FOLLOWING-UP ON OPPORTUNITIES FOR A CIRCULAR ECONOMY

BETTER DATA FOR ROBUST POLICY MAKING

FOLLOWING-UP ON OPPORTUNITIES FOR A CIRCULAR ECONOMY

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8 year old: I've got thirty-six
5- year old: thirthy-six trillion!
8 year old: six times six is thirty-six
5 year old: is that what I'm supposed to pay?
8 year old: you'll get three presents for that
5 year old: I don't want those
8 year old: what?
5 year old: all four of them should be blue
8 year old: you can be so obnoxious
5 year old: what are we having for lunch?

Domestic conversation overheard at some point in 2019

We want to dedicate this book to all who have been dedicating (significant parts of) their professional life to improving the data quality and information that is made available to the general public. This is also true if your work is mostly focused on biological nutrients and you find that many examples in this book are about technical nutrients.

We would like to express our appreciation to those who provided their knowledge preparing this book. They are Ton van Dril, David Peck, Kees Baldé, Rutger Hoekstra, Andre Rodenburg, Serena Oggero and Kathleen Sheridan.

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EXECUTIVE SUMMARY

For 2050, between one and two billion people are expected to rise out of poverty, resulting in a worldwide GDP growth of a factor of four. This is supposed to be done while reducing greenhouse-gas emissions by 80% and facing a global situation of land use where, since 1990, over 60% of potential land (given the current state of technology) has already been transformed from ecosystem to agriculture. To date, there is no conclusive evidence, merely the hope, that on a global scale, it will be possible to decouple raw-material extraction and economic growth in an absolute way. A growing economy currently equals a growing amount of raw-material extraction. If we cannot change current trends, we will need almost three times the amount of primary raw materials in 2050, compared to 2013. This shows the relevance for a transition to a circular economy: the opportunity to grow an economy without growing abiotic raw-material extraction.

We present these abovementioned key figures to ascertain once more that our planet will not treat our children well if we do not enable transitions in our economy: transitions in greenhouse-gas emissions and transitions in raw-material extraction and the use of natural resources.

We do not expect markets to autonomously shape the economic system in order to meet the demand for raw materials in 2050 (or find another planet—or two—by that time). Policymakers are clearly also needed to guide the circular economy transition. These policymakers need to be supported by better public data. They obviously also need new technology, society, politics, eco-systems and legislation on their side to guide markets, but for all these aspects, better data are essential. The main message of this book is therefore:

Public authorities need better data to design robust policies, enabling businesses to follow up on opportunities that shape a transition to a circular economy

There has been progress in recent years. The ambition to shift to a circular economy has resulted in the development of goals and circular strategies (reduce, re-use, recycle) within nations, regions and companies. But barriers to following up that process have also emerged. This book explores how better data can overcome those barriers. It demonstrates that without better data and resulting information, opportunities for a circular economy that require public involvement will probably be futile; market opportunities will, in most cases, simply have no follow-up to speak of.

Business decisions are driven by such things as the positive attitudes of employees and customers, cost savings and competitive product innovation. Businesses encounter barriers related to habitual behaviour, the high costs of research and development and entrenched monetary business models, for instance. Effective circular public policies should enable these drivers and overcome these barriers. Based on the work of the authors, we can see plenty of reasons for entrepreneurs to act upon available circular strategies. But we fear that barriers will prove stronger than drivers if people are kept in the dark about the facts that provide the evidence on a societal scale for economic opportunities and the ability to be truly sustainable.

IMPACTS OF A CIRCULAR ECONOMY BETWEEN 2013 AND 2019

The 2012 report of the Ellen MacArthur Foundation gave the Circular Economy (CE) a prominent place in the European policymaking process, and it has so far endured as a relevant concept. That is why we look at the impacts of a circular economy since that time. The Ellen MacArthur report introduced a broad range of circular strategies, not just improvements in waste management (however incremental). Yet we fear that circular strategies are not equally translated into policy. Strategies based on longer or more intensive use of products are underrepresented. Moreover, we observe that the circular economy has not become part of the main political discourse or main corporate decision making. What we need are data to either confirm or contest this claim.

So, what has happened over the last six years? In short, overall policy goals, some more ambitious than others, have been put in place, and academic research on the circular economy has gained momentum.

There have been some numeric conclusions from CE assessments that have caught mainstream attention. The Ellen MacArthur Foundation report advertised cost savings of $480 to $630 million for the EU economy. In recent years, the relevance of circular strategies for reducing CO_2 emissions has become more important. Studies indicate an additional 15% to 50% contribution to climate goals by attaining circularity policy goals. But these estimations are not convincing enough once real decisions that shape the future of an enterprise, a policy or the circular transition in general must be made. Innovations in life cycle assessment (LCA) can be observed, but mostly only relating to the analytical framework, not in the data that are used (even though these data are updated every two to three years). Perhaps the best illustration of the message of this book is that it makes no sense to redo existing CE assessments in 2019 because there are no new types of data. **A first key conclusion is that the circular economy is probably not meeting expectations, but we do not even have the data to support that ex post assessment.**

STATUS QUO OF CIRCULAR ECONOMY ASSESSMENT

To demonstrate the need for better data, we discuss the status quo of CE assessment. The underlying thought is that decisions made by responsible public authorities are data-driven. Indicators suggested by academia, policy documents and corporate consultants are abundantly available. When we look at these indicators in detail, a lack of reliable data can be seen, preventing the indicator to convincingly support enforceable policy targets.

This leads to the second key conclusion of this book: indicators and their analytical frameworks are much more developed than the available data required for these frameworks. Furthermore, there are still indicators lacking. There is too little focus on information that captures price-per-service, on more detailed statistics on the size and shape of capital assets or on performance data about products during their use phase. These are the kinds of data that enable value-retaining business models.

Several indicators that describe a circular economy are time dependant and therefore, by definition, not circular. Moreover, material science is often not understood properly when material flows and recycling opportunities are discussed. It is not feasible to improve the sustainability of our economic processes by thinking that all waste can be “melted into a virgin state”, if we would just close material loops. **This leads to the third key conclusion of this book: aiming to “close the material loop” can be a misguided and even detrimental concept when decisions that shape a circular transition are made.** For the foreseeable future, it will, in many cases, be better to aim at retaining value and maximizing product utility.

PUTTING THE ECONOMY INTO CIRCULAR ECONOMY

For assessing value and utility, we need insights from economics. CE research has far too seldom asked the question: “Why is the use of raw materials and products organized as it is, and how can we obtain the highest value for society?” At the other end, economists seem underrepresented in the circular economy discourse. We state that it is futile to talk about specific CE policies on a national scale without introducing a general understanding of economic concepts like market failures, utility, behavioural economics, disruptive innovation, elasticity of production factors, incidence, labour productivity, raw-material productivity, rebound effects, transaction costs, etc.

Using these concepts, one can quickly observe that most circular business models suffer from the inability to increase their market size. **But much more problematic are the many instances where markets for circular goods and services are completely absent: a fourth key conclusion of this book.**

MAKING CIRCULAR ECONOMY ASSESSMENTS FIT FOR FOLLOW-UP

Considering the impact of the circular economy since 2012, the status quo of CE assessments and the need to include more economic concepts in circular assessments, what are our recommendations to get new and better data in the coming years? **We recommend** organizing data so that they clearly relate to a product or a product group as described by official statistics, collecting data that clearly relate to economic sectors of activity, creating a more detailed system of national accounts, making use of data from product lots in the European Union’s Ecodesign Directive, centralizing and formalizing data on general waste flows, starting to collect data on repair and refurbishment, combining public life-cycle inventories, mapping the relevance of critical raw materials and hazardous substances in products, documenting product lifetimes better, collecting better data on the market for secondary materials and starting to collect data to monitor the operational performance of capital stock. In total, we offer twenty specific data recommendations.

The funds to manage and publish these data will, in a majority of the cases, come from national statistical offices or governmental agencies like the Joint Research Centre of the European Commission. It seems a trivial conclusion that funding for policy-supporting research should be balanced against funding for data collection. It is unfortunately no trivial conclusion.

Again, we cannot claim to be certain that better data will guarantee that businesses follow up on opportunities for a circular economy. But we can be quite certain that without proper data, new markets for a CE transition will be nonexistent. We can be certain that reduced negative environmental impacts related to circular strategies cannot be quantified properly without better data. And we can be certain that markets have not organized themselves into systems that respect the boundaries of our planet. If the circular economy, or climate policy for that matter, remains associated with “pain, but no gain”, it is likely to be inconsequential.

We live in a 21st century world, where uncertainties around the introduction of new technologies are tolerated less than before. Where markets for investigatory journalism are in decline. Where the legitimacy of democratic institutions is questioned. Where our fondness of the quality of life seems to enforce the confirmation bias that already comes naturally to human beings. Where arguments seem increasingly aimed at discrediting the opponent rather than offering facts. In this 21st century, reliable public data are more important than ever.

OLD BUT TRUE. A TRANSITION TOWARDS A CIRCULAR ECONOMY IS NECESSARY

This chapter acts as a prologue. The messages in this chapter should be superfluous by now, and yet we feel that it is extremely necessary to highlight certain facts and fact-based predictions in any discussion about the necessity of a circular economy. It contains reasoning and key figures that support the need for a more circular economy (or to fight climate change, for that matter).

HOW DO ARGUMENTS IN 2019 COMPARE TO THOSE FROM 1987?

Although 1972 (Club of Rome) or 2015 (Paris Agreement) deserve their place in raising awareness about the environment, 1987 was the iconic year for sustainability. The Brundtland report was instrumental to this, and its first line read “We all depend on one biosphere for sustaining our lives. Yet each community, each country, strives for survival and prosperity with little regard for its impact on others” (World Commission on Environment and Development 1987). We want to enable humankind to continue to strive for survival and prosperity, within the realms of the declaration of Human Rights. Progress will be the result of enabling human inventiveness, but the result of a failure to disable human flaws will be catastrophic.

In 1987 a UN commission chaired by Gro Harlem Brundtland, then Norwegian Prime Minister, defined sustainability as a “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development 1987: Chapter 2, Conclusion).

The 1987 study sketched a timeline. At the beginning of the 20th century there were around **1.6 billion** people and we had a perceived abundance of raw materials and land. Technological progress increasingly enabled the improvement of living conditions and human health. The use of fossil fuels enabled the use of raw materials at an unprecedented increasing pace. After 1945, this resulted in an exponential growth in the population, and in greenhouse gas emissions. The standard of living for a majority of the current world population is much better today than it was a hundred years ago, and that is a major gain. However, for the first time in centuries, the question arises whether future generations will be better off than the present one.

most recent framework to anticipate the needs of future generations. At Rio+20 in 2002 and with the SDG agenda in 2012, the United Nations set two main goals: eradicating poverty and achieving a green economy. This aim was underpinned by using the concept of the well-known IPAT equation (Impact = Population level * Affluence per capita * Technical efficiency), which shows that such goals can have trade-offs.

The member countries of the Organisation for Economic Co-operation and Development (OECD) of the "old" affluent West have a combined population of around one billion and a GDP that comes to around **USD50,000** per person per year. In China, India, Russia and Brazil, we are currently seeing the extraordinarily rapid development of a new middle class of between **one and two billion** people, who also expect to have a similar income by 2050. No politician from such countries is in the position to suggest that people in those OECD countries and fast-developing economies should be satisfied with less than those **USD50,000** per person. With a world population of at least nine billion in 2050, this still leaves around six to seven billion people who live in the poorer countries and regions. Fischer-Kowalski (2009) have shown that an average GDP of **USD10,000** per person per year is needed for a reasonable life expectancy and access to basic facilities such as education and clean drinking water. If the GDP falls below this level, people's lives very soon become worse: shorter life expectancy, higher child mortality and so on. Leaders of those countries will therefore want to aim for a minimum GDP level of around **USD10,000** per person per year, and will not want to see this thwarted by, for instance, the environmental goals of Rio+20 or the recent COP21 in Paris in 2015. This wish list—which the world leaders have in the back of their mind at international sustainability conferences—means that in 2050 the size of the global economy would need to be USD200 trillion. This is **four** times as much as in 2005, and coincides with an observed rise in long-term inflation-adjusted commodity prices compared to the period of1900–2011, as shown in Figure 1 (Dobbs et al. 2011). Commodity prices plunged in early 2014 but started to rise again after 2017.

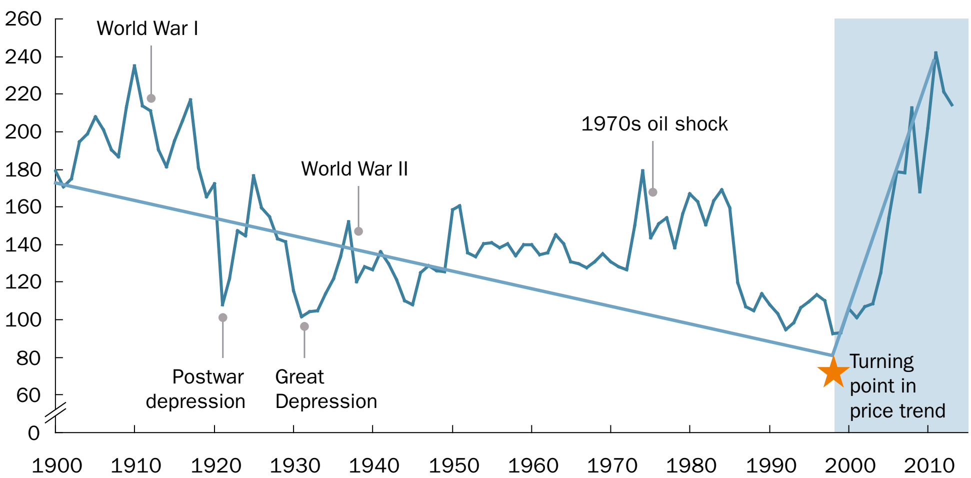


Figure 1 *Inflation-adjusted global commodity prices, 1900–2011 (Dobbs et al. 2011)*

The tremendous economic growth that we want to achieve by 2050 will represent challenges for our social and environmental system. The UN International Resources Panel showed the huge growth in material and energy extraction since 1900 (IRP 2019). We can already see that the effort required to tap new fossil energy sources has increased **300%**, increasing production by only **14%** in 2012 compared to the year 2000 (Lewis 2014). In 2030 the world will need 40% more fresh water than can be sustainably extracted at current levels. Global fishing fleets can, in spite of more advanced techniques, catch fewer fish than in the 1970s. A stable atmosphere requires an **80%** reduction in CO_2 emissions by 2050. Using yet more land for agriculture or bioenergy has major implications for ecosystems and therefore biodiversity (van Vuuren & Faber 2009). Compared to 1900, over **60%** of fertile land areas have been cultivated at the expense of natural eco-systems (MES 2005; Alexandros & Bruinsma 2012). The quality of ore is declining because we have already exhausted the best sources. This does not mean that depletion is imminent before 2050, but it does mean that the energy requirements for extracting metals will increase. We are starting to see instances of the politicization of access to raw materials. For instance, the "rare earths" crisis in 2010 and 2011 had a serious impact on the high-tech industry, mainly in Japan but also in the US and Europe.

HOW REALISTIC ARE THE SUSTAINABLE DEVELOPMENT GOALS RELATED TO NATURAL RESOURCES?

Ever since the Report for the Club of Rome in 1972 (Meadows et al. 1972), there have been warnings that it is impossible to grow the economy forever on a finite planet. This in turn (see the recent falling prices of oil and other raw materials) has led to the assertion that this same Club of Rome turned out to be a group of misinformed pessimists. From that perspective, problems that the extraction of raw materials can cause are not insurmountable by human inventiveness. Optimists point to the fact that, so far at least, there has not been a fundamental crisis in terms of natural resources. But what would it have meant for Electronic Vehicle market uptake if all battery materials had all been as abundant as, say, iron ore?

Apart from technical innovations, other growth engines that have resulted from freed production factors can be identified. The addition of the American continent to the world economy, the harnessing of fossil fuels and electricity as sources of energy, the introduction of the welfare state, the end of the cold war and the inclusion of females into the work force are clear examples of major and enduring absolute growth of production factors. For the SDGs to be realized, we need a similar stimulus in the first half of the 21st century. At the same time, there seem to be two inconvenient truths about the realism of SDGs related to natural resources.

The first inconvenient truth is that at present, even if one could recycle all the materials released as waste, a vast amount of primary raw materials would still be required. Countries in the non-Western world are still building their infrastructure at a rate equal to their economic growth. They are intensively engaged in building the houses, factories, offices, railways, electrical networks, motorways and bridges that we have had for a long time in Europe and the US. The only way to do this is to move materials from the natural system into the economic system. Once the ideal circular economy has been achieved, one can perhaps use old, existing buildings to make the same number of new ones. But if one wants any extra buildings, one quite simply needs extra steel and cement.

The second inconvenient truth is that decoupling (reducing resource use while increasing economic output) can not only be an absolute metric, but a relative one as well. Economic growth of 3% per year will result after 23 years in an economy that is twice as large as today. As shown in Figure 2, there is no evidence for decoupling, so we have to assume that the use of raw materials will grow in the same order of magnitude. In fact, the graph shows a recoupling of economic growth and resource use since 2000. We should be very careful in saying that decoupling will be a guaranteed result of market incentives to reduce the use of raw materials. We should also be cognizant of the allure of a disruptively large energy source, like nuclear fusion. We can stake all our hope on future technologies. However, if we want to make SDGs a reality, we cannot afford to simply wait for the miracles. We have to take stock of the existing economic, social and natural capital and carefully monitor global developments and requirements for development.

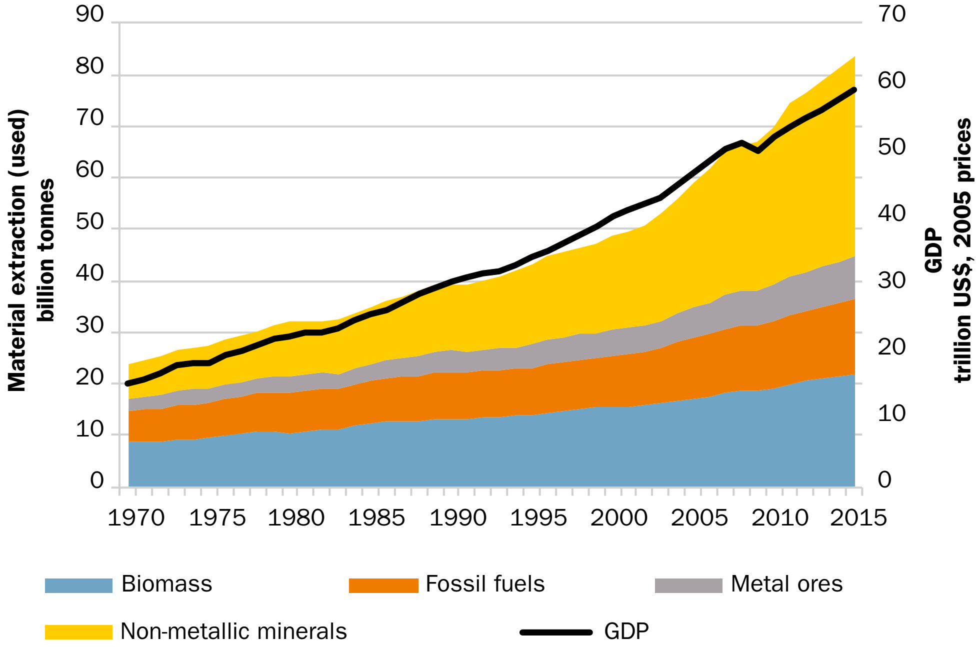


Figure 2 *Global primary raw material extraction and GDP growth (UNEP 2016)*

For the **four-fold** economic growth required up to 2050, the question is whether we can decouple economic growth, but there is no evidence than we can decouple economic growth from the extraction of primary minerals and metals. With that in mind, we would, in 2050, need almost three times the amount of raw materials compared to 2014. Combined with the pledges of the climate agreement, this decoupling must be achieved in an economy that must be about five times less emission-intensive compared to 2014.

When should a circular transition start to contribute to the Sustainable Development Goals and what impacts can be expected from that transition?

A circular economy is not something that can be constructed overnight. A great deal of infrastructure and many durable consumer goods will last for years. Business models, legal frameworks and cultural patterns will probably last even longer if they remain unchallenged. Unless one starts to think now about how to make economic systems and infrastructures circular, and how to minimize energy and material use over their lifetime, it will be too late. And it can then—just as with the fossil energy system—cost a lot of money to make them circular later.

CE strategies can contribute to meeting the challenge of decoupling economic growth from the primary extraction of metals and minerals. The other two contributions to decoupling can come from autonomous technological innovation or reduced consumption through price signals. An observation from the International Resource Panel (IRP 2018) identifies impacts from a circular economy on the SDGs to be mainly represented by SDG 8 and SDG 12: Decent Work and Economic Growth and Responsible Production and Consumption. Also, SDG 9 and SDG 13, about Industrial and Agricultural Innovation and Climate Action, respectively, are among the SDGs to benefit from circular strategies.

1. SDG 9: Corporate monetary gains, Corporate competitiveness, WTO disputes, Security of supply
2. SDG 12: Household monetary gains, Price level of household expenditures, Improving or at least maintaining purchasing power of citizens, Fighting inflation by managing lasting products in your life better and consuming less inflation-prone production factors (Obviously, we do not mean here the price effect of “Warm Glow”: paying more for a product based on the real or imaginary notion that a product is more sustainable.)
3. SDG 13: Reduced negative environmental externalities, like GHG reduction
4. SDG 8: Seizing positive societal externalities, Opportunities for growth in jobs and skills as a result of local and accessible employment, Creating economic activities for lasting communities

In (Mancini et al. 2018), **several other direct links between the circular economy and the SDGs are identified**. This study sees a real contribution from the circular economy also being applied to SDG 3 (Good Health and Wellbeing), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 14 (Life below Water) and SDG 15 (Life on Land).

Like a circular economy, progress towards the SDGs is monitored by several indicators (SDG Resources 2017). If the global community has better data* and better information resulting from those data, it will not only aid and improve government and corporate decisions, it will also enable us to follow up on opportunities to achieve the SDGs. **This could generate attention and investment for circular strategies** around the world. But given the primary use of SDGs as a strong communication tool (rather than an analytical tool), **one should be careful to express the progress of a circular economy in terms of the SDGs. We should follow up on more humble ambitions first: to get the information we need.**

* **suggestions for better data? See 3, 5, 8, 14 and 18 in section 5.2**

It is unfortunate if we do not care about SDSs because of things we don't know. Understanding the implications of this chapter, it is completely unacceptable that we don't know what we need because we do not care. Or even worse, don't want to care to retain a state of blessed ignorance. The ambition to hand over our planet to future generations responsibly starts with meeting the need for proper data.

