ~2.4 billion on physical goods.[270] Based on what types of products are already offered in the form of performance models, an estimated 38% of the total purchases could be addressable (Figure 33). This includes a range of advanced equipment (e.g. MRI scanners, radiation treatment equipment, and laboratory instruments) and also (semi-)durable goods (e.g. scalpels, cuffs, and surgical apparel). It does not include the long tail of smaller product categories in 'other medical equipment', so the estimate is likely on the conservative side.

There are also large quantities of structural waste in healthcare that could be addressed using circular principles. Though these were not explicitly analysed in the Denmark pilot, a few deserve mentioning:

- **Virtualisation.** Although the technology is not yet mature beyond the level of isolated trials, it is anticipated that the efficiency of part of the healthcare system could be significantly improved by leveraging connectivity and technology-driven cost reduction of diagnosis. Two existing examples are the blood glucose monitor for diabetic patients and the various 'e-health' applications; a plausible development is that patients take a variety of samples at home using a connected table-top device, send the diagnostic outcome electronically, and consult physicians remotely using a videoconference application.

- **Preventive healthcare.** Increasing healthcare costs have prompted the idea of governments reducing the need for costly healthcare interventions by increasing the overall health of the population. Shifting the focus to disease prevention could offer a tremendous opportunity, not only in terms of avoided investment

269 The King's Fund, *Spending on health and social care over the next 50 years. Why think long term?* (2013).

270 Expenses for Denmark's 5 major regions, data from Danish regions. Purchase of goods represents ~15% of total hospital budgets; hospitals purchase services for an additional EUR 2,400 million.

in hospital beds (and the materials associated with construction and usage/management) but also in terms of reduced productivity loss in the society. The Alzira model from Valencia offers an early example: driven by the nature of the public-private partnerships in the model, healthcare providers are incentivised to focus on health promotion and in the long-term reduce the patients' need for healthcare.[271] It is also highly relevant to address the increasing caloric intake that has been growing steadily in Europe other developed economics, and could drive exceedingly high healthcare costs.[272]

3.6.1 Performance models in procurement

Opportunity:	**Shift towards performance models in procurement of advanced and (semi)durable equipment.**
2035 economic potential:	**EUR 70–90 million p.a.**
Key barriers:	**Insufficient capabilities and skills due to lack of experience; imperfect information; custom and habit.**
Sample policy options:	**Guidelines and targets; capability building; procurement rules.**

The central idea in 'performance'[273] models is a contract in which the customer pays for the use, or the performance, of a product rather than the product itself. The rationale is that there is no inherent benefit in owning the product. On the contrary, ownership can entail additional costs (upfront investment), risk (unpredicted repair, maintenance or obsolescence), and end-of-use treatment costs.

THE OPPORTUNITY FOR DENMARK

Performance models are relevant for many of Danish hospitals' purchasing categories, whether it is leasing clothing and bed linens or contracting the full management of scanning and radiation equipment. At the heart of each such model lies a mutual benefit for suppliers and customers to reduce the total cost of ownership. While the customer is able to reduce purchasing and maintenance costs, as well as maximise performance and uptime, the supplier is able to secure sustainable revenue streams, maximise resource utilisation, and drive efficiency during the use phase.[274] Importantly, performance models also incentivise manufacturers to design more durable products that are easier to maintain, repair and refurbish or remanufacture (see Chapter 3.4).

There are already multiple examples of suppliers providing performance that are relevant to, or directed exclusively towards, hospitals. In the healthcare sector, suppliers like Siemens, Philips and GE are already rolling out performance models for their equipment, in addition to having existing refurbishment operations.[275] Some of the most well-known examples outside the healthcare sector include Ricoh's and Xerox' service contracts for high-volume printers, Desso's carpet tile concept,[276] and Philips' lighting services (selling

271 271: NHS European Office, *The search for low-cost integrated healthcare. The Alzira model – from the region of Valencia* (2011).

272 Today, the average caloric intake exceeds 3,500 kcal per day, 40% above the recommended daily intake. In addition, the diet has become more fatty, salty, and sweet over the past 40 years. EEA, 2008; Food Standards Agency; European Food Safety Authority; J. Schmidhuber, *The EU Diet – Evolution, Evaluation and Impacts of the CAP* (FAO, Rome, 2008).

273 Performance models used to collectively denote performance contracts, leasing, asset centralisation contracts and other models designed for supplier to help customer minimise total cost of ownership.

274 For a more in-depth discussion on performance-based business models, see Stahel, W. R., Palgrave McMillan, *The Performance Economy* (2006).

275 www.healthcare.siemens.com/refurbished-systems-medical-imaging-and-therapy; www.healthcare.philips.com/main/products/refurbished_systems/; www3.gehealthcare.com/en/products/categories/goldseal_-_refurbished_systems/

276 www.desso-businesscarpets.com/corporate-responsibility/cradle-to-cradler/

'lux' instead of lighting fixtures[277]).

The partnership between Stockholm County Council and Philips Healthcare for the Nya Karolinska hospital has received a great deal of attention.[278] The 20-year comprehensive, function-based delivery and service agreement covers the delivery, installation, maintenance, updating and replacement of medical imaging equipment such as MRI and ultrasound equipment, where the cost risk is carried by Philips and the upside potential (e.g. future lowered prices) is shared. This coincides with Philips opening a new, dedicated refurbishment and remanufacturing facility in Best, the Netherlands in 2014, announced as 'the next step in our circular economy journey'.[279] Allowing suppliers to retain control over their equipment and making full use of parts and components throughout their entire life cycle could generate substantial savings for the hospitals. Jens Ole Pedersen at Philips Healthcare Nordics notes that hospitals could save approximately 25% on TCO of the provided equipment.

Performance-based contractual models could cover more than technically advanced equipment or installations. Uniforms, bed and bathroom linens are commonly procured on a leasing contract. And even semi-durables, which are often used as one-way disposable equipment, are addressable for performance models. In Catalonia, which like Denmark focuses increasingly on the circular economy, Axioma Solucions provides sterilised surgical clothing as a service, while Matachana Group provides sterilisation solutions for equipment at hospitals' facilities. Axioma Solucions notes that according to an independent study, their 'Steripak' can be cycled 75 times and consequently has a resource footprint one eighth that of corresponding one-way clothing, while being up to 15% more cost efficient.[280]

Danish hospitals have not yet adopted performance models to a large extent. The only category where there is a large penetration is in textiles; laundry services and leasing are already widely adopted.[281] There is therefore a large opportunity to initiate such a shift, and the timing to do so appears very good. There are currently 16 large hospital projects in Denmark, seven greenfield projects and nine that are major renovations or expansions.[282] Similar to the Nya Karolinska example, they could take a holistic, performance-based approach to procurement of equipment. These new hospitals will open within the next five to ten years, sufficient time to build a new procurement organisation and culture, with less concern for legacy equipment or old habits.

Given the current starting point, Denmark could gradually shift purchasing of goods towards performance models for the addressable share of the purchasing budget (Figure 33):

- By **2020**, hospitals could seek to adopt performance contracts for up to 10% of selected product categories (diagnostic imaging and radiation equipment, IT equipment, and laboratory, observation and test equipment).

- By **2035**, overall adoption of performance models could have increased to as much as 40%. In addition to product categories already addressed in the short term, similar procurement models could also have begun to penetrate other durable and semi-durable goods, such as selected surgical tools and apparel, where the safety/hygiene issues with looping materials can be properly addressed.

277 By owning the energy bill, Philips is able to significantly reduce energy consumption and cost. www.ellenmacarthurfoundation.org/case_studies/philips-and-turntoo.

278 Katharine Earley in The Guardian, *Hospital innovation partnership set to deliver high quality, sustainable patient care* (13 November 2014).

279 philips.exposure.co/behind-the-factory-doors,.

280 The resource efficiency study was conducted by the Autonomous University of Barcelona.

281 Interview with De Forenede Dampvaskerier. Global players like Berendsen plc are also active in this field; www.berendsen.dk/hospital

282 Information provided by Danish Regions.

With total estimated savings of 15–30%[283] compared to traditional procurement, applied to an addressable cost base of 38% of total hospital procurement (see Figure 33), modelling suggests Danish hospitals and equipment suppliers could by 2035 (2020) save EUR 70–90 (10–15) million annually.[284] These findings give a directional view of the magnitude of this opportunity for Denmark. They rely by necessity on a number of assumptions, the most important of which are detailed in Appendix B. The estimate has not included more 'generic' products, such as lighting, flooring or printers.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'performance models in hospital procurement' opportunity (see Section 2.2.4 for the barriers framework). Sector experts from both suppliers and hospitals have noted that the critical barrier to hospitals increasing their use of performance models is that hospital procurement staff are not trained and have limited experience of other forms of tenders such as performance contracts or assessing offerings based on total cost of ownership (TCO) – as well as limited time to change practices. Another social factor mentioned in interviews is the customary perception that leasing is often more expensive than buying and the uneasiness that performance contracts could allow increased private sector influence in public healthcare. Furthermore, hospital management and procurement departments in many cases lack information compared to equipment providers on the economic case for access over ownership. These barriers combine to provide a powerful force of inertia in procurement departments.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Guidelines and targets.**
    - **Creating guidelines** for regions or hospitals for the procurement of solutions rather than products, and how to work with target setting on different levels. International examples may serve as 'blueprints', such as the Philips–Nya Karolinska contract in Sweden. Through an innovative contract structure, the hospital secures access to a pre-defined level of functionality rather than the availability of specific equipment. Target setting also occurs in regional procurement partnerships in Denmark, e.g. the partnership for green procurement.
    - **Stimulating shared/centralised procurement amongst hospitals** where appropriate, to reap economies of scale and leverage purchasing power. This could take the shape of a centrally negotiated performance-based contract across all regional hospitals, e.g. for lighting. The resulting additional cost savings could further accelerate a large-scale move towards such access-based contractual models.
    - **Supporting measures to optimise equipment utilisation** such as equipment loan programmes between hospitals could round out the benefits from reshaping procurement procedures and skillsets.
- **Capability building.**
    - **Developing skillsets for circular economy-oriented procurement, e.g.**

283 Savings rate depends on product category. Based on expert interviews with healthcare equipment providers and case studies from performance contracts in other industries (e.g. white goods, automotive, printers).

284 Based on current procurement volumes. This *sector-specific* impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling. In addition, the distribution of savings between hospitals and suppliers has not been modelled. It could be argued that it is skewed towards hospitals in the short term since suppliers want to create incentives for hospitals to set up performance contracts, but could equilibrate at a more even split in the long-term as the model gets established and consolidated.

        - **Training staff** in optimal procurement design for access over ownership (e.g. the hospital could provide specialist training courses based on a nationally developed curriculum).

        - **Initiating a performance model pilot to develop and apply the total cost of ownership (TCO) concept** to allow a more holistic view of cost in hospital procurement – thereby creating a mindset as well as bidding rules that are more conducive towards performance contracts.

        - **Building a repository of case studies** from national and international examples to build confidence around issues such as e.g. cost efficiency, long-term benefits, contractual flexibility, and dependence on fewer suppliers.

    - **Establishing a government advisory body** with the explicit mission of promoting performance-based contractual models in hospital procurement. Hospitals could be given the option to seek such advice for all or specific procurement projects. This could take the form of a partnership, task force, or network to facilitate knowledge sharing.

- **Procurement rules**

    - **Adjusting budget rules** to enable joint budgets and closer working between procurement and technical teams ("breaking down siloes"). This could enable more performance-based contracts (with more procurement staff and fewer technical maintenance staff). Removing regulatory or governance barriers that impede interaction of hospital teams and supplier teams could also help.

    - **Adjusting procurement rules and procedures**.

