# The Resilient Economy

A Historical Investigation of Policy on Material Constraint in Britain During the Second World War: Creating Resilience to Critical Materials Problems in the Netherlands

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by

E.C. Schiltkamp

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The Netherlands

# Preface

Before you lies the master thesis *The Resilient Economy*, based on a historical case study of policy on material constraint in Britain during the Second World War. From the beginning my studies at TU Delft, my interest in history has been growing, ultimately expressed in taking the minor Europe in the Middle Ages and the Early Modern Period at Leiden University as part of the bachelor of Industrial Design Engineering. Simultaneously, I felt compelled to contribute to the world's increasing sustainability problems through my studies and decided to study Industrial Ecology for my master's degree.

By the end of 2016, as I was searching for a topic for my master thesis, we had a guest lecture by David Peck on his PhD dissertation for which he had analysed several case studies from wartime Britain and extracted lessons for circular product design. However, the observation that stood out for me was that Britain had made extensive plans in advance on how to secure resources in times of resource constraint caused by an event of war, while today there is no government that has such a plan while threats of materials problems were becoming increasingly severe. A few weeks later, a government official provided another guest lecture where he talked about the Dutch ambition to have a fully circular economy by 2050. The combination of the two lectures gave me the idea to study the historical case of Britain to provide insights for the Dutch transition.

This thesis provides recommendations for increasing a country's resilience to situations of material constraint and reviews the effectiveness of the circular economy as a solution to critical materials problems. The results are therefore interesting for both policy-makers and academic researchers. The *Governance for resilience to material constraint framework* framework that is produced based on the results of this study can be used by policy-makers to further specify actions for a transition pathway towards a more resilient society and by scholars to further develop research on the circular economy or other concepts that propose to answer critical materials problems.

I was engaged in researching and writing this master's thesis from March 2017 to August 2018. The process was intense and challenging, since the topic is deeply complex and all-encompassing. Additionally, the methodology touched upon fields that were not explored during my bachelor or master, such as sociology and history (the minor did not involve conducting historical research). Moreover, except for David's work, there are no other examples of the use of historical case studies in the field of critical materials. Personally, I have gone through a rough period of burn-out and depression, however, I am glad to say that I have almost fully recovered.

Therefore, I am deeply grateful for the blessing of having David as my first supervisor, for his enthusiasm, kindness, patience, valuable time, insight, and encouragement, but most of all for his endless knowledge of British history, circular economy and the field of critical materials. Thank you for your excellent guidance and support. Additionally, I would like to thank Arnold Tukker for his sharp insight into the academic quality of my work, his valuable comments and impressive knowledge. I would also like to thank the three Dutch government officials, Mattheüs van de Pol, Kees Veerman, and Dirk-Jan Koch, who were so kind to participate in my interviews. Thank you for being open and happy to share such useful information.

Of similar importance to me, I would love to thank my parents, Teun and Ineke Schiltkamp and my brother and sister Michaël and Judith Schiltkamp, who have supported me all the way. Thank you for your unwavering believe in me, even when I lost all believe in my own abilities. I love you. The same applies to my boyfriend, Salomon Brummel, it was sometimes stressful to be working on our theses at the same time, we are even graduating one day apart, but we were also able to

understand each other and support each other. You truly helped me to persevere, I cannot believe how lucky I am to have you in my life. Furthermore, I would like to thank everyone from my Bible study group, Chris and Anne Rijneveld, Matt and Liesbeth Rebel, Rolf and Petra Bruins, Werner and Laura Vos, and Ruud and Sharon Wisse. Thank you for your concern with how I was doing, for reading my entire thesis and your helpful comments, and most of all, for praying with me. I also want to extent my thanks to Beaufort, thank you for teaching me everything about reading the wind and the waves, thanks to all the time I have spent on a sailing boat I was able to navigate my thesis safely to the shore. Also, thank you for the times I was able to go sailing during this period, which allowed me to find some rest and clear my mind. Finally, I want to thank my Heavenly Father, Creator of Heaven and Earth, my Lord and Saviour. Thank You for the strength and wisdom You have provided, thank You for carrying me and for Your healing power.

I hope you enjoy reading my thesis.

*Elise Schiltkamp*
*Delft, 17 July 2018*

# Abstract

The Netherlands is vulnerable to supply restrictions because of the importance of materials for economic development: materials are at the basis of the society. The materials that are particularly vulnerable to supply disruptions and are of high importance to the economy are called critical raw materials. The Dutch government has adopted the goal of having an entirely circular economy by 2050 to reduce the vulnerability of the economy to critical materials problems. However, the literature indicates that adopting a new economic model is not sufficient and that a sustainability transformation is essential. According to literature, both a sustainability transformation and economic degrowth are essential to reach a situation of sustainable material use and therefore resilience to supply disruptions. Moreover, the literature emphasises that governance, and especially political leadership, is indispensable in achieving a successful transformation. This research shows how governance can bring about the desired sustainability transformation to reach a social and economic system that is resilient to situations of material constraint in the Netherlands. This study presents a theoretical framework that is tested using the case of governance on material constraint in Britain during the Second World War. The results are applied to the case of the Netherlands to provide insight into the way forward towards a society that is resilient to situations of material constraint.

The results show that a broad approach, including the entire social-ecological system, is essential and that the government can use selective pressures and windows of opportunity to steer and accelerate the transformation. The case study of policy on material constraint in Britain underlines the importance of planning besides the transformation. Additionally, the research has uncovered trust, and therefore the importance of equal and just distribution, as the foundation of resilience.

The Dutch government should take the responsibility of bringing about sustainable development and use its authority to define a sharp vision and specific goals for the sustainability transformation. If diversity and distribution are adequately addressed during the transformation process, the Netherlands is in the position to achieve a high level of resilience to critical materials problems. Resilience does not mean that situations of material constraint will not occur, or that they will not affect the society. It does mean that the Dutch social-ecological system will be flexible enough to change according to the new situation while maintaining its function and provide its society with the basic needs for living, even in times of severe material constraint. The new system is a system that is balanced and diverse, and, therefore, far less dependent on economic growth or material supplies.

Valuable research that could be done to build on this work would be to conduct a similar analysis using one or more different cases, such as the period of resource constraint during the 1970s. Additionally, further research could be done into the different phases of the framework, to provide more insight into specific actions that can be taken to transform a social-ecological system. In a practical sense, this theoretical framework that has been developed in this research can be used by government officials to test its usefulness in helping to develop a transition pathway for the government, including a timeline.

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# List of Abbreviations

| | |
|---|---|
| BBE | Bio-based Economy |
| BZ | Ministry of Foreign Affairs (Ministerie van Buitenlandse Zaken) |
| CBS | Statistics Netherlands (Centraal Bureau voor de Statistiek) |
| CML | Institute of Environmental Sciences Leiden (Centrum voor Milieuwetenschappen Leiden) |
| CPB | Bureau for Economic Policy Analysis (Centraal Planbureau) |
| CRMs | critical raw materials |
| DRC | Democratic Republic of Congo |
| EIP | European Innovation Partnership |
| EPR | Extended Producer Responsibility |
| EU | European Union |
| EZ | Ministry of Economic Affairs (Ministerie van Economische Zaken) |
| GDP | Gross Domestic Product |
| IenW | Ministry of Infrastructure and Water Management (Minsterie van Infrastructuur en Waterstaat) |
| M2i | Materials innovation institute |
| MLP | multi-level perspective |
| NMP | National Environmental Policy plan (Nationaal Milieu Beleidsplan) |
| NSOB | Netherlands School of Public Administration (Nederlandse School voor Openbaar Bestuur) |
| OECD | Organisation for Economic Cooperation and Development |
| PBL | Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving) |
| PGMs | platinum-group metals |
| PSOC | Principal Supply Officers' Committee |
| QCA | Qualitative Content Analysis |
| R2G2 | Smart Regulation for Green Growth (Ruimte in Regels voor Groene Groei) |
| REEs | rare earth elements |
| Rli | Environmental and Sustainable Development Council (Raad voor de Leefomgeving en Infrastructuur) |

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| SDGs | Sustainable Development Goals |
| SER | Social and Economic Council of the Netherlands (Sociaal-Economische Raad) |
| SESs | Social-ecological systems |
| SCP | Social and Cultural Planning Bureau (Sociaal en Cultureel Planbureau) |
| TNO | Netherlands Organisation for applied scientific research (Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek) |
| UFAC | Utility Furniture Advisory Committee |
| UN | United Nations |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| VANG | From Waste To Resource (Van Afval Naar Grondstof) |
| VROM | Ministry of Housing, Spatial Planning and the Environment (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer) – from 1982-2010 |
| WCED | World Commission on Environment and Development |
| WTO | World Trade Organization |
| WWII | Second World War |

# Glossary

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| circular economy | '*a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling*' (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, p. 759) |
| critical raw material | '*a raw material [that faces] high risks with regard to access to it, i.e. high supply risks or high environmental risks, and be of high economic importance*' |
| degrowth | a socially sustainable and redistributive downscaling of production and consumption to assure that society's throughput – resource use and waste – stays within safe ecosystem boundaries |
| (earth system) governance | '*the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development*' (Biermann, et al., 2010, p. 279) |
| material constraint | a limitation in the supply of materials obtained from naturally occurring assets that can be traded in their unprocessed or semi-processed forms and are essential to industrial production processes, of which the economic value arises from their economic usefulness in industrial production, their scarcity and, in the case of industrial raw materials, their exhaustibility |
| raw materials | products obtained from naturally occurring assets that can be traded in their unprocessed or semi-processed forms and are essential to industrial production processes. The economic value of raw materials arises from their economic usefulness in industrial production, their scarcity and, in the case of industrial raw materials, their exhaustibility. |
| resilience | the capacity of a social-ecological system to absorb a spectrum of shocks or disturbances and to sustain and develop its fundamental function, structure, identity and feedbacks as a result of recovery or reorganisation in a new context |

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| sustainability transformations | processes of fundamental change in complex and dynamic social-ecological systems resulting in a use of the environment and resources that meets the needs of the present without compromising the ability of future generations to meet their needs, accomplished through considering the defining of goals specific to the particular social and ecological situation, the promotion of resilience through diversity, and the ensuring of equal distribution of advantages and disadvantages |
| sustainable development | *'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'* (WCED, |

Iceberg at Narsaq, Greenland, the planned location for a uranium and rare earth minerals mine. Recent global warming permits access without the sea being iced all year long. Fridrik Magnusson: 'You know you can go and sit and watch the icebergs for half a day, a whole day.' Photograph: Sirio Magnabosco/Arctic Times Project. Reprinted from Walsh, 2017.

# *Chapter 1*
# Introduction

## 1.1 The materials challenge

After the end of the First World War in 1918, Britain had learnt that their success in securing the supply of materials had been a crucial factor in the Allied victory. The victory had been achieved by drastically changing the British way of government during the war to meet the demands they were facing. From this experience, they began planning their allocation of resources so that the country would be fit for a future war. When the political situation in Europe started to change with the Nazi party taking power in Germany in 1933, Britain intensified their preparations and made detailed plans for the supply of primary materials required for a modern war. By July 1939 the initial plans were finalised, just before Britain declared war on Germany on 1 September 1939, after Germany had invaded Poland. (Peck, 2016; Hancock & Gowing, 1949)

Today, concerns about material supply problems are becoming increasingly relevant again. A study by the United Nations Environment Programme (UNEP) on global material flows, shows that over the past decades global material use, as well as the material intensity of the world economy, have seen great acceleration. (UNEP, 2016) The study demonstrates that every unit of Gross Domestic Product (GDP) requires an increasingly vast amount of material, indicating the importance of materials for economic development. At the same time, the supply of materials is under pressure, thus directly threatening financial stability. This pressure has already resulted in severe competition over access to materials. (Tukker, 2016) Several countries and regions, such as the European Union (EU), have composed lists of materials that are under the most significant threat of supply shortages. These materials are called critical materials, in order to be defined as critical, '*a raw material must face high risks with regard to access to it, i.e. high supply risks or high environmental risks, and be of high economic importance*' (European Commission, 2010, p. 32). Supply risks arise, for example, because of conflict caused by the uneven geographical distribution of raw materials, the declining quality of deposits, natural disasters or market developments. These risks increase as demand grows because of growing population, increasing wealth, development of new technologies and progress in the field of renewable energy production and smart systems. (Allwood, Ashby, Gutowski, & Worrell, 2011; Erdmann & Graedel, 2011)

Similar to Britain after the First World War, countries are increasingly aware of the issues around resource security and in particular the risks concerning critical materials. In the Netherlands, the government recognises these critical materials problems as well. Additionally, by 2050, the global population will have

increased to nine billion (from seven billion in 2016), and the linear system will not be able to provide the required resources for the desired standard of living for all of these people. Furthermore, the extraction of raw materials puts a high burden on the environment. These developments create risks for the supply of resources, primarily since the Netherlands depends on the import of resources from other countries for the production of, for example, electronics. In 2016, the Netherlands imported 68 per cent of its resources from other countries, especially China. The increasing global demand for resources is not a sustainable situation and poses a significant threat to economic and political stability, as well as the quality of natural capital, biodiversity and the climate of the planet (Rijksoverheid, 2016; SER, 2016; TNO, 2013; UNEP, 2016). Therefore, in September 2016, secretary of state Dijksma (Ministry of Infrastructure & Environment) and minister Kamp (Ministry of Economic Affairs), announced the ambition of the Dutch government for the Netherlands to become circular by 2050. Moving from a linear to a circular economy was seen as the adequate answer to the complex and growing critical materials problems. A circular economy should secure resource supply while at the same time reducing the burden of material extraction on the planet and people. (Rijksoverheid, 2016) Research performed by the Netherlands Organisation for Applied Scientific Research (TNO, 2013) indicates that a circular economy would provide an economic boost by adding a value of 7.3 billion euro per year and 54.000 jobs to the Dutch economy. The Dutch transition towards a circular economy should be seen in the light of European and global developments. On a European level, the European Commission launched an action plan for the circular economy in 2015 (European Commission, 2015). In this plan, the European Commission promises to develop effective measures to decrease the demand for primary raw materials, focusing on five priority areas: plastics, food waste, critical raw materials, construction & demolition and biomass & bio-based products. On a global level, concerns about the availability of resources were expressed by the Club of Rome in their book *The Limits to Growth* in which they discuss the extent to which the planet can sustain the exponential population and industrial growth. (Meadows, Meadows, Randers, & Behrens III, 1972) More recently, in 2016, the sustainable development goals (SDGs) were presented by the United Nations (UN), which followed up on the millennium goals. The goals are the global sustainability goals for 2030 and include responsible consumption and production, affordable and clean energy and climate action, but also economic growth. (United Nations, n.d.)

The Dutch government defines the ambition to move to a circular economy in the *Grondstoffenakkoord* (National Agreement on the Circular Economy) (Rijksoverheid, 2017). This document is an agreement between several partners who commit themselves to defining a transition plan for themselves and executing this. The Dutch government is one of the partners, and its contribution is the programme *Nederland Circulair in 2050* (A Circular Economy in the Netherlands by 2050) (Rijksoverheid, 2016). The programme focuses on the preservation of natural capital by reducing the use of primary raw materials as much as possible. The government approach is based on three principles: smart design using fewer resources, using products over an extended period, and recycling waste to become resources again (Figure 1). The document *A Circular Economy in the Netherlands by 2050* describes the reasoning behind the planned transition, the vision and the strategy. The strategy consists of plans for legislative alterations, supporting of initiatives and international collaborations and agreements, focusing on the stimulation of reuse of valuable resources in the economy. The *National Agreement on the Circular Economy* includes the midterm goal of reducing the national consumption of (critical) resources such as oil, gas and metals by fifty per cent by 2030. This enormous ambition bears a resemblance to wartime Britain. In the period between 1936 and around 1942, the British government achieved a reduction in resource use of up to sixty per cent. These were times of war, but at the same time, they showed that significantly reducing resource use is possible with the right strategy. (Peck, 2016)

This research focuses on developing a framework to aid the development of governmental policy on increasing resilience to critical materials problems

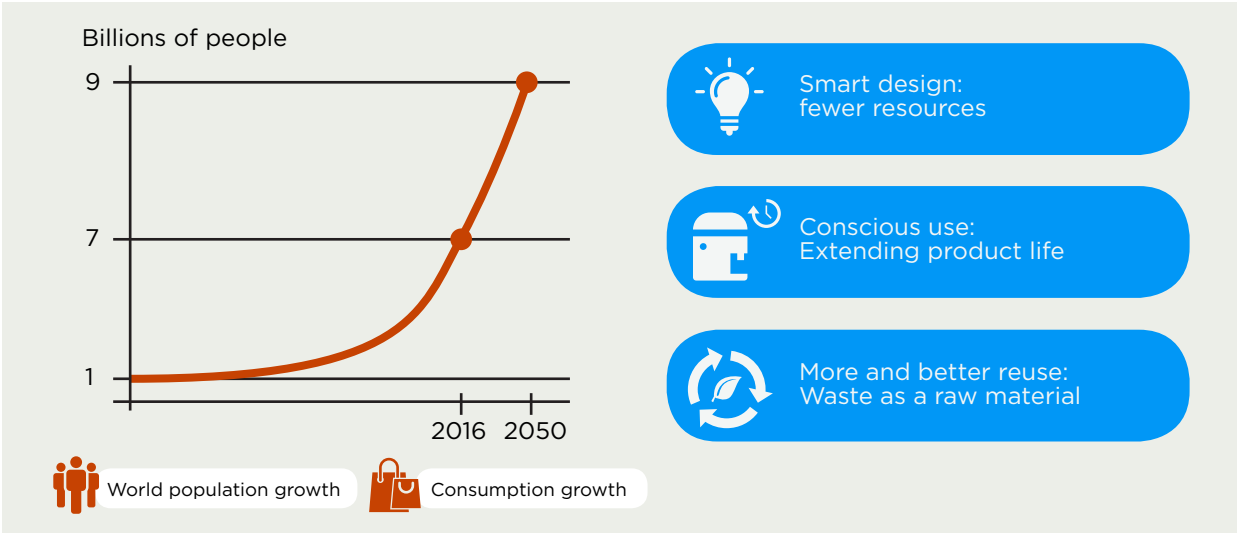



Figure 1 A circular economy in the Netherlands by 2050. Reprinted from Ministry of Infrastructure and the Environment, 2016.

in the Netherlands. Developing a complete transition pathway or emergency plan (necessary in case of sudden severe supply disruptions) is outside of the scope of this work. Additionally, this study focuses on the effects of a situation of material constraint within the civilian society. The war effort in Britain is therefore outside the scope of this work. The war effort is seen as the cause of civilian material supply problems and is not the subject of this study itself.

The fact that some materials are classified as critical is in itself not a problem for the Dutch economy or society. The classification is merely an indication of the high chance that disrupting supply problems may occur. However, *when* severe supply problems arise, resulting in a situation of material constraint, they will gravely affect the functioning of the economy and society. Therefore, the importance lies with building resilience to situations of material constraint, especially for materials that are of high importance to the economy. Britain during the Second World War (WII) was in a situation of material constraint. The general availability of materials was significantly reduced because of the losses of supply while the amount of material available to the civilian society was even further reduced because most of the supplies were directed towards the war effort. The term 'critical materials' was not used at that time. Therefore, for both the historical case of Britain and the contemporary case of the Netherlands, the term material constraint is used. The policy on the material constraint in Britain during WWII is selected as an empirical case of material constraint policy that is used to test the theoretical framework. This research builds on the work of Peck (2016), who has used five cases from Britain during WWII and interviews with the industry to extract product design strategies that can be used to address critical materials problems. Besides, Peck adapted Ashby's (2016) framework for a circular materials economy based on the outcomes of the research. Peck's new framework for critical materials and circular product design gives a more substantial role to policy and regulation than what was present in Ashby's model. The outcomes of Peck's research suggest that the government is responsible for data collection and distribution, planning of material supply, taxes on materials, and maintaining the trust of the society. Furthermore, Peck notes that a cultural shift is needed to address critical materials problems adequately.

Recommendations following upon Peck's research include exploring the government's leadership role with regards to critical materials problems, further analysis of historical cases and the development of the concept of a circular economy as a framework for managing critical materials problems. This research further explores the governance and policy aspects that came forward in Peck's work, but on which Peck did not elaborate. Additionally, this research adopts a neutral starting position towards addressing critical materials problems, since the circular economy is seen as one of the multiple possible solutions.

This research provides an overarching approach to increasing resilience to situations of material constraint and uses case study research to test the developed theory. Not many researchers have used historical case studies to develop an approach to contemporary situations of material constraint. Peck's (2016) research, as mentioned in the previous paragraph, has used historical case studies to assess the role of product design in addressing critical materials problems. Peck's research shows that the historical cases should be used carefully because of the numerous differences between the historical cases and the 21st-century critical materials perspective. However, the parallels that are also present attest that the historical cases are valuable for analysis when conducted thoughtfully. Peck concludes that past situations of material constraint provide a wealth of knowledge to develop solutions today and recognises the need for further research into the role of the circular economy in addressing critical materials problems. Regarding this role of the circular economy for critical materials problems, Ashby (2016) has developed a circular materials economy framework and poses that applying the concept of a circular economy, through improving efficiency in extraction, design and production, new business models, and reducing consumption will result in a sustainable use of materials. André, Söderman and Tillman (2016) have shown that the circular economy principles could indeed be useful in improving the efficiency of scarce metal use. However, there are significant limitations to the circular economy's effectiveness. The limited availability of functional recycling technologies for specific scarce materials affects recycling efficiency. Additionally, the principle of prolonging product lifetimes often requires additional scarce metals, which can offset the gains of the extended lifetime. Nevertheless, the results of André, Söderman and Tillman make the circular economy sound promising as a solution to critical materials problems.

Allwood (2014) argues that besides reusing products and materials, reducing demand is vital in curtailing impacts. Additionally, Allwood shows that substitution, innovation and reducing the number of compositions for the different material classes are not likely to provide an answer to overconsumption of bulk materials such as concrete and steel. Instead, regulation is currently the best tool at hand to control consumption and protect the environment. However, the public is often only willing to accept such restricting regulations in times of war or crisis, or when the underlying paradigm has become more familiar. Tukker (2016) points at three other inconvenient truths regarding the circular economy concept; the materials required for renewable energy technologies, the growing demand from emerging economies, and the materials basis of the society which means that decoupling can only happen to a certain extent. According to Tukker, reaching an entirely circular economy is not realistic, but the circular economy principles can contribute to more efficient material use, especially when combined with finding ways to increase well-being which is not based on money or materials. Skene (2017) has conducted an in-depth analysis of the fundamental principles underpinning the circular economy concept and concludes that the circular economy works against the laws of thermodynamics and the principles of nature and suggests to focus on bio-participation rather than biomimicry. Bio-participation involves the reintegration of humans into the biosphere, as opposed to lifting parts of the biosphere into the human context.

The reduction in demand which Allwood (2014) suggests, is also described by Charonis (2012), who advocates a degrowth transition towards a steady-state economy, which could be combined with the main principles of the circular economy. Kallis (2017) argues that indeed dematerialisation and economic degrowth go hand in hand, and has provided three policies that

would allow degrowth to become socially sustainable. However, Kallis also realises that probably '*the politically acceptable is ecologically disastrous while the ecologically necessary is politically impossible'* (Wackernagel and Rees, as cited in Kallis, 2017) in this case. The existing body of literature suggests that an essential aspect of answering critical materials problems is achieving a reduction in demand, or dematerialisation, which has to be achieved through economic degrowth. According to some authors, dematerialisation could be combined with the circular economy concept to reach a situation of sustainable development. Besides the circular economy, regulation and focusing on human well-being which is not based on materials are also suggested to move towards a more sustainable situation.

This overview of the existing research displays a focus on the circular economy and other concepts as solutions to sustainability issues, however, generally directed towards the environmental aspects of sustainability. Except for Peck, the authors do not mention critical materials problems. Peck addresses increasing resilience towards critical materials problems in the field of product design and gives a primary role to governance in his framework, but does not provide arguments for the importance of governance or explain what this governance should entail. Moreover, apart from Peck, no research in this field looks at historical case studies to obtain insight into the current situation. Missing from all research, including Peck's work, is an analysis of the suitability of the circular economy to adequately address situations of material constraint. Also, even though some policies are mentioned, limited research has been done on comprehensive governmental policy and planning to increase resilience towards critical materials problems, even though government regulation has been mentioned as a critical aspect of moving towards a more sustainable society. This research attempts to fill these gaps, by analysing the relation between the concept of a circular economy and critical materials problems and by obtaining insight into increasing resilience to situations of material constraint through government policy.

Further research into the circular economy as a solution to critical materials problems and the role of the government in addressing critical materials problems will aid the development of a more resilient economy and society with regards to situations of material constraint. Improving resilience is of growing importance to the Netherlands, as geopolitical tensions intensify and material demand keeps rising. Additionally, the effects of climate change and the continuous destruction of the ecosystem's services demand a systems change. The results of this research provide a scientific assessment of the effectiveness of the circular economy as a solution-path to increase the resilience to material constraint for the Netherlands. Moreover, the resulting framework can be used by the government to develop an overarching strategy as well as concrete actions to address critical materials problems. Adopting the framework will contribute to reducing geopolitical tensions, dependence on other countries, depletion of resources, climate change, environmental pollution, and social inequality. All of which will contribute to a more sustainable world, one that '*meets the needs of the present without compromising the ability of future generations to meet their own needs*' (WCED, 1987, p. 41), as sustainable development is defined by the World Commission on Environment and Development (WCED).