1 ARE PEOPLE FOLLOWING UP ON OPPORTUNITIES FOR A CIRCULAR ECONOMY?

Millions of people around the world have worked hard in recent years to shape a global transition towards a circular economy. To move this transition along, business needs to follow up on real opportunities that require an informed da decision-making process that, in too many cases, is waiting on robust public policies that create markets for circular goods and services. Robust policies need to be facilitated by better public data. The main message of this book is therefore:

Public authorities need better data to design robust policies, enabling businesses to follow up on opportunities that shape a transition to a circular economy

This book is born out of both anticipation and fear. First, let's consider the anticipation. In our work on the CE transition, we have observed that several opportunities have been seized by frontrunners that can recognize changes in technology, business, legislation and/or society. And we have observed that opportunities of scale require the involvement of public authorities. We thus need data to be able to support policymaking. Without these data, the analytical frameworks aimed at maximizing benefits for all members of society will remain theoretical. Challenging, let alone changing, the status quo of technology, business, law and society is an ever-increasingly more difficult thing to do, given our current state of development. Our fear originates from the underestimation of this complexity. As a result, certain parts of public policymaking have lacked the progress that comes from underpinning policy decisions with accurate data, information and knowledge.

Several studies implicitly or explicitly highlight the need for better data

- However, some caution is needed in interpreting this data, as many Member States have different definitions for, and ways of measuring, waste recycling (Ellen MacArthur Foundation 2015a)
- The European Commission acknowledges the existence of data gaps and inconsistencies and has initiated a number of steps in view of future data improvement (EC 2018b).
- Existing sources can be further integrated, better exploited and enhanced/complemented them with ad-hoc studies and other information (EC (2019c).
- Because good decision-making requires good and sufficient data, the effort of gathering and analysing data and knowledge on (critical) raw materials in a context of circular economy needs to be continued and even intensified (Mathieux et al. 2017)
- Frequent resales of light commercial vehicles during intra-EU lifespan are not considered due to lack of data (Ellen MacArthur Foundation 2013).
- The key barriers between indicators on a macro/meso level on the one hand and on a micro level on the other hand are lack of data (from macro to micro) and time and effort constraints (from micro to macro) (Vercalsteren et al. 2017)
- A major obstacle to broad uptake of the Material Footprint indicator by the policy community is remaining uncertainties about methodological maturity and data reliability (Giljum et al. 2019)

Table 1 maps out relevant phases for decision making around CE policy[1]. Between 2013 and 2019, one could see many examples of generic goal setting and formulation of strategies by nation states and regional authorities. These phases are highlighted in green. This book will try to demonstrate that subsequent phases were entered less often than should have been possible. Without better data, no informed decision can be made about specific targets and investments to reach those targets, especially when partnerships around public-private decisions are made. We can never tap into the full potential of the innovation of entrepreneurship and technical knowledge without authoritative facts and established ways to interpret them.

	Phases relevant for decisions that shape a Circular Economy transition						
	Formulating generic goals	Formulating strategies	Estimating potentials	Setting quantified targets	Choosing and tuning instru-ments	Policy implemen-tation	Result monitoring and evaluation
Data, information and knowledge							

"Plan-Do-Check-Act"

Table 1 *Relevant phases in a decision-making process.*

1 A more elaborate description of this table can be found in chapter 5, where Table 13 is a developed version of Table 1 based on the contents of this book.

There is ample evidence that nation states struggle to specify and operationalize their generic goals for a circular economy (Pauliuk 2018). From the point of view of corporate decision makers, a sense of reluctance or disinterest can be observed if markets are not adequately created by robust policies. An insightful overview of drivers and barriers that can highlight causes for reluctance or disinterest in implementing circular strategies is represented by Figure 3. Overcoming barriers requires reliable information, as does initiating drivers that signify an opportunity worth following up.

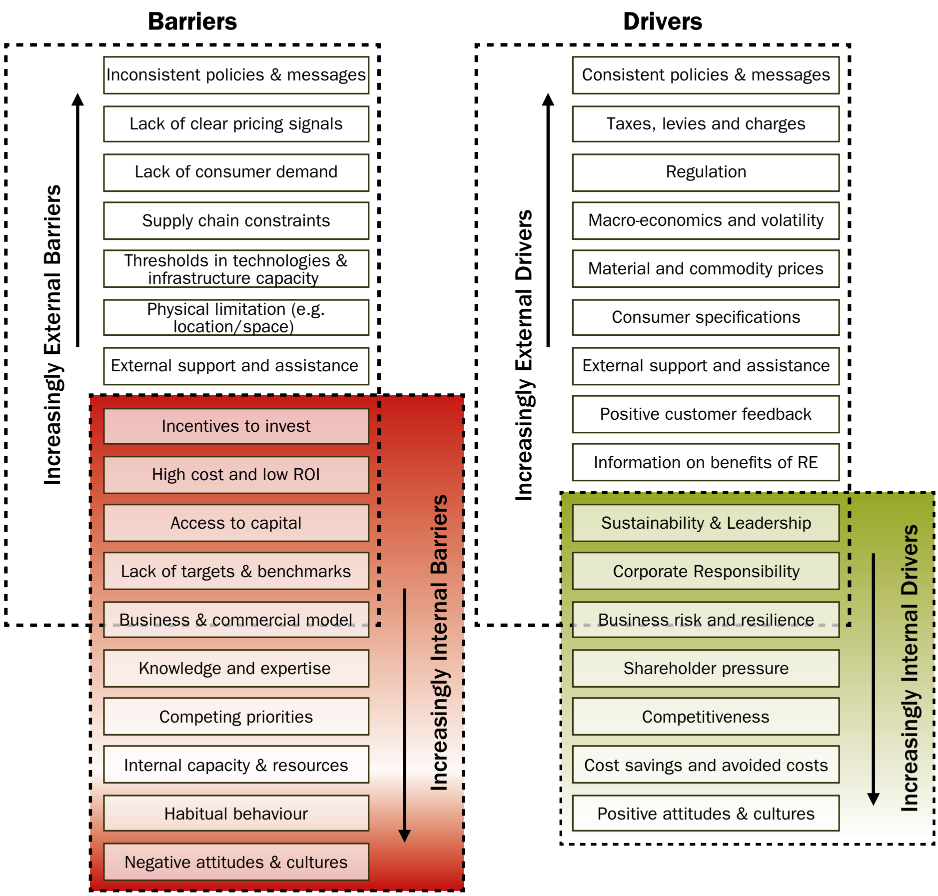


Figure 3 *Drivers and barriers to business becoming more resource efficient (source: EC 2013)*

An interesting finding related to Figure 3 is that even a positive potential business case, leading to lower environmental footprints, has to compete in internal decision-making processes with other positive business cases that might not lead to lower footprints yet yield a higher return on investment (Weizsäcker 2009). Some of the most pressing barriers identified are cultural, namely “Lacking consumer interest and awareness” and “Hesitant company culture” (Kirchherr 2017). Such arguments, retrieved from interviews with frontrunners, go against arguments put forward by activists in the sustainability arena, claiming that “we should stop talking and just do it.” The complexity of day-to-day policymaking and day-to-day entrepreneurship requires a more in-depth understanding and recognition of these barriers.

Without a common understanding of the problems and possible solutions discussed in this book, the circular economy runs the risk of not making it past the policy stages of the generic goals and formulation of strategies shown in Table 1. If that is the case, the economy will never return to using natural resources within a safe space, continuing as it has for the greater part of human history. The growth of global prosperity, shaped in 17 Sustainable Development Goals, may be frustrated if the supply of natural resources is taken for granted by political and business leaders. This book aims to represent all persons active in policy or business, who are looking to equip their daily work with as much fact-based reasoning as possible.

Better (i.e., well-documented, periodically updated, standardized) data are the essential fuel for informed decision making by public and private actors. Proper data are indispensable to creating a causal link between policies that create a clear and level playing field for circular goods and services, investments in circular strategies by businesses, and the benefits enjoyed by society. This will prevent a CE transition from being regarded as elitist, which would offer the same or worse utility in return for external benefits that remain mostly outside the scope of the average citizen. Better data* to underpin decisions about a circular economy can justify fundamental multi-disciplinary research. Moving a transition forward requires opportunities to harness major technological innovations (data science, material science, life sciences, human-machine operations), opportunities that will remain underused given current business-case propositions (Lewandowski 2016).

Figure 4 demonstrates how these observations shape the scope of this book.

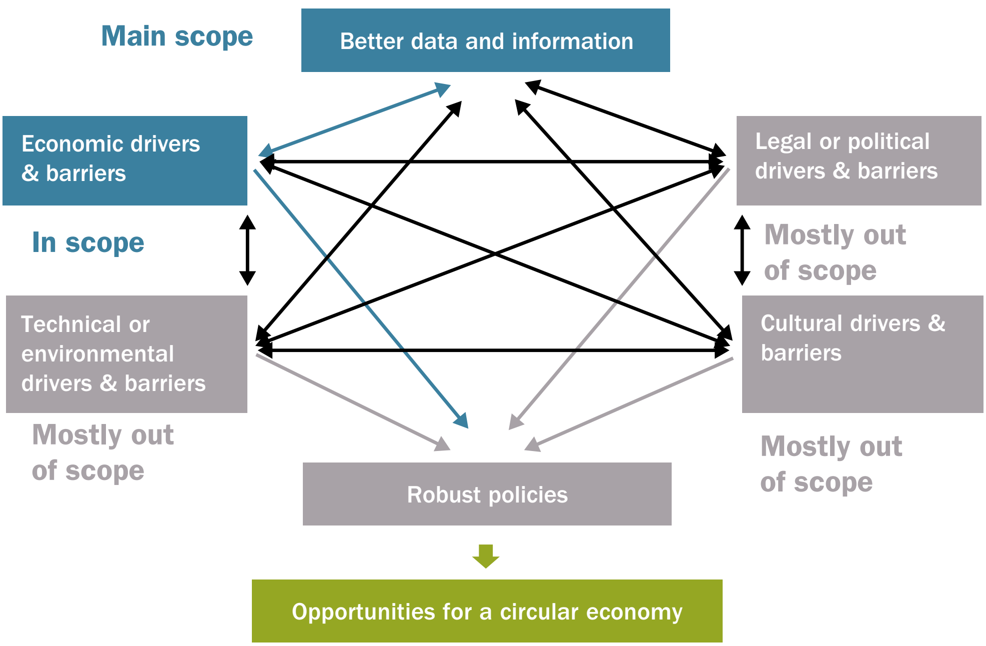


Figure 4 *The scope of this book: highlighting the need for better data and information, to harness drivers and barriers to create robust policies that enable business to follow up on opportunities for a circular economy*

*** suggestions for better data? See 8, 17, 19 and 20 in section 5.2**

We would love to include technical opportunities for a circular economy in this book as well: for example, extracting styrene from biowaste, recycling used rubber tyres that match the technical properties of new ones, block-chain options to track metal components over the supply chain, intelligent performance monitoring of devices that epitomize the next industrial revolution, online self-assessment tools that enable businesses to seek rent in optimizing their capital assets, etc. But those will not be in this book. Here, we argue that for robust policy making there is still an essential need to improve the data and information that can shape a circular economy. That need should be met first.

To this end, this book looks at the impacts of a circular economy in recent years, discusses the status quo of assessing the circular economy, explores the benefit of giving economic theory a more prominent place in CE thinking and makes recommendations in chapter 5.

2 IMPACTS OF A CIRCULAR ECONOMY BETWEEN 2013 AND 2019

To claim that decisions shaping the transition to a circular economy need better data, we start by observing the CE decisions that have been made over the last six years. This chapter looks at organizational responses, policies, developments in life-cycle assessments and the role of study results.

2.1 WHAT HAPPENED IN EUROPE AFTER THE ELLEN MACARTHUR FOUNDATION LAUNCHED ITS FIRST CIRCULAR ECONOMY REPORT JANUARY 2012?

Many ground-breaking papers had been published well before 2012, introducing concepts like a performance economy, biomimicry, cradle-to-cradle, industrial symbiosis, urban metabolism and explicitly the general circular economy. In 2008, Geng and Doberstein (2008) observed that “the terminology [circular economy] may not be very familiar to Western readers, but in China it is understood to mean the realisation of a closed loop of materials flow in the whole economic system.” By 2013, that situation had changed. The publication by the Ellen MacArthur Foundation (2012) at the World Economic Forum in Davos confirmed the position of a circular economy as the concept that combined many related concepts describing the sustainable use of natural resources. **It gave sustainability goals a firm position in European policy, on many levels.**

In 2012 and 2013 the “economy” in circular economy was the element that captured the imagination of those policymakers, rather than the element of material flows. A convincing cost-reduction exercise for expenditures on raw materials was done in the EllenMacArthur Foundation report, resulting in an estimation of between USD 380 and 630 billion in annual material cost savings for the EU economy. This cost-reduction was expected to coincide with new employment, although that statement was made without quantified underpinning. The perspective of new employment mattered to policymakers. Labour markets throughout Europe had suffered from oversupply ever since the economic crisis that started in 2008. A concept that promised to create jobs in many sectors and locations was a wonderful proposition. Environmental research, some of it half a century old, had never before been presented in such a compelling way. So, from 2012 on, people started using the CE framework to explain portfolios that dated from years or decades before. It comprehensively and convincingly put these portfolios into context.

After 2014, the labour market tightened and the raw material markets mostly slackened. This meant that labour got more expansive and job creation was less of an urgent political topic. It also meant that many metal/mineral commodities—from steel to fertilizer to precious metals—were facing oversupply, for several reasons. The Paris agreement of 2015 marked a definitive shift in the focus of the circular economy: from labour markets to the reduction of environmental pressures, notably greenhouse gas emission. **This also might have given the circular economy a front seat in terms of political priorities, but the urgency of a more circular economy and its relation to greenhouse gas emissions could not be expressed through generally accepted and quantifiable indicators.** Another shift could be observed as well. The demand for concepts and general analysis seemed to be satisfied by reports like that of the Ellen MacArthur Foundation (2015a); whereas, the demand for analytical frameworks, quantitative indicators and technologically underpinned policy guidelines became more pronounced (Ellen MacArthur Foundation 2015b).

2.2 WHY HAS THE CIRCULAR ECONOMY ENDURED AS A CONCEPT?

The impact of the 2012 report from the Ellen MacArthur Foundation was considerable. At the same time, even some authors of this book expected the CE concept to take its humble place in the sustainability spectrum within a year. This was, after all, the fate of other concepts that aimed to rethink how the global economy uses natural resources. Examples of these concepts are Industrial symbiosis, biomimicry, cradle-to-cradle, ecosystem services, resilience, beyond GDP, performance economy, regenerative economy, etc. Industrial ecology is the scientific field that arguably covers most of the CE concepts, but it is scarcely known by the general public.

To repeat the opening line of this book: “Millions of people around the world have worked hard in recent years to make a global transition towards a circular economy.”[2] This is an astonishing number when you think of it, even prompting some people to say that “circular is the new sustainability”. Yet it was and it is by no means self-evident that circularity will remain a leading concept that aims to have the economy operate within the boundaries of our planet. Attention to circularity in the main societal debate seems to have subsided between 2016 and 2019. **It is not part of the main political discourse[3], at least not in the Netherlands.** Yet circular economy as a theoretical concept and a set of strategies has hardly moved to the background at the time of this writing. It is still an active part of policy on urban and regional levels. This can be observed by the share of research programs labelled “circular”, innumerable conferences, curricula offered in higher education, and the number of policy documents on the regional, national and European level[4]. Reviews of academic publications are given by Lieder and Rashid (2016) and Kirchherr et al. (2017).

The only analytical framework that seems as sturdy as that of the circular economy is the triple P set of the Brundtland Report (World Commission on Environment and Development 1987). And although the sustainability concept has supported the natural resource dialogue for decades, even that does not seem to be as motivating as the prospect of a circular transition.

2 Counting all people around the world involved in green agriculture, lease and rental agencies, repair shops, waste and water treatment operations, circular designers, online platforms offering circular solutions, researchers etc.
3 as witnessed by only a single reference to circularity in the Dutch Government Agreement (‘Regeerakkoord) of the Rutte III administration in 2017
4 https://publications.europa.eu/en/linked-data

It appears that the CE concept has endured because it was defined as a delicate combination of a broad scope and a galvanizing set of strategies. The concept of the circular economy seemed to act as Harry Potter's Mirror of Erised[5] as many people could identify their existing agendas. Many people could identify their existing work as circular, which resulted in the remarkable situation the circular transition was propelled by many initiatives from existing policy packages.

2.3 WHAT CIRCULAR ECONOMY POLICIES HAVE BEEN ADOPTED?

In chapter 1, we claimed that CE policy initiatives were in risk of stagnation, in both public and private organizations. This implies that there were many policy initiatives to begin with—and there were.

A nice overview of global policy progress before 2013 is given by Ghisellini et al. (2016). Japan implemented the circular economy in 1991 with the Law for Effective Utilization of Recyclables. The United States passed the Resource Conservation and Recovery Act of 1976, and since the 1980s, most US States have also adopted a solid-waste management hierarchy, placing reduction and reuse at the top of the hierarchy. China's main national-level framework for pursuing the CE is the Circular Economy Promotion Law, which came into effect in 2009 (National People's Congress 2008). Before 2012, China had already developed a large network of industrial sites, consisting of around sixty parks that were part of the Circular Transformation of Industrial Park program. Although China has over 2500 national or provincial-level industrial parks, they expect the transformation to expand rapidly. By 2020, China aims to have transformed fifty to seventy-five percent of their industrial parks. Asian countries such as Korea and Vietnam have promoted 3R policies. Korea issued the Waste Management Act in 2007 and the Act on Promotion of Resources Saving and Recycling in 2008 as the basis for material reuse, for a fee system for waste treatment and the extended producers' responsibility (EPR). In 2005, Vietnam amended the Environmental Protection Law and the National Strategy on Integrated Solid Waste Management with targets in 2025 and 2050.

In Europe, circular policies were adopted swiftly between 2013 and 2019. The CE package of the European Commission (EC 2015) is the policy document at the highest geographical level. It contained quantified targets per EU Member State on waste treatment. The scoping study of the Commission (EC 2014a; EC 2014b) offered part of the underpinning for the package. There was a strong plea for a European Industrial Policy, that resulted in several links being made between this Industrial Policy and circular strategies (EC 2017). In the EC report on implementation of the CE action plan (EC 2019a), progress on the action package was reported, concluding that within three years, over fifty percent of the initiatives had been delivered. Common EU targets are now set for recycling of solid municipal waste (SMW) at sixty-five percent by 2030 and of packaging at seventy-five percent by the same date. As the targets demonstrate, the focus of the EU's CE package is centred around progressively stringent targets with respect to waste management. The other value-capturing aspects of the circular concept are, understandably, less visible but also not as easy for policymakers to set targets on.

5 The Mirror of Erised is a magical mirror, which, according to Albus Dumbledore, shows the "deepest, most desperate desire of our hearts"

The five directives of the European Union that are most relevant for the circular economy are Directive 2000/53 on end-of-life vehicles, Directive 2004/12 on packaging and packaging waste, Directive 2006/66 on batteries and accumulators and waste batteries and accumulators, Directive 2008/98 on waste, Directive 2012/19 on waste electric and electronic equipment (WEEE) (EASAC 2016).

Other examples of policy initiatives can obviously be found throughout Europe and, indeed, all over the world. A non-exhaustive sample (based on EEA 2016 and RLI 2017) of initiatives within Europe is given in Table 2, underpinning the fact that nation states are keen to formulate visions and generic goals to seize the benefits that can result from a more circular economy. It also demonstrates the need to inform the decision-making processes on a national level by harmonizing and improving data (Potting et al. 2017).

Table 2 *Illustration of policy initiatives in the EU28 (non-exhaustive)*

Member State	What	When
Netherlands	See Table 3	
Portugal	Resource productivity target, Extended producer responsibility	2014 and 2017
Denmark	Strategies for prevention of waste, collection of WEEE	2014
Finland	Resource productivity target	2014
Ireland	Extend the lifespan of products	2014
Austria	REPANET and REVITAL initiatives	2014
France	Has adopted a national strategy on the circular economy as part of its Law on energy transition and green growth (in French). There is a resource productivity target as well: 30% between 2010 and 2030. A fifty-point roadmap	August 2015 and April 2018
Hungary	Resource productivity target, Reduce municipal solid waste	2015
Poland	Transform waste into resources	2015
Estonia	Resource productivity target	2015
Germany	Double resource productivity compared to 1994 (bear in mind that the circular economy legislation has been in place since at least 1994. (“Kreislaufwirtschaftsgesetz”)	2016
Belgium	The federal government published a communication (in Dutch) outlining a set of 21 measures it wants to implement before the end of 2019. The Flemish long-term circular economy strategy is part of a broader vision on a sustainable future for Flanders (2050). Pay-as-you-throw schemes.	October 2016
Sweden	Recycling rates	2016

Switzerland	Expansion of MONET indicators to SDGs	2018
Luxembourg	Resource productivity target	2018
Slovenia	Resource productivity target	2018
Bulgaria	Eco-innovation action plan	2018

The resource productivity policies appear to have had a positive impact. Resource productivity in the EU-28 has improved by 3.3% between 2013 and 2018.[6] In nine member states, among which Denmark, Spain and Austria, resource productivity decreased. Resource productivity on a global level has improved by 4.3% in the 2013-2017 period. However, looking at the material management parts of global economy (agriculture, mining, manufacturing, utilities), resource productivity decreased by around 6% between 2000 and 2017. These number show a continuation of the trend shown in Figure 2.

The following policy initiatives in the Netherlands have been in place since 2013 (see Table 3). **At first glance, the policies do not seem to justify the claim of this book that the circular transition is underperforming. However, the challenge that this book addresses is how to achieve a visible impact by enabling the loops in the policy cycle as shown in Table 1.** We fear that the current policies are not robust enough to have that impact. The projects in the “uitvoeringsprogramma” by themselves will probably have little impact on the circular economy in the Netherlands. This policy program will only have an impact if enough enterprises adopt the strategies that are supported by the program. Moreover, after a closer look, the table shows that policy documents related to fiscal-economic and social aspects of a transition towards a circular economy are all but absent. Involvement of policy makers in Ministries of Social Affairs and Finance has indeed been weak in circular policy making in the Netherlands.

