OPPORTUNITIES FOR A CIRCULAR ECONOMY IN THE NETHERLANDS

Ton Bastein | Elsbeth Roelofs | Elmer Rietveld | Alwin Hoogendoorn

OPPORTUNITIES FOR A CIRCULAR ECONOMY IN THE NETHERLANDS

The Netherlands Organisation for Applied Scientific Research (TNO)

TNO is a not-for-profit research and technology organisation that was founded in 1932 by an act of the Dutch parliament to make scientific research accessible and applicable for businesses and government. By law, TNO is required to operate in an independent and objective way. TNO's trademark is the application of rigorous scientific principles to a wide variety of disciplines. At the start of 2013 TNO employed around 4,000 highly qualified professionals. TNO is active in seven main themes: industrial innovation, healthy living, energy, mobility, the built environment, the information society, and defence, safety and security.

TNO is one of the most internationally oriented research and technology organisations in Europe. Maintaining and improving an excellent knowledge base is a major focus of TNO as it continues to increase its presence in the international knowledge arena. In 2009 TNO's internationally generated revenue was €153 million, which represents approximately 39% of the total revenue from the market.

TNO Strategy & Policy is one of Europe's leading centres of expertise in the areas of innovation, sustainability and (interactive) policy making, with a staff of about 55 multidisciplinary policy advisors. The group also provides support for complex decision-making processes ranging from learning trajectories, spatial-economic analyses and cost–benefit analysis (CBA), monitoring and evaluation, foresight and scenario development, actor and system analyses aimed at, for instance, urban renewal, industrial innovation, innovation trajectories, sustainability issues and environmental risks. International clients include the European Commission (e.g. DG Environment, DG Regio, DG Research, DG Enterprise & Industry). More information is available on www.tno.nl

OPPORTUNITIES FOR A CIRCULAR ECONOMY IN THE NETHERLANDS

Ton Bastein | Elsbeth Roelofs | Elmer Rietveld | Alwin Hoogendoorn

TNO 2013 R10864

TNO innovation for life

TNO 2013 R10864
This report was commissioned by the Netherlands Ministry of Infrastructure and the Environment.

© 2013 TNO

All rights reserved.
No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of TNO.

TNO
Behavioural and Societal Sciences
Van Mourik Broekmanweg 6
2628 XE Delft
Postbus 49
2600 AA Delft
The Netherlands

www.tno.nl

Tel. +31 88 866 30 00
Fax +31 88 866 30 10
infodesk@tno.nl

Publisher	TNO
Authors	Ton Bastein, Elsbeth Roelofs, Elmer Rietveld, Alwin Hoogendoorn
Production	Contactivity BV, Leiden
Translation	Mark Speer
Editing	Valerie Jones
Design/layout	Anita Weisz-Toebosch
Graphics	Cédric Jeanneret
Printing/binding	Drukkerij Holland, Alphen aan den Rijn, the Netherlands

ISBN 978-90-5986-436-8

Acknowledgements

The publication of this report would not have been possible without the support and contributions of many people.

First and foremost, the authors wish to thank the Ministry of Infrastructure and Environment of the Netherlands for the grant that has enabled this work and this publication. Without the active and critical support of Tjeerd Meester and Kees Veerman, this report would not have seen the light of day.

The quality (and readability) of the report has greatly benefited from the contributions of a very active advisory board. We wish to thank Wytske van der Mei (chairman of the advisory board), Aldert Hanemaaijer, Hermien Busschbach, Marnix Koopmans, Matthéus van de Pol, Michel Schuurman, Mark Overman, Frans Vollenbroek, Harry Wilting, Remko ter Weijden and Willem-Henk Streekstra for their patient and constructive efforts in assessing the format, style and content of this report.

We are grateful to the many societal stakeholders (their names and affiliations are presented in Appendices 2 and 3) who devoted their time and effort by participating in interviews and workshops that have resulted in a clear view on the circular economy and how stakeholders can stimulate such an economy.

The results presented here would not have been possible without the support of TNO colleagues Arnold Tukker, Walter Manshanden, Sophie Emmert, Thijmen van Bree, Jinxu Hu and others for their contributions and critical comments.

Finally, the authors wish to thank the staff of Contactivity for their accurate, flexible and high-quality translation, editing and production of this report.

About the authors

Ton (A.G.T.M.) Bastein has a PhD in chemistry (heterogeneous catalysis). He joined TNO in 1993, and has been active as research, project and programme manager in the field of contamination control, nanotechnology, nano-instrumentation and the semiconductor industry. He is currently programme manager and coordinator of TNO's activities in the field of resource efficiency (ranging from technology, the biobased economy, to transition-related activities). He is co-founder of the Material Scarcity Platform, an initiative in which government, industry and academia collaborate in exploring and monitoring resource efficiency activities. He is involved in creating and developing national and European projects and programmes to identify ways to address the emerging resource scarcity problems.

Elmer Rietveld has a bachelor's degree in civil engineering from Delft University of Technology, and a master's degree in transport and planning. He joined Tauw BV, an engineering company, where he gained hands-on experience in major civil engineering projects. Since November 2006, he has worked at TNO in the area of spatial economics, spatial planning and cost–benefit analysis. In recent years he has focused on resource efficiency, material flow analysis, the circular economy and national accounts analysis, as a participant in several large EU projects such as CREEA, RHOMELO, COMPLEX and DESIRE. He is also involved in various first- and second-opinion societal cost–benefit analyses.

Elsbeth Roelofs joined TNO in 2000 after having worked with Tebodin Consultants & Engineers. She is now a senior business consultant on sustainable innovation. Elsbeth has a master's degree in chemical technology and the philosophy of science, technology and society. Since 2009 she has focused on research and consultancy in the area of the biobased economy and resource efficiency. She was closely involved in the development of two European programmes, BRIDGE and BIO-TIC, both in the area of developing the biobased economy. The BIO-TIC programme is developing a roadmap for the development of industrial biotechnology in Europe in the coming decades. Her fields of expertise include transition processes, systems innovation and value chain innovation (with an emphasis on construction and energy).

Alwin Hoogendoorn has a master's degree in mechanical engineering from Delft University of Technology and has worked as a consultant for Dutch engineering companies for almost 20 years. He is an expert in the fields of power production, renewable energy, biomass, bioenergy, biofuels and biobased products. He has been involved in due diligence work for investors and banks. As a result of a long-term R&D effort into innovative biofuel production pathways, Alwin was lead author of *Transportation Biofuels: Novel Pathways for the Production of Ethanol, Biogas and Biodiesel*, published by the UK's Royal Society of Chemistry (2010).

Contents

Summary **ix**

1 Introduction **1**
1.1 Population, resources and the environment 3
1.2 Circular economy 4
1.2.1 The concept of the circular economy 6
1.2.2 A closer look at recycling 9
1.2.3 Reuse, redesign, innovation and substitution 10
1.3 Sustainable use of resources and closing cycles 12
1.4 The methodological approach 13
1.5 Reader's guide 15

2 The abiotic circular economy: products from the metal and electrical sectors **17**
2.1 Metal and electrical products and the circular economy 19
2.2 Current status of the circular economy 20
2.3 The value of increasing circularity 25
2.4 Environmental impacts of increased circularity in the metal and electrical sectors 33
2.5 There's no such thing as a free lunch: the cost of transition 34

3 The biotic circular economy: waste streams as raw materials **35**
3.1 Waste streams from the agro-food sector 37
3.2 Getting more out of biotic waste streams 42
3.3 Environmental impacts of increased circularity in the use of biotic waste streams 47

4 The impacts of increased circularity on the Dutch economy **49**
4.1 Scaling up: the potential value of the circular economy 51
4.2 External effects of the circular economy for the Netherlands 55
4.3 Indirect benefits of the circular economy 55

5 Drivers and obstacles on the way to a circular economy **59**
5.1 Introduction 61
5.2 Developing and disseminating knowledge 61
5.3 Business: entrepreneurs, markets and resources 65
5.3.1 Entrepreneurs 65
5.3.2 Markets and new business models 67
5.3.3 Resources from waste 69
5.3.4 Product components 72

5.4 Policy and rules and regulations 72
5.5 Lobbying and framework activities (non-government-related) 76
5.6 Observations on the transition to a circular economy 78

6 Towards a circular economy: an action plan for the Dutch government 81
6.1 Creating and seizing the opportunities 83
6.2 An action plan for the Dutch government 83
6.2.1 Create a clear, cross-departmental, consistent strategy for the circular economy 84
6.2.2 Develop a coherent education and research plan for the circular economy 85
6.2.3 Make a comprehensive assessment of the pros and cons of existing rules and regulations regarding waste 86
6.2.4 Increase knowledge and awareness of raw materials in each value chain 86
6.2.5 Ensure that frontrunners receive a permanent and true advantage 87
6.2.6 Review the effectiveness of a broad set of fiscal and financial incentives to promote circular behaviour 88
6.2.7 Determine the impact of incineration plants on the viability of circular business cases and take appropriate action 89
6.2.8 Use the government as an active and expert 'launching customer' 89
6.2.9 Use the international playing field to help the circular economy move forward 89
6.3 Dealing with uncertainty: a government that learns and networks 90
6.4 Conclusion: opportunities for the circular economy in the Netherlands 91

Appendices 93
Appendix 1: Innovation systems: functions and innovation engines 95
Appendix 2: Interviewees 99
Appendix 3: Workshop participants, 19 March 2013 101
Appendix 4 Summary of technological options for creating added value from biotic waste streams 102

Summary

This report analyses the opportunities and obstacles that will present themselves as the Netherlands moves towards a more circular economy. It proposes a number of actions that can be taken, particularly by the government, to accelerate this process. The concept of a 'circular economy' refers to an economic and industrial system that is based on the reusability of products and raw materials, and the restorative capacity of natural resources. It also attempts to minimize value destruction in the overall system and to maximize value creation in each link in the system.

This report quantifies these economic and other opportunities to the greatest degree possible and examines their potential impact on employment and the environment. This analysis focuses primarily on the overall Dutch economy, but begins by examining two cases – the circular economy for products from the metal and electrical sectors, and the use of waste streams from biomass. The first case focuses on 'abiotic' materials, and the second on 'biotic' materials, both of which present their own specific challenges and opportunities. This report aims to answer the following questions:

- What opportunities would present themselves if the Netherlands were to accelerate the transition to a circular economy?
- How can these opportunities be used, how can obstacles be removed, and what shape should this transition take?
- What part can the government play in this process?

An expansion of the circular economy for technical products in the Netherlands initially means advocating more maintenance and repair work, intensive reuse and increased recycling. Of course, these activities are already happening. So we can already speak, to a certain extent, of a circular economy. By looking at 17 product categories from the metal and electrical sectors, we estimate that the current value of the circular economy for these products is €3.3 billion and that an additional market value of €573 million per year could be achieved by responding to a broad range of opportunities identified by stakeholders and experts.

With respect to value creation with biotic waste streams, the Netherlands has the advantage of being a densely populated country with an active agricultural sector and a large agro-food industry. As a result, significant biotic waste streams are available. The 34 most important waste streams have been identified: the use of these waste streams already represents a value of €3.5 billion. An estimated investment of €4 billion to €8 billion per year in new technologies could create added value of €1 billion per year for the circular economy in the areas of biorefining, biogas extraction and more comprehensive systems for sorting household waste.

The detailed analyses of an expanding circular economy of products from the metal and electrical sector and the use of biotic waste streams enables us to estimate the impact of an expanding circular economy on the Netherlands as a whole: we estimate the overall impact to be €7.3 billion, involving the creation of approximately 54,000 jobs. In addition there are a number of spin-off opportunities for the Dutch economy in terms of strengthening the country's knowledge position.

In order to develop an initial outline of useful and realistic actions that can be taken, we have examined the opportunities and obstacles from different angles based on a review of the literature, interviews and a workshop with selected stakeholders from the biotic and abiotic case studies. In doing so, we looked at the following: knowledge development and dissemination, entrepreneurial activities, market forces and mobilizing resources, policy and rules and regulations, and lobbying activities.

If the Netherlands is to take full advantage of the opportunities identified in this report, the government needs to develop a consistent, multidisciplinary and well-founded long-term strategy intended to lead to a circular economy. The following actions (and supporting studies) are needed now in order to identify areas of research, regulations, financial and fiscal incentives and strategies that will encourage frontrunners, promote the role of the government as a 'launching customer' and enhance international relations:

- create a clear, cross-departmental, consistent strategy for the circular economy;
- develop a coherent education and research plan for the circular economy;
- make a comprehensive assessment of the pros and cons of existing rules and regulations regarding waste;
- increase knowledge and awareness of raw materials in each value chain;
- ensure that leaders and others who stick their necks out receive a permanent and true advantage, for example through value chain management;
- review the effectiveness of a broad set of fiscal and financial incentives to promote circular behaviour;
- determine the impact of incineration plants on the viability of circular business cases and take appropriate action;
- develop the role of the government as active and expert 'launching customer'; and
- use the international playing field to help the circular economy move forward.

The current state of recycling, repair and reuse of a wide range of products in the Netherlands gives good reason to assume that there is further potential to make the transition to a more circular economy. However, clear and consistent communications across government departments are crucial to success. Dutch society seems very willing to join in, but is undoubtedly sensitive to conflicting information and incentives. In any case, citizens will be further encouraged if they are kept well informed about what has already been achieved, and if well-chosen transition experiments are launched. That the action plan for the government proposed here is by nature very exploratory and investigative is related to this. Measures to do with fiscal policy and rules and regulations are complex, and there must be some confidence that they will have the intended effects.

Throughout this study, the inputs from stakeholders have been extremely important in identifying in which direction the transition should go, and the obstacles that are likely to emerge. The views of these stakeholders do not by definition represent balanced judgements, which is why an expert and analytical government can contribute to what is in all respects a sustainable shift to a circular economy.

Raw material efficiency and rolling out the circular economy are goals that are clearly embraced at the European level. Nonetheless, the measures proposed here show that in many areas the Netherlands does not need to wait for approval at the European level.

More than once, this report stresses that a transition to a circular economy will benefit from initiatives that improve (sometimes drastically) circularity, as well as more radical measures that, in a more restricted sense, aspire to an ideal circular economic model in which circularity is already incorporated in the design phase. Based on the methods used here it is difficult to assess what the economic contribution of these more radical innovations and transitions would be. Still, the government can certainly support radical design innovations by identifying the leaders and removing obstacles for them or by acting as a launching customer to help these risky and radical initiatives get off to a good start.

Introduction

1 Introduction

This report analyses the opportunities and obstacles that will present themselves as the Netherlands moves towards a more circular economy. It proposes a number of actions that could be taken, particularly by the government, to accelerate this process. This report quantifies these economic and other opportunities to the greatest degree possible, and examines their potential impact on employment and the environment. The analysis focuses on the overall Dutch economy, but it begins by examining two cases – the circular economy for products from the metal and electrical sectors, and the use of waste streams from biomass. The first case focuses on the recycling of 'abiotic' materials, and the second 'biotic' materials, both of which present their own specific challenges and opportunities.

This report aims to answer the following questions:
- What opportunities would present themselves if the Netherlands were to accelerate the transition to a circular economy?
- How can these opportunities be used, how can obstacles be overcome, and what shape should this transition take?
- What part should the government play in this process?

1.1 Population, resources and the environment

During the 20th century, population growth led to an increase in the extraction of construction materials by a factor of 34, ores and minerals by a factor of 27, fossil fuels by a factor of 12 and biomass by a factor of 3.6.[1] As the demand for natural resources such as water, energy, raw materials and fertile land continues to rise, they are becoming scarce and more expensive. Moreover, rising consumption is putting a strain on the environment, leading to the depletion of large areas of forest and fish stocks, and to the extinction of many animals and plants.

The most important 'engines' of this increased consumption are the continued population growth and the simultaneous increase in prosperity in many parts of the world. The global population is expected to reach 9 billion by 2050 and 10.1 billion by 2100.[2] Despite the recent economic crisis, the global economy is expected to continue to grow at an average rate of 3.6% per year, especially in emerging and non-western economies, where growth rates of 6.3% per year are predicted.[3] As a result, in the coming decades the demand for natural resources will continue to rise.[4] A realistic prediction is that the global consumption of materials will triple by 2050.[5]

The fact that economic growth requires an extra input of natural resources is mainly attributable to increased urbanization and changing consumption patterns.

Urbanization results in the use of raw materials for building urban infrastructures, such as water supply systems, sewage systems, road and building construction, and other facilities to meet the need for transport to and from cities, and to deal with the rising volumes of waste. The growing middle class means changing consumption patterns and rising demand for luxury goods and food products. [6] The production of these goods requires the input of many natural resources.[7]

The growing world population and the desire for more prosperity are irreversible facts. In order to avoid overstepping our boundaries we will have to improve significantly the way we manage our resources. Major steps have been taken in recent decades in that respect. The world economy used approximately 30% fewer resources in 2005 to produce one unit of GDP than it did in 1980, for example. Nevertheless, in absolute terms the use of natural resources is still increasing. A 'normal' increase in the efficiency with which we manage resources is insufficient. We will have to find ways that lead to even greater prosperity for more people and that put less pressure on the environment in absolute terms – what is referred to as 'absolute decoupling'. The challenge we face is to make the transition to a society and an economic system that is tailored to this absolute decoupling. This transition is already underway, and one of its central tenets is the concept of a circular economy.

1.2 Circular economy

A circular economy is an economic and industrial system based on the reuse of products and raw materials, and the restorative capacity of natural resources. It attempts to minimize value destruction in the overall system and to maximize value creation in each link in the system.[8] The goals of the system are to counteract the depletion of natural resources; phase out waste, greenhouse gas emissions and the use of hazardous substances; and make a complete transition to renewable and sustainable energy supplies. We can only change our mindset once we prevent mankind from 'passing on' waste streams to nature and make waste prevention a primary focus of the design phase of products and systems. This would not only further improve current process optimization measures, but it requires a truly different and systematic way of thinking. However, it is conceivable that process optimization could prevent more radical changes from occurring in the transition to a circular economy. The increasing miniaturization of products and components, for example, may mean that repairs become much more complicated, or that recycling no longer pays.

Ideally, in a circular economy, waste streams and emissions would be used to create value, providing secure and affordable supplies of raw materials and reducing the pressure on the environment. This is an essential condition for a resilient industrial system that facilitates new kinds of economic activity, strengthens competitiveness and generates employment. In the transition to a circular economy the focus is no longer solely on decoupling environmental pressures from economic growth, but also on the opportunities created if these things remain coupled.

While an ideal circular economy resembles an inspiring 'point on the horizon', our present economy is often described as a linear economy, in which we are continually extracting new raw materials and creating – and then destroying – something with them ('*take, make, waste*'). Perhaps this is a somewhat gloomy picture of today's consumer society. In a transition to a circular economy, cost considerations and rules and regulations mean that energy and raw materials are managed more consciously, not necessarily because products, processes or systems have new, revolutionary designs. The existence of a recycling infrastructure, an active market for repairs and maintenance, and a lively second-hand market (the success of sites such as eBay and Marktplaats.nl in the Netherlands being prime examples) show that society is capable of moving towards a more circular economy. Increasingly, businesses in various industrial supply chains are cooperating in order to generate industrial symbiosis – by reusing waste, energy, water and material streams, for example – in an economically responsible way. This report highlights the benefits of continued optimization.

It is difficult to determine at what stage we are in the transition to an ideal circular economy. In the Netherlands we already recycle 78% of our waste, incinerate 19% and dump only 3%.[9] Within Europe, the Netherlands is one of the leaders when it comes to processing waste; as an example, figure 1.1 compares the different ways that the 27 EU countries[10] dispose of household waste. The statistics also illustrate that part of the economic potential and the potential to save materials have already been achieved. The potential of a transition to a more circular economy will probably be lower for the Netherlands compared to the average EU country (which is the case in the study by the Ellen MacArthur Foundation; see box and the discussion in section 1.2.1).

The Netherlands has made excellent progress in its endeavour to move towards circularity, but at the same time it is necessary to explore other opportunities. We are a long way from our target if our only goal is a high rate of recycling!

The move towards a circular economy represents an additional transitional step that requires chain optimization at the source. There are notably few examples of this optimization, which is in part attributable to the complex value chains that characterize our global economy. The products in these value chains are not only redesigned elsewhere in the world, but it is difficult to calculate accurately their production costs.

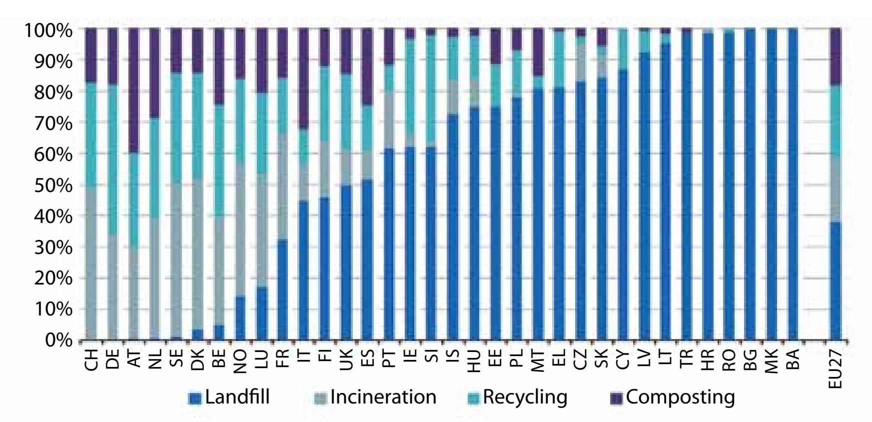


Figure 1.1. Processing of household waste in Europe (EU-27), 2009.
Source: Eurostat, 2009.

Putting all one's money on the creation of an ideal circular economy runs the risk of undermining the positive contributions of existing developments. These developments have tangibly helped to reduce pressure on the environment and create value, and this contribution is likely to increase considerably. In that sense a two-track policy, in which existing developments (as mentioned above) are driven by the 'pack', while the 'frontrunners' who embrace the principle of a circular economy deserve specific attention and support.

1.2.1 The concept of the circular economy

The Ellen MacArthur Foundation has presented an inspiring and appealing picture of a circular economy in its report, *Towards the Circular Economy*. The central notion is to take full advantage of the reusability of products and raw materials and the restorative capacity of natural resources, and to minimize value destruction. The report distinguishes between biotic and technical nutrients (green and blue loops, respectively, in figure 1.2), which find their way into the circular economy in different ways. Ideally, products made from technical nutrients are designed at the outset for advanced forms of reuse. In a circular economy, biotic nutrients, in any case, are non-toxic and so can be returned to the biosphere, preferably in a cascade of uses that tap as much value from them as possible.

In terms of economics, the report concludes that at the EU-27 level, cost savings could amount to US$380 billion (€286 billion) per year in a transition scenario, and US$630 billion (€474 billion) in a more advanced scenario.

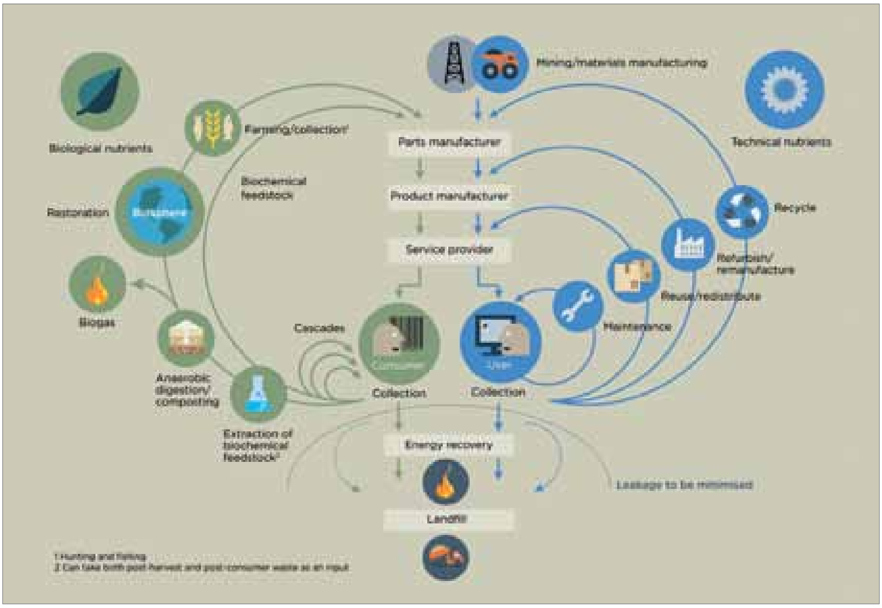


Figure 1.2. The circular economy – an industrial system that is restorative by design.
Source: Ellen MacArthur Foundation (2012) *Towards the Circular Economy*.