        - **Augmenting the procedures for assessing the quality** of competing bids with tightly defined 'circularity' criteria or KPIs. Such criteria could be part of the (non-binding) guidelines for public procurement and could include promotion, piloting, and knowledge sharing of purchasing criteria). Examples include length of lifetime, reparability, presence of chemicals that hinder recycling, design for disassembling features.

        - **Incorporating accounting for externalities** (e.g. the life cycle carbon/water/virgin materials footprint) into the guidelines or rules for all public procurement to create full cost transparency.

3.6.2 Waste reduction and recycling in hospitals

Opportunity:	**Centrally managed and systematic initiative to reduce waste and increase recycling.**
2035 economic potential:	**Not quantified.**
Key barriers:	**Insufficient capabilities and skills due to lack of experience; custom and habit; imperfect information.**
Sample policy options:	**Pilot of waste reduction and recycling management integrated into staff training; waste minimisation and recycling targets; increased fiscal incentives to avoid waste generation.**

Large hospitals are like miniature cities, with many sizable and complex flows of materials and information. And, similar to cities, they produce large quantities of waste.

Hospitals are run by a central management that coordinates staff and sets a strategic direction for the whole organisation, and thus might have the potential to holistically optimise their waste management. Therefore, as is the case for other centrally and tightly controlled systems such as airports, it is reasonable to envision hospitals as champions in both waste prevention and recycling.

THE OPPORTUNITY FOR DENMARK

The largest source of (non-hazardous) waste in hospitals is the purchasing and preparation of food and beverage. As explained by one sector expert, it is common for departments to order too many meals from the kitchen to add a safety margin, which risks being magnified by the kitchen's safety margins. As a result hospital kitchens may end up purchasing more food and ingredients than needed, which ultimately produces avoidable food waste.

The approach to prevent avoidable food waste for large institutions such as hospitals differs from the alternatives laid out for the consumer-facing market (Section 3.2.2) in that it is more centred on right-sizing procured volumes. One way of incentivising this planning challenge is to set standards on sustainable procurement of the food and catering services, such as introduced by the NHS in the UK.[285]

Given its scale, hospitals could systemise and improve recycling beyond the already ambitious targets of the Danish society set by the 'Denmark Without Waste' strategy. Hospitals are part of the service sector where the target for recycling packaging waste in 2018 is 70% (paper, glass, metal and plastic) and 60% for recycling of organic waste in 2018.[286] In comparison, Danish hospitals today note recycling rates of 15–30%, with an average below 20%.[287]

Danish hospitals therefore have an opportunity to make a systematic effort with strong management commitment to improve recycling, while at the same time reducing waste generation. While this effort needs to be driven primarily by a well-informed and committed staff, it could be guided by, for example, working with waste management suppliers that increasingly provide waste minimisation services apart from operating the logistics and treatment. While the potential has not been fully quantified in this case, it should be feasible to achieve overall recycling rates above of approximately 85% (70%) by 2035 (2020). This corresponds to being aligned with the 'Denmark Without Waste' target by 2020 and then gradually outpacing it.

BARRIERS AND POTENTIAL POLICY OPTIONS

The following paragraphs provide an initial perspective on the barriers limiting the 'waste reduction and recycling in hospitals' opportunity (see Section 2.2.4 for the barriers framework). Hospitals face similar social factor and information barriers when aiming to reduce waste generation and increase recycling as when trying to increase the use of performance models in procurement. There is limited capacity within hospital administrations to consider waste prevention and waste handling and, while procurement departments are already highly professional, hospitals lack expertise in waste prevention and management. Furthermore, hospital targets are centred on quality of healthcare; expert interviews indicate that there is resistance to the idea of adding to or diluting such targets with targets relating to waste. Furthermore, there is limited information on the economic benefits of reducing waste and increasing recycling due to a lack of analysis of procured and disposed materials in hospitals. As in the food and packaging sectors, the incentive to reduce waste and increase recycling would rise if the market prices of packaging, food and other consumables reflected their true environmental costs.

As before, at the level of individual hospitals, the main short-term challenge is improving

285 UK Department of Health, *The Hospital Food Standards Panel's report on standards for food and drink in NHS hospitals* (2014).

286 Danish Government, *Denmark Without Waste. Recycle more – incinerate less* (2013).

287 Excluding construction and garden waste. Based on interviews and correspondence with representatives from hospital environmental managers and Danish Regions.

capabilities and skills as well as changing mindsets. Over a longer time horizon, policymakers might choose to play a role by creating supporting guidelines (non-binding) and rules (binding) as well as appropriate incentives. Central government might also also take on the externalities barrier by internalising more externalities in the production of food, packaging and other products that may end up being disposed of by hospitals as waste. Doing so would likely increase hospitals' monetary incentive for waste avoidance and recycling.

To address these barriers, the following policy options could be further investigated. These options are the result of an initial assessment of how cost-effectively different policy options might overcome the identified barriers (see Section 2.3.4):

- **Piloting the integration of waste reduction and recycling management into staff training** across all hospital functions in new or leading hospitals, and syndicating the results into case studies for wider knowledge building.

- **Setting waste minimisation and recycling targets** for hospitals in line with overall national targets but taking into account its different, challenging) character, and include associated circular economy metrics in the performance criteria for hospital management.

- **Investigate fiscal incentives to avoid non-hazardous waste streams to level the playing field for recycling initiatives** as part of a national initiative for all sectors. A complementary measure would be the publication of waste avoidance/management performance league tables for hospitals.

- **Creating or supporting a platform for Danish hospitals** to share information, exchange best practices and develop a joint strategy for reducing waste and increasing recycling rates with a view to establishing the country as a frontrunner.

- **Initiating a discussion on pricing in of externalities** (but balancing with distributional effects) so that the market prices of food, packaging and other consumables reflect the full social and environmental costs of their production, consumption and disposal—and ultimately inform better procurement and operational decisions.

APPENDIX

APPENDIX

A A detailed overview of sector selection in the Denmark pilot

This appendix summarises the details underlying the sector selection 'matrix' developed for the Denmark case study and shown in Figure 11 in Part 2: the selection of sub-dimensions, the data collection and the calculations. The list of sub-dimensions does not aim to be exhaustive and is not necessarily the optimal one for other regions, but could serve as an inspiration when conducting the sector selection elsewhere.

Figure A1 provides an overview of the sub-dimensions used in the Denmark pilot for the dimensions 'Role in national economy' (A) and 'Circularity potential' (B). It displays the type of assessment (quantitative vs. qualitative), an indication of how the calculations were performed and the relative weight of quantities within each sub-dimension. When the assessment was qualitative, a scoring-based assessment was performed to yield a 'semi-quantitative' result. The sources behind the data and analyses are reported. Figures A2 and A3 provide an overview of the relative scoring of each sub-dimension in the Denmark pilot.

A brief description of the sub-dimensions follows below.

Dimension A. Role in national economy.

A.1. **Contribution to the national economy in terms of gross value added.** Both the relative size of each sector's gross value added and the relative growth rate were taken into account, in order to reflect shifting long-term trends as well as current contributions.

A.2. **Contribution to national employment and job creation**. Employment is obviously a key priority for any policymaker and was thus included in dimension A. Both the relative importance of each sector in terms of full time equivalents and the relative growth rate were taken into account, in order to reflect shifting long-term trends as well as current contributions.

A.3. **Competitiveness – trade openness and security of supply.** Export and import volumes were included to reflect each sector's competitiveness on the international market.

A.4. **Competitiveness – strategic dimensions.** This sub-dimension is the *sum* of four qualitatively or quantitatively evaluated quantities illustrating the strategic importance of each sector for Denmark's competitiveness in terms of technology, productivity and sensitivity to global trends. The *sum* synthesis was selected to reflect that all quantities are important but not necessarily interdependent. The qualitative evaluation was done by assigning a score of 'high', 'medium' or 'low' to each quantity, associated with scores of 10, 5 and 1 respectively.

- *Patent activity* – Danish patent activity in relation to other countries in the EU, by technology area mapped on Danish sectors.
- *Export specialisation* – Classification based on whether each sector's share of Danish exports is significantly above, similar to, or below the average share of exports within the OECD.
- *Productivity advantage* – Reflects how productive Danish sectors are in comparison with the same sectors in international peers.
- *Energy price sensitivity* – Energy expenditure as share of output value, included to reflect each sector's sensitivity to changes in energy prices.

Dimension B. Circularity potential.

B.1. **Material intensity –** *Purchase of commodities are shown as a share of the sector's turnover to reflect how dependent the sector is on physical resources.*

B.2. **Environmental profile –** Includes weights of both total waste volumes and recycling, in order to reflect both the tendency to create a leakage of material, which could potentially be avoided, and the proficiency with which the material is recovered today, which could potentially be improved.

B.3. **Scope for improved circularity** – The *product* of three qualitatively evaluations. A score of 'high', 'medium' or 'low' was assigned to each quantity, associated with scores of 10, 5 and 1 respectively. The *product* synthesis was selected due to the interdependence of the four quantities.

- *Intrinsic material value of output (and waste).* Qualitatively estimates the intrinsic value of the material handled in each sector. Both raw materials and value-added parts are taken into account. Implies both economic and environmental value.

- *Potential for higher value-add from circular activities.* States how much more value could potentially be added through circular economy activities; e.g. the theoretical amount of intrinsic material value, value added services, and longer lifetime. Implies both economic and environmental value.

- *Feasibility in terms of cost and complexity of implementation.* Sizes the estimated feasibility of improving circularity, accounting for e.g. whether products/materials cross borders or not, how materials are mixed, the cost of separation, and feasibility to engage customers.

Figure A1: Summary of methods and data used in the sector selection in the Denmark pilot

A	Prioritisation sectors based on role in the national economy	A.1	Sector contribution to national economy in terms of gross value add	Total GVA	Quantitative	Normalised index	2/3	Statistics Denmark.
				10-year GVA CAGR	Quantitative	Normalised index, shifted so that lowest value = 0	1/3	
		A.2	Sector contribution to national employment and job creation	Total Employment	Quantitative	Normalised index	2/3	Statistics Denmark.
				10-year GVA CAGR	Quantitative	Normalised index, shifted so that lowest value = 0	1/3	
		A.3	Competitiveness – trade openness and security of supply	Export volume	Quantitative	Normalised index	2/3	Statistics Denmark.
				Import volume	Quantitative	Normalised index	1/3	
		A.4	Competitiveness – strategic dimensions	Patent activity, productivity advantage, and energy price sensitivity	Qualitative	Normalised, semi-quantiative scoring where high=10, mid=5, low=1	1/4	Based on patent activity in relation to other countries distributed on technology areas 2006-2009. Danish Ministry of Business and Growth, *Competitiveness – strength and potential* (2012); European Patent Office.
				Export specialization	Qualitative		1/4	Based on whether sector's share of export was larger relative to OECD average in 2009. Danish Ministry of Business and Growth, *Competitiveness – strength and potential* (2012); OECD.
				Productivity advantage	Quantitative	Normalised index	1/4	Indexed sector productivity compared international peers. to Danish Ministry of Business and Growth, *Competitiveness – strength and potential* (2012); EU KLEMS.
				Energy price sensitivity	Quantitative	Normalised energy expenditure as share of output value	1/4	Statistics Denmark.
			Sum of A subdimensions			A.1 + A.2 + A.4 + A.4		
B	Prioritisation of sectors based on Circularity potential	B.1	Material intensity	Sector's purchase of commodities as share turnover	Quantitative	Normalised index	1	Statistics Denmark; data only available for manufacturing sectors and mining & quarrying.
		B.2	Environmental profile	Waste volumes	Quantitative		2/3	Danish Environmental Protection Agency, *Affaldsstatistikken 2012* (2014)Affaldsstatistikken 2012 (2014); Statistics Denmark.
				Share of waste not recovered	Quantitative		1/3	Average manufacturing taken as value for all manufacturing sectors. Danish Environmental Protection Agency, *Affaldsstatistikken 2012* (2014)
		B.3	Scope for improved circularity	Intrinsic material value of output and waste	Qualitative	Semi-quantiative scoring of each quantity, where high=10, mid=5, low=1; total score is the normalised product of all 4 scores		Ellen MacArthur circular economy team analysis; industry and environmental experts.
				Potential for higher value-add from circular activities	Qualitative			
				Feasibility in terms of cost and complexity of implementation	Qualitative			
			Sum of B subdimensions			B.1 + B.2 + B.3		