Table 3 *Examples of policy initiatives in The Netherlands*

	Developed policy, per decision-making phase, for a circular economy in the Netherlands						
	Formulating generic goals	Formulating strategies	Estimating potentials	Setting quantified targets	Choosing and tuning instru-ments	Imple-menting policy	Monitoring and evaluating results
Published policy documents and actions	Three main goals of circular economy in the Nether-lands[7]	Five national transition agendas[8]	Ex ante assess-ment[9]	From Waste To Resource (VANG)[10]	Uitvoerings-Programma 2019-2023[11]	Raw material scanner	

6 Expressed as change between 2013 and 2018, NOT as annual incremental improvement. Expressed in so called “chain-linked volumes”, normalized to constant 2010 prices. https://ec.europa.eu/eurostat/data/database
7 Government of the Netherlands (2016): https://www.government.nl/binaries/government/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050/17037+Circulaire+Economie_EN.PDF
8 Government of the Netherlands (2018a,b): https://hollandcircularhotspot.nl/wp-content/uploads/2018/06/TRANSITION-AGENDA-PLASTICS_EN.pdf and https://hollandcircularhotspot.nl/wp-content/uploads/2018/06/TRANSITION-AGENDA-CONSUMER-GOODS_EN.pdf
9 TNO (2017): https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2017/07/06/tno-rapport-ex-ante-evaluatie-van-het-rijksbrede-programma-circulaire-economie/tno-rapport-ex-ante-evaluatie-van-het-rijksbrede-programma-circulaire-economie.pdf
10 Government of the Netherlands (undated): https://rwsenvironment.eu/subjects/from-waste-resources/
11 Government of the Netherlands (2019): https://www.rijksoverheid.nl/documenten/rapporten/2019/02/08/uitvoeringsprogramma-2019-2023

The adoption of circular activities by corporates is initiated by these corporates themselves based on business considerations. If we want to get beyond Corporate Social Responsibility reports, the impact of companies in a circular economy is measured in economic activity. The nature of business is business, after all, signified on a macroeconomic level by for instance Value Added. We will explore measuring business progress in the Netherland in section 2.5.

Actual legislation in the Netherlands has not been adopted on a wide scale.[12] The fact that it was made illegal to hand out free plastic bags in shops, was heralded as one of the greatest achievements of CE policy by Dutch policy directors early 2017. The ISO TC/323 standards have been adopted in 2019, but they provide a base for legislation rather than a legal tool. The French government has put some clear ambitions about regulation in their fifty-point roadmap, notably a ban on destruction of unsold clothing and extending the guarantee period of household equipment (and scaling that ambition up to the EU level). But these ambitions have not yet resulted in regulation. And without legislation an obvious driver for companies to innovated and to invest is absent, illustrating the point made previously (see chapter 1) about the circular transition facing barriers that are difficult to overcome.

A more enabling result of policy measures was a public investment in relevant on-line and publicly available web-based tools that provide intelligence about raw material consumption and production. Without the proper policy attention these tools would not have seen the light. Among these instruments are the IRP database,[13] the ROSYS tool from the German Raw Material Agency,[14] the RMIS 2.0[15] from the JRC, the Circular Toolkit[16] and the Raw Material Scanner[17] of the Netherlands Enterprise Agency.

2.4 WHAT ARE THE MOST WELL-KNOWN CONCLUSIONS OF PUBLICIZED CE ASSESSMENTS?

The Ellen MacArthur Foundation (2012) study was the first to monetize the benefits of a more circular economy on a continental (EU-28) scale. After that, there were some studies that had quantified conclusions that were advertised in boardrooms and conferences. See Table 4 for a selection.

12 wetten.overheid.nl
13 UNEP (undated): http://uneplive.unep.org/downloader#
14 BGR (undated): https://rosys.dera.bgr.de/mapapps/resources/apps/rosys/index.html?lang=de
15 EC (2019b): https://rmis.jrc.ec.europa.eu/
16 Circular Economy Toolkit (undated): http://circulareconomytoolkit.org/about.html
17 CREM (2017): https://www.grondstoffenscanner.nl/#/

Table 4 *Some prominent assessments of the benefits of a circular economy*

Who	Main conclusions
Ellen MacArthur Foundation (2012)	Annual global net material cost savings opportunity of up to USD 380 billion in a transition scenario and of up to USD 630 billion in an advanced scenario
Bohringer and Rutherford (2015)	Benefits the circular economy can have on the economy and jobs; GDP could be 11% higher in 2030 and 20% higher in 2050 than the baseline development scenario
EC (2014c)	Within a scenario of a 2% improvement of resource productivity per annum, the model predicts approximately two million additional jobs in the EU by 2030
Ellen MacArthur Foundation (2015a)	Europe is to grow resource productivity by up to 3% annually, generating a primary resource benefit of as much as €0.6 trillion per year to Europe's economies by 2030. In addition, it would generate €1.2 trillion in non-resource and externality benefits, bringing the annual total benefits to around €1.8 trillion, as compared to today.
Geerken et al. (2019)	A 20Mton CO_2eq reduction from maximized recycling, prevention of food waste and lifetime extension; up to 55Mton CO_2eq if sustainable material management scaled highly successfully
Groothuis (2016)	The GDP and employment results are positive in each of the 27 countries. In 2020, GDP levels will be, on average, 2.0% higher and employment levels 2.9% higher than business as usual, meaning that 6.6 million more people are employed
Haas et al. (2015)	Globally roughly 4 gigatonnes per year (Gt/yr) of waste materials are currently recycled. This flow was deemed to be of moderate size compared to the 62 Gt/yr of processed materials and outputs of 41 Gt/yr.
IRP (2018)	Remanufactured products are of the same quality as new products, and moreover led to cost savings per unit of up to 44%
Morgan and Mitchell (2015)	Circular strategies of reuse, recycling, repair and remanufacturing and servitization create over gross 200,000 jobs in the UK by 2030
Svatikova et al. (2018)	The overall net impact on EU employment (# of jobs) across all sectors is positive (+0.3%)
Mayer et al. (2019)	Contributing to the debate of potentials and limitations of a more circular economy by developing a mass-based monitoring framework for the European Union. Share of domestic material consumption (see also Figure 8) of primary biomass is no less than 24.6%
EEA (2019)	The greenhouse-gas (GHG) potential of the sum of the circular actions covered is estimated to be around 80-150 Mtons of CO_2eq per year by 2030 in Europe, which equals to around 2% to 4% of the GHG baseline emissions by 2030 in the EU reference scenario

Adding to this selection, there was the TNO (2013) study that publicized opportunities for a circular economy in the Netherlands. The net annual added value (7.3 billion EUR) and FTE (54,000) were results that were widely referenced and, in some cases, used for an informed conversation about the ideas behind the analysis.

We conclude that quantified results have been publicized, but that both the actual results and the underlying assumptions have been underrepresented in conversations about a circular economy. Assessment methods were deemed too boring to be discussed. Catchy “snack facts” (“China used more cement between 2011 and 2013 than the US in the whole of the 20th century”) resonated better and were therefore more convenient to present than, for instance, dilemmas for a particular business. The quantified results from Table 4 that were publicized were enough to get the circular economy to the policymaker. **But for businesses to follow-up on opportunities that risk wealth and employment, such macro-economic assessments provide no incentives**; effective policies (besides making use of technological progress) provide the preconditions for companies to innovate in sustainable and circular products and processes.

2.5 AN EX POST EVALUATION OF “OPPORTUNITIES OF A CIRCULAR ECONOMY IN THE NETHERLANDS” IN 2019 SUFFERS FROM POOR DATA

The TNO (2013) study assessed circular opportunities for biowaste, metal products, electronics and electrical equipment. It did so by first assessing the current value of circular strategies, second by using expert judgement to estimate incremental value or volume changes as a result of the circular strategies and third by scaling the results of these case studies to the entire economy of the Netherlands. Fair warning: some parts of this section will be hard to grasp if one is unfamiliar with the TNO study.

It would have been interesting to redo that study seven years later, expecting another result for the coming 10 years based on recent technological advancements. However, this ambition quickly ran into problems. One reason is because many promising innovations remain promising. The most valid reason not to redo the assessment is because the same heterogeneous and unofficial data sources would have to be used. No new and/or extended data are gathered about the market size of products offered as a service, the amount of repair and maintenance activities for households or the value and size of secondary material flows.

The reason not to redo the study makes even more sense when looking at the available data in more detail. We can use the international classification of products by activity (CPA) to consider the disaggregated and confidential data at CPA3 level (describing for instance product groups labelled lighting, washing machines, laptop PCs, etc.) from the Netherlands Statistical Office (CBS). These data helped to assess the annual flow of products from the case study sectors (metals and EEE). Considering capital stock formation (expenditures from businesses) and final consumption (from households and governments), the total value of lighting products, household appliances, computers and measuring equipment, etc., placed on the Dutch market was assessed at 16.4 billion EUR for 2010. But the size of the annual flow of products onto the market in itself offers no new assessment of a circular economy, even if we have the similar CPA3 level data from CBS from 2016[18] instead of 2010. Cause and effect relations between circular strategies and use/consumption of products can’t be attributed on this level using existing data. The potential for change of the CPA3 products can still only be assessed by expert judgement. There is no evidence of lifetime extension of products, size of repair activities within the manufacturing sector, size of servitization services offered by manufacturing sectors (instead of rental and leasing agents), or uptake of materials in closed loops on this detail level (lighting, washing machines, laptop PCs, etc.). **This explains further why it made no sense to redo the study, since we would be using the same one-off product-based**

18 Statistics are usually only available one or two years later

estimated potential for change on the CPA3 level. Value creation of circular services is inextricably linked to the original value of the product, the risk of the circular service provider and the remaining utility to the user of the product. It is precisely those types of data that are not known in any detail, let alone monitored over the years.

So, the only remaining option is to look at the inputs of sectors that best represent circular strategies. These can be considered NACE[19] 33 (Repair and Installation of machines), NACE 37-39 (Waste treatment), NACE 77 (Rental services) and NACE 95 (Repair of household goods). The overall picture: there are many minus signs, which represent a diminishing role for sectors representing circular strategies (shown in the columns) in the general economic activities (shown in rows in Table 5). An example of an interesting change is the 34.9% representing a hefty increase of the use of Rental services by the Manufacture of computer, electronic and optical products. **It is as interesting as its true meaning is unclear**. It could be that these products are now marketed by rental or lease companies. It could also just mean that the manufacturer has rented machinery or even items that are not related to the primary production process (buildings, office furniture, leasing vehicles for employees etc.)

Table 5 *Change of use of circular sectors (in columns) by all sector in the economy (in rows) in the Netherlands between 2010 and 2017*

	33 Repair and installation	37-39 Waste treatment	77 Rental services	95 Repair of consumer goods
Agriculture, Hunting and Forestry	4.8%	-1.0%	0.2%	0.1%
Mining and quarrying	5.9%	-0.3%	6.8%	0.2%
Manufacture of food/beverages/ tobacco/textiles/apparel	1.4%	-0.4%	0.0%	0.0%
Manufacture of wood and paper products, printing, coke, refined petroleum products, pharmaceuticals	1.4%	0.0%	-0.6%	0.0%
Manufacture of rubber and plastic products, and other non-metallic mineral products	2.3%	-1.3%	-1.8%	0.1%
Manufacture of basic metals	7.6%	0.5%	-1.2%	0.1%
Manufacture of fabricated metal products, except machinery and equipment	-0.2%	-0.8%	-1.7%	0.0%
Manufacture of computer, electronic and optical products	-1.1%	-0.2%	34.9%	-0.1%
Manufacture of electrical equipment	-6.5%	-0.6%	-3.1%	0.1%
Manufacture of machinery and equipment n.e.c.	-8.0%	-0.9%	-1.5%	0.0%
Manufacture of transport equipment	-3.1%	-0.3%	-1.2%	0.0%
Manufacture of furniture and other manufacturing	-1.3%	-0.4%	-1.0%	-3.6%

19 Nomenclature statistique des activités économiques dans la Communauté européenne (NACE rev.2), based on UN standard called ISIC.

Repair and installation of machinery and equipment	-17.9%	-0.6%	-0.6%	0.0%
Waste management and remediation activities	3.5%	7.5%	-0.9%	0.2%
Electricity, gas, steam, water supply, sewerage	1.7%	-0.7%	0.0%	0.0%
Repair of motor vehicles, motorcycles	0.1%	-0.3%	3.4%	0.0%
Wholesale and retail trade, information and communication, financial intermediation, financial and insurance activities, real estate, renting and other business activities	0.9%	-0.1%	4.4%	0.1%
Rental services	1.0%	0.3%	1.3%	0.7%
Public administration	1.2%	-6.1%	0.0%	0.1%
Repair or household goods	0.5%	0.0%	-0.9%	0.9%
Final consumption (households, NGOs, government)	0.5%	0.0%	0.7%	0.1%
Gross fixed capital stock formation by businesses	-0.6%	1.5%	1.4%	-0.2%

Ex post, if we look at SBI2, the net addition to autonomous growth is 100 million, a far cry from the 7.3 billion assessed in 2013. This is a result for 2010–2017 inflation corrected value added and full time equivalent on the NACE (i.e., SBI) 2-digit level. The key results for the circular economy SBI2 sectors between 2010 and 2017 are shown in Table 6.

Table 6 *Development of employment and Value Added at SBI2-level (2010–2017) source STATLINE (extracted december 2018)*

Sectors (NACE)	2010 FTE	2017 FTE	Percentage-growth	Absolute growth (FTE)	2010 Value Added (2015 prices)	2017 Value Added (2015 prices)	Absolute growth value added	delta EUR/FTE
	x 1 000	x 1 000		x 1 000	(Million EUR)	(Million EUR)	(Million EUR)	
A-U All economic activities	7025	7273	3.5%	248	593884	651116	57 232	4.99
33 Repair and installation	36	42	16.7%	6	3423	3011	-412	-23.39
37-39 Waste treatment	26	26	0.0%	0	2210	3153	943	36.27
77 Rental services	26	31	19.2%	5	8184	7690	-494	-66.70
95 Repair of consumer goods	11	11	0.0%	0	426	489	63	5.73
Total 33, 37-39,77,95	**99**	**110**	**11.1%**	**11**	**14243**	**14343**	**100**	**-9.4**
All other sectors	6926	7163	3.4%	237	579641	636773	57132	6.22

Focusing on these "circular" sectors, we observe a growth in employment of 11,000 fte in an economy that witnessed a growth of 237,000 fte. In 2013, we estimated a growth of 54.000 fte over 10 years The relatively rapid growth of these few "circular" sectors may serve as an indication for a lowered barrier towards such circular activities through the years.

2.6 HOW HAS LIFE-CYCLE ASSESSMENT RESPONDED TO THE NEED TO ANALYZE THE CIRCULAR ECONOMY?

Soon after the re-introduction of the circularity concept in 2012, the question arose if the circular economy equals an environmentally sustainable economy.

The measurement of environmental sustainability as a discipline started in the 1960s. In the beginning, sustainability assessment was mainly regarding the effects of products on the environment, from life cycle perspective. This assessment methodology is called environmental Life Cycle Assessment or shortly LCA and described in detail in the ISO 14040-14044 standards. With each decade, new insights and relevant environmental issues have been incorporated in LCA methodologies, for example waste problems, ozone layer depletion, air quality, toxic substances, climate change, micro plastics and water scarcity. Moreover, the focus on merely product assessment has been broadened to the assessment of services, organizations and even whole systems or countries.

The role of circularity in LCA is thus not only relevant on a product level. In a recent literature review, Elia et al. (2017) attributed studies to areas of CE interventions: macro, meso and micro levels. More than half of the studies referred to the macro level (cities to countries), followed by meso (industrial parks) and micro (single companies or customers). This is striking because although strategies and targets start at the macro level, innovations and changes have to take place at the micro level. Considering them jointly seems important for identifying successful CE strategies, but the analytical methods to do so are widely lacking. Nevertheless, it is possible to combine current methodologies to overcome their individual shortcomings and produce an analysis that covers all areas of interest, for instance, combining a macro-economic model with LCA to evaluate CE impacts considering current and future policies. Achieving this combination without errors has methodological challenges, but approaches on various levels have been proposed (De Koning et al. 2018; Suh 2004).

An important feature of LCA is that it is a comparative measure. This feature, however, is also a shortcoming when addressing CE strategies: choosing the most circular or environmentally friendly option does not necessarily mean that absolute environmental pressure or resource consumption will decrease. The circular strategies can be (and have been) out paced by innovation, for instance re-use being less sustainable than purchasing a new refrigerator that consumes less electricity. A way to introduce an absolute measure for environmental sustainability is the planetary boundary (PB) concept. Various ways to match PB to LCA have been proposed (Roos et al. 2015), based on (Sandin et al. 2015; Ryberg et al. 2018) However, as with sustainable development goals (SDGs), there is still a long way to go before this concept can be used to guide company strategies (Clift et al. 2016).

Circularity and sustainability therefore still have an equivocal relationship, **whereas on some aspects they are complementary or even reinforcing each other, while in other cases they might even be contradictory**.

The first question in an LCA of circular alternatives, is whether the circular alternatives cause fewer environmental impacts than conventional products or systems. This happens not to be always the case. For example, a short-lived product which can be incinerated with energy recovery after its lifetime might have a lower life cycle impact than a reusable and therefor highly over dimensioned and non-incinerable alternative. This means that although new concepts -in some cases- might be favourable from a circular perspective, this does not always lead to a calculated lower impact on the environment and might be considered more circular but less sustainable. However, more complex factors are playing a role in the LCA of circular concepts.

In classical LCAs as we know them since the 1980s, the product's environmental impacts are inventoried from "cradle to grave", meaning from the mining of the raw materials until the final waste disposal of a product. In a circular economy, this linear line of reasoning is outdated and waste streams should not exist. Consequently, the incorporation of "waste" streams in a product chain requires new calculation methodologies which take into account the multiple and diverse life cycles of materials. What part of the environmental burden for raw material mining should be attributed to the first, second, third or even further life cycles? Which impacts from waste processing should be attributed to a "waste" stage and which part should be considered as a result from a new product's life cycle? And hidden behind these system boundary questions, lies the more critical, societal question: what environmental hazards do "waste" materials possess when they move on to a next cycle? The awareness of (inter)national organisations of the sensitivity of these materials and the need for monitoring and regulating them is growing. For example, the European Chemical Agency is setting up a database to gather information and to improve knowledge about substances of concern in products and in products when they become waste.

Comparability (and, therefore, use) in CE monitoring of product footprints is hampered by wide differences in methodological choices. Harmonization of assessment methods aim to create uniformity. The product environmental footprint (PEF) method (EC 2016d), partly based on ISO 14025 (environmental labels and declarations—type III environmental declarations) is a way to achieve this. The PEF methodology also prescribes calculations to better capture circularity aspects—the circular footprint formula, which includes:
- A quality measure for primary and secondary materials;
- Allocation factors to include demand and supply of secondary materials;
- Allocation factors to include energy recovery costs and benefits;
- Differentiation between fractions of secondary materials as input, output and for energy recovery.

However, although the harmonisation of international LCA methodologies towards a central, PEF based approach is currently happening (for example the harmonization of the EN15804 for LCAs building products in line with the PEF), existing LCA information is not fit for this purpose. **Even after this harmonization has been established, it will take additional years to update (inter)national databases towards a complete set of circular indicators**.

Although the environmental sustainability of any circular aspect of a product life cycle can and should be assessed using LCA, the indicators and calculation rules that explicitly address the circular economy are still under development (e.g., Haupt and Zschokke 2017; Huysman et al. 2017). This is mainly related to the fact that current LCIs are not finetuned to address several life cycles/uses of a material, and LCA and MFA methods do not differentiate between quality of materials for different uses and different levels of recycling (e.g., Elia et al. 2017; Moriguchi 2007). **Before the sustainability of circular alternatives can be assessed integrally, the issues addressed above need to be further developed in existing LCA methodologies and above all LCA data**.

In addition to these metrics to analyse the environmental sustainability, similar methodologies have been developed to analyse the economic sustainability. The main methodology for this purpose can be summarized as Life Cycle Costing or shortly LCC. Although LCA and LCC seem very similar from a semantic point of view, their working procedures are profoundly different. In general, LCC can help to inform a product developer or future user about the life cycle costs of a new product. The data needed to perform LCC with the same rigor as an LCA requires publicly available data on costs if outcomes of an LCC should be interpreted beyond a company or product specific scope.

2.7 WHICH SUCCESSFUL CIRCULAR PRODUCTS OR SERVICES HAVE BEEN DEVELOPED IN RECENT YEARS?

Thanks to several professional initiatives, the web can offer inspiring overviews of case studies, best practices and/or successful new circular businesses.[20] These relate to circular strategies for all possible products in our society, ranging from textile recycling, phasing out toxins in metallurgy, turning biowaste into feedstock using solutions from nature, determined companies offering complex and highly circular electronics in a highly competitive global market (such as Fairphone). To get a sense of potentially disruptive technical innovations, one might look at lists like those on the MIT innovation monitor.[21]

Specific examples are not mentioned here, simply because presenting a showcase should be done thoroughly. Describing successful initiatives costs money. It takes considerable time to understand and describe a successful business or public initiative. We argue that a CE transition needs facts and explanation more than another success story. Helping businesses overcome barriers and seize opportunities requires better data* regarding raw material content of their products and the responsible sourcing aspects thereof, supply chain resilience, toxins regulation, environmental footprints etc. It takes sector/product-specific knowledge, understanding the power of knowledge and contacts based on trust. This is the reason to treat outcomes of case studies as carefully and systematically as possible. They are evidence of opportunities that have proven to be worth following up, but we need evidence of circular strategies in corporate accounts and widely acknowledged methods to make sure that the flow of relevant information about circular case studies can be shared and interpreted.

20 Ellen MacArthur Foundation (undated), EU (undated) and PACE (Platform for Accelerating the Circular Economy): https://www.acceleratecirculareconomy.org/projects.

21 Popular Science (2012).

* **suggestions for better data? See 1, 2, 7 and 13 in section 5.2**


RECYCLING

3 STATUS QUO OF CIRCULAR ECONOMY ASSESSMENT

The message that decisions shaping a circular economy transition need better data can be supported by looking at (sometimes very technical) assessment techniques. This chapter describes mainstream assessments of the circular economy and the issues that arise when the need for relevant data remains undiscussed in the face of conceptual debate.

3.1 WHY WOULD ONE NEED A STRATEGIC ASSESSMENT OF OPPORTUNITIES FOR A CIRCULAR ECONOMY?

Any professional investment decision, especially made with public money, needs thorough decision support. Investments that are part of the circular economy transition are made every day. For instance, waste creation and resource use are minimized, and when a product reaches the end of its life, it is used again to create additional value. This can bring major economic benefits, contributing to innovation, growth and job creation (EC 2015). Or, as envisioned by the originators, a circular economy is a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows (Ellen MacArthur Foundation 2013).