The report uses several key principles that lead to circular value (see box).

The various steps or feedback loops for manufactured products and materials ('technical nutrients' in figure 1.2) include the following:

– Maintaining and repairing products to keep them in circulation for as long as possible, and at as high a value as possible.

– Reusing and redistributing goods, which includes the second-hand market, lead to only a slight loss of the product's function, and therefore they make a positive contribution to a circular economy.

– Refurbishing and remanufacturing goods involve repairing or replacing failed parts or components, but the resulting product will have a shorter lifetime than the original product when new. When a product is remanufactured, the components are removed and used in new products. These processes generally include quality control to ensure high-quality products (with a guarantee).

– Recycling involves recovering materials that can be put back into one or more production processes. While the value of the raw materials is preserved, the added value of the original product (in the form of energy, labour and capital goods) will be lost (see section 1.2.3).

Obviously biotic nutrients cannot be kept in circulation in the same way as technical nutrients. It is assumed that biomass and biotic waste streams ('biological nutrients' in figure 1.2) will eventually be returned to the soil as nutrients, after they have been given as much value as possible through a cascade of processes:

– The extraction of high-quality raw materials ('extraction of biochemical feedstock'): processes known as biorefining can extract fuels, power, materials and high-quality chemicals from biomass, but often in small volumes.

– During anaerobic digestion micro-organisms break down organic material in the absence of oxygen. The result, among other things, is biogas (methane), which can be used as an energy carrier, thereby contributing to energy supplies ('biogases').

– Eventually it should be possible to use all biotic nutrients as non-toxic ingredients in agricultural fertilizers (for example 'restoration', 'farming/collection').

Value creation in a circular economy

As described in the report of Ellen MacArthur Foundation, the circular economy is based on several key principles, which drive four sources of value creation:

– 'The power of the inner circle': the more that hidden costs (such as materials, labour, energy and capital) are retained in a product, the greater will be the savings (or potential benefits). Repairs and maintenance retain much more of a product's value than recycling its individual component.
– 'The power of circling longer': the more often a product re-enters a cycle, or the longer it is used, the higher will be the value created.
– 'The power of cascaded use': if materials (as opposed to products) are to be reused (as a result of wear, for example), they can create added value if people look for other, more complex uses for them instead of breaking them down to the level of raw materials.
– 'The power of pure cycles', i.e. it is easier to separate inputs and designs: reuse, repair and recycling all benefit if the final phase of the life of a product has been taken into consideration when it is designed, by ensuring, for example, the use of non-toxic components and combinations of materials that are easy to separate.

Source: Ellen MacArthur Foundation (2012) *Towards the Circular Economy*.

1.2.2 A closer look at recycling

Recycling involves retrieving the materials contained in a product at the end of its life that can be used in other production processes. During recycling, in contrast with 'reuse', components and materials lose their function.

As an industrial practice, recycling has been around for a long time and is driven by solid business cases (in which scarcity and the rising prices of raw materials play a role) and environmental regulations, either national or European. Significant progress was made in the 1980s and 1990s in response to mounting environmental concerns regarding the wholesale dumping of waste. Recycling has regained attention in recent years, but for different reasons, including the rising prices of raw materials (making recycling processes profitable again) and concerns about supply security (recycled materials contribute to 'local' resources). On the other hand, future market developments are highly uncertain due to shifting geopolitical alignments, the complexity of markets and the volatility of raw material prices, as well as the rapid changes in technologies and products. Investing in large-scale recycling is therefore perceived as very risky.

Over the last decade consumer products have become considerably more complex, so that effective and efficient recovery is a massive challenge. There are as yet no effective processes for separating some combinations of materials, and in some cases such processes are even fundamentally impossible. The development of printed circuit boards, a familiar component of electrical and electronic products, is a good example. Process optimization has led to huge performance improvements and also to sharp reductions in the use of some materials.

Although at first glance these may appear to be positive developments, in the case of some products economically viable recycling is no longer possible. So what initially seemed to be a good first step – using fewer raw materials – has led to the sub-optimimal reuse of materials. Redesigning products could be a huge step in the right direction if it meant that manufacturers could avoid using combinations of materials likely to lead to recycling problems, and if components could be chosen in such a way that they would be easy to separate at the end of the economic life of a product. In light of the low concentrations of materials in many consumer products, it is important that the recycling collection rate is high: this is the only way of achieving sufficient scale, and thus also a potentially solid business case for the recycling of many materials.

Recycling is undoubtedly an important strategy for a society that wishes to increase material efficiency. Primary extraction will remain important (the most recycling can do is to keep what already exists in circulation) in societies experiencing strong economic growth. And in light of the problems mentioned above it would be naive to suppose that in the future, with the right science, regulations and attitudes, we would be able to recycle everything that has not yet been recycled and achieve an ideal and theoretically complete recycling stream.

1.2.3 Reuse, redesign, innovation and substitution

In order to move towards a circular economy we need to be innovative in the area of design – not only of technology and production processes, but also in terms of the social and economic processes that are necessary to change existing habits.

Intensifying the use of products is an important goal, but to achieve this it is necessary for both businesses and consumers to change their behaviour, and a solid and profitable business case needs to be made. We need to encourage the use of second-hand products and innovative rental and leasing arrangements. We also need to set up services that promote the sharing of consumer products, and encourage repair and maintenance services that extend their technical lifespan. In particular, we need to redesign products so that they and their components are easier to reuse.

Although such activities and concepts already exist, many of them have not yet been implemented on a large scale. The further introduction of leasing arrangements, for example, may be stifled by economic motives (suppliers will have to make higher initial investments), vested interests (that stand in the way of the introduction of new ideas) and behavioural factors (of both businesses and consumers). Although initiatives such as setting up a car-sharing scheme could greatly reduce the use of raw materials, people's desire for individuality, status or freedom often stand in their way.

This type of product sharing is a more obvious way to go for more expensive products that are not used on a daily basis and do not generate particular feelings of status or freedom, and is already in use in the form of tools and equipment rental services at DIY stores, for example.

One example of an innovative concept is that consumers 'buy' the service provided by a product rather than the product itself. In the case of professional copy shops, for example, customers pay for the copying service and for the materials (paper and ink), while the supplier remains the owner of the copying machines. The copiers are designed with the reuse of components in mind. Because the printers have continued ownership, this kind of design makes sense.

Another example is Turntoo, a model developed by Amsterdam-based architect Thomas Rau. An early application of this model is the 'Pay-per-lux' lighting concept introduced by Philips, where the customer pays for an agreed amount of light, while Philips is responsible for maintaining the lamps and lighting system. Because the manufacturer, Philips, remains the owner of the materials and system, it is encouraged not only to take production costs into account in the design of its products, but also the costs related to their use. Concepts such as this can lead to more efficient product designs and more intensive recycling, as well as save energy.

In order to take full advantage of concepts such as this it is important that manufacturers acknowledge that products and components can be given a second or longer life during the design process (‘*design for disassembly, for repair, for reuse, for remanufacturing, for recycling*’). This is true when the producer remains owner of the product, and is therefore responsible for extending its life, as well as when the manufacturer has lost track of the product and more generic service providers become involved. Therefore, materials should be used that are easy to recycle (even in complex products), and whose fragile and frequently replaced parts are easy to incorporate. This is more easily said than done. For generations, designers were required to take into account criteria such as effectiveness, efficiency, cost and function, but they now have to consider requirements that may even push up costs. However, if the potential costs of a new design and different materials, and the benefits resulting from the more intensive use of parts and materials occur in different parts of the value chain, there will be no incentive to redesign a product.
More radical changes can be brought about by looking for alternative (for example, circular) solutions or substitutes.

Substitution implies replacing a material, product or service with another while retaining or even improving the same function. In recent years, when many Dutch high-tech companies experienced supply shortfalls, their first response was to try to make their supply chains more robust by stockpiling components or by looking for alternative suppliers.[11] Only later did they decide to look for substitutes. But these substitutes were not regarded as ideal alternatives and so were abandoned as soon as the supply interruptions were resolved. This leads to the question of to what extent substitution can play a role within existing patterns of production and consumption, or whether it will only be accepted if and when consumption patterns shift and new demands emerge.

With many ‘examples’ of substitution the purpose has not been to improve raw material efficiency. More often products have been radically redesigned so that they provide completely different or better services, and are marketed on that basis. Examples include the digital cameras that have largely displaced film cameras, or the wireless networks that are replacing fixed telecommunication systems. Pioneering or innovative products often fulfil a need that previously did not exist, as entrepreneurs such as Henry Ford and Steve Jobs have so convincingly demonstrated in the past.

It is not a foregone conclusion that a substituted product necessarily helps to reduce pressure on the environment. Many kinds of modern entertainment equipment, such as plasma display panels, have led to substantial increases in energy consumption. Another example is biofuels and the question whether they are circular. Analyzing the impacts of substitution requires a broad systems approach, which will inevitably give rise to tensions between the desire for innovation and prosperity on the one hand, and pressure on the environment on the other.

Using waste streams from biomass

The Netherlands imports large quantities of biotic materials for its intensive dairy and food processing industries. The products of the food industry are partly exported and partly consumed in the Netherlands. Ultimately, the waste products (such as sewage sludge from treatment plants) can enter the circular economy, and so will not replace the original raw materials. In order to make a quantitative estimate of the opportunities that a biotic circular economy could generate, this study looks at ways of using all biotic waste streams with an eye to maximizing the potential added value. Of course, the food chain, which is broader than the food industry, gives rise to many significant biotic waste streams, including from agriculture, the retail trade (discarded food products) and society (organic waste and sewage sludge). This study attempts to quantify and analyze these streams and the opportunities to use them.

Although the circular economy is still in its infancy, many actors within the government, academia and industry are already actively supporting the transition. One example is the Nutrient Platform NL, a consortium of businesses, knowledge institutes, NGOs and the government that are working together to implement the phosphate chain agreement (see section 5.3).

1.3 Sustainable use of resources and closing cycles

The various strategies outlined above are undoubtedly important for achieving a circular economy. Primary extraction, however, remains important in societies experiencing rapid growth: after all, the most we can keep in circulation is what is already in circulation, and even that is a very ambitious objective. It would be unrealistic to expect complete recycling in the foreseeable future. Some material streams, such as food and energy, cannot be recycled or reused, and have to be continually renewed so that we can be sure of constant supplies.

A number of organizations have agreed on a definition of the circular economy as 'the regional production of goods, using an optimized cascade of nutrients and energy, assuming there is optimization in both the region's own chain and between different businesses and industry'.[12] This study does not consider efforts to promote regional production (glocalization), important though they may be. For example, a more circular perspective can lead to new ideas in terms of environmental planning and the problem of whether to condense, reduce and separate or, rather, combine functions such as living and working. The study also does not examine the function of logistics in connecting the various links in a circular economy.

Opting for products from the metal and electrical sectors

The authors of *Towards the Circular Economy* advocate the use of products with a medium life expectancy (mobile phones, washing machines, etc.) that can be expected to retain their value once introduced into the circular economy. This study takes a slightly broader view and looks at the products that are manufactured and traded by the metal and electrical sectors, including base metals, metal products, electrical engineering and electrical appliances. These sectors contribute about €10 billion (1.9%) to the Dutch economy and about 9% to the total value added, and have made a significant contribution to the country's position as an exporting nation. In 2010, the two sectors produced and exported goods worth more than €20 billion, offsetting by more than €5 billion the costs of the goods and services they imported in that year.

The analysis uses both sector data and detailed information about specific products (see chapter 3). The goods produced by the metal and electrical sectors are all, to a significant extent, recycled, repaired, rented or leased, or traded on the second-hand market. Data from the Central Bureau of Statistics indicate that the sectors are so closely interwoven with other service sectors that it seems that the circular economy is already happening. They therefore provide interesting insights into the degree to which the circular economy has already taken root in the Netherlands.

Many companies in these sectors are willing to comply with the demands of a transition to a circular economy. They are accustomed to dealing with change and innovation, involving both manufacturers and waste processors in the Netherlands. They are also aware of the sense of urgency at the European level, in view of the extensive attention to the raw materials used in their products in settings such as the European Innovation Partnership on Raw Materials.

1.4 The methodological approach

This report analyses the opportunities and obstacles that will present themselves as the Netherlands moves towards a more circular economy. In doing so, it quantifies the economic and other opportunities as accurately as possible and examines their potential impacts on employment and the environment. While the focus of the analysis is on the overall Dutch economy, it begins by examining two cases – the circular economy for metal and electrical products and the use of waste streams from biomass (see box).

Determining the potential of a circular economy

To assess the potential of increasing circularity for abiotic waste streams, and the Dutch economy as a whole, we used the following methodology.

Regarding the circular economy for products from the metal and electrical sectors:
- The metal and electrical sectors are described by means of 17 discrete product groups.
- The starting point of the analysis was that making estimates for each product category will generate a characteristic picture of the Netherlands. For example, simple or inexpensive household appliances are unlikely to be repaired, but some of them will find their way into recycling streams, while more complicated and expensive appliances (washing machines, etc.) are already being repaired. In order to estimate their circular potential, a realistic scenario is developed for each category of products and its potential in terms of maintenance, rental services, etc. These estimates are initially based on figures for 'urban mining' in the Netherlands, i.e. final consumption and investments in fixed assets.
- For each of the 17 product groups, we then estimate the degree to which an expansion of the circular economy could occur. These estimates are based on insights from the literature, interviews and the workshop organized for this study.
- This expansion is described in terms of the number of products, their value and the consequences in terms of the land use, water use, CO_2 emissions and use of raw materials avoided.

Regarding the circular use of biotic waste streams:
- Based on data from the literature and information from interviews, we outline the nature and scale of the most important biotic waste streams and the ways in which they are already being used (or not) in the economy.
- For each waste stream, we then identify the technological or other initiatives and opportunities for creating greater added value (for example, by using improved biorefining processes for valuable chemicals).
- This added value represents the potential for the expansion of the circular economy.

Regarding the overall Dutch economy:
- By extrapolating the findings from the abiotic and biotic cases, we estimate the impact on the Dutch economy and the associated impact on the environment.

We analyze these streams in the current system and assess what would be possible now, based on technological and social trends. In doing so, we draw on the work of the Ellen MacArthur Foundation, which outlines the potential savings in terms of materials, labour, energy and emissions. This approach therefore does not have as its ultimate goal an ideal circular economy, but rather outlines the prospects for the coming years. We must not forget that radical social and economic changes could accelerate the transition to a circular economy, but these changes are difficult to quantify.

This report aims to answer the following questions:
- What opportunities would present themselves if the Netherlands were to accelerate the transition to a circular economy?
- How can these opportunities be used, how can obstacles be removed, and what shape should this transition take?
- What part should the various societal actors, including the government, play in this process?

In answering these questions, the report attempts to complete another step in the exploration of the concept of the circular economy for the Netherlands. It is a SMART (specific, measurable, attainable, relevant and time-bound) interpretation of the notion of circularity that is intended to raise the awareness of stakeholders of the opportunities in that area in the Netherlands.

1.5 Reader's guide

This report is structured as follows:
- chapter 2 presents a quantitative analysis of the opportunities that could emerge by incorporating more intensively products from the metal and electrical sectors into the circular economy;
- chapter 3 presents a quantitative analysis of the opportunities for the circular economy using biotic waste streams;
- chapter 4 extrapolates the analyses in chapters 2 and 3 to identify the potential economic and other opportunities for the overall economy;
- chapter 5 discusses the drivers and operational obstacles to a circular economy identified in the literature, interviews and workshop; and
- chapter 6 discusses the role that the government could play in accelerating the transition to a more circular economy.

Details of the analyses will be published separately in a background document (in Dutch only).

The abiotic circular economy: products from the metal and electrical sectors


Power
Time
Start / Stop

2 The abiotic circular economy: products from the metal and electrical sectors

Expanding the circular economy for technical products in the Netherlands will mean more maintenance and repairs, more intensive reuse and increased recycling. Of course these activities are already taking place, so one can say that the circular economy already exists to some extent. For 17 product groups in the metal and electrical sectors, the current value of the circular economy is €3.3 billion, and an additional €573 million per year could be achieved by responding to a broad range of opportunities identified by stakeholders and experts.

2.1 Metal and electrical products and the circular economy

The more circular an economy becomes, the more products will be maintained and repaired, reused (entire products or some or all of their components), refurbished and recycled. The degree to which that is already happening, and could increase in the future, will largely depend on the nature and characteristics of each product. For this analysis, we defined 17 groups of products from the metal and electrical sectors that demonstrate some similarities, such as price, expected lifespan, the number of links in the value chain, their complexity and sensitivity to changing fashions. These product groups are listed in table 2.1.

In this analysis of the potential of a more circular economy, the starting point is the current flows of goods in Dutch society. In economic terms, this refers to the combination of final consumption by households and businesses in the Netherlands (approximately €7.5 billion in 2010, or 1.7% of final consumption) and the investment in fixed assets and capital goods (approximately €9 billion in 2010, or 8.6% of all investments in fixed assets).[1]

Table 2.1. Products from the metal and electrical sectors divided into 17 user-defined product groups

Product group	Examples of products
1 Base metals	Beams, cylinders, plates, wire, pipes, metal briquettes, railings, reinforcement, grating, etc.
2 Metal products	Construction parts, girders, doors, window frames, containers, gates, radiators, tools, DIY materials, faucets, food packaging, kitchen tools, engine parts, pistons, vehicle parts, gauges, coils, magnets, springs, weapons, coatings, blades
3 Electronic components	Semiconductors, printed circuit boards (chips), integrated circuits
4 Home computers	Printers, laptops , desktops, scanners, fax machines, PC parts
5 Mobile appliances	Mobile telephones, smartphones
6 Televisions	Televisions
7 Video and DVD players	Video recorders, DVD players, video cameras, accessories
8 Other consumer electronics	Transmitters, audio equipment, fixed telephones, alarm systems, etc.
9 Measuring equipment	Measuring and monitoring instruments, other cameras, sensors, radiation equipment, appliances using magnetism
10 Electrical capacity	Electrical engines, transformers, batteries, etc.
11 Electrical parts	Batteries, capacitors, switches, cables, disconnectors, wires, etc.
12 Bulbs	Incandescent light bulbs, cold-cathode fluorescent lamps (CCFLs), light-emitting diode (LED) lamps, fluorescent lamps, etc.
13 Washing machines	Washing machines, driers, dishwashers
14 Air conditioners	Air conditioners
15 Microwave ovens	Microwave ovens
16 Refrigeration	Refrigerators and freezers
17 Other household appliances	Ovens, electric heaters, radiators, cosmetic appliances, etc.

2.2 Current status of the circular economy

For each of the product groups listed in table 2.1, a quantitative analysis was made of the number of items (and their prices) that enter circulation each year and the number of products that are offered for maintenance and repair, reused (second-hand), refurbished (products and components) and/or recycled. These are the various steps that were identified in the report *Towards the Circular Economy* (see section 1.2.1).

The value of new products from the metal and electrical sectors that are sold on the Dutch market amounts to approximately €16.5 billion every year. This figure is based on information obtained from the National Accounts and supplementary data from professional trade organizations. Information on repair cycles was obtained from certified statistical agencies[2] on maintenance, and the depreciation of capital goods (for both businesses and households). This information was used to estimate how many products have been offered for repair. The size of the economic sectors associated with repairs was also used as a control in the estimates. The estimated value of a product in need of repair in the feedback loop was compared with its value in the eyes of the owner before it needed repairing.

The reuse of products, through second-hand markets, is an important part of the circular economy. An impression of the second-hand market for products from the metal and electrical sectors was obtained from empirical research on sales outlets, especially online selling points such as Marktplaats.nl and Speurders.nl. Data from the Central Bureau of Statistics (CBS) on used capital goods were used as controls. The estimated value of a product destined for reuse is the price of the second-hand product, including an estimate of the price that consumers would be willing to pay.

The reuse of product components (parts such as engines, wheels or microchips) is strongly linked to the estimated number of products on the second-hand market. The data for this feedback loop were obtained from core figures from the literature[3] describing the relationship between the reuse of complete products and of components. It is interesting to note that in the literature, a part is considered to be more valuable if it has been removed from the original product. For example, a computer disc drive is worth more if it has been removed, cleaned and is ready for reuse. Here too the estimated value of products in the 'reuse of components' feedback loop tallies with the sales value of the components destined for reuse.

Finally, we determined the value of the recycling feedback loop, based primarily on a recent study by the United Nations University.[4] In addition to providing useful estimates of the various waste streams, in particular of waste electrical and electronic equipment (WEEE), the UNU study makes assumptions about the relationship between recycled products and new products entering the market, which creates an additional control option. The value of a recycled good is estimated based on the total costs of recycling – including the costs of collection and disassembly/processessing – and the revenues from the sale of the secondary raw materials.

Table 2.2 summarizes the extent to which elements of the circular economy are already being applied in relation to products from the metal and electrical sectors.

Table 2.2. Status of the current circular economy for metal and electrical products (numbers of items, 2010)

Products	New products ('000s)	Repairs ('000s)	Reuse of products ('000s)	Reuse of components ('000s)	Recycling ('000s)
Light bulbs	52,540	0	4	89	44,444
Base metals	2,226	0	4	2	2,020
Air conditioners	1,273	153	512	238	952
Mobile telephones	9,627	1,444	105	2,250	9,000
Electronic components	809	0	400	375	750
Metal products	16,510	330	2,740	81	8,080
Microwave ovens	730	15	525	30	595
Televisions	3,806	457	2,052	180	3,600
Electrical parts	775	39	682	6	565
Other consumer electronics	3,150	378	4	340	2,267
Home computers	18,611	2,792	639	1,667	16,667
Video and DVD players	4,548	364	106	200	4,000
Refrigerators/freezers	922	46	53	38	750
Washing machines	1,183	177	1,025	300	857
Other domestic appliances	1,193	143	733	143	950
Electrical capacity	693	14	77	75	500
Measuring equipment	4,234	423	3,209	375	3,750
Total	122,828	6,774	12,873	6,387	99,747

The distribution by product category across the various feedback loops obviously fluctuates depending on the nature of the product. Almost all light bulbs, for example, will end up in the recycling loop since they cannot be repaired when they are broken. Appliances such as home computers represent so much value in terms of use that a significant number of defective computers are repaired.

The annual stream of products from the two sectors that are repaired and reused represents about 16% of the number of new products that enter the Dutch market each year. About 81% of products from these sectors are offered for recycling. These numbers suggests that, in these two sectors at least, a certain degree of circularity has already gained acceptance in the Netherlands.

Of course, what is even more interesting is the analysis of the value of the current level of circularity. Table 2.3 shows the value of repairs, reuse (of products and components) and recycling by product category. The total value of these feedback loops for the six most valuable product categories is depicted in figure 2.1, while figure 2.2 shows the distribution of this value across the various feedback loops.