Literature indicates that a sustainable society could be achieved in the form of a circular economy, but only when combined with a significant reduction in demand. Allwood (2014) and Andersen (2007) state that as long as the global demand for the number and the type of products does not stabilise, a circular economy is not technically feasible. The stabilisation of material demand still lies far in the future for many countries outside of the Western world. (Tukker, 2016) Moreover, even if the demand stabilises, the recycling of the materials used in these products will cost far more energy than obtaining them in other ways. On top of that, materials can never be recycled infinitely. Allwood (2014) describes how before the industrial revolution when fossil fuels became available, economic (and population) growth was naturally limited by the available land; a limitation that is now gone. Quite the contrary: (unlimited) growth is now the goal of every business and government. Ashby

(2016) poses that a circular economy, where products were repaired, reused and recycled, has been the norm for ages. It was only once material costs dwindled that it became more cost effective to dispose of products instead of recirculating them. Today's economic system depends on infinite growth for its stability, a growth that is supported by innovation, a process where new technologies keep emerging while overthrowing existing products and technologies. On the demand side, this system is held in place by the value new products add to people's social identity. On the supply side, this growth is based on materials. However, assuming an annual global growth of seven per cent, an amount of primary materials equal to the volume of the earth's crust is needed (assuming the number of materials required per euro is constant). (Tukker, 2016) An economic system based on infinite growth is therefore not an option for a sustainable future. Merely decoupling economic growth from resource use and environmental impact will not result in the desired sustainable system, if true decoupling is possible at all. With an economy based on growth, the decoupling that needs to be realised is severe. Again assuming that the global economy grows by seven per cent annually, in a hundred years the economy will be a thousand times larger than it is today, requiring a reduction of material use per euro with a factor of thousand. (Tukker, 2016) André, Söderman and Tillman (2016) explored whether the circular economy leads to efficient use of scarce metals. Based on three case studies, the study concluded that it is possible to increase efficiency by applying the principles of the circular economy, but the results strongly depend on the particular conditions of a situation, showing that even when using the circular economy principles, decoupling is hard to achieve. Something more profound is needed, a system's change that ends the idolising of growth and enables a decrease in material use. In order to change a system, a transition is essential, as described in the fields of transition management, social-ecological transformations, transformative pathways to sustainability and transformative adaptation. (Jackson, 2009; Meadowcroft, 2009; Olsson, Galaz, & Boonstra, 2014; Chapin III, et al., 2009; Patterson, et al., 2017; Diederen, 2009) The overarching term of sustainability transformations is used in this study to describe this kind of transition since it entails a transformation of the system towards a sustainable situation. The general term of sustainability is used here, even when the study focuses on critical materials since sustainability is about a long-term balance between the human system and the ecological system, of which material use is a part. Transforming towards a society that is resilient to critical materials problems or material constraint, is, therefore, in essence, a sustainability transformation.

Achieving a reduction in demand is probably one of the leading challenges of our time. When people are not able to reduce their food consumption where the overconsumption directly affects the health of their bodies, how will they be able to reduce their materials consumption when the effects are often spread over the population and far away (both physically and temporarily)? Allwood (2014) argues that the key to a sustainable future is not having the market solve the problem, because the market is not able to control itself to that extent. Regulation is required as the most effective way to reduce demand, and this should start with preparing the public for overall demand regulation. A similar conclusion is reached by Andersen (2007), who says that the circular economy should be seen as a socio-economic challenge that requires governmental regulation.

## 1.2 Objective

Materials form the basis of all societies, and as a part of the global strive for continuous economic growth, currently especially visible in emerging economies, global material demand keeps increasing. Apart for the growing demand for bulk materials such as steel or concrete, the number of elements from the periodic table used in products has significantly expanded over the past decades, and their demand is rapidly increasing as well. Several factors, such as the physical scarcity of some of these materials or geopolitical tensions, are threatening the availability of various materials, some of which have

become essential to many economies. Materials that have a high risk of supply disruptions and that are of great importance to the economy are called critical materials. Currently, the world is facing increasing problems around critical materials. The EU list of critical materials has been updated with nine more materials in September 2017, as compared to 2014. (European Commission, 2017) Twenty-seven materials are now classified as critical, indicating the risk of general material constraint. Severe disruptions in the supply of these materials could have disastrous ramifications for the affected economies. Additionally, the large-scale extraction of these materials is significantly harming the environment which threatens a sustainable future. The Dutch government has identified the concept of a circular economy as a method to reduce the dependence on the import of resources, which should contribute to economic and political stability. At the same time, the circular economy should reduce environmental impacts. However, the literature indicates that solely transitioning towards a circular economy without dematerialisation and the accompanying economic degrowth might not result in a sustainable future, in general as well as in material supply. The subject is becoming increasingly urgent since worldwide resource extraction is increasing every year, a growth that cannot be sustained in the long run and additionally comes with detrimental effects on the global environment and climate. (UNEP, 2016)

Research has been done to assess the ability of the circular economy concept to contribute to a sustainable future, and several authors have identified significant gaps in the theory, though, in general, the transition towards a circular economy is not seen as harmful, but as insufficient. It is often suggested that the circular economy can provide a sustainable alternative economic model in combination with degrowth. Additionally, many scholars mention the role of policy and regulation as essential to lead the transition towards a more sustainable society. (Allwood, 2014; Charonis, 2012; Tukker, 2016; Peck, 2016; Ashby, 2016; Jackson, 2009) However, an analysis of the circular economy as a solution to critical materials problems has not yet been conducted, and the role of governance in increasing resilience to critical materials problems has not been addressed.

The study focuses on increasing resilience to critical materials problems in the Netherlands, with particular attention for the concept of a circular economy, which is the approach that is currently adopted. A historical as well as a contemporary case study will be used to obtain insight into the role of governance, policy and regulation. This research focuses on the conceptual level and, therefore, does not attempt to produce a specific transition pathway. It provides a starting point for government officials to develop such as pathway and its actions, and for researchers to further develop this direction. This research adds a system thinking perspective to the goal of the Dutch government to have a circular economy in the Netherlands by 2050, by looking at the interplay between material flows, economy, government and society.

The problem statement is, therefore, defined as: *Literature indicates that a sustainability transformation is essential to increase a country's resilience to critical materials problems significantly and that government policy and regulation plays a vital role in bringing about such a transition. However, the knowledge about how this transition should be shaped and what policy and regulation instruments could be used is lacking.*

This study aims to give more insight into societies that effectively cope with situations of material constraint and the transition that is necessary to reach such a society. This research will add new understanding of the regulatory strategy that governments could implement to achieve such a change. To gain insight into possible effective approaches, analysing a historical case of reduced material use provides guidance.

The primary research question for this research is defined as:

**How can governance bring about a sustainability transformation aimed at creating resilience to situations of material constraint in the Netherlands?**

The primary research question is divided into three sub-questions that help to answer it.

1. What framework best describes governance for sustainability transformations to create resilience to situations of material constraint?

2. What governance approaches to create resilience to situations of material constraint have been taken in the past?

3. What is the current governance approach to creating resilience in situations of material constraint in the Netherlands?

## 1.3 Research design

An answer to the research question will be found by conducting case study research, consisting of two cases. The first case under analysis is, as stated before, the historical case of policy on the material constraint in Britain from 1939 – 1945. During the first years of this period, Britain used their experience with the importance of materials supply from the First World War to develop a strategy for securing supplies in case of war, although it was at that time not expected this would happen soon. When from 1933 when the Nazi party took power, and even more from 1936, the situation in Europe worsened, and the threat of war became a reality, the first parts of the strategy were put into effect. When the war broke out in 1939, the plans were fully adopted. However, during the war, the situation around the supply of materials worsened, and additional measures had to be developed to be able to continue to assure the necessary quantity of materials. The combination between the development of the plans, the actual implementation and the additions made at a later stage forms a useful case for answering the research question of this research. A literature review using literature from 1939-2018 is conducted to identify valuable lessons for situations of material constraint. The second case is the contemporary case of policy on critical materials problems in the Netherlands from 2008-2018. In 2008, the Dutch government issued the first extensive research on developing knowledge regarding critical materials problems. From that point onwards, research has developed further and has resulted in the implementation of several successive programmes to increase resilience to critical materials problems, with the last one being that of becoming entirely circular by 2050. A literature study using literature on the topic from 2008-2018 is conducted, as well as three interviews with government officials to provide further insight. The results from the literature for both cases and the interviews are analysed according to the theoretical framework which is developed in Chapter 2. The results of the two cases are combined with the results of the literature study to develop the most promising strategy to increase resilience to critical materials problems in the 21st century. Finally, the outcome of the synthesis is used to develop a concrete starting point for government officials to develop a transition pathway.

This research will not attempt to come up with an emergency plan in the case of sudden events that affect the supply of critical resources. It is important to note that the plans in Britain were designed for such an exceptional event. However, here the decision has been made to focus on a lasting change. Where in the previous century the foremost concern was winning a possible war, in the 21st century a systems change is required in the light of global developments. Topics that are not covered (in detail) are energy, food and other organic materials, water, $CO_2$ emissions and climate change, ecosystem services, ethical aspects of mining and conflict minerals, geopolitics and emerging economies.

## 1.4 Outline

The following chapter provides an in-depth overview of the literature around the topics of material constraint, governance for sustainability transformations, and resilience. Additionally, it describes a theoretical framework of governance for resilience to a situation of material constraint which answers the first sub-question and is used as the foundation of this research. The third

chapter describes the methodological approach of this study, which consists of case study research using a literature study and interviews. In Chapter 4, the results of the study are presented in two parts, the first part contains the results of the case of governance on the material constraint in Britain and answers the second sub-question and the second part presents a description of the governance on the material constraint in the Netherlands which answers the third sub-question. The results of both parts include a description of the case and the answers to the instrumental questions as defined in the methodology chapter. Finally, the fifth chapter consists of a conclusion which provides the answer to the primary research question, and a discussion of the results and conclusion, including recommendations for further work.

The following page (Table 1) provides an overview of the chapters of this thesis, the research questions covered in these chapters and the used methodology, resulting in the structure of the thesis.

Table 1 Thesis outline.

| Chapters | Research questions | Structure | Methodology |
|---|---|---|---|
| Chapter 1 Introduction | RQ How can governance bring about a sustainability transformation aimed at creating resilience to situations of material constraint in the Netherlands? | Introduction Problem statement Research questions | |
| Chapter 2 Theoretical framework | SUB-RQ1 What framework best describes governance for sustainability transformations to create resilience to situations of material constraint? | Development of framework | |
| Chapter 3 Methodology | | Description of the methodology used in this research | Structured, focused comparison: Material constraint; Governance; Resilience |
| Chapter 4 Results | SUB-RQ2 What governance approaches to create resilience to situations of material constraint have been taken in the past? | Historical case of policy on material constraint in Britain during WWII | Literature study |
| | SUB-RQ3 What is the current governance approach to creating resilience in situations of material constraint in the Netherlands? | Contemporary case of policy on material constraint in the Netherlands from 2008-2018 | Literature study; Interviews |
| Chapter 5 Conclusion and Discussion | RQ How can governance bring about a sustainability transformation aimed at creating resilience to situations of material constraint in the Netherlands? | Answer to main research question and discussion | |

The ore monazite can contain different rare-earth minerals important in energy applications, like neodymium. Reprinted from Yang, 2012.

# *Chapter 2*
# Theoretical framework

## 2.1 Introduction

This chapter starts by providing an overview of the existing body of literature related to this research to develop a theoretical framework for this study. First, it will discuss the existing body of literature on material constraint and critical raw materials, followed by a discussion of the dominant frameworks for sustainable material use, including a discussion of the extent to which the circular economy is useful in solving critical materials problems. The frameworks that are discussed are used to create one framework for sustainable material use that forms the first part of the theoretical framework. The second part of this chapter consists of a discussion of the topics of sustainability transformations, governance, and resilience and the approaches that exist in these fields. A combination of these approaches provides the foundation of the second half of the theoretical framework. The third part of this chapter describes the theoretical framework for governance to create resilience to material constraint.

## 2.2 Material constraint

### 2.2.1 Defining material constraint

The goal of this is research is to evaluate what government transition strategy could be adequate in times of material constraint; a situation in which particular materials that are of importance to the economy have become scarce, or critical, in the sense that there is a limited supply. A supply shortage does not have to be caused by physical depletion, but occurs because of various reasons, from natural disasters to export restrictions. To define the term 'material constraint,' it is necessary first to know what kind of materials are under consideration. In the context of constraint and supply shortages, the existing literature generally looks at natural resources, since supply shortages are typically related to the first stages of the value chain. The term natural resources is often interchanged with expressions such as raw materials, primary products and primary commodities. However, these terms are not the same. (Espa, 2015) Following from the definition of natural resources in The Glossary of Statistical Terms from the Organisation for Economic Cooperation and Development (OECD), raw materials are finite assets that are directly obtainable from the world's natural resources. The group of natural resources

can be divided into four categories: mineral and energy resources, soil resources, water resources and biological resources. (OECD, 2008) Additionally, the definition of natural resources by the World Trade Organization (WTO) adds the notion that naturally occurring assets should be scarce and economically desirable to qualify as natural resources (e.g. sea water, in this respect, is not a natural resource). The raw materials obtained from natural resources can be traded directly or after minimal processing and are then used as inputs in the manufacturing sector. (Espa, 2015; WTO, 2010) Therefore, the terms primary products and primary commodities cannot be used interchangeably with raw materials. Food-related agricultural commodities are, according to the generally used definitions, not considered raw materials, since they are cultivated rather than extracted from the natural environment. However, agricultural products are commonly distinguished as agricultural raw materials while extracted materials are referred to as industrial raw materials (e.g. fuels and mining products). To define the term material constraint, Espa's (2015) definition of raw materials, which has been derived from the definitions of the OECD and the WTO of natural resources, will be used. Espa defines raw materials as

> *'products obtained from naturally occurring assets that can be traded in their unprocessed or semi-processed forms and are essential to industrial production processes. The economic value of raw materials arises from their economic usefulness in industrial production, their scarcity and, in the case of industrial raw materials, their exhaustibility.'*
>
> (Espa, 2015, p. 44)

In this study, only the industrial raw materials will be considered. Forestry products is an ambivalent category since it can be both cultivated and extracted from naturally existing assets. The WTO has classified forestry products as agricultural raw materials. For this study, however, forestry products will be considered under the category of industrial raw materials to be able to include wood in the historical case study, since wood was an essential material during WWII.

The word constraint means limitation or restriction; the term material constraint is therefore defined for this study as a limitation in the supply of raw materials. Or, including the definition of raw materials, as a limitation in the supply of materials obtained from naturally occurring assets that can be traded in their unprocessed or semi-processed forms and are essential to industrial production processes, of which the economic value arises from their economic usefulness in industrial production, their scarcity and, in the case of industrial raw materials, their exhaustibility. (Espa, 2015)

### 2.2.2 Identifying critical minerals and metals

Based on the definition of raw materials given in the previous paragraph, industrial, or mineral, raw materials are obtained from mineral resources, after which they might undergo minimal processing and are then traded internationally because of their economic value. This definition describes the 'mine output', which are the ores that are mined at a certain site. Almost all ores go through some form of processing to increase their price per unit of weight before they are traded internationally. (Espa, 2015) Mineral raw materials are classified in the following categories:

1. Iron and ferro-alloy metals (e.g. iron, nickel, tantalum, titanium and tungsten)
2. Non-ferrous metals (e.g. aluminium, copper, mercury, rare earth elements and zinc)
3. Precious metals (gold, platinum-group metals (PGMs) and silver)
4. Industrial minerals (e.g. asbestos, bentonite, diamond, phosphates, salt and vermiculite)

Minerals and metals are essential to the manufacturing sector, though they account for a relatively small share of the global goods trade. (Espa, 2015) However, over the past forty years, the global economy has expanded over three times while the population only doubled. Global material extraction followed the developments of the economy closely and tripled as well. UNEP (2011) shows

that compared to a hundred years ago, today 34 times more construction materials are extracted, 27 times more ores and minerals, 12 times more fossil fuels and 3.6 times more biomass. One of the main contributors to this growth is the urban transformation of China, which has required unprecedented amounts of construction materials and energy. Another factor is the increased global material use per capita over the past decades, indicating the effects of improved living standards in emerging economies. (UNEP, 2016; Behrens, Giljum, Kovanda, & Niza, 2007 Many of the countries who extract the raw materials are so-called emerging economies. The export of the materials they produce as well as other economic and societal developments in these countries, increase their wealth and give way to a rising middle class. This rising middle class desires a certain lifestyle, which is accompanied by certain products, often reflecting trends that originated in the developed countries. It is expected that three billion people from developing economies will become middle class by 2030 which will increase global material consumption from the current 77 billion tonnes per year to 100 billion. (Ashby, 2016)

Besides the increasing amount of material needed, the diversity of used materials increases as well. While in the 1980s the number of elements employed in integrated circuits in most electronic products was no more than twelve, today this figure is over sixty. A similar trend occurs in the development of superalloys, required for turbine blades in jet engines. (National Research Council, 2008b). Where only half a century ago only relatively simple alloys of two or three metals were used, high-end alloys today consist of at least ten different elements and come in innumerable variations. Every material has specific properties required for its technological application, or as a competitive advantage for companies.

Therefore, materials are at the base of our society and economic infrastructure. Insufficient supplies of materials could disrupt businesses and (inter)national economies which greatly depend on supplies of materials, parts and products. The study on global material flows conducted by UNEP (2016) shows the close relationship between natural resource use and economic development. It shows, for example, that global material use slowed down at the time of the financial crisis in 2008 and 2009 and started to rise again as the economy recovered. The correlation between resource use and the economy is not surprising since materials are at the base of any economic development – everything is made from materials. All industries rely on direct or indirect material inputs, the primary industries support the industries further down the value chain, such as digital or service-based businesses. At the end of this chain, the materials support the quality of life in all societies. However, various demand and supply factors may hamper the availability of mineral raw materials, and therefore directly threaten human well-being. The following paragraphs discuss the most relevant aspects.

### *Physical depletion*

Mineral resources are fixed endowments that cannot be regenerated after exploitation. The exploitation of mining products inevitably brings their point of depletion closer. At the same time, minerals never disappear from the face of the earth; they are only dispersed. However, the more dispersed – or mixed with other minerals – they become, the harder and more energy-intensive it becomes to obtain a usable amount of pure material. It is often thought that some materials are to be depleted soon. However, calculating the moment when a particular material is depleted is hard because these calculations are based on many assumptions. Also, when is a material depleted? Often, there is a significant difference between the amount of a material that is available in the earth's crust and the amount that is economically extractable. Material that is not economically extractable now could be in the future.

Still, Henckens (2016), for example, has attempted to identify the most geologically scarce metals. His calculations show that antimony is under the most significant threat at the moment, with the prospect of being depleted before 2050. Gold, molybdenum (used in, e.g. rocket engines, paint and fertiliser), rhenium (used in superalloys for jet engines) and zinc are next, with the expectation to be depleted before 2150. Because these calculations are based on conservative assumptions and

these periods seem quite long, some tend to argue that physical depletion is not an actual issue when it comes to critical materials. Henckens shows that even though it is not an immediate threat, the physical limitations on what we can extract are there.

### *The mining industry*

A lack of investment in the mining sector poses another challenge to the physical availability of mineral raw materials. Investing in the mining sector is risky because of the generally low material prices, the capital-intensive operations, and the long payback times of mining activities. The mining industry has a low short-term supply and demand elasticity, which often results in fast-rising mineral prices due to pressures on the supply of mineral raw materials in times of economic growth. However, this short-term elasticity does not match with the long timeframes involved with investments in the mining industry. Because, even if the mining industry increases investments, the actual expansion of capital requires at least five years, but more often decades to become operational. Another aspect of the mining activities is that many of the materials are only produced as by-products of other materials, making their supply uncertain. Also, natural disasters pose a threat to the stable supply of primary material, although this threat is of a more temporary nature. Furthermore, supply is regularly disrupted by rebel invasions since mines are often located in countries with high levels of conflict. Such rebel invasions have, for example, occurred in Congo and Sierra Leone, resulting in rapid prices increases and global shortages. Finally, mines can be closed for a specific period because of facility maintenance which can result in shortages, price rise and even smuggling. (Espa, 2015; National Research Council, 2008a)

### *Geographical distribution and geopolitical tensions*

A more immediate concern with regards to critical materials is that the ores of many of these materials are not spread uniformly across the globe, but can be found in specific places (Figure 2). China, for example, produces 95 per cent of all rare earth metals and has put restrictions on their export of these materials in the past. A concentrated supply of mineral raw materials allows countries to exercise power over importing countries and can be a source of income for the national economy. The use of export restrictions (mostly in the form of export duties or taxes), for mineral products, as a policy tool has seen a considerable rise over the past years. The number of WTO members applying export restrictions has more than doubled between 2002 and 2014, from 38 in 2002 to 79 in 2014. The highest increase was seen in Africa, but the Americas, Asia and the Pacific also use many export restrictions. Europe and the Middle East, on the other hand, barely use export restrictions as a policy tool. (Espa, 2015) Export restrictions are often applied to protect the domestic supply, as well as promoting downstream processing to increase the revenues from the export of mineral products. Restricting exports to stimulate the vertical integration of the value chain, primarily applies to developing countries, attempting to achieve economic diversification. Additionally, export restrictions are sometimes used to protect public health and the environment. (Espa, 2015) The situation is made even more complicated because some of these exporting countries are emerging economies that see a rising middle class because of the increased wealth from the exploitation of their mines. This rising middle class is adopting the Western lifestyle and the technology that comes with it, which further increases the demand in general and specifically in these countries. Additionally, finished products have a significantly higher value than primary materials, motivating emerging economies to move down the value chain with their industries, and thus also keep the extracted materials within their economy. (Ashby, 2016; Peck, 2016; Cohen, 2007; Wouters & Bol, 2009; European Commission, 2014)

### *Technological development*

Physical depletion, the low price elasticity of the mining sector and the geographical distribution and geopolitical tensions are the main factors on the supply side that may hamper the availability of mineral raw materials. This point will look further into the demand side. As described previously, the world has seen a rapid (for some materials even exponential) increase of materials extraction

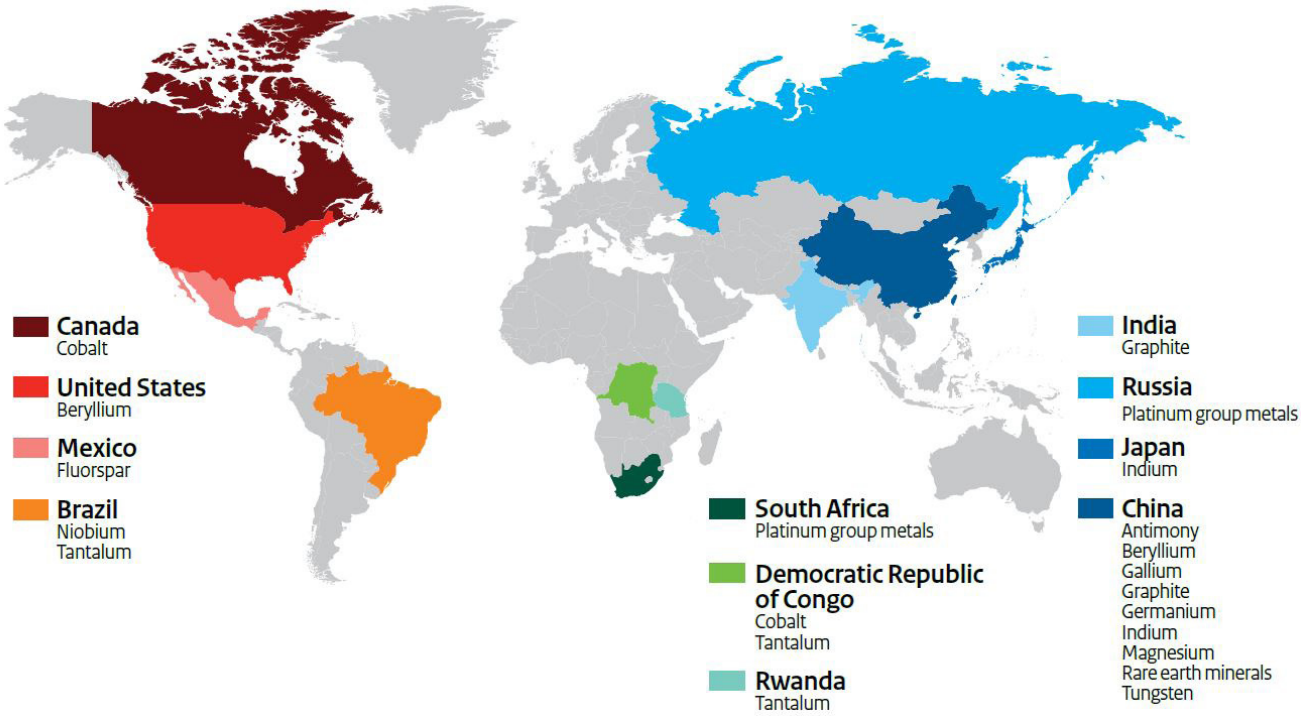



Figure 2 Production concentration of critical mineral materials – Europe is dependent on other continents. Reprinted from Rijksoverheid, 2016.

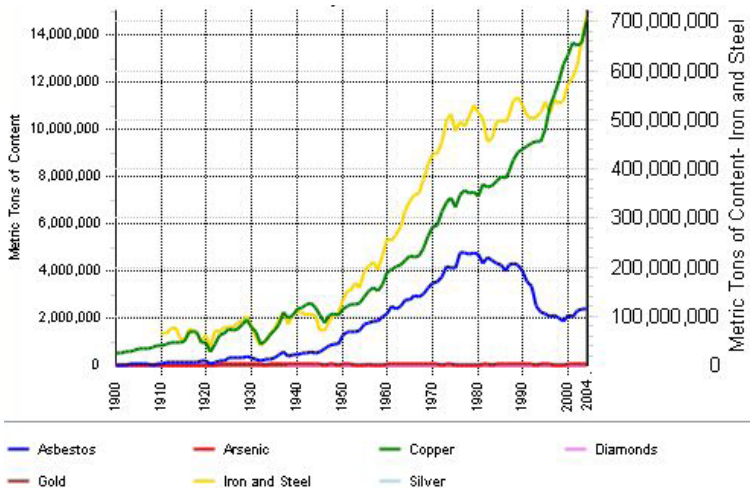



Figure 3 Commodity production- world 1900-2004. Reprinted from Data360, 2017.

(Figure 3), directly related to economic growth. A material with unusual behaviour in this graph is asbestos. It shows a similar growth to iron, steel and copper until the 1970s, after which the other three materials continue to grow, but the production of asbestos starts to decrease. Around 1980 it was announced that in ten years the material would be banned. From that point onwards, a steady decrease in its production can be seen, which becomes even stronger after the ban has been implemented. The production does not reach zero because exceptions were made for specific products. This example shows the significant effect that regulation can have on material production.

Besides a general increase in material use, technological development has also resulted in a drastic increase in the number of materials used (Figure 4). The development of new materials is a process that is still going on, with the pursuit of better performing materials to achieve superior products to serve the needs of the twenty-first-century human being and our modern society. These high-performance materials are often alloys of commonly used commodities such as copper or iron (in steel) with additional elements from almost the entire Periodic Table of Elements to enhance the performance. (National Research Council, 2008b; Peck, Kandachar, & Tempelman, 2015)

Additionally, the world is facing the (first) consequences of global warming, which are (mainly) due to emitting large quantities of $CO_2$ into the atmosphere from the burning of fossil fuels. The world needs an energy transition within a few years to stay below a 2°C global average temperature increase. The world finds itself at the beginning of this transition, moving towards a technology-based energy supply. These are advanced technologies such as wind turbines and solar panels. The sun and the wind, as sources of the new, renewable energy, are, however, fluctuating sources and require storage such as batteries, and smart systems that can manage the dynamic supply and demand. All the technologies required for this new energy system contain critical materials, and copious amounts are needed. It is expected that the renewable energy technologies required for the EU to meet its climate goals will increase the demand for particular mineral raw materials by a factor of twenty by 2030. (European Commission, 2018) The global energy transition from resource-based energy to technology-based energy creates a self-reinforcing material demand cycle since the mining of mineral raw materials is energy intensive and will only become more energy intensive with decreasing ore grades, thus requiring ever-increasing amounts of (renewable) energy. (Henckens, 2016)

### *Environment, health and ethics*

Besides the question whether there is enough supply of the materials required to maintain our standard of living now and in the future, there are the ecological and ethical aspects of our hunger for materials. The mining and refining of the metals cause significant harm to landscapes and ecosystems because of the physical destruction of habitats and the emission of toxins into the environment. (Nuss & Eckelman, 2014) Besides harming the planet through the mining operations with often long-term and dispersed effects, the individual workers and local communities experience the short-term and local harmful effects of mining, as they suffer on a day-to-day basis under unethical and unhealthy working conditions and toxic waste. The mining of mineral raw materials is, therefore, an issue of more than just securing supplies for economic stability. It is a matter of sustainability as the WCED committee intended it to be: providing the needs of today's and future generations. Not only the needs of the developed world but especially the needs of the poor, starting today. Sustainable development in relation to material extraction means not only fulfilling demand, but also guaranteeing safe working conditions, protecting local communities, equally distributing benefits, and preventing waste and emissions.