The potential benefits indicated in early analyses by the Ellen MacArthur Foundation spurred significant attention and hence an impressive flow of additional analyses. It is ironic that the impact of circular strategies on economic value has diminished in recent years. This is problematic because, first of all, assessing economic value has a disciplining effect: harmonizing concepts, data interpretation and analytical frameworks. Second, this situation alienates economic theory. It prevents policymakers from analyzing the potential impact of their (often) macro-economic instruments on the desired environmental outcome. The global economy, human society and our planet cannot be analyzed as separate entities in a meaningful macro-economic analysis (Korhonen et al. 2018). Not in an intricate 21st century society at least.

Yet overcomplicating assessments of circular economy can be as much of a threat as oversimplifying can be. When the first assessments in 2013 and 2014 seemed to fail to invoke action, "analysis paralysis" was seen by some as the phenomenon that frustrated the circular economy transition. If this paralysis was indeed a useless obstacle, it would imply that the analytical framework for a circular economy was clear and available to everyone. It would imply that the concepts, objectives and performance indicators for policymaking were in place. This book aims to demonstrate that they are not. **Rather, a lack of quality data and corresponding standardized assessments seems to lead to a "wait and see" approach**: an approach based on considered inaction waiting for a clear opportunity ("wait and see"), rather than a state of fearful indecisiveness ("paralysis").

3.2 HOW DO PEOPLE DEFINE A CIRCULAR ECONOMY IN WORDS?

Before we can discuss circular strategies, it pays to look at proposed **definitions of a circular economy. There have been many**. We can consider both the body of academic work and the parlance of mainstream media and public representatives.

Let's start by looking at academia. Comparing definitions of a circular economy was done by, amongst others, Kirchherr et al. (2017), Lieder and Rashid (2016) and Ghisellini et al. (2016). A deceivingly trivial conclusion from these studies is that many definitions refer to material flows and the aim to close the system of flows. For instance, "The basic premises of the CE appear to be closing and slowing loops" (Bocken et al. 2017). Or, "the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases" (Yuan et al. 2006), or the very title of the 2015 European Circular Economy Package, namely "Closing the loop" (EC 2015). Many definitions seem to have overlooked one important thing: money. Omitting economic value in material flow analyses turns out not to be a trivial decision.

To be fair to these definitions, economic theory is often only a few lines away. Take for example in a definition like "A [CE] is a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops" (Geissdoerfer et al. 2017). The next line of this article reads "This can be achieved through long-lasting design, maintenance, repair, re-use, remanufacturing, refurbishing, and recycling", thereby clearly pointing at economic processes. **Yet we observe an possible absence in linking the circular economy definitions to quantified data and statistical classifications that enable linking circular opportunities to value**.

If we look at the wording in general media publications, definitions of a circular economy become obviously less rigorous. Most communications aimed for the general public start with the simple question: "what is a circular economy?" It is not this question, or rather the broad scope of answers that follow the question, that identifies a worrying issue. People see a circular economy as a panacea, representing a path to a utopian world. Such generic views usually steer a conversation into the convenient realm of inconsequential chatter.

Answering the question "what is a circular economy" might still best be done by citing the Ellen MacArthur Foundation (2012): the circular economy refers to an industrial economy that is restorative by intention… designed for ease of re-use, disassembly and refurbishment, or recycling. However, to follow up on the prospect of a more circular economy, we need more than words.

3.3 HOW ARE PEOPLE DEFINING A CIRCULAR ECONOMY IN TERMS OF STRATEGIES?

In relatively few ways. Perhaps this was due to the Ellen MacArthur Foundation (2012) report that presented a comprehensive and visually attractive analytical framework.[22] It described decades' worth of ideas in an elegant illustration, carving circular shapes to support the words that tried to convey the message of rethinking the use of natural resources in our economy. It defined the circular strategies the shape of feedback loops. Like playing a hit single once more, let's take another look at Figure 5.

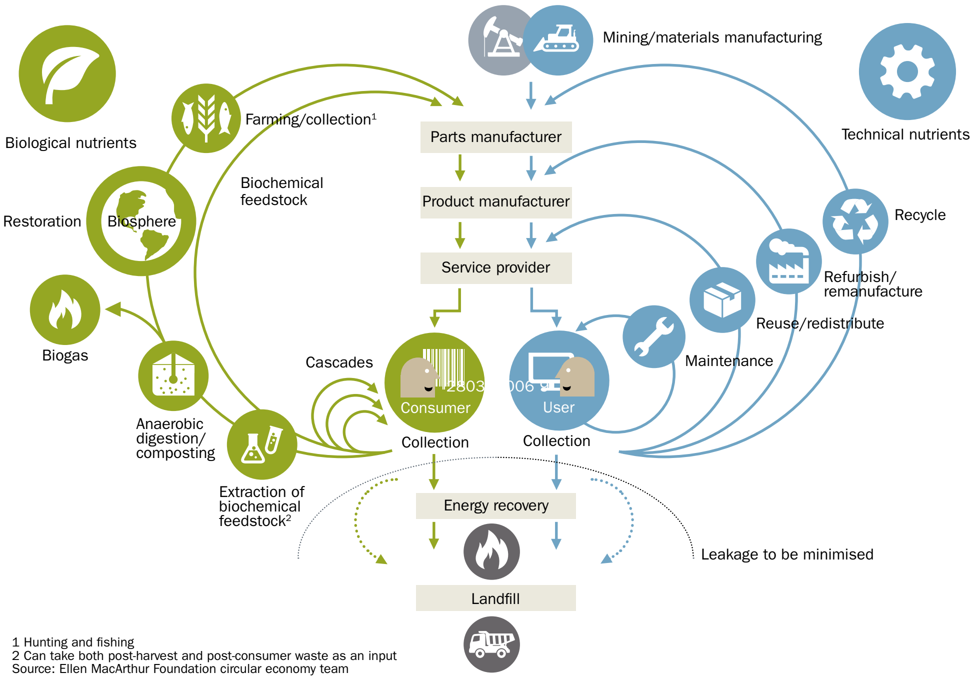


Figure 5 *The often-referenced Ellen MacArthur Foundation representation of the circular economy*

The challenge thus became developing the definition of a circular economy by circular economy strategies (CES) or value retention processes (VRP). Several authors from several institutes set out to elaborate the feedback loops described in Figure 5. Given the size of the intellectual canvas, there was room for the scope and number of circular strategies to grow.

22 It invited many organizations to develop their own analytical framework, although these were not fundamentally different from this one.

The technical feedback loops that were not explicitly part of the right-hand side of Figure 5 especially invited people to add more circular strategies. Follow-up studies added strategies like shared use, repair and re-use of components. Most of all, it was felt that the major opportunities that design strategies and servitization had to offer were not adequately represented. More detail to the biotic part of the analytical framework saw less intensive contemplation, even though the regenerative qualities of nature seem to not be fully understood.

The RESOLVE network presented in 2015 (Ellen MacArthur Foundation 2015a) was presented as a way to further improve the circular framework. Various organizations added their five-, seven-, or eight-legged framework to the fray. The number of strategies prevalent in the Netherlands are defined by the R9 (later even R10) framework (Cramer 2015). This expanded set of strategies came with a set of problems. Above, we mentioned the study that gathered 114 definitions of a circular economy. With that array in mind, more strategies meant an exponentially growing need to discuss the specifics ("What exactly is this company doing?"). Moreover, many conversations about possible actions got bogged down in long and sometimes frustrating debates. In this sense the "analysis paralysis" issue that we introduced before indeed seemed to play a role. Once the discussion centred around the scope and the definitions, real decision making suffered. Moreover, in these discussions, the role of key economic concepts, such as risk, utility, negative externalities and price, was too often left out of the conversation.

We propose to classify strategies (once again) according to three product life cycle stages: Reduce (design in the production phase), Re-use (an either longer or more intensive use phase) and the inevitable Recycle at the end-of-life phase, see Figure 6.

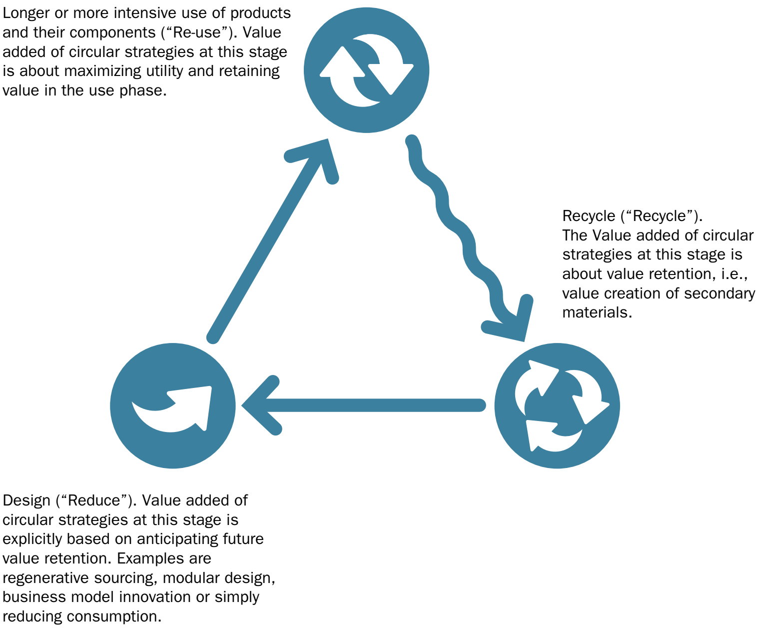


Figure 6 *A concise way to define circular strategies*

This simple representation is similar to definitions that emerged in the literature as observed by (Ghisellini et al. 2016): that a CE was mostly represented through three main "actions", i.e., the so-called 3R Principles: Reduction, Reuse and Recycle. Note that many biological nutrients have relevant strategies only in terms of Reduce and Recycle in this sense.

3.4 WHERE TO DRAW THE LINE BETWEEN AN ECONOMIC STRATEGY AND A CIRCULAR ECONOMY STRATEGY?

At this point, one might wonder where "regular" strategies, innovation and entrepreneurship fit into this framework. Some authors seem to want a circular economy to fix all flaws in modern society, something that is detrimental to any societal transition (Flynn and Hacking 2019). It will aggravate other transitions aimed at sustainable society if CE assessments are overreaching when discussing innovations that are not aimed at Reuse, Reduce, or Recycle. But what about the design phase? It is crucial to note that longer or more intense use and recycling are enabled by design and that these designs can be classified as circular. It might even be defendable to say that "designing for circular", using policy tools such as Eco-design guidelines, could reduce the supply risk of critical materials or "conflict minerals" (Peck 2016). Here we arrive at two questions that, if not properly answered, muddle any proper economic assessment of a circular economy. First: which product innovations can be considered part of a circular transition? Second: at which stage in the product cycle is the value created by innovation valorized (i.e., turned into money)? To answer these questions, we draw upon Table 7.

Table 7 *Examples of potential circular innovations that increase the value that will fall to producers, consumers or circular service providers during the use phase*

	Question 1 Does innovation create value during the production phase, because, well, it's a better product?	**Question 2** Does innovation create value during the production phase by anticipating longer use, more intensive use or more value-retaining recycling?	**Question 3** Can the innovation retain extra value during the use phase or at end-of-use phase, regardless of the production phase?	So, a regular innovation or a circular innovation?
More ergonomic design of a passenger car seat	Yes	No	No	Regular innovation
Modular design of a smartphone	No	Yes	No	Circular innovation
Phasing out toxins used in production (i.e., not the actual product)	No, only if externalizations are valued	No	No	Regular innovation, if externalizations are valued

Better manure treatment	No	No	Yes	Circular innovation
Designing eyewear frame with interchange-able lenses	Yes	Yes?	No	Probably a regular innova-tion, except if the lifetime of the frame is significantly extended
Install a take-back system on CdTe solar panels	No	Yes	No	Circular innovation
Bioplastic from polylactic acid (PLA)	Maybe it will be cheaper?	No	No	Regular innova-tion, if it offers cost reduction
Manufacturer of barbecues now offering lease option	No	Yes	No	A circular innovation, even if decision is solely based on business considerations

How to use this table
- Only "yes" in question 1 > probably a regular innovation
- A "yes" in question 2 and/or 3 > a circular innovation.

Question 1 contains examples of "non-CE" innovation. Question 2 contains examples of circular strategies enabled by design decisions in the production phase. Question 3 contains examples of circular strategies that retain value regardless of the design decisions. Note that an innovation that fits into question 2 automatically means that value retention is undertaken in the use phase or the end-of use phase.

The relevance of Table 2 is that it invites us to do a mental exercise, with the aim of identifying possible CE innovations. Furthermore, it is an important reminder that several product innovations will take place without any relation to a circular economy, probably also regardless of public intervention.

3.5 CIRCULAR ECONOMY INDICATORS ARE MUCH BETTER DEVELOPED THAN AVAILABLE DATA

Quite a few (EEA 2016; EC 2016a; EC 2016b; EC 2018a; Potting et al. 2017; Moraga 2019). If all indicators were mentioned here, it would add between 5 and 10 pages to the length of this book. And these are mostly excellent indicators. A call for better data should therefore not be seen as criticism of the intention and character of existing indicators, but merely as a reminder to see if the existing indicators can be made operational by the currently available data and to allow economic concepts to take a more prominent position.

If we would meet the challenge of singling out the most relevant indicator, it would be the Lead Indicator of Potting et al. (2017), which is the productivity of raw materials, and several other resource efficiency frameworks. This metric is expressed as gross domestic product (GDP) divided by raw material consumption (RMC): GDP/RMC, which equals the total amount of value (i.e., money created in a year) divided by all the extracted raw materials that were used in creating this value (the raw material footprint). As a metric, it provides no target that resembles an economy that can be described as circular. An economy like the Netherlands, Luxembourg or Switzerland could see spectacular increases in resource efficiency only by increasing high-value services, not by using less primary extracted material. In a world consisting of global value chains, it could be misleading to compare national economies by the GDP/RMC ratio (see also section 2.3). It seems more useful to use the Lead Indicator for an assessment of the global economy or of a comparison of specific sectors between countries. Given current data availability, GDP/RMC is the least misleading lead indicator around provided that the RMC in absolute sense decreases.

The first set of indicators that illustrates how policymakers frame a circular economy comes from the European Commission (EC 2018a), shown in Table 8. This table also draws from related work captured in the European Resource efficiency scoreboard (EC 2016a) and the Raw Material scoreboard (EC 2016b) that concentrate circular indicators in the thematic cluster of circular economy and recycling. The second indicator set that we have chosen to show is the core of CE monitoring in the Netherlands (Table 9).

Table 8 *Ten indicators of the European Commission monitoring framework for the circular economy (EC 2018a)*

Name of indicator	Relevance	Examples of EU policy lever(s)
1. EU self-sufficiency for raw materials	The circular economy should help to address the supply risks for raw materials, particularly critical raw materials.	Raw Material Initiative; Resource Efficiency Roadmap
2. Green public procurement*	Public procurement accounts for a large share of consumption and can drive the circular economy.	Public Procurement Strategy; EU support schemes and voluntary criteria for green public procurement
3. a-c Waste generation	In a circular economy, waste generation is minimized.	Waste Framework Directive; directives on specific waste streams; Strategy for Plastics

4. Food waste	Discarding food has negative environmental, climate and economic impacts.	General Food Law Regulation; Waste Framework Directive; various initiatives (e.g., Platform on Food Losses and Food Waste)
5. a-b Overall recycling rates	Increasing recycling is part of the transition to a circular economy.	Waste Framework Directive
6. a-f Recycling rates for specific waste streams	This reflects the progress in recycling key waste streams.	Waste Framework Directive; Landfill Directive; directives on specific waste streams
7. a-b Contribution of recycled materials to demand for raw materials	In a circular economy, secondary raw materials are commonly used to make new products.	Waste Framework Directive; Ecodesign Directive; EU Ecolabel; REACH; initiative on the interface between chemicals, products and waste policies; Strategy for Plastics; quality standards for secondary raw materials
8. Trade in recyclable raw materials	Trade in recyclables reflects the importance of the internal market and global participation in the circular economy.	Internal Market policy; Waste Shipment Regulation; Trade policy
9. a-c Private investments, jobs and gross value added	This reflects the contribution of the circular economy to the creation of jobs and growth.	Investment Plan for Europe; Structural and Investment Funds; InnovFin; Circular Economy Finance Support Platform; Sustainable Finance Strategy; Green Employment Initiative; New Skills Agenda for Europe; Internal Market policy
10. Patents	Innovative technologies related to the circular economy boost the EU's global competitiveness.	Horizon 2020

Table 9 *Selected indicators for CE monitoring in the Netherlands (Hanemaaijer et al. 2018)*

Indicator	Unit
Resource use, direct (DMI resource)	kton
Resource use, chain (RMI resource)	kton
Resource consumption chain (RMC)	kton
Land use, direct	% cultivated land
Water use, direct	MiO m^3
CO_2 emission direct	Mton
CO_2 emission footprint	Mton
Economic growth (CE sectors)	EUR
Employment (CE sectors)	% of total FTE
Added value recycling sectors	EUR, 2014 prices
Self-sufficiency resources	DEU/DMI
Resources used, excluding export	DMC
Material productivity	GDP/DMC
Waste production	kton
Relative waste production	kton waste/DMC
Circular Material Use Rate	% of secondary material in DMC
Value Based Recycling Index	Price of recyclable waste/price of ingoing waste flows

The colours represent if data are readily available (green), available partly based on models (yellow) or mostly unavailable (red). But indicators highlighted yellow have no unambiguous data after closer inspection. For instance, if a DMC datapoint is created by assuming crude ratio's about metal content of electronics, it can't effectively monitor and evaluate circular strategies on a national level.

The indicators relating to CE sectors are likely to overlook some aspects of CE (such as value preserving activities in re-use repair and maintenance) given the crude definition of sectors, and therefore do not support policies (indicated in table 1) and do not link CE to mainstream economic thinking. We want to state again that this is no negative evaluation of the design of the indicators. It is a negative evaluation of monitoring i.e. policy robustness that can be obtained by using existing public data.

There are obviously many reported indicators that are missing or not explicitly present in Table 8 or Table 9, such as energy productivity, expressed GDP in purchasing power standard ($), kg oil equivalent, eco-innovation indicators, gross nitrogen balance in agricultural land, gross phosphorus balance in agricultural land, changes in land cover, depreciation of fixed capital, mineral depletion, waste of electronics and electrical equipment (WEEE) officially reported as collected prepared for re-use and recycling, collected municipal solid waste (MSW), generation of Hazardous waste (i.e., subject to regulation of hazardous substances (RoHS), human exposure to toxins or particulate matter, net forest depletion water productivity, physical trade balance that includes waste, R&D expenditures to green growth, etc.

Apart from the fact that there are many indicators available, the level of detail and exact definition can be very important for evaluating policy (Scott 2005; Kuczenski et al. 2016). All of these metrics need to be defined carefully, as seemingly common units like money and material content can be expressed in many ways. For instance, is GDP expressed in inflation-rate adjusted values? Do volumes expressed include packaging and water content? Which waste criteria are used? They stand the risk of being misrepresented (OECD 2017; World Bank 2016; EC 2016b; EASAC 2016), and most of these indicators are time bound: set in one year (1 January to 31 December), for instance.

A set of indicators that is at the core of mainstream material flow analysis is shown in Figure 7. Domestic material consumption (DMC) and raw material consumption are widely used metrics from this framework.

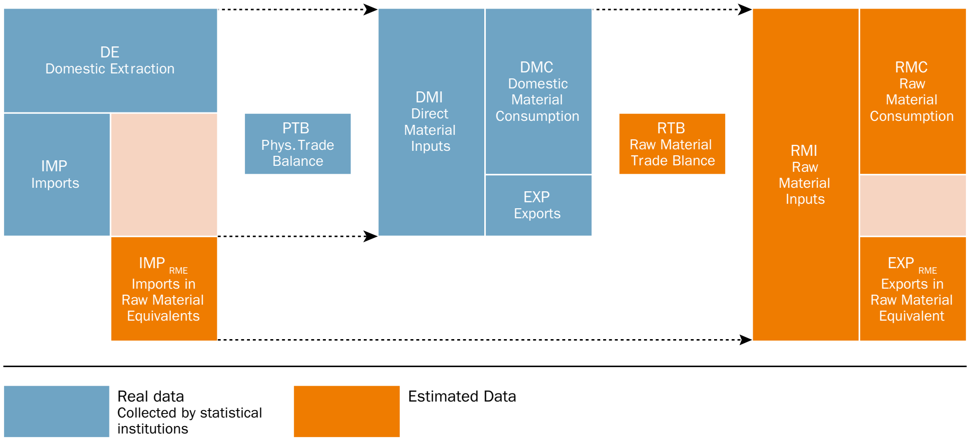


Figure 7 *Material flow analysis indicators (see materialflows.net)*

An interesting additional framework is offered by the system of environmental-economic accounting (SEEA) (Hoekstra et al. 2015). It offers an essential new dimension to other indicators that are usually based on the annual timeframe mentioned above. The framework shows how economic and environmental stocks can be accounted for (see Table 10).

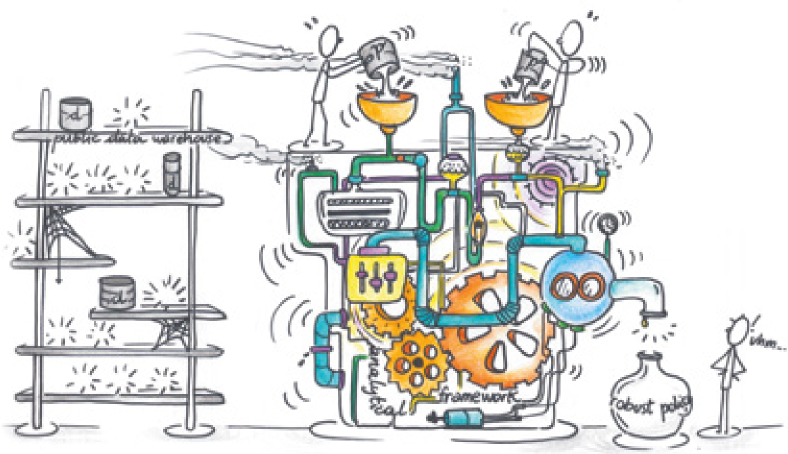
Table 10 *Environmental and physical asset structure of the SEEA (Hoekstra et al. 2015)*

		Produced assets	Environmental assets
Additions to stock	Growth in stock	Gross capital	Extracted natural resources
	Discoveries of new stock		
	Upward reappraisals		
	Reclassifications		
Reductions of stock	Extractions	Waste	Residuals flowing into the environment
	Normal loss of stock		
	Catastrophic losses		
	Downward reappraisals		
	Reclassifications		

These indicators add intelligence about stocks in society. These data are relevant because they are related to potential and economically relevant activities in a circular economy: repair, maintenance, utility maximization through asset sharing and ultimately recycling. These strategies are all applied on the "urban mine" (Allwood & Cullen 2017).