Table 2.3. Value of the current circular economy for metal and electrical products (2010)

Products	Value of new products (€ million)	Repair, reuse of products and components (€ million)	Recycling value (€ million)	'Circular' value (€ million)
Light bulbs	482.8	0	−33.3	−33.3
Base metals	113.5	0	−5.1	−5.1
Air conditioners	73.9	16.9	9.9	26.7
Mobile telephones	898.3	165.6	−74.9	90.6
Electrical components	80.6	25.4	18.6	43.9
Metal products	2212.4	150.1	−33.4	116.7
Microwave ovens	122.0	9.2	34.7	43.9
Televisions	679.9	255.5	26.3	281.8
Electrical parts	135.8	61.0	35.3	96.3
Other consumer electronics	576.9	42.2	27.0	69.2
Home computers	4202.3	379.8	−114.2	265.6
Video and DVD players	1137.4	54.6	30.9	85.4
Refrigerators/freezers	248.1	13.3	54.8	68.1
Washing machines	384.9	147.5	66.9	214.5
Other domestic appliances	370.2	201.6	69.4	271.0
Electrical capacity	441.8	32.8	56.0	88.8
Measuring equipment	4324.1	1,391.8	206.6	1,598.4
Total	16,484.9	2,947.2	375.5	3,322.7

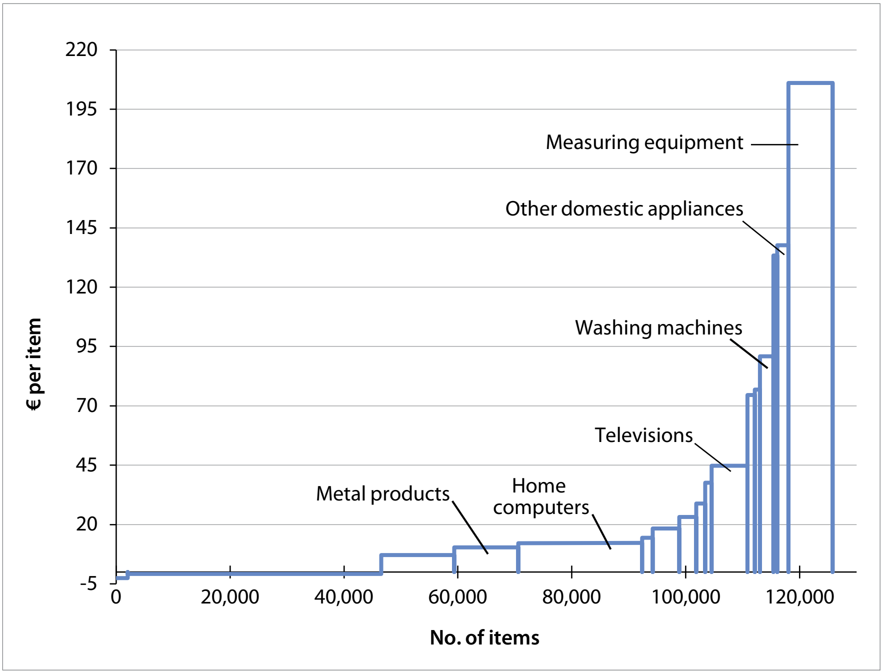


Figure 2.1. Current value of circularity for the six highest-value products from the metal and electrical sectors.

Based on these estimates, the value of the current circular economy for the metal and electrical sectors is approximately €3.3 billion. The most important contributions come from the repair and reuse of measuring equipment, followed by a broad group that includes computers, televisions and other household appliances. Recycling contributes only slightly more than 11% of the total, despite the large share of recycling in terms of the number of items. The largest contribution comes from the reuse of products, at approximately 54% (see figure 2.2).

The metal and electrical sectors represent almost €16.5 billion in terms of new value. The total value of the circular feedback loops (€3.3 billion) is therefore only 20% of the new value.

This is understandable in view of the depreciation in value that occurs, for example, when goods are reused (second-hand goods) or recycled. Take the example of recycling. Although the share of recycling (measured in terms of the number of items) is large, the intrinsic value of the materials and raw materials contained in a recycled product (especially in metal and electrical goods) is generally only a fraction of the value of that product when new. According to a recent report by the United

Nations Environment Programme, for example,[5] the total commodity value of a PC (which is worth €1,100 when new) is only €8.60. The 'lost' value includes the costs of labour, energy and capital goods (the operating costs of machines, write-down on the machines) during production. This value is a relatively large write-down that naturally disappears when products are recycled. It explains the relatively low value of the share of recycling, which is also under pressure because of the additional costs of collection and processing.

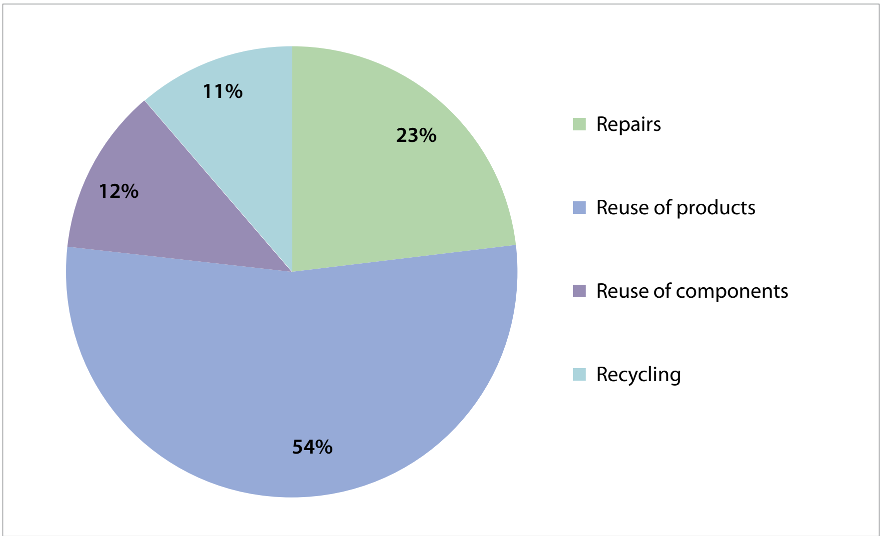


Figure 2.2. Contributions of repairs, reuse and recycling to the value of the current circular economy for metal and electrical products (2010).

2.3 The value of increasing circularity

Increasing the circularity of products in the metal and electrical sectors will require strengthening commercial activities that will enable the reuse of product components, the shared use of products and a higher rate of recycling. There are many social changes that will affect shifts of this kind, although of course the extent of such changes is impossible to predict. In order provide a rationale for the type and degree of change, we have relied on information about the driving forces and the likely obstacles on the road to a circular economy obtained from the literature, interviews with experts and other interested parties, and the workshop held in the context of this study (see chapter 5). We then assessed the possible consequences for the circular economy of a number of these driving forces in order to generate an overall picture of the potential shifts. It should be noted that our assessments of shifts rely heavily on ‘expert judgement’ (in this case that of the authors, based on information from the field) and have a major impact on the results of the assessment. The current values are conservative, and so too is the outcome; it is certainly not a ‘point on the horizon’.

Table 2.4 summarizes the most important opportunities and the degree to which the volumes (number of items) and value (euro per product) could change. The increased value is determined by increases in both the number of items that enter the circular economy (for example, more electrical appliances collected), and/or the value of this shift in activities (for example, more appliances are repaired than recycled). Simply projecting these changes in terms of the percentage of items and/or value per item onto the current situation gives us an idea of what the consequences would be if these changes took place. For example, if previous studies indicate that 177,000 washing machines are being repaired at the moment, then an increase of 5% would mean that the value of an additional 8,850 washing machines being offered for repair can be deemed positive.

In determining the value of these washing machines offered for repair we took their material value as the starting point. What is a washing machine worth if it is broken but can be repaired? The repair service was not included in this value because the value to a repairman is the same as the cost to the customer. We will not forget the increase in the demand for repair services, which will be included when we determine the increase for the overall Dutch economy (in chapter 4).

As circularity increases, there will be losers at first. In any economy, as more goods are reused and repaired, fewer new goods will be bought, which in turn means a loss of income for manufacturers, transporters and dealers. In this case we assume that an increase in the number of products reused and repaired has a reciprocal effect on purchases of new products, that the reuse of components leads to a gradual decline in purchases (we assume by 75%) and that an increase in recycling does not affect purchases of new products. These corrections are included in table 2.4 under ‘new value’, for which a negative contribution was estimated in all cases.

Some of the pain caused by declining sales will not be felt in the Dutch economy, since many metal and electrical products are manufactured abroad. For example, if the avoided value of new products is €200,000, but it is known that only 13% of the final consumption of televisions involves value that is not imported, then this means that only 13% of the €200,000 is calculated to be negative for the Dutch economy.

It is worth noting something about the nature of the shifts suggested here. In chapter 1, the concept of a circular economy was introduced as one based on the radical redesign of products and services that takes as its starting point the reusability of products and raw materials and the restorative capacity of natural resources, and which aims to minimize value destruction in the overall system. It has been noted that many Dutch businesses are actively trying to use raw materials, existing products, processes and systems more efficiently, both as individual companies but also in the context of entire value chains.

With regard to the reasons for the shifts listed in table 2.4, it is striking that most measures are applicable to existing products, processes and systems, as well as (obviously) products, processes and systems that have been designed or redesigned according to the principles of the circular economy. Using subsidy schemes such as the Random Depreciation of Environmental Investments (VAMIL[6]) or reduced rates of VAT can act as incentives for both circular products and services, and products and services in a transitional phase.

Other shifts may also lead to more circularity without products having to be radically redesigned. These include innovative leasing and rental contracts, different attitudes to possession, the introduction of lending and sharing schemes such as 'Neemby', and the introduction of collective insurance schemes that offer cover for repaired goods and products containing used parts.

These are examples of an approach that will bring us a step closer to a circular economy. Various efforts are already being made to consider different kinds of reuse during the design process, such as the development of recyclable plastics and the introduction of 'assembly for disassembly' PCs. Such examples are most often found in business services: for example, including reusable parts in the design of professional copying machines is now accepted practice.

Table 2.4. Estimated shifts in the circular economy of metal and electrical products in the coming years. The reasons for these shifts are discussed in chapter 5

Product group*	Feedback loop	Reason for shift	No. of items	Value (€/item)
13	Repairs	Lease and rental contracts for washing machines; see section 5.3	+10%	+1%
13	New value		−1,5%	0
1–17	Reuse	Different attitudes towards possession, see section 5.5	+3%	0
1–17	New value		−1%	0
1–17	New value	Subsidies such as the Environment Investment Allowance (MIA) or Random Depreciation of Environmental Investments (VAMIL), to encourage longer product lifetimes; see section 5.4	−1%	2%
1–17	Recycling	Changing location of waste incinerators; see section 5.3	+1%	−1%
4–8, 13–17	Reuse	Sharing systems such as Neemby, Floow2; see section 5.3	+2%	0
4–8, 13–17	New value		−1%	0
12	Recycling	Increased recycling due to the high value of LEDs; see section 5.3	+1%	0
3–17	Recycling	Development of plastics designed for recycling; see section 5.3	+1%	0
4	Recycling	'Assembly for disassembly' PCs; see section 5.3	+1%	+2%
3–17	Recycling	Reassessment of the EU's Waste from Electrical and Electronic Equipment (WEEE) directive; see section 5.4	+2%	0
2, 4, 5, 9, 10	Reuse (components)	Divestment of 'stranded assets' strategies; see section 5.2	+2%	−1%
2, 4, 5, 9, 10	New value		−1%	−1%
1–17	Recycling	Use logistical knowledge about main ports; see section 5.2	+1%	0
1, 2–17	Recycling	Introduction of raw materials passports; see section 5.3	+1%	+2%
2–17	Reuse (components), repairs	Collective insurance covering repaired goods/products with used parts; see section 5.4	+2%	+5%
2–17	New value		−1%	0

Table 2.4. (Continued)

Product group*	Feedback loop	Reason for shift	No. of items	Value (€/item)
1–17	Recycling	Lifting the ban on stockpiling; see section 5.5	+1%	1%
1–17	Reuse (components), repairs, recycling	Rising prices of raw materials; see section 5.3	+12% +1%	0 0
1–17	New value		−6%	2%
3–17	Components, repairs	Conditions for the supply of parts incorporated in B2B contracts; see section 5.3	+3%	0
3–17	New value		−1%	0
3–17	Recycling	Use reserve from collection contributions; see section 5.4	+1%	2%
4–10, 13–17	Reuse, (components), repairs, recycling	Reduced rate of VAT on circular services; see section 5.4	+5% 1%	+1% +1%
4–10, 13–17	New value		−3%	0
4, 8–10, 13, 17	Reuse, (components), repairs	Development of product service systems (PSS) for the most expensive metal and electrical products; see section 5.3	+3%	0
4, 8–10, 13, 17	New value		−1%	0

* Product groups: 1 Base metals; 2 Metal products; 3 Electrical components; 4 Home computers; 5 Mobile telephones; 6 Televisions; 7 Video and DVD players; 8 Other consumer electronics; 9 Observation equipment; 10 Electrical capacitors; 11 Electrical parts; 12 Light bulbs; 13 Washing machines; 14 Air conditioners; 15 Microwave ovens; 16 Refrigerators; 17 Other household appliances.

Table 2.5 shows our estimates of the changes in the value of all product categories following the introduction of these measures and actions, while figure 2.3 highlights those changes for six products that are likely to benefit most from such measures.

Table 2.5. Changes in the value of products following the introduction of measures to promote a circular economy

Products	Change in value after introduction of measures (€ million)	Total value after introduction of measures (€ million)
Light bulbs	−4.3	−37.6
Base metals	−0.4	−5.5
Air conditioners	4.8	31.5
Mobile telephones	25.7	116.4
Electrical components	6.4	50.3
Metal products	17.6	134.3
Microwave ovens	−1.3	42.6
Televisions	64.3	346.2
Electrical parts	15.2	111.4
Other consumer electronics	13.0	82.3
Home computers	54.0	319.6
Video and DVD players	15.2	100.6
Refrigerators and freezers	11.0	79.1
Washing machines	40.7	255.2
Other domestic appliances	64.5	335.5
Electrical capacity	14.8	103.6
Measuring equipment	231.7	1,830.1
Total	572.9	3,895.6

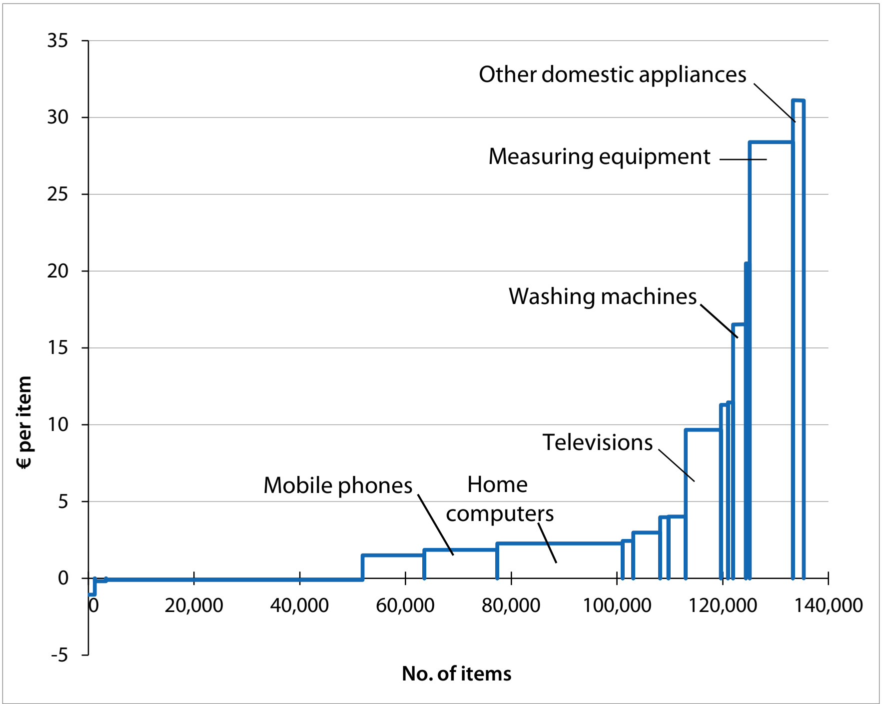


Figure 2.3. Changes in the value of six products likely to benefit most from measures to promote a circular economy.

The total increase in the market value of the circular economy for products from the metal and electrical sectors amounts to €573 million per year. If this figure is adjusted to take into account the decline in purchases of new products, which we estimate will amount to approximately €387 million, then the total value of the four feedback loops – repairs, reuse of products and components, and recycling – increases to €960 million. This increase is derived from the repairs and reuse of products and components feedback loops (about 30% each), and from recycling (10%). Figure 2.4 shows the increase in the value of the four feedback loops in a circular economy compared with the current situation.

This increase – based on conservative estimates – is significant if we consider that the total added value in the metal and electrical sectors is €9,983 million. Few developments in recent history, whether technical, institutional or social have generated this kind of a rise in prosperity in real terms (corrected for inflation) in so short a time.

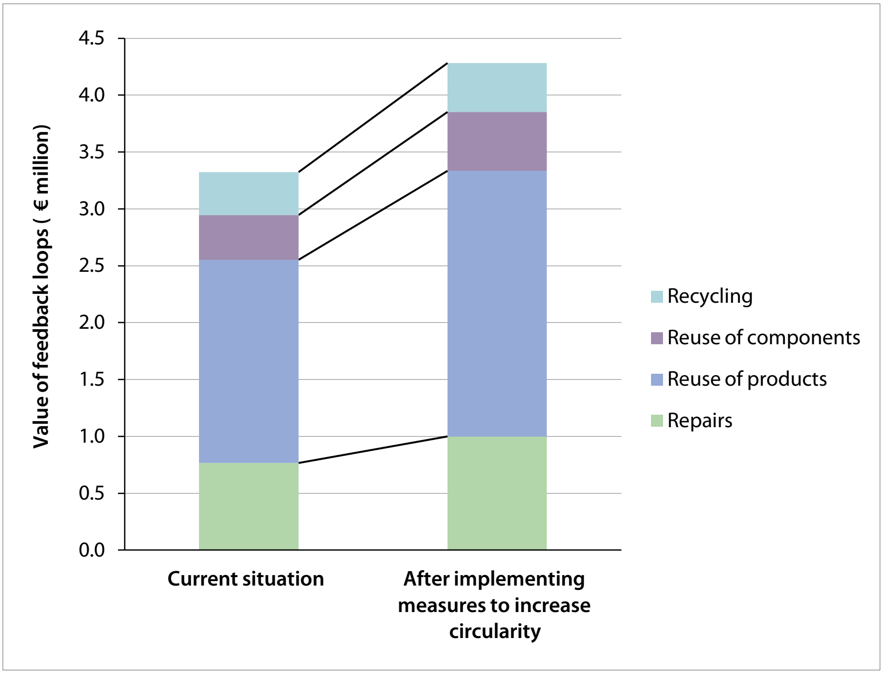


Figure 2.4. Increase in the value of the four feedback loops in the circular economy.

Since we know the shares of labour in the various sectors, we can determine quite precisely that this increased market value of €573 million would lead to the creation of 10,583 new jobs in the metal and electrical sectors (see table 2.6).

Table 2.6. Changes in employment in the metal and electrical sectors due to an expanded circular economy

	Change in market value (€ '000)	Share of labour costs in value added	No. of new jobs created
Base metal industry	−390	0.54	4
Metal product industry	17,628	0.55	198
Electronics industry	236,758	1.15[7]	4,449
Electrical appliance industry	318,954	0.66	5,933
Total	572,950		10,583

2.4 Environmental impacts of increased circularity in the metal and electrical sectors

In addition to the increase in monetary value (part of which can be translated into permanent employment growth), moving towards a circular economy would lead to a decline in what are referred to as negative external effects on the environment in the Netherlands and beyond its borders, but have no use or offer no compensation.

In this study, these negative external effects are examined using four indicators:[8]
- CO_2 emissions;
- use of freshwater;[9]
- land use (ecological footprint); and
- the Raw Material Equivalent (RME), which represents the 'package' of all the raw materials used to manufacture a product that is consumed in the Netherlands.

For the Netherlands as a whole, we estimate that a more circular economy could help to avoid CO_2 emissions amounting to 747 kt per year, which is just 9.7% of the current annual CO_2 emissions produced by the metal and electrical sectors. Note, however, that this figure does not include the CO_2 emissions avoided in other countries due to the use of fewer raw materials (RME; see box).

Raw Material Equivalent

The Raw Material Equivalent (RME) is a measure that takes into account the complexity of today's economy and its value chains. It indicates the quantities of all the raw materials a sector uses to manufacture its products, both domestically and abroad. The raw materials are divided into 52 groups, including grain, wood, natural gas, rubber and iron ore. In 2009, the metal and electrical sectors in the 27 EU countries used almost 1 billion tonnes of raw materials. Of this, Dutch industries accounted for approximately 81.9 million tonnes, even after deducting the RME used in products that were subsequently exported

The water use avoided for the metal and electrical sectors could amount to approximately 37 million m^3, with a total use of 280 million m^3 presently throughout the Netherlands. The base metal industry in particular could take measures to reduce this volume.

The avoided land use resulting from more circularity in the metal and electrical sectors would amount to only 20 km^2. This rather modest improvement is attributable to the fact that the impacts of the extraction of minerals and raw materials used in these sectors on land use are not expressed in existing indicators.10 If land use figures were included in these indicators, the ecological footprint due to increased circularity could be reduced by more than 20 km^2.

The RME avoided could amount to 5.2 billion tonnes of raw materials (for a breakdown, see the background document), which amounts to 6.3% of the RME currently used in the metal and electrical sectors. This figure has been calculated by looking at specific product groups.

2.5 There's no such thing as a free lunch: the cost of transition

The previous section calculated the benefits of using the opportunities presented by a circular economy. The cost of a transition to a circular economy will to a large extent depend on its estimated potential. This is true, for example, of the costs related to collecting and processing materials, and the investments repair businesses would have to make, etc. These costs have been included to the greatest extent possible in the concept of value and therefore in the calculations. We cannot give detailed estimates of these costs, just as we cannot specify who will have to pay them, or when.

The biotic circular economy: waste streams as raw materials

3 The biotic circular economy: waste streams as raw materials

The Netherlands is a densely populated country with an intensive agricultural sector and large agro-food industry, both of which generate significant waste streams. This chapter identifies the 34 most important biotic waste streams and their current uses, which already represent a value of €3.5 billion. The application of new technologies, such as biorefining, biogas extraction and improved means of sorting household waste could add another €1 billion to the Dutch economy.

3.1 Waste streams from the agro-food sector

The Dutch circular economy would benefit from adding as much value as possible to biotic waste streams. We would not be starting from scratch: many processes that add value to biotic waste streams are already in place. But to gain insight into the potential of a more circular economy, we have to look carefully at all the data on the nature and size of existing biotic waste streams, and at the ways in which they are already being (and could be) converted into valuable product streams.

A distinction can be made between three waste streams:[1]

- *primary waste streams* are generated during harvesting, storage and transport prior to primary processing;
- *secondary waste streams* are generated during primary processing within the agro-food industry; and
- *tertiary waste streams* are generated during production or consumption by end users.

These waste streams are significant because agricultural sector and the food, drink and beverages (e.g. beer) industry are extremely important to the Dutch economy. In 2010, for example, agriculture accounted for 5.3% of Dutch exports, and employed 240,000 people. The food industry contributed as much as 12.9% of exports (total value €32.9 billion) and provided work for approximately 120,000 people.

Approximately 2.66 million ha, or 64% of the area of the Netherlands, has been earmarked for agricultural uses, such as horticulture, arable farming and cattle farming.[2] Figure 3.1 shows the yields of arable crops grown in the Netherlands, which together amounted to approximately 28 Mt in 2011 on 711,000 ha of land.[3] The predominant crops include maize for animal fodder (complete plants, 46 t/ha per year), sugar beet (80 t/ha per year) and potatoes (approximately 50 t/ha per year).