The overview of developments on the supply and the demand side of the production of mineral raw materials shows how societal, political, technological and environmental developments, as well as processes initiated by the mining of (critical) mineral raw materials, result in an increased demand for critical raw materials. The overview also demonstrates the complexity of the critical raw materials problems, indicating that there are no simple solutions and a system change is needed.

There is an increasing awareness among

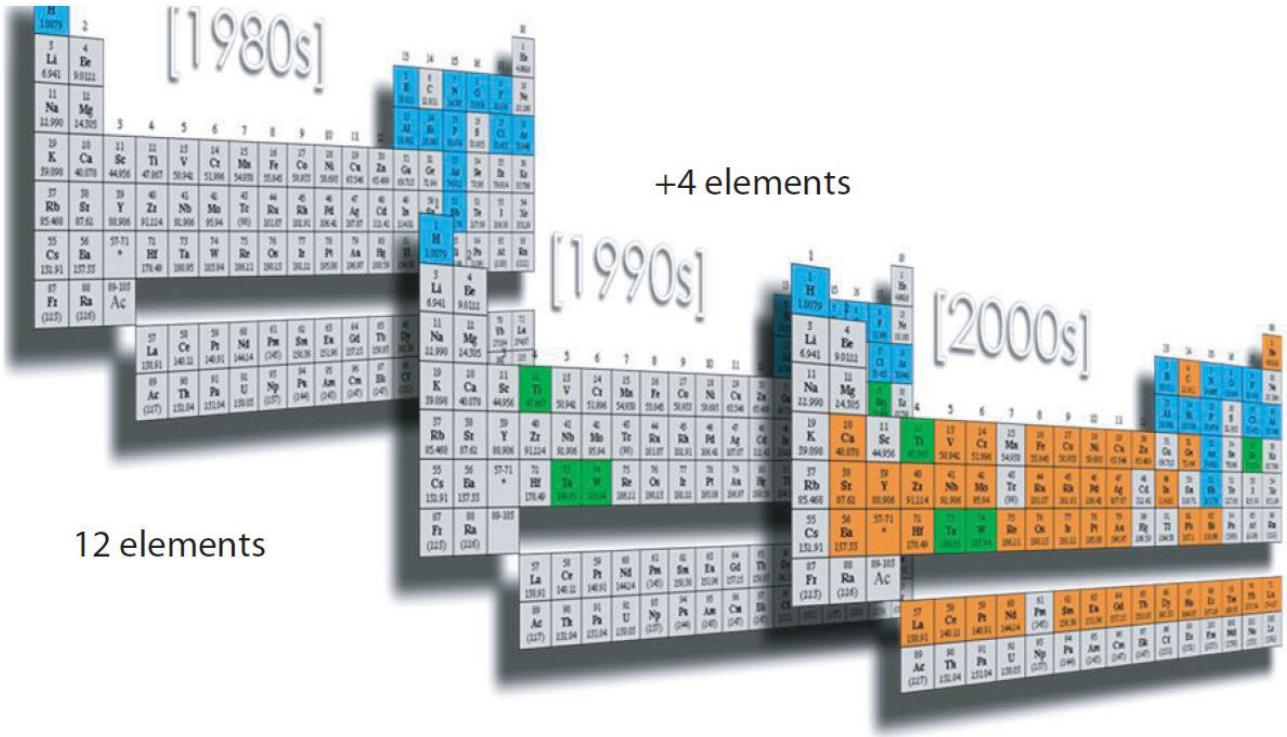



Figure 4 The dynamics of two decades of computer chip technology development and its mineral and element impacts. Reprinted from National Research Council, 2008.

industry players as well as national governments that severe shortages could become a reality in the future. Therefore, the need has been born to identify materials that have a high risk to experience supply shortages, in order to develop adequate strategies to mitigate the dependence on the import of these materials. Non-energy raw materials with a high risk for such a shortage are called critical raw materials (CRMs). Several expert groups have developed standard methodologies for determining CRMs. In 2008, a committee of experts formed under the umbrella of the US National Research Council of the National Academies developed a criticality matrix based on the impact of supply restriction and supply risk and used it to define a list of CRMs for the US economy. In the same year, the EU launched the Raw Materials Initiative, a policy based on three pillars:

1. reducing the consumption of raw material in the EU;
2. increasing the availability of raw materials sourced within the EU;
3. promoting the sustainable supply from countries outside of the EU.

In this context, the EU also created the Ad-hoc Working Group on defining critical raw materials which had the task to develop a methodology for defining CRMs and use

it to establish a list of CRMs for the EU. The first list was published in 2011, consisting of 14 materials qualified as critical. The European Commision has committed to updating the list every three years. Therefore, in 2014, a second list was published, including 20 CRMs. The third list was published in 2017 and includes 27 CRMs. In 2017, the methodology was also refined by emphasising the criticality status of materials as a snapshot in time and therefore deliberately not taking possible future developments into account. However, the foundation of the analysis was still the same as what was used for the previous two lists, and high priority was given to ensuring compatibility with the previous two criticality analyses. The results of these three analyses show a steady increase in the number of materials classified as critical, emphasising the growing urgency of the issue. (Blengini, et al., 2017; Espa, 2015; Deloitte Sustainability, British Geological Survey, Bureau de Recherches Géologiques et Minières & Netherlands Organisation for Applied Scientific Research, 2017)

The criticality of a material is determined by its supply versus its demand, where supply entails both the physical reserves and the amount that is made available to the industry and demand is more often defined as economic importance. Often, these materials are extracted through mining activities and, to a far lesser extent, through recycling. On the demand side, the economic importance of a material is the guiding criterion to assess its criticality. To determine the economic importance, the EU Ad-hoc Working Group calculates the contribution of each mineral raw material to seventeen different manufacturing mega-sectors of the EU economy. The US Committee uses a similar concept of economic importance and matches the economic value of US consumption of a specific mineral with the estimated growth in emerging uses that could require a significant increase in production capacity in the short-term. For both methodologies, the calculation results in higher economic importance of a material when the demand for the material is higher. On the supply side, both the US Committee and the EU Ad-hoc Working Group use the supply risk factor to assess a material's criticality. The US Committee uses four indicators to determine the supply risk factor: geological availability, technological availability, social and environmental availability, and political availability. The EU Ad-hoc Working Group uses the following three indicators to determine the supply risk factor: the concentration of primary production in countries with weak governance, substitutability prospects, and end-of-life recycling rates. Of these three indicators, the first combines the geological and political indicators of the US Committee and has the most weight out of the three in the calculation of the supply risk; the other two indicators serve as filters. (Espa, 2015)

It is essential to know the amount of material that is still available in the earth's crust to determine its geological availability. This amount can be defined in three ways (Figure 5). The resource base is the known amount of material available on the planet; resources are the part of the resource base that can be economically extracted and reserves are the part of the resources that is proven. Figure 5 helps to understand that for most materials, criticality is a matter of economic feasibility rather than geological quantity. Both the mining process as well as the extraction from the ore require much energy. The energy demand of mining increases over time, as the more accessible and concentrated mines are exhausted. Even though this effect is decreased to a certain extent by the development of new and more efficient technologies that reduce the energy requirements. A new dimension to this is added with the extraction of 'new' elements required for advanced technologies such as computer chips or wind turbines. When energy production transitions towards renewable energy technologies, the demand for these elements will increase, therefore increasing the energy demand again. The reserves, together with the demand determine the risk of supply shortages. The demand for a material depends primarily on the global population, the prosperity of the population and new products and emerging technologies. Further aspects of consideration are the possibilities of substituting the material, recycling rates and whether there is a high concentration of the reserves in countries with weak governance. The economic importance of a material is determined by analysing the economic importance of the industrial sectors in which materials

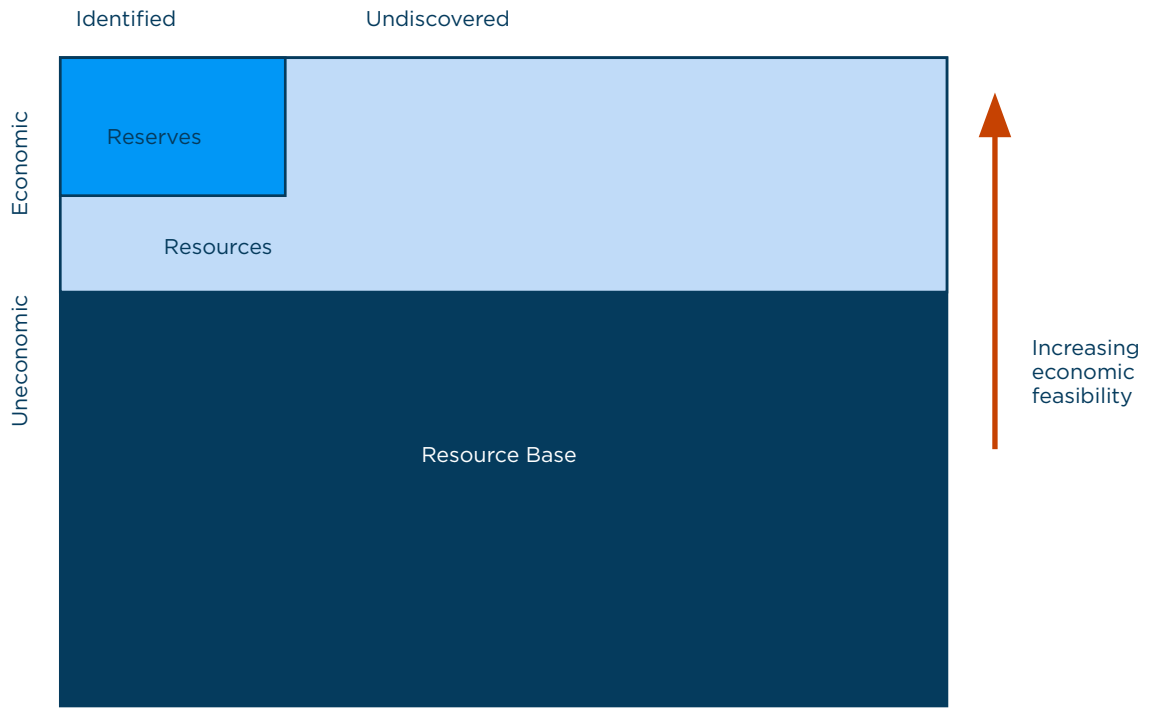



Figure 5 Defining the amount of available material. Reprinted from Wouters & Bol, 2009.

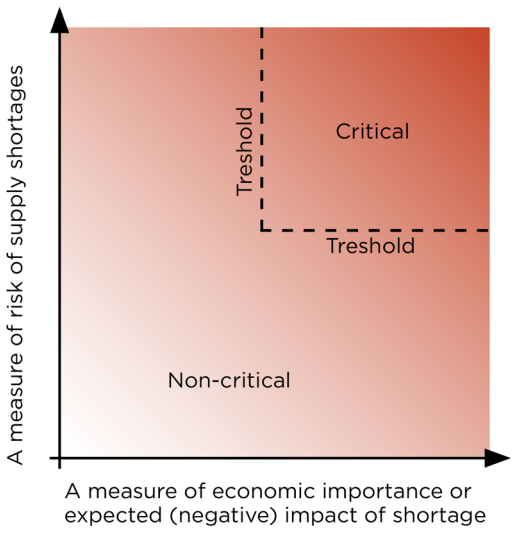



Figure 6 General scheme of criticality concept. Reprinted from European Commission, 2014b.

are used. (Wouters & Bol, 2009; European Commission, 2014)

Figure 6 shows how the two aspects, the risk of supply shortages and economic importance, relate to each other. Materials can be plotted in such a graph, and any material that falls within the predetermined threshold area is characterised as critical. Graedel, Harper, Nassar and Reck (2015) describe a slightly different approach, using a model with three axes: vulnerability to supply restriction, supply risk, and environmental implications. In this model, vulnerability to supply restriction covers the (economic) importance and substitutability of a material, supply risk consists of the depletion time and companion metal fraction (the extent to which a material is produced as a by-product) and environmental implications consists of the effects of a material on aspects such as ecosystems and human health. Although this is the most extensive framework, it is often not used because using the two-axis version is already complicated and environmental data are difficult to obtain.

The list of critical materials is different for every country or region and can also change over time. A particularly vulnerable continent, however, is Europe. A region with a highly developed economy and living standards, but minimal primary production within its member states. Hence, a transition towards a more sustainable materials situation is especially relevant for European countries. (European Commission, 2014)

### 2.2.3 Sustainable materials frameworks

Looking at the issue of critical materials, it appears that a solution that merely ensures the continuation of business-as-usual is not sufficient. A business-as-usual scenario cannot be maintained because reserves will sooner or later be depleted in the current "take – make – use – dispose" system. Additionally, the extraction of raw materials and the related industries put high pressure on the environment, for which a solution needs to be found. Therefore, a different system of how natural resources are used is essential. Several frameworks have been developed that propose a system for sustainable material use. The frameworks that are selected for this study are the circular economy, degrowth, the circular materials economy, critical materials and product design, and the doughnut economy. The different frameworks are first introduced and then discussed to obtain a sustainable materials framework that is used in this study.

#### *Circular economy*

The circular economy concept is currently viewed by many, including the Dutch government, as the most promising alternative to the current system. Although the application of the circular economy is relatively new, the idea of a circular economy is not. Already in 1976, Stahel and Reday described an economy in loops that could prevent waste and improve resource efficiency. Nonetheless, the majority of the scientific writers credits Pearce and Turner (1989) for introducing the concept of a circular economy in 1989. In their publication, they identify the traditional open-ended economy as providing an incentive to use the environment as a sink for waste. The understanding of a circular economy today is influenced by different theories, among which are the functional-service economy by Walter Stahel, cradle-to-cradle of William McDonough and Michael Braungart, the field of industrial ecology of Reid Lifset and Thomas Graedel, biomimicry as described by Janine Benyus and the blue economy by Gunter Pauli. (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Ellen MacArthur Foundation, 2015) The Ellen MacArthur Foundation, which was founded in 2010, is a leading organisation in the field of circular economy and defines the circular economy as *'an industrial economy that is restorative or regenerative by intention and design'* (Ellen MacArthur Foundation, 2013, p. 14). Geissdoerfer, Savaget, Bocken, and Hultink (2017) have combined this definition with several other definitions and define the circular economy as:

> *'a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling'.*
> (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, p. 759)

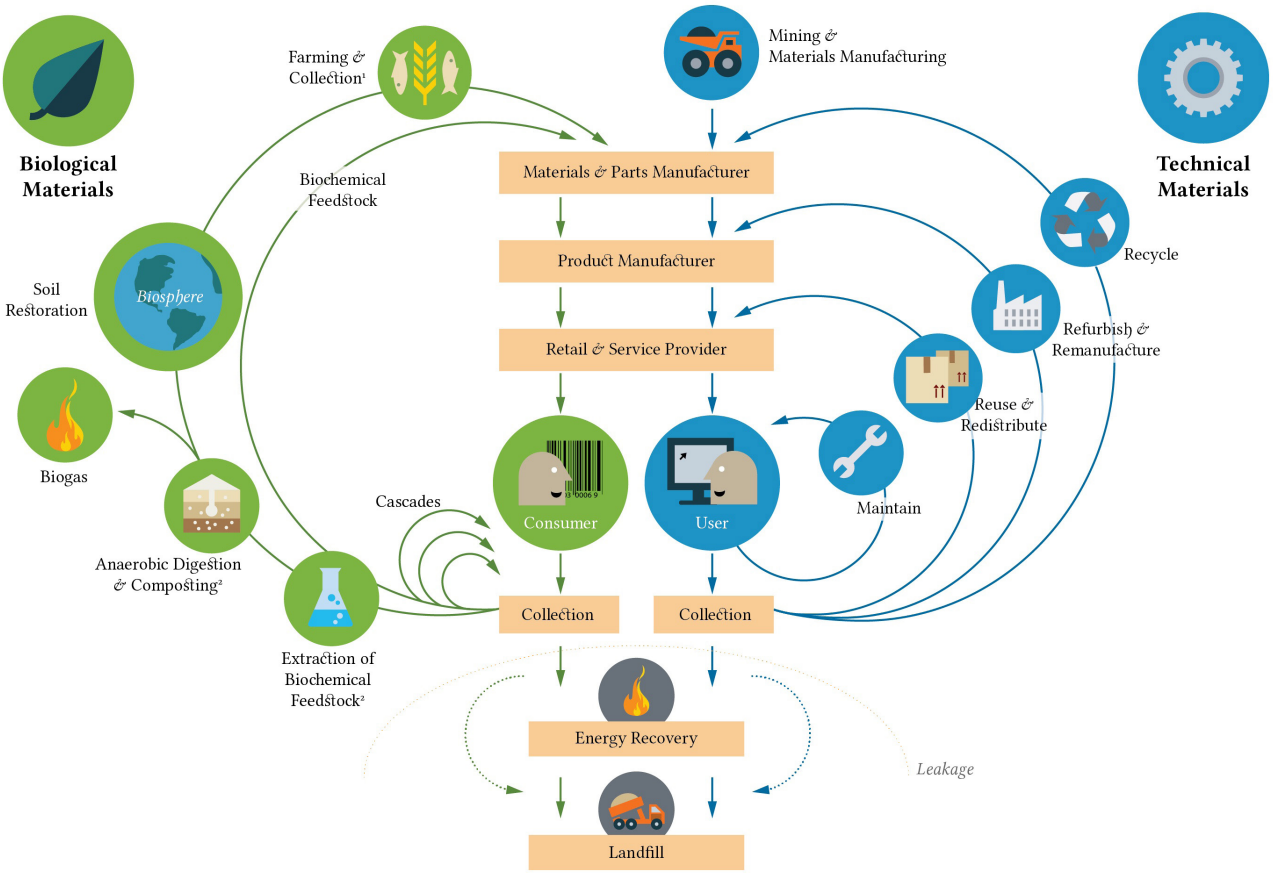



Figure 7 The principles of the circular economy. Reprinted from Van Renssen, 2013.

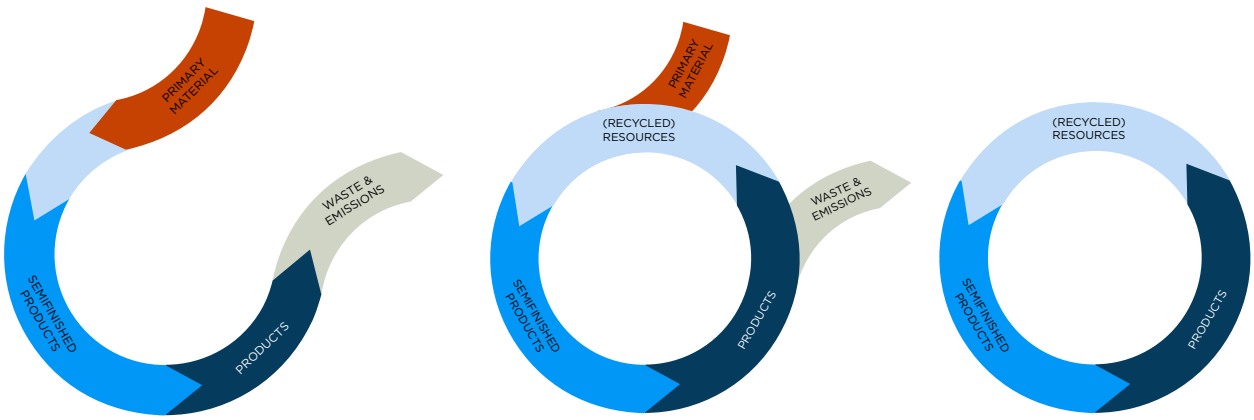



Figure 8 Schematic representation of the circular economy principles.

This definition shows that a truly circular economy is not only about minimising resource input and output in the form of waste but emphasises reducing emissions and energy leakage as well. In a circular economy, all energy comes from renewable energy sources, materials are tracked, and products are designed to allow the reuse of the materials with minimal processing. The focus is on using materials as opposed to consuming them, which should reduce the demand for primary materials. (Ashby, 2016)

The circular economy is based on three main principles:

1. *Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.*
2. *Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles.*
3. *Foster system effectiveness by revealing and designing out negative externalities.*

(Ellen MacArthur Foundation, 2015, p. 5 and 7)

These three key points can be achieved by strictly separating the technical and biological cycle, keeping products, components and materials at their highest value at all times and restoring or regenerating materials at their end of life. (Ellen MacArthur Foundation, 2015) Figure 7 shows the principles of the circular economy, with the separated biological and technical cycles. The aim is to keep the loops as small as possible, so, for example, seek solutions to maintain or reuse a product before looking into recycling. Figure 8 shows how these loops help to move from a linear to a circular economy.

The circular economy principles are sometimes also summarised into three key actions, the 3 R's: Reduce, Reuse and Recycle. The first action, reducing, focuses on the reduction of primary input through efficiency gains. One can think of energy reduction through monitoring use (e.g. using sensors to see which rooms of a house are used and should be heated) and managing energy supply with smart systems to increase efficiency. Reduction of materials demand can be achieved by, for example, designing lightweight products or reduce packaging. Another important aspect of the circular economy is replacing harmful or critical substances with healthier or more abundant ones. For every product that is produced, the second and third R apply. Once a product reaches the end of its lifetime, which can be for many different reasons, the product or parts of the product that can still be used for the same purpose should be reused in that way. If necessary, it can be refurbished to meet the demands to be able to enter the market again. When reusing appears not to be possible anymore, the materials of the product should be recycled, preferably with the waste materials being reprocessed into products or materials of similar quality as the original product. (Ghisellini, Cialani, & Ulgiati, 2016)

### *Degrowth*

Resource extraction is closely linked to economic growth. UNEP (2011) shows that economic growth has a direct relationship with resource extraction. When the economy tripled, this was based on a tripling in resource extraction over the same period. At the same time, there is a rising notion that the world we live in, facing continuous environmental and economic crises, does not meet the idea of sustainable development as described by the Brundtland commission twenty years ago. (WCED, 1987) The system is still based on unrestrained consumerism, excessive materials use and a fossil fuel addiction, which can be called a *'promethean economic growth paradigm'* (Martínez-Alier, Pascual, Vivien, & Zaccai, 2010, p. 1741). (Martínez-Alier, Pascual, Vivien, & Zaccai, 2010)

An alternative paradigm that is being developed in the fields of social ecology, human ecology and ecological economics is that of degrowth. A normative concept that proposes a prosperous way down to a smaller economy with less production and consumption. This process is called sustainable degrowth, as opposed to an unsustainable economic crisis. The term is a literal translation of the French word décroissance, first brought up in this context by Nicholas Georgescu-Roegen. The concept is based on the idea that a world of finite resources cannot sustain an economy based on infinite growth. The required reduction in demand, or degrowth, is sometimes associated with decoupling, a

term coined by economists that describes the decoupling of economic growth from growth in material demand and environmental impact. Where other scholars propose improved efficiency through technological solutions that should lead to a decoupling of economic growth and resource use, the degrowth movement believes this will not be sufficient. Decoupling does not address a vital characteristic of the current economic system: that stability is not possible without growth. Therefore, merely improving efficiency cannot provide a sustainable solution. The extent of decoupling required to stay within the limits of the planet is staggering, and no substantial decoupling has yet been achieved (relative decoupling has been achieved to a certain extent, but no absolute decoupling). Even worse, relative decoupling sometimes has the perverse potential to decrease the chances of absolute decoupling because of the rebound effect. Decoupling is, therefore, no adequate solution and not comparable to the degrowth paradigm. Sustainable degrowth involves diverting from the belief that infinite growth should be pursued. This paradigm therefore also involves the recreation of the economic system, since the current system depends on growth for its stability. As soon as there is even a notion of growth stagnating or even decreasing, a recession is near. Degrowth consists of reducing production and consumption to reach environmental sustainability. Also, it is expected that societal well-being will not suffer from degrowth but will instead thrive. The potential of this development is based on the Easterlin paradox which shows that beyond a certain level of satisfaction of basic needs, happiness does not increase as material wealth increases. Sustainable degrowth describes the pursuit of well-being, ecological sustainability and social equity while reducing GDP through a considerable reduction in consumption and therefore production. At the same time, opponents argue that suggesting the reduction of consumption is nothing new and that achieving a decrease of GDP is impossible without implementing draconian state interventions such as rationing. (Schneider, Kallis, & Martínez-Alier, 2010; Jackson, 2009; Joutsenvirta, 2016; Kallis, 2011; van den Bergh, 2011)

Sustainable degrowth is defined by Schneider, Kallis and Martínez-Alier (2010) as

> *'an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level, in short, and long-term'.*
> (Schneider, Kallis, & Martínez-Alier, 2010, p. 512)

This definition sees sustainable degrowth as a deliberate reduction in both consumption and production that enables ecological and human well-being. What misses is how this reduction will result in the desired increase in wellbeing and how this will affect the short-term and is extended to the long-term.

Kallis (2011) defines sustainable degrowth as

> *'a socially sustainable and equitable reduction (and eventually stabilisation) of society's throughput'.*
> (Kallis, 2011, p. 874)

In his definition, Kallis has added that the reduction should be socially sustainable, in addition to the demand that it should be equitable which was proposed by Schneider, Kallis and Martínez-Alier. Also, what should be reduced here is defined as society's throughput, which refers to resource use and waste, instead of production and consumption. Cutting production and consumption would be a way to reach this reduction in society's throughput, though this is not explicitly mentioned in Kallis' definition. A second difference is that this definition does not comment on the intended result of the reduction, such as the increased societal wellbeing as discussed by Schneider, Kallis and Martínez-Alier.