The narrative of churning analytical framework running on empty
The available range of indicators represents years of research and a great ability to model the complex reality of raw material and product flows. When we look at these indicators in detail, a lack of reliable data can be seen, preventing the indicator to convincingly support enforceable policy targets. The analytical framework is overwhelming the available public data, and it is the credibility of the framework that suffers.

(drawing by S. Oggero)



The wide array of indicators demonstrates that a circular economy policy development requires a wide array of research questions to guide public policy making. Without the right indicators and data, accelerating an economy would be the same as banking before currency was invented. The link with the message of this book is that **indicators should be based on official, periodically updated, detailed and transparent data** (Parchomenko et al. 2018). If not, indicators and their corresponding methods stand the risk of being orphaned and then rejected. Any meaningful indicator is under threat of being irrelevant if it can't be made operational for robust policy making. Consider, for instance, some indicators from EEA (2017, table A1.3): a wonderful listing of highly relevant indicators such as reparability, exergy losses, functional lifetime of a product and "key material losses". If official, updated and transparent data are lacking, none of this relevant analytical strength will ever be harnessed.

Even considering the many indicators listed in this section, **we emphasize the fact that indicators creating an economic mindset are missing among the ones presented above**. We suggest to include indicators **capturing price per service** ("how useful was using this product for a consumer, company or macro-economic sector?"), **detailed statistics on the size and shape of capital assets, performance data about products during their use phase or physical transformation of products within supply chains**. These indicators can be taken from aggregated tax and accounting obligations, anonymized and respected just as corporate information has been carefully treated by statistical offices for decades. We will discuss these needs in more detail in chapter 5.

3.6 CLOSING MATERIAL LOOPS DOES NOT COME FOR FREE

As demonstrated in the previous section, most of the indicators of a circular economy that we have discussed relate to time-bound material flows or environmental impacts. The problem is that material flow analyses often overlook the laws of physics or, more specifically, thermodynamics (Dewulf and van Langenhove 2005; Reuter 2018). **It is therefore not feasible to improve the sustainability of our economic processes by thinking that all waste can be "melted into a virgin state"**. The ambition to close material flows implies that materials not only move around in circles (mass cannot be produced or destroyed) but can retain their material qualities with a relatively minor effort, known as exergy. In many cases, it is not "relatively minor", depending on the purpose for which the material is used within society. This exergetic effort relates to knowledge (time dependant), capital stock (time dependant), labour (time dependant) and energy[23] (that has its own challenges related to the second law of thermodynamics). The two issues thus mean that creating meaningful diagrams of material flows is very difficult and that it **can even be misleading, suggesting that societal benefits are best realized by closing material loops**.

To put it differently: you cannot expect electronic waste to be fully recycled given current technologies, let alone current business models (Reuter et al. 2018). You cannot reverse the chemical reaction that turns cement into concrete (yet—provided exergy is added). You can expect biowaste to turn into valuable raw materials, such as secondary timber, but it takes time. You can expect glass waste to be collected and recycled at near 100% quality, but it takes labour and energy. As the old saying goes: you cannot unscramble scrambled eggs.

23 Most of the time we will mean exergy when discussing energy, but for the sake of simplicity, we refer to energy.

If time is considered linear, we can see a remarkable characteristic of the circular economy emerge. The scheme below shows that many relevant aspects of a circular economy are strictly time dependent and/or subject to the laws of natural science related to entropy. Entropy is a measure of the level of order or disorder of a system[24]. **This makes several aspects that are at the core of circular strategies strictly linear**.

Drivers of a CE transition	What can be characterized as moving in circles?	The resources that circular strategies use
Strictly linear, time dependent	*Possibly circular, depending on accounting method*	*Strictly linear, time dependent*
Need to compete (produce better, faster, cheaper)	Material (on molecular level or below) and energy[25] (Jørgensen 2006)	Economic capital stock (buildings, infrastructure, machinery, transport equipment, ICT, etc.) and monetary reserves
Need for an inclusive society (distribution of knowledge, economic opportunity, wealth and income over national and global societies)		Social capital (knowledge, education, institutions, legislation, culture, etc.)
Need to neutralize environmental impact		Natural capital stock (DNA, regenerative capacity of biomass, etc.)

Figure 8 *characterisation of drivers, flows and resources to steer flows*

The strictly linear quality of many aspects of the circular economy represents a challenge to all existing Sankey diagrams (see Figure 8), as powerful and insightful as they are. **The improved Sankey diagrams should also illustrate the effort (labour, knowledge, capital and energy)** that could shift certain flows and are therefore instrumental in the circular transition.

24 There are several authoritative works that discuss the practical limits of recycling in terms of entropy, like Ayres (1999) or Rifkin (1980). It is beyond the scope of this book to discuss them further

25 Energy moves in circles as it cannot be created or destroyed, according to the first law of thermodynamics. However, on the level of our planet, it can accumulate (which is actually at the core of climate change) thanks to the influx of energy from the sun.

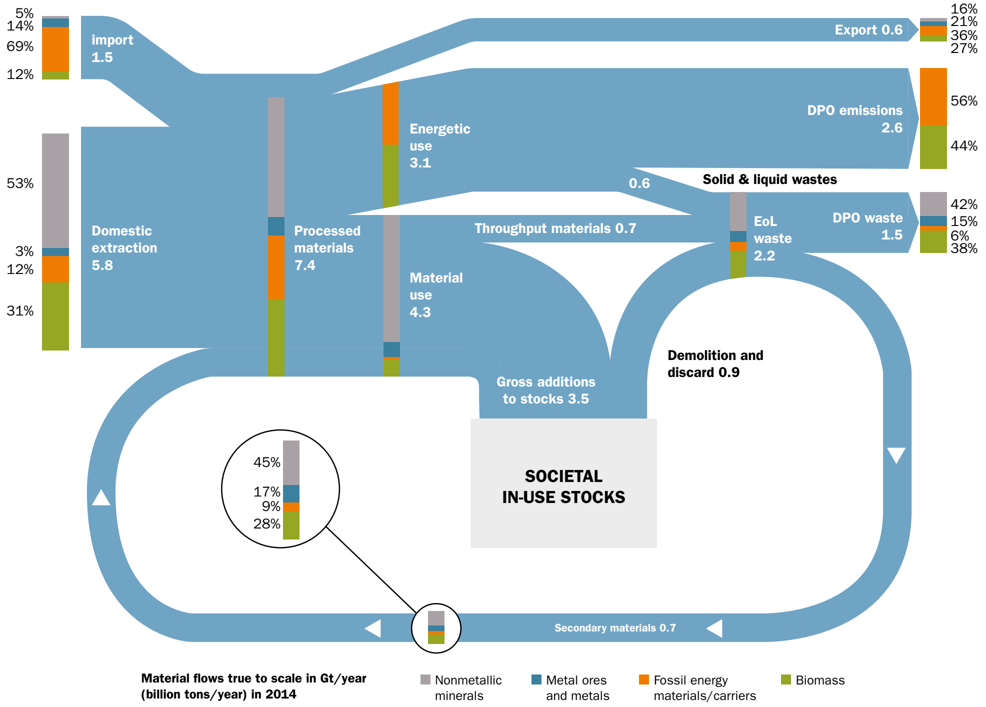


Figure 9 *A typical Sankey diagram (Mayer et al. 2019), in this case showing material flows through the EU-28 in 2014*

3.7 HOW IS POTENTIAL FOR GROWTH (€) OR REDUCED NEGATIVE IMPACT (E.G., CO_2) ASSESSED?

It is one thing to measure the current state of a circular economy, it is another to assess the potential of markets for circular business models, especially those related to business or governmental interventions. The following methods are available (based on an overview of methodologies for the assessment of potential given by Geerken et al. (2019):

- Difference between BAT (best available technology) being applied to all sectors of regions and DTP (disruptive technology potential) growth
- Economic structure (comparing the shares of agriculture, manufacturing, services, with emphasis on CE related services)
- Balassa index, describing which sectors are over- or underrepresented in a specific region
- Value chain analysis (how value added is dispersed over an input-output structure, enabling analysis of how a domestic euro spent on final consumption will increase the national value added and allow for products to circulate within national boundaries)
- Substitution potential of sustainable materials management (SMM) strategies
- Waste treatment scenarios based on physical and hybrid input-output analysis (using existing material consumption to analyze what share of that material consumption can be satisfied by secondary materials)

Another method to assess potential can be found in the Ellen MacArthur Foundation (2015b) publication on circularity indicators, where an elaborate set of formulas expresses product potential on a detailed level. The indicator used to assess the potential for market growth proposed on a product basis (in contrast to country economy or organization) is the material circularity indicator (MCI), which includes reuse and lifetime extension. Because the MCI lacks publicly available data, its complementarity with other indicators is advised, making the approach very similar to life-cycle assessment (LCA) frameworks, such as ReCiPe and ILCD (JRC-IES 2011; Huijbregts et al. 2016). These potential MCI indicators, however, cannot be made operational on a societal level as a result of the lack of public data. It could be tailored to be used for confidential business purposes instead.

A more qualitative approach is based on expert judgement. In a report by TNO (2013), a series of three workshops with around 25 experts provided inputs for quantifying the benefits of a circular transition between 2013 and 2025. These were based on expert judgements without a further analytical framework. The theoretical concepts to create such a framework are available, but the data and information to underpin the expert judgements are not.

We conclude that assessing potential is even more difficult than assessing the current situation of the economy. **Therefore, assessment of potential depends more on cause-and-effect relations, that can be expressed by better data***. The difficulty in predicting opportunities for a circular economy might justify the slogan of “Circular economy? Just get on with it!” Our rebuttal to this potentially reckless investment strategy would be a simple question: would you support public investments of a significant sum based on anxious statements? The sense that people get from studies that assess the potential of a circular economy is similar to a cost-benefit analysis (CBA): useful from a methodological viewpoint but frustratingly demanding in terms of data and information. We suggest making the effort to collect this data and information nonetheless. A CBA will probably not accurately predict the outcome of an investment, but it provides some sense of the size of the prize to be won if interventions using circular strategies result in real economic opportunities.

* **suggestions for better data? See 1, 2, 5, 9 and 17 and 19 in section 5.2**

4 PUTTING ECONOMY INTO CIRCULAR ECONOMY

One thing we take from chapter 3, is that there is surprisingly little economic theory incorporated into mainstream circular assessments. In this chapter, we explore the use of parts of standard economic theory to assess opportunities for a circular economy. We observe that too often there is an inexplicable distance between people active in the study of the circular economy on the one hand and economics on the other.

4.1 WHAT IS THE BENEFIT OF INTRODUCING ECONOMIC THEORY INTO CIRCULAR ANALYTICAL FRAMEWORKS AND VICE VERSA?

CE thinking can only advance if there is a proper understanding of markets and business models. The field of economics can only deliver useful conclusions if the use of natural resources is considered at a relevant level of detail—or at all. **The greatest benefit of taking an economic look at the circular economy is arguably asking the question: "Is the use of raw materials and products organized in such a way that it delivers the highest value for society?"**

There is a clear distinction between modelling natural science or modelling human nature. Yet, economics has at times looked at the natural sciences for parallels that would give economic models the same prescriptive power as models from fields like chemistry and physics. Over the last few decades, the stature of economic models has not seemed to suffer from a less-than-optimal representation of technology or physical phenomena, such as combustion efficiencies, relations between prices and physical quantities, ecological boundaries, or the components required to make complex machinery. These models proved accurate for the research questions asked, and modelling results were accepted and made their way into mainstream media and major policy decisions.

However, modelling major global transitions challenges the value of existing economic models. This is perhaps best illustrated by the creation of the shared socioeconomic pathways (SSP) of climate modelling. The interaction between complex geophysical effects (rain, wind, temperature, evaporation, etc.) and the impact that it has on economic processes (agricultural land, dwellings, transport systems, etc.) is obviously complicated. It took years (roughly ten years between 2005 and 2015) to develop the economic models to the point where they could be integrated back into the geophysical models. And even then, these models had severe limitations in terms of details (i.e., no actual detailed modelling of resources) and possibilities for modelling different or historically unobserved relationships (such as are required for a circular economy).

CE research requires technical knowledge that could be as complex as the geophysical climate models: for example, things like assembly techniques used in products, toxicity related to production processes, tracking components over supply chains, assessing the availability of spare parts for repair or remanufacturing, energy requirements of metal recycling, ease of illegal disposal of a product, etc. The externalities are especially complex. The effects of economic processes on society that are not incorporated into market prices (True Price 2014), for example, could require in-depth technical knowledge, which is scarce, given high requirements for specialization and confidentiality—and considering that the d**ecisions of economic agents, behavioural considerations and straightforward consumer preferences are a different class of modelling complexities. However, these are the kinds of decisions we need to understand better in the context of a circular economy**. The purpose of economic modelling is to learn how we can most efficiently organize the economy (and maximize utility) given scarce resources: the economic objective. The purpose of modelling a circular economy, as with any policy-relevant modelling in the 21st century, has a similar objective: to properly incentivize, test draft legal regulations and convince decision makers. If one were to investigate the characteristics of the various individual elements in the circular flow of an economy, one would be forced to enlist the aid of a large number of the social and natural sciences (Leontief 1991). This might be the time for economists give the circular economy a more prominent role in the intellectual discourse.[26] And just as economics shaped the public statistical institutions in the 20th century focusing on employment data, it could shape public statistics in the 21th century by also focusing on environmental data.

A simple scheme that can be useful in this exploration is shown below in Table 11. It lists key concepts that define a circular economy. Policymakers can simply check to see how many key elements are present in their everyday work, and whether these key elements are more or less balanced. If not, one might find inspiration on where to look for improved political engagement for their policy.

Table 11 *Synonymous concepts from natural science (left) and economics (right) that could define a circular economy*

Circular	Economy
Kilogram	€, $ or any other currency
Planet	Society
Exergy	Utility associated with a product or service
Increasing entropy	Consumption
Decreasing entropy	Production and investment
Biodiversity	Inclusiveness
DNA	Transactions within intricate value chains
Ageing	Depreciation
Eco-system services	Social capital
Waste	Structural unemployment
Hazardous substances	Fraud

26 A Sciencedirect keyword search within journals with “economics” in title was done; “model” had 86.000 hits, “price” had 68.000 hits, “trade” had 47.000 hits, “capital” had 47.000 hits, “nature” had 42.000 hits, environment” had 40.000 hits, “raw material” had 5.500 hits, “circular economy” had 144 hits.

4.2 CIRCULAR BUSINESS MODELS FACE FAILING OR EVEN ABSENT MARKETS

We take the conclusion from Stegeman (2019) that in order to have a circular economy, you have to examine the institutions and rules that set up our economy and economic processes under a looking glass. Economics is about markets: markets are formed by demand (expression of utility) and supply to meet that demand. Markets direct priced scarcity and are therefore the most efficient way to maximize utility.

One of the central ideas of a circular economy is to create new loops. In economic language, in most cases that implies creating new markets because more than one firm will be needed to create those loops. We can call those new markets circular markets. However, one often overlooked question is whether circular markets can even be established. Derived from the existence of current markets, non-existent markets can never be more efficient than current markets; otherwise, they would already exist. **So, there is something wrong with circular markets in terms of economist market failures**.

For a circular economy, some typical examples stand out:

- Externalities: Market prices do not reflect the social costs of production and consumption of resources. Simply said, the cost of using materials and resources is too low. If this is not corrected (by means of regulation or taxation), other technically feasible options (such as using secondary materials) will remain too expensive. Hence, we still buy new (i.e., “virgin”) products.
- Imperfect markets: What quite often happens is that only one producer has a new technology that can reuse or replace virgin materials. Normally, this might be seen as a competitive edge. However, if the company depends for its inputs on waste streams from one or only a few suppliers, in the value chain this dependency makes this model riskier. What also sometimes happens is that repair services, for instance, are so specialized that they are only useful for the machinery of one company. Dependency in the chain is then also a risk factor. In general, the few suppliers or few parties who demand the product or service can be seen as incomplete markets and hence there is a risk that they will not emerge.
- Information problems: Creating markets requires that demand and supply can meet. In a circular economy these requirements are even greater, involving new technology, new demand, and quite often, the supply of discarded products, recycled materials, etc,. that has to be available to firms in large enough quantities to be used as inputs. This requires, first, information, data, which is nowadays either not available or scarcely available. A second challenge is that gathering these inputs often involves a lot of costs. If these transaction costs are too high, it might also impede the emergence of new markets.

Some of these problems can be overcome by more and better data*, regulation or simply time. However, in addition, markets can also fail systemically. The biggest threat for some circular strategies is the “locked-in” status of current markets. A telling example is the evolution of a typical automobile by the manufacturing industry. The idea about what a typical automotive vehicle should be (“a car carrying 4 to 9 people, with an internal combustion engine”) got established about halfway through the 20th century. After that, a relatively limited number of manufacturers set the pace and the direction of innovations in car manufacturing. Investments in infrastructure create a lock-in that impedes new enterprises from starting to make cars for new markets. Lock-ins are everywhere. You can spot them where the talk is only about “eco-efficiency” and “doing less” harm and where huge financial interests are involved.

* **suggestions for better data? See 3, 4, 8, 9, 11 and 13 in section 5.2**

So, the difference between failing markets and completely absent markets is what needs to be understood first. **Why are opportunities for a circular economy not followed up in (too) many cases? Because there is no market at all. therefore, policies are essential to create such robust markets** And, as we learn from the circular paradigm, it takes much more resources to create something new than it takes to repair its failings.

Market failure
Standard neoclassical economic theory can describe demand, supply and resulting prices in markets as a perfect reflection of human needs, with actual humans as “homo economics”: perfectly informed, moved by invisible forces and poised to make individual decisions that lead to an optimal societal outcome. This is the ideal model-exercise representation. But markets normally operate in a less than perfect way, and invisible forces are sometimes merely absent forces. The ways in which markets can fail this perfect image is extensively described in the economic literature and is very relevant for the circular economy. Market failures can be of a primary nature, such as negative externalities (e.g., “the polluter does not pay”), an imperfect market clearing (e.g., a monopoly or a situation where many suppliers can only serve a few customers) or a lack of information (e.g., “the one that tells me to repair my car is the one that benefits from that advice”). The secondary nature of market failures can come from the benefit of being a “free rider” (“over-consuming as a result of absent checks/feedbacks on consumption”), taking advantage of different tax regimes or suffering from lock-in/path dependency (“too late to change now”).

Sustainability to the core of the debate in economics
We finalise by pointing at recent publications on the contribution of economics to solving major societal challenges. There is a long-standing tradition on research on externalities (e.g. Tirole, 2017) and nobel-prize winners modelling climate change (Nordhaus) or how to work together as commons (Ostrom). Standard economics still has at its core the strong belief that markets can deliver sustainability outcomes and putting thereby the economic process central. There are other economic theories, such as ecological economics that start with the biophysical world and see the economy as a part of that total world. In the best-selling work of (Raworth 2018) some well-known heterodox research field are taken together and brought together in a visually compelling “doughnut”. Recently the OECD (2018) published a paper on ‘going beyond GDP’ and putting sustainability challenges at the core of economic policies. For the years to come, it is expected that there will be a lot more research on putting circular economy and sustainability to the core of economic modelling. An extensive overview on beyond GDP concepts is also provided by Hoekstra (2019).

4.3 COULD YOU GIVE SOME EXAMPLES OF HOW ECONOMIC CONCEPTS COULD IMPROVE THE CE FRAMEWORK AND RELATED DATA?

The concept of utility matters when discussing business or consumer decisions
One of the best things about CE research is that it is relatively easy to think about the possible decisions a person can make to apply circular strategies. We are all part of a household, and being an adult in a household means making decisions about transactions worth over 25 EUR a day. One should use these consumer expenditures to empathize with any transaction, including professional transactions worth a multitude of 25 EUR.

The set of circular strategies in the use phase are concisely listed in the value hill framework (Achterberg et al. 2016). **Depending on the available household budget and the expected utility of a product, one can (1) decide to reuse or share a product, including commercial sharing (i.e., leasing), (2) refurbish or repair an existing product or (3) see if there is any value (often money) to be made by offering a product up for recycling**. All of these actions are mirrored by enterprises offering the products or services that enable these micro-economic decisions.

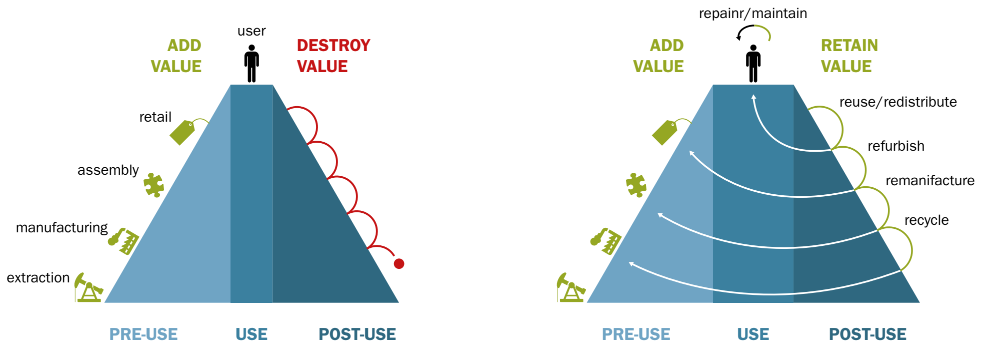


Figure 10 *The value hill (Achterberg et al. 2016)*

Utility
Utility describes the use, the value, the satisfaction that a consumer gets out of consuming a product. Measuring conventional utility in a quantitative way is not straightforward and, according to some authors, not even possible. As a proxy for utility, standard economic concepts take the (monetized) value that a market participant is willing to offer for a good or service, and this is proxied by observed transaction prices. This is, however, problematic, since (1) we can have market failures/incorrect prices and (2) it does not tell what utility is derived over the lifetime of a product, an element crucial in the circular economy. In spite of this, or maybe because of this, utility it is a vital concept, since it lies at the heart of the CE challenge: how can you maximize the value for a consumer of a good/product while minimizing the material use and environmental impacts that come with producing that good/product? Discussing utility opens the possibility of consuming something in a way that makes value retention possible.

Understanding mentalities and behaviour is essential if we want to achieve consumption reduction
There is another circular strategy that is rarely discussed as a serious option: consume less. It seems to be an inconvenient strategy. Practitioners frequently neglect “reduce” in their CE definitions, though, since this might imply curbing consumption and economic growth (Kirchherr et al. 2017). If you look very thoroughly at circular economy strategies, less resource consumption is also an implication of other strategies, such as lifetime extension of the use of products. The idea is, of course, that by using products longer, repairing them etc. the utility derived over the lifetime of a product increases. Therefore, the consumer derives the same utility of the product over longer product lifetime which implies less production of this product in the same time period.