The Netherlands is also a net importer of grain (6.7 Mt per year of wheat, barley and maize), oilseeds such as soybean, sunflower seed and rapeseed (about 5 Mt per year),[4] and meat and vegetables (CBS). The Netherlands produces approximately 3.1 Mt (slaughter weight) of beef, pork and poultry, and 11.3 Mt of milk per year.[5]

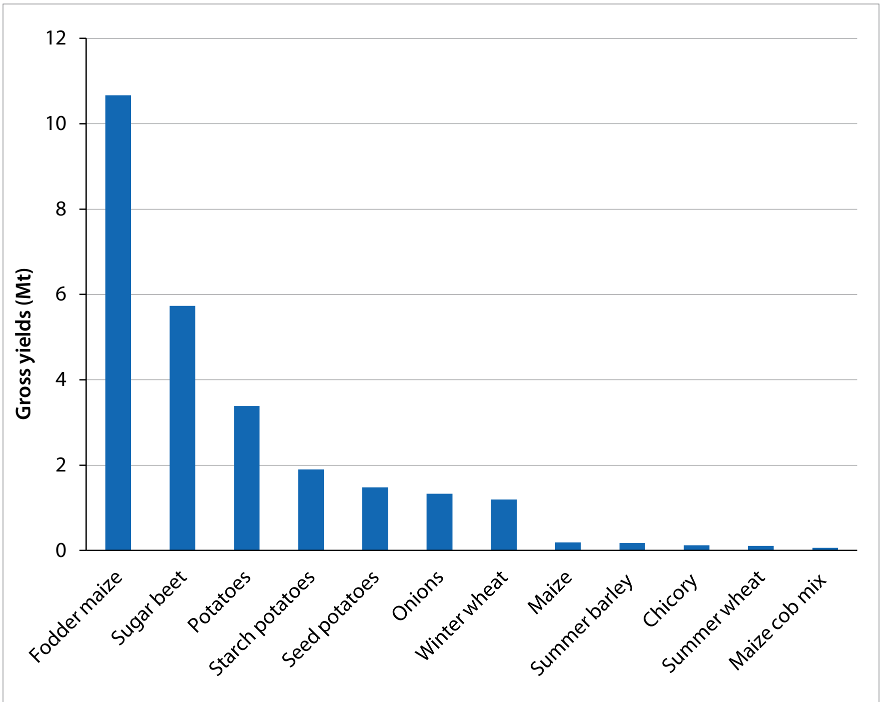


Figure 3.1. Yields of arable crops grown in the Netherlands, 2011.
Source: CBS.

As well as the waste streams from the agriculture and food sectors, this study has also examined a number of human waste streams, such as organic waste, household waste and sewage sludge.

Table 3.1 provides an overview of 34 waste streams generated by the agro-food sector, and how they are currently used. Although these waste streams together represent a volume of 42.9 Mt (wet weight) per year, this analysis considered only those streams larger than 50 kt per year. The table also provides indicative prices, although it should be noted that prices fluctuate significantly depending on factors such as location, season, quality and, in the case of a market notable for its lack of transparency, the intended purpose of the product. Primary waste streams are indicated in green, secondary in blue and tertiary in black.

Figure 3.2 shows the most important current uses of the primary, secondary and tertiary waste streams. The secondary streams are the largest in terms of volume due to the large amount of transported fertilizer (17.4 Mt, wet weight). Figure 3.3 plots the current values of the 34 waste streams, which amount to approximately €3.5 billion, while figure 3.4 shows the waste streams that represent the most value in absolute terms.

The uses of these waste streams can be roughly divided into five categories: incineration (substantial negative price), composting (negative price), waste that remains or is spread on the land, wet and dry cattle feed, and biodiesel production. The total value of dry and wet cattle feed is €2.1 billion, making it by far the largest area of use. The use of soybean meal as cattle feed accounts for 35% of the current market value of biotic waste streams.

The prices of a number of waste products have risen in recent years (or are less negative), partly because of rising energy and agricultural commodity prices, the surplus waste incineration capacity in the Netherlands26 and fierce competition regarding the procurement of organic and biodegradable waste for composting.

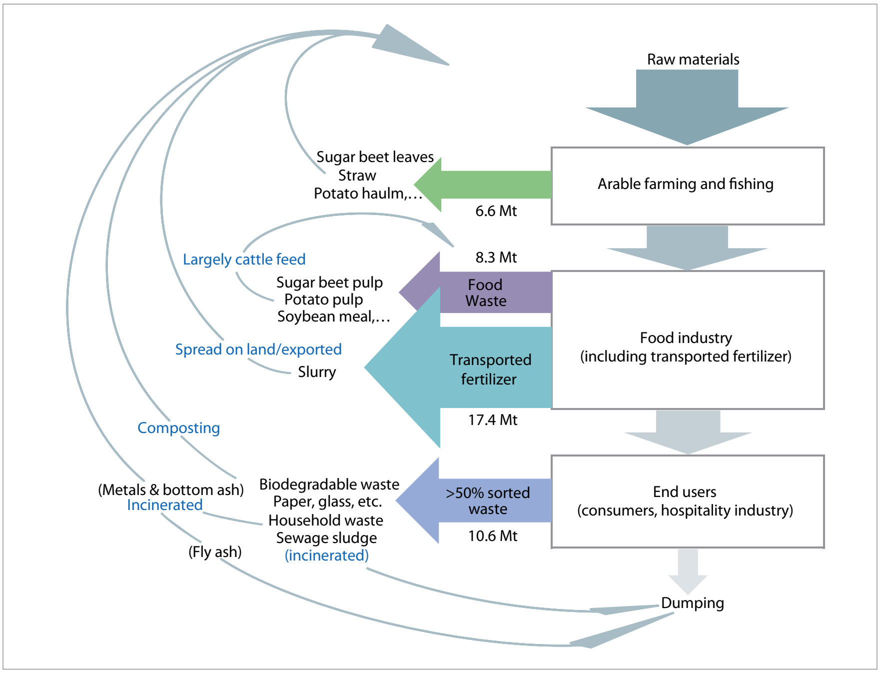


Figure 3.2. Waste streams from the agro–food sector and their circular applications.

Table 3.1. Summary of the 34 waste streams from the agro-food sector (ranked in order of indicative prices)

Biotic waste stream	Current uses	Indicative price (€/tonne)	Generated in NL (t/yr a.r.)[6]	Water content (%)
Mixed kitchen & supermarket waste[7]		−90	100,000	30%
Meat & bone meal (Cat. 1 & 2)[8]	Processed (to avoid risk of prion transmission)	−90	90,000	10%
Household waste (excl. biodegradable waste)[9,10]	4.4 Mt incinerated; metal extraction; road building; heating networks[11]	−80	7,600,000	30%
Sewage sludge[9]	Biogas, heat	−50	1,500,000	78%
Feather meal[7]	Heat	−50	37,000	5%
Flower auction waste[12]	Composting	−30	125,000	60%
Horticultural crop residues[13]	Composting	−30	220,000	60%
Biodegradable waste[14]	Composting, biogas[15]	−30	1,297,000	55%
Onion crop waste[11]	Biogas	−15	60,000	86%
Poultry manure & other[16]	Fertilizer	−15	1,160,000	30%
Cattle slurry[15]	Biogas, soil additive in phosphate- and nitrogen-deficient areas	−15	7,400,000	90%
Pig slurry[15]	Biogas, soil additive in phosphate- and nitrogen-deficient areas	−15	8,800,000	90%
Spent mushroom compost[12]		−10	780,000	30%
Sugar beet leaves[17]	–	0	3,000,000	87%
Fish waste[11]	Mink feed, biogas	0	76,000	75%
Potato haulm[18]	–	0	1,756,700	75%
Yeast extract (wet)[19]	Cattle feed	18	67,500	89%
Potato peel[20]	Cattle feed	20	450,000	80%
Maize grain, stalks and cobs[21]	Cattle feed	30	512,000	65%
Potato pulp[18]	Cattle feed	36	395,000	84%
Wet sugar beet pulp[19, 22]	Cattle feed, biogas	50	445,000	76%
Cocoa shells[18]		50	66,000	15%
Draff[18]	Cattle feed, biogas	50	500,000	78%
Straw (wheat, barley)[18, 21]	Stall bedding, second-generation biodiesel	150	1,100,000[23]	15%

Table 3.1. (continued)

Biotic waste stream	Current uses	Indicative price (€/tonne)	Generated in NL (t/yr a.r.)[6]	Water content (%)
Grain byproducts[24]	Cattle feed, wheat semolina	210	250,000	13%
Dry sugar beet pulp[19, 21]	Cattle feed	240	310,000	10%
Rapeseed meal[23]	Cattle feed	300	1,105,000	13%
Sunflower meal[23]	Cattle feed	300	555,000	11%
Meat & bone meal (Cat.3 food)[7, 25]	Pet food	300	300,000	5%
Frying oil[19, 21]	Cattle feed, second-generation biodiesel	450	120,000	5%
Animal fat (Cat.1)[7]	Cattle feed, pet food, second-generation biodiesel	450	40,000	5%
Whey powder[23]	Cattle feed	500	93,000	5%
Soybean meal[23]	Cattle feed	505	2,390,000	5%
Animal fat (Cat.3 food)[7]	Cattle feed, pet food	550	200,000	6%
TOTAL (tonnes/yr)			42,900,200	

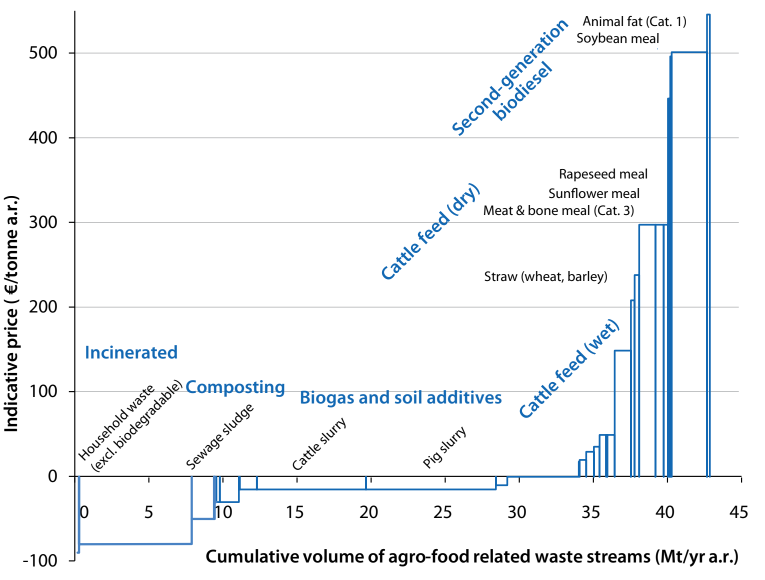


Figure 3.3. Cumulative current value of the 34 biotic waste streams.

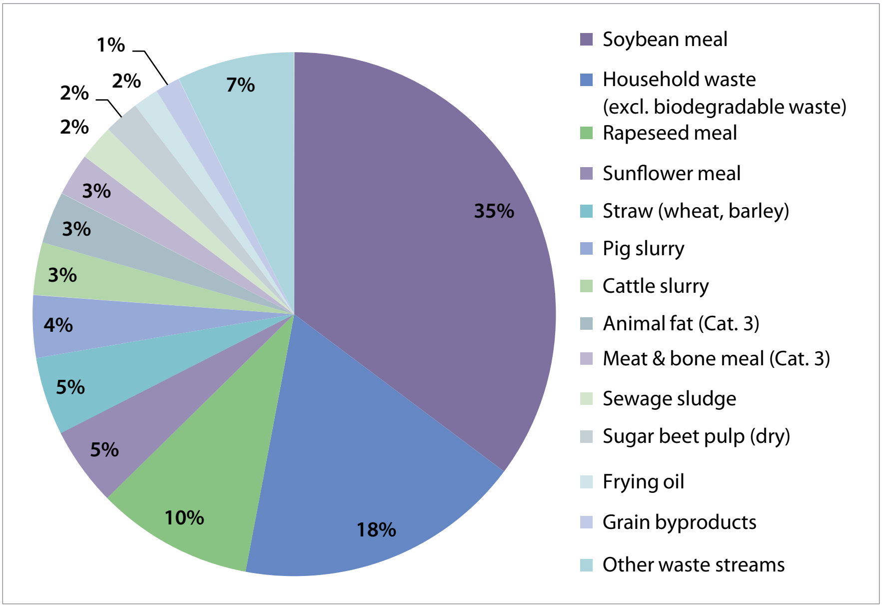


Figure 3.4. Breakdown of the current market value of the 34 biotic waste streams (total value €3.5 billion in 2012).

3.2 Getting more out of biotic waste streams

The previous section has demonstrated that a large proportion of biotic waste streams are already being used as cattle feed or raw materials for biogas or second-generation biodiesel. Researchers are working to develop novel applications and processes that could potentially generate a higher added value than existing uses, such as biorefining, insect breeding, the production of C_5 and C_6 sugars,[27] solid state fermentation, and more efficient biogas production processes. A summary of the technological options for creating added value from biotic waste streams can be found in appendix 4. The technical and commercial feasibility of many of these applications still have to be demonstrated.

In the most optimistic scenario, in which these 34 biotic waste streams are indeed used more efficiently and effectively than they are now, they could generate a net added value of €1 billion per year for the Dutch economy. Approximately 50% of this added value will be created by increasing biogas production, 42% by applying novel biorefining techniques and the remaining 8% by increasing the volume of household waste being sorted.[28] These values can be regarded as 'points on the horizon'. Figure 3.5 shows the added value for each biotic waste stream (where this can be compared with the current value). The sources of this added value are shown graphically in figure 3.6, and the underlying assumptions are explained in table 3.2.

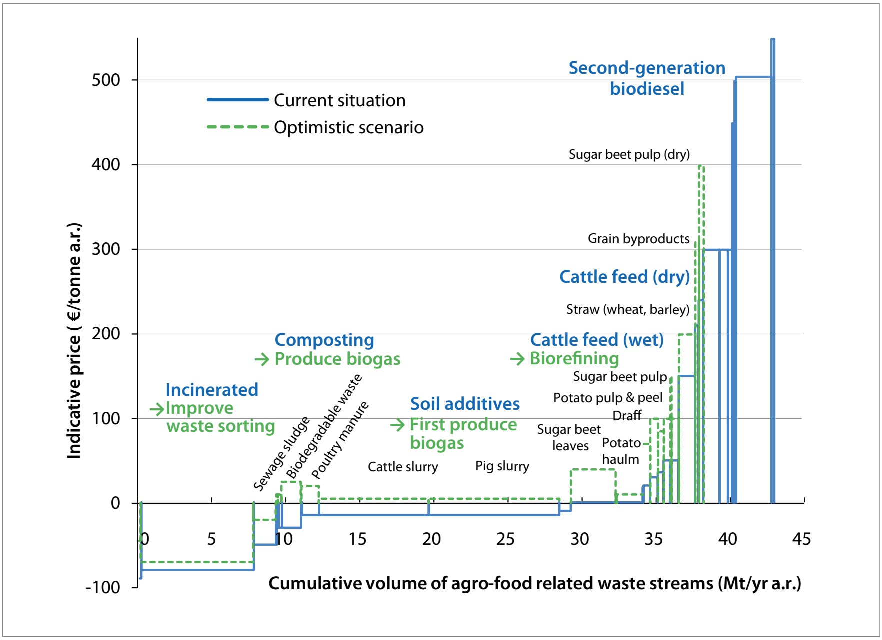


Figure 3.5. Indicative price–volume curves for the 34 biotic waste streams: current situation (blue) and the optimistic circular scenario (green).

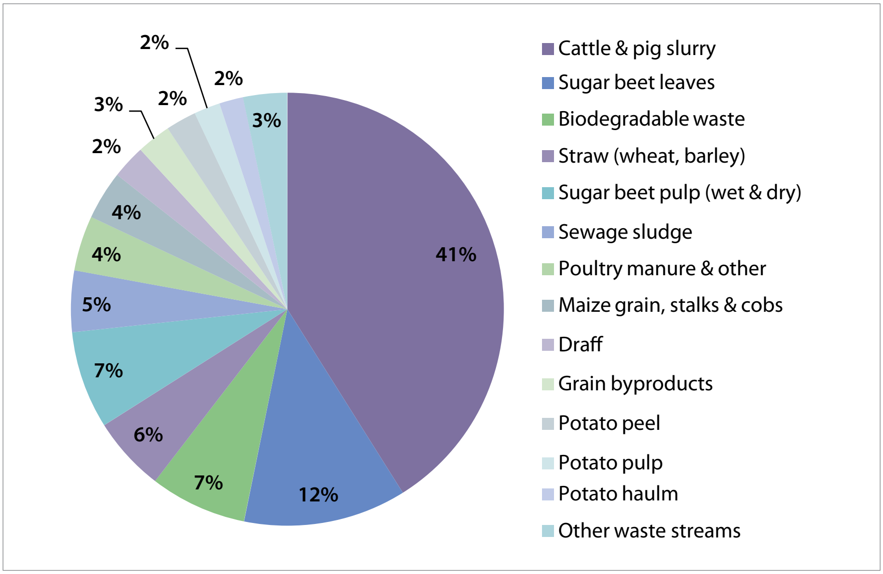


Figure 3.6. Sources of added value – approximately €1 billion per year – for the Dutch economy.

Table 3.2. Starting points and assumptions made in calculating the added value of biotic waste streams

Waste stream	Assumption regarding new circular application	New products	Indicative new 'value' (€/tonne)	Comment
Mixed kitchen & supermarket waste	Biogas production	Biogas	−45	Contains a large amount of cardboard and packaging
Household waste (excl. biodegradable waste)	Improved waste sorting	Paper, glass, textiles, biodegradable waste	−70	Savings of €250 million if the volume of waste being sorted were to be increased by one third
Biodegradable waste	Biogas production	80 m^3 biogas/t	+25	
Slurry	Biogas production	30 m^3 biogas/t[29]	+5	Value as fertilizer approximately +€8/t
Sugar beet leaves	Extraction of 1 wt% RuBisCO[30]	RuBisCO protein (€4/kg)	+40	7 Mt/yr
Sugar beet pulp	Biorefining	Diet products, cosmetics, fibre	+100	According to Benschop (2012)[31] and Elbersen (2010)[32]
Draff	Biorefining	Protein, fibre (sugars)	+100	Path according to Elbersen (2010)
Potato pulp	Biorefining	Starch, pectin, fibre	+85	Path according to Elbersen (2010)
Maize residue	Biorefining	$C_5 + C_6$ sugars	+100	Use of sugars for ethanol production
Straw	Biorefining	$C_5 + C_6$ sugars	+200	Use of sugars for ethanol production
Waste streams costing >€200/t	No change	–	–	High-quality applications already exist

In the following we look at some of these waste streams in the Netherlands, and the prospects for getting more out of them.

Biodegradable waste

Each year Dutch households produce approximately 1.3 Mt of biodegradable waste, most of which is sorted and processed into compost in 22 waste plants for use in arable farming, for example. These composting companies are facing increasing competition in public tender processes and, as a result, sharply declining margins.

A growing number of waste management companies, such as VAR, HVC and Shanks Orgaworld, are converting biodegradable waste into biogas (approximately 40–100 m^3 per tonne of waste) so that a compost fraction can be produced after all. There are currently seven biogas plants in the Netherlands, which in 2011 processed a total of approximately 220,000 tonnes of biodegradable waste. In 2010 these companies signed a 'sustainability declaration', in which they agreed on a target of processing 1 million tonnes of biodegradable waste by mid-2015.[33]

Fertilizer

Approximately 67 Mt of slurry (wet weight) is collected from Dutch farms every year, of which about 7.4 Mt is cattle slurry and 8.8 Mt pig slurry, which are transported to other locations to be used to produce biogas or spread on agricultural land deficient in organic nutrients such as nitrogen and phosphate in the provinces of Zeeland or Groningen. The use of fertilizers is subject to strict government regulations, as well as the EU Nitrates Directive (2006), which sets limits on the use of phosphate fertilizers in order to protect groundwater quality. A bill recently presented to the Dutch parliament aims to promote the responsible use of fertilizers by specifying the obligations of manufacturers regarding processing (for example, its conversion into granules). Companies such as Ferm O Feed are already producing organic granular fertilizer from poultry manure, much of which is exported to China.

Sugar beet

Approximately 3 Mt (wet weight) of sugar beet leaves are currently left on the land, and so seldom appear in statistics. The leaves contain small quantities of RuBisCO, a high-quality protein that could be used as a food supplement. Studies are currently under way to identify ways to extract it.

Approximately 1.1 Mt (wet weight)[34] of sugar beet pulp is sold as cattle feed, and a small proportion ends up in biogas plants. Some of the pulp is dried into pellets and some is sold wet. Cosun, the owner of the only two remaining sugar factories left in the Netherlands, in Dinteloord and Groningen, is considering opening a biorefinery at one of these sites to generate a range of products that could cause the value of sugar beet pulp to increase from approximately €200–240 to €400 per tonne (dry weight).[35]

Draff

Draff is the residue of malt and grains used in the production of beer that is used as cattle feed because of its high protein content (approximately 25% dry weight). Some companies are considering biorefining the draff in a process that would separate the protein (for use as cattle feed) and the fibres (for starch, for example[36]).

Potatoes

Potato pulp and peel waste streams, which amount to 395,000 tonnes and 450,000 tonnes (wet weight) respectively, are currently used as cattle feed, but their starch, fibre and pectin fractions make them potentially attractive for refining for use as food, cattle feed and for applications such as starch or paper production.

Maize stalks and cobs

Maize production generates approximately 30 tonnes/ha of stalks and cobs. As mentioned above, these residues could be biorefined to produce sugars.

Straw

Each year the Netherlands produces about 1.1 Mt of barley and wheat straw,[37] about 75% of which is already put to good use as bedding in animal stalls, for example, and 25% is left on the land to improve the organic content of the soil and soil structure. Straw and maize stalks are now being used as raw materials in the new second-generation bioethanol plants being built in the United States (e.g. POET-DSM in South Dakota and Abengoa in Kansas) and Italy (Chemtex in Crescentino near Turin).

Potato haulm

Potato plants are sprayed with pesticides or mechanically 'folded' several weeks before the harvest, after which the haulm – the leaves and stems – is left on the land. The 1.7 Mt of potato haulm produced in the Netherlands has an interesting potential for biorefining because the potato plant contains two natural toxins (alkaloids chaconine and solanine) that protect the plant against fungi, insects and other parasites.

The authors of this report estimate that a one-off investment of about €4–8 billion would be needed to achieve the required biodigestion and biorefining capacity, which could have an annual market value of €1 billion.[38] In the end, the exact amount will depend on factors such as scale, steel prices, biogas revenues, the number of annual operating hours and the selected process concepts. Producing biogas through fermentation and improving the sorting of household waste are technologies with a proven track record. Biorefining has been shown to be feasible in the laboratory, but not yet commercially.

In some cases, the new value of a waste stream that could be used more effectively in a circular economy would represent an immediate saving if that product is normally imported. Examples include RuBisCo protein extracted from sugar beet leaves (reducing imports of high-quality proteins), the production of biogas from animal slurry (eliminating imports of natural gas) or the production of ethanol from maize cobs (reducing imports of ethanol). In other cases, such as the biorefining of protein-rich draff, the potential benefits are not so clear. Indeed, draff is already used as cattle feed and so has helped to reduce imports of soya.

3.3 Environmental impacts of increased circularity in the use of biotic waste streams

Extending or intensifying the uses of biotic waste streams could help to avoid many negative environmental impacts, expressed in terms of indicators such as CO_2 emissions, the use of freshwater, land use and the Raw Material Equivalent (RME).