Joutsenvirta (2016) defined degrowth as

> *'a democratic and redistributive downscaling of production and consumption to assure that society's throughput – resource use and waste – stays within safe ecosystem boundaries'.*
> (Joutsenvirta, 2016, p. 23)

In this definition, 'socially sustainable and equitable

reduction' is replaced by 'democratic and redistributive downscaling of production and consumption'. Democratic probably refers to socially sustainable. However, that is assuming that democratic processes are socially sustainable. Aristotle already identified democracy as a corrupt form of government, as opposed to a polity. (Stanford Encyclopedia of Philosophy, 2011)

Therefore, for this research, the term socially sustainable will be used. Redistributive then would refer to the equitable reduction from Kallis' definition. Here, equitable would describe a way of reducing consumption that has an equal impact on all people/businesses (e.g. everyone reduces 50%), which sounds reasonable. However, a redistributive reduction goes further since its aim is an equal distribution of wealth which makes it the preferred term for this research. Joutsenvirta combined the two other definitions to come to the concept of reducing production and consumption to reach a safe use of resources and production of waste. Then, when resource use and waste production stay within safe ecosystem boundaries, ecological conditions are improved as a consequence. The benefits for human well-being are not included in this definition, which makes the definition stronger since it is not sure whether this will be the case.

The definition of sustainable degrowth used for this research is, therefore, a slight adaptation of the definition by Joutsenvirta and is formulated as a socially sustainable and redistributive downscaling of production and consumption to assure that society's throughput – resource use and waste – stays within safe ecosystem boundaries.

### *A circular materials economy*

In his book *Materials and Sustainable Development*, Ashby (2016) describes his vision for a circular materials economy, based on the idea that at the end-of-life of products, the materials that they are made of are still there and can be reused instead of dumped on a landfill. Ashby's vision addresses the linear materials economy by designing products differently from the start, rather than focusing on more efficient recycling of products that were not designed to be effectively recycled in the first place. His framework goes back to natural cycles of transforming materials and energy, such as the carbon cycle and the nitrogen cycle, to provide a starting point for the redesign of the industrial cycle. However, Ashby notes a fundamental difference between the natural and the industrial cycle: the natural system seeks a state of balance to achieve well-being, while the industrial system seeks growth. The result of having growth as a measure of well-being is a need for ever-increasing consumption of materials and energy, resulting in an ever-increasing amount of waste. The circular materials economy focuses on conserving materials from the existing stock and minimising leakage to waste, to reduce the need for primary materials. The diagram in Figure 9 represents the tools required to achieve such a circular materials economy. As the image shows, material scientists and engineers have the most significant role since they have to focus on improving materials and recycling technologies. They should also design products that use fewer materials, have a longer life and can be easily disassembled for the materials to be reused. Additionally, there is a role for companies to change their businesses to service-based business models and for society to adapt to both a circular economy and doing with less. The legislative aspect is included in the societal part of the diagram. Though Ashby has noticed the difference in goals between the natural system (balance) and industrial system (growth), this is not addressed in the framework since it does not address the functioning of the economic system. Ashby argues that even the natural system goes through significant disruptions from time to time and that there are always at least some species that survive because of the diversity of the system. However, these disruptions are catastrophes that were not the goal of the system but are often caused by external influences such as volcanic eruptions or meteorite impacts. A (small) part of the previous natural system can survive thanks to its resilience. It is, therefore, not desirable to create a non-resilient industrial system or aim for imbalance through seeking infinite growth.

### *Critical materials and product design*

Since Ashby's framework is the only critical materials model that includes the aspect of product design, it was

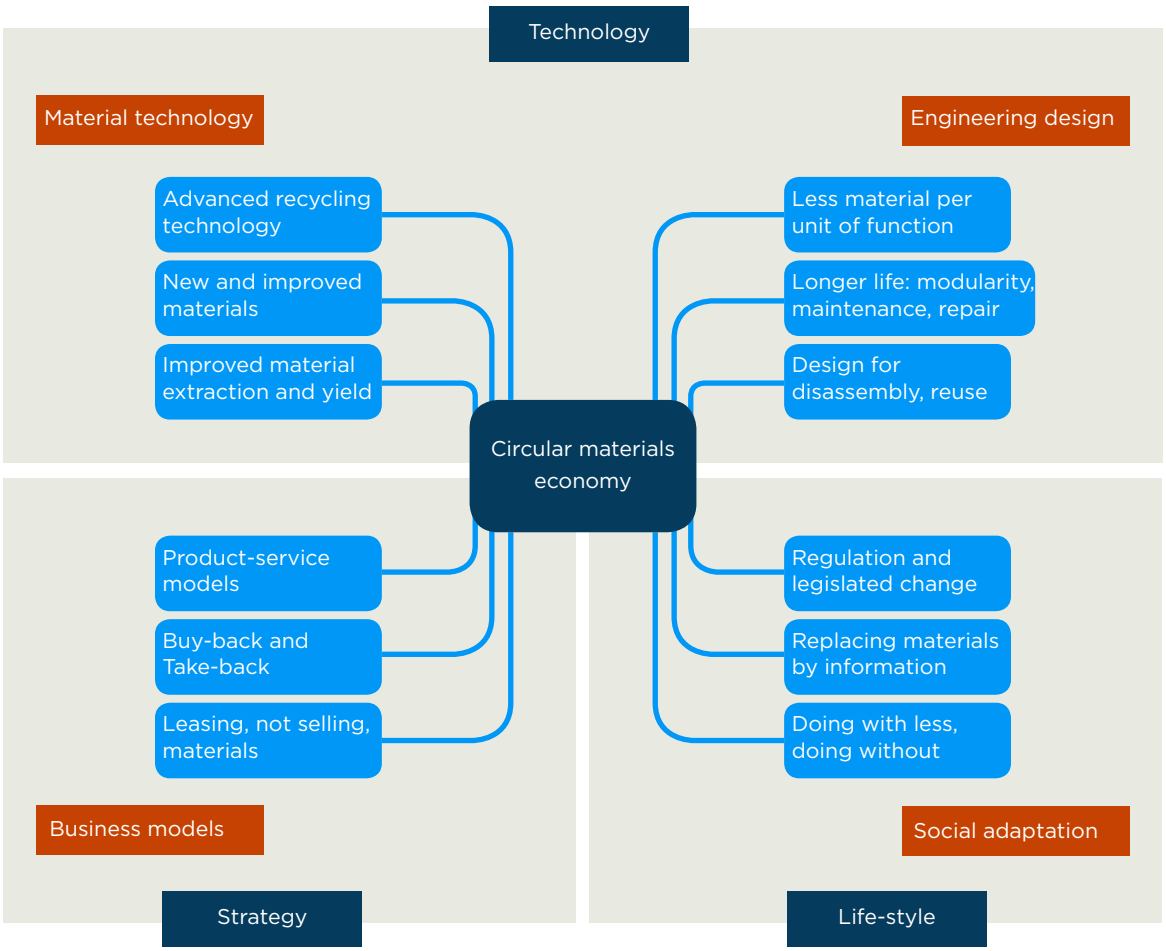



Figure 9 Ashby's Circular materials economy framework. Reprinted from Ashby, 2016.

used by Peck (2016) for the study of five historical cases of product design to address materials scarcity in war-time Britain. Peck compared the results obtained from these cases to Ashby's model and found several differences as well as parallels, mainly related to different historical periods to which the cases and Ashby's framework apply.

The most significant differences are in government control, the materials used, the complexity of the supply chain, the sizes of the economies and the size of the change, the attention to environmental problems, the willingness and the ability of the government and market to invest in changes, and the time frame of the problems. Today, attempts by the government to develop legislation for product design, are often met with stiff resistance from companies. Additionally, governments themselves are reluctant to do so, because the current predominant belief is that the free market will regulate itself and should not be interrupted by governmental regulation. Furthermore, in the 21st century, nearly all of the elements in the Periodic Table are used in products, in an endless number of compositions. While during the 1940's this was less than twelve. Today, supply chains are often complex and opaque. However, in the past century, supply chains were also often global and involved many intermediaries. The market system today is dominated by the belief in the free market and is increasingly complex, global and growing; making it hard for governments to intervene. Today, there is more awareness of the impact of material extraction, processing, use and disposal on the environment, and legislation is developed to protect the earth's ecosystems. In the past century, the environment was not considered an issue, and the focus was on merely acquiring the desired materials. In the current situation, banks are often not willing and governments not able to provide the financial investment required for a circular economy. The materials problem in wartime Britain was of a temporary nature, and global material stocks were seen as unlimited, the only access was temporarily limited because of the war. Today, critical materials problems are not expected to disappear after a few years but are only expected to increase for decades to come. Therefore, any new system will not be something we have to endure for a couple of years but has to become the new normal. (Peck, 2016)

The main parallels include the activities undertaken to mitigate material constraint, the development of new business models, the development of governmental policy on scarce or critical materials, and national planning for shortages. Both in wartime Britain and today, the field of product design is aiming for longer life, modularity, maintenance, repair, disassembly, reuse, remanufacturing and recycling. Additionally, in both times, critical materials are replaced for less critical ones where possible. Today, companies are seeking new business models that reduce material use. They produce, for example, higher quality products with a longer life and generate revenue by providing it as a service, or from additional services. Companies in Britain during the war were following the same strategy. Both now and in the historical cases, the government developed policies that fund research and education and requires changes in product design. Both now and in the 1940's the government is actively involved in identifying which materials are critical and stockpiles these for situations of emergency. (Peck, 2016)

Peck has used Brezet and van Hemel's eco-design checklist, the results of the historical case studies and gaps from current company practices to design a new framework, based on Ashby's circular materials framework. (Figure 10) In this new framework, a fourth section is added, named 'Policy & Regulation', since the government turned out to have a very prominent role in the case studies. Therefore, the 'Material technology' and 'Engineering design' sections were merged into one category: 'Materials, engineering and design'. Furthermore, 'Strategy/Business models', was renamed 'Business', and 'product and service activity through open, fair and managed product life cycles' was added, to allow the primary goal of businesses, to adopt service-based business models, to succeed. Lastly, the section 'Lifestyle/ Social adaptation' was named 'society' and now focuses on the shift from owning to access, awareness of the value of materials and societal wellbeing instead of consumption. However, one aspect seems to be missing from the new framework, which is the environmental component, which is only represented by the label 'Using renewable

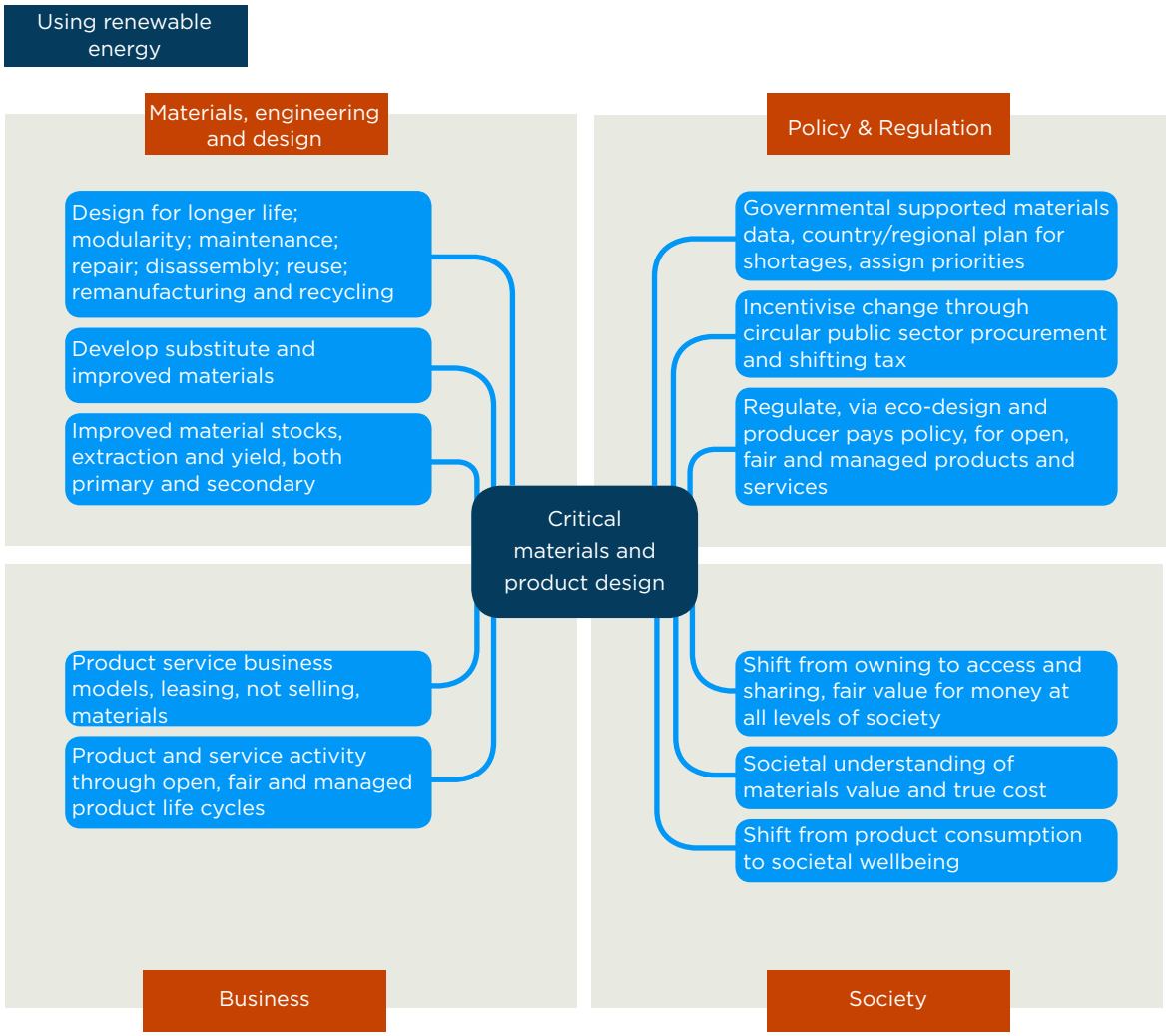



Figure 10 Critical materials and product design framework. Reprinted from Peck, 2016.

energy'. Environmental issues are, however, at the core of the critical materials issue, since material extraction is, on the one hand, degrading the earth's ecosystems and on the other hand the effects of high carbon dioxide emissions from burning fossil fuels are threatening the industrial system and therefore require an energy transition with vast implications for material use.

### *The doughnut economy*

In her book *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*, Raworth (2018) describes a framework to redesign the economic system, with the society and the environment as a starting point (Figure 11). Raworth's framework is based on the idea that humanity should stay above a social baseline, which consists of twelve human rights, but below the ecological ceiling, which consists of nine planetary boundaries. Staying within the doughnut will provide wellbeing to every human, while at the same time staying within the boundaries of the earth's ecosystems. To achieve this, Raworth envisions a regenerative and distributive economy based on seven principles:

1. *A new goal*
   The current goal of every nation is GDP growth, which is, however, far from suitable to achieve well-being for every person and leads to overproduction and overconsumption. Therefore, a new goal is needed, a goal that resembles the inside of the doughnut. For example human prosperity in a flourishing web of life.

2. *Embedded economy*
   The economy is generally thought of as self-contained and self-sustaining, but the opposite is the case. The economy involves the household, market, commons and the state, embedded within and dependent upon society, which is in turn embedded in the living world. Wealth does not only consist of the flow of income, but of natural, social, human, physical and financial capital, on which our well-being depends.

3. *Social, adaptable humans*
   People are not 'rational economic man' as they are often thought to be by economists, but also by governments, companies and each other. However, people are instead represented as part of a community; sowers and reapers embedded in the web of life and acrobats with skills of trusting, reciprocating and cooperating with each other to achieve things that we cannot do on our own. Additionally, we are not only consumers but also, amongst others, employees, citizens, neighbours, parents, friends, entrepreneurs, and voters.

4. *Dynamic and complex systems*
   Economists have been looking for economic laws to turn economics in science just like physics. However, the economy does not function like a machine that obeys simple rules. The economy is instead a complex and dynamic system that changes because of its behaviour. Therefore, it cannot be 'fixed' with simple tools. It should instead be cared for, like a garden, and steered in the right direction.

5. *Distributive by design*
   It is often believed that a developing economy should first go through a phase of increasing inequality before it automatically redistributes the wealth more equally when a certain level of development is reached. However, in reality, this does not happen, and inequality keeps growing. Equitable economies need to be designed to be distributive from the start. In designing such an economy, equal attention needs to be paid to redistributing income as well as wealth (e.g. assets such as land, enterprise, technology or knowledge).

6. *Regenerative by design*
   Similar to the idea that economies become more egalitarian after a certain point of peak-inequality, it is believed that environmental harm is inherently a part of a developing economy and will first reach a peak after which it will automatically decrease when a certain level of wealth is achieved. However, often on

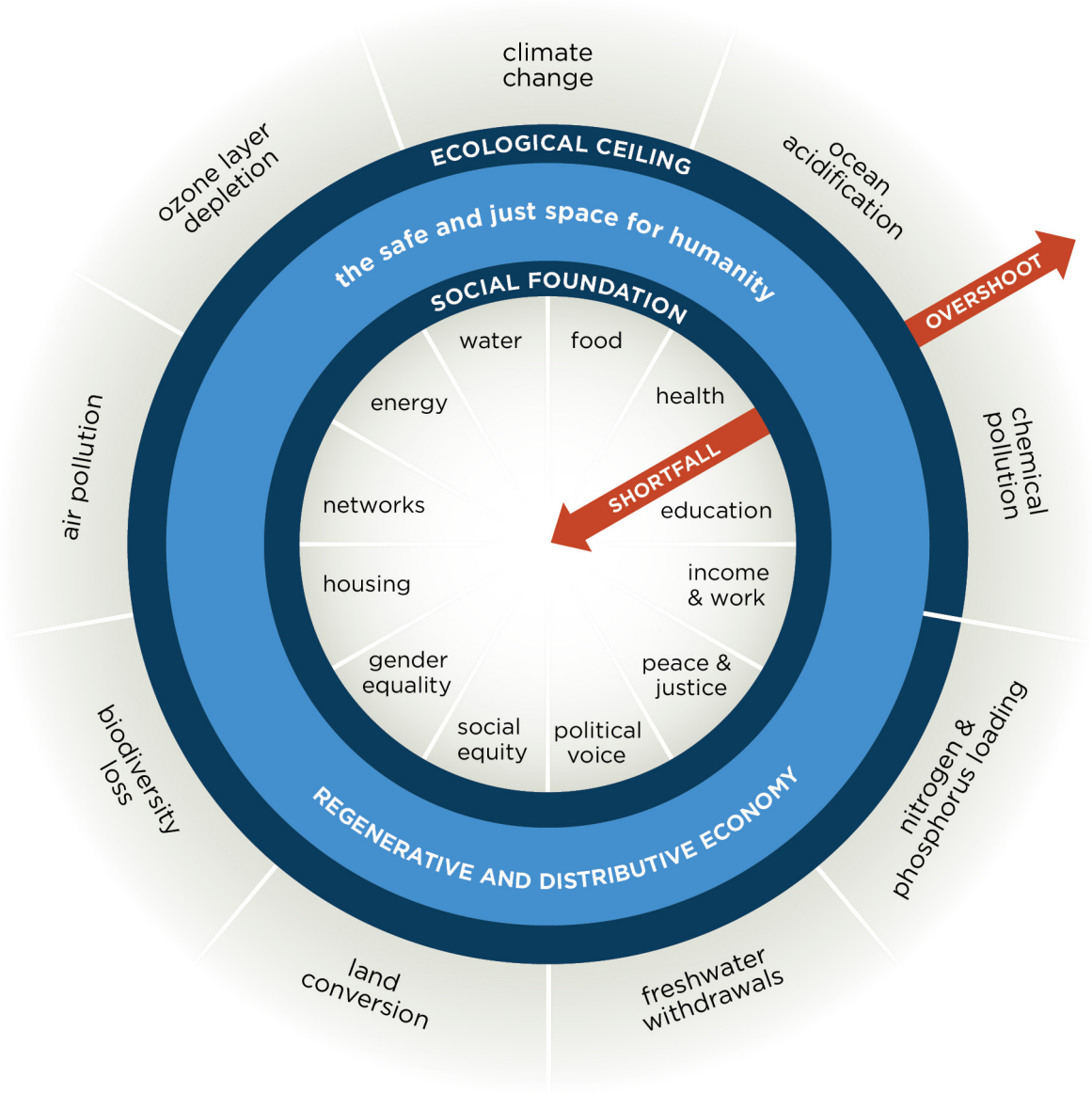



Figure 11 Doughnut economy framework. Reprinted from Raworth, 2018.

a local level, the environment indeed improves when wealth increases, but this improvement often occurs because of the outsourcing of the production to other countries. Therefore, the global environmental burden keeps growing. To counter this effect, we need to design the economy as regenerative from the start, a redesign that does not only involve engineers but also economists and policymakers.

7. *Growth agnostic*
   It appears that growth is required to end human deprivation, but at the same time, growth will make it impossible to end ecological degradation. So, how to end up in the doughnut's safe space? Raworth makes a case for designing an economy that promotes human prosperity whether GDP is going up, down or holding steady. Some growth is needed, just like a human, or a small business, growth is needed to reach a state where it can sustain itself, but growth beyond that point is unnecessary and will eventually become harmful.

(Raworth, 2018)

With this framework, Raworth provides the economic, societal and environmental context of what a circular economy should provide and how economic thinking should change for the circular economy to provide an alternative. However, what is missing from the model are critical materials, the material demand for renewable energy technologies, current consumption and lifestyle patterns and the material demand of developing countries.

### 2.2.4 The circular economy and critical raw materials

The most well-known and applied practical solution of the frameworks described in the previous paragraph is the circular economy. (Skene, 2017) It promises to be a solution to today's sustainability issues by concentrating on reducing waste (and emissions) by reducing, reusing, and recycling materials from the production and consumption cycle. Besides reducing waste and emissions, and, therefore, pollution, reusing materials also leads to a reduction in the demand for primary material. The EU, and also the Netherlands, have adopted the circular economy as the way forward towards sustainable development, while at the same time reducing the dependence on other countries for the import (critical) raw materials. Both Ashby and Peck's frameworks are based on the circular economy, with an application aimed at sustainable materials use. The circular economy, in these frameworks, is viewed as the solution to critical materials problems. However, some tensions between the two concepts could point in a different direction.

First, the circular economy is entirely powered by renewable energy sources. The renewable energy sources that are currently most prevalent are solar and wind power, and on a smaller scale, wave and tidal energy, hydropower and geothermal power. In addition to the power sources themselves, specific infrastructure is indispensable. The fluctuating nature of renewable energy sources demands infrastructure such as smart grids and batteries, as well as new distribution cables to transport energy from (offshore or remote) solar or wind parks to the habited world. All of the sustainable energy technologies are product-based as opposed to fossil fuels which are resource-based. Therefore, powering the global economy using sustainable energy technologies requires a vast amount of industrial raw materials. According to research conducted by Ecofys (2014), solar energy requires the critical raw materials copper, gallium, germanium, indium, selenium, tellurium, and tin, and wind power requires cobalt, copper, manganese, molybdenum, nickel and rare earth elements (REEs). Ecofys concludes that mainly the demand for lithium and cobalt will markedly exceed the existing reserves and resources. The supply of REEs such as neodymium and yttrium, which are used in wind turbines, is less critical since it is expected to exceed the demand. However, supply problems could still arise due to geopolitical tensions since the majority of the production is concentrated in China. Overall, transitioning towards a circular economy increases the global demand for industrial raw materials substantially and, therefore, does not contribute to reducing critical materials problems.

Even without taking the material demand for sustainable energy technologies into account, it will be a challenge to meet the global energy demand with solely sustainable energy. Therefore, energy efficiency is a significant part of matching supply and demand. In a circular economy, this is done by using both energy efficient applications, as well as smart systems that optimise energy use. Additionally, energy efficient lighting, smart electronics, batteries and electricity distribution networks are all essential for an entirely sustainable energy future, and all of these use several critical materials as well.

Another energy-related tension comes from the production of (critical) raw materials. As more material is extracted, ores degrade, and the mining of the same amount of a particular mineral or metal becomes increasingly energy intensive. The energy will be produced sustainably, and therefore additional critical raw materials are needed.

The solution to the high critical material requirement of a circular economy is often increasing recycling efficiency to close the loop and reduce the demand for primary material. In a circular economy, this should be possible since all products or buildings are designed for disassembly, and the individual materials are easily separated. However, CRMs are usually alloyed and therefore hard to separate. Nevertheless, the recycling of magnets and batteries is possible. Research by Binnemans, et al. (2013) indicates that recycling rates of up to 33 per cent for the global recycling of magnets and up to 35 per cent for the global recycling of nickel-metal-hydride batteries could be reached. At the same time, these numbers show that recycling efficiencies close to a hundred per cent are far from reality. Additionally, even if a recycling rate of a hundred per cent were reached, this would not account for annual demand growth and the losses and dilution of materials during the production and use phases. Also, recycling has a high energy demand, which progressively increases for higher recycling rates, which contributes to the demand for (renewable) energy and, therefore, critical raw materials. (Diederen, 2009)

The circular economy concept suggests that the demand for primary material will decline because of longer product life, secondary use of products, and recycling. However, these measures shift the problem to a later point in time. Additionally, the global consumption of materials is still growing fast, and it is not expected to slow down shortly due to emerging economies and technological developments. The concept of a circular economy is built on the premise that societies will reach a level of saturation where demand levels off, and that this point is near for the developed societies. Research indicates that saturation points have already been reached in several countries for iron and it is expected that the same will happen for other metals. (Graedel, Harper, Nassar, & Reck, 2015; Müller, Wang, & Duval, 2011) However, iron is a material that has been used since the Iron Age, while new materials are introduced on a daily basis, which is still far away from reaching their point of saturation. Also, saturation only occurs in developed countries, and the majority of the countries worldwide are far from reaching the level of development that the developed countries have. Even if material demand for the majority of the materials used in society levels off, recycling rates have to be (close to) 100 per cent or too much material will be lost. To achieve optimal recycling, producers have to significantly reduce the number of materials in products, or at least track them accurately. Also, every system, building or product needs to be designed for disassembly onto a material level, which is still a tremendous challenge. Lastly, economic growth is directly related to material extraction increase. Since this increase will become zero, the economic systems need to be remodelled to decouple economic growth from material use.

A solution within the domain of circular economy is to digitise and focus on service-based instead of technology-based products. Going from service-based to technology-based is, however, merely shifting the problem since services are still based on materials. Online services require computers and large data centres (which devour energy). Using products as a service merely shifts ownership, though it does reduce the number of products needed to some extent.