The question is whether the general utility of a consumer can be greater with the consumption of less raw material. The different perspectives of groups in society, as described by Motivaction’s[27] Mentality Model, is helpful. It shows that only a few, relatively small, groups of society can be expected to sacrifice personal gain by the promise of a potential unknown reward. The general utility of total household consumption needs to be safeguarded before large groups in society can be expected to consume less raw material as a result of a free choice in the current interpretation of consumption (buying new stuff). If consumption can be defined more in line with its original economic meaning of utility, it might be possible that consumption of raw materials can be decoupled from consumption of goods and services. But that will probably take a shift from how people nowadays perceive consumption.

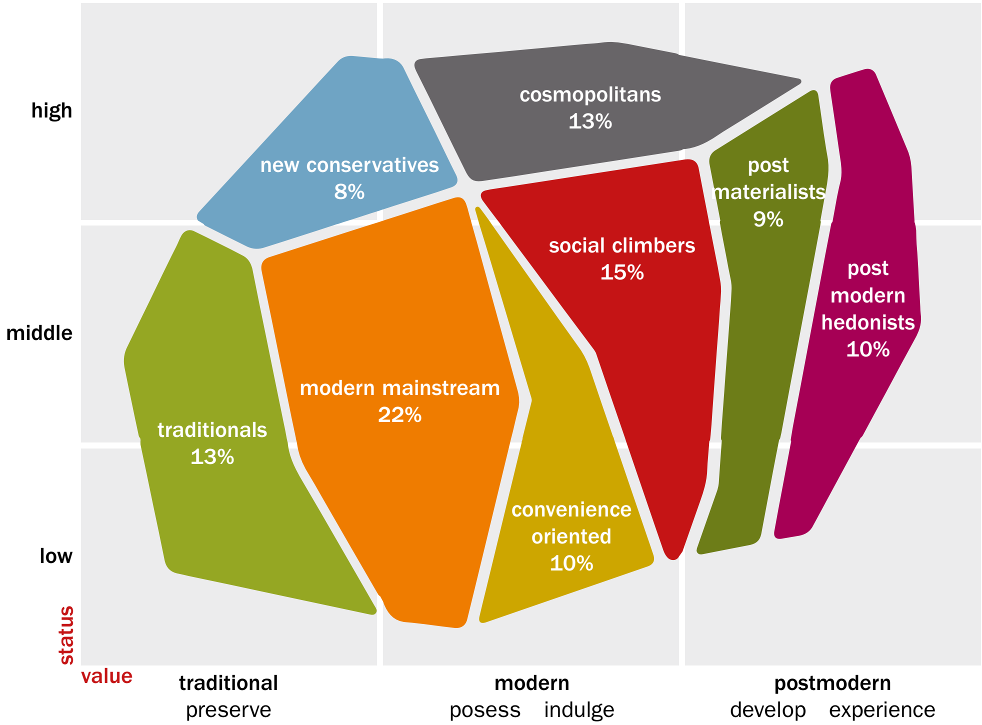


Figure 11 *Mentality model (Motivaction)*

27 Available at (accessed 11 October 2019): https://www.motivaction.nl/en.

The “mentality milieus” represent cultural backgrounds. By introducing this illustration, we highlight the possible relevance of strong behavioural barriers defining circular strategies. These behavioural barriers have implications for research aimed at supporting specific consumer behaviours. Trying to influence behaviour by offering information in the right way at the right time can be described as “nudging”. There is nothing wrong with nudging, **but observations suggest that there is something wrong with expecting major behavioural shifts by households as a result of nudging**. The resources aimed at influencing consumer behaviour should be focused on and linked to specific targets. Umpfenbach (2014) gives a robust overview of policies that go beyond nudging. If significant research resources are spent on nudging and nothing else, we can only hope it is worth the investment.

Behavioural economics
This field of economics describes the cultural, psychological and social concepts behind economic decisions. It can help to describe and predict circular opportunities in the context of their market, which can be done without having to engage in the many complex issues that drive human behaviour. It is already useful to take a limited set of key phenomena from behavioural economics, like regret, nudging and the types of bias that interfere with human decision making. These kinds of ideas are necessary to let economic agents behave along the ideas embedded in CE strategies: reduce, reuse, recycle.

Factors of production show how labour can substitute raw materials on a macro-economic level
Human progress is shaped by exchanging labour for capital stock and/or natural resources (Webster 2015): replacing muscle power with jet engines. Circular strategies substitute factors of production in the opposite direction, where labour can substitute for capital stock. This stems from the fact that labour is not constrained in the same way our planet is. Moreover, society has an intrinsic need for its members to participate in the economy. Economically and mentally, this is challenging. The reason for substituting labour for capital was productivity gain. The other way around means a loss in labour productivity. Employers will be aware of the fact that they produce less economic value per hour.

A production function expresses the technical relationship between the physical quantities of inputs that go into the production process (called factors of production, such as labour, capital, land, energy, materials) and the physical quantities of the resulting output. Physical quantities can be expressed in monetary terms, given the prevailing factor prices for the factors of production, and the output price. In some economic models, such as Cobb-Douglas, natural resources or raw materials are not even considered to be an explicit production factor.

A circular economy, as any economy, has production functions that describe, for instance, how labour (L), capital stock (K), energy (E) and raw materials (M) are used in the whole of the economy. However, when looking for research on CE production functions, the topic is still sparse in the literature (McCarthy et al. 2018).

One important aspect of the production function of circular activities is the possibility of substitution of labour for materials, energy and other inputs. As a result, labour input for one euro of output goes up. This is contrary to the usual direction of factor substitution in linear activities when energy, material and capital substitute for labour, and hence labour input for one euro of output goes down. This type of factor substitution is known in the environmental economics (Morgenstern et al. 2002; Deschenes 2012; Bovenberg and Van der Ploeg 1996; 1998). In that case, cleaner activities require more labour per on euro of output than more polluting activities. The report by CPB and PBL (CPB/PBL 2018) discusses the issue of the substitution between labour and other production factors in the framework of environmental goods and services sector, which is much larger than circular activities. In this case, such substitution effect is not clear. However, if we consider circular activities in the proper (narrow) sense (refurbishing; reuse and remarketing; product life extension; recycling; and servitisation and biorefining) then this effect appears quite pronounced. We illustrate this effect and its economic consequences in the example below.

We can illustrate the use of production functions with a comparison between repairing an older car and buying a new one. We consider a two-period production function: period 1 (same as a linear activity) is characterized by the standard production function of producing the virgin product. Volume of output is the function of inputs, such as labour, capital, materials and energy. After the life of the virgin product comes to an end, period 2 starts (the circular activity). The virgin product is reprocessed (refurbished) in order to give it a second life. The reprocessing is also characterized by its own production function, which specifies the relationship between the quantity of the refurbished virgin product and the same factors of production as in period 1. However, there is an additional factor, which is the residual virgin product at the end of its life.

This can be translated into a simplified example (Table 12) of refurbishing a Jaguar auto engine, with two aggregate production factors—labour and other (approximated by materials). The value of the new car is 30,000 EUR. The value of refurbishing the used engine at the end of its life is 10,000 EUR. The labour cost of making a new auto equals 40 units (hours) while the labour cost of refurbishing the used engine at the end of its life is 120 units, that is six times the cost of the original manufacturing. The use of materials that represent all other inputs for the new engine is 220 units, while the use of materials to refurbish the old engine is 20 units: one-eleventh of the cost of the original manufacturing. This can be summarized as shown below.

We can identify two production processes in this table. Period 1 represents the traditional linear manufacturing activity and period 2 represents the circular activity. Period 1 production comprises 40 units of labour and 1640 units of other inputs (represented by materials) to yield 30,000 EUR of value of the new auto. Period 2 production comprises 120 units of labour and 20 units of extra (added to the original 1640) inputs to produce 10,000 EUR value of the new engine. Therefore, in the second period, the labour intensity is twelve times higher than in period 1 while material intensity is one-twenty-seventh that of period 1. Hence, there is a clear substitution of labour for materials in the period 2 production function compared with the period 1 production function.

Table 12 *Production factors in linear and circular business models*

	Period 1: Manufacturing the auto	Period 2: Refurbishing the engine
Value (euro)	30,000	10,000
Labour	40	120
Other (materials)	1640	20
Labour per value	0.001	0.012
Material per value	0.055	0.002

If saving the remaining 20,000 EUR of value after refurbishing is considered (total cost)

Labour per value	0.001	0.004
Material per value	0.055	0.001

To make a further clarification, we can take into account the savings of the remaining 20,000 EUR of the cost of the auto from refurbishing of the engine. Assume for simplicity that a refurbished auto has the same life as the new auto. In this case, the labour intensity of period 2 is twenty-four times higher than that of period 1, and material intensity is just one-fifty-fifth of that in period 1. We conclude two things from this exercise. First, the inevitable but acceptable fact that circular strategies may lead to lower labour productivity. Second, if the activities discussed in this example take place in one and the same sector, the impressive shifts in labour productivity are not observable in any macro-economic assessment of that sector.

The refurbishing process could lead to fewer new cars manufactured and sold, so this process of replacement of secondary production over virgin production should be taken into account when assessing the overall economic effects of circular activities. It is also possible that refurbished cars represent a new market that is complementary to the new car market (Zink &Geyer 2017).

Introducing a simple scheme showing how job growth and added value are influenced by (circular) innovation

Public authorities will want to know the impact of (disruptive) innovations on the labour market. This is especially true for possible circular economy innovations that want to combine the promise of economic growth with social and environmental benefits. A simple tree diagram can show how one can explore the claim of real economic growth, using three discrete choices: Is an innovation disruptive or incremental? Is there labour productivity (“amount of euro produced per time unit”)? And is the elasticity of demand smaller or greater than 1?

We can look how the demand for specific tasks of a labour force can be carried out. This list of tasks will include activities such as operating specific machinery, keeping records about certain aspects of the process, maintaining relations with external partners, and managing tasks. The exact nature of the tasks required within the organization results from both the organizational structure of the firm and the technical nature of the process. Tasks must be combined into jobs, i.e., specific lists of tasks that are carried out by a single worker or in cooperation with others, which must be filled by trying to match labour demand with existing labour supply in the market. This matching process is likely to be influenced by frictional factors, leading to adjustment costs associated with changes in the terms of how jobs and tasks are filled. All of this is captured by labour productivity: What can a worker produce in terms of real value within a time unit?

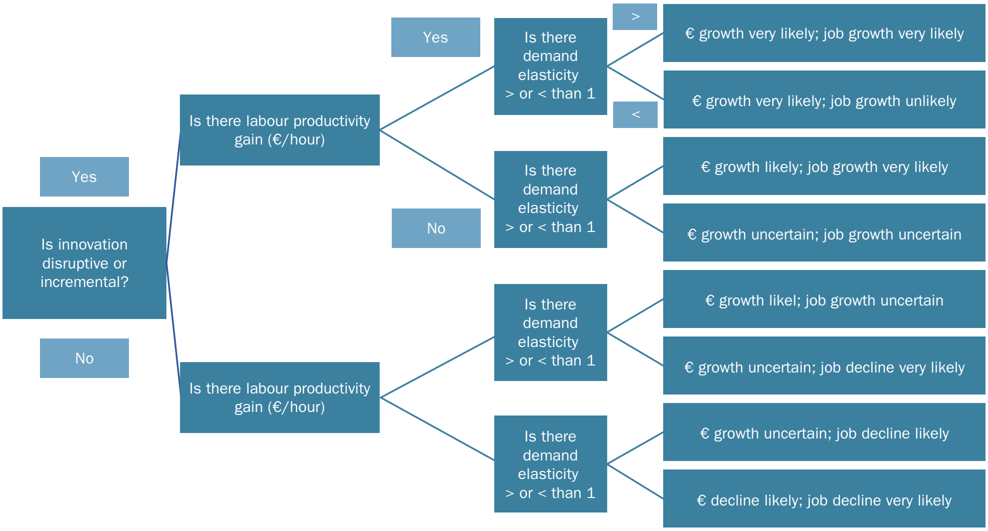


Figure 12 *A tree diagram using three discrete key questions (disruptive/incremental, labour productivity gain Y/N, demand elasticity > or < than 1) to quickly estimate growth in value added and jobs as a result of innovation.*

The diagram in Figure 11 might be simplistic, but it directs any conversation about innovation, labour productivity and elasticity of demand in a fact-based direction.

Disruptive innovation
This is the “mutation” of economic processes into products and services that are radically new compared to the existing economy. It is also referred to as Schumpeterian creative destruction. One might describe this type of innovation by a simple set of questions that help differentiate disruptive innovation from incremental innovation:
– Has a product the potential to decimate the market share of an incumbent company?
– Are consumers to give up the utility related to a creatively disrupted old product (e.g., the sound quality of a gramophone record)?
– Does a new product require public investments in capital stock?
– Does a new product require new or extended law enforcement?

Examples of potentially disruptive technologies relevant for a circular economy:
– Additive manufacturing
– Analyzing data marketing on sold products
– Enabling novel structures for buildings, electronics, vehicles, etc., from composite materials
– Monitoring operations through the internet-of-things

Price elasticity of demand/supply or elasticity between production factors
This refers to the tendency to consume or supply a certain product or production factors given price shifts. Elasticity can also describe the production factors (capital stock, labour, raw materials, energy, etc.) being used at a fixed rate of increase or decrease of one unit. We mentioned the possibility of substitution between the factors of production from capital stock to labour. For instance, using more capital and less labour can produce the same output as before. The ease of substitution is mathematically expressed by the coefficient of elasticity of substitution. If the elasticity of substitution is zero, then substitution between factors is impossible. Therefore, if the use of one factor decreases, output decreases as well, even if we use other factors of production. If the elasticity of substation is infinite, then factors can be substituted: one unit of one factor for a fixed number of units of another factor. In this case, the production function has a linear relationship between inputs and output.

Labour productivity growth, capital productivity and raw-material productivity growth:
Productivity growth simply means doing more with the same, or the same with less. Labour productivity describes the amount of value resulting from the number of hours worked. Capital productivity describes the amount of value resulting from the amount of capital stock (buildings, transport equipment, machinery, ICT systems, etc.). Raw material productivity describes the amount of value resulting from a specific quantity of raw materials, be it primary or secondary. Other types of growth (of the population, expenditures, use of raw materials) are less likely to increase prosperity than productivity growth is.

Rebound effects and market size need to be better understood for circular economy robust policy
A fundamental reduction of negative environmental impacts happens when final consumption patterns shift from products with large footprints to products with small footprints (or reducing production footprints altogether, but that is not discussed here). Alternatively, when rebound effects prevent consumption from shifting to products with smaller footprints, the desirable reduction of environmental impact is diminished. When looking at final consumption patterns, a crucial phenomenon is the long described rebound effect, which comes from energy consumption. It was observed that cheaper energy costs induce more energy consumption, which is a direct rebound effect. But one can also think about increased consumption in other markets; therefore, rebound effects are both relevant and painstakingly difficult to account for in the CE context. The concept of the rebound effect, as defined in energy economics, is insufficient to describe the different secondary effects that are of interest in industrial ecology or sustainable consumption. Additional mechanisms and multiple environmental endpoints need to be considered (Hertwich 2005). Another complication is offered by the prospect of a theoretical maximum market size: when the demand for a highly specific good or service is met, opportunities for growth are non-existent. Examples of these highly specialized markets could be the need for insulation for a limited number of houses. To assess CE opportunities, the size of the market must pass a certain threshold to enable analysis of how a circular strategy can be applied so that it will “show up on the radar”.

Rebound effects
Rebound effects in general can lead to unintended consequences from an ex ante more sustainable idea. For example, when the price of a certain product or service decreases, it can result in increased consumption of the same product or service, or increased consumption elsewhere in the economy. This is also known as the Jevons paradox (Jevons 1866). Rebound effects are relevant for a circular economy because they require expenditure patterns to be modelled on a macro-economic basis and the resulting set of expenditures of a consumer after applying circular strategies to be assessed.

Theoretical maximum market size
This refers to the size of the market of a product if all potential customers are served. Affiliated concepts are the total available market (TAM) and the serviceable available market (SAM). It shows limits to the growth potential of products, such as niche products in a circular economy. For example, a substitute for cement with reduced CO_2 emissions and similar or reduced toxic emissions has a large maximum market size, but for instance musical instruments in Peru made from plastic waste are likely to have a significantly smaller market size.

The regional perspective is highly relevant for following up on CE opportunities
The promise of a circular economy has arguably struck the strongest chord on a regional (i.e., sub-national) level. Regions all over the world see CE strategies as an opportunity to revive local economies and preserve the strengths of geographical or cultural characteristics. Regional economics is the study of economic phenomena that have a spatial dimension. Some of those phenomena are relevant to circular strategies are the notion of the economic base, tacit knowledge, and transaction costs. The concept of an economic base can look at a region and ask which economic activities are generating an inflow of capital, and how new circular activities can expand on that economic base. The so-called Balassa index is an indicator that relates to this. The Balassa index describes an apparent advantage, or specialisation, of a region in terms of imported and exported goods and services. Questions that need to consider the economic base are, for instance: What should the catchment area of a repair service or waste collection be? What circular strategies fit with the current specialisation of a region, such as horticulture, industrial maintenance or a certain construction material? Tacit knowledge is an enigmatic but observable factor in developing new economic activity, whereby trust and strong cultural networks can allow an innovation to be shared and developed. The trust ensures that the knowledge is retained in the region. The role of family-owned businesses, for instance, which are particularly relevant on the European continent, can be characterized by reduced transaction costs relating to new investments. Last, transaction costs can be significantly reduced in regional exchanges of material flows. In innovative products especially, the fact that individuals are embedded in a region reduces the costs of finding transaction partners, arranging deals and verifying the actual delivery of goods and services. It is important to note that the regional economy phenomena have trade-offs: lower transaction costs (“can I get it from a friend around the corner”) contradict the opportunity for specialisation. A strong economic base can result in a monoculture, reducing opportunities for tacit knowledge spill-overs.

(Tax) Incidence
Where (in terms of geography or in the social landscape) do impacts take place? This concept is usually used in taxation policymaking when discussing which part of the economy (upstream suppliers, retail, households, etc.) will carry a tax burden. In a more general sense, incidence can be used to describe that part of the economy that will feel the costs or benefits of regulation or subsidy. One can't adopt a circular policy without having some notion of incidence and how incidence interacts with concepts supply and demand elasticity. This is very similar to the tax incidence, which also depends on supply and demand elasticities.

Economic base & comparative advantage
Every economic activity in every region or nation can be described as being basic or non-basic. An economic base can be expressed by activities that can be exported and drive the region towards prosperity, such as transport equipment, genetics R&D, measuring equipment, tourism, etc. Non-basic activities are generic activities aimed at serving the economic base, such as restaurants, construction work or waste treatment. This theoretical distinction is often accredited to Werner Sombart (Krumme 1968). A related concept is the way to express the specialization of a certain sector in a region. When the size of a sector is incommensurately large in a region in terms of employment (for instance, transport services or aircraft manufacturing), then this offers evidence of specialization. It is relevant for CE research since it might more accurately identify potential, either for growing existing activities or developing related new activities.

Tacit knowledge
This is knowledge that is obtained gradually, on the job, and is disseminated very slowly because it is hard to transfer through conventional documentation. It is relevant for a circular economy since it can ascertain whether enterprises involved in circular strategies have the possibility of protecting or scaling new business models.

Transaction costs
These are all costs involved in finding, buying and verifying an economic transaction, which can apply to something as simple as buying disposal bins or as complex as purchasing an apartment building. It can also refer to transactions within an organization; then these costs are called coordination costs. Transaction costs are crucial in circular strategies. Every extra step in making a loop involves transaction costs and can only be created if these costs are lower than the benefit (for each participant) of taking that extra step

SNA-based macro-economic models should incorporate essential circular strategies
One of the cornerstones of the field of economics is the political power that macro-economic models have in predicting economic growth in the short term (Hoekstra 2019). Many of these macro-economic models are based around the concepts of an System of National Accounts (SNA). Policymakers can appreciate the capacity of models to explain the consequences of major changes in a particular sector in relation to the economy as a whole (André et al. 2010; Aguilar-Hernandez et al. 2018), And policymakers of global institutions emphasize the importance of growing the economy in sustainable ways (Lagarde 2019), which is almost impossible

without circular strategies. These statements lead to the expectation that SNA-based models are a vital tool for assessing opportunities for a circular economy. Yet the available data and corresponding models are not mature enough to estimate the impact on economic growth, job growth and global competitiveness in a way that is robust enough for political leaders to build their message. It is necessary to establish a causal link between economic activity that is created as a result of circular strategies and the effects on the labour market, a need highlighted in SER (2016).

Macro-economic models are determined first and foremost by scenario assumptions. The assumptions that are fed into these models—those concerning future rates of productivity growth, the substitutability between different material types, and future consumption patterns—are key determinants of model outcomes (McCarthy et al. 2018). In most case parameters in the models estimated on timeseries based on the SNA and in other cases derived from theory and models are thereafter calibrated to deliver plausible and usable outcomes. For example, Meyer et al. (2016) state that technical coefficients are exogenously adjusted for the manufacturing of metals, non-metallic minerals and paper. Using material-, sector- or product-specific underlying studies can be very useful in helping to frame the scenarios (Winning et al. 2017).

To make meaningful scenarios and forecasts, the modeller should, for instance, have the costs of component recycling, better use of industrial waste, reparability, possibility to communicate through the web or compare transport costs. Long story short, the empirical evidence, predominantly in the shape of data, is scarcely available to do this. An example can be taken from Exiobase[28] or EORA[29]. For instance, available data for the repair, lease, waste and recycling sectors need to be verified with further field surveys.

With proper data, one can assess proper scenarios. Substitution between materials and capital and labour can be analyzed by these models. One can think of material-for-material substitution, product-for-product or functionality-for-functionality. An endogenous model could choose to enable the substitution for materials (i.e., product groups for better performing capital stock or services). In the few cases that these substitution options have been modelled, these options were based on existing technologies or simply exogenous input. This means that innovations in product or process design not can be taken into account or that there is no feedback at all between production factors. The model should also identify the part of the sector/industry that represents the circular strategy. Where can repair, maintenance, leasing, etc., be seen in the model? Finally, it should capture the demand for the product and the production volume of the circular activity versus the demand and production of existing products and processes.