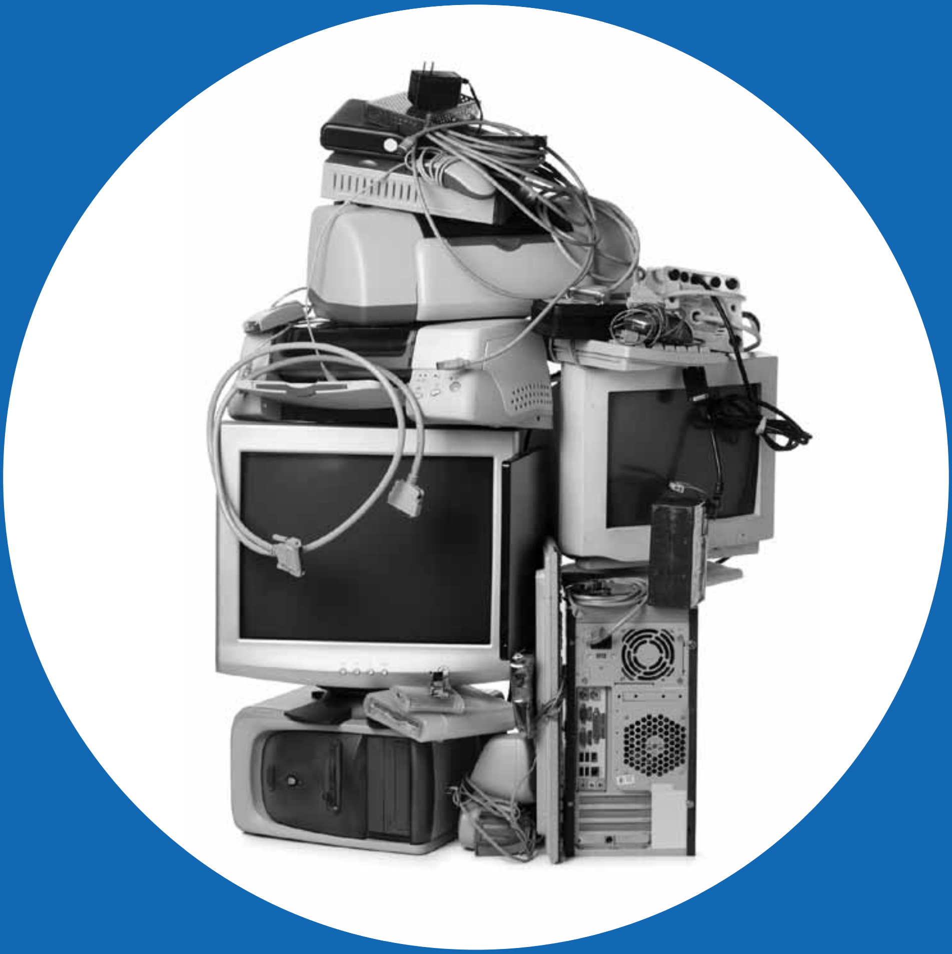
CO_2 emissions can be avoided by burning less fossil fuel. In the Netherlands increasing the share of biogas in the energy mix could help to reduce CO_2 emissions by an estimated 150 kt (based on an average energy value of biogas of 15 MJ/m^3), which is 1.2% of the emissions currently produced by the Dutch agriculture and fisheries sectors. If the CO_2 emissions avoided are the result of biogas (or ethanol) production, that would also contribute to the government's target of meeting 16% of the energy demand from renewable sources by 2020.

The RME avoided is the result of a slight reduction in exports of raw materials due to the use of biorefining techniques and burning less fossil fuel. The potential is estimated at 0.4 million kt of raw materials.

In this study the use of fresh ('blue') water avoided was not calculated because no clear relation between water use and biotic waste streams could be determined.

However, following from this study of biotic waste streams, it is possible to calculate the land use avoided due to the use of biowaste. This is the result of a reduction in imports of some inputs used in the Dutch agricultural sector. Even using conservative estimates, the ecological footprint would be reduced by no less than 2,000 km^2, considerably more than in the case of abiotic waste streams discussed in chapter 2, because of the predominance of agriculture in the calculation of ecological footprints.

The impacts of increased circularity on the Dutch economy



4 The impacts of increased circularity on the Dutch economy

After analyzing the uses of biotic waste streams and the effects of an expanded circular economy on products from the metal and electrical sectors, we can estimate the impacts of moving towards a circular economy on the Netherlands as a whole. We estimate that the added value could amount to €7.3 billion per year, involving 54,000 jobs. It would also provide a number of spin-off benefits for the Netherlands, including strengthening the country's knowledge position.

4.1 Scaling up: the potential value of the circular economy

In chapters 2 and 3 we estimated the economic opportunities presented by an expansion of the circular economy for two cases: the more intensive use of and greater efforts to keep in circulation products from the metal and electrical sectors and biotic waste streams. But of course these areas of activity represent only part of the Dutch economy.

To estimate the influence of increased circularity on the entire Dutch economy (and the environmental effects) we considered various other sectors that are linked in some way to those examined in chapters 2 and 3. In other words, we looked at the opportunities for increased circularity in the food, textile and clothing, and wood and paper industries the same way as we did for biotic waste streams. For other industrial sectors (such as the automotive, printing and graphics, and construction industries) we assume that the opportunities for increased circularity are comparable with those for products from the metal and electrical sectors. The growth in value in the base metal, metal, electronic and electrical appliance sectors are 0%, 0.3%, 12.1% and 35.5%, respectively (see table 2.4).

We assume a fixed increase in value of 0.1% for the various service sectors, while the activities in the service sectors involved in repairs, rental, maintenance and recycling will increase proportionately to the estimates for these activities in chapter 2.

Based on this extrapolation, we estimate the total market value of the opportunities presented by the circular economy for the Dutch economy could amount to €7.3 billion a year, or 1.4% of today's GDP. This corresponds, given the market value of salaries in all sectors, to approximately 54,000 jobs (including those created from the biotic and abiotic cases).

This €7.3 billion can be accounted for as follows: slightly more than €1 billion by an expanding services sector, €0.93 billion in agriculture and €5.3 billion in the industrial sectors.

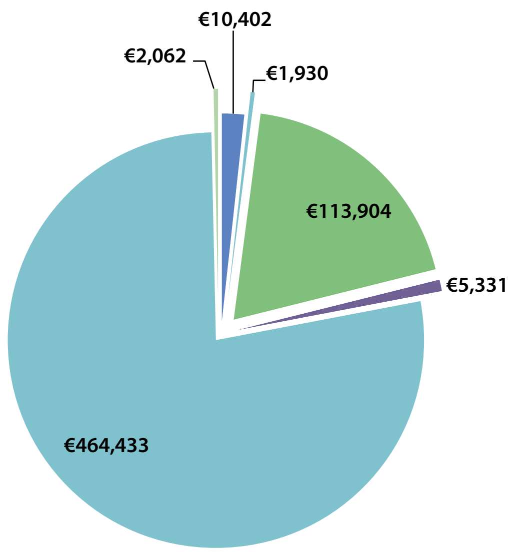


Figure 4.1 Breakdown of Dutch economy in 2010 expressed in gross domestic product (GDP) and the shares of potential GDP growth (in euros) as a result of circular economy.

Obviously this €7.3 billion will not find its way into the Dutch economy immediately. A number of steps will need to be taken, some of which will require long-term research, drastic changes in behaviour or amendments to laws and regulations, while others could be implemented relatively quickly. We have assessed the various steps and the time it would take for them to help develop a circular economy, and identify three phases:

Phase 1: short term (0–3 years)
- leasing and rental contracts for washing machines;
- subsidies such as the Environment Investment Allowance (MIA) or Random Depreciation of Environmental Investments (VAMIL), to lengthen product lifetimes;
- loan schemes such as Neemby, Floow2[1];
- increased recycling of LEDs due to their high value;
- reassessment of the WEEE directive;
- use of logistical knowledge of major ports;
- collective insurance to cover repaired goods/products with used parts;

– lift ban on stockpiling;
– rising prices of raw materials;
– use of reserve from collection contributions; and
– reduced rate of VAT on circular services.

Phase 2: medium term — the period of Horizon 2020, the EU's Framework Programme for Research and Innovation (3–7 years)
– changing the location of incineration plants;
– 'assembly for disassembly' computers;
– changes in attitude towards possession;
– rising prices of raw materials (continuing incentive);
– conditions for the supply of parts incorporated into B2B contracts; and
– new technologies to intensify the use of biotic waste streams.

Phase 3: long term – point on the horizon (>7 years)
– development of plastics that are designed for recycling;
– divestment of 'stranded assets' strategies;
– introduction of raw materials passports;
– rising prices of raw materials (continuing incentive);
– development of product service systems (PSS) for the most expensive metal and electrical product groups; and
– introduction of new technologies to intensify the use of biotic waste streams.

In each of these three phases, the opportunities provided by an expanding circular economy could generate an estimated value of €3.3 billion in the short term, €1.7 billion in the medium term (3–7 years) and €2.3 billion in the long term (after 2020, see figure 4.2).

Clearly, in order for the Netherlands to benefit from the long-term opportunities, action needs to be taken now.

In its report, Towards the Circular Economy, the Ellen MacArthur Foundation (EMF, 2012/2013) estimates that the circular economy could add US$380 billion (€287 billion) to the European economy during the transition stage, increasing to US$630 billion (€476 billion) in a more advanced stage. These estimates are based on a more restricted group of industrial sectors than the one we used to derive our estimate of €7.3 billion for the Dutch economy. The question now is how our assessment compares with that of the EMF report.

For the sectors examined in the EMF report, the Dutch contribution to the European economy (EU 27) is 2.9%.[2] If we restrict our analysis to this set of industrial sectors, then according to our calculations the contribution to the Dutch circular economy could be worth €2.7 billion (rather than the indicated €7.3 billion). This is approximately 1% of the €287 billion that the EMF estimates for the EU-27. The potential that we estimate is rather lower than the EMF's estimate, for three reasons:

- The estimates of the shifts that were introduced in chapter 2 (and used for the extrapolation in this chapter) were conservative; the potential effects of more radical changes and business models that could help the move towards a circular economy are particularly difficult to calculate.
- The negative economic effects of a transition have been taken into account to the greatest extent possible. For example, a shift towards more recycling can result in higher costs in some cases, and a circular economy would also lead to fewer new products being bought.
- The Netherlands is already affected by the 'frontrunner's handicap' (i.e. an initial headstart that can turn into a disadvantage in the long term) when it comes to the amounts of materials being saved through recycling, etc. Figure 1.1 showed that within the EU the Netherlands is a leader in terms of the volumes of materials being recovered from household waste. The net savings in terms of materials in the Netherlands could therefore be higher than what is assumed to be the European average (note, however, that the costs associated with more intensive recycling have not been included here).

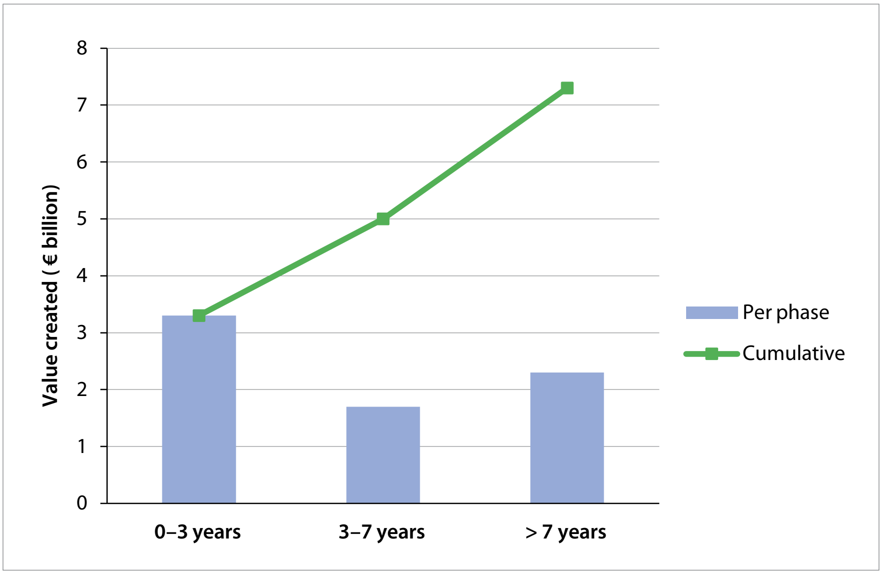


Figure 4.2. The three phases in the creation of value in the circular economy.

4.2 External effects of the circular economy for the Netherlands

A simple extrapolation of the reduction in CO_2 emissions from the two cases to the national level reveals a potential reduction of 17,150 kt, almost double the CO_2 emissions that are being saved now by using renewable energy. By comparison, national CO_2 emissions in the Netherlands in the base year 2010 were 214,000 kt, some 172,000 kt of which was produced by economic activity.

A reduction in land use would come to 2,180 km^2, whereby the contribution from the abiotic waste streams would be marginal compared with the biotic case. Given that at present the ecological footprint of the Netherlands is three times larger than its land area (41,500 km^2), an expanded circular economy would reduce this footprint by approximately 2.5%.

The avoided use of fresh water due to expanded circularity would amount roughly to 0.7 billion m^3. The Netherlands currently uses approximately 16 billion m^3 of water per year, which industry uses about 3.5 billion m^3.

The avoided use of raw materials (represented by the Raw Material Equivalent, RME) is 100,400 kt, which is more than 25% of the total imports of goods by weight in the Netherlands each year.

4.3 Indirect benefits of the circular economy

The move towards circularity in the Dutch economy is likely to generate a number of direct benefits, including increased GDP, and therefore jobs, as well as indirect benefits (the value of which has not been analyzed in detail here), such as:

Development of knowledge for export

There is a clear opportunity in terms of developing and spreading knowledge about the development of a circular economy in the Netherlands. Such knowledge and expertise can be used within and outside the country, as is the case with Dutch water expertise. The location of the Netherlands on a delta with high rates of production and consumption means that circularity will require a number of breakthroughs. The knowledge that will be needed to make these breakthroughs can be used subsequently in other densely populated areas, which are expected to increase worldwide.

More secure supply of raw materials

Ensuring the security of raw material supplies has become an important strategic imperative for companies, national governments and the European Union. The literature and interviews held for this study reveal that many companies are already experiencing supply interruptions. A circular economy will make companies less dependent on imports of raw materials and therefore less vulnerable to trade restrictions and price fluctuations.

New incentives for the manufacturing sector

In addition to trade, the manufacturing sector plays an important part in the Dutch economy. Manufacturing industries are important innovators (in production processes, as well as products themselves). However, the share of manufacturing in total GDP in the Netherlands is shrinking. The circular economy will provide a number of opportunities for the further development of manufacturing industry, including in areas such as product design and related production techniques, as well as the repair and reuse of products and components. Regenersis, a UK company, is an example of a company that is already putting this idea into action.[3]

New incentives for the recycling industry

BRBS Recycling, a Dutch trade association, believes that recycling is still in its infancy,[4] and has recently conducted a survey to gauge how much further recycling can be developed in the Netherlands. Preliminary results suggest that one condition for creating an ideal recycling scenario would be to weaken the dominance of incineration plants in the processing of biotic and abiotic waste streams. Recycling companies are introducing increasingly accurate technologies for sorting waste streams. Examples include Van Baetsen Recycling, which is using robots for hand-sorting waste, and HKS Metals, which uses X-ray analysis to separate metals from waste streams.

In another development, several major producers are examining ways of reusing plastics from old appliances in new ones, although this is still more expensive than 'downcycling'. Plastics from waste electronic and electrical equipment (WEEE) contain a mix of acrylonitrile butadiene styrene, polyethylene/polypropylene, polystyrene and polyvinyl chloride, and are not suitable for disassembly or recycling.

Innovation in the logistics sector

A circular economy will have a significant impact on the Dutch logistics sector. Logistics operations will change, and in some areas increase, as the collection of products, components and waste streams become everyday practice. On the other hand, a circular economy would ideally mean reducing the use of primary raw materials and semi-manufactured goods, and increasing the lifespan of products, thus reducing the demand for logistics. What the balance would be in terms of volume and value needs to be examined in more detail. In mid-2013, the Council for the Environment and Infrastructure was expected to present its outlook for the logistics sector between now and 2040, and role of the circular economy.[5]

Development of new economic activity

The circular economy will also encourage the development of new economic activity. These could include, for example, businesses that focus on repairing and reusing electronic products and reusing components, such as Regenersis, or introduce different kinds of product services, such as Turntoo, Neemby and Floow2. Other kinds of economic activity might also emerge that we cannot yet anticipate. All of these activities will reduce the transaction costs of circular services, both as a result of economies of scale and the closer proximity (and visibility) of these services to consumers.

Drivers and obstacles on the way to a circular economy

5 Drivers and obstacles on the way to a circular economy

Chapter 4 presented a picture, based on an economic analysis, of the potential of a circular economy in the Netherlands. This chapter examines those aspects that could either impede or encourage this potential, and chapter 6 focuses on the role of the government can play in that respect.

5.1 Introduction

In order to create a circular economy that has the potential as described in chapter 4, a number of preconditions have to be met and various hurdles have to be cleared. This chapter presents a summary of these hurdles, based on the literature, interviews and a workshop that was held in the context of this study. They give an idea of the preconditions, obstacles and incentives in the eyes of the stakeholders we consulted. The summary also provides guidelines for an action plan for various stakeholders, including the government (see chapter 6). The driving forces and obstacles identified by the stakeholders are discussed in light of each of the key processes in the innovation system in the Netherlands (see box).

5.2 Developing and disseminating knowledge

One precondition for the transition to a circular economy is the capacity to innovate. What is the general state of the Netherlands' innovative capacity? Compared with other EU countries, the Netherlands is above average, an 'innovation follower', but certainly not a leader. Dutch companies are innovative –almost 40% of industrial companies and 21% of businesses in the services sector have produced at least one technological innovation – but the number of innovative companies is not rising. Both public and private investments in R&D are under pressure. The Netherlands is a global frontrunner in the area of patents, but the absorption and transfer of technology could be better. The Netherlands scores well in the sciences, but future employment opportunities in the sciences and engineering are not developing adequately.[1] In short, when it comes to developing and disseminating knowledge and entrepreneurial activities, the picture is mixed.

Categorizing obstacles and creating opportunities

In order to draft a useful and realistic initial action plan, it is important to explore the opportunities and obstacles from different perspectives. In this chapter, we examine the results of a qualitative analysis of the incentives and obstacles regarding a transition to a circular economy using the concept of an innovation systems analysis (for further details, see the background document and Appendix 1).

In any innovation system a number of specific functions or key processes must work well together in order for the system to succeed in generating innovations. These system functions can grouped into four categories:
- knowledge: developing and disseminating knowledge;
- business: entrepreneurial activities, market mechanisms and mobilizing resources;
- policy and rules and regulations (government-related framework activities); and
- lobbying and framework activities (non-government-related).

This classification will be used to identify the opportunities and obstacles to developing a circular economy, is based on a review of the literature, interviews and a workshop with stakeholders selected from the biotic and abiotic cases and TNO experts. We conducted interviews with 14 representatives of three research and education institutes, five businesses, a government agency, two trade associations and three other intermediary organizations. The workshop participants included 16 representatives of nine businesses, two research institutes, one government agency, two trade associations and one other intermediary organization (see appendices 2 and 3).We have included the sources (literature, interviews) in the analysis whenever possible; if the source is not mentioned, it means the analysis was based on TNO expertise.

The standard of knowledge on transitions and transition management in the Netherlands is up to par

In the last two decades, adequate knowledge has been developed in the Netherlands in the area of transitions. Various programmes have been launched to develop and disseminate knowledge and implement innovations, such as Sustainable Technological Development (DTO), the National Initiative for Sustainable Development (NIDO) and the Knowledge Network for Systems Innovations and Transitions (KSI).[2] This knowledge has also been used in the various transition platforms set up by the government between 2004 and 2010 and in CSR Netherlands (MVO Nederland) and the Sustainable Trade initiative (IDH). Agency NL, a division of the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) hosted the Competence Centre for Transitions from 2005 to

2009, where knowledge about transitions, the required competences and learning experiences from actual transitions was collected, developed and disseminated.[3] Various knowledge institutes, universities, intermediary organizations and research bureaus are developing knowledge that could be used to explore an action plan for the government, set up experiments and monitor the development of a circular economy. There has to be a guarantee, however, that this knowledge dovetails with technological competences.

If we are to make full use of the opportunities for biotic waste streams, then in addition to the large-scale introduction of biogas plants, biorefining technologies need to be further researched and developed. Biorefining entails a series of technologies that aim to use as effectively as possible all of the valuable components of biomass, one of the most promising options for making the most efficient uses of biotic waste streams. It involves 'whole crop' biorefining (using maize and grain as raw materials), lignocellulose biorefining (using dry ligneous biomass) and organic biorefining (using wet biomass). All over the world, including in the Netherlands, many research and pilot projects have been set up related to biorefining. A number of commercial operations are under way, especially in the United States, based on maize, sugarcane, grain and sugar beet as raw materials, but as yet the focus is not on the production of industrial products from biotic waste streams.[4] Research is being carried out in the Netherlands on various biotic waste streams, including ways to extract the valuable RuBisCo protein from sugar beet leaves and tomatine from the leaves of tomato plants.[5]

In addition to the required technological developments, another precondition for the successful application of biorefining is the creation of integrated bioconversion chains. These chains should cut across the agricultural, energy, chemical, pharmaceutical and agro-food sectors so that they all work together to generate high-quality products, while the waste streams can be used to produce materials, bulk chemicals and energy. These achievements, together with the development of biorefining technology, will contribute to the circular economy in the long term.[5]

Closing the phosphate cycle is a priority for the Netherlands and has been supported by the Nutrient Platform NL since 2011. Nutrient Platform NL is a network of stakeholders from various sectors that focuses on creating operational conditions for the more sustainable use of nutrients throughout the entire value chain. The platform has launched a number of pilot projects[6] and is developing and disseminating knowledge on ways to close the phosphate cycle, and to strengthen the platform's position.

Knowledge that will contribute to the circular economy should be integrated into the creative industries and design schools

In order to close material cycles, knowledge is needed that can be used to 'design for disassembly, refurbish and recycle'. This notion is not included in most design school curricula.[7] The circular economy most likely will have to go hand in hand with far-reaching standardization to facilitate the reuse of product parts. Knowledge development for the design process will therefore have to focus on the art of combining constantly evolving standardization with designs that still allow manufacturers to distinguish themselves from their competitors. Perhaps the internationally acknowledged 'Dutch design' of the future will be instantly associated with circularity. This design knowledge can also grow as a result of skills acquired during the repair and disassembly phases of products. Businesses already learning to do this are clearly developing knowledge on the (dys)functioning of parts and how to discover manufacturing or design errors.[8]

But several major obstacles are impeding the development and dissemination of this knowledge:

Knowledge management is fragmented and rarely cuts across sectors

An important obstacle impeding knowledge development in the Netherlands is linked to how it is currently organized. The government's 'top sector' policy identifies nine priority sectors and envisages a multitude of innovation contracts. This kind of knowledge policy could be an effective way of improving efficiency within individual sectors. But if the aim is to take more concrete steps towards a circular economy, then the government will have to forge strong links with a variety of sectors and be particularly strongly rooted in a biobased economy. There is already a 'top consortium' for knowledge and innovation in the biobased economy in the Netherlands, but that is no guarantee of targeted and ongoing cooperation between businesses, knowledge institutes and government agencies.[5] The question is how to develop knowledge for a circular economy in an effective and focused way and, just as important, how to introduce this knowledge to the market. Indeed, focusing on reducing pressures on the environment, increasing energy efficiency and the use of raw materials in particular sectors could result in suboptimization, which could prevent the next step on the path to a circular economy. The top sector policy should be assessed for these kinds of negative effects.

The lack of a coherent approach to training and the development of skills and competences[9]

In general, a circular economy means restructuring society. Every business will have to adopt new business models, and the nature of many jobs will change to some degree. As a new point of departure for society in many disciplines, the concept of a circular economy will also have to be introduced into education. A coherent plan for a circular economy should ensure that these topics are clearly identified on the research agendas of the top sectors (and of the Top Consortium for knowledge and innovation), and in the curricula at all levels of higher education, from intermediate vocational colleges to universities. In addition to focusing on detailed knowledge of the concept of a circular economy in education, more thought could be devoted to developing the 'circular' skills and competences of graduates, including:

- their knowledge and skills in applying the principles of systems thinking;

- their ability to work together in multidisciplinary settings, and, for that matter, to work together in general. Circular working practices within and between businesses requires thinking in terms of chains and thinking outside the box. To do this, people must be able to work together with professionals from other fields; and

- their acceptance of 'not knowing'. A 'process-driven' approach to education involves and engages students in issues that affect them and others, but does not rely on getting answers from students based on current knowledge and desired behaviour (expert-driven education). Indeed, the circular economy means new ways of working and thinking that people will have had little or no experience with.[10]

The lack of knowledge within businesses and poor dissemination of knowledge

Many businesses are unaware of the exact origin or the composition of the raw materials they use. Moreover, the dissemination of knowledge about the development of new materials is often poor. There is little understanding of which materials are 'good' in terms of environmental impact, and it is often difficult for businesses to access such information. Finally, many businesses are not aware of the fact that they could reduce their waste streams or put them to use by working together with other businesses in the chain.[11]

5.3 Business: entrepreneurs, markets and resources

As described in the previous section, the Dutch business sector offers a mixed a picture in terms of innovative capacity. Dutch companies are just as innovative as those in other countries, but on the whole their numbers are not increasing.