The circular economy asks for the decoupling of material extraction and economic growth through

increased efficiency. However, this idea does not recognise that materials are at the basis of our society. Scientific literature indicates that relative decoupling is not sufficient and that not a single country has demonstrated achieving absolute decoupling of economic growth. (Akenji, Bengtsson, Bleischwitz, Tukker, & Schandl, 2016) The study *Decoupling natural resource use and environmental impacts from economic growth* by UNEP (2011) shows that global material use has only increased over the past decades and is closely linked to economic development. Moreover, Jevon's paradox states that increasing material use efficiency leads to an increase in the consumption rate of that material. (Diederen, 2009)

Additionally, the concept of a circular economy aims for independent and entirely self-sufficient systems, preferably starting at the smallest level (e.g. individual houses) and then moving upwards to the national and global levels. Being self-sufficient also decreases dependence and therefore reduces the risk of supply shortages that could arise due to geopolitical tensions or natural disasters. However, a typical characteristic of CRMs is that they are only found in specific locations, and their production is often located in one or two countries. If a country without primary production of these materials wants to become self-sufficient, it would need to rely on recycling. Even if demand would stabilise, a recycling rate close to a hundred per cent is needed to eliminate the need for primary material, while research shows that the most optimistic recycling rates today lie around 30-35 per cent. (Binnemans, et al., 2013) Therefore, adopting the circular economy concept as a country is not likely to increase the independence of imports of CRMs. At the same time, CRMs increase geopolitical tensions because of the economic importance of the materials.

Other discrepancies between the circular economy and critical raw materials are the focus of circular economy on the elimination of all toxins, while the extraction and processing of CRMs are particularly harmful to the environment. Additionally, in a circular economy, intensive value chain collaboration is essential to track and trace the materials and improve production and design processes to complement each other and avoid waste streams. An industry transformation will have to take place to reach such a situation since the CRMs supply chain is relatively opaque.

Lastly, managing CRMs needs government involvement. At the same time, the circular economy transition is expected to come from businesses, even though governments have developed ambitions to become circular, the actual change is dependent on the willingness of businesses to adopt the transition. The incentive for businesses would primarily be the promise of profits from, for example, the service-based business model. At the same time, CRMs have a profit challenge, since it is hard to incorporate them in a service-based business model.

Overall, it is not evident that incorporating the circular economy concept will provide the desired solution to critical materials problems. There are still challenges regarding recycling rates, the stabilisation of demand, toxicity, the transparency of the supply chain, the decoupling of material extraction and economic growth, the role of the government, and incorporating critical raw materials into service-based business models. Even though materials are not the only concern addressed by the circular economy, they are at the core of the concept because they need to be extracted, used and reused in loops to solve environmental as well as criticality issues. The primary goal of the circular economy is to reduce input (mining & materials manufacturing) and output (energy recovery and landfill) as much as possible (preferably to zero to reach an entirely circular system) by reusing the materials in the system as effectively as possible. The circular economy can only function in a truly circular manner when demand is levelled off.

### 2.2.5 Developing a sustainable materials framework

The concept or principles of the circular economy seem to appear in some form in all of the frameworks. Mainly the degrowth framework criticises the circular economy, posing that it does not propose an alternative economic system but rather an alternative industrial system and that degrowth describes a more valuable approach to sustainable economic change. Allwood,

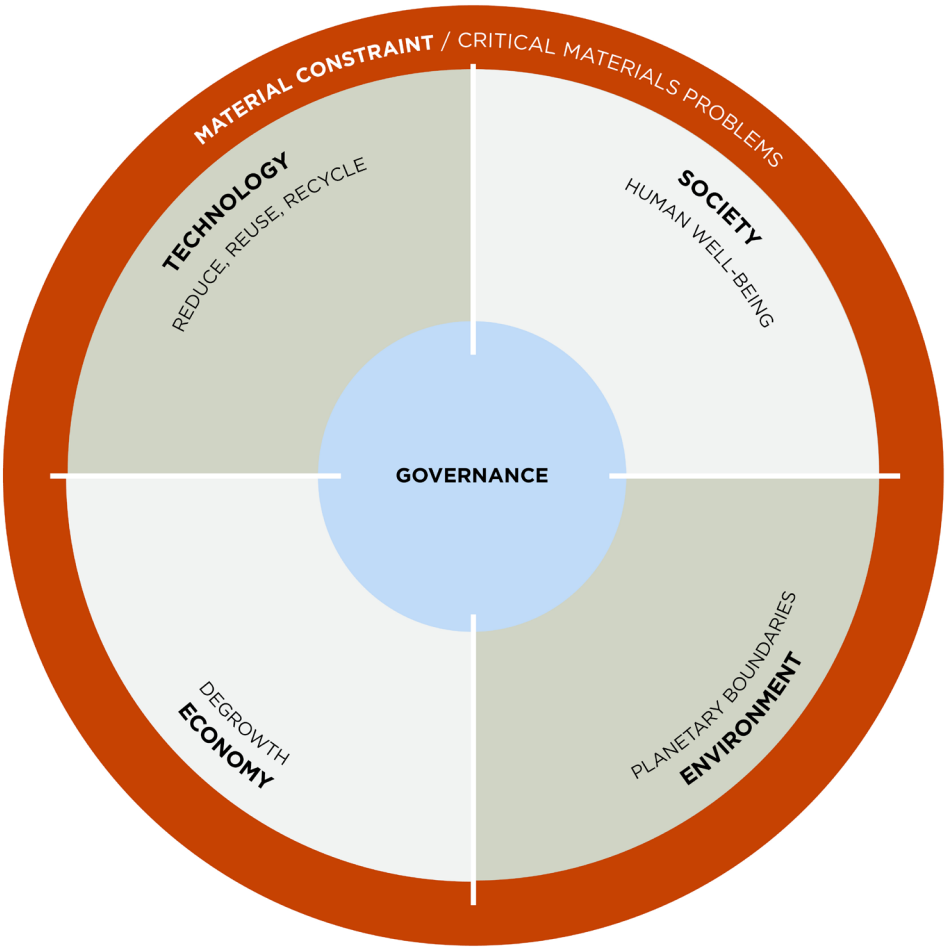



Figure 12 A sustainable materials framework.

Gutowski, Serrenho, Skelton, and Worrell (2017) agree with the degrowth framework that the current system is not going to provide an adequate answer to the current climate change problems and a solution has to be found in demand reduction. Allwood stresses that demand reduction is not achieved by the pursuit of more efficiency or decoupling, which has only limited potential. The circular materials economy and critical materials and product design frameworks provide variations on the circular economy framework with a focus on material use. The critical materials and product design framework adds emphasis on the governance aspect of the functioning of the new system but has limited attention for social and environmental aspects. These last aspects are covered by the doughnut economy, which provides a social baseline and planetary boundaries.

The frameworks have been combined into one sustainable materials framework (Figure 12). It balances the technological, societal, environmental, and economic facets of the system, and goals are defined for each section.

Since governance is at the heart of this research, it

is placed in the middle of the framework. The government is also a part of society, however, with the unique ability to develop legislation and steer its direction. Governance influences the four quadrants: economy, technology, society, and environment.

Each of the four quadrants has an individual goal that has been derived from the literature. The society is there to provide human well-being. It should ensure that human rights are met for every person. In order to do so, it is essential to stimulate human well-being by providing community instead of increasing consumption. The environment should be protected by staying within the planetary boundaries. The economy should allow businesses to thrive and allow the exchange of goods to support people's lives but needs to let go of the goal of infinite growth. The goal for the economy is to achieve a period of degrowth to move to a sustainable steady-state or 'a-growth' situation. Since material use is directly related to economic development, degrowth will lead to a reduction in material use. Finally, technological development should support the goals of the other three quadrants, by, for example, improving recycling technologies or developing more efficient sustainable energy sources. In general, technological development should be guided by the principles of reducing, reusing, and recycling to prevent unnecessary material use or waste.

For this research, the world of influence of policymakers is viewed through the lens of the issue of material constraint and more specific: critical raw materials problems, which explains the ring around the framework. Furthermore, the opposing quadrants in the framework are often in tension with each other: human well-being as opposed to ever-growing profits and wealth accumulation and the environment as opposed to the degradation of the earth's ecosystems due to the extraction, processing and discarding of materials, used in all kinds of technologies. However, this does not mean that there are no tensions between the adjacent quadrants or that there are no congruencies between any of the quadrants. Another division can be made between the right-hand side and the left-hand side. On the right are the two systems, the social and ecological system, that need to be protected, and on the left are the two systems that support them.

This research explores possibilities available to governments to move towards a situation where there are no critical materials problems. The literature discussed in this section signals that only a systems change including all four quadrants will result in a sustainable solution. Focusing exclusively on one or two of the quadrants, such as technology (improving recycling rates) or economy (circular economy) will at best only provide a temporary patch-up. The following section explores the content of the core of this framework: governance towards sustainable materials use.

## 2.3 Governance for sustainability transformations

### 2.3.1 Defining sustainability transformations

Authors such as Peck (2016), Jackson (2009), Kallis (2017), Folke, et al. (2010), Meadowcroft (2009), Skene (2017), and the WCED (1987) have suggested that a societal transition is essential to adequately address critical materials problems, aiming for a transition of an entire society with all of its components towards a more sustainable situation, including a sustainable supply of materials. The overarching term used for these kinds of transitions is that of *sustainability transformations*. The field of sustainability transformations has been developed over the past years and currently includes a variety of approaches, the ones discussed for this study are socio-technical transitions, transition management, social-ecological transformations, transformative pathways to sustainability and transformative adaptation. (Patterson, et al., 2017) The different approaches use a variety of terms for the transformation as well as the system. This study uses the terms sustainability transformation and social-ecological system. The following paragraphs describe the different approaches and the definition they provide for transitions or transformations. These definitions are then compared to derive a definition that is used in this study.

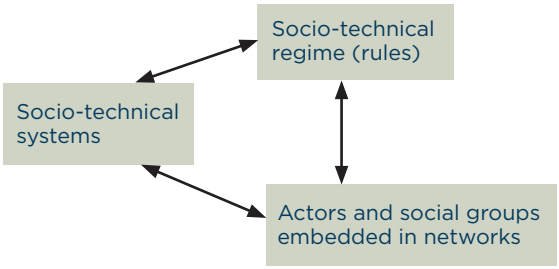



Figure 13 The interrelated dimensions of the multi-level perspective. Reprinted from Geels & Kemp, 2007.

The following paragraphs also include a description of the frameworks used in each approach and discuss their use for this study.

### *Socio-technical transitions*

Geels and Schot (2007) describe a typology for socio-technical transition pathways based on the multi-level perspective (MLP). Here, transitions are defined as

> *'changes from one sociotechnical regime to another'*
> (Geels & Schot, 2007, p. 399)

The MLP shows the relationship between three essential dimensions in socio-technical change: the socio-technical system (the physical elements that fulfil societal functions, the actors and social groups (who maintain and refine the physical elements of the system), and the socio-technical regime (the dominant rules that guide the actors and social groups) (Figure 13).

Note that the arrows all go in both directions and to both of the two other directions since all dimensions influence each other. The actors in social groups behave in the context of structure and rules of the regime, this also applies to actors from the industry, but they are also guided by the technological developments which are aspects of the socio-technical system. Products become part of the socio-technical regime in the form of consumption patterns, and the infrastructure (socio-technical system) determines the economics of use. Rules can be government legislation or standards but are not limited to rules in the narrow sense of the world. Ways of life, routines and understandings of consumers are seen as rules too. All these rules together form the regime. (Geels & Kemp, 2007)

Geels and Kemp (2007) indicate that system changes generally start with niches as incubation rooms for innovation and change builds around them. Niches are small-scale phenomena that influence the established regime on a meso-level within the macro-landscape. Regimes change because of internal (niche developments) or external pressures (e.g. climate change or war), and these two often come together. At the macro level, change occurs slowly while at the lower levels it goes faster. Developments at all three levels need to work together to make a societal transition happen, and quick developments on the micro-level can be used to accelerate or steer the transition. (Geels & Kemp, 2007; Rotmans, Kemp, & van Asselt, 2001)

### *Transition management*

The field of transition management builds on the field of socio-technical transitions and aims to provide a practical, prescriptive framework (Loorbach, 2010). Where the concept of socio-technical transitions describes how change happens in socio-technical systems, transition management aims to develop knowledge on how to bring about the desired transition. As described previously, it is now widely recognised that a transition of the current socio-technical system, which supports the existing production and consumption patterns, is fundamental to bring human activities back within the planetary boundaries and, therefore, reach a situation of sustainable development. (Meadowcroft, 2009; Quist & Vergragt, 2006) Rotmans and Kemp (2003) define a transition as

'*a long-term, continuous process of change during which a society or a subsystem of society fundamentally changes*' (Rotmans & Kemp, 2003, p. 9). Discussions about creating and accelerating such transition have led to the development of the notion of transition management, of which its main concern is to enable long-term change in large socio-technical systems. Socio-technical systems can be defined as '*the systems of social and technological practice by which we satisfy our needs for housing, mobility, food, communications, leisure and so forth.*' (Smith, Stirling, & Berkhout, 2005, p. 1491) The socio-technical system consists of elements such as '*technology, science, regulation, user practices, markets, cultural meaning, infrastructure, production and supply networks*', (Geels & Kemp, 2007, p. 442) and is created and maintained by supply- and demand-side actors.

Transitions, in this sense, are understood as the

> *'processes of structural change in major societal subsystems.'*
>
> (Meadowcroft, 2009, p. 324).

These processes involve a shift in the dominant rules, innovation in technologies and societal practices and the movement towards a new equilibrium. Such a transition generally lasts several decades, from 25 up to 50 years. Management entails the deliberate effort to guide such transitions along preferable pathways. In general, in national policy agendas, the short-term prevails, just as in the field of technology, the focus is on incremental improvements to existing designs. Transition management, on the other hand, tries to accelerate change by opening up a wider perspective and generally involves backcasting. When using backcasting, a long-term vision is defined, and then a pathway of small steps is determined that should lead towards this vision. (Meadowcroft, 2009) Therefore, Kemp and Rotmans define transition management as '*a deliberate attempt to bring about structural change in a stepwise manner*'. (Kemp & Rotmans, 2005, p. 42)

The transition management framework is a descriptive multilevel framework aimed at directing a long-term change in large socio-technical systems. Transition management recognises the limited time-scale on which governmental institutions often operate, and therefore focuses on involving stakeholders from relevant industrial stakeholders. The transition management process starts with defining collective goals as a cooperative process between the government and the key stakeholders, after which the same stakeholders develop matching visions for these goals, together shaping the desirable future. From that starting point, transition experiments are designed, which can be both social and technological. These experiments are organised to discover pathways towards the desirable future. The framework uses evolution principles. The different experiments create variation, and selective pressures from politics and the market determine which experiments survive. The surviving experiments then build up momentum and contribute to learning processes, and become more cost-effective. When simultaneously external pressures at the landscape level destabilise the existing regime, windows of opportunity for the experiments come into existence, and these experiments can break through in mainstream markets. A regime change comes about as the number of breakthroughs increases. (Meadowcroft, 2009; Geels & Schot, 2007)

### *Social-ecological transformations*

Generally, two directions of scientific sustainability literature can be distinguished. One aimed at the conservation of ecological systems and biodiversity, which originates from ecology. The second one addresses the '*socio-economic sustainability of human well-being*' (Chapin III, et al., 2009, p. 242) and stems from geography and the United Nations development goals. The field of social-ecological transformations has integrated these two approaches into a social-ecological systems (SESs) approach, which observes that people are an inveterate component of the ecosystem and affect and respond to ecosystem processes. (Chapin III, et al., 2009)

Olsson, et al. (2004; 2006) have developed the adaptive co-management framework for social-ecological transformations, based on the theory of complex adaptive systems. Social-ecological transformations are closely connected to resilience since '*transformational change at*

*smaller scales enables resilience at larger scales'* (Folke, et al., 2010, p. 7).

Chapin III, et al. (2009) have defined transformation as

> *'fundamental change in a social-ecological system resulting in different controls over system properties, new ways of making a living and often changes in scales of crucial feedbacks'.*
>
> (Chapin III, et al., 2009, p. 241)

The social-ecological transformations field, similarly to the field of socio-technical transitions, recognises that transformations can be both intendedly steered towards, or be emergent. Again, the focus is on the steered transformation, since this is the type of transformation that can move in the desired direction, which is, in this case, increased sustainability. Three phases have been identified in the transformation process: first, actively preparing the system for change, second, navigating the transition in governance systems when a window of opportunity appears in the current system, usually in times of crisis, and third, augment resilience of the new governance system through building trust. (Chapin III, et al., 2009; Patterson, et al., 2017)

The social-ecological systems approach focuses less on niche experiments and views transformative change to be brought about by the interplay between top-down institutional settings and bottom-up innovation, managed by institutional networks at different levels of organisation. (Patterson, et al., 2017)

### *Transformative pathways to sustainability*

The field of transformative pathways to sustainability focuses on the complex and dynamic nature of sustainability problems and sees a primary role for governance in finding a solution. Additionally, the field recognises the intersubjective nature of the problems, which require a joint approach and political leadership. Finding a solution is challenging, and transformative pathways need to be navigated carefully to reach a sustainable outcome. Therefore, when transitioning towards a more sustainable situation, dealing with '*contested values, multiple narratives of change, and the politics of knowledge*' (Patterson, et al., 2017, p. 6) is inevitable. (Patterson, et al., 2017)

The transformative pathways to sustainability should stay within the safe operating space for humanity; below the planetary boundaries (Rockström, et al., 2009) and above a set of social boundaries (Raworth, 2018). The adoption of these social and ecological boundaries moves the field closer to the field of social-ecological transformation. However, here the focus is on the complexity of the problems and the role of politics in providing an answer. Because even though the boundaries are defined on a global level, the required transformation differs for individual societies with their specific social and ecological situations. Therefore, the model of the 3 Ds has been developed, where the 3 Ds stand for Direction, Diversity, and Distribution. Government officials can use this model to develop the specifics of their transformation towards sustainability. First, the direction of the change needs to be determined, and clearly defined as particular goals and principles, applicable to the specific situation. Second, diversity in social and technological innovation is crucial, between and within societies, to foster resilience and fit the specific local social and ecological realities. Finally, the distribution of the safe operating space between people should be taken seriously. Sustainability policies always involve trade-offs, for example between the large-scale sustainability benefits and the local, small-scale effects on living situations when building a massive dam to generate hydroelectric power. Therefore, these trade-offs should be carefully balanced to ensure an equal distribution of advantages and disadvantages. (Leach, et al., 2012) The literature does not define these transformations, but they could be described as navigating the complex dynamic social-ecological systems, providing solutions to global problems while considering local dynamics.
(Leach, Scoones, & Stirling, 2010)

### *Transformative adaptation*

The field of transformative adaptation has roots in geography, political ecology, and development studies. It has been developed because the fields gained increasing

awareness of the vulnerability of human systems to problems emerging because of climate change. The field aims to change the human systems that increase this vulnerability. It is argued that incremental adaptation to changes in the earth's ecosystems which occur due to climate change will not be sufficient to move human systems to a more sustainable situation. (Patterson, et al., 2017)

In this field, the distinction between transformation as an unintended outcome, either positive or negative, and deliberate transformation is made. In case of deliberate transformation, it is recognised that a fundamental shift is needed to realise the desired future, in other words, continuing with business, as usual, will not lead to the desired future and minor adjustments are not sufficient to alter the direction of the system. Although, views of what a desirable future is are not the same for everyone, there are numerous normative arguments for prioritising ethical and sustainability aspects. (O'Brien, 2012)

O'Brien (2012) defines (deliberate) transformation as

> *'physical and/or qualitative changes in form, structure or meaning-making. [...] a psycho-social process involving the unleashing of human potential to commit, care and effect change for a better life'.*
>
> (O'Brien, 2012, p. 670)

The transformation occurs on three levels: within the institutions, on a technological level and within society. Institutional transformation requires institutional reforms, technological transformation requires technological innovations, and societal transformation requires changes in behaviour, culture, values, and beliefs. (Patterson, et al., 2017)

### *Defining sustainability transformations*

The definition by Meadowcroft (2009) is the broadest definition of the four, based on the concept of socio-technical systems. The socio-technical system is useful to critical materials problems since they are extracted, processed and used in production in the technical field, and are used in society to enhance the comfort for humans. However, many of the problems with critical materials are due to the impact the extraction, processing and use have on the environment. The definition by Chapin III, et al. (2009) uses the term social-ecological system, denoting the importance of the ecological system, of which humans – including their technology – are an integral part. Social-ecological systems are also used by Leach, Scoones, and Stirling (2010), but they are described as complex and dynamic. The definition by O'Brien (2012) does not include a term for the system that changes. The term social-ecological systems will be used in this study since this includes the social, technical and ecological aspects and carries the importance of bringing sustainability in human well-being and ecological sustainability together, an issue that is at the heart of the critical materials problems.

The transition itself is described as (processes of) structural change, fundamental change, and physical and/or qualitative change. The expressions physical and qualitative are not concrete enough to describe the nature of the process and will, therefore, not be used. Fundamental change suggests a change of the principles on which a system's functioning is based, whereas structural change points in the direction of the system's structures while the foundations could stay intact. For this research, the term fundamental change is used, because large-scale transformations often require new principles according to which the system should function, and the necessary structure follows from these principles. The ideas of a transition consisting of processes and the complex and dynamic nature of social-ecological systems are also included for this study, to indicate that such a transformation involves all aspects of society, takes time, and is not straight-forward.

The second part of the definition comprises of the aim of the transformation, in this case, sustainability. When authors have defined the sustainability aspect, the WCED (1987) definition of sustainable development is used, which is used in this study as well. Finally, since sustainability transformations are deliberate transformations and, therefore, do not occur

spontaneously but involve specific activities according to a methodology, the 3 Ds approach is incorporated as well. The 3 Ds from Leach, et al. (2012) provide sound boundary conditions for bringing about sustainability transformations. For this study, sustainability transformations are defined as processes of fundamental change in complex and dynamic social-ecological systems resulting in a use of the environment and resources that meets the needs of the present without compromising the ability of future generations to meet their needs, accomplished through considering the defining of goals specific to the particular social and ecological situation, the promotion of resilience through diversity, and the ensuring of equal distribution of advantages and disadvantages.

### 2.3.2 Defining resilience of social-ecological systems

Where transformability regards deliberately and fundamentally changing a system, resilience is a property of the system and is one of the factors that determine the dynamic behaviour of the system. (Walker, Holling, Carpenter, & Kinzig, 2004) Knowledge about the resilience of a system and the functioning of resilience, in general, is essential when transforming from one SES to another. The resilience of the old system needs to be broken down carefully while reinforcing the resilience of the new system. (Folke, et al., 2010) The field of resilience is closely linked to that of SESs and resilience is generally discussed together with adaptability and transformability. The three elements together provide dynamic stability in all human and natural systems. Four elemental system properties determine its resilience: latitude, resistance, precariousness, and panarchy. Latitude is the maximum change a system can endure before losing its ability to recover. Second, resistance describes the extent to which a system resists change, its flexibility. Precariousness is a parameter that describes the position of a system on its latitude, so whether a system is close to a boundary which would prevent recovery to the system's original state when crossed. Change and resilience are observed at different levels of a system, and the changes at these levels influence each other. The dependence on developments on other levels is called panarchy, which is a manner to describe the nature of the system and not a measurable property. The adaptability of a system is determined by the human actors operating within the system. They can alter a system's resilience by influencing the four properties, and adaptability is the capacity of actors to do so. Transformability is the capacity to fundamentally change towards a new system when the existing system is irredeemably flawed, requiring a change as described in the previous paragraph. (Walker, Holling, Carpenter, & Kinzig, 2004)

Walker, Holling, Carpenter, and Kinzig (2004) define resilience as

> *'the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks'.*
>
> (Walker, Holling, Carpenter, & Kinzig, 2004, p. 2)

This definition is also used by Westley, et al. (2011). In this definition, resilience is the *capacity* of a system, which corresponds to the dictionary definition which uses the words power or ability. The definition also expresses that the system *absorbs* disturbance *while* undergoing change. Resilience can indeed be described as absorbing disturbances, but the phrase *while undergoing change* is unclear. Does resilience only apply or show when a system is undergoing change? Or do these disturbances only occur when a system undergoes change? The definition also describes that a system *reorganises* because of the disturbances. However, this is not necessarily the case. The second part describes the state to which a system returns after disturbances, because of its resilience.

In 2009, Walker, Abel, Anderies, and Ryan defined resilience as

> *'a measure of a system's capacity to cope with shocks and undergo change while retaining essentially the same structure and function'.*
>
> (Walker, Abel, Anderies, & Ryan, 2009, p. 1)

In this definition, *capacity* is replaced by *measure* of the capacity. However, the word measure appears less accurate than the word capacity since it is hard to measure resilience and, therefore, capacity is sufficient. The word *absorb* is replaced by *cope with*, of which the first seems more appropriate since a system does not actively cope with disturbances or shocks. The difference between *disturbances* and *shocks* is the third alteration, where disturbance is preferred since disturbances can include shocks but also other types of disturbances. *While undergoing change* has been replaced by *undergo change*, which is more clear. The second part has been slightly altered and shortened, which appears to be an improvement.

A third definition is provided by Chapin III, et al. (2009), who define resilience as

> '[the] capacity of a social-ecological system to absorb a spectrum of shocks or perturbations and to sustain and develop its fundamental function, structure, identity and feedbacks as a result of recovery or reorganization in a new context'.
>
> (Chapin III, et al., 2009, p. 241)

This definition also uses the terms *capacity* and *absorb*, and has expanded the term *system* to *social-ecological system*. Furthermore, the question of disturbances or shocks has been combined into *a spectrum of shocks or perturbations*. The undergoing of change is not mentioned, probably because a spectrum of shocks and perturbations is a part of undergoing change. The second part of the definition contains the sustaining of the original function of the system, but also to develop this function further in the new context. Adding this part provides the image of a system that, after enduring the effects of change, maintains its fundamental function and manages to thrive in the new context. A lack of resilience would then mean that a system that undergoes change is fundamentally altered and has to adopt a new structure, identity, and feedback system to thrive in the new context. The second situation would be what happens during a sustainability transformation, and the first situation is the goal of such a transformation. In this comparison, in the second situation, the change comes from the deliberate transformation, while in the first situation shocks or disturbances involve external, undesired factors, such as climate change or supply disruptions, which require a resilient social-ecological system. For this study, the definition of resilience is mainly derived from the definition provided by Chapin III, et al. (2009). Therefore, resilience is defined as the capacity of a social-ecological system to absorb a spectrum of shocks or disturbances and to sustain and develop its fundamental function, structure, identity and feedbacks as a result of recovery or reorganisation in a new context.