28 https://www.exiobase.eu/ (accessed 11 October 2019).
29 https://worldmrio.com

System of national accounts (SNA)

The last concept we want to mention is not only a concept, but a set of methodologies and tools, developed in the 1930s and 1940s to measure how national economies operate and how they respond to centralized interventions. One of the most frequently used elements of an SNA is an input-output (IO) table (see Figure 12). It creates the opportunity for a region (i.e., nation) or a set of regions to assess the annual flow of products, as well as how they are used by sectors as intermediate products and by consumers as final products. The use of labour and capital (amortization) by sector is described as factor inputs in the value added block of the input-output table. An environmentally extended input-output table (EEIO) can link environmental effects such as GHG-emissions or toxicity to specific products and specific sectors in certain regions.
The power of SNA and IO tables can also be illustrated by what they can describe, such as the flow of iron ore to China and from there in all products containing iron (more than a few!) from China to the world, or the environmental interventions (e.g., emissions) associated with oil-seed operations in Malaysia when chemical products are produced in Italy, or the final consumption of poultry from Brazil served in a restaurant in Canada.
The disadvantage of using an SNA lies in the “homogeneity assumption”, which by default treats large parts of the economy as completely similar. This lack of detail limits its analytical strength when assessing specific products, sectors or regions. Another disadvantage of making IO tables into EEIO is when proportionality between monetary and physical flows is assumed.

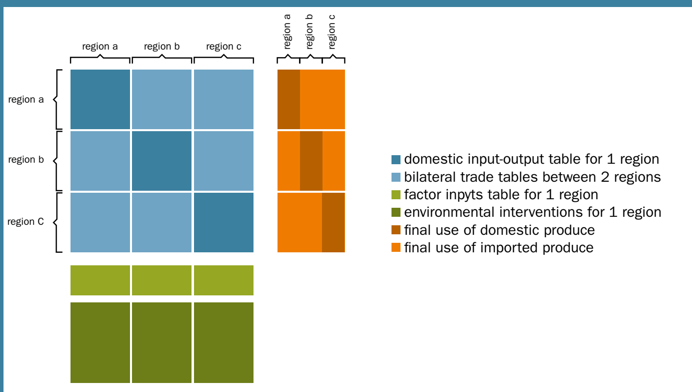


Figure 13 *Basic representation of a multi-regional IO table (Tukker et al. 2016)*

Economic growth / GDP growth

Economic growth is the core concept that puts economic news in the centre of political or public attention. One of the central outcomes on a macro level of the SNA is gross domestic product (GDP). The growth of GDP within a region (a country) in a certain period (e.g., a year) is referred to as economic growth. This equals the growth of production, income or expenditure in a country in a year and is measured as the financial values of all market transactions in the economy. This concept is crucial in standard economics, and normally more growth is perceived as desirable. However, some elements are at odds with circular strategies. For instance, using a product longer (so not buying a new product) will diminish GDP.

5 MAKING A CIRCULAR ECONOMY ASSESSMENT FIT FOR FOLLOW-UP

This chapter offers the recommendations that we think will enable the creation of robust policies, that will in turn enable business decision makers to follow up on CE opportunities.

5.1 HOW CAN BETTER DATA SUPPORT A ROBUST POLICY MAKING PROCESS?

Wisdom comes from knowledge, knowledge is created by good information, good information can only be driven by good data. Robust policy making obviously needs more than just good public and reliable data. The initial need of policymakers in recent years has been to find a match between politically urgent problems and the solutions offered by circular strategies. Themes in the news may influence the policy agenda, and in recent years, subjects like microplastic pollution in the oceans and microplastics in food have drawn a lot of attention. Prominent policy debates like mitigating climate change also have significant CE dimensions. For example, avoiding the production of fossil-fuel-intensive materials will reduce emissions of greenhouse gases, and so does avoiding the incineration of waste plastics, or reducing the consumption of animal protein. Verified and updated data can demonstrate how much reduction can be expected from different scenarios, thereby enabling generic goals to be more likely to be turned into action. **Policymakers are under increasing scrutiny from the public and media regarding their efforts and results**. Progress on realizing a sustainable system needs to be illustrated with highly visible steps forward in the short run. In this respect, accurate, quantified information on progress is an essential requisite for policymakers.

Referring to Table 1 from chapter 1, Table 13 presents an overview of the policy cycle phases, starting, from left to right, with goal formulation leading to evaluation of policies. Based on chapters 2, 3 and 4, we highlight the different phases and data that enable robust policy making. Dark green shading represents expertise that is deemed sufficiently present. Dark red shading represents expertise that seems to be absent. Lighter shades of green and red represent less prevalent instances of these situations. In some cases, a reference is given to a section. If no reference is given, no information could be found about existing data that can inform policy makers in that particular phase.

The discern the following phases in the policy cycles for a circular economy transition.

Generic goals

The policy cycle starts with generic, now quantified, goals that are Safe, Clean, Just, Reliable, Sustainable, Affordable. This addresses the need for common principles upon which the further actions have to be assessed. Politicians will, in some cases, already have strategies in mind on how to pursue the generic goals (recycle more, improve material efficiency, mitigate negative impacts, ban products)—strategies that might require compromises and social or political support. The strategies need to be illustrated and underpinned by general indicators (e.g., Primary use, Recycling rate, Specific Material consumption) and research is needed to define them and identify reliable and continuous data sources. Typically, this requires a protocol or standard, preferably international.

Formulating strategies, estimating potential and setting targets

Setting quantitative targets for the indicators is the most important first action of policymakers. At the same time, as the shading in the table indicates this phase struggles to match policymaking with available data and expertise. Ambitious target figures (for instance the goal set in the Netherlands to reduce 50% of primary raw materials by 2030) present both a challenge and an attractive future perspective. Often, these are not founded on research, but on various political and strategic considerations. Responsible politicians want to know what their real challenge is but might not want to share that publicly. Insights into which potentials must be aimed at might be proprietary or confidential information.

Formulating strategies, estimating physical potentials and setting quantified targets are closely related. A desirable, or at least rational policy cycle would (based on accepted goals) start with identifying the ‘hard’ physical potential that a transition towards a more circular economy could deliver. Insights in recent innovations (and on a more modest level: best practices), cost-benefit-analyses of these innovations, fundamental limits dictated by the laws of thermodynamics, all play a role in setting these physical potentials. A subsequent step is the assessment of the proportion of these potentials that might be harvested: in other words, which are the targets that can be set, taking into account (amongst others) the broader socio-economic consequences of these targets. These targets then lead to a fact-based and analysed strategy.

Choosing and implementing policies

The next phase is the design and launch of a package of policy instruments and actions, which will include one or more taxes, subsidies, standards, regulations, or communications and is made SMART with budgets, timelines and responsibilities. This package has to pass through democratic institutions, normally requiring an impact assessment (which needs independent information) to check all the social, economic, environmental and legal consequences. But subsidy schemes may also require support from elaborate independent knowledge, remaining deliberately vague on all the consequences, for strategic reasons.

Impact monitoring and evaluation

The last element in the policy cycle is typically monitoring and evaluation. How a decision works out in real life has to be evaluated. There are many policy evaluations available that assess the impact of decisions that shape a circular economy. After all, only the real world can be used to test policies, and target groups may respond differently than expected. Moreover, external conditions may change. Research on actor behaviour or even participation in implementation processes, requires multidisciplinary knowledge. Monitoring has to be designed and prepared in the stage where indicators are chosen. Top-down data availability largely affects the design of monitoring systems. Additional and bottom-up monitoring has to be implemented not later than the launch of the policy package. For policymakers, monitoring is a mixed blessing: the results help with the tuning of instruments and can pose an early warning system, **but monitoring results may create criticism and resistance if they overlook the vital positive effects of a CE transition**.

Table 13 *Policy phases relevant for a circular economy (with references to sections in this book where an issue related to a phase is discussed)*

	Formulating generic goals	Formulating strategies	Estimating potentials	Setting quantified targets	Choosing and tuning instruments	Policy implemen-tation	Result monitoring and evaluation
See section	2.1, 3.1, 3.2	2.2, 2.6, 2.7, 3.3	2.4, 2.7	2.5, 2.6, 3.5	3.5		2.5, 3.4
Existing methods to define robust policy	Problem signalling or agenda setting	Societal and political validation and analysis	Based on innovation policy and best practices, or best available technology	Visionary targets, based on calculations of target feasibility	Ex ante, ex durante or ex post policy impact analysis	Target group behaviour/ cultural analysis. Providing frontrunners (businesses, branches, regions) with the necessary conditions	Evaluating impact on effects ("what you want in the end") and actual achieve-ments ("policy output")
See section	2.1, 2.5, 4.1, 4.2	2.4, 2.5, 3.3, 3.5	2.7, 3.5, 3.6, 4.3	2.5, 3.5, 4.3	3.6		3.5
Required data to support existing methods, as identified (#) in section 5.2	6, 10, 11, 18	1, 2, 9, 12, 13, 14, 18, 20	All	1, 2, 5, 10, 11, 14, 15, 18	1, 2, 3, 4, 5, 9, 12, 13, 15, 16, 19, 20	1, 2, 5, 17, 19, 20	All

"Plan-Do-Check-Act"

- Present and successfully provided
- Expected to be present but not yet provided
- Possibly absent, not yet explicitly demanded
- Absent

The narrative of the coastline village

Researchers who aim to be published in the public realm can be characterized as fishers. There is a sea of data and information, available to anyone venturing out onto this sea. At the other end, corporate activities, featuring intellectual property and entrepreneurship, can be imagined taking place on an industrious wooded hillside, delivering highly valuable products and corresponding services in a hard-to-penetrate and opaque environment. Fishers do not go onto the hills and indeed should not go there: confidentiality is a precondition for a competitive business. Society can be characterized as the village between the hillside and the sea, served by both public research and private industries. The area where these two worlds meet is the scarce space available in or around the village. Meetings with both fishers, villagers and industries take effort, and it's unclear what can come out of these meetings. It is therefore no wonder that it takes patience, stamina and extensive deliberation to identify the need for relevant information from one world to another. After all, the quality of life in the village, and the delivered necessities and conveniences of life, is the result of the quality of the interaction between the public sea and the private hillside. Solutions carried by the ongoing information revolution will greatly improve the quality of this interaction.

(drawing by S. Oggero)

5.2 HOW CAN WE FIND BETTER DATA FOR ASSESSING THE CIRCULAR ECONOMY?

This book provides the basis for specific recommendations for generating improved or new data to support a CE transition.

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
1	Data that are clearly related to a product or a product group	What are products? And what are the materials involved? A seemingly trivial question, but fuzzy product definitions can cause enormous amounts of ambiguity in many conversations and studies. We suggest considering international trade data and products that are directly linked to current economic activities. Trade data are made available in a global classification called the Harmonized System or Combined Nomenclature (HS/CN). Economic activities are linked to products by the classificati-ons of products by activity (CPA). The HS/CN and CPA classification are the most detailed in terms of product specification, and they are geographically specified by nation state. These classifications should be improved by increasing the level of detail on product groups, getting from general labels such as “electronics” to 6–8 or even 10 digits that describe relevant and specific products.	Benchmarking a product innovation to the rest of the product group.
2	Data that are clearly related to economic sectors of activity that are clearly related to economic sectors of activity	Arguably the most used public data are organized by economic sector, describing labour markets, capital stock and sector-specific taxes and subsidies. These data are described by the global International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 4 from the UN or Nomenclature statistique des Activités économiques dans la Communauté Européenne (NACE) Rev. 2 from the EU. Currently, sectors are described on a 1-, 2-, 3- or 4-digit level. The NACE and ISIC classifications are the same on a 4-digit level, representing over 600 sectors or “classes”. The coverage of global data should improve to a 4-digit standard.	Liaising sectors to all relevant ISO standards of the ISO/TC 323 circular economy (ISO 2018).

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
3	More detailed system of national accounts (SNAs) or input-output tables	Better sector and product data lead to better national accounts. The abovementioned better product and sector detail will improve the analytical power of any SNA. The best examples of accounts with an existing high level of detail ("granularity") are the ones from the United States and Japan. Bringing the European system of national and regional accounts (ESA) to the level of the US or Japan would already be a huge leap forward in assessing impacts over supply chains. Also, accounts should be assembled at least once every five years by tho-rough surveys using state-of-the-art ICT techniques.	Assessing an impact related to a product or sector in a region, nation state or world economy, including assessing typical supply chains, which are generally global and therefore described by data with global multiregional SNA scope.
4	Improve physical supply-and-use tables	Where SNAs are expressed in monetary terms ("money"), it is necessary to have consistent physical extensions: materials. Detailed physical supply and use data (e.g., 400 product groups in physical weight units) are available for research purposes from the German and Netherlands Statistical Offices. Raw material extraction sectors at the very first stages of the supply chain can cause over 50% of the total deviations in modelling results, stemming from the technology matrices (Giljum et al. 2019). These are not published at that level of detail because of confidentiality requirements, but they could be used at an aggregated level to update public SNAs at a European level. Conversely, material flow analyses on a national level, based on other sources than a SNA, should transparently be mapped to the SNA to create mutual analytical strength.	Unlocking a wealth of material flow analysis by merging it with SNAs; discipli-ning monetary data by matching it with possible limits to the use of natural resources.

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
5	Make use of data from product lots of eco-directive	There is a wealth of information available about products subject to the EU Ecodesign Directive (ECEE 2019). The EU Ecodesign Directive covers all energy-related products sold in the domestic, commercial and industrial sectors. This information needs to be linked to databases that can be queried and directly related to macro-economic statistics. Such properties as energy consumption, material composition, components used and lifetime distribution can be mapped in a consistent way, using or referring to existing information	Discussing the viability of proposals for extended producer responsibility.
6	Better data on general waste flows	Waste flow data are currently collected using classifications like the Waste Statistics Regulation, the Extractive Waste Directive in the EU or, globally, under the Basel Convention. But these data can show many data gaps and curious or outright unreliable results, which frustrate making accurate estimations on size and purity/quality of a flow. The waste data problem is described as the “hole in the circular economy”. Furthermore, the data should enable us to answer questions about the vital “end-of-waste criteria” and the circular strategy that involves recycling that is highly dependent on sensible and dynamic end-of-waste criteria. The need for better waste data is also described in the Raw Materials Scoreboard (EC 2016b), which has, for almost all circular indicators, a section dedicated to “The search for suitable data…” For the most relevant waste flows like waste of electronics and electrical equipment (WEEE), it is difficult but highly relevant to have a clear picture of how much waste is actually generated, collected and then prepared for re-use/recycling/recovering at national and EU levels.	Giving a boost to the market for secondary materials and thereby stimulating new circular businesses, optimizing public invest-ment in waste treatment while respecting available social capital and the labour market.

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
7	Better data on industrial waste flows	The waste streams generated during the manufacturing process have some characteristics that are different from general waste flows. As a result, opportunities to retain value of industrial waste, through industrial symbiosis for instance, have different enforcement and data requirements. Industrial waste is often measured as part of regulatory monitored emissions, such as the European Pollutant Release and Transfer Register (E-PRTR). Evaluations (EC 2016c) of this legal register mention issues with data quality. For example, shortcomings in the data provided by operators, shortcomings in validation, lack of time-series data, too strong dependency on modelled or estimated data, etc.	Assessing quality (i.e., technical value) of possible streams within a processing plant or chain whilst adding the option to compare it to similar waste flows.
8	Expanding the use of open-source life-cycle inventories	The data that fuels life-cycle assessments is delivered by life-cycle inventories (LCI). These are often made public, for instance when providing supporting information for academic papers. Some excellent initiatives have even centralized these data.[30] As an example, the ILCD database (EC approved) is available at no charge. PEF also provides a database to be used in product declarations. This is free to users that are developing assessments for product categories.	Free and online LCI will strengthen the base for common methodologies such as PEF.

We think efforts to collect and create the following data should be increased, expressing the concern that there is little evidence that this search for data has started in recent years.

30 See PEP Ecopassport (www.pep-ecopassport.org/), Ecoinvent (https://www.ecoinvent.org/) and AusLCI (www.auslci.com.au/index.php/Home), accessed 14 October 2019.

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
9	Data on repair & refurbishment	Waste data might be suboptimal, but data on materials and components used in repair and refurbishment are almost absent (Hoekstra et al. 2015). Allocating research budgets to document repair and refurbishment activities is a no-brain investment when developing a circular economy.	Offering perspective to policy makers to enable business models aimed at economical lifetime extension strategies
10	Combining life-cycle inventories and macro-econo-mic models	LCI sources should be linked to macro-economic models (Wiebe et al. 2019), to create a definitive link between the micro-level products and processes and the macro-level national economic accounts. This would significantly improve the usefulness of hybrid LCA approaches (Crawford et al. 2018).	Benchmarking a product to the rest of the product group; developing policies on sector and product level (production and consumption); relating specific CE innovations to national targets.
11	Quantity of (specific) raw materials	Despite an extensive body of work containing material flow analyses, a direct link between products from official classifications and raw material content is not formally available below a 2-digit level, let alone amounts of materials per product. Given the existing macro-economic data (for instance, about products that are put on the market annually), this presents a real opportunity for future research (EIT RawMaterials 2019).	Mapping the amount of specific metals embedded in intermediate and final goods traded around the world. It would subse-quently help to assess the impact of strategic police measures in reinforcing such supply chains.

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
12	Size of the urban mine	Urban mining considers stocks of materials in society as potential mines. Existing urban mine studies should be promoted to official statistics, introducing stock data in regular corporate and governmental statistics. Future research could be linked to public GIS data and data on monetary capital stock (Aguilar-Hernandez et al. 2019).	Estimating the amount of secondary major metals that we can expect to be offered for processing in the coming five years.
13	Documented product lifetimes	Every product group has a typical lifetime distribution that can be described statistically. Some studies have started to model these lifetimes (Bakker et al. 2014b), but these are not monitored or documented in a central database. Lack of knowledge about the aging dynamics of in-use stocks means that future end-of-life recycling input rates (EoL-RIR) cannot be effectively modelled (Mayer et al. 2019). The impact of lifetime extension strategies cannot be assessed without these data.	Improving corporate accounting and stock assessment for households and corporate slow-moving equipment.
14	Reliable waste exports	The quantity of end-of-life products exported legally or illegally (for example, by building on the CWIT e-waste exports report, sensors in public infrastructure or waste-collection systems) is important given the need to assess required catchment areas. Another relevant use of these data will be to fight the devastating effects of waste dumping on a global scale.	Assessing the optimal size of end-of-life recycling on an international level.
15	Better data on secondary materials	Data on secondary materials that are put back into the economy as “quasi” raw materials are still inadequate for many policy decisions. The data should be able to compare quantities of primary and secondary material to ascertain the EoL-RIR of materials (including waste treated outside of the EU). This EoL-RIR rate means recycling that can truly replace the need for primary extracted raw materials.	Chasing the holy grail of the most common circular strategy: recycling. To what extent can we truly circulate material after a use cycle? And updating the influential work of UNEP (2011).

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
16	Better data on secondary components	For suggestions about the value of components, the initial public data effort should be focused on linking into corporate data using the latest ICT technology (Goodall et al. 2019). The term “closed-loop remanufacturing” should be introduced to label all the remanufacturing that is already going on within corporate supply chains, clearly identifying what part of that chain can be mapped with public information.	Enabling credible assessments of remanufacturing on any level, also enabling the assessment of options for servitization business models.
17	Price data as proxy for secondary material potential and progress	Apart from quantity, we should be able to determine the quality of secondary material. Prices of secondary flows, apart from metals, prioritizing plastics, wood, rubber, glass should be published in a centralized way. We should also consider these prices as the best proxy for the quality of the recycled materials. Estimates that assess the potential recycling rates of metals should, apart from price signals, be based on sound metallurgy and the laws of thermodynamics (Maio and Rem 2015).	Using value-per-unit as a proxy for entropy: how valuable is recycled material compared to virgin material?
18	Updated footprint coefficients	Footprint calculations try to estimate the material use and corresponding environmental impacts all along the value chain, for instance from cradle-to-gate or from cradle-to-grave. The current raw material equivalent (RME) coefficients used by Eurostat are a very helpful tool for that, but they need to be updated and improved (Eurostat 2017).	Assessing the contribution of a circular strategy to GHG emission reduction
19	Data to monitor operational performance of capital stock	Big data from opertions, for instance from servitization enterprises, should be gathered to get a general and aggregated sense of the performance of the products that are offered as-a-service. Providing these data at a sector level is considered realistic (Linder et al. 2017). These data should only be collected to overcome barriers in an emerging type of service, provided that both authorities and service providers see the need to overcome this barrier (see textbox “The narrative of the coastline village”). Simply gathering these data for the sake of fundamental research is probably not feasible.	Improving asset accounting by introducing functional units and predictive maintenance.

#	What better data do we need?	Why do we need the better data and where to find them?	How would this help robust policy, for example?
20	Basic data about innovati-ons that are relevant for a circular transition	Innovations are recorded through patent systems. Researchers are increasingly finding that these systems work well for a decreasing number of sectors and products. This means that there is a need to monitor R&D, especially publicly funded R&D, in a more detailed way in terms of sectors and products (Mazzucato 2013). Better information about the destination (again, sectors and products) and size of venture capital could also provide important evidence to support decision making. Examples of innovations since 2013 could include new biogenetics, block-chain products, additive manufacturing/3D printing, e-commerce and delivery apps, etc. The technology readiness level (TRL) of these data can probably only be between 7 and 9, which means that only innovations that (almost) found their way to the marketplace are documented. If an innovation has a TRL lower than 6 or less, it is still likely to be a wonderful possibility for innovation at some point in the future.	Distributing funds in the next round of public R&D.

All of the suggestions below attempt to adhere to the SMART or RACER criteria.[31] Moreover, many of the suggestions would require a data infrastructure such as RMIS or INSPIRE[32].

Cities sharing research efforts and deep diving on specific product flows
In the Netherlands, a group consisting of large cities and waste-treatment companies have pooled their resources to improve the data they have on waste flows. The driver of this initiative is an ever-increasing requirement for waste treatment on an urban level. All participants "adopt" a particular waste stream in their territory to see what kind of information they can gather. Examples of targeted waste flows are clothing, kitchen appliances and plastic toys. The initiative is expected to deliver new insights and practical knowledge in possibilities and limitations in tracking, collecting and treatment of specific waste flows. This project demonstrates how cost sharing and focus on detail can create further opportunities for a circular economy. And it is needed to develop further opportunities. As residents of the largest cities in the Netherlands, we haven't been able to observe new ways of waste collection over the last six years.

5.3 WHAT CAN WE ASK FROM PUBLIC DATA PROVIDERS?

If we ask for improved or new data sources, one has to appreciate the role of statistical offices and governmental agencies like the Joint Research Center of the European Commission. These agencies face a combination of demand for data and decreasing annual budgets (CBS 2013). Eurostat found that the European Statistical System (ESS) faced four challenges related to volume, complexity, timeliness and costs (Eurostat 2016). Important current challenges are about big data use, standardization to save costs, improvement of quality control and reduction of the administrative burden with organizations outside the statistical offices. Another challenge is to channel and combine all huge amounts of new data and information on raw material use in a central Intelligence System on a European level. This demonstrates that any new or greater demand for data requires justification and resulting political support.