5.3.1 Entrepreneurs

A good way to assess the innovative power and vitality of the Dutch economy is to look at whether the numbers of rapidly growing companies and young startup businesses are increasing. In that respect, the Netherlands lags behind other European countries. Many of the fastest-growing young businesses are in fields such as IT services, software, apps, webshops and gaming, but are all but absent from the heavy industry sector, which is extremely important for the development of a circular economy. Investments in R&D are about the same as in previous years. The range of major investors is becoming broader. R&D spending by small and medium enterprises (SMEs) is decreasing, while for major companies R&D expenditure overseas is becoming an increasingly high priority. Most of them are already spending more than half of their R&D budgets outside the Netherlands. At the same time, the interest of foreign companies in the Dutch knowledge economy has risen steadily over the past 10 years.[12]

Nonetheless, if we look at entrepreneurial activities related to the circular economy in the Netherlands, it is evident that there are a considerable number of frontrunners. They range from companies that emphasize corporate social responsibility (CSR) and are implementing the 'cradle to cradle' concept in their business practices and in the use of their waste streams, to companies that are developing and implementing new business models by using different product service systems.[13] These frontrunners are becoming increasingly well organized thanks to organizations such as CSR Netherlands, De Groene Zaak (entrepreneurs for a sustainable economy) and the Circle Economy, as well as government initiatives such as the 'Green Deals' to promote sustainable energy or energy-saving projects.

An inspiring example of how the business sector, knowledge institutes, NGOs and the government can work together to create a value-enhancing chain approach, is the Nutrient Platform and its efforts to implement the *phosphate chain agreement*. Their ambition is to create a sustainable market where as many phosphate streams as possible will either be returned to the environmental system or be exported as products. In doing so, a more 'energetic' society will take the lead in solving social problems (based on solid business cases), with the government as an equal partner. The platform brings together various market players, removes obstacles if necessary and desirable, establishes operating conditions, explains the advantages and drawbacks of national and European rules and regulations, and is helping to generate support for a European market in Europe and beyond.[14]

A growing number of businesses are viewing *corporate social responsibility* as the inevitable way of doing business in the future. Some aspects of CSR would support a move towards a circular economy, including more sustainable business operations, products and services, the value chain development approach and stakeholder dialogue.

The development of *biorefining* is necessary for a transition to a biotic circular economy. The biorefining activities related to biotic waste streams are generally conducted by companies that use specific plant or animal ingredients in their products. In many cases, the market prospects for such applications are still unclear, although in a technical sense many existing waste streams could be put to use. Experiments are under way in the Netherlands to set up new value chains across several sectors, involving SMEs and government agencies, although they are often poorly organized. The opportunities to develop further the biorefining of waste streams will depend on a growing consumer demand for high-quality products that contain only natural, biologically degradable ingredients.[15]

The use of *biodigesters for treating biotic waste streams* will have to be expanded. Composting businesses are now building digesters that can produce biogas as well as compost.[16] The Netherlands has 113 digestion plants that can process a total of 1 Mt (wet weight) of manure, usually by means of co-digestion, in which approximately half of the stream of material is manure. The cost-effectiveness of these plants leaves a lot to be desired, however.

Newly planned digestion plants are often larger than their predecessors and are equipped with digestate drying units.[17] As a result, exporting organic digestate granules as fertilizer and soil improvers is an obvious path to explore. The market for digestate granules from biogas plants still needs to be developed. Biodigesters with drying units appear to be an interesting application for biotic waste streams that cannot be utilized in better ways. They would mean, for example, that the large volumes of poultry and pig manure produced in the Netherlands could be used to generate energy, and would also dovetail with a new regulation obliging farmers to make the necessary investments to build their capacity to process manure.

5.3.2 Markets and new business models

The transition to a circular economy should be accompanied by greater efforts to experiment and work with new business models that encourage consumers to 'buy' the service provided by a product rather than the product itself. Examples include results-driven product service systems (PSS) such as Turntoo, or marketplaces such as Floow2,[18] where businesses can share equipment and services. Various studies have shown that results-driven PSS are the most interesting option in terms of sustainability,[19] and in theory could correct the uneven distribution of environmental costs and benefits of the production and consumption of products.[20] Indeed, it is in the interests of both producers and consumers to reduce the lifecycle costs and the use of raw materials during the use of a product. Furthermore, if it is true that producers really want to meet consumer demands, then they will have far greater freedom to design more sustainable product service systems.

The challenges of results-driven PSS lie in drawing up agreements that are sufficiently clear about what functional result will be, and limiting the risks for producers when it comes to delivering on their promises. The starting point of this is to 'replace' a product with a suitable results-driven PSS – one that will not clash with the desire for status, convenience or freedom. Based on a number of experiments with product service systems, the following lessons have been learned:

- Being customer-driven and eco-efficient is an extremely strong incentive for producers. It creates customer intimacy, because of the contact producers have with customers during the use phase. However, there is also the drawback that users can become dependent on the producers, either because of long-term contracts or other conditions included by the producers in the PSS.

- The transition to a results-driven PSS represents a huge change for companies whose core business is selling new products. Initially, they will experience the transition as undermining their business sector. Sales of new products are likely to decline because consumers will no longer focus on products but on the functions they perform. But manufacturers stand to gain from selling products with a long lifespan and meet consumers' needs.

- The transaction costs of switching from current business practices to PSS should not be too high.

- The risks of PSS should not be too high for producers, and should be reasonably easy to predict. This is more the case in the business-to-business (B2B) market than in the business-to-consumer (B2C) market, and also if the use phase is closer to the company's core business. Consider a company that is responsible for maintaining a swimming pool, for example, that is also asked to prevent teenagers from vandalizing it. Since security was never the company's core business, this gives rise to unanticipated problems and financial risks. On the other hand, one could view this situation as providing an extra incentive for the company to think about the use phase of its product.

The introduction of *new kinds of warranties* could act as an incentive to repair and reuse parts of appliances. For example, collective insurance could be developed to guarantee repaired goods and products with used parts. Regenersis, a company in the UK, is a good example of a company that focuses on this element of the circular economy. Regenersis profiles itself as a repairer of electronic appliances and their parts, and offers a warranty extension as one of its products.

5.3.3 Resources from waste

The system for collecting electronic and household appliances is well developed in the Netherlands, but there are many opportunities for improvement in the following areas:

- Lowering the threshold for recycling by citizens. For example, councils could develop mobile phone apps to inform citizens about waste collection points,[21] although such efforts would require the cooperation of all parties involved in waste collection.

- Financial incentives could encourage citizens and businesses to separate their waste for collection. One example is DIFTAR, a system of differentiated tariffs (*gedifferentieerd tarieven*), where citizens are charged according to the amount and type of waste they generate. Studies have shown that in municipalities where DIFTAR regulations have been introduced, the amount of waste electrical and electronic equipment (WEEE) ending up in household waste has halved. This may be because the financial incentive makes people less lazy, or the authorities have provided information to raise awareness about the need to separate waste.[22] The introduction of DIFTAR has also led to lower waste collection fees, probably because waste is sorted more comprehensively before being offered for collection, which produces less residual waste.

- The EU's WEEE directive should be reassessed to provide better incentives for recycling electrical and electronic waste streams. The directive requires EU member states to collect 45 tonnes of e-waste for every 100 tonnes of electronic goods put on sale during the previous three years, with a target of 65 tonnes by 2019. In practical terms, this will mean that more e-waste will have to be collected than is now the case. The extra effort that producers will need to make will vary according to the product.[23]

- Manufacturers' associations estimate that they lose track of about two-thirds of used electrical and electronic equipment when it is resold to scrap dealers via municipalities, the retail trade and installation companies. Introducing legislation obliging individuals and businesses to hand in this kind of equipment for disposal could help fill the gap. Opinions in the field are divided about the need for such legislation, however.[24]

For businesses involved in waste collection and recycling, the obstacles on the road to circularity lie include:

- *Entrepreneurs tend to focus on themselves, while trade associations focus on traditional chains.* Most entrepreneurs focus on themselves, on their own company.[25] This is evident in the practice of collective sustainable development of industrial estates, for example, and closed-loop recycling projects in the construction sector.[26] As a result, many entrepreneurs ignore opportunities for innovation in the chain and fail to cash in on the value of waste streams. Many are also unaware of where their raw materials come from or what they are composed of. It is not a given that trade associations will offer their support during the development of a circular economy, since they often focus on traditional chains and much less, if at all, on cross-sector cooperation and international cooperation. Moreover, the priorities of company initiatives related to raw material efficiency and the circular economy often conflict, and there is little internal capacity to consider new business models or to change a company's culture.[27]

This is not the case with frontrunners in the circular economy, such as businesses that acknowledge their corporate social responsibility, develop closed-loop recycling initiatives for their raw materials, use cradle-to-cradle principles or introduce product service systems. Various studies have shown that frontrunners do recognize the opportunities of chain innovation. Yet these frontrunners also face a number of obstacles:[28]

- *Uneven distribution of costs and benefits.* The costs and benefits of innovations at the chain level are often unevenly distributed across the links in the chain. This may happen if a business designs its products differently in order to reduce waste, for example, or it collects and reprocesses waste materials so that they have a secondary use. While the entire chain – and society as a whole – saves costs through these kinds of initiatives, the initiator faces additional costs. In such cases, it is extremely difficult for a business to make a viable business case if agreements have not been made within the chain to spread the costs. This has to do with the uneven distribution of power and resources in the chain. The government can play an important role in controlling the chain, as the implementation of the phosphate chain agreement has shown.

- *Uneven distribution of power and resources.* The actors in material and product chains are unequal in size and financial strength. While medium-sized and large companies generally have the staff and resources to develop new solutions, approach partners in business and ask the government for support, this is barely the case, if at all, with small companies. Many frontrunner businesses are relatively small companies that try to secure a position for themselves in the sector as newcomers. They do not have the time to build networks and find partners, nor do they occupy positions of power in the chain to 'command' certain changes. Long-standing market conditions can therefore cause economically promising initiatives to run aground.

- *There is no leeway for innovation.* A general obstacle often cited by frontrunners is that there is no leeway for innovation, or 'space to experiment'. The government, for example, not only determines policy objectives in some domains, but also specifies which resources market players must use to achieve these objectives. This is common practice with building regulations. The ways in which existing rules are interpreted are equally important. For example, a government information service for entrepreneurs was obstructed because the competent authority clung to a risk-averse interpretation of the rules, or perhaps was not capable of dealing with the uncertainty that is inherent in innovative solutions. As result, it may take so long for an entrepreneur to obtain a necessary license or to issue a practical test that sponsors are forced to withdraw. Unintentionally, a government bent on risk aversion is more likely to discourage than encourage innovative frontrunners to develop and bring to market their new, sustainable technologies.

Frontrunners involved in biotic waste streams face a number of specific obstacles:[29]

- *Investing in biorefining entails significant risk*. The effective use of biotic waste streams requires substantial investment in a financially difficult time in the context of strongly volatile agro-commodity prices. Many of the biorefining technologies that are needed to utilize biotic waste streams as effectively as possible are still being developed and their feasibility has not yet been proven. Investing in these technologies therefore entails significant risk.

- *Writing off existing biorefining investments*. In order to take advantage of the opportunities offered by biorefining, significant changes will have to be made in existing product chains. Established players will have to be quicker in writing off existing investments.

- *Considerable investments need to be made in biodigesters for treating manure*. Biodigesters, used in combination with digestate drying units, provide clear benefits in terms of the transport and processing of manure. But they also require investments in new forms of animal stalls, and in the plants themselves.

- *The risks related to biobased products based on biotic waste streams*. Biobased products have different properties (for example, composition, colour and smell) and many have not yet been approved in terms of regulations such as the EU directive on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Because of these different properties entrepreneurs are uncertain whether consumers will accept biobased products.

- *Suppliers*. Suppliers of cheaper and better-known primary raw materials have an advantage over suppliers of secondary raw materials.

– *The overcapacity of waste incineration plants* since 2008 is not encouraging the effective use of biotic waste streams. As a result, their rates have fallen, encouraging companies to incinerate their biotic waste rather than exploring opportunities to use them more effectively.

5.3.4 Product components

There are several factors obstructing the use of used product parts and components:

– Used components are often more expensive than the resale margin and so are less attractive options for producers or second-hand dealers.[30]

– Businesses need to work together on repairing and reusing components. This requires close communication and trust, and takes time. One problem is that the availability of products components for repair by independent operators is often blocked by businesses that have a monopoly on supplies of components or products.

– Consumers tend to look more at the price of a product and less, if at all, at the entire lifecycle costs. In the construction sector, for example, there is huge potential for the use of better materials and modular systems that are easily replaced, but in practice buyers focus on price rather than on entire lifecycle costs.[31]

These obstacles highlight the importance of changing the culture within companies in order to bring about a transition to a circular economy. Internal barriers have to be removed and company purchasing departments have to become part of integrated business strategies.

5.4 Policy and rules and regulations

The disposal of waste was one of the first pillars of Dutch environmental policy. Several of the most serious waste problems have now been solved, and the government is turning its attention to other policy areas, such as climate change and raw materials. These are important for the transition to a circular economy. Innovation policy will also play an important part. The current policy for the business sector involves the redistribution of resources across nine broadly defined 'top sectors', but without increased funding for public sector R&D and innovation. The government's intention to use taxation as part of the R&D policy as a way of encouraging R&D and moving away from specific innovation subsidies is a risky endeavour, especially during the current economic crisis when for many businesses turnover and profits are under increasing pressure.[32]

The government could introduce a number of tax initiatives that would promote a more circular economy. It could, for example, tax lost value instead of added value, and reduce the rate of VAT on circular services such as repairs and reuse of components.[33] Chapter 6 addresses this and other government plans.

A recent study of the obstacles to a biobased economy conducted for the Ministry of Economic Affairs has shown that several of the obstacles faced by entrepreneurs have now been removed.[34] These efforts have included, for example, the interdepartmental catalyst team of Green Gas, a foundation that collects information on green gas and biogas to accelerate market developments; a programme of the Ministry of Economic Affairs to reduce administrative burdens; previously implemented changes and evaluations of regulations by ministerial departments (such as changes to the Ministry of Infrastructure and the Environment's waste regulations); and the government's top sector policy.

One example of the obstacles that have been removed concerned the appeal and review procedures that delayed plans to build a co-digestion plant (the simultaneous fermentation of manure and other biotic waste streams). The lack of knowledge about co-digestion among local-level civil servants, and their fear of the risks, led them to object to the plans. As a result of this risk-averse behaviour, it look longer than necessary for them to process the permits and to issue unnecessarily strict requirements that would affect the plant's profitability. The solution involved providing them with information: InfoMil, a knowledge centre within the Ministry of Infrastructure and the Environment, has launched a new initiative, 'Assistance in co-digestion of manure', so that these issues receive consistent attention, and is organizing information sessions for businesses and for civil servants.

The removal of a number of regulatory obstacles to the use of biotic waste streams has made it easier to use them as biobased raw materials.[35] An amendment to Dutch waste regulations (Dutch Environmental Management Act, chapter 10), which came into effect in March 2011, has meant that some agricultural and forestry waste streams are no longer regarded as waste products, so that the waste regulations no longer apply. The amendment originates from the European Waste Framework Directive and has removed many obstacles, although there are conditions. Materials such as crop residues and wood shavings must be used for agricultural or forestry purposes, or to generate energy, and they must not be harmful to humans or the environment. Stakeholders involved in organic waste streams are now discussing whether they should also be exempt from the waste regulations.

According to the experts consulted during interviews and the workshop for this study, government policies and rules and regulations create a number of obstacles to a circular economy:

– *Risk-averse behaviour by local governments regarding innovation*. The interviewees felt that the government's responses to business and citizen initiatives is inadequate. The long wait for licences for technologies unfamiliar to new or low-level local government officials is a sign of risk aversion – as in the case of co-digestion plants – which creates business continuity problems particularly for small, innovative companies.[36]

– *Government inconsistency with regard to potentially encouraging measures*. Governments are often uncertain and need to respond to constantly changing political conditions. One recent example has been the changing policy on subsidies for green energy (feed-in tariffs for solar and wind power).

– *The thinking behind waste rules and regulations is that 'we have to get rid of waste' rather than regarding it as a raw material*. It would be interesting to view the waste rules and regulations, but also other regulations, from the perspective of a circular economy to see whether they provide insights into when they act as incentives and when they create obstacles. The study of conflicting interests in a biobased economy, referred to above, is an excellent example of what can be accomplished by looking at matters from a different perspective.[37]

– *It takes too long to implement new rules and regulations*. It often takes less time to bring products to market then it does to draft new rules and regulations. As a result, licencing procedures can take a long time or are accompanied by strict requirements, and this has a negative impact on profitability. According to the interviewees, these procedures take longer in the Netherlands than in other countries. This observation merits examination and could potentially lead to a benchmark process.

Efforts to make more effective use of biotic waste streams are obstructed by various policy and regulatory factors:[38]

– *The lack of a level playing field for fossil and biotic raw materials, for the use of biotic raw materials for energy and for the use of industrial materials*. This comes at the expense of developing potential business cases for the effective use of biotic waste streams. The causes are import levies, excise duties at national and European levels, and the incentives for biofuels through the EU's Renewable Energy Directive and the Emissions Trading System. An energy tax is only levied on fossil fuels, but not on products based on fossil raw materials. Fossil-based products and fuels are not subject to import levies within the EU, but biobased products and biofuels such as bioethanol are. All in all, biobased products are at a disadvantage.

- *The overcapacity of incineration plants in the Netherlands*. Waste incineration has its place in waste stream processing, even if it is a low-value process. From the point of view of climate and energy policies (the Renewable Energy Directive) the co-incineration of biomass in large incineration plants is a good alternative to the production of heat and electricity from fossil fuels. But the reality is different: the low rates charged by incineration plants for treating biomass and biotic waste are standing in the way of more effective and high-grade uses of biomass. The use of biomass for energy is becoming more efficient, but the development of truly effective uses of biomass is at a standstill. The low rates currently charged by waste incineration plants, incidentally, have also had a negative impact on the economic feasibility of comprehensive recycling of abiotic waste streams.[39]

- *The rules and regulations regarding food security are obstructing the effective use of raw materials and energy from biotic waste streams*. For example, the use of swill as food for insects (a novel source of protein) is not permitted.[40]

- *The rules and regulations regarding minerals are obstructing the use of digestate from biodigestion plants as a substitute for artificial fertilizers*.[41] This digestate is regarded as a fertilizer and its sale costs entrepreneurs money. As a result, the profitability of plants producing biogas from fertilizer is limited.

The interviewees from industry also identified a number of restrictive policies and rules and regulations that are acting as obstacles to the expansion of the abiotic economy:

- *Complicated regulations regarding the export and import of waste streams*. For example, the rules and regulations for plastics vary for each type of plastic, complicating the recycling of plastics from electrical and electronic appliances.[42]

- *The EU's WEEE directive sets targets for waste collection based on weight and not on the value of raw materials*. This provides little incentive to recycle scarce materials because the amounts per product are so small.

- *Subsidy schemes such as MIA and VAMIL only encourage purchases of environmentally friendly and energy-efficient appliances*. It would be useful to explore the potential of these and other subsidy schemes to encourage circular behaviour, such as the shared use of appliances and other ways to reduce the use of raw materials.[42]

- *Imports of used products for recycling are regularly blocked*. The workshop participants revealed that imports into the Netherlands of used products after their first life cycle were not allowed because of the uncertainty about processing rules. It is unclear whether this is because the regulations are ambiguous, or whether the competent authorities lack relevant knowledge or have misinterpreted the rules.

5.5 Lobbying and framework activities (non-government-related)

This section highlights the impacts of initiatives launched by non-government-related interest groups, such as business lobby groups, NGOs, citizens and consumers.

MVO Nederland (CSR Netherlands) is a national network that promotes corporate social responsibility and is working to put the circular economy on the business agenda by supporting the Circle Economy, setting up communities of practice and organizing 'BOOSTcamps' where businessmen, scientists and politicians work together. CSR Netherlands encourages businesses to reflect on what the circular economy can mean for them.

Citizens' initiatives such as energy cooperatives could be encouraged to support local initiatives that could lead to a circular economy.

Citizens' attitudes to the circular economy. My 2030's is an extensive study, conducted by Tertium, of the desires and concerns of citizens regarding a biobased economy, using inputs from the BE-Basic Foundation, a public–private partnership based in Delft. Although the study focused on a biobased economy, the results are also applicable to the circular economy and the use of biotic waste streams:[43]

- Citizens appear to be easily influenced by the concept of 'biobased', even though it is not clearly defined. Its interpretation therefore relies on individual impressions. If the various aspects of a biobased economy (or circular economy) are not clearly communicated, there is a danger that the term could come to have negative connotations. It is not yet clear what citizens think of the 'circular economy', but the concept should be clearly and unambiguously defined by the government, businesses, knowledge institutes and NGOs so that it can be communicated to the largest possible audience as effectively as possible.

- The circular economy seems to dovetail well with citizens' views of a biobased economy. Many believe that they should 'be more conscious about raw materials, recycling and reducing waste' (*My 2030's*, p.24). But product service systems are a different story. 'That is not true yet for a significant variation of the circular economy: "the lease society", in which consumers' belongings are all pretty much on loan instead of owned. … This vision of the future evokes a fundamental discussion. A "lease society" is a desirable thing for some people, while for others it is an unrealistic and undesirable vision of the future'. This means that product service systems and what they have to offer citizens will have to be clearly explained before they are introduced.

– Citizens are unlikely to take a leading role in a biobased economy, according to *My 2030's*. However, they do expect the government and the business sector to take the lead. If that happens, then they would be willing to contribute as consumers and employees. It is unclear whether this attitude would apply to a circular economy as well, in view of the many citizens' initiatives that have been launched related to sustainable development. How citizens view and interpret their role in a circular economy is as yet unclear.

– Citizens see the government as important for achieving a biobased economy. 'The government has to inform people about the advantages and disadvantages and encourage or force businesses to work with biobased practices. For that purpose, a consistent policy needs to be put in place. The government can also encourage consumer demand for biobased products with tax incentives.' The citizens consulted think that 'only a combination of information and financial incentives can change consumer behaviour' (*My 2030's*, p.21). This is a clear sign of what the government's role should be in a biobased economy. Of course these statements in themselves are not surprising: financial incentives – as yet unquantified – should have an impact on behaviour. The degree to which they will act as incentives in a circular economy has often been mentioned, but has not been substantiated, and so deserves to be looked at more closely.

– Citizens want to see results close to home. 'Biobased inventions have to contribute to clear improvements in the environment or in people's own lives if they are to inspire individuals to actively start using them.' In a circular economy, these achievements could take the shape of lower production costs by wasting less energy and raw materials, or by offering new services at lower rates of VAT.

– Citizens are accustomed to sorting waste. The citizens interviewed for *My 2030's* expect that comprehensive waste sorting is possible, as long as there is something in it for them and it does not require too much extra effort.

The younger generation (generation Y) seems to be less preoccupied with possessions than their older counterparts, and more concerned with experience and fulfilment,[44] according to a survey conducted by MotivAction. This trend should be acted on by rolling out product service systems, for example, or innovative leasing concepts.

Some interest groups may resist wholesale change, and place several obstacles on the path to circularity.

For various parties with vested interests, the economic returns on their investments, and perhaps even their existence, will depend on how a more circular economy develops. Incineration and power plants, for example, still have substantial economic value because their core activities are dependent on the purchase and sale of consumer goods, or are related to the existing infrastructure for waste collection and recycling. These parties do not necessarily stand to benefit from a transition to a circular economy, and so cannot be expected to give their immediate support. The lobbying activities of these kinds of stakeholders could affect our picture and the development of a circular economy.