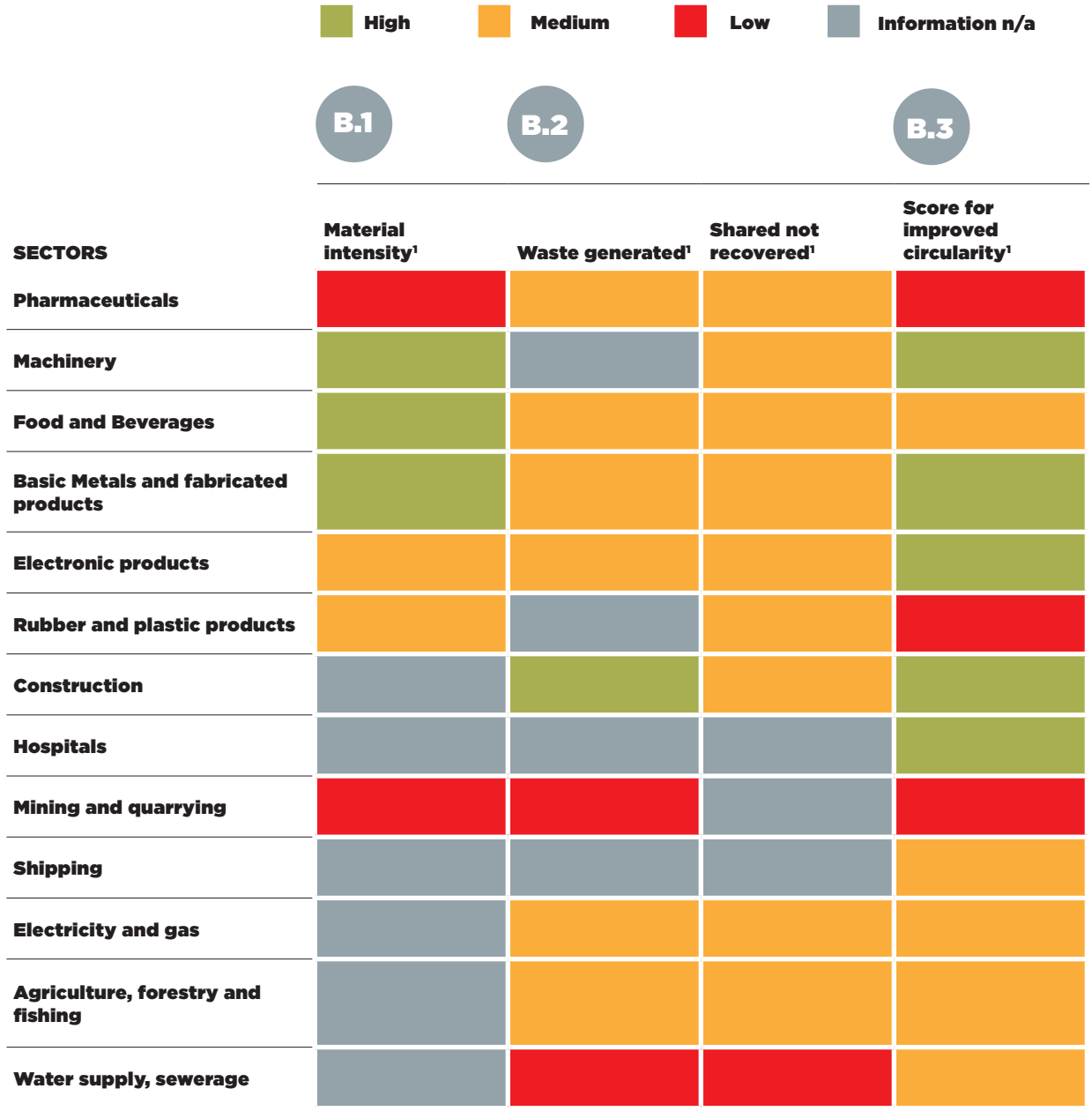
NOTE: GVA = gross value added; CAGR = compound annual growth rate.

Figure A2: Overview of scoring of 'Role in national economy' in the Denmark pilot

SECTORS	GVA[1]	CAGR[1]	FTEs[1]	CAGR[1]	Imports[2]	Exports[2]	Strategic dimensions[3]
Pharmaceuticals							
Machinery							
Food and Beverages							
Basic Metals and fabricated products							
Electronic products							
Rubber and plastic products							
Construction							
Hospitals							
Mining and quarrying							
Shipping							
Electricity and gas							
Agriculture, forestry and fishing							
Water supply, sewerage							

1 Green: value add/employees >4% of total, CAGR >3%; Red: value add/employees <1% of total; CAGR <0%, Orange: value add/employees 1-4% of total, CAGR 0-3%.
2 Green: imports/exports >5% of total; Red: imports/exports <1% of total; Orange: Imports/exports 1-5% of total.
3 Semi-quantitative.
SOURCE: Ellen MacArthur Foundation circular economy team.

Figure A3: Qualitative overview of scoring of dimension B: Circularity potential



1 Green: material value >40% of sales turnover; Red: material value ,10% of sales turnover; Yellow: material value 10-40% of sales turnover
2 Green: waste generated ≥10%; Red: waste generated <1%; Yellow: waste generated is 1%-10% of total waste in Denmark 3 Share of waste not recycled.
SOURCE: Ellen MacArthur Foundation circular economy team.

B Opportunity prioritisation and sector impact assessment

This appendix describes the assumptions and calculations behind the opportunity prioritisation and impact assessment for each focus sector in the Denmark case study. The methodology for the assessment is described in Sections 2.2.1 – 2.2.3, and the broader context of the results are presented in Part 3 of this report.

As described in Section 2.2.2, two scenarios were defined for the Denmark pilot, one for 2020 and one for 2035. The scenario description serves as a guideline for how the business environment and consumer behaviour, as well as technology, could have evolved in a circular economy. One could interpret the scenarios and the ensuing opportunity descriptions as illustrations of how far the circular economy could advance if all identified barriers were overcome.

Figure B2 gives an overview of how the opportunities identified and mapped using the ReSOLVE framework, were assessed and prioritised, as described in Sections 2.2.1 and 2.2.2. The ten prioritised opportunities span one or more actions in the framework outlined below. An economic impact assessment was conducted for seven of these opportunities. In addition, an estimate of the increased tonnage of plastic packaging recycling was computed, driven by estimates of increased collection rates and yields at recycling facilities. Figures B2–B8 summarise the assumptions, estimates and scaling for each of these assessments, along with the sources used. These assumptions should be read in light of the scenario description detailed in Figure B1. It should be noted that due to variations in the use of scale-factors between the conservative and ambitious circular economy scenarios, the relative contribution of each opportunity to the total sector-specific impact are different and the overview of sector-specific impact presented in Figure 27 is an *average* of these two scenarios.

Figure B1: Short-term and long-term scenarios enabling a circular economy

	Short-term (2020)	Long-term (2035)
BUSINESS & CONSUMER BEHAVIOUR	• Increased acceptance of performance based business models in businesses and the public sector, but still for niche product categories (e.g. ~10% of imaging / radiation equipment in hospitals, ~10% of machinery products) • Households are comfortable using new separation systems introduced by municipalities as part of the "Denmark Without Waste" strategy (e.g. increase in collection rate of household plastic packaging waste by 15 percentage points) • Significant remaining margins for improvement in waste reduction • Rapidly increasing interest in sharing business models (e.g. shared residential and office space)	• Broad acceptance of access over ownership business models in businesses and public sector (e.g. ~30% of a broad range of products in hospitals, ~30-70% of machinery products) • Fully optimised waste collection and separation infrastructure provided by municipalities and waste managers (collection of 70-80% of plastics for recycling) • Avoidable food waste reduction approaching theoretical limits due to improved knowledge and use of best practices among consumers, businesses and public institutions (e.g. hospitals) • Sharing has become the new norm for traditionally underutilised assets (buildings, cars, and durables)
TECHNOLOGY	• Key circular economy technologies (e.g. cascading bio-refineries, bio-based alternatives to plastics, 3D printing and design for disassembly in construction, remanufacturing techniques), existing today at late R&D or early commercial stage, have been successfully piloted	• Key circular economy technologies existing today at R&D or early commercial stage have reached maturity due to accelerated innovation • Increasing remanufacturing of machinery components for use in "as new" products enabled by increasing importance of software for performance

Source: Expert interviews; DBA; Danish EPA; Ellen MacArthur Foundation circular economy team

Food and beverage:

- Value capture in cascading bio-refineries (Loop; implicitly Regenerate if more organic materials are returned to the bio-cycle). Impact assessment described in Figure B3.
- Reduction of avoidable food waste (Optimise). Impact assessment described in Figure B4.

Construction and real estate:

- Industrialised production and 3D printing of building modules (Optimise, Exchange). Impact assessment described in Figure B5.
- Reuse and high-value recycling of components and materials (Loop). Impact assessment described in Figure B5.
- Sharing and multi-purposing of buildings (Share; implicitly Virtualise as an enabler). Impact assessment described in Figure B6.

Machinery:

- Remanufacturing and new business models (Loop; implicitly Share as opportunity is partly enabled by performance models that imply access over ownership and design for upgradability). Impact assessment described in Figure B7.

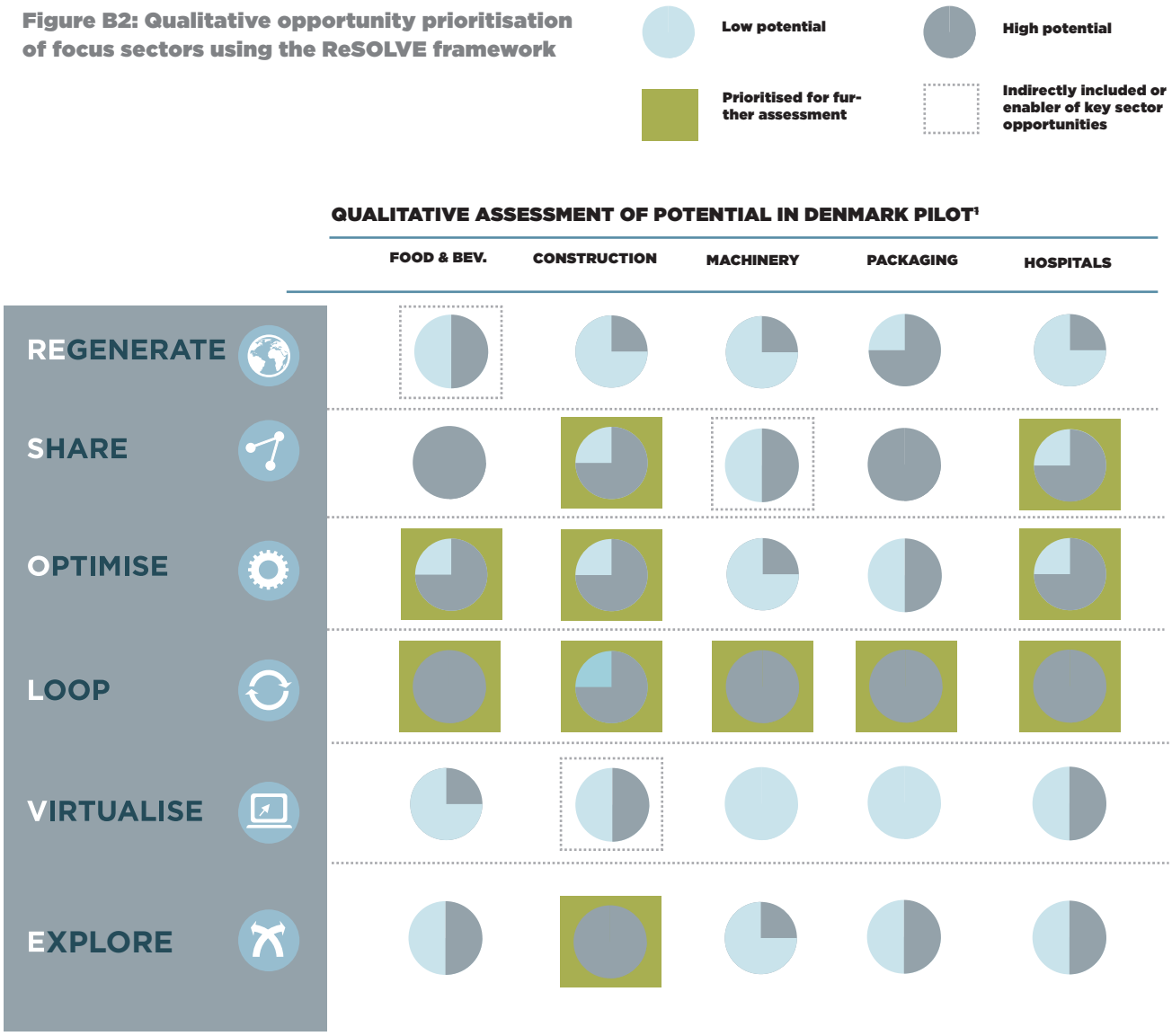
Packaging:

- Increased recycling of plastic packaging (Loop). Calculation of additional plastic material recycling described in Figure B8.
- Bio-based packaging where beneficial (Regenerate).

Hospitals:

- Performance models in procurement (Loop, Share). Impact assessment described in Figure B9.
- Waste reduction and recycling in hospitals (Loop, Optimise).

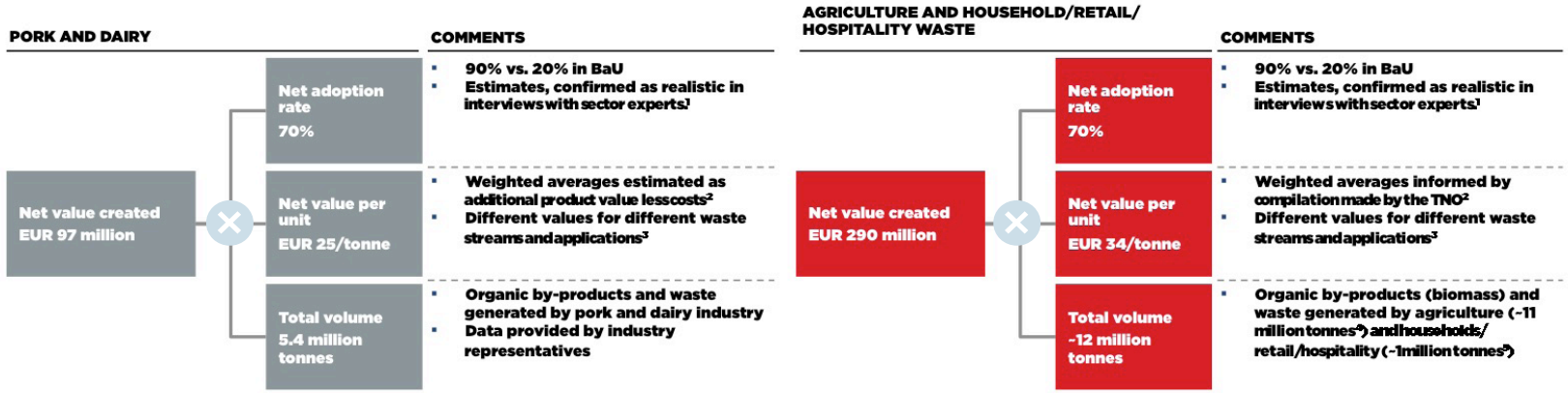
Figure B2: Qualitative opportunity prioritisation of focus sectors using the ReSOLVE framework



1 Assessment based on focus subsector, product category or material stream in each sector. Food & beverage: Waste/by-products from pork / dairy processing, residual biomass from agriculture, organic waste from households, retail & hospitality. Construction: New buildings. Machinery: Manufacturing of pumps and wind turbines. Packaging: Plastic packaging. Hospitals: Purchasing of goods.
SOURCE: Ellen MacArthur Foundation circular economy team

Figure B3: Value capture in cascading bio-refineries

Impact assessment summary, 2035



		Size as share of construction sector	CONSERVATIVE Scalability factor	CONSERVATIVE Impact EUR mn	AMBITIOUS Scalability factor	AMBITIOUS Impact EUR mn	COMMENTS & ASSUMPTIONS
Food & Beverage	Pork and Dairy	30%	1.0	97	1.0	97	1.0 by definition; Scale up to other sub-sectors based on this impact
	Other meat and poultry	21%	0.8	55	1.0	69	Similar to pork industry
	Beverage industry	7%	0.5	12	1.0	24	Similar to dairy industry, but lower up-cycle potential compared to current operations
	Bakeries, bread factories etc.	6%	0.5	10	1.0	20	Analogous to pork/dairy but downscaled due to lower value of waste (less protein)
	Fishing industry	8%	0.5	13	1.0	26	Similar to pork industry, but downscaled due to lack of detailed insight
	Other food industry	25%	0.1	8	0.5	40	Conservative estimate due to fragmentation and lack of insight
	Tobacco	2%	0	0	0	0	Not included
	Food and Beverage total	100%		195		275	Not scaled up in ambitious scenario
	Agriculture and household/retail/ hospitality waste			290		290	

NOTE: Results estimated for impact of industries inside Denmark only. This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling. BaU = business as usual.

SOURCES:

1 5 company / industrial organisation interviews and 5 sector expert interviews.

2 Additional price per tonne dependent on type of by-product/waste and its application. Energy production as biofuell/biogas estimated to generate additional EUR 20–30/tonne. New chemicals estimated to generate EUR 70–80/tonne. Costs estimated to 40–50% of product value.

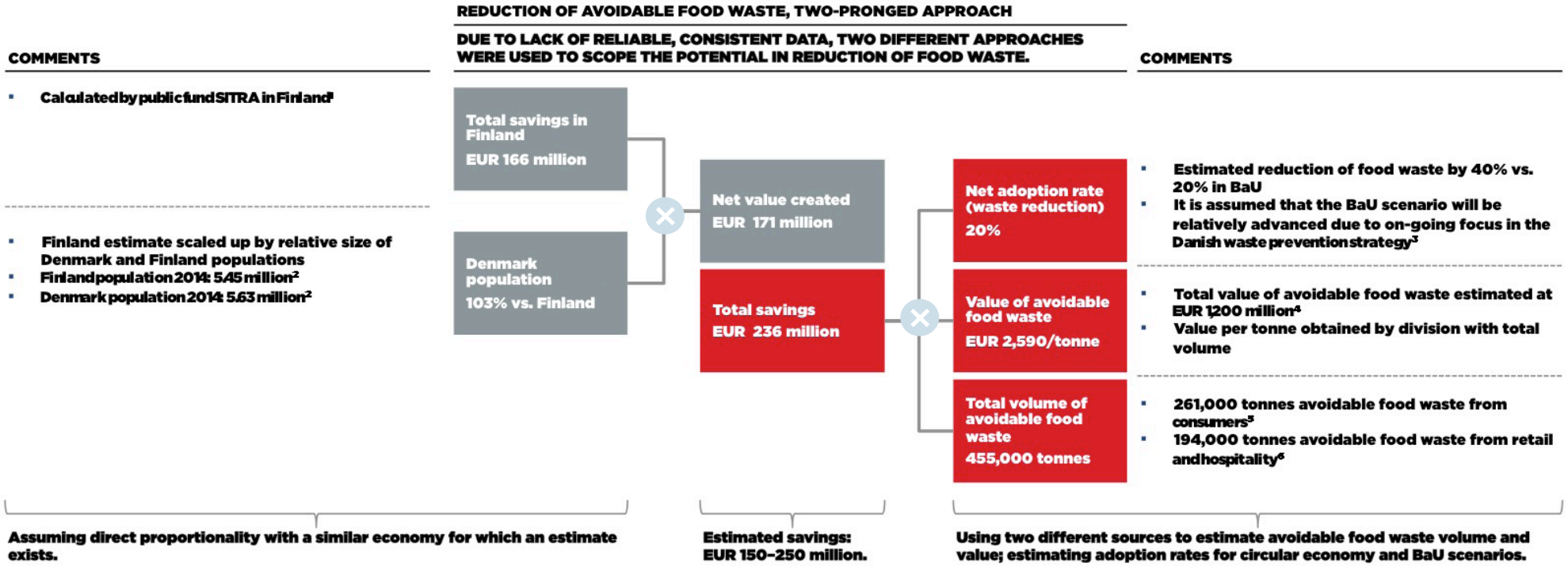
3 The Netherlands Organisation for Applied Scientific Research, Opportunities for a Circular Economy in the Netherlands (2013). Pricing estimates derived from approximate current and future prices for a 34 waste / by-product streams.

4 Danish EPA, Organiske restprodukter - vurdering af potentiale og behandlet mængde (2014); Kortlægning af madaffald i servicesektoren (2014); Kortlaegning af dagrenovation i Danmark - Med fokus på etageboliger og madspild (2014).

5 Estimate, taken as 80% of waste generated by the food and beverage industry per EUR of GVA (from Statistics Denmark). See also M. Gylling et al., The 10+ million tonnes study: increasing the sustainable production of biomass for biorefineries, University of Copenhagen (2013), concluding that the agricultural sector could produce an additional 10 million tonnes of by-products for use in bio-refineries.

Figure B4: Reduction of avoidable food waste

Impact assessment summary, 2035



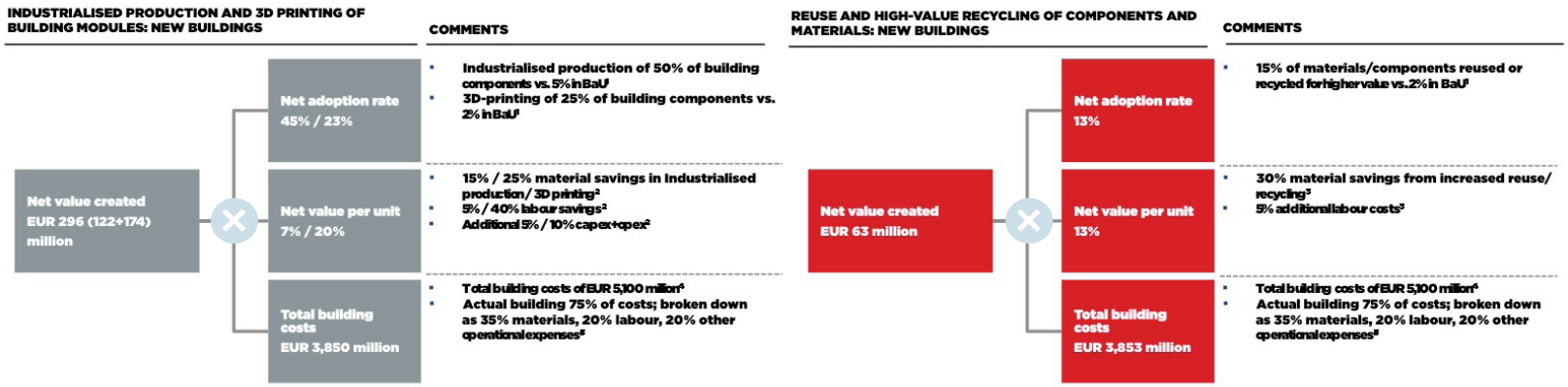
NOTE: Results estimated inside Denmark only. This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling. BaU = business as usual.