### 2.3.3 Defining governance for sustainability transformations

In its publication *Our Common Future*, the WCED (1987) describes how sustainable development is a process of change that involves all aspects of society, including resource use, financing, technological development, and institutional change. All of these are interlinked and profoundly influence each other, and therefore, have to be carefully managed. Consequently, governance is essential in moving towards a sustainable future, as *'politics and political processes lie at the heart of governance for sustainable development'* (Meadowcroft, 2009, p. 335). Governance for sustainable development includes the more traditional policy tools such as regulation, planning, and tax-based instruments. Institutions often operate separately, with narrow mandates, and those managing natural resources or protecting the environment are not the same as those who are concerned with economic regulation. The economic and ecological systems are so intertwined that an isolated approach will not be able to make a lasting change. Instead, a combined effort is essential. Patterson, et al. (2017) agree that transformations demand governance and require a change in all systems within the social-ecological system. Often, change emerges from simultaneous, but relatively separate developments in the distinct systems. The developments then result in a change that is often not bringing about the desired transformation. While

undesired transitions might happen unexpectedly, achieving a deliberate transformation towards sustainability is incredibly challenging because of the dynamic and multifaceted ways the different sub-systems are related and influence each other. Moreover, the fragmented and imperfect institutional system combined with the complex nature of societal change reduce the ability to provide effective governance. (Patterson, et al., 2017) Therefore, a sustainability transformation needs to begin with reforming governance practices to accommodate the process. (Meadowcroft, 2009)

According to Patterson, et al. (2017) governance can be described as '*the structures, processes, rules and traditions that determine how people in societies make decisions and share power, exercise responsibility and ensure accountability'* (Patterson, et al., 2017, p. 3). Since there is no academic consensus on the definition of governance, the definition of earth system governance, as defined by the Earth System Governance Project, is used. Here, earth system governance is defined as

> *'the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development'*
>
> (Biermann, et al., 2010, p. 279)

The definition includes a normative aspect of what governance aims to achieve, in this case, sustainable development, something that does not necessarily apply to all governance systems but should apply to all systems with the right intentions. Therefore, the definition by Biermann, et al. is used here, since for this study governance is always related to realising sustainability transformations. Governance consists of all rules and structures that shape society and is therefore not purely governmental. Any guidance, for example within organisations or informal rules, that steer society are included. However, Meadowcroft (2009) observes that politics are essential to governance in sustainability transformations. Hence, this research focuses on the political aspect of governance, so governance related to the government and governmental policy.
There are three different positions for governance in relation to transformations. First, governance *for* transformation, which is governance that aims to create the conditions that allow transformations to emerge. Second, the governance *of* transformations, which is a type of governance that actively starts and navigates the transformation process. Third, transformations *in* governance, which means that the governance regimes themselves are changed. (Patterson, et al., 2017)

The Netherlands School of Public Administration (NSOB) has noticed that the role of the government in general shifts over time as the demands from and interactions with society change. The NSOB has proposed a model that provides a clear picture of the shift (Figure 14). The observed shift moves in a circle around the model, starting at the bottom left and is currently at the bottom right. Even though the overarching government style displays this transition, this does not mean that only the dominant style of government is present. At all times, all styles of government are applied, as the government selects the most appropriate role for a specific goal or field. In general, two changes can be observed. Over the longer-term, the government has adopted a more society-oriented approach, taking a more networking position. On a shorter timeframe, a shift can be observed from a result-oriented approach towards focusing on creating space for societal actors to provide results within government-defined boundary conditions.

The two axes create a distinction between four government styles. The directive government puts the legitimacy and lawfulness of governmental decision-making in a central position. In this situation, the government is organised hierarchically, separating politics and the private sector. The performing government works more from the viewpoint of market thinking, but there is still a hierarchical role for the government. The focus is on the purposefulness of interventions, and a lot is outsourced to private parties.

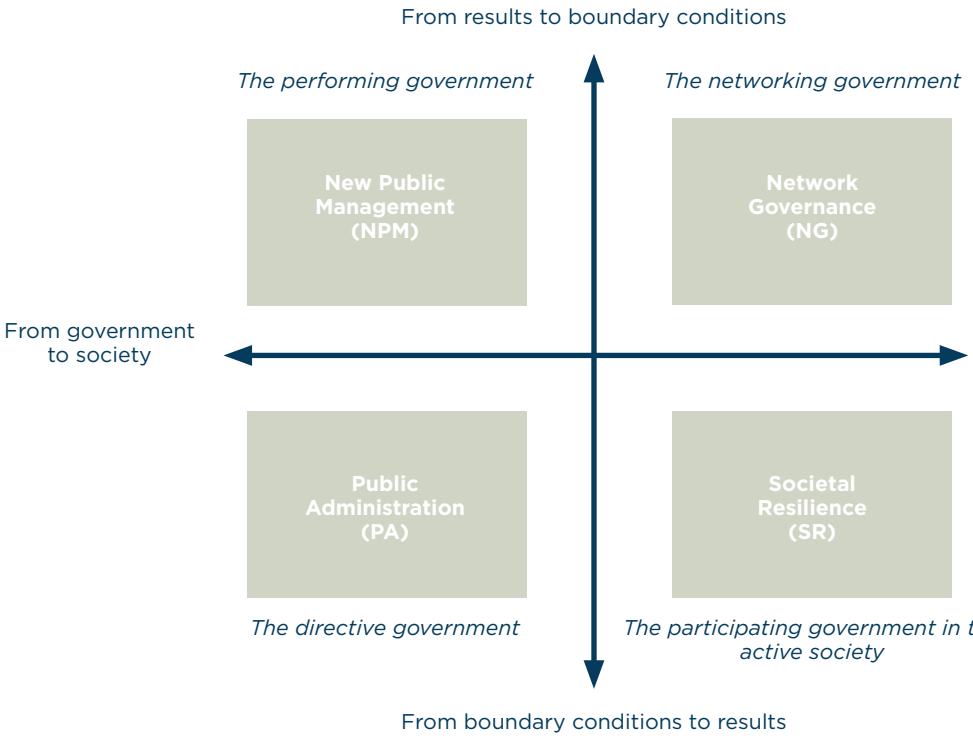



Figure 14 The four roles of the government. Reprinted from Van der Steen, Scherpenisse & Twist, 2015.

The networking government collaborates with others and in a more horizontal relationship. Goals are determined together with leading partners from the society and businesses and agreements are often used. With a participating government, the relationship between the government and the society is reversed when compared to the directive government. The government believes firmly in the resilience of the society and resorts less to established actors and organisations. The government adopts a facilitating role. (van der Steen, Hajer, Scherpenisse, van Gerwen, & Kruitwagen, 2014).

The decision on which role to apply in which situation is always political to some extent, but should primarily be based on a substantive and structural analysis of the situation. The decision should preferably be made at the start of a process and should be openly communicated. When during the process it appears that another role needs to be adopted, this is possible, but the decision should not be delayed and, again, should be communicated clearly. The government needs to master each of the roles, which require different structures, competencies, skills, instruments, and approaches. The governmental organisations and their systems should also be set up in such a way that each of the roles can be accommodated, not necessarily next to each other, but rather in an overlapping, sedimentary way. Additionally, for governments, it is essential to take into account that in the case of a networking role, the government can still set boundaries and make decisions. Also in a networking situation, the government does not have to move with the desires of the other parties, and therefore the role of the government always functions within the political context.

Any decision that is made, in any role, even when deciding to do nothing, demands strong political ambition and conscious decisions. (van der Steen, Scherpenisse, & van Twist, 2015)

### 2.3.4 Developing a framework for governance of sustainability transformations

The numerous approaches to sustainability transformations and governance for sustainability transformations are translated into several governance frameworks such as transition management, ecosystem stewardship, and adaptive co-management. These approaches and frameworks are closely related. Rather than forming distinctly separate frameworks, they all illuminate different perspectives on the same event of bringing about sustainability transformations. Therefore, the most useful aspects of the different approaches and frameworks are combined into one framework for the governance of sustainability transformations.

A deliberate sustainability transformation starts with the government recognising the need for such a transformation. The government then begins to reform government practices to accommodate the process. Government reformation includes aligning the different institutions to facilitate cooperation on joint goals and preparing the institutions to work with all the four roles of the government simultaneously and quickly switch between these roles.

The second step is defining a vision and the accompanying goals, together with industrial and societal actors (assuring a distributive selection of the actors). The government takes on a networking role here, but still has the authority to set boundaries and make decisions. The government has the responsibility to guarantee that the resulting vision entails a view of humans and nature as an integral whole. Within this vision, a healthy planet is a premise for economic and social development; that the goals enable the global SES to stay below planetary boundaries and above the social baseline; and that goals enable humanity to reconnect to the biosphere. These are the general objectives, but visions and goals that are developed should be specific to the individual society with its particular social and ecological situation.

Third, the actual transformation is brought about by an interplay between top-down institutional settings and bottom-up innovation. The government has the responsibility to create windows of opportunity as well as a selection pressure for social and technological niche experiments which are brought about by societal actors. The selection procedure gives the government the opportunity to select innovations that match the goals, have the potential to transform the SES, and are specific to the local social and ecological situation. The government should also use the selection procedure to ensure a diversity of innovations to enhance resilience, and balance the advantages and disadvantages of the innovations to allow equal distribution of benefits and pressures. The windows of opportunity in, for example, governance structure, legislation, and the use of crisis situations (such as extreme weather conditions) provide a chance for the selected innovations to become successful and enter mainstream markets.

Finally, is crucial to building the resilience of the new SES is crucial. Transformational change at small scales already enables resilience at larger scales, especially when brought about through diverse and distributive social and technological innovations which create a balance between the social and the ecological system and enable long-term sustainability. On a governance level, the resilience of the new governance system is augmented through building trust by being honest, open, and reliable.

## 2.4 Governance for resilience to material constraint framework

The existing body of literature indicates that the current SES needs a complete transformation to facilitate sustainable development. It needs all-encompassing sustainability, now and in the future, within all the intertwined aspects of the SES: climate, resources, biodiversity, energy, human well-being, and many more, thus including material use. A sustainable situation with regards to material use means that no materials need

to be classified as critical and that the materials that are used are distributed in a fair and ethical way. Additionally, that any benefits or harms that come with the extraction of these materials are equally distributed among people locally and globally to ensure sustainability of the social system, and that the extraction of materials does not harm ecosystems or contributes to overshooting the planetary boundaries, to ensure sustainability of the ecological system. Such a sustainable SES would be highly resilient to material supply problems and therefore improves the well-being of the people living in the system. Literature also points to the fact that the current ecological and economic systems will not be able to create such a sustainability transformation by themselves, because of how these systems are connected and function. Political governance is essential to determine the goals that steer the transition. However, the government should start with changing the way government functions itself, to be able to accommodate the process of change. It needs to learn to use the four roles as needed in different aspects of the transition and should not be afraid to set goals and boundaries and show a strong political will.
The sustainable materials framework from paragraph 2.2 and the governance for sustainability framework from paragraph 2.3 are combined to form one conceptual framework for this study (Figure 15).

The four quadrants of the framework represent the social-ecological system. Society, technology, and economy belonging to the social system and the environment to the ecological system. The ecological system should be protected in such a way as to enable sustainable development of the social system. Therefore, the primary goal for the environment is to stay within the planetary boundaries as the global social system.

Within the social system, technology and the economy are there to enhance human well-being. However, the human efforts to enhance well-being through technology and economy have resulted in exceeding the planetary boundaries, and therefore a period of degrowth, and as a result, dematerialisation is essential to return to a situation of balance with the ecosystem services.

## 2.5 Conclusion

Material constraint is defined as a limitation in the supply of materials obtained from naturally occurring assets that can be traded in their unprocessed or semi-processed forms and are essential to industrial production processes. The economic value of the materials arises from their economic usefulness in industrial production, their scarcity and, in the case of industrial raw materials, their exhaustibility. Material constraint can arise due to physical depletion, lack of investment in the mining industry, concentrated geographical distribution of ores, geopolitical tensions, increasing material demand, increasing complexity of and the number of elements used in alloys, the energy transition, and the environmental and ethical aspects of material extraction. All of these issues are intertwined to form an incredibly complex problem. Lists of critical materials have been defined to be able to target activities aimed at decreasing supply risks. Several frameworks for achieving sustainable material use have been developed which have been combined to provide a sustainable material use framework for this research. The frameworks show that governance lies at the heart of moving towards a situation of sustainable materials use, as governance needs to steer towards and guard the goals of four main policy areas: environment, society, technology, and economy.

Literature indicates that the transition towards such a society cannot be brought about gradually, but entails a sustainability transformation. Sustainability transformations consist of processes of fundamental change in complex and dynamic social-ecological systems resulting in a use of the environment and resources ‘that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (WCED, 1987, p. 41). Such a transformation is accomplished by defining goals specific to the particular social and ecological situation, promoting resilience through diversity, and ensuring an equal distribution of advantages and disadvantages. Thus, the goal of the transformation is to reach a sustainable situation with regards to material use, and particularly, a society that is

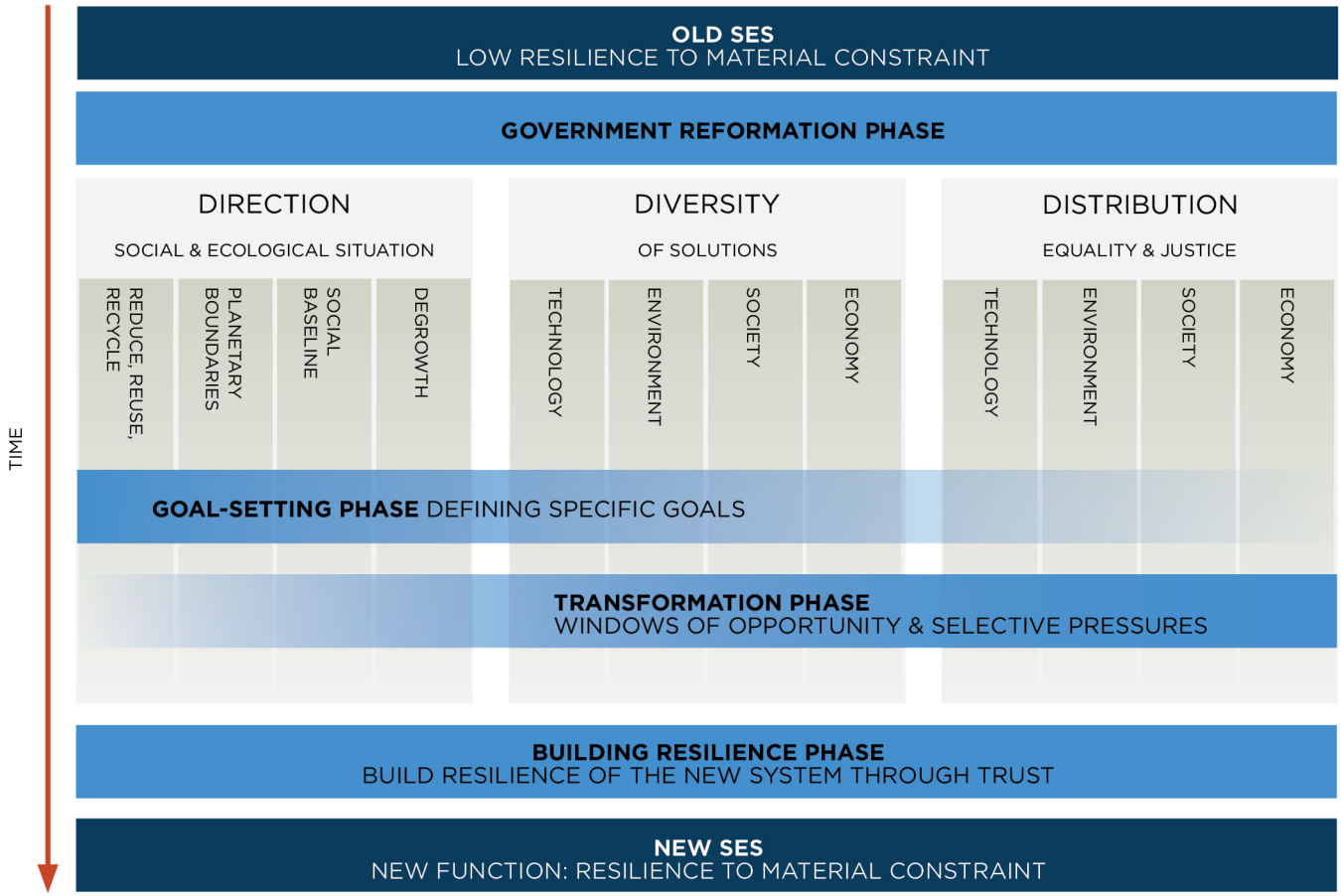
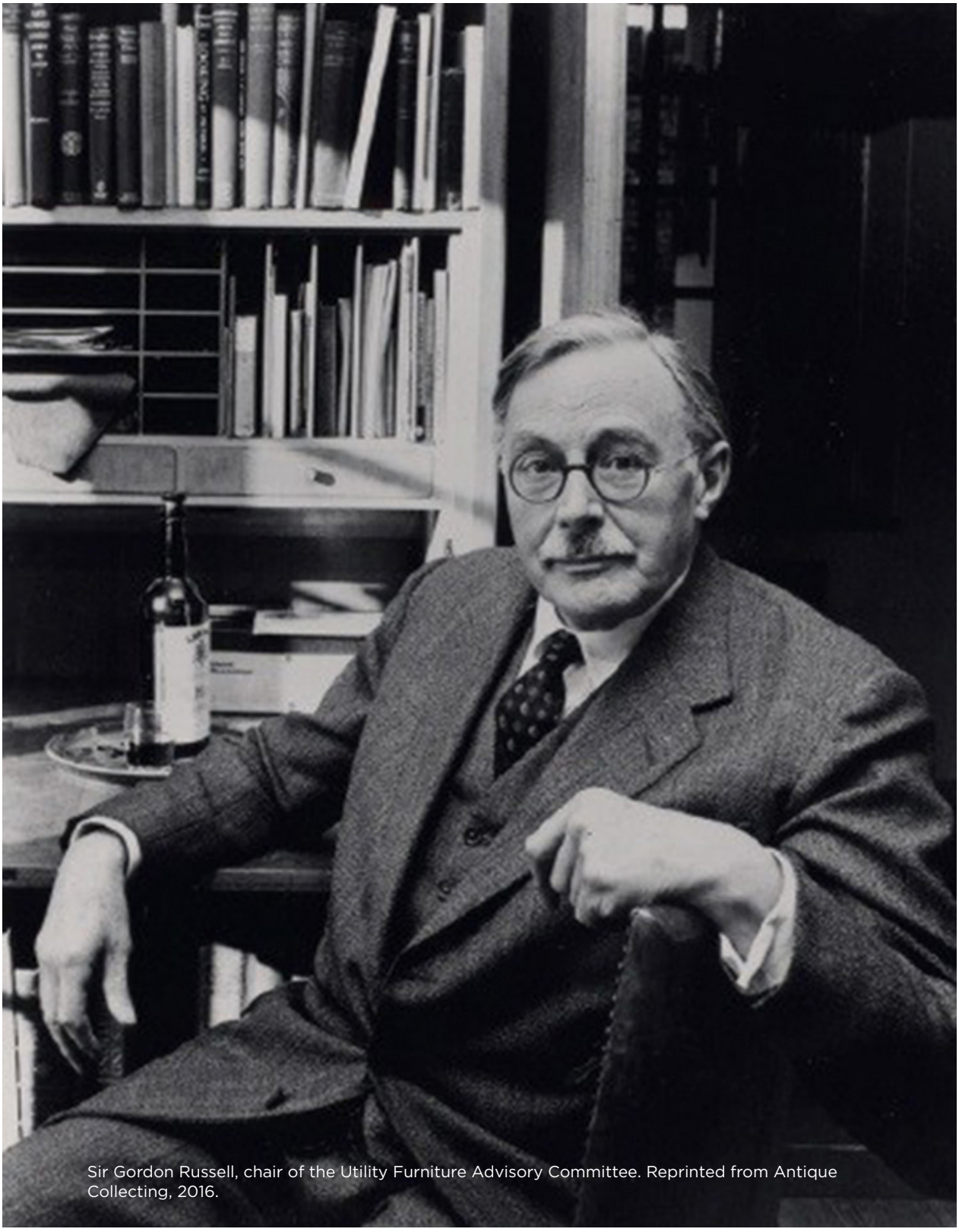



Figure 15 Governance for resilience to material constraint framework.

resilient to disturbances or shocks in materials supply and therefore can retain its original function and structure whenever situations of material constraint occur. Strong political leadership is essential to bring about such a sustainability transformation and reach a sustainable use of materials and resilience to material constraint in society. The government needs to transform itself first to be able to accommodate the transformation process, after which the transformation process can commence. The process fundamentally consists of defining a vision and goals, creating windows of opportunity and selective pressures for social and technological innovations which should bring about the transformation, and finally, building resilience of the new SES and governance functioning through building trust.

The sustainable materials use framework, and the governance for sustainability transformations frameworks have been combined to create *Governance for resilience to material constraint framework* that is used for this study.



Sir Gordon Russell, chair of the Utility Furniture Advisory Committee. Reprinted from Antique Collecting, 2016.

# *Chapter 3*
# Methodology

## 3.1 Introduction

In this methodology chapter, the theoretical framework from Chapter 2 is translated into research methodology. The research that is described in this thesis is a case study research of a historical and contemporary case that is used to test the theoretical framework. A literature study is conducted to analyse the historical case, for the contemporary case a literature study is used as well, combined with qualitative interviews. This chapter provides the reasoning behind the selection of these methods as well as an explanation of their functioning. Furthermore, this chapter explains how the different methods combine to provide an answer to the research question.

## 3.2 Research design

### 3.2.1 Case study research

This research combines a historical and contemporary case about situations of material constraint. The first case is the historical case study of British policy on material constraint during WWII. The second case is the contemporary case study of Dutch policy on material constraint from 2008 to 2018. The method of case study research is chosen since because a detailed investigation of an aspect of history can be used to test or develop theories that can be used in future strategy or policy development for similar situations. Therefore, in this research case studies are used to answer the research question and further develop the theory described in the previous chapter. Historical case study research as a research methodology stems from the social sciences and is commonly used for theory development in this field. Case study research had lost its popularity during the 1960s and 1970s because of the fast development of statistical methods. However, developments in the field of case study research have resulted in the more widespread use of the method once again and recognition of its value to the social sciences. George and Bennett (2005) have collected past literature on case study research and theory development and developed a comprehensive method which is used in this research. Historical instances of generic problems can be used to draw lessons, that can be useful to current or future policymakers. Studying a case study in detail can be used to test or develop historical explanations or theories that can be used to draw more general conclusions. The case study approach has been developed to help draw these lessons in a scientifically sound manner. The case(s) under examination should be a well-defined aspect of a historical episode, rather

than a historical event itself. For example, a case is not 'The Cuban missile crisis', but rather 'crisis management during the Cuban missile crisis'. The case study, therefore, focuses on a class, or even sub-class, of events of which one or more cases can be identified. Case studies are generally well suited for testing hypotheses and especially for theory development since they allow for a high level of causal complexity and offer insight into causal mechanisms. Even single case studies can offer great insight when studying them in detail, looking at a large number of variables. (George & Bennett, 2005)

George and Bennett (2005) distinguish three types of case study research: Structured, focused comparison; Controlled comparison and Within-case analysis. The first two methods are aimed at comparing a small number of cases, and the last one is designed for single case studies (but can also be used to analyse a small number of cases) and consists of the congruence method, the process-tracing method, or a combination of the two. This study will use a structured, focused comparison to study a historical situation of material constraint. The analysis is structured according to the foundations of the theoretical framework and is focused on governance related to material constraint.

The objective of this study is to provide more insight into the role of governance in bringing about a sustainability transformation that increases resilience to critical materials problems. In order to so, a literature study is conducted to develop a theoretical framework that describes the most effective strategy according to scientific literature. The case study research is used to test this theory to give more insight into societies that effectively cope with situations of material constraint and the transition that is necessary to reach such a society. The historical case is selected to answer the second sub-question *What governance approaches to create resilience to situations of material constraint have been taken in the past?* The contemporary case answers the third sub-question *What is the current governance approach to creating resilience in situations of material constraint in the Netherlands?* Together with the theoretical framework that is developed in Chapter 2, the research question *How can governance bring about a sustainability transformation aimed at creating resilience to situations of material constraint in the Netherlands?* can be answered. Both cases are compared to the theoretical framework to test whether the framework can be applied practically. Where necessary, the framework is adapted using insights from the historical case. The framework and the insights from the historical case are used to provide direction for the way forward towards resilience for the Netherlands.

This research uses the level of material constraint in society as the first independent variable. The level of material constraint is determined by a decrease of supply in percentages and price increase in percentages, regarding the essential or critical materials. The second independent variable is the governance on material constraint, adopted by the government. The strength of governance is specified by the 3 Ds, Direction, Diversity and Distribution. For each D, the presence of policy regarding each of the four quadrants, technology, economy, environment, and society is incorporated in the score. The dependent variable is the observed level of resilience, which is determined by examining the three characteristics that indicate resilience: latitude, resistance, and precariousness. The historical case seeks to find an explanation for the observed level of material constraint, while for the contemporary case a prediction is made since there is no outcome yet for this case.

Table 2 provides an overview of the variance classifications for each variable. The variance between the different values of the dependent and independent variables is determined by taking the average value of the sub-variables.

This research compares two cases of situations of material constraint, a contemporary and a historical case. The research is limited to two cases because of the time limitations of this study. A historical case, from the modern period, is used because the outcome of such a case is known and can, therefore, be analysed from the start to the outcome and no predictions have to be made. A case of successful governance on materials management is used to test the theory. The historical case that is chosen is the case of policy on material constraint in Britain from 1939 to 1945, during WWII. The case is useful for further developing the theory posed in the previous chapter. The

Table 2 Variance in variables.

| ***Variable*** | **Value** | **Variance description** |
|---|---|---|
| **Material constraint in society** | Average of two sub-variables | Not present |
| | | Low |
| | | Average |
| | | High |
| • Supply reduction (%) | Negative reduction | Not present |
| | 0-25% | Low |
| | 26-50% | Average |
| | 51-100% | High |
| • Price increase (%) | Negative | Not present |
| | 0-25% | Low |
| | 26-75% | Average |
| | More than 75% | High |
| **Governance on material constraint** | Average of sub-variables | Weak |
| | | Average |
| | | Strong |
| • Direction | Limited definition of goals | Weak |
| | Definition of goals, but specificity is limited | Average |
| | Goals specific to social and ecological situation | Strong |
| • Diversity | No diversity | Weak |
| | Some diversity | Average |
| | Abundant diversity, and innovations specific to situation | Strong |
| • Distribution | Unfair distribution of advantages and disadvantages | Weak |
| | Some attention to equal distribution | Average |
| | Fair distribution of advantages and disadvantages | Strong |
| **Resilience of the new system** | Average of sub-variables | Low |
| | | Average |
| | | High |
| • Latitude | Small maximum change | Low |
| | Average maximum change | Average |
| | Large maximum change | High |
| • Resistance | Low flexibility | Low |
| | Average flexibility | Average |
| | High flexibility | High |
| • Precariousness | Close to a boundary | Low |
| | Halfway | Average |
| | Far from boundaries | High |

policy on material constraint in Britain during WWII was selected because it is an example of a case of severe material constraint, with a significant role for policy and political leadership, and the government was successful in achieving resilience. It is the most controlled case managed on a national level in the modern period, starting in 1939 and ending in 1945. The planning for this case started already in 1918. The governance in this period brought about a significant societal change. Also, the policy and governance developments are well documented and occurred several decades ago, which means that the data is fully disclosed and easily accessible. Finally, many aspects of the policy were non-military, making the case applicable to the theoretical framework on societal transitions. The second case is a contemporary case because this research aims to provide useful insights for today's critical materials problems. Therefore, the contemporary case of governance on material constraint caused by critical materials problems in the Netherlands is selected. The case is chosen because the Dutch government has developed a strategy to increase its resilience to critical materials problems, which can be used to test the theoretical framework, while the same theoretical framework combined with insights from the historical case study, can be used to predict the effectiveness of the Dutch strategy. The Netherlands is one of the Western countries that primarily imports critical materials and is, therefore, vulnerable to supply issues. The Dutch economy is built on trade, making the country particularly vulnerable because the economic situation depends on many different actors, among which are trade partners as well as their suppliers. The starting point for this case is set in 2008 when the Dutch Cabinet asked several ministries and organisations to develop more knowledge on the subject of the global scarcity of essential resources such as food, water, energy, minerals and metals because of the growing concern about the availability of resources. The research into this case ends in 2018, while the case is expected to continue until 2050, the target date for the governments circular economy policy. Therefore, the theory is used to predict the outcome of this case.