Obstacles resulting from the anticipated attitudes of citizens and consumers:[45]

- Many citizens feel that their individual contributions to sustainability are much smaller than those made by the business sector or the government.
- The extra effort required to contribute to a biobased economy should not be too great or cost too much. These preconditions probably apply to a circular economy as well.
- For most consumers, the price of a product is a more important consideration than whether it contains sustainable raw materials, for example.
- Consumer sensitivity to the latest fashions could be at odds with circular consumer behaviour. The rapid succession of new electronic appliances is a good example, where the sensitivity to fashion is based on continually improved functionality rather than on seasonal influences, as is the case with clothing. On the other hand, the desire for individuality, so as not to blend in with the masses, also could support circular behaviour (reusing products to make vintage clothing, for instance).[46]

5.6 Observations on the transition to a circular economy

Chapter 1 examined the transitional steps between a linear economy ('take, make, waste') at one extreme, a *transition on the road to a circular economy* (based on cost considerations and rules and regulations, the more conscious use of energy and raw materials, without radically redesigned products, processes and systems), and at the other extreme the *circular economy*, an economic and industrial system that takes as its starting point the reusability of products and raw materials and the restorative capacity of natural resources and minimizes value destruction in the overall system.

If we look at the obstacles, on the one hand, and the activities that a circular economy would promote, on the other, then we could argue that each of these aspects could make a tangible contribution to increased circularity. That was already clear in the discussion in chapter 2 (particularly about table 2.3), where various aspects were used to make an educated guess of the potential shifts towards increased circularity. Indeed, removing most of the obstacles and introducing incentives could gradually set events in motion before introducing more radical steps. Again, this is an argument in favour of a policy that is geared not only to the frontrunners who aspire to an 'ideal' circular economy, but also to keeping the 'followers' in motion.

In terms of *developing and disseminating knowledge*, it is the innovative capacity, the available knowledge and expertise of transition, the incentives for multidisciplinary and integrated education and the increasing awareness among businesses of the significant general value of a transition to more circularity.

Biorefining has an important place in the circular economy in terms of added value (see the discussion of the Ellen MacArthur Foundation report in chapter 1); chapter 3 showed that biorefining constitutes a significant part of the circular economy's potential. That is why consistent knowledge development in this area is extremely important. This is reinforced by the fact that the risks are still high, and many innovative entrepreneurs in this sector are still unwilling to take the risk. The creative industries and industrial design schools must be approached in a transition to a circular economy as well. Their competences will be essential for creating new product and service concepts that are indeed based on reusability and preventing value destruction.

In the area of *entrepreneurial activities and market mechanisms,* the innovative capacity and increasing awareness (in addition to long-standing regulations) in the Netherlands seem to have created a country that is experiencing the 'frontrunner's handicap'.

Various activities respond to *financial incentives* (different warranty systems, financial incentives for waste processing) or in improvements in infrastructure that will promote cooperation in value chains in general and in recycling in particular. These measures are again generally applicable to the majority of businesses that hope to use raw materials more efficiently and circularity.

The circular economy stands to benefit from *critical encouragement and support* from frontrunners in the business world who are taking risks (including, for example, cradle-to-cradle initiatives). Investing in product service systems belongs to the same category, although rolling out a successful product service system does not necessarily mean that the products would have to be adapted.

The observations on *rules and regulations* are primarily motivated by the wish to have a government that responds more quickly and develops consistent policies, and does not shy away from taking risks.

Observations such as these are applicable to all changes that lead to more circularity and not only to 'purely' circular initiatives.

Towards a circular economy: an action plan for the Dutch government

6 Towards a circular economy: an action plan for the Dutch government

If the Netherlands is to take full advantage of the opportunities identified in this report, the government needs to develop a consistent, multidisciplinary and well-founded long-term strategy intended to lead to a circular economy. This chapter highlights the actions (and supporting studies) that are needed now in order to identify areas of research, regulations, financial and fiscal incentives and strategies that will encourage frontrunners, the role of the government as a 'launching customer' and international relations.

6.1 Creating and seizing the opportunities

A circular economy would present the Netherlands with excellent opportunities, not only to strengthen its own economy and reduce its ecological footprint, but also to develop a powerful proposition that is convincing internationally and provides Dutch businesses with international opportunities. The Netherlands already holds a strong knowledge position in areas such as water, chemicals, agro-food and life sciences, its strong logistics and recycling sectors, and its extensive experience in waste management puts it in a prime position to capture an internationally competitive position.

For the government, the most important condition for success in creating these opportunities is to roll out a consistent long-term strategy that is strong multidisciplinary and cross-departmental in character and based on firm foundations – one that can take a blow. Such a strategy requires joint and targeted efforts by the government, businesses, consumers and social organizations. Based on the discussions in previous chapters, this chapter presents an action plan for the government that gives shape to this joint strategy.

6.2 An action plan for the Dutch government

This section proposes an action plan with the following elements:
- create a clear, cross-departmental, consistent strategy for building a circular economy;
- develop a coherent education and research plan for the circular economy;
- make a comprehensive assessment of the pros and cons of existing rules and regulations regarding waste;
- increase knowledge and awareness of raw materials in each value chain;

- ensure that frontrunners and others who stick their necks out receive a permanent and true advantage, for example through value chain management;
- review the effectiveness of a broad set of fiscal and financial incentives to promote circular behaviour;
- determine the impact of incineration plants on the viability of circular business cases and take appropriate action;
- develop the role of the government as an active and expert 'launching customer'; and
- use the international playing field to help the circular economy move forward.

6.2.1 Create a clear, cross-departmental, consistent strategy for the circular economy

In order to launch a successful transition to a circular economy it is important that the Dutch government clearly communicates its ideas about the circular economy and the rationale behind it. For many actors in civil society, the circular economy is a new concept. What does it actually entail? Why should the Dutch government get involved, and is there a point on the horizon they should be working towards?

The rationale behind these recommendations is that a circular economy transcends sectors and requires investments in the long term from various civil society stakeholders. One of the long-term conditions for these investments is that the government's strategy and policy are transparent, cross-departmental and consistent. This has emerged from research on transitional processes and from the interviews conducted in the context of this project.

Subsequently, the consequences of this vision for all areas of policy, regulation and communications will have to be consistently and clearly explained. A call to consume more and a simultaneous call to promote services that could have a negative impact on consumption will create a disjointed impression and will not lead to the desired unity of direction. For example, how does this strategy relate to the government's top sector policy and green growth strategy, or the Netherlands' inputs to Horizon 2020, the EU's framework programme for research and innovation? If there is clarity about the long-term direction, then businesses, investors, education and research institutes will want to take appropriate action and organize themselves.

This strategy is explicitly cross-departmental. The steps that need to be taken on the path to a circular economy are pre-eminently systematic in character, as a result of which policy areas such as energy, sustainability and climate, agriculture, trade, waste, raw materials, foreign affairs and development cooperation, education and research funding, and fiscal tools have to join forces.

At the very least, a coherent vision and strategy must address the following:
- What are the dominant knowledge issues and what does the corresponding knowledge agenda look like?
- How to guarantee the development of much-needed knowledge of materials, products, raw materials, etc.?
- Which rules and regulations are potentially restrictive and which encourage a transition to a circular economy?
- What financial and fiscal tools can be used and what would their impact be?
- What role should the frontrunners have and how can they be encouraged?
- How can the stragglers be encouraged to draw inspiration from the activities of the frontrunners?
- What points should the Dutch government act on, and what points should it leave to others?
- Which international partnerships should the Netherlands seek in the framework of a circular economy?

Based on this study, several of these points can be more specifically addressed in formulating a future government agenda.

6.2.2 Develop a coherent education and research plan for the circular economy

The previous chapters identified several research questions in the following areas that need to be addressed in a transition to a circular economy:
- technology development for biorefining, biogas extraction and phosphate recycling;
- design for reuse and recycling;
- developments in the area of tracking and tracing of consumer products;
- promoting systems thinking (in terms of technology and economics); and
- the development of appropriate new business models for a circular economy.

A coherent plan for a circular economy would have to ensure that these issues are clearly included in the research agendas of the top sectors (and the corresponding 'top consortia' for knowledge and innovation), and in the curricula at all levels of education, from vocational colleges to universities (see section 5.3).

If the government manages to involve all these levels when explaining and rolling out the philosophy of the circular economy, it would create a strong driving force to seize opportunities as they emerge.

A powerful research agenda is a prerequisite for the Netherlands if it is to seize the opportunity to export knowledge.

6.2.3 Make a comprehensive assessment of the pros and cons of existing rules and regulations regarding waste

Stakeholders have repeatedly called for the rules and regulations to be amended during our talks with them, so that a solid business case can be developed based on the use of waste streams. Some regulations effectively prevent small-scale experiments using waste materials or erect barriers to the transport of waste materials. More generally, many regulations do not view waste as a potential raw material.

At the same time, the existing rules and regulations for waste materials are based on historical developments and are often created to prevent or fix environmental problems. That is why the government should thoroughly reassess the existing rules and regulations on how waste materials are handled, with an emphasis on the following:
- how to create leeway for experimentation with new value chains; concerns about food safety could negatively affect the freedom to experiment with the use of biotic waste streams, for example;
- the opportunities that could be created by amending the rules and regulations (will a significant new value chain actually emerge?); and
- the use of inspections to urge stragglers to improve their behaviour when it comes to waste materials.

There seems to be broad support for improving the percentage of waste that is collected, which would be preferably based on its value and not on its mass. The government can play an important role in the introduction of and the compliance with the EU's WEEE Directive, the introduction of differentiated tariffs (DIFTAR) for the collection of household waste, and the introduction of mandatory systems for disposing of household waste.

Practice shows that knowledge about rules and regulations – especially when they concern obstacles that have been removed – does not always reach stakeholders. Clear and effective communication about amendments to rules and regulations is also a prerequisite for removing obstacles on the path to a circular economy.

6.2.4 Increase knowledge and awareness of raw materials in each value chain

Many companies seriously lack knowledge about their own products. Steps that will point the way to a more circular economy are difficult to make without this background knowledge. Improving this knowledge is primarily the responsibility of the business sector, which cannot assess the vulnerability of their own value chains and so are unable to respond to risks. The complexity and long-term character of the raw material problem is particularly an obstacle for smaller businesses. The government should actively encourage the foundation of an extensive raw materials information service.

To make it easier to develop circular business cases, the government should support research on the feasibility, desirability and character of a raw materials passport. The government could consider using these passports at a level that would still offer added value to processors of waste streams. The administrative burden and technological feasibility of such measures need to be carefully considered.

6.2.5 Ensure that frontrunners and others who stick their necks out receive a permanent and true advantage, for example through value chain management

We observed above that there are many players who could take the lead in creating opportunities for a circular economy. Examples include the members of the 'Frontrunners Counter' (Koplopersloket), a dedicated service for innovators, the Circle Economy, parties that have completed 'green deals', and the broad range of companies that take corporate social responsibility seriously. Moreover, the government can act as value chain manager in certain chains or ask parties to take on that responsibility themselves. An example of a successful approach is the Nutrient Platform that was set up to close the phosphate cycle and to appoint a government chain manager. The results have been impressive. The government's role is not just that of a value chain manager, but it also identifies and removes regulatory obstacles, brings together parties in the value chain, outlines the advantages and drawbacks of national and European rules and regulations, and generates support for a European market in Europe and beyond.[1]

To help these parties move forward, it is important to guarantee support at a strategic level with heavy and integrated involvement from the core ministries. Moreover, any potential incentives (financial ones, for example) should preferably be directed at these frontrunners. Belonging to the frontrunner group should be seen as a great advantage. Enthusiastic frontrunners would then become and remain active advocates of the circular economy.

The involvement of these pioneers in setting up and implementing transition experiments aimed at encouraging the development of a circular economy is also important. The hallmarks[2] of a transition experiment should be that it can make a significant contribution to the circular economy, make an important contribution in the Netherlands, set a positive example (from which lessons can be learnt) and clearly adds to already existing initiatives or joins them together.

6.2.6 Review the effectiveness of a broad set of fiscal and financial incentives to promote circular behaviour

Interviews conducted in the context of this study show that civil society actors have expectations regarding the promotion of circular behaviour by changing tax regimes (see section 5.4). Clearly it is in the government's hands to make these changes. Examples include:

- lowering the rate of VAT on services in the circular economy (maintenance, repairs, refurbishment, various product service systems);
- taxing extracted value instead of added value (a shift from taxing income to taxing materials);
- creating contributions meant to extend warranty periods on products;
- actively using financial resources from guarantee and disposal funds to further encourage business activity (although it is not up to the government to act on this); and
- actively using financial resources from existing fiscal subsidy instruments promoting environmentally benign investments (MIA or VAMIL) for a broader series of investments or activities that would help increase circularity.

These developments are not new: work is being done at the European level, for example, to use market-based instruments, as described in the *Roadmap to a Resource-efficient Europe*.[3] A quantitative study focused on this set of fiscal measures, and their impacts on different kinds of circular activities, is still lacking. Before the government can introduce clear measures in that respect, a study would need to be conducted to create support for them. Although this study estimated the impacts of a lower rate of VAT on maintenance and repairs services at the macro-level, the effectiveness of this measure could be studied based on targeted consumer research: what other kinds of behaviour could be encouraged by this kind of a fiscal shift? Would these measures result in more goods being repaired, as opposed to recycled or thrown away? Would a shift from taxing income to taxing the value of extracted raw materials have a significant impact on our behaviour towards products whose material or component costs are only a fraction of the purchase price?

A study of the financial incentives should also focus on 'perverse' incentives that could potentially have a negative impact on circular business cases. An example of this is the lack of a level playing field – in many respects – for the use of fossil raw materials and biobased raw materials. An energy tax is only levied on fossil *fuels*, but not on products based on fossil raw materials. Fossil-based products and fuels are not subject to import levies within the EU, but biobased products and biofuels are.

6.2.7 Determine the impact of incineration plants on the viability of circular business cases and take appropriate action

In order to promote the circular economy, it is recommended that the government critically examines the role of incineration plants and current regulations in creating obstacles to circular business cases. The argument that incineration creates obstacles to recycling is regularly put forward, but a thorough investigation would clarify whether the appeal of low processing tariffs at incineration plants actually makes it impossible to develop concrete and viable business cases for recycling.

6.2.8 Use the government as an active and expert 'launching customer'

The government can encourage circular business cases, especially in the initial phase, by demanding the use of circular products or services in government procurement tenders. This kind of behaviour sets a positive example and reinforces the picture of a government that is seriously embarking on this path at all levels. It goes without saying that these tenders have to be transparent and based on solid facts.

6.2.9 Use the international playing field to help the circular economy move forward

The Netherlands has a good starting position when it comes to the circular economy, but it is obviously not the only country working on this front. The government should (for example, via the TWA network, a network of attachés with engineering and science backgrounds) seek to work together or exchange information with countries that are frontrunners in certain fields. For example, Germany and Denmark are at an advanced stage of developing 'multiple value creation' through the combined use of natural resources for recreational purposes and to produce biomass. Japan has a more intensive recycling programme than the Netherlands. Germany has established a Raw Materials Agency (DERA) that is developing knowledge and recommendations on raw materials. Sweden has established a chair to take care of the management of knowledge about the recycling of electronic goods. Israel gives start-ups excellent support, which benefits the innovation climate. And the United States is developing knowledge, according to the interviewees, on good divestment strategies for large plants that are going to be shut down.

The EU is particularly active in several areas that would affect the transition to a circular economy, as the *Roadmap to a Resource-efficient Europe*, the 'Blue Growth' agenda, and the Common Agricultural Policy all show. Encouraging business activity in the Netherlands aimed at a transition to a circular economy requires the Dutch government not only to take into account European policy, but also to attempt to influence it in favour of a circular economy. In that respect, European waste regulations are extremely important. They reflect the policy on the dumping, incinerating, collecting and processing of end-of-life products (cars, electrical and electronic appliances, batteries and packaging), and the 'extended producer responsibility'. In the latter case, member states can even decide to hold producers responsible for processing waste generated by their products. The creation of solid business cases related to recycling requires sufficient critical mass: achieving critical mass could rely heavily on the international transport of waste materials. The EU Waste Shipment Regulation is a potential (practically or bureaucratically speaking) obstacle in that respect.

It should be clear that the importance of a level playing field is that the various member states can coordinate the implementation and enforcement of these measures, and that the Dutch government, in its efforts to move closer to a circular economy, will have to play an active role at the European policy level.

6.3 Dealing with uncertainty: a government that learns and networks

Because all this involves complex changes that will undoubtedly cause uncertainty, and because the government's resources are limited, the government will have to operate in a manner fitting the situation. *Networking* is one useful strategy. It prioritizes relationships with other parties, who are therefore equally motivated to achieve a circular economy. 'Networking is different from "ordinary" ways of working because the government cannot achieve its own objectives without the help of others, while the other parties have the option of withdrawing from the process and the objectives. So the other party can make an independent assessment, which is also crucial for achieving the policy. […] Networking therefore is about emphasizing the interaction between the government and the parties in the environment'.[4] Several authorities are experimenting with networking, including within the Dutch Ministry of Economic Affairs and the province of South Holland.[5]

A transition to a circular economy requires changes at many different levels and by many different stakeholders. This was mentioned in chapter 5 in the section on developing and disseminating knowledge. The nature of every job will change, because every business will have to adapt, to some degree or another. How exactly is something we will only discover once the process is under way. To deal with uncertainty and still provide direction when possible requires the government to assume a *learning attitude*. That means, for example, that the government will have to set up experiments together with other civil society stakeholders, without knowing whether they will succeed. And there will have to be leeway in these experiments to allow regular reflection on the kinds of activities the government is promoting.

6.4 Conclusion: opportunities for the circular economy in the Netherlands

The current state of recycling, repair and reuse of a wide range of products in the Netherlands gives good reason to assume that there is further potential to make the transition to a more circular economy. However, clear and consistent communications across government departments are crucial to success. Dutch society seems very willing to join in, but is undoubtedly sensitive to conflicting information and incentives. In any case, citizens will be further encouraged if they are kept well informed about what has already been achieved, and if well-chosen transition experiments are launched. That the action plan for the government proposed here is by nature very exploratory and investigative is related to this. Measures to do with fiscal arrangements and rules and regulations are complex, and there must be some confidence that they will have the intended effects. The highly exploratory and investigative nature of the proposed action plan for the government is related to this. Measures to do with fiscal policy and rules and regulations are complex, and it should be clear before they are implemented that they will have the intended effects.

Throughout this study, the inputs from stakeholders have been extremely important in identifying in which direction the transition should go, and the obstacles that are likely to emerge. The views of these stakeholders do not by definition represent balanced judgements, which is why an expert and analytical government can contribute to what is in all respects a sustainable shift to a circular economy.

Improving raw materials efficiency and rolling out the circular economy are goals that are clearly embraced at the European level. Nonetheless, the measures proposed here show that the Netherlands for the most part does not need to wait for approval at the European level. And of course that is less the case when it comes to rationalizing the rules and regulations for waste, implementing fiscal and financial incentives, and potential regulations for incineration plants. These are imbedded in European regulations and will affect whether or not a level playing field can be created for the parties involved.

More than once, this report has stressed that a transition to a circular economy will benefit both from initiatives that improve the circularity of current practices and from radical initiatives that aspire to an ideal circular economic model: an economy in which circularity is already incorporated in the design phase. Based on the methods used here it is difficult to assess what the economic contribution of these more radical innovations and transitions would be. Still, the government can certainly support radical design innovations by identifying the frontrunners and removing obstacles for them, or by acting as a launching customer to help these risky and radical initiatives get off to a good start.

Appendices

Appendix 1: Innovation systems: functions and innovation engines

Innovation systems analysis of a transition to a circular economy

The innovation system analysis (ISA) was carried out to identify the actors and processes that affect the development and use of specific technologies. The fundamental idea behind ISA is that the success of emerging technologies is not only determined by technological and economic characteristics, but also by the quality of the interaction between actors in the system (businesses, governments, knowledge institutes, social groups), institutions (rule, laws, routines) and technologies.

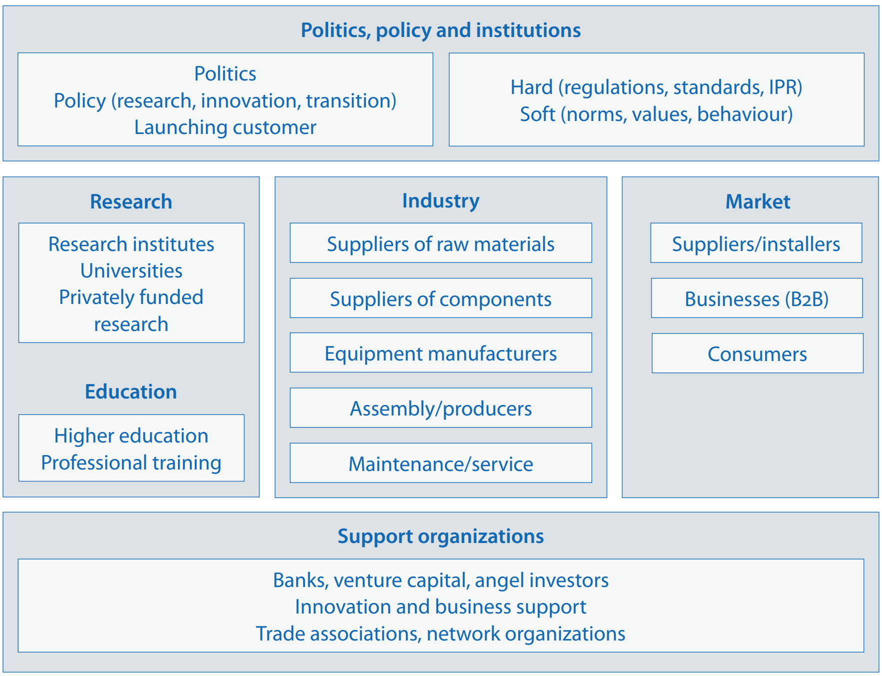


Figure 1. An innovation system.
Source: Hekkert et al. (2011).[1]

Table 1 summarizes the most important characteristics of each innovation engine.

Table 1. Characteristics of innovation engines

	S&T engine	Entrepreneurial engine
Developing knowledge: Develop new knowledge or new combinations of existing knowledge	Fundamental knowledge Concept development Studies in laboratory	Knowledge that can be used Feasibility studies Pilot studies
Disseminating knowledge: Knowledge diffusion and exchange of practical experiences Share positive expectations	Knowledge sharing between developers and through academic channels	Exchange knowledge within projects, between developers, funders and launching customers
Entrepreneurial activities: Develop new products and services and introduce them to market	Entrepreneurs not involved Potentially a later role when articulating market demand or as potential launching customer	Entrepreneurs (often SMEs) identify market opportunities Businesses initiate feasibility and pilot studies
Mobilizing resources: People, skills, facilities, funding and risk capital	Public funding Temporary programmes Limited use of people and resources	Public–private funding Businesses participate with R&D resources Cooperation at project level
Market mechanisms: Develop niche market into mature market, develop user demand	There is no real market Positive market expectations communicated in visions/ roadmaps	Market prospects very uncertain. Market niches for initial applications Test and communicate positive market expectations in pilots
Guiding the search process: Ideas and expectations converge, develop appeal and support	Large diversity of expectations Ideas guide knowledge programmes Appeal and support are limited and diffused	Ideas converge Interaction between developers and governments feed promise and support Result of pilot studies determine strength of appeal
Support from interest groups: Lobbying by opinion leaders and stakeholders	Lobbying only by well-organized interest groups with controversial issues	Parties position themselves Signs of criticism spark debate Entrepreneurs lobby for project funding Political playing field not fully developed yet

Sources: Based on Suurs (2009); Suurs and Hekkert (2011).