SOURCES:

1 SITRA, Assessing the circular economy potential for Finland (2015).
2 Eurostat.
3 Danish Government, Denmark without waste I (2013); Danmark uden affald II (2015).
4 A. Halloran et al., Adressing food waste reduction in Denmark (Food policy 49, 2014).
5 Danish Environmental Protection Agency, Kortlægning af dagsrenovation i Danmark – Med fokus på etageboliger og madspild (2014).
6 Danish Environmental Protection Agency, Kortlægning af madaffald i servicesektoren: Detaljhandel, restauranter og storkøkkener (2014).

Figure B5: Industrialised production and 3D printing of building modules; reuse and high-value recycling of components and materials

Impact assessment summary, 2035



			CONSERVATIVE			AMBITIOUS			
		Size as share of construction sector	Scalability factor	Impact A EUR mn	Impact B EUR mn	Scalability factor	Impact A EUR mn	Impact B EUR mn	COMMENTS & ASSUMPTIONS
CONSTRUCTION	Construction of new buildings	25%	1.0	296	63	1.0	296	63	• 1.0 by definition; Scale up to other sub-sectors based on this impact
	Civil engineering	30%	0.2	72	15	1.0	361	77	• Conservative estimate due to significant differences from new buildings activity • Still significant a potential for reuse of asphalt in infrastructure • Large potential for industrialised production, but also larger current adoption rates
	Professional repair and maintenance	33%	0.4	157	34	1.0	393	84	• Large share of activities in full building renovation • Conservative estimate due to lack of transferability of activities from new buildings
	Own-account repair and maintenance	11%	0.1	13	3	0.2	27	6	• Low scale factor since professional sector has little potential for industrialisation sector • Some potential especially in 3D printing and reuse of materials
	Construction total	100%		539	116		1,077	231	

NOTE: Results estimated for impact of industries inside Denmark only. This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling. BaU = business as usual.

SOURCES:

1 Estimate, informed by three company interviews and three sector expert interviews.

2 Estimates based on reported savings by the Broad Group and WinSun, consolidated in expert interviews. 3D printing savings estimated as 50% of WinSun's reported savings, since there is still very little data to exemplify cost savings. Actual savings will vary on a case-by-case basis and be dependent on the size and complexity of components being 3D printed. See also Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015); www.archdaily.com/289496/; http://www.yhbm.com/index.php?siteid=3

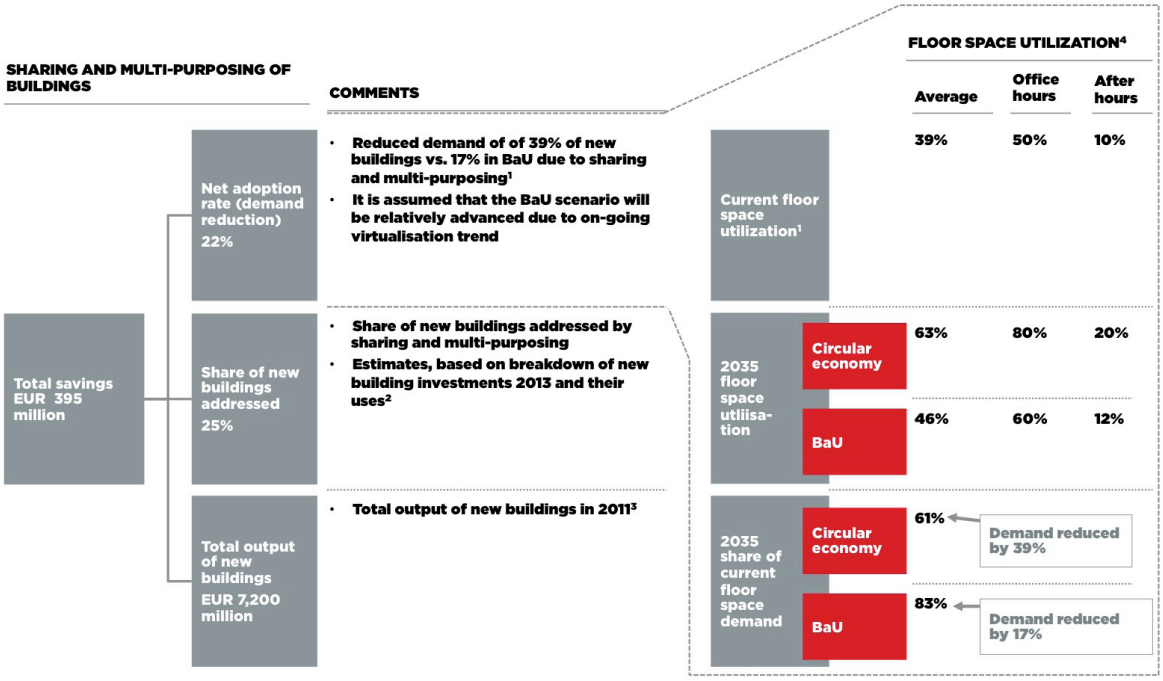
3 Estimates, informed by literature and expert interviews. See, e.g. US Environmental Protection Agency, Using Recycled Industrial Materials in Buildings (2008); Skive municipality, Afslutningsrapport Projekt Genbyg Skive (2015).

4 Statistics Denmark.

5 P.-E. Josephson & L. Saukkoriipi, Waste in construction projects: call for a new approach (Chalmers University of Technology, 2007); M. Hogan, The Real Costs of Building Housing (SPUR, 2014).

Figure B6: Sharing and multi-purposing of buildings

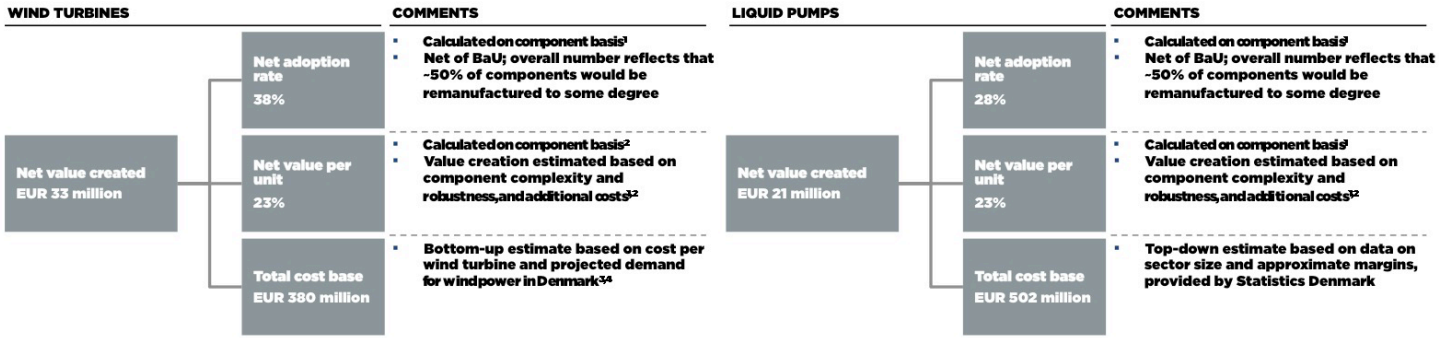
Impact assessment summary, 2035



NOTE: Results estimated for impact inside Denmark only. This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling. BaU = business as usual.
SOURCES:
1 Estimate, informed by literature: GSA Office of Government-wide Policy, Workspace utilisation and allocation benchmark (2011); Cushman & Wakefield, Office space across the world (2013); vasakronan.se/artikel/det-digitala-arbetslivet-ar-har; SITRA, Assessing the circular economy potential for Finland (2015); Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).
2 Statistics Denmark; 100% of commerical buildings; 10% of residential, small residential, small non-residential buildings; 50% of public buildings and sports buildings.
3 Statistics Denmark.
4 Office hours = 10 hours per day, After hours = 4 hours per day. Current utilization during office hours taken as 20% higher than reported by GSA.

Figure B7: Remanufacturing and new business models

Impact assessment summary, 2035



		Size as share of machinery sector	Conservative: Scalability factor	Conservative: Impact EUR mn	Ambitious: Scalability factor	Ambitious: Impact EUR mn	Comments & assumptions
Machinery	Pumps & wind turbines	34%	1.0	54	1.0	54	1.0 by definition; Scale up to other sub-sectors based on this impact
	Other engines	29%	1.0	45	1.0	45	Analogous to pumps & wind turbines
	Other machinery	37%	0.8	46	1.0	58	Analogous to pumps & wind turbines but more diverse
	Machinery total	100%		145		157	Scale up to adjacent sectors based on this impact
Adjacent sectors	Electronic products	42%	0.8	49	1.0	66	Difficult to remanufacture high value of components in EEEs[5]
	Basic metals and fabricated metal products	47%	0.3	20	1.0	73	Less complex products; most potential in synergies with downstream remanufacturers
	Mining	7%	0.2	2	1.0	11	Lower potential as raw material producer
	Other manufacturing	135%	0.5	98	1.0	212	Varied industries. At least 50% deemed to have similar potential as machinery
	Total adjacent sectors	231%		169		362	

NOTE: Results estimated for impact of industries inside Denmark only. This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling. BaU = business as usual.
SOURCES:
1 Five sector experts were interviewed for the analysis of cost breakdown and value potential; findings tested on high level with six Danish company and industry representatives.
2 Towards the Circular Economy Vol. I, Ellen MacArthur Foundation (2012); Assessing Circular Economy potential for Finland, SITRA/McKInsey (2014).
3 Cost breakdown and technical complexity per component gathered from, a.o.: LCA analysis on Vestas V112 model, PE (2011); E.ON Wind Turbine Technology and Operations Factbook (2013); Windpower Engineering & Development (2012), http://www.windpowerengineering.com/design/mechanical/understanding-costs-for-large-wind-turbine-drivetrains; EWEA (2009).
4 Wind power demand: Coarse grained estimates based on projections by BTM/Navigant, McKinsey & Co., and DWIA.
5 However, larger secondary value may be derived from successfully remanufactured / refurbished EEEs, as stated by, e.g. Ricoh.