An increase in volume, detail or scope of data on natural resources seems feasible from a technical point of view. We suggest answering the question of what is fair to ask public data providers by asking for two conditions to be met, followed by a third. First, before expanding surveys of data users (that are already held on an annual basis), current users must be specifically asked about their needs for data that might come from this survey ("what's in it for them"). Second, before changing the level of detail or scope of the data, it should be demonstrated that there is more than 50% growth of product use/sectors. Third, after it is clear that investments in data collection are necessary, it is advised that a commensurate part of public expenditures into a circular transition be dedicated to data gathering, as proper data provide the basis for all other publicly funded activities.

31 SMART = specific, measurable, attainable, relevant and timely; RACER = relevance, acceptability, clarity, easiness and robustness.
32 The INSPIRE Directive aims to create a European Union spatial data infrastructure for the purposes of EU environmental policies and policies or activities which may have an impact on the environment. https://inspire.ec.europa.eu/about-inspire/563

General drivers for better data are technologies from the field of big data (Boulton et al. 2017). At the same time, statistical offices often have large amounts of additional confidential data available. What is more important is that they have the experience to process and interpret these data, abiding privacy or proprietary legislation. The Dutch statistical office has additional “micro-data” that are made available to researchers whilst adhering to confidentiality requirements.[33]

Another driver for better data is also illustrated by the way the media deal with such data. In recent years, facts and truth for the general public have proven to become an even more important aspect of modern society. In search of data for a circular economy, there is a real danger of fake data. Existing statistical offices should and could meet the need for trustworthy, validated data.

In a belated disclosure of interest, we should point to Statistics Netherlands (CBS), the Environmental Assessment Agency (PBL), the Bureau of Economic Policy Analysis (CPB), the National Institute for Health and the Environment (RIVM), the Netherlands Enterprise Agency (RVO), Institute of Environmental Science (CML), the Directorate-General for Public Works and Water Management (RWS) and the Netherlands Organisation for Applied Scientific Research (TNO). These organizations are pooling their research efforts to tackle some of the data requirements described in section 5.2; however, there is still a need to shape the work program for the coming years.

5.4 GIVEN BETTER DATA, WHICH METHODS COULD BE INSTRUMENTAL IN POLICY MAKING?

Throughout chapters 1 to 4, we have highlighted shortcomings of public data. If the suggestions to solve these issues will result in better data, we can inevitably also see possible improvements in existing methods.

1. From section 3.6, we take the need to innovate the use of Sankey diagrams (Graedel et al. 2011, fig. 2; EASAC 2016, fig. 3.3; Nuss et al. 2017; Mayer et al. 2019, fig. 1). In current Sankey diagrams, the economic effort to define the quality of a certain material flow is lacking. We need a Sankey diagram standard that captures the knowledge, capital stock, labour and energy value that all need to be invested to get from one stage in the Sankey to another. The Sankey diagram showing global value flows is a good example (TCE 2019b).
2. From sections 3.3 and 4.3, we take the need to innovate environmentally extended input output (EEIO) analysis. As concluded by Aguilar-Hernandez et al. (2018), circular strategies can be observed in current EEIO analyses. To identify remanufacturing and servitization in existing manufacturing sectors, we need to further disaggregate existing sectors/industries; otherwise, no one will notice the effects of an extended producer responsibility on a macro-economic level or an increase in value retention processes such as servitization.
3. From sections 2.5 and 2.6, we take the need for further technological details in life-cycle inventory work. How can we for instance express reparability and modularity (Bakker et al. 2014a)? Applying learning curves in LCA will evidently benefit from better data.

33 See CBS Microdata Catalogue: https://www.cbs.nl/en-gb/our-services/customised-services-microdata/microdata-conducting-your-own-research/microdata-catalogue (accessed 14 October 2019).

4. From section 4.2, we take the need for indicators that capture economic value beyond the mere price of services and goods and the development of a standardized way to describe the impact of technologies on society, everyday lives and households. The "functional unit" is the label for this standard. It describes the unit of utility that a typical person enjoys from consuming a product or a service, such as the number of kilometres or kilograms of textiles being cleaned to the expected level. The academic literature offers ample suggestions for functional units of most products and services used in the current global economy (e.g., Weidema and Hansen 2004). The book "The Rise and Fall of American Growth" (Gordon 2016) is another demonstration of many possible performance indicators, using standard units like joule, kilogram, lumen etc. One could also look for existing standards in cost-benefit handbooks (e.g., Sartori et al. 2015) that feature relevant but complex concepts such as the value of statistical life and willingness-to-pay.
5. Assign an organisation as data custodian, which could be a network of academic partners or the OECD or UN statistics division. An exemplary initiative is described in (Myers et al. 2019)

5.5 GIVEN BETTER DATA AND ROBUST POLICIES, HOW CAN BUSINESS FOLLOW UP?

Robust policies created by public authorities are imperative to a circular economy transition. But decisions that eventually shape the circular transition are mostly taken within companies. In persuit of better data and robust public policy, it pays to appreciate the responsibility that entrepreneurial decision makers in mainstream capitalism have. Examples of such decisions, translated into performance indicators, are given by Figure 13 and Figure 14.

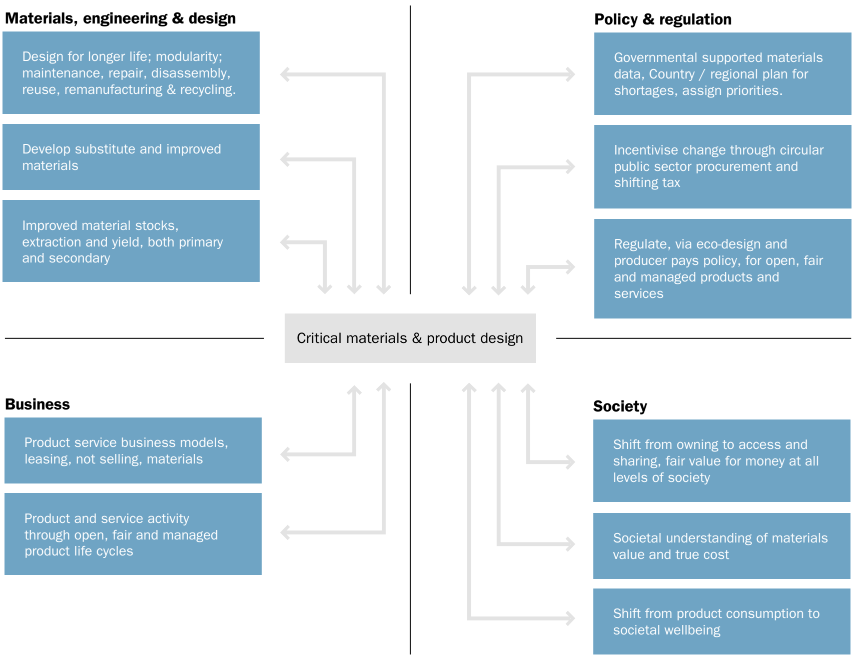


Figure 14 *Aspects of technology, strategy and life-style (Peck 2016; Ashby 2016)*

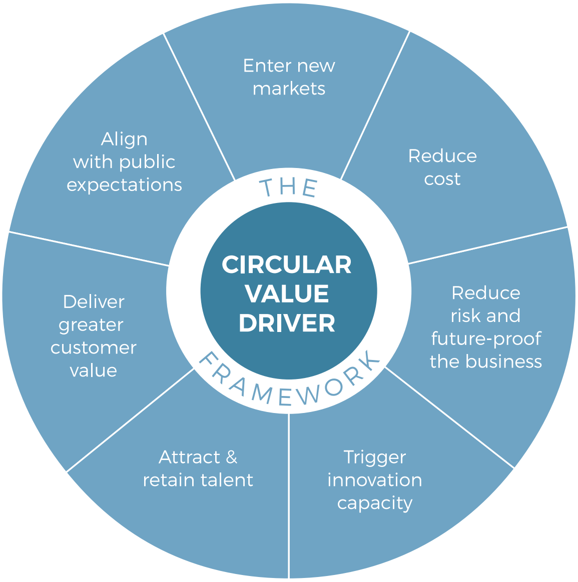


Figure 15 *Value drivers for corporate decision makers (TCE 2019a)*

The one recommendation to business would be to align their corporate data and accounting systems in such a way that they can interact with public data in an optimal way.

Some specific examples of this are taken from the book. From sections 4.1 and 4.3 we take the need to introduce into business accounting standards those negative externalities that have been avoided (True Price 2014). Any serious business takes account of monetary flows; almost every business has insights in their procurement expenses. Using standardized coefficients based on generally accepted data, major accounting firms have the opportunity to “save the world” (Bakker 2013). From section 2.5, we take the need to improve our definitions of capital stock, including scrap rates. For manufacturing sectors, capital stock that is used in servitization needs to be accounted for. This way a metric such as the material stock per service (MSPS) can be expressed in a way that is relevant at both the corporate and societal level (see, for example, Figure 15).

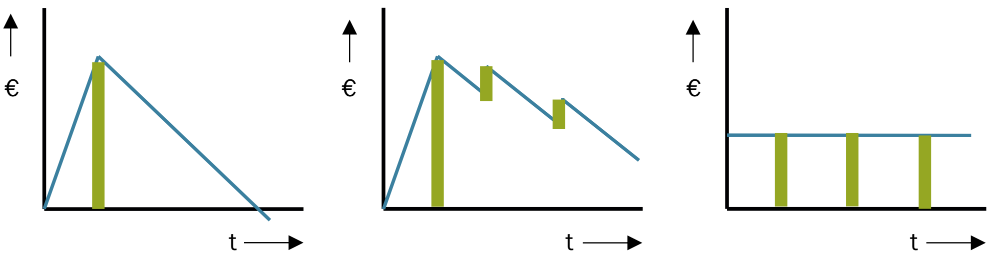


Figure 16 *Simple illustration of different value creation and retention patterns, to be measured at company, sector and national levels*

Finally, there is the parallel between circular economy accounting (raw materials, substances, products) and the International Accounting Standards (IAS) that are set by a committee since the early 1970s. This would be a momentous task indeed, but one can take the example of existing harmonized accounting standards (Mendoza 2005). At a more general level, questions like the following should be answered: How can existing (monetary) accounting standards be extended in such a way that they become part of the global reporting of any corporation?

6 DISCUSSION

The main thesis of this book is that government and corporate decisions that enable a follow-up to opportunities that shape a transition to a circular economy need better data. To what extend has this book succeeded in supporting this message?

6.1 WILL THE SUGGESTIONS FOR BETTER DATA HELP TO FOLLOW UP ON OPPORTUNITIES FOR A CIRCULAR ECONOMY?

Fortunately, there is no shortage of people showing a relentless drive and enthusiasm in pushing the circular transition forward. But people responsible for decisions related to major investments, public or private investments, should be sceptical. We stated in chapter 1 that changing the economic status quo requires knowledge about business models of technology, business, law and society. We will explore if this knowledge can come from better data by raising and answering some sceptical questions.

These opportunities you speak of, are they real business opportunities or opportunities to be more environmentally sustainable?

As we learned from the Brundtland report (World Commission on Environment and Development 1987), the one cannot exist without the other. They need to be societal sustainable to boot. Overwhelming evidence suggests that economies can increase environmental sustainability by using circular strategies, retaining or even increasing economic utility. If a circular economy, or climate policy for that matter, remains associated with “pain, but no gain”, it is likely to be inconsequential. In general, it can be argued that several innovations that shape a CE transition (or energy transition for that matter) do not offer any direct surplus utility to the consumer. They offer the same utility at reduced negative external costs. They just offer a prospect on a situation where we do not treat natural or human capital as waste. Blood, sweat and tears are part of any real transition. It probably might not be a real transition without inefficiencies, frustration, losers and anxiety. To deal with these negative aspects, relevant and reliable data being applied in a set of generally accepted methods are an essential cornerstone of any conversation. Even with perfect information, moving the transition forward to get the effects we need will be very hard.

If innovation and entrepreneurship are the real engines of a circular transition, why bog down those growth engines with boring talk about official data?

As stated in chapter 1 and illustrated in Table 13, better public data now face a bottleneck in the decision-making process. Given the expected role of public-private partnerships (PPS), unlocking the entrepreneurial spirit and technical know-how will be hard without it. A simple example is the development of new bio-based plastics. A clear causal link between CO_2 emissions and plastic production and consumption would steer innovation in the right direction. Data gaps and uncertainty about how to account for reductions of CO_2 emissions could make decision makers, that oversee public investment, sceptical about circular alternatives since environmental benefits remain unclear (Verrips et al. 2017).

Won't innovation solve societal problems once they are obvious in daily life?
We refer to section 3.4 to highlight the fact that significant autonomous developments will take place, regardless of government efforts to increase the reliability of official data. Innovations that would lead to viable business models within the current global economic framework probably do not need more official data (Vollebergh et al. 2017), but many innovations that shape the CE transition probably do. These innovations are often not fully valued by money. They disrupt, they internalize externalities, they might be dependent on regulations and subsidies, etc. We cannot expect innovations to solve societal problems autonomously. Government intervention is needed to create a viable business model for such problems (e.g. see phasing out CFKs, lead in solder, phosphates in detergents). At the same time, we cannot accept government intervention related to problems and solutions that are not clearly accounted for, let alone clearly defined.

Is it really necessary for decision makers to have a thorough understanding of the data suggested in this chapter?
Mostly, yes. The level of abstraction of the suggestions made in this chapter is the same as the suggested level of abstraction of corporate or private CE communications. To explain this, we make a comparison with the information needed in order to reach the Paris Agreement. It was not necessary for decision makers to understand the full physics of climate change. It was, however, very relevant (and a communication effort for that matter) to have reported to decision makers which impacts on their natural resources are expected, which greenhouse gases are relevant, which economic activities emit those gases, which technologies could reduce emissions, which economic activities and technologies are most relevant for their country, etc.

Even if we had perfect data and standardized methodological interpretations, isn't governance a missing element?
Yes, data and information need knowledge to be turned into wisdom. Interpretation of data and standardized methods to interpret them are an indispensable step in decision making (Peck and Rietveld 2015). We argue that better data allow for the all-important follow-up to turn information into informed decisions that shape a CE transition. There are many schemes available for evaluating policy. One suggested diagram is shown in Figure 16.

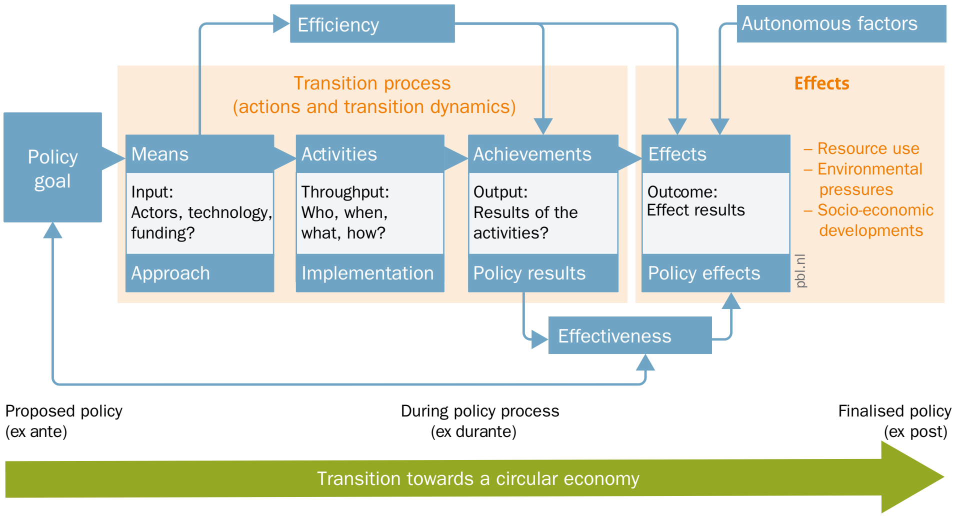


Figure 17 *Policy-monitoring framework (Hanemaaijer et al. 2018)*

A prime example of the need for standardized syntax is the difference between Achievements (output) and Effects (outcome). It will be virtually impossible to assess the contribution of a specific activity on desirable effects such as inclusive growth or respecting planetary boundaries. Instead, efforts should be focused on consistent gathering of data and information on quantifiable achievements. At the same time, Figure 16 shows that means and activities cannot be expected to have a "one-to-one" relationship with a desirable effect. Frameworks should assist a structured debate, not dominate decision making based merely on a numeric value (SITRA 2016).

6.2 SHOULD WE EXPECT ANOTHER BOOK ON OPPORTUNITIES FOR A CIRCULAR ECONOMY IN SIX YEARS?

Considering the contents of this book, it is highly likely that the circular economy concept will be at the heart of public policy making and academic research in 2025. It is virtually certain that the challenges related to natural resource use and resulting environmental pressures will be greater than ever.

Political urgency felt in Western societies related to a CE transition, or environmental issues in general, has proven to be volatile and often modest. The 14th (and latest) Global Risk Report of the World Economic Forum (2019) begs to differ. The "risk landscape" of this report is expressed by the axes Impact and Likelihood, where the top-right corner is dominated by the environmental risks, being one of the five categories of risks in the diagram (see Figure 17). At the same time, a remarkable observation is that supply risks for raw materials, critical or otherwise, are not even considered significant enough to be included in the picture.

The circular economy as a set of strategies can certainly alleviate these environmental risks but is obviously not part of this diagram as it poses no risk. We therefore take an analogy from the field of climate change research. It is said that “We cannot avoid climate change, but we can still avoid catastrophic climate change.” A CE version of that statement would be “We cannot perfectly define a circular economy, but we can avoid a catastrophic linear economy”. A catastrophe characterized by poverty, absence of conveniences and getting acquainted with hardship.

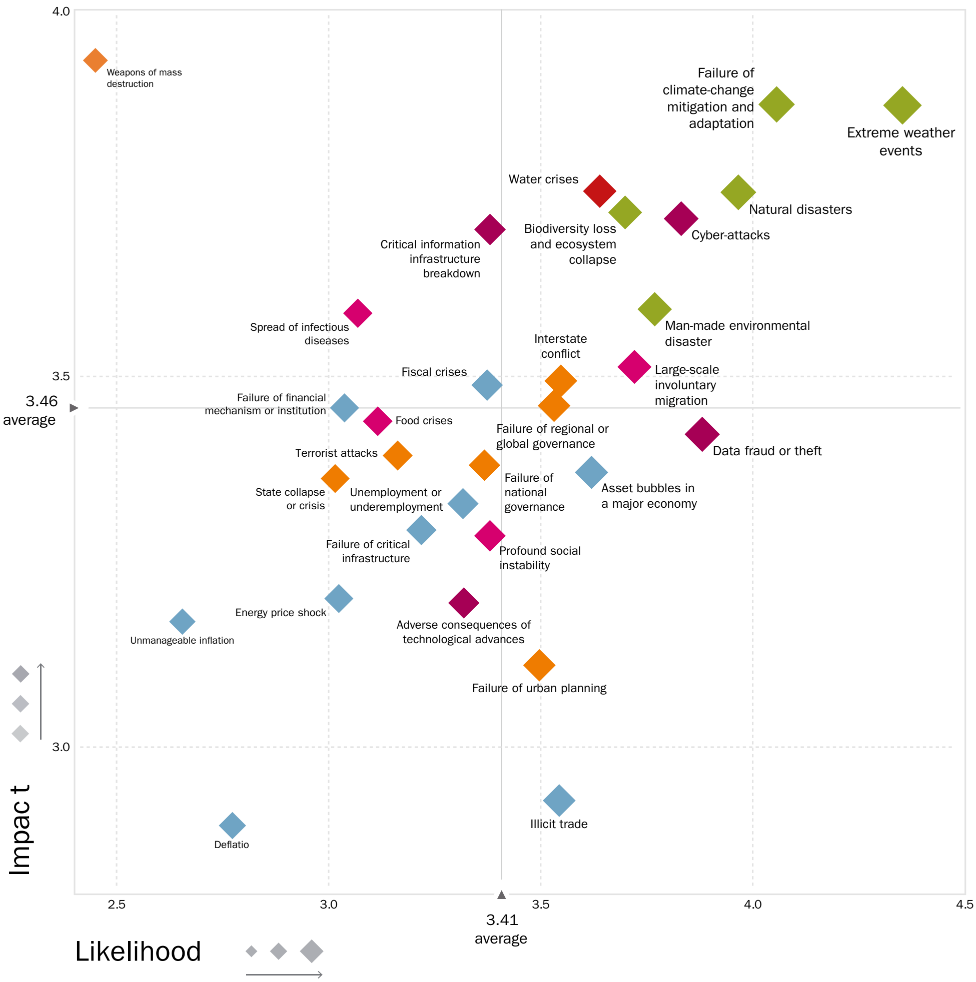


Figure 18 *Global risk report (World Economic Forum 2019)*

The general media in Western countries are demonstrably dominated by political issues that are, or appear to be, totally disconnected from the concept of a circular economy. In the Prologue, we argued that not all Societal Development Goals can be addressed with CE concepts. But there are some problems that can. Here a few: provide access to education that leads to jobs that enable a lifelong career enforcing the capability of communities to sustain themselves, increase household non-financial contributions to climate policies, emancipate people in developing countries with decentralized access to resources like protein/energy/ water and self-actualization to build a life in the place where they live. In case this sounds awfully esoteric, these are likely to be the aspects that drive several of the risks mentioned in Figure 17.

In the search of a political sense of urgency related to a CE transition, our recommendation would be to explore causal links between popular political discourses and socially desirable effects that can be pursued by a circular economy. These links seem only to be robust if the data and recommendations are used as discussed previously in this chapter.
And it will need robust data to impose any public policy that causes real price increases and/or prohibitions of the consumption of certain products.

We live in a 21st century world, where uncertainties around the introduction of new technologies are tolerated less than before. Where markets for investigatory journalism are in decline. Where the legitimacy of democratic institutions is questioned. Where our fondness of the quality of life seems to enforce the confirmation bias that already comes natural to human beings. Where arguments seem increasingly aimed at discrediting the opponent rather than offering facts (LSE commission 2018).

This means that monitoring, enforcement, data gathering, and controlled experiments are of even greater importance than they were in the 20th century. The only easy way forward will be an economy that finds a way to decouple economic value from the consumption raw of material, which, on a global level, is still theoretical. We hope this book shows how following up on circular opportunities can be made into a reality—a reality that starts with having better data.

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