	System engine	Market engine
	Research and pilot projects Knowledge to upscale commercialization	Knowledge for optimization Knowledge about market trends Mitigate negative side effects
	Disseminate knowledge to projects Coordinate knowledge flow through platform organizations or intermediaries	Dissemination of knowledge completely formalized in networks and training institutes Coordination by trade and sector associations
	Entrepreneurial activities are developed by financially strong businesses	Entrepreneurial activities have become part of mainstream developments within trade/sectors
	Public–private funding Financially strong businesses invest in production facilities and infrastructure Coordinated cooperation in consortiums and temporary institutes Scarcity of well-educated labour	Private funding by banks, among others Investment decisions in relatively stable market conditions Production resources, such as raw materials and staff, sufficiently available
	Concrete prospects of a substantial market size Scaling up requires technology, facilities, infrastructure organization and regulations to be adapted	Mature, relatively stable market conditions Substantial market size Companies aim to expand market share and develop spin-offs
	Ideas and expectations are underpinned by financially strong businesses and formal structures Substantial appeal and support Social acceptance still uncertain Negotiations about desired regulations, infrastructure and standards	Ideas consolidated in regulations, infrastructure and organization of market Businesses operate within boundaries and routines of this market
	Professional lobbying by newly formed platforms and existing interest groups Negotiations and/or conflict about political-economic issues Playing field levels out	Professional lobbying by trade associations aimed at safeguarding existing market structures

In a well-functioning innovation system, illustrated in figure 1, the various elements, actors, institutions and technologies are more or less geared towards each other. A transition to a circular economy can only be understood if we examine the underlying processes that take place at the organizational, chain and sector levels. Technological innovation as a process plays an important part in this, as well as social and economic innovation. Innovation system analysis focuses on the dynamics that encourage or impede technological innovation. As soon as a technological innovation begins to circulate, it is expected to replace or alter the key structures supporting the existing technology. This enables the innovation to make a potential contribution to a transition. In the case of a transition to a circular economy, various technological innovations have to developed, circulated and used in society for them to be able to contribute to a transition. The theory behind innovation system analysis assumes that there are specific conditions and elements that either impede or encourage the development of a technological innovation. An ISA provides an understanding of the situation related to this development by describing and analyzing these elements and their development.[2]

In this innovation system there are seven specific functions or key processes that must function well if the system is to have any success in generating innovations. For this study, these system functions have been grouped into four categories:
- knowledge: developing and disseminating knowledge;
- business: entrepreneurial activities, market mechanisms and mobilizing resources;
- policy and rules and regulations (government-related framework activities); and
- lobbying activities and framework activities (non-government-related).

These system functions have to be sufficiently well defined to enable innovations to be used in the market. Support for this argument can be found in the work of Roald Suurs, Simona Negro and Marko Hekkert.

The development of an innovation system accelerates when the system functions begin to reinforce each other. The term innovation engine was introduced to describe this kind of interaction. Four innovation engines have been identified to date: the science and technology engine, the entrepreneurial engine, the system engine and the market engine. Even if innovation engines are ideal characterizations of a complex reality, their relative simplicity makes appropriate tools for envisioning how the development phases of an innovation system will evolve towards maturity. Every innovation engine has specific strengths and weaknesses. It is important to be aware that a weak engine needs to instigate the development of emerging innovation systems before it can become strong. Coincidences and external factors still have a great deal of influence during the early stages of an innovation process, but as the innovation process progresses, and the innovation process matures as an entity, the sensitivity of the process to external factors diminishes.

Appendix 2: Interviewees

The individuals interviewed for this study included representatives of:

- research and education (knowledge institutes, universities, higher education, professional training);
- industry and marketing (suppliers of raw material and components, equipment manufacturers, assembly, producers, maintenance and service, installers, B2B businesses, consumers);
- politics, policy and institutions (politics, policy, rules and regulations, standards, values); and
- support organizations (banks and investors, trade associations, network organizations, innovation and business support).

Biotic waste streams:

- Port of Rotterdam: Monique de Moel, Nico van Dooren (industry and marketing);
- Company from food industry, CSR officer (marketing);
- Ministry of Infrastructure and the Environment: Arnoud Passenier (politics, policy and institutions);
- Netherlands Institute of Ecology (NIOO-KNAW): Professor Louise Vet (research and education); and
- BVOR, trade association for organic waste: Arjan Brinkmann (support organization).

Abiotic waste streams:

- WE Cycle: Hendrik Bijker (support organization);
- BRBS Recycling trade association: Max de Vries (support organization);
- TNO: Professor Arnold Tukker (research and education); and
- Agency NL: Hans Paul Siderius (support organization).

General:

- Rabobank: Daan Dijk (support organization);
- Turntoo®: Ruben van Doorn (market);
- Radboud University Nijmegen: Professor Jan Jonker (research and education);
- CSR Netherlands: Michel Schuurman (support organization); and
- Interstudie NDO (consultancy firm): Jan Oosting (research and education).

Appendix 3: Workshop participants, 19 March 2013

Biotic session (led by Elsbeth Roelofs and Alwin Hoogendoorn, TNO):
- Floow2: Kim Tjoa;
- Port of Rotterdam: Monique de Moel;
- MUD Jeans: Bert van Son;
- Ministry of Infrastructure and the Environment: Kees Veerman;
- Ministry of Infrastructure and the Environment: Daphne Blokhuis;
- SuikerUnie: Paul Hagens; and
- Wageningen University and Research Centre: Wolter Elbersen.

Abiotic session (led by Ton Bastein and Elmer Rietveld, TNO):
- ACE Reuse: Ad Comperen;
- Agency NL: Ellen Hoog Antink;
- EERA: Norbert Zonneveld;
- FME-CWM: Kasper Beuting;
- FNsteel: Tjitze Postma;
- HKS Metals: Dominique Martens;
- Ministry of Infrastructure and the Environment: Tjeerd Meester;
- Shanks: Marcel Koen; and
- UMICORE: Christina Meskers.

Appendix 4: Summary of technological options for creating added value from biotic waste streams

	Biorefining	Pet food	Insect breeding
Mixed kitchen and supermarket waste		×	×
Animal fat (Cat. 1/2)	×	×	×
Household waste			
Sewage sludge	×		
Feather meal	×	×	
Flower auction waste	×	×	×
Horticultural crop residues	×		×
Biodegradable waste			×
Onion waste	×		
Poultry manure			×
Cattle slurry			×
Pig slurry			×
Spent mushroom compost			×
Sugar beet leaves	×		
Fish waste	×		×
Potato haulm	×		
Yeast extract (wet)	×		
Potato peel	×	×	×
Maize stalks and cobs			×
Potato pulp	×		×
Wet sugar beet pulp	×		
Cocoa shells			
Draff	×		
Straw (wheat, barley)	×		
Grain byproducts	×		
Dry sugar beet pulp	×		
Rapeseed meal	×		
Sunflower meal			
Meat and bone meal (Cat.3 food)			
Frying oil			
Animal fat C1			
Whey powder	×		
Soybean meal	×		
Animal fat (Cat.3 + food)		×	

	C_5 & C_6 sugars	Fermentation of solids	Tech. use of paper/ packaging/ bioplastics	Biogas	Soil improvement
				×	
	×				×
				×	
			×		×
				×	
			×		
	×			×	
				×	×
				×	×
				×	×
				×	×
					×
				×	
				×	×
	×	×	×		×
	×	×			
	×	×			
	×	×			
	×	×			
	×	×	×		
	×	×			

Notes

Chapter 1: Introduction

1 UNEP (2011) *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth.* Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M. et al. www.unep.org/resourcepanel/decoupling/files/pdf/Decoupling_Report_English.pdf

2 UN Population Fund (n.d.) 'Population trends', www.unfpa.org/pds/trends.htm

3 World Bank (2011) Global Economic Prospects, vol. 3: *Maintaining Progress amid Turmoil*. http://hdl.handle.net/10986/12103

4 European Commission (2011) *Commission Staff Working Paper: Key Facts and Figures on the External Dimension of the EU Energy Policy*, p.2. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=sec:2011:1022:fin:en:pdf

5 UNEP (2011) *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth.*

6 Brown, L.R. (2011) The new geopolitics of food, *Foreign Policy*, May/June.

7 WWF (2007) *One Planet Business: Creating Value within Planetary Limits.* World Wide Fund for Nature. http://assets.wwf.org.uk/downloads/one_planet_business_first_report.pdf

8 Ellen MacArthur Foundation (2012, 2013) *Towards the Circular Economy: Opportunities for the Consumer Goods Sector.* vols 1 & 2.

9 Rijkswaterstaat (2013) *Dutch Waste in Figures: Data for 2006–2010.* Utrecht: Rijkswaterstaat Leefomgeving, p.35.

10 Note that this report was written before Croatia joined the European Union.

11 Bol, D. and Bastein, T. (2012) *Kritieke Materialen van de Nederlandse High-tech-industrie*. Study by TNO and the Materials Innovation Institute (M2i) for the FME Association.

12 Organizations such as SHFT (www.shft.nl/themas/circulaire-economie) and Duurzaam Middelbaar BeroepsOnderwijs (DMBO: www.duurzaammbo.nl/index.php/kennisbank/concepten/circular-economy).

Chapter 2: The abiotic circular economy

1 Note that the total value of new products from the metal and electrical sectors given here deviates slightly from the totals published by these sectors. This is because a new classification of sectors and products was recently introduced; see background document.

2 Eurostat (1997) *The Capital Stock in the European Union: Structural Diagnosis and Analytical Aspects; Cambridge Econometrics;* CBS (1998) Perpetual Inventory Method. Central Statistical Bureau.

3 Kimura, F. et al. (2000) Product modularization for parts reuse in inverse manufacturing. *Ann. Int. Acad. Production Engineering (CIRP)*, 50(1): 89–92.

4 Huisman, J. et al. (2012) *The Dutch WEEE Flows*, UN University Institute for Sustainability and Peace, Sustainable Cycles Unit (ISP–SCYCLE). www.vie.unu.edu/file/get/9654

5 UNEP (2011) *Recycling Rates of Metals: A Status Report*. UNEP International Resource Panel.

6 VAMIL – willekeurige afschrijving milieu-investeringen.

7 The electrical engineering industry as a whole paid more in salaries than it made in profits in 2010. This points to a negative operating result, i.e. a loss. An appraisal of the potential situation after 2010 has not been included in the calculation.
8 All emissions are based on 2010 figures.
9 Surface water, groundwater and tap water.
10 Sevenster, M.N. et al. (2010) *Nederland importland: Landgebruik en emissies van grondstofstromen*, CE Delft.

Chapter 3: The biotic circular economy

1 Elbersen, W. et al. (2010) *De beschikbaarheid van biomassa voor energie in de agro-industrie*. Wageningen University and Research Centre.
2 CBS Statline.
3 CBS Statline on arable crops.
4 PDV, 2011.
5 Elbersen, W. et al. (2010) *De beschikbaarheid van biomassa voor energie in de agro-industrie*. WUR.
6 a.r. = as received (or wet) basis.
7 Bouwmeester, H., Bokma-Bakker, M.H., Bondt, N. and van der Roest, J. (2006) *Alternatieveaanwending van (incidentele) reststromen buiten de diervoedersector*. Rapport 2006.008. Rikilt, Wageningen.
8 Broekema, R. and Blonk, H. (2009) *Milieukundige vergelijkingen van vleesvervangers*. Blonk Milieuadvies.
9 Of this, 3.2 Mt were collected as sorted waste; the price indication is derived from incineration plant rates. Dutch citizens pay a higher amount through a waste tax.
10 *Compendium voor de leefomgeving 2010; Afval!* Jaarboek 2011.
11 E.g. AEB Amsterdam, E.ON Energy from Waste Delfzijl, Attero Wijster.
12 Koppejan, J.H.W. et al. (2009) *Beschikbaarheid van Nederlandse biomassa voor elektriciteit en warmte in 2020*. SenterNovem.
13 Bondt, N. et al. (2010) *Afval uit de landbouw*. LEI/WUR.
14 CBS, figures for 2011.
15 VAR, HVC, Shanks Orgaworld: 40–100 m3 biogas per tonne of biodegradable waste.
16 CBS Statline 2010, transported.
17 Huisman (2009), own calculations, 40 tonnes leaf/ha.
18 Approximately 11 t/ha (159,700 ha surface area) according to CBS Statline 2011, and Rabou, L.P.L.M et al. (2006) *Biomassa in de Nederlandse energiehuishouding in 2030*. ECN and WUR.
19 Elbersen, W. et al. (2010) *De beschikbaarheid van biomassa voor energie in de agro-industrie*. WUR.
20 Vis, M. (2002) B*eschikbaarheid van reststromen uit de voedings- en genotmiddelenindustrie voor energieproductie*. BTG Biomass Technology Group BV, Enschede.
21 16,000 ha times 32 t/ha. CBS Statline.
22 DEN /LEI (2012).
23 Approximately 25% of this is assumed to remain on the land.
24 PDV (2010), *Veevoedergrondstof 2010* / LEI, *2012 tarwegriesprijs*.

25 Oosterkamp, E.B., Hoste, R. and Aramyan, L.H. (2012) *Liberalisering verwerking categorie 1- en categorie 2-slachtbijproducten: een marktanalyse.* LEI/WUR.

26 A number of new incineration plants have been built in recent years. There are now 12 plants that can each handle 7.5 Mt of waste, and there is now surplus capacity so that incineration fees have been under pressure for some time.

27 C_5 sugars – hemicellulose; C_6 sugars – starch and cellulose.

28 In this scenario, DHV, a consultancy group, estimates that savings of €250 million could be achieved if the volume of waste being sorted were increased about a third, although it may not be easy to achieve such an improvement in large cities. Further research is necessary.

29 Delivering solid manure (for example by introducing new forms of animal stalls) to biogas plants seems an obvious thing to do. After all, solid manure will provide more biogas, which will improve profitability.

30 RuBisCo (ribulose-1,5-bisphosphate carboxylase oxygenase) is an enzyme involved in carbon fixation, a process by which plants convert atmospheric CO_2 to produce sugars.

31 Benschop, A. (2012) *Nieuwe materialen uit bestaande teelten*. Paper presented at the Biobased Economy symposium, Emmen, 29 November.

32 Elbersen, W. et al. (2011) *De beschikbaarheid van biomassa voor energie in de agro-industrie.* WUR Food & Biobased Research.

33 Van der Eijk, A. et al. (2012) *Meer waarde uit GFT-afval*, Vereniging van Afvalbedrijven.

34 Elbersen, W. et al. (2010) *De beschikbaarheid van biomassa voor energie in de agro-industrie*. WUR.

35 Benschop, A. (2012) *Nieuwe materialen uit bestaande teelten*. Paper presented at the Biobased Economy symposium, Emmen, 29 November.

36 Elbersen, W. et al. (2011) *De beschikbaarheid van biomassa voor energie in de agro-industrie*. WUR Food & Biobased Research.

37 Koppejan, J.H.W. et al. (2009) *Beschikbaarheid van Nederlandse biomassa voor elektriciteit en warmte in 2020*. SenterNovem.

38 Rough estimate based on investment indicators for fermentation plants, and sugar and ethanol plants, for example. As specific investment indicators, the following general values (for reference) have been used: fermentation plants €0.1 million/kt input, conventional ethanol plants €0.3 million/kt input and second-generation ethanol plants based on lignocellulose €0.5 million/kt input. The authors assume that the investment indicators for biorefining are similar to those for second-generation ethanol production processes.

Chapter 4: The impacts of increased circularity on the Dutch economy

1 Floow2 describes itself as a 'business-to-business marketplace where companies and institutions can rent out or rent equipment and the skills and knowledge of personnel' (www.floow2.com).

2 The share of the entire Dutch economy vis-à-vis the EU 27 is 4.8%.

3 Regenersis (www.regenersis.com) organizes the repair of consumer electronic goods and professional equipment, such as MRI scanners and cash dispensers. An extensive range of consumer products are repaired and acquired for further sale if they do not meet the standards

when purchased: mobile phones, laptops, tablets, TVs, etc. The company has branches in 12 countries worldwide.

4 Interview conducted for this project.

5 Discussion with colleague from the Council for the Environment and Infrastructure (Raad voor de leefomgeving en infrastructuur, Rli), a strategic advisory council for the Dutch government.

Chapter 5: Drivers and obstacles on the road to a circular economy

1 HCSS, TNO (2012) *Staat van Nederland innovatieland 2012*, Amsterdam University Press.

2 www.ksinetwork.nl; the websites of the other two programmes can no longer be accessed.

3 Competence Centre for Transitions: www.transitiepraktijk.nl/en/

4 Kamm, B. (2008) *Definition and Technical Status of Biorefineries*, presentation at BioFuture 2008, Brussels.

5 Weterings, R., Roelofs, E., Suurs, R. and Van der Zee, F. (2011) *Tussen gouden bergen en groene business. Systeemverkenning van een biobased economie*, TNO report 2011-08, HCSS and TNO.

6 Sources: interview conducted for this project; www.nutrientplatform.org

7 Sources: interview conducted for this project, and interviews organized by a sustainable supply chain platform. Roelofs, E. and Willems, M. (2010) *Op weg naar duurzame materiaalketens*. TNO-034-DTM-2010-00733, TNO, Delft.

8 Sources: interviews and workshop conducted for this project; Ellen MacArthur Foundation (2012) *Towards the Circular Economy*.

9 Aldersgate Group (2012) *Skills for a New Economy: A paradigm shift in education and learning to ensure future economic success.*

10 Interview conducted for this project.*

11 Interviews in the context of previous research on sustainable supply chains; Roelofs, E. and Willems, M. (2010) *Op weg naar duurzame materiaalketens*. TNO-034-DTM-2010-00733, TNO, Delft.

12 HCSS, TNO (2012) *Staat van Nederland innovatieland 2012*, Amsterdam University Press, p.25.

13 Roelofs, E. and Willems, M. (2009) *Op weg naar duurzame materiaalketens*. TNO memorandum TNO-2009-RSE-21683. TNO Delft. Huppherts, P., Embrechts, F., Crol, J., Bor, A., and de Nijs, I. (2012) *Cradle to Cradle loont! Bedrijven uit de C2C Leercommunity over hun ervaringen en leerpunten.* The Terrace & Agentschap NL symposium, 'Closing the loop', November 2012.

14 Letter from the Nutrient Platform to the Dutch House of Representatives, 'Uitvoering Ketenakkoord Fosfaatkringloop', 15 February 2013.

15 Weterings, R., Roelofs, E., Suurs, R. and Van der Zee, F. (2011) *Tussen gouden bergen en groene business. Systeemverkenning van een biobased economie,* TNO report 2011-08, HCSS and TNO.

16 *Afval! Jaarboek 2012*.

17 Peene, A., Velghe, F. and Wierinck, I. (2011). *Evaluatie van de vergisters in Nederland.* Organic Waste Systems and Agency NL.

18 www.turntoo.com and www.floow2.com

19 For an assessment of various product service systems based on their contribution to sustainable development, see Tukker, A. (2004) Eight types of product service systems: eight ways to sustainability? Experiences form SUSPRONET. *Business Strategy and the Environment* 13(4): 246–260.

20 UNEP (2022) *Product Service Systems and Sustainability: Opportunities for Sustainable Solutions*. UNEP–DTIE, Paris, p.9 (cited in Tukker, 2004).

21 Interview conducted for this project; such an app was being developed at the time of writing.

22 *Afval! Jaarboek 2012*, and NRC, 'Beloon burgers voor hun afval', 4 June 2011, based on research by DHV.

23 Interviews conducted for this project

24 *Afval! Jaarboek 2012*.

25 Interviews conducted for this project.

26 Bordes, O., Feenstra, L. and Roelofs, E. (2001) *Materiaalkringloopsluiting gips in de bouwsector. Haalbaarheidsproject*, TNO report, R-2004/046; Roelofs and Ekelenkamp (2001).

27 See AMEC and Bio Intelligence Service (2011) *The Opportunities to Business of Improving Resource Efficiency* (European Commission contract 070307/2011/ 610181/ETU/F.1), p.85.

28 Willems, M. and Weterings, R. (2011) *Eindnotitie Duurzame Materiaalketens;* Van Elburg, J.C. (2009) *Het perspectief van de koploper – 10 oplossingen om een groene loper voor innovatie te realiseren*. RebelGroup.

29 Sources: TNO experts; Weterings, R., Roelofs, E., Suurs, R. and Van der Zee, F. (2011) *Tussen gouden bergen en groene business. Systeemverkenning van een biobased economie,* TNO report 2011-08, HCSS and TNO; interviews conducted for this project.

30 Ellen MacArthur Foundation (2012, 2013) *Towards the Circular Economy*.

31 Information from the workshop with stakeholders.

32 HCSS, TNO (2012) *Staat van Nederland innovatieland 2012*, Amsterdam University Press.

33 Interviews conducted for this project.

34 Bex, P.M.H.H. and Blank, R.E. (2011) *Botsende belangen in de biobased economy. Een inventarisatie en een analyse van de belemmeringen in de transitie naar een biobased economy.* SIRA Consulting.

35 Bex, P.M.H.H. and Blank, R.E. (2011) *Botsende belangen in de biobased economy*, SIRA Consulting.

36 Willems, M. and Weterings, R. (2011) *Eindnotitie Duurzaam Materiaalbeheer*, TNO-060-DTM-2011-02308-WSR-PEM-21683. TNO.

37 Bex, P.M.H.H. and Blank, R.E. (2011) *Botsende belangen in de biobased economy*. SIRA Consulting.

38 Nova Institut, presentation 28 November 2012; Weterings, R., Roelofs, E., Suurs, R. and Van der Zee, F. (2011) *Tussen gouden bergen en groene business. Systeemverkenning van een biobased economie*, TNO report 2011-08, HCSS and TNO.

39 Sources: interview conducted for this project and *Afval! Jaarboek 2012*; Weterings, R., Roelofs, E., Suurs, R. and Van der Zee, F. (2011) *Tussen gouden bergen en groene business. Systeemverkenning van een biobased economie*, TNO report 2011-08, HCSS and TNO.

40 Source: interview conducted for this project.

41 This obstacle was also identified in the SIRA study. Bex, P.M.H.H. and Blank, R.E. (2011) *Botsende belangen in de biobased economy*. SIRA Consulting.

42 Source: interviews conducted for this project.

43 Tertium (2013) My 2030's. *Burgers over de Biobased Economy.* Study commissioned by the BE-Basic Foundation. www.tertium.nl/my2030s/

44 MotivAction study of *Generation Y*, www.motivaction.nl

45 Tertium (2013) *My 2030's. Burgers over de Biobased Economy.*

46 Science of the Time (www.scienceofthetime.com), a company run by Carl Rohde, professor of trendwatching and innovation at Fontys Universities of Applied Sciences in the Netherlands; *NIMA Trendkompas 2008*, Netherlands Institute of Marketing.

Chapter 6: Towards a circular economy: an action plan for the Dutch government

1 Letter from the Nutrient Platform to the Dutch House of Representatives, 'Uitvoering Ketenakkoord Fosfaatkringloop', 15 February 2013, regarding progress with the phosphate chain agreement.

2 Based on Willems, M. and Weterings, R. (2011) *Eindnotitie Duurzaam Materialenbeheer*. TNO.

3 The European Commission is very clear about this: 'Member states should review their fiscal policies and instruments with a view to supporting resource efficiency more effectively, and in this context reflect on incentives to support consumer choices and producer action in favour of resource efficiency (by 2013)'. EC (2011) *Roadmap to a Resource Efficient Europe.* SEC(2011) 1067 final, p.11.

4 NSOB (2012) *Visie op NWW – Provincie Zuid Holland in het netwerk*, 26 November.

5 EL&I (2021) *EL&I als netwerkpartner in beleidsprocessen. Eindrapport fase 1: Verkenning van ervaringen op de EL&I werkvloer en uit de literatuur*. Ministry of Economics, Agriculture and Innovatiion (EL&I).

Appendix 1: Innovation systems

1 Hekkert, M., de Boer, S. and Eveleens, C. (2011) *Innovatiesysteemanalyse voor beleidsanalisten, een handleiding*, Universiteit Utrecht.

2 Suurs and Hekkert (2012), p.152.

A circular economy is a realistic way to provide an expanding world economy with the raw materials that will be required. A more circular economy envisages increased reuse, repair and recycling of manufactured goods and the utilization of the waste streams generated by modern society. This book analyzes the economic, social and environmental impacts of increased circularity, and presents an action plan for the government to accelerate the transition to a circular economy in the Netherlands.

TNO innovation for life