The cases are analysed according to general questions that allow comparable data to be obtained. The questions are posed in a general manner so that they could potentially be used in other cases that address the same topic as well. The goal of these questions is to investigate the answers that the political leaders in the case might have given. The questions are derived from the theoretical framework and are instrumental questions that focus on the practical side of reaching their goals.

*Instrumental questions*

- How to reduce material use?
- How can the government best reform to accommodate the transformation?
- How can the government ensure a societal distributive selection of actors to cooperate in the transformation process?
- How to balance authority and networking in defining a vision and goals?
- What goals specific to the local situation can be defined?
- How to encourage social and technological bottom-up innovation?
- What selective pressures should be used to stimulate innovations that contribute to the goals and ensure a diversity of innovations?
- How to create windows of opportunity in the governance system?
- How can the advantages and disadvantages be distributed equally?
- How to build the resilience of the new SES?

The answers to these questions for the historical case of Britain during WWII are found using a literature review. For the contemporary case study of the Netherlands, a literature review is used as well but is complemented by a set of interviews to gain more insight into the process.

### 3.2.2 Literature review

A literature review is conducted to answer the general questions used for the comparison and therefore help to answer the primary research question. The literature review is done in a structured way to ensure that the collected material is used optimally and correctly. This

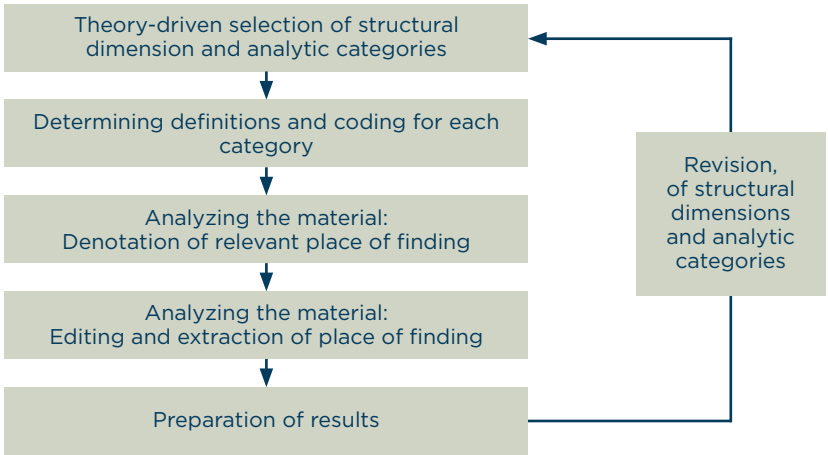



Figure 16 Research process of structuring content analysis. Reprinted from Seuring & Müller, 2008.

section introduces the framework that is used for this part of the research. A literature review is generally conducted to create new content from an existing body of work, with the objective to summarise the existing literature to identify similarities and differences to identify patterns or an overall concept (Meredith, 1993). Seuring and Müller (2008) describe a model for literature review, based on Mayring's (2003) description of qualitative content analysis, a methodology '*where quantitative and qualitative aspects are mixed to assess structural (descriptive) as well as content criteria'* (Seuring & Müller, 2008, p. 1700). The proposed process model contains four steps:

1. *Material collection*
   In this step, the boundaries for the literature study are defined to determine the scope of the material to be collected. Here, also the unit of analysis and key search terms are defined.

2. *Descriptive analysis*
   Secondly, the collected material undergoes a descriptive analysis which describes formal aspects of the material, e.g. the number of publications per year. This step provides a background for the following theoretical analysis in step 3 and 4.

3. *Category selection*
   Structural dimensions and related analytic categories are selected, which are to be applied to the collected material. Structural dimensions form the significant topics of analysis, which are constituted by single analytic categories.

4. *Material evaluation*
   The material is analysed according to the structural dimensions. The structuring enables identification of relevant issues and interpretation of results.

(Seuring & Müller, 2008)

For step 3 and 4, which together form the theoretical analysis, a more detailed process description has been provided, as depicted in Figure 16. The feedback loop in this picture not only applies to these separate steps, but also to the process as a whole.

The structural dimensions that are used for the theoretical analysis allow for classification of the reviewed material and can be derived inductively or deductively. When using the deductive method, the structural dimensions are developed before analysing the material while the inductive method entails the development of these dimensions from the materials through generalisation (Seuring & Müller, 2008). In this research, a

Table 3 Concept matrix used for the literature review.

| *Literature* | Concepts | | | | |
|---|---|---|---|---|---|
| | Governance | Society | Environment | Technology | Economy |
| | | | | | |
| *1* | | | | | |
| *2* | | | | | |
| *3* | | | | | |

combination of the two methods is used. Before the start of the analysis, the main categories are defined, which can then be further developed by adding sub-categories specific to that category throughout the literature review. The main categories are the four quadrants and the centre of the theoretical framework: governance, society, environment, technology, and economy.

In a practical sense, the literature review is documented in a table using the principle of a concept matrix as described by Webster and Watson (2002). Table 3 gives an impression of the table used for this study. The rows are the different sources, and the columns contain the (sub-)categories. The sub-categories are not included in this example because of limited space. Two of these tables are made, one for each case study.

### 3.2.3 Interviews

The interviews are used to obtain additional, qualitative insight into the governance process in the Netherlands, about the development of the circular economy strategy, the threats related to critical materials problems and possible future situations of material constraint, and the role of the government in finding a solution.

Since the goal of these interviews is to obtain in-depth information on the governance and political processes, and the literature review part of this research has a qualitative nature, the interviews are aimed to obtain qualitative data. The interviews are conducted in a semi-structured manner. The starting point for each interview is a predetermined list of questions, which ensures comparability of the interviews, but further questions can be asked during the interview to reveal more detailed information. The interviews are conducted in a face-to-face manner to create a personal connection with the participants which enhances the quality and depth of the answers to the questions and makes it easier to ask further questions whenever something interesting is mentioned. Additionally, a face-to-face interview allows for the observation of body language which provides context to what is mentioned, from both sides.

This study uses three interviews of 30 to 60 minutes each, the number of interviews that could be conducted was limited by the amount of time available for this study. The interviews are conducted among government officials who are related to the topic of circular economy or materials policy and have senior positions. Furthermore, the three participants are from the three ministries that are most involved in circular economy and materials policy: the Ministry of Infrastructure and Water Management, the Ministry of Economic Affairs and Climate, and the Ministry of Foreign Affairs. The following government officials are interviewed:

- Mattheüs van de Pol, Ministry of Economic Affairs and Climate
- Kees Veerman, Ministry of Infrastructure and Water Management
- Dirk-Jan Koch, Ministry of Foreign Affairs

The interview consists of nine questions, divided into

three sections. The interviews are conducted in Dutch; the Dutch interview questions can be found in Appendix A.

PART I INTRODUCTION

1. Could you introduce yourself and your role in the government, especially related to the circular economy and critical materials problems?

PART II CRITICAL MATERIALS PROBLEMS AND SOCIETY

2. In what way does or will the Netherlands experience problems with material constraint?

3. In what way does a situation of material constraint influence the society?

4. In what way does the current society contribute to critical materials problems?

5. How can major problems with critical materials or situations of material constraint in the Netherlands be prevented?

6. What is your opinion on economic growth? Is it necessary to reduce growth in the light of resource use? Is it possible to reduce economic growth?

PART III ROLE OF THE GOVERNMENT

7. What is the experienced urgency of critical materials problems to the government?

8. What is the role of the government in solving critical materials and material constraint problems?

9. Is the government possibly interested in the results of this research?

The interviews are recorded (the participants are informed about the recording and need to consent) and transcribed. The transcribed texts are then coded to categorise the information.

### *Coding*

The coding of the interviews is done according to the methodology by Saldaña (2016). For this method, the page of the transcription is divided into three columns; the first column contains the transcription or raw data, the second column the preliminary codes, and the third column the final codes (Figure 17). The codes receive a reference number that is added in superscript to the raw data as well as the code itself. The code then applies to the piece that starts at the corresponding number of reference and ends where the next code starts. When there is a piece of data that is not relevant to the research and therefore should not receive a code, it is coded with N/A. The code is put between quotation marks when it uses a phrase from the raw data. Since the interviews for this study are conducted in Dutch while the thesis is written in English, the coding is done in English using the Dutch text. The codes are always written in capital letters. The preliminary codes can be distinguished from the final codes because they are in italics and lowercase.

The coding is conducted using the following steps:

1. *Pre-coding*
   Going through the text and marking all significant passages by, among others, circling, highlighting, and underlining.

2. *Preliminary coding*
   Writing down any preliminary words, codes or analytic thoughts, already starting with this process while working on the transcription or pre-coding.

3. *A priori codebook*
   Creating a list of pre-set codes, including the meaning of the codes, derived from the research questions and theoretical framework of this study. The a priori codebook for this research can be found in Appendix B.

Question 2. In which way will the Netherlands experience problems with critical materials?

| Raw Data | Preliminary Codes | Final Code |
|---|---|---|
| [12]Vooral met leveringszekerheid. Of je wel aan grondstoffen kunt komen en voor wat voor prijs ook. [13]Nou is Nederland niet zo erg een ruwe grondstoffenconsument, maar meer in halfproducten en dat soort zaken. [14]En daar is, daar heeft men nog heel weinig... ik denk dat de wereld die zich daarmee bezig houdt, dat die nog niet zo goed zich realiseren, behalve een aantal bedrijven wel, van wat er allemaal | *"security of supply"* | [12]"SECURITY OF SUPPLY" |
| | *"primary resources"* | [13]"SEMI-FINISHED PRODUCTS" |
| | *"semi-finished products"* | [14]AWARENESS |

Figure 17 Example of the table used for coding.

4. *Coding round 1*
The first round of the actual coding. In this round, every sentence receives a code, using the a priori codebook as a guide. During the coding, new codes can emerge which are on their turn added to the codebook as emergent codes.

5. *Codebook categorisation*
The a priori and emergent codes in the codebook are organised according to the main categories that are identified. Any a priori codes that have not been used are removed.

6. *Coding round 2*
The starting point of the second round of coding is the reorganised codebook including the emergent codes. As codes were added to the codebook in the previous round, text that was coded before a specific code was added might fit better under this code as well. Therefore, the second round reviews all the coding to match it with the categorisation and a new set of codes. At this point, sentences can also be merged into a longer piece of text with one code, as several consecutive sentences might have received the same code.

7. *Codebook reorganisation*
The categories are reviewed again and updated with the latest codes.

8. *Coding round 3*
The third round of coding to match the codes with the updated codebook.

## 3.3 Scope

The research focuses on situations of material constraint in society and policy measures directed towards the society. All material flows or policy measures contributed to the war effort are therefore not within the scope of this research, since they are part of the cause of the material constraint in society.

Table 4 Starting and ending dates of the two world wars for the Netherlands, Britain and the USA.

| ***Country*** | **End WWI** | **Start WWII** | **End WWII** |
|---|---|---|---|
| The Netherlands | - | 19 May 1940 | 5 May 1945 |
| Britain | 11 November 1918 | 3 September 1939 | 2 September 1945 |
| USA | 11 November 1918 | 7 December 1941 | 2 September 1945 |

With regards to British policy on material constraint around WWII, three main periods can be distinguished:

1. *1918 - 1939*
   The period of preparing for a future period of resource constraints (war), which is mostly linked to the current situation; there is no urgent situation of material constraint, but there is a severe threat of such a case occurring soon (critical materials)

2. *1939 - 1945*
   The period of the war itself. In this period the plan from the previous period was put into effect and often improved because of new insights. This period can help to under

3. *1945 - 1952*
   The period after the war, that first saw a worsening of the constraint situation, and many policy measures from the war continued during this period but were also already aimed at facilitating fast growth once materials would be available in abundance again.

The period that is under analysis for the historical case study is the period from 1939 - 1945, the war itself. The period from 1918 – 1939 is included in the analysis to provide context for the period under examination. The third period, though still facing material constraint, is not included in this research since the policy was already aimed at the period of abundance that would follow. This research aims to analyse the governmental structure, national material management, policy and regulation aimed at businesses and people and the effects on society and material constraint situation. All measures directed at the war effort will be excluded. For the historical case study, all materials except water, food and fuels are included. The analysis focuses on industrial raw materials such as metals and wood. The literature that is used for this case study is both primary and secondary literature, ranging from 1939 - 2018.

For the analysis of the contemporary case in the Netherlands, in the context of European and global developments. The analysis starts with 2008, as this year marked the first official recognition of critical materials problems by the government. The analysis continues up to 2018. The analysis focuses on industrial raw materials, especially the critical raw materials, as defined by the European Commission. The literature that is used for this case study is both primary and secondary literature, ranging from 2008 - 2018.

## 3.4 Limitations

When looking at the two case studies and attempting a comparison, the first aspect that should be noted is are some of the differences that make a direct comparison impossible and demand careful analysis. First, the two cases are on different time scales. The case of Britain

covers 26.5 years, divided into three periods. The first 18 years being a period of theoretical planning, starting with the first notion of the importance of security of supply in 1918, the next 2.5 years a period of intensified and actual planning, and the last six years a period of war and executing and refining the plans. The case of the Netherlands covers 10 years, starting in 2008 with the first notion of the importance of security of supply and critical raw materials – this applies to this recent period in history related to the current ambition towards a Circular Economy, since there have been periods with concerns about security of supplies in the past as well. This period matches with the first period in the case of Britain but is shorter since it ends today and it is unknown when this period will end. In Britain, the second period started when the threat of a war happening soon became more evident, around 2.5 years before the actual start of the war. Two of the interviewees have mentioned that they expect a real crisis in the supply of critical raw materials in two to five years. Therefore, an intensification of planning and therefore the end of the first period could be in a couple of years. In that case, the first period would be a lot shorter than the first period in the case of Britain. However, there is no certainty about what will happen in the future. Consequently, the comparison is limited to comparing the first periods of both cases. However, the following two periods in the case of Britain can be used to develop recommendations for the continuation of the Dutch policy.

Second, both cases happened during a different time in history. The case in Britain starts in 1918 and ends in 1945, while the case in the Netherlands starts in 2008, almost a hundred years later, and ends in 2018. Consequently, there are many differences between the two cases in all aspects of the conceptual model. During and before WWII, technology was not as advanced as it is today. Also, the number of elements used in products and machinery was limited while today almost all elements from the Periodic Table are used. Additionally, neoliberalism was not yet the dominant economic paradigm, while the society was coming from a class system and becoming more egalitarian. Finally, environmental issues were not a matter of concern. Therefore, the government's actions and policy measures should be understood in the light of the particular situation. Moreover, it is possible that the British case has influenced the case in the Netherlands since it had happened almost a century ago. As history progresses, lessons might have been learned, especially during the seventies with the oil crisis which also drew the attention towards the dependence on other countries for essential supplies.

Third, the material constraint that the British civilian society experienced during WWII was caused by a situation of total war. The supply of materials was severely restricted, and the majority of the available supplies were directed towards the war effort. It is unknown which kind of crisis will cause a (similar) situation of material constraint in the Netherlands, and whether this will happen at all. However, it is generally not believed that the most urgent threat is a war, but rather extensive export restrictions or preferential treatment of national or befriended industries in the extracting countries.
The research develops and then uses two case studies, a historical and contemporary case to test the theoretical framework. Using multiple historical cases, especially cases from different areas and periods would result in a more valid test of the theory. Additionally, historical lessons cannot be used straightforwardly to draw lessons for a current situation, so this should be done carefully. Also, the chosen case is a country at war, which changes the perspective of the situation. Even though the war effort is excluded from the research, the societal measures are implemented with the notion that the circumstances are only temporary. In a state of war, people are also more likely to see the urgency of the situation and understand that it is only temporary, so that they will accept strong measures such as rationing. When measures are more likely to be part of a permanent societal change, such as the one that is required in the current situation, the measures should provide a level of comfort that people can accept as permanent.

Furthermore, although there is much information available online, the people who lived, or were even part of the government, in this period are not available for questions anymore. The lack of direct

sources adds quite a few interpretation steps since the written documents are already an interpretation of the actual historical event. Choices have been made as to what to include in and what to leave out of the documents. Another interpretation layer is added when the researcher interprets the data. Also, the research is done by a Dutch person, which could lead to misinterpretation of specific information or data. For the contemporary case study, interviews can be used, and the case is about the Netherlands, decreasing the levels of interpretation. However, only three interviews are conducted with participants from three different ministries. A more substantial number of participants from each ministry and more ministries and other organisations would increase the validity of the research. Also, semi-structured interviews are conducted, which have a lower validity than structured interviews because they are harder to quantify.

## 3.5 Conclusion

This study uses the historical case study of policy on material constraint in Britain during WWII and the contemporary case of policy on material constraint in the Netherlands from 2008-2018 to test the theoretical framework as developed in Chapter 2. The cases are analysed according to a structured, focused comparison aimed at providing insight into the role of governance in bringing about a sustainability transformation that increases resilience to critical materials problems. The primary dependent variable for the comparison is the level of material constraint in society for the cases, and the independent variable is governance on material constraint. The values for these variables are found using a set of philosophical and instrumental questions. The answers to these questions for the historical case of Britain during WWII are found using a literature review. For the contemporary case of the Netherlands, a literature study is used as well, combined with three interviews with government officials.

The first examples of the new utility furniture were shown to the trade in London on Oct. 15, 1942. The show included tables chairs, sideboards and beds. Plywood and all the "Trimmings" of peacetime furniture have been cut out. A utility dining-room suite, with his furniture given a light oak finish. (AP Photo). Reprinted from Baker, 2014.

# *Chapter 4*
# Results

## 4.1 Introduction

This chapter presents the results of both the historical and the contemporary case study, and forms an answer to the second and third sub-question. The results consist of a case description, followed by several sections that provide the answers to the instrumental questions, resulting in an indication of the observed level of material constraint, governance, and resilience.

## 4.2 Material constraint in Britain during WWII

### 4.2.1 Case description

*Theoretical planning from 1918-1936*

During the twenties, after the end of the First World War, there were high hopes of an extended period of peace, and no considerable war was expected in the coming years. From 1919, a peace hypothesis had been formulated, which stated that '*it should be assumed that there will be no major war for ten years*' (Committee of Imperial Defence, as cited in Postan, 1952, p. 1). At the same time, the First World War was not long ago, and from this war, they still had the importance of material supply freshly in mind. Even though war was not expected shortly, plans were made to ensure material supplies in case of any war effort. (Postan, 1952; Hancock & Gowing, 1949; Peck, 2016) Under the Committee of Imperial Defence, the Principal Supply Officers' Committee (PSOC) was set up in May 1924 and was there to investigate all matters connected with supply in war. In 1933, the Nazi party took power in Germany, and the political situation worsened. The 'ten-year hypothesis' was repealed, and Germany came to be considered a real threat. The safe period was halved to five years, and these years would be used to adopt an actual rearmament programme. By the end of 1933, Britain appointed an advisory group of leading people from the industry who produced an assessment of the resources that manufacturing needed for the production of armaments. In 1934, the first army expansion programme began to be discussed by the Services and the Government. From 1935 onwards, the first rearmament programme was adopted. From the start, the process appeared to go slow, but a lot was done. There was not yet the intention of creating a war economy, something that would not have been accepted at that time. The rearmament aimed to create peace instead of waging war. It was designed to look powerful on paper but was not necessarily backed up by sufficient establishments or industrial reserves. Additionally, economic and financial factors prevented an all-out deployment of

national resources. (Postan, 1952; Peck, 2016) Until 1936, there was an awareness of the importance of access to materials, especially in times of war, but there was no situation of material constraint at that point. Britain had access to materials from homeland production, Europe, the Empire and global trade. However, they were well aware that the acquisition of specific raw materials would become critical during a war and a list of these was kept so that they could be bought as soon as a warning of an emergency was received. (Postan, 1952)

### *Planning from 1937-1939*

By the turn of 1936-37, the work of the PSOC was taken over by the planning officers in the Service departments. As war was expected sooner than what was previously thought, the Government's attitude towards the accumulation of strategic reserves changed. Planning officers were appointed that conducted detailed planning of production, firm by firm, including a thorough understanding of the company material requirements. Additionally, preparations were made on the supply of raw materials, including the final detailed planning for the required actions to secure strategic supplies. It was assumed that the material demand in the first stages of war would be especially high, while at the same time, war in Europe would severely dislocate European supplies. Because of the neutral state of the United States, no supplies from them could be expected as well. Therefore, the government decided to start building reserve stocks. During the last year of peace, several schemes for reorganising materials supply were developed, taking into account the expected changes in international materials supply, the development of domestic supplies of timber and iron ore, the identification of scarce materials and the opportunities to substitute these with other materials. Production was based on a system of priorities, and the entire materials planning was deliberately kept flexible. (Postan, 1952; Peck, 2016) In March 1938, the assumption that rearmament should not impede the course of regular trade was cancelled, mainly because of the aircraft industry, which pointed out that it would not be able to complete the rearmament programme by 1939, but that it would take up to two years longer if regular trade would continue as it was. From that point onwards, the rearmament programme had the priority in the nation's efforts. (Postan, 1952) About a month before the outbreak of the war, in August 1939, the Ministry of Supply and its Raw Materials Department were set up, and a group of essential commodities was placed under control. In the later stages of the war, more and more materials were placed under control.

### *War from 1939-1945*

On the third of September 1939, Britain declared war on Germany after the invasion of Poland. Prime Minister Neville Chamberlain declared:

> *'The Government have made plans under which it will be possible to carry on the work of the nation in the days of stress and strain that may be ahead. But these plans need your help.'*
>
> (BBC Archive, 1939)

Shipping was obstructed right way, which meant that timber in extremely short supply. Speedy action was taken to regulate supplies, using the system of rationing that already existed for food. (Dover, 1991) The war brought about an improvement of living standards, partly as a result of widening government control. An immediate and direct consequence of the war was the reduction of unemployment, which had virtually disappeared by 1941. The need to maintain a healthy workforce meant that the government put a great deal of care into social planning and the provision of goods.

On the fifth of September 1939, a Timber Control Department was set up under the Ministry of Supply, which ensured that all industrial consumers of wood obtained a licence to continue manufacturing. A little less than a year later, in July 1940, all timber supplies for domestic furniture were withdrawn. In the beginning, there were sufficient pre-war hardwood stocks to continue production. Also, plywood had not yet been diverted to the manufacture of the Mosquito aircraft and was therefore still available. When the bombing began in September 1940, the regulation was somewhat relaxed to make timber available for the reconstruction work.