Figure B8: Increased recycling of plastic packaging

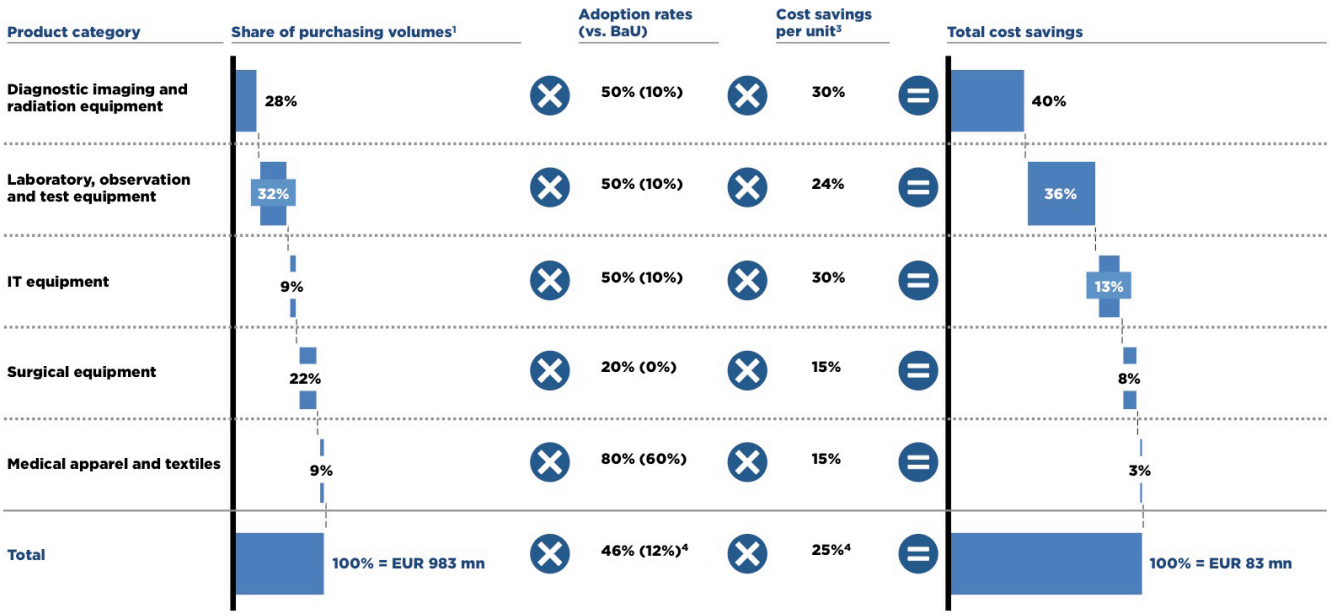
Impact assessment 2013

		Packaging waste generated[1]	Baseline collection rate[1]	Baseline recycling yield[2]	2035 collection rate[3]	2035 recycling yield[4]	Net additional recycling[5]
Businesses	LDPE	47	41%	80%	85%	90%	21
	HDPE	13	62%	80%	85%	90%	3
	PET[2]	N/A	N/A	N/A	N/A	90%	N/A
	PP	10	69%	80%	85%	90%	2
	PS+EPS	7	58%	80%	85%	90%	2
	Other	6	93%	80%	93%	90%	1
	Total	83	53%	80%	86%	90%	29
Households	LDPE	58	3%	50%	68%	75%	29
	HDPE	15	5%	50%	68%	75%	7
	PET	7	90%	95%	90%	95%	-
	PP	12	5%	50%	68%	75%	6
	PS+EPS	9	5%	50%	68%	75%	4
	Other	1	65%	50%	68%	75%	0
	Total	101	10%	50%	69%	75%	48

NOTE: This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling.
SOURCES:
1 Total volumes: Danish Environmental Protection Agency, Statistik for emballageforsyning og indsamling af emballageaffald 2012 (2015). Volume distribution and recycling rates are reconciled from 2008 data provided by the Danish Environmental Protection Agency.
2 Accurate data for PET not inluded in used data set. The the recycling rate is therefore assumed not to change, thus giving a zero contribution to the 2035 scenario.
3 Estimates, based on interviews with sector experts from the waste management industry and the Danish Environmental Protection Agency.
4 Estimates, based on interviews with sector experts and ambition levels presentet in the Denmark without waste strategy. Danish Government, Denmark without waste. Recycle more, incinerate less (2013).
5 Calculated as the sum of addtional volume collected by 2035 at 2035 yield and the additional yield of the collected baseline volume.

Figure B9: Performance models in procurement

Impact assessment summary, 2035



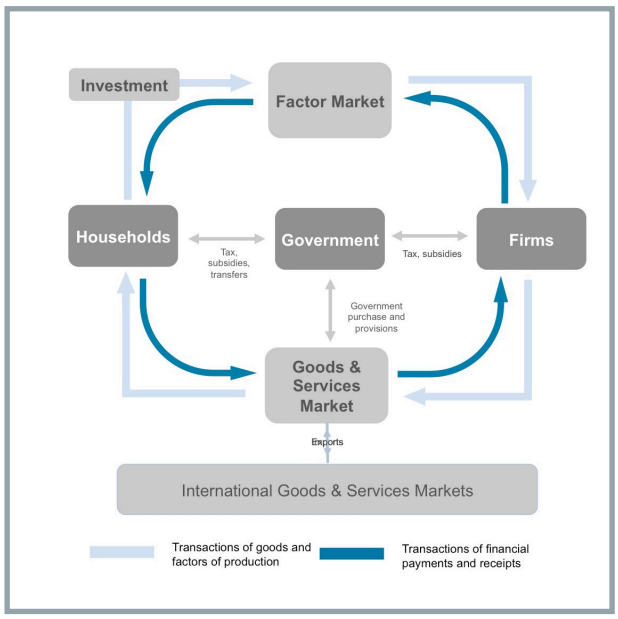
NOTE: This sector-specific impact does not include indirect effects, e.g. on supply chains, that are captured in the economy-wide CGE modelling. BaU = business as usual.
SOURCES:
1 Statistics Denmark, Danish Regions
2 Estimates, informed by 4 company interviews; 4 hospital / sector expert interviews
3 Savings rate depends on product category. Based on expert interviews with healthcare equipment providers and case studies from performance contracts in other industries (e.g. white goods, automotive, printers). The distribution of savings between hospitals and suppliers has not been modelled. It could be argued that it is skewed towards hospitals in the short term since suppliers want to create incentives for hospitals to set up performance contracts, but could equilibrate at a more even split in the long-term as the model gets established and consolidated.
4 Weighted averages of product categories

C Economy-wide impact quantification

Economy-wide impact assessment methodology

The economy-wide impact assessment was conducted using NERA Economic Consulting's N_{ew}ERA global model. A multi-sector, multi-region trade, dynamic computable general equilibrium model. The model uses standard macro and microeconomic theory to represent the flow of goods and factors of production within the economy. A simplified version of these interdependent economic flows is shown in Figure C1. It illustrates the flow of goods, services and payments in a typical CGE set up between the different economic agents in the domestic and international markets.

Figure C1: Overview of a Computable general equilibrium (CGE) model



In the model, there is a representative household in each region. Households supply factors of production, including labour and capital, to firms. In return, firms provide households with payments for the factors of production. Firm output is produced from a combination of productive factors and intermediate inputs of goods and services supplied by other firms. The final output of individual firms can be consumed within Denmark or exported. The model also accounts for imports into Denmark. Goods and services in the model are treated as 'Armington' goods and services, that is, imported and domestically produced goods and services are assumed to be only imperfect substitutes.

In addition to consuming goods and services, households can accumulate savings, which they provide to firms for investments in new capital. Taxes are collected by a passive government, which recycles tax receipts back to the households as lump-sum transfers.

Another feature of the CGE framework is that all markets are required to clear, meaning that the sum of regional products and factors of production must equal their demands, and that the income of each household must equal its factor endowments plus any net transfers received. In other words, there can be 'no free lunches'. The model assumes general equilibrium, which requires that for all sectors, regions and time periods, there is a global equilibrium where supply and demand are equated simultaneously, as producers and households anticipate all future changes. The mechanism by which this is achieved is through price changes.

To analyse the economic impact of scenarios (e.g. structural change from increased circularity in the economy), CGE models such as the N_{ew}ERA model represent the interactions and feedback effects in the exchange of goods and services simultaneously between consumers, producers and government and across sectors, regions and time.

They are therefore particularly useful to assess both the direct and indirect effects of structural changes and are able to analyse scenarios of changes to the economy with potentially large impacts that have not been implemented in the past.

Limited work has been done to date in modelling the circular economy in a CGE framework. Our review of the literature identified just two sources that would qualify as economic impact assessments of the circular economy using hybrid or CGE frameworks.[1] At the time of writing, to our knowledge, there are no CGE models that can fully represent the attributes of a truly circular economy. These include: inputs and material substitutions; changes in resource productivity and production technology; new circular economic sectors, their services and products; priced externalities; and the generalised changes in the stocks and flows of goods, capital, labour and materials.

CGE model description

The CGE model used for the analysis represents five world regions: Denmark and its main trading partners, which have been aggregated as the Rest of Europe, China, Oil exporting countries and Rest of the world. Different aggregations of the economic sectors were used for Denmark and the other regions. In Denmark there are 21 economic sectors (16 non-energy and 5 energy sectors), while in the rest of the world 17 economic sectors (12 non-energy and 5 energy) were represented. From a time perspective, the model was set up to span between 2015 and 2035 and was run in 5-year time increments. These sectoral and geographic dimensions are summarised in Figure C2.

1 *Assessment of Scenarios and Options towards a Resource Efficient Europe*, European Commission (2014), and *A National CGE modeling for Resource Circular Economy*, Korea Environment Institute (2006).

Figure C2: Sectoral and geographical aggregates in the CGE Model

SECTOR	DESCRIPTION	REGION	
		Denmark	EU, China, OPEC, RoW
GAS	Natural gas works	Yes	Yes
OIL	Refined oil products	Yes	Yes
COL	Coal transformation	Yes	Yes
CRU	Crude oil	Yes	Yes
ELE	Electricity, gas and heat	Yes	Yes
MEP	Machinery and electronic products	Yes	Yes
CNS	Construction - New buildings and infrastructure	Yes	Yes
CNS-Repair	Construction - Repair and maintenance of buildings	Yes	
FBV	Food and beverages	Yes	Yes
CHM	Chemical industry, plastics and pharmaceuticals	Yes	Yes
AGR	Agriculture, forestry and fishing	Yes	Yes
FAB	Basic metals and fabricated metal products	Yes	Yes
MIN	Mining	Yes	Yes
AOG	Other manufacturing	Yes	Yes
WRH	Services - wholesale, retail and hospitality	Yes	Yes
SER	Services		Yes
RPD	Services - Repair of machinery and other durables	Yes	
RNT	Services - Renting of buildings	Yes	
HSP	Services - Hospitals	Yes	
SOT	Services - other	Yes	
TRN	Transport	Yes	Yes
WTR	Sewerage and waste management	Yes	Yes

SOURCE: NERA Economic Consulting.

Producer behaviour in the model is characterised by a 'production function'. A production function represents how different inputs are used to manufacture a commodity or service. For example, production of machinery requires capital, labour, energy, and other materials as inputs. Parameters in the production function define the way in which substitution between inputs and outputs changes in response to changes in the relative prices of inputs and outputs. These price-induced substitution relationships are called 'elasticities'. Figure C3 provides an illustrative representation of a production function. The sigmas (σ) shown are illustrative substitution elasticities between the different inputs. Consumer behaviour, the production of natural resources and regional trade are similarly represented in the CGE model by these 'nested' functions.

Theoretically, there are several ways to represent the circular economy within a CGE framework and, as with any modelling exercise, choosing between options involves an effort versus quality trade-off. This trade-off will be between the availability of time, effort and data on the one hand, and the required quantity and quality of detail in representing circular economy activities, sectors and flows of goods, materials and externalities, on the other.

Figure C4 presents four potential approaches to represent circularity in a CGE framework and their pros and cons. For policymakers to select which of those approaches is best suited to their needs, there are three important aspects to consider:

1. Detail and precision in representation of economic relations in the circular economy (e.g. are sectors and services associated with circular economy activities to be explicitly modelled, e.g. product dismantlers in the refurbished goods supply chain?).

2. Degree and scope of representation of economic and materials flows (e.g. in addition to monetary flows, does the model need to explicitly represent physical flows of virgin materials, recovered/recycled materials, different by-product and waste types?).

3. Time and effort requirements,(duration of the assessment, access to internal and external experts and modellers) and data and assumption requirements (quantity of primary data readily available to model the required level of detail).

As shown in Figure C4, the approach selected for the Denmark pilot study was chosen as a balanced compromise between the three criteria above.

As described in Section 2.3.1, the hybrid approach consists of several steps preceding the actual CGE modelling. As described in Figure 19, it begins with representing the impact induced by circular economy scenarios in the focus sectors in the form of an input-output table. These changes are then used to 're-parametrise' production (and utility) functions according to the following procedure:

- Interpolate input effects from cost savings (or increases) as well as output effects of revenue increases per focus sector for intermediate model years 2025 and 2030 based on the sector-specific quantification for years 2020 and 2035.

- Re-parametrise production functions (i.e. estimate new parameter values) to match decreases (or increases) in the values of input factors into the focus sectors relative to the baseline value.

- Re-parametrise production functions to match increases (or decreases) in the values of the output from focus sectors relative to the baseline value.

- Impose these time-varying changes in inputs and outputs for all model years (i.e. the input-output value structure of implementing the circular economy opportunities) by redefining (re-calibrating) the production formulae of all focus sectors.

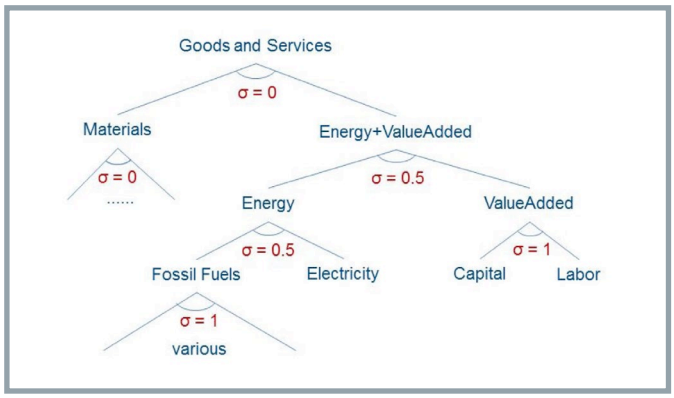
After re-parametrisation, the model is run and will optimise supply and demand of all commodities and services in the economy via price impacts. The results for the re-parametrised version of the production (and utility) functions now represent the circular economy scenario(s) in the CGE model and can then be compared to the baseline scenario.

Scenario descriptions, key assumptions and sources

- The macro-economic impact modelling was conducted by calibrating the CGE model to a 'baseline' (or business as usual) reference scenario and then quantifying the changes to key macroeconomic indicators after running a 'circular economy' scenario through the model. Two scenarios were assessed, a 'conservative' and an 'ambitious' version of the circular economy.

- As described above, the scenario inputs to the CGE model were modified input-output tables for Denmark for the years 2020 and 2035, where input and output values were adjusted based on the impact from the sector-specific opportunity assessment (see Section 2.2.3, Chapters 3.2–3.6 and Appendix B). The macro-economic model therefore quantified the direct and indirect economy-wide effects that the sector specific structural changes would have on the

Figure C3: Generic structure of production functions in the CGE Model



SOURCE: NERA Economic Consulting.

Figure C4: Potential approaches and trade-offs for representing circularity within a CGE framework

APPROACH DESCRIPTION	PROS	CONS
Use an existing CGE framework to model circularity as an increase in resource efficiency or changes in consumption preferences	**Simplest approach to (partially) modelling circularity**	**Very general representation** **Impacts depend on exogenous parameters (productivity or preferences)** **Partial representation or circularity, no structural change**
As part of a hybrid approach, re-estimate production functions in existing CGE structure to match the sector specific estimates of circularity	**Easy to implement bottom-up cost and output effects** **Captures direct effects on focus sectors and indirect effects on the economy** **Limited data requirements and easily replicable**	**Bottom-up cost and output effects are exogenous** **Materials flows not explicitly modelled (captured indirectly by financial flows)** **Only partial representation of structural change (no new technologies or sectors)**
Develop CGE structure that includes new circular activities (e.g. regenerate, share) as separate economic activities. Works with hybrid approaches.	**Does not require quantifying effects in an ad hoc manner** **Approximate size and some effects of circular economy can be quantified**	**Important time and effort requirement** **Significant requirement of detailed data / assumptions of new activities to calibrate model**
Develop CGE structure that represents all materials and value flows and represents all externalities in production and utility functions. Works with hybrid approaches.	**Highly detailed representation of circular sectors and flows** **Size and effects of circular economy quantified** **Circularity levers endogenously determined**	**Very time-intensive and complex modelling exercise** **Substantial data and assumptions requirements**

SOURCE: NERA Economic Consulting.

APPROACH SELECTED FOR DENMARK PILOT

Figure C5: Data sources used in the baseline calibration and CGE modelling

Data	Data source			
	Denmark	Rest of World		
Benchmark year input/output table	Statistics Denmark	GTAP 8 database		
Primary factor and commodity tax rates, output and export tax (subsidy) rates, and import tax rates	GTAP 8 database			
Substitution elasticities for production, consumptions functions	• GTAP 8 dataset includes Armington elasticities, intra-import elasticity of substitution, factor substitution elasticities, factor transformation elasticities. • Other sources include: - Paltsev, S., J.M. Reilly, H.D. Jacoby, R.S. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005: The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4. - Mikkel Barslund, Ulrik R. Beck, Jens Hauch, Peter B. Nellemann, "MUSE: Model documentation and applications," Danish Economic Council, Working Paper 2010:4.			
GDP and employment data and projections to 2035	DREAM group			
Energy demand data and projections to 2035	Danish Energy Agency (ENS) Statistics Denmark Own calculations		1.A.1.1.1.1.1	EIA IEO 2013[1]
Energy price data and projections to 2035				
Energy production data and projections				
CO2 emissions data and projection to 2035				

1 US Energy Information Administration – International Energy Outlook 2013 http://www.eia.gov/forecasts/archive/ieo13/
SOURCE: NERA Economic Consulting.

broader Danish economy.

Baseline scenario. The baseline scenario was developed through the following steps:

- Incorporating the Denmark 2011 input-output table within the GTAP8 dataset and scaling other regions' economic flows by actual GDP growth from 2007 till 2011 such that a globally balanced dataset was achieved.
- Building in exogenously specified regional forecasts, including Danish projections
- Calibrating the baseline: Adjusting model parameters such that they replicate the macroeconomic outlook by targeting GDP, carbon emissions by sector and by fuel, energy price, and energy production projections. This baseline calibration resulted in a projection consistent with the baseline scenario assumptions.

Circular economy scenarios. From a macroeconomic modelling perspective, the key assumptions of the circular economy scenarios (for both the ambitious and conservative cases) were as follows:

- The functional form of the production and utility functions remain the same between the baseline and the circular economy scenarios.
- Behavioural parameter values of the utility function remain the same between the baseline and the circular economy scenarios.
- Energy sector assumptions remain the same between the baseline and the circular economy scenarios (i.e. no explicit modelling of an additional shift towards renewable energy).

Each circular economy scenario is represented by producing an input-output table that represents the changes induced by the circular economy opportunities, quantified as described in section 2.2.3. The allocation of changes in input factors (labour, materials, energy and capital) was done based on an analysis of the changes in demand due to the circular economy activities,[2] and from which sectors' key material inputs are provided in the current (2011) input-output table.

The main difference between the 'conservative' and 'ambitious' scenarios are how the impact assessed for the deep-dive sub-sector is scaled up to adjacent (sub-)sectors. This difference is described in detail in Appendix B.

Several data sources were combined to construct the baseline calibration and circular economy scenario analysis. These are summarised in Figure C5.

D Assessment of policy options

Figure D1 provides an overview of the basic arithmetic of the policy assessment tool developed for the Denmark pilot study. The tool is a workbook that contains 87 policy interventions identified to address the barriers to the circular economy opportunities in the five focus sectors. The goal of the tool is to rank the policies by their relative cost-effectiveness using a semi-quantitative scoring function. This is done by scoring each intervention on two dimensions, 'impact' and 'cost', from which a weighted 'cost-effectiveness score' is derived.

The development and implementation of the tool described here is one of many alternatives that policymakers can use as a first step to narrow down a long list of policy options to those with the best potential to address the barriers to circular economy opportunities. It should be noted that the main benefit of this tool was that it facilitated discussion. Ultimately, the final sets of policy options for each sector as presented in Part 3 of this report were determined with the help of significant input from government stakeholders and sector experts. While the approach outlined here is a useful first step, it is underlined that it is not meant as a substitute for adequate due diligence and impact assessment in the standard policy making process.

The scoring rules and methodology used to arrive at a prioritised set of policy options are described in detail below. Each policy intervention was scored independently of others, i.e. not allowing them to work in conjunction with any other policy, but keeping in mind their potential to work well as part of a package. All scores are relative, with comparisons made across several dimensions including policy types, circular economy opportunities and sectors to ensure adequate scoring distributions.

Scoring of impact dimension

The 'impact score' of a policy is the product of two equally weighted factors: the 'importance of a barrier', which builds on the detailed barrier analysis described in Section 2.2.4; and the tentative effectiveness of the policy intervention at overcoming the barrier. The methodology, described in detail below, was systematically applied to all policy interventions to obtain a first set of impact scores, which were discussed and iterated in sector 'deep dive' sessions with multiple stakeholders.

- **Scoring the 'importance of barrier':** Based on expert judgment on the size/importance of the barrier to deliver the circular economy opportunity.
- **Scoring the 'effectiveness' in 2020 and 2035:** Based on an expert-guided estimate of how effective the policy intervention would be in addressing the barrier, given existing initiatives, over two time periods, equally weighted:

2 For example: reduced demand for materials and increased demand for labour due to remanufacturing in machinery; reduced demand for labour and increased need for capital for industrialised production and 3D printing of building modules.

- Short-term effectiveness (by 2020) with higher scores given to economic/fiscal incentives (subsidies, taxes, guarantees) and lower scores to information or R&D interventions

- Long-term effectiveness (by 2035) with the same scores for economic/fiscal incentives and those for information or R&D increased or decreased where relevant.

Scoring of cost dimension

The 'cost' score of a policy is the product of two equally weighted factors: 'administrative and transaction costs', determined by estimates and expert consultation; and wider economic costs of the intervention. The methodology, described in detail below, was systematically applied to arrive at a first set of cost scores, which were discussed and iterated in sector 'deep dive' sessions with multiple stakeholders.

- **Scoring the 'administrative and transaction costs'**: Based on an expert-guided estimate of the combined cost incurred by government to set up and operate the policy and the cost to the private sector of complying with it.

  - Cost incurred by government refers to any foregone revenue or additional spending commitment entered into by the government by virtue of the policy.

  - Cost to the private sector refers to one-off adjustment costs and any increase in the cost of doing business caused by the policy.

- **Scoring the 'wider economic cost':** based on an expert-guided estimate of the cost–benefit trade-off between economic advantages and disadvantages in a sector created by the policy across government, businesses and consumers.

  - An example is a policy that reduces market competition creates advantages for businesses, but disadvantages for consumers. Similarly, a subsidy creates an advantage for its recipients, but disadvantages for the government.

  - The 'economic advantage and disadvantage' component focuses on each particular sector. The scoring has not taken into account the intrinsic benefits of the policy supporting circular economy activities, since they are addressed in the 'impact' score.

  - The 'balance across the economy' component looks at the average net disadvantage in other parts of the economy due to a sector-directed policy, but not on the distribution of advantages and disadvantages, which belongs to the political viability sphere.

The assessment does not incorporate the economy-wide computational general equilibrium modelling of the impact of circular economy opportunities.

1. The total impact and cost scores are combined to provide a rank between 1 and 3:

2. Impact and cost are both greater than 50 (out of 100), putting the policy on the short-list

3. One or other of the impact and cost scores is 50 or above, putting the policy in a 'supporting policy' category

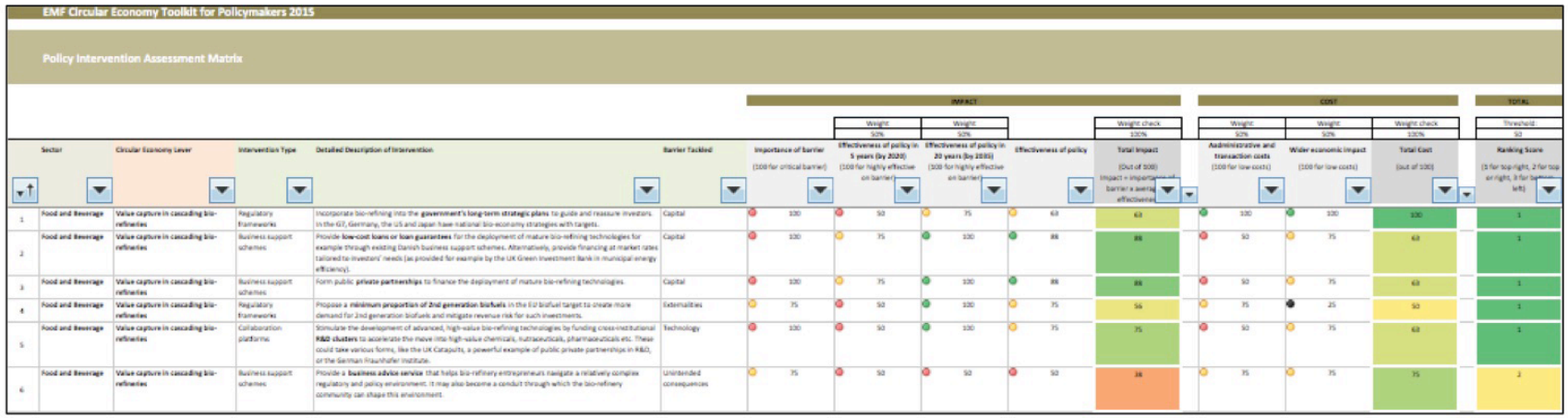
Neither impact nor cost score reaches 50, putting the policy in the unattractive category

Figure D2 shows a worked example of how the tool was used to provide an initial score for a particular policy option. All of these individual scores that comprise the total impact and total cost scores were subsequently discussed with the project team and Danish government stakeholders and adjusted accordingly.

Figure D1: Snapshot and description of the policy assessment tool

Long list of policy interventions to address barriers to circularity

Scoring on 2 dimensions for each policy intervention: (1) impact and (2) cost



EMF Circular Economy Toolkit for Policymakers 2015

Policy Intervention Assessment Matrix

	Sector	Circular Economy Lever	Intervention Type	Detailed Description of Intervention	Barrier Tackled	IMPACT: Importance of Barrier (100 for critical barrier)	IMPACT: Effectiveness of policy in 5 years (by 2020) (100 for highly effective on barrier)	IMPACT: Effectiveness of policy in 20 years (by 2035) (100 for highly effective on barrier)	IMPACT: Effectiveness of policy	IMPACT: Total Impact (Out of 100) Impact = importance of barrier x average effectiveness	COST: Administrative and transaction costs (100 for low costs)	COST: Wider economic impact (100 for low costs)	COST: Total Cost (out of 100)	TOTAL: Ranking Score (1 for top right, 2 for top or right, 3 for bottom left)
						Weight 50%	Weight 50%			Weight check 100%	Weight 50%	Weight 50%	Weight check 100%	Threshold 50
1	Food and Beverage	Value capture in cascading bio-refineries	Regulatory frameworks	Incorporate bio-refining into the **government's long-term strategic plans** to guide and reassure investors. In the G7, Germany, the US and Japan have national bio-economy strategies with targets.	Capital	100	50	75	63	63	100	100	100	1
2	Food and Beverage	Value capture in cascading bio-refineries	Business support schemes	Provide **low-cost loans or loan guarantees** for the deployment of mature bio-refining technologies for example through existing Danish business support schemes. Alternatively, provide financing at market rates tailored to investors' needs (as provided for example by the UK Green Investment Bank in municipal energy efficiency).	Capital	100	75	100	88	88	50	75	63	1
3	Food and Beverage	Value capture in cascading bio-refineries	Business support schemes	Form public **private partnerships** to finance the deployment of mature bio-refining technologies.	Capital	100	75	100	88	88	50	75	63	1
4	Food and Beverage	Value capture in cascading bio-refineries	Regulatory frameworks	Propose a **minimum proportion of 2nd generation biofuels** in the EU biofuel target to create more demand for 2nd generation biofuels and mitigate revenue risk for such investments.	Externalities	75	50	100	75	56	75	25	50	1
5	Food and Beverage	Value capture in cascading bio-refineries	Collaboration platforms	Stimulate the development of advanced, high-value bio-refining technologies by funding cross-institutional **R&D clusters** to accelerate the move into high-value chemicals, nutraceuticals, pharmaceuticals etc. These could take various forms, like the UK Catapults, a powerful example of public private partnerships in R&D, or the German Fraunhofer Institute.	Technology	100	50	100	75	75	50	75	63	1
6	Food and Beverage	Value capture in cascading bio-refineries	Business support schemes	Provide a **business advice service** that helps bio-refinery entrepreneurs navigate a relatively complex regulatory and policy environment. It may also become a conduit through which the bio-refinery community can shape this environment.	Unintended consequences	75	50	50	50	38	75	75	75	2

Categorisation of policy interventions:

Focus sector, associated circular economy opportunity, detailed policy description, associated barrier addressed

Impact:

Importance of Barrier x Weighted Average of effectiveness by 2020 and effectiveness by 2035

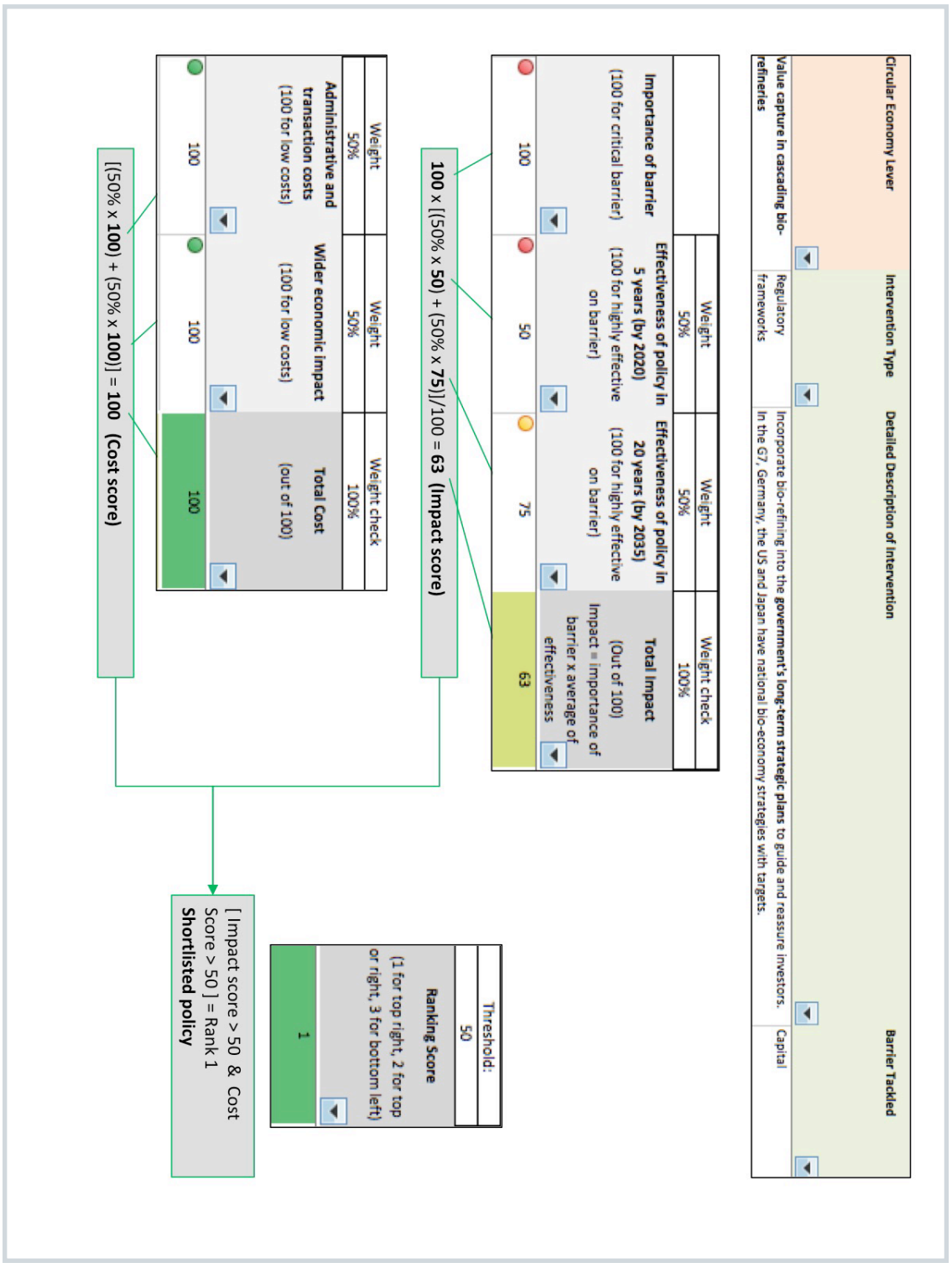
Cost:

Weighted average of administrative & transaction costs and wider economic impact

Ranking:

"1" top half on both dimensions, "2" top half in one, "3" others

Figure D2: Worked example of the implementation of the scoring methodology.



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ABOUT THE ELLEN MACARTHUR FOUNDATION

The Ellen MacArthur Foundation was established in 2010 with the aim of accelerating the transition to the circular economy. Since its creation the Foundation has emerged as a global thought leader, establishing circular economy on the agenda of decision makers across business, government and academia. The Foundation's work focuses on three interlinking areas:

Insight and Analysis - Providing robust evidence about the benefits of the transition

The Foundation works to quantify the economic potential of the circular model and develop approaches for capturing this value. The Foundation has created a series of economic reports highlighting the rationale for an accelerated transition towards the circular economy, and exploring the potential benefits across different stakeholders and sectors. The Foundation believes the circular economy is an evolving framework, and continues to widen its understanding by working with international experts including key thinkers and leading academics. Our insight and analysis feed into a growing body of reports, case studies, publications and multimedia resources presented on our websites, which include Circulatenews.org, our portal for circular economy news and feature articles.

Business and Government - Catalysing circular innovation, creating the conditions for it to flourish

Since its launch the Foundation has emphasised the real-world relevance of its activities, and understands that business innovation sits at the heart of any transition to the circular economy. The Foundation works with its Global Partners (Cisco, Kingfisher, Philips, Renault, and Unilever) to develop circular business initiatives and to address challenges to implementing them. In 2013, with the support of its Global Partners, it created the world's first dedicated circular economy innovation programme, the Circular Economy 100. Programme members comprise industry leading corporations, emerging innovators (SMEs), affiliate networks, government authorities, regions and cities. The CE100 provides a unique forum for building circular capabilities, addressing common barriers to progress, understanding the necessary enabling conditions, and piloting circular practices in a collaborative environment.

Education - Inspiring learners to re-think the future through the circular economy framework

The Foundation is creating a global teaching and learning platform built around the circular economy framework, working in both formal and informal education. With an emphasis on online learning, the Foundation provides cutting edge insights and content to support circular economy education and the systems thinking required to accelerate a transition. Our formal education work includes comprehensive Higher Education programmes with partners in Europe, the US, India, China and South America, international curriculum development with schools and colleges, and corporate capacity building programmes. In the informal education arena the Foundation's work includes Re-thinking Progress, an open house educational event, and the Disruptive Innovation Festival, a global online and face-to-face opportunity to explore the changing economy and how best to respond to it.