In the beginning, it was assumed that the challenges that would arise for the supply of materials would be responded to accordingly. Therefore, no overarching single materials control policy was applied during this period. The government primarily used price controls and conditions of material purchase, sale and use. The government used a company licensing system for controlling material use at this stage which was primarily on a voluntary basis. However, the loose system of material priorities and price controls did not function correctly. It appeared inefficient and did not manage conflicts in material demand well. As a result, the government shifted to the system of allocations, which allowed for the assessment of the importance to war production for each material. Materials were allocated to government departments, based on quota that were determined for a period between a year and three months. (Peck, 2016)

Many ships were lost due to U-boats which meant losses of supplies. Therefore, the government had to resort to all kinds of solutions to meet materials supply problems, such as larger orders from abroad and economic measures. Overall, it was inevitable to reduce material use drastically in the civilian sector, due to both the losses of supplies and the high demands of the war effort. For example, it has been estimated that around 17 per cent of the wartime supply of timber was directed towards the civilian industry, while the total supply was already far lower than before the war. (Peck, 2016)

The Board of Trade administered the reduction in the supply of various consumer goods and also arranged the controls over the supplies of these goods. Food was rationed from 1940 onwards and clothing and footwear from 1941. They also intended to ration goods such as furniture or silverware, but this proved impracticable. So, the system of priority schemes was introduced to govern the distribution of the most necessary items. During the war, the Board of Trade commendably turned into a production department carrying out increasingly tight controls over many goods. Auxiliary items such as jewellery were banned entirely. Price regulation, limiting supply orders, and concentration of production, licences, and consumer rationing were all tools that were used to control resource use. The primary goal was to divert as many resources as possible to the war effort and also to prevent inflation. Therefore, soon the utility schemes and austerity regulations were introduced as well. The introduction of the utility schemes meant that the Board of Trade got involved in the planning of production by designating the allocation of raw materials and determining the designs of the output in many industries. Such extensive government control over resource distribution and supply and demand had never happened before, and in 1939 the board *'was limited both in knowledge and preparations'* (Hargreaves & Gowing, 1952, p. 14). The planning and executing of the utility and austerity schemes was conducted in close cooperation with several committees which consisted of people from society and the industry. (Zweiniger-Bargielowska, 2000; van Helvert, 2016)

Improved organisation of supply and demand, caused the allocations system to function satisfactorily by April 1941. Allocations could be made to either a specific department, which could then further issue the supplies to contractors, or to the end use, which is the product to be manufactured. The system did not function perfectly, but no system would. (Postan, 1952)

In 1942, the situation around the supply of materials worsened due to the conflict with Japan, the American shift in priorities towards their war production and the increased number of successful U-boat attacks in the Atlantic. However, the allocations systems proved to be robust and kept functioning well throughout the period. In April 1943, consumption of goods was further restricted not to disrupt the production of munitions. In the same period, the Utility Furniture Scheme was introduced to control the production and distribution of furniture. Besides controlling how much was produced, the utility scheme also aimed to reduce power, labour and material used during production. Therefore, detailed recordings and inspections of all stages of the supply chain were kept. Producers needed a licence to produce furniture, and licences were provided strategically since the production was allocated geographically to reduce transportation distances. Specific designs were specified, and it was strictly forbidden to produce anything else than these designs. All of the designs had a unique specification

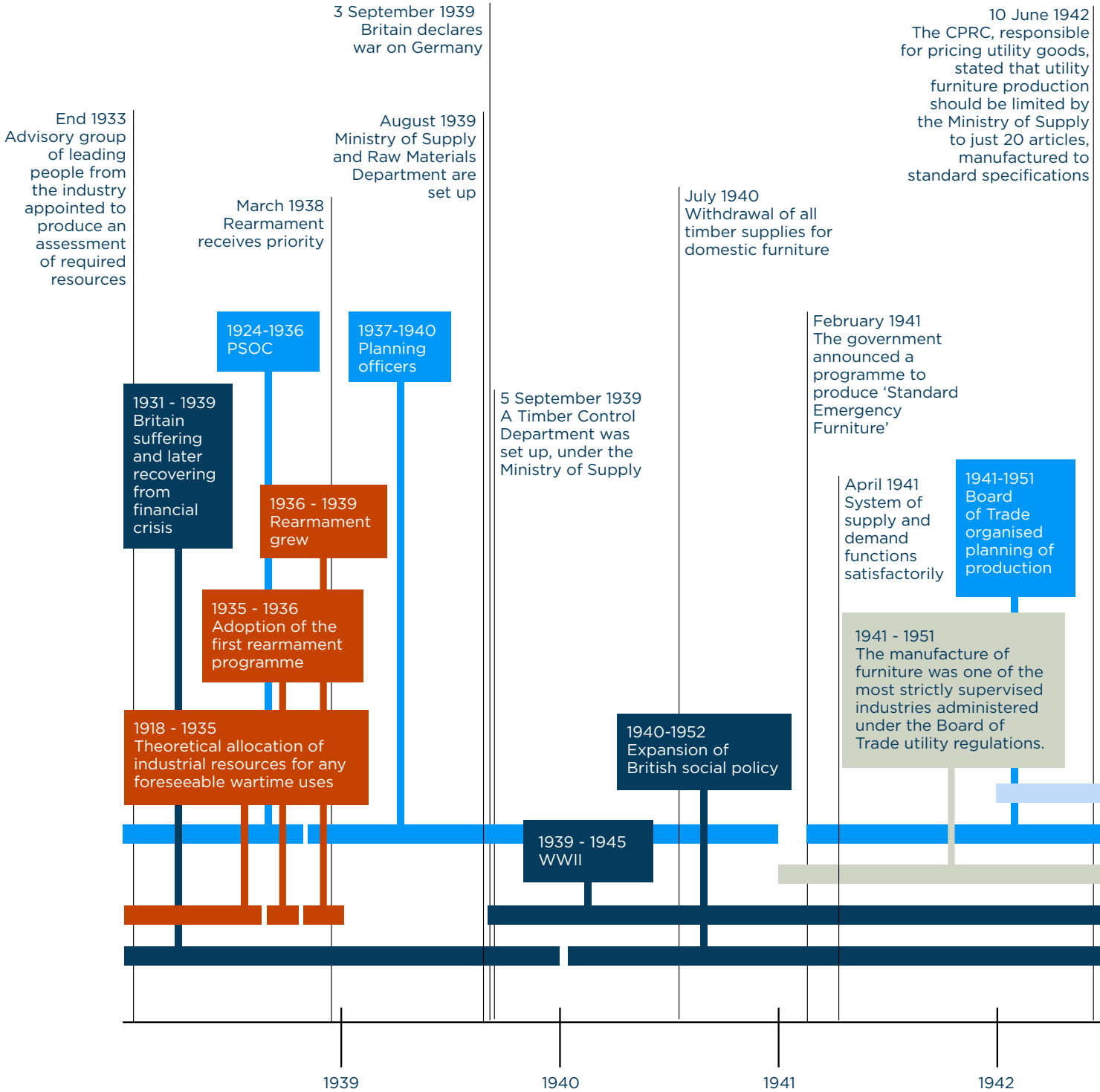
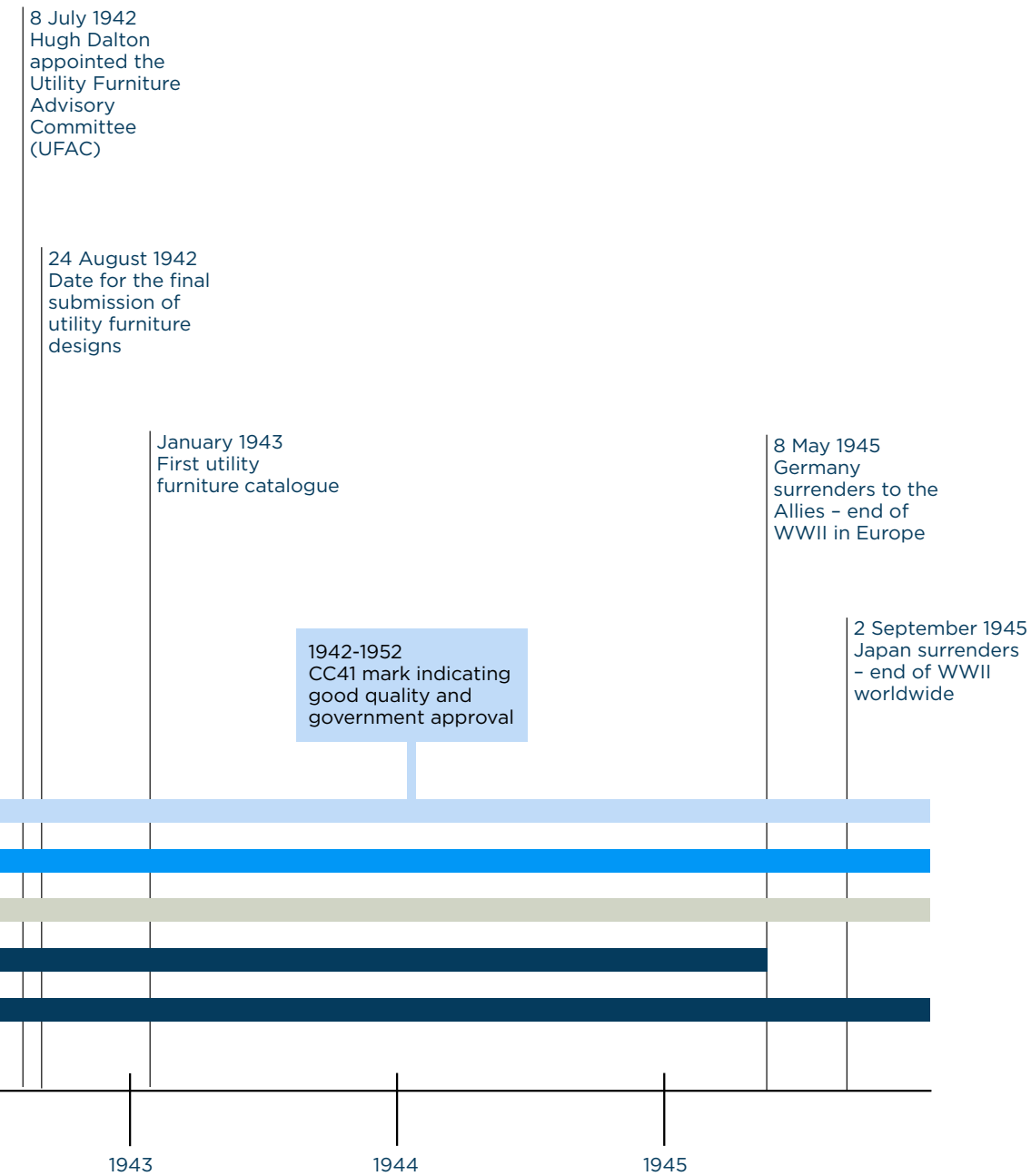



Figure 18 Timeline of material constraint in Britain during WWII.


8 July 1942
Hugh Dalton appointed the Utility Furniture Advisory Committee (UFAC)
24 August 1942
Date for the final submission of utility furniture designs
January 1943
First utility furniture catalogue
8 May 1945
Germany surrenders to the Allies – end of WWII in Europe
2 September 1945
Japan surrenders – end of WWII worldwide
1942-1952
CC41 mark indicating good quality and government approval
1943
1944
1945

number, which was approved by the government. The government encouraged batch production in large runs. The designs were also made in such a way that less skilled workers were needed for the production so that the higher skilled workers were available for the war effort. The government attached much value to ensuring that the furniture that was produced, though limited in quantity, was high in quality to increase durability and provide people with valuable furniture. The Board of Trade gave the items the CC41 Utility logo, in which CC stood for 'controlled commodity', which indicated that the item conformed to the government austerity regulations. After the utility scheme ended in 1952, manufacturers could still use the CC41 logo to indicate that it was an item of high quality. Additionally, it was important that the items were easy to repair and did not have any features that wasted material, such as additional style elements like carvings. Utility furniture had wooden handles instead of plastic ones and solutions were sought to reduce the need for steel screws. (Peck, 2016; Mills, 2008; van Helvert, 2016)

Figure 18 provides an overview of the period of material constraint in Britain and the measures that were applied by the government. A more extensive description of the economic, technological, societal and environmental contexts of the case can be found in Appendix C.

### 4.2.2 Material supplies and price developments

At the time of the start of the war, the principal materials were bauxite, zinc concentrates, wool, flax and rubber. Other essential commodities such as iron and steel, some non-ferrous metals, wool, leather, timber, hemp, flax, jute, paper and aluminium, that were scarce or were in danger of becoming scarce were placed under full control. (Postan, 1952) Right at the beginning of the war, materials such as wood, metals, and rubber were already in short supply. Several measures were taken to minimise the use of materials in the civilian society. For household goods such as ceramics and furniture, utility schemes were introduced to control the number of items produced and the use of materials. Only specified designs could be produced and one needed a licence to produce and to purchase an item. The designs were made to use high quality material, but also had a minimalist style to avoid unnecessary waste of materials on decorative shapes. Also, parts made of scarce materials were avoided or replaced by more commonly available materials. Furthermore, citizens were encouraged and educated to apply the reduce, repair and reuse principles on their items to minimise demand. Auxiliary items such as jewellery were banned entirely. Price regulation, limiting supply orders, and concentration of production, licences, and consumer rationing were all tools that were used to control resource use. The primary goal was to divert as many resources as possible to the war effort and also to prevent inflation. Therefore, soon the utility schemes and austerity regulations were introduced as well. (Zweiniger-Bargielowska, 2000; Peck, 2016; van Helvert, 2016)

Through these measures, material use in the home civilian society was significantly reduced. Several statistics on material use and production, as well as consumption, have been made available in the *Monthly Digest of Statistics* of January 1946 (Central Statistical Office, 1946). Figure 19 shows the British home consumption of some essential metals. Though the consumption of some materials decreases during the war, the overall trend is an increase in material consumption, which can be explained by the high material demand for the war effort. The average increase in the use of aluminium, copper, zinc, lead, and tin is 36.7 per cent, comparing the period before the war (1935-1939) to the war period (1940-1945) (see Table D.1 in Appendix D). The increased demand could be supplied through, for example, increasing home production of these materials. Figure 20 and Figure 21 show the increased levels of iron, aluminium, and magnesium production during the war. However, the majority of the materials available to Britain was directed towards the war effort, causing a severe reduction in materials available to the civilian society. The *Monthly Digest of Statistics* does not provide any information on the distribution of the total amount of materials between the war effort and the civilian society, or any other data on raw materials available to the civilian society. Nonetheless, it does provide numbers

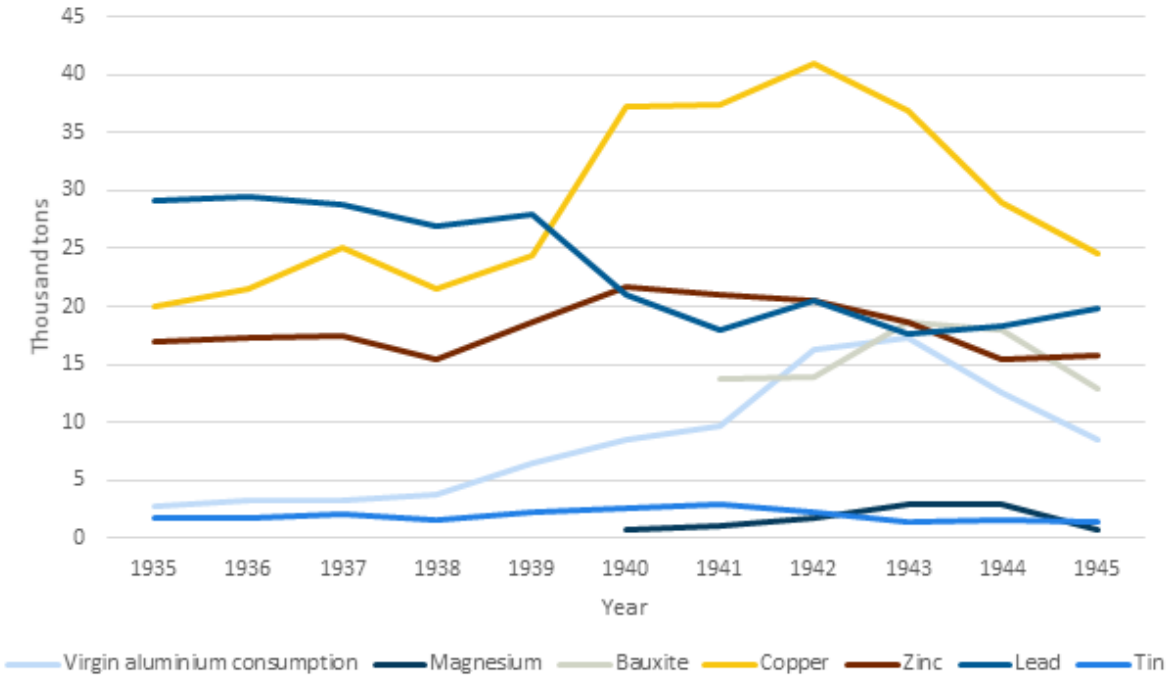



Figure 19 Home consumption of essential raw materials, monthly averages. Data from Central Statistical Office (1946).

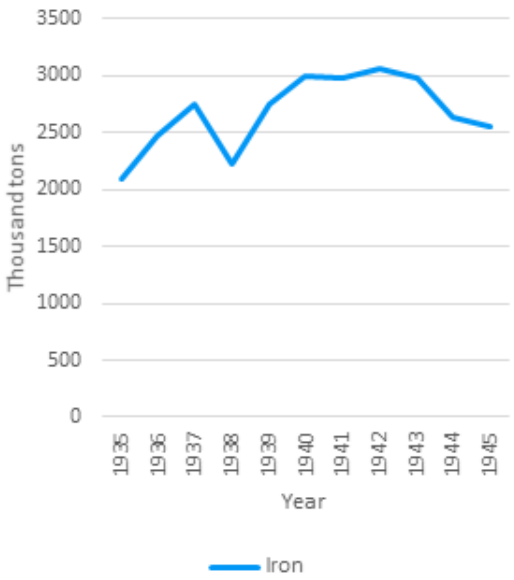



Figure 20 Home iron production, monthly averages. Data from Central Statistical Office (1946).

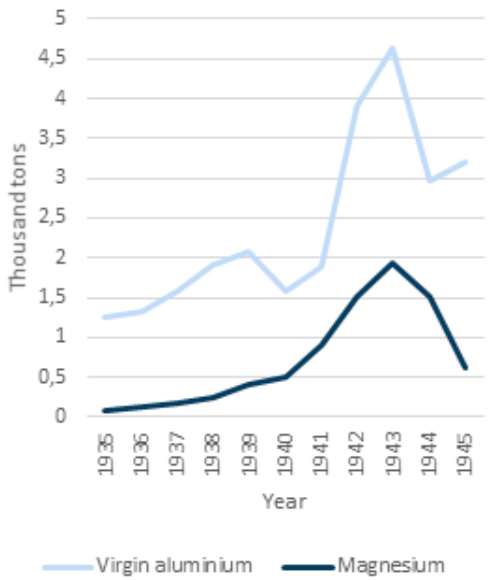



Figure 21 Home aluminium and magnesium production, monthly averages. Data from Central Statistical Office (1946).

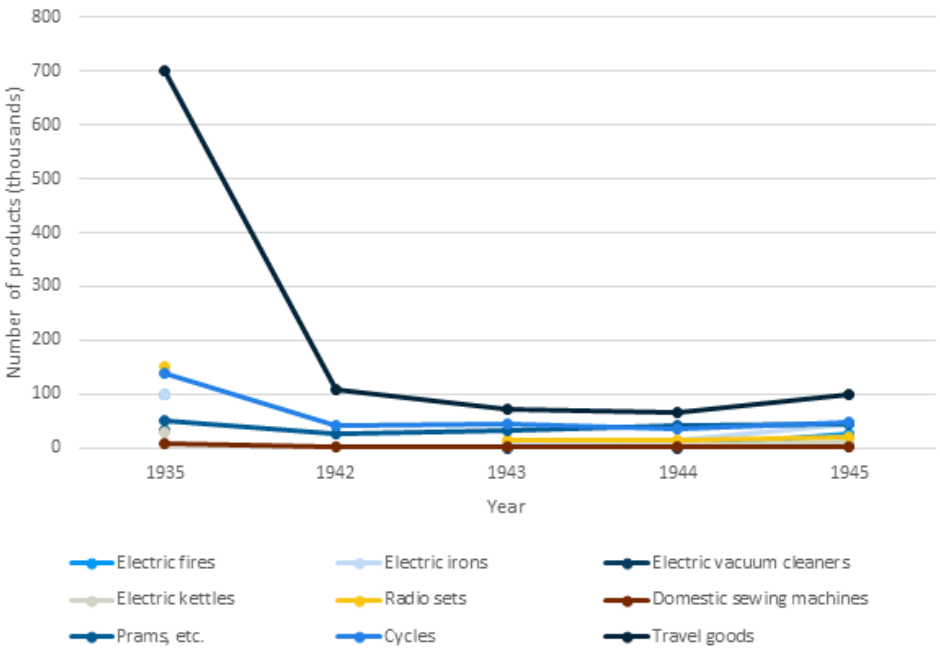



Figure 22 Supplies of household appliances for the home civilian market, monthly averages. Data from Central Statistical Office (1946).

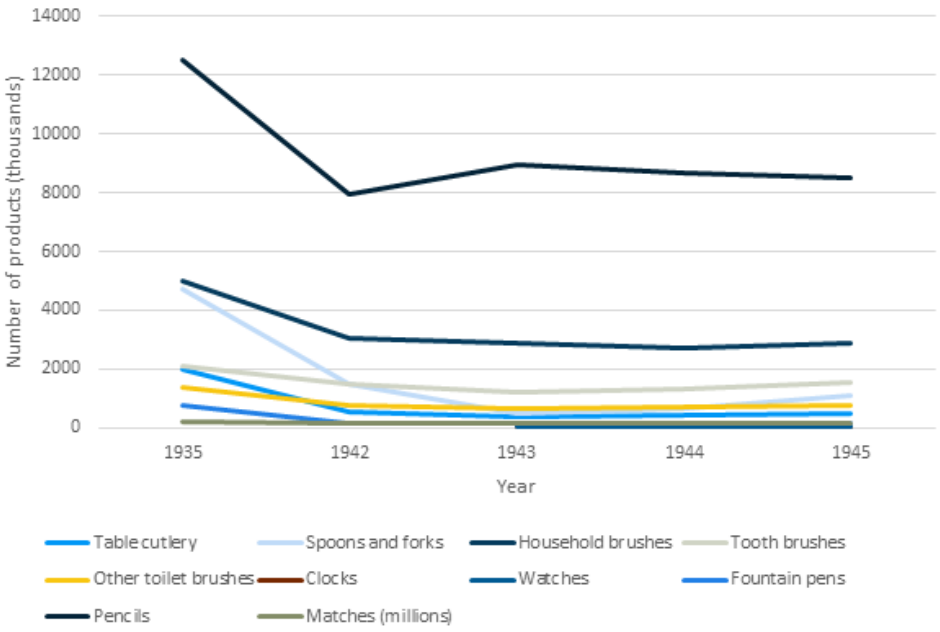



Figure 23 Supplies of miscellaneous goods for the home civilian market. Data from Central Statistical Office (1946).

on the supplies of products to the home civilian market. Since these products were produced using the available materials, these numbers provide an indication of the severity of material constraint experienced by the civilian society in Britain during WWII.

The statistics show an average decrease in the number of household appliances available to the home civilian market of 76 per cent (Figure 22) and a decrease in miscellaneous goods of 61 per cent (Figure 23), which is an average of 69 per cent (see Table D.2 and Table D.3 in Appendix D).

Figure 24 confirms the observation that the availability of goods to the civilian society was significantly reduced. The graph in Figure 24 is based on constant prices to correct for any price increases that could arise because of the supply shortages. When looking at the raw data, a drop of 20 per cent in consumer expenditure between around 1938 and 1944 can be observed. These data include categories such as food and clothing. The purchasing of miscellaneous household goods decreased by 27-75 per cent (Hargreaves & Gowing, 1952), a range that matches the calculation of 69 per cent. Therefore, the level of supply reduction in Britain is rated as high.

A second aspect of the availability of goods is the price of the materials and the products. The known sources do not report on any price developments in consumer products. However, in general, it is known that the government aimed to stabilise prices as much as possible and to apply rationing to make supplies available to people of all income groups. Therefore, the price developments of raw materials might provide the best indication of the constraint of these materials.

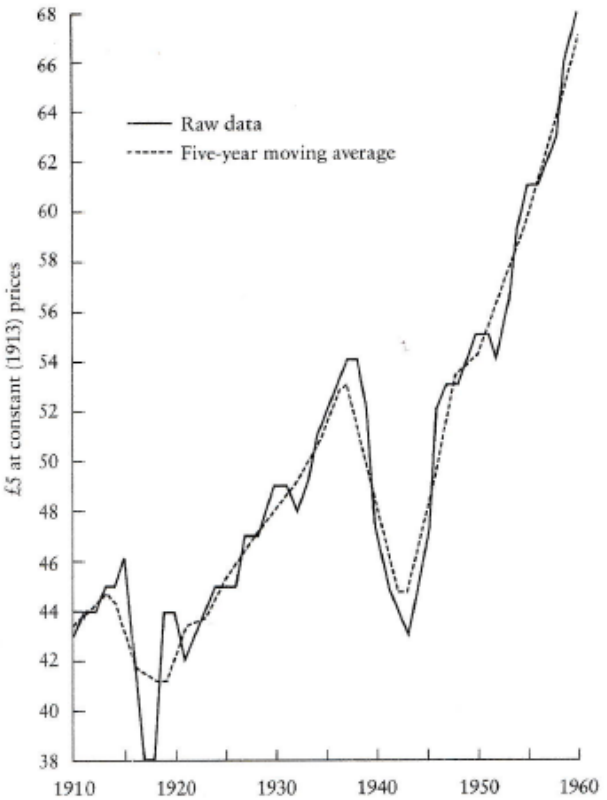



Figure 24 Consumers' expenditure per capita at constant (1913) prices, 1910-1960. Reprinted from Zweiniger-Bargielowska, 2000.

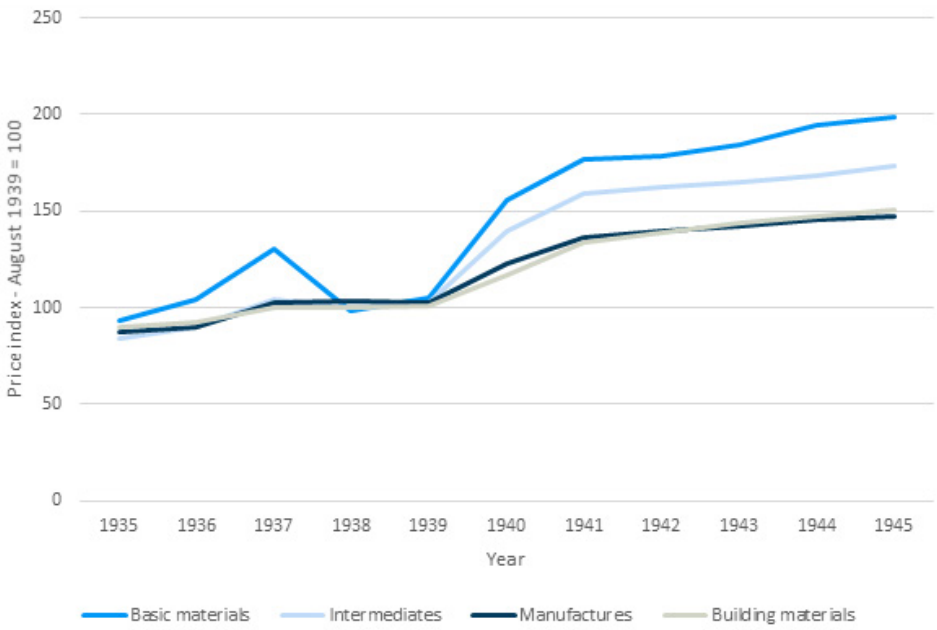



Figure 25 Price developments of industrial materials and manufactures. Data from Central Statistical Office (1946).

Figure 25 shows that the prices of industrial materials rose substantially during the war, between 50 and 100 per cent. The average price increase of these four categories, comparing the period of 1935-1939 to 1949-1945, is 83 per cent (see Table D.4 in Appendix D). Therefore, the level of price increase in Britain is rated as high.

### 4.2.3 Governance of change

The full process of developing and executing the plan for times of material constraint in Britain took a total of 26.5 years. The first eighteen years were a period of theoretical planning which stemmed from the realisation of the importance of access to materials during times of war. Sooner than expected, the investigations needed to be accelerated and actual planning was started. However, during the period from 1933-1936, the primary focus was on (theoretical) rearmament instead of adopting strategies to secure supplies. From 1936 onwards, the necessity of detailed planning of supplies was recognised, and planning was conducted in a detailed manner over a period of 2.5 years. In May 1924, the Principal Supply Officers' Committee (PSOC ) was set up to investigate all matters connected to supply in war. They prepared plans for the provision of commodities essential to a war effort, watch stocks of raw material, and maintain a list of contractors. Part of the PSOC was the Board of Trade Supply Organisation which looked after raw materials, and the Supply Board which planned for the production of war-stores. The Supply Board again was split into several committees dealing with different sectors. By the turn of 1936-37, the plans were sufficiently advanced, and the work of the PSOC was taken over by the planning officers in the Service departments. The planning officers conducted detailed planning of production by conducting a firm by firm analysis to develop a thorough understanding of the material requirements of the companies. Additionally, preparations with regards to the supply of raw materials were made. These preparations included final detailed planning for the required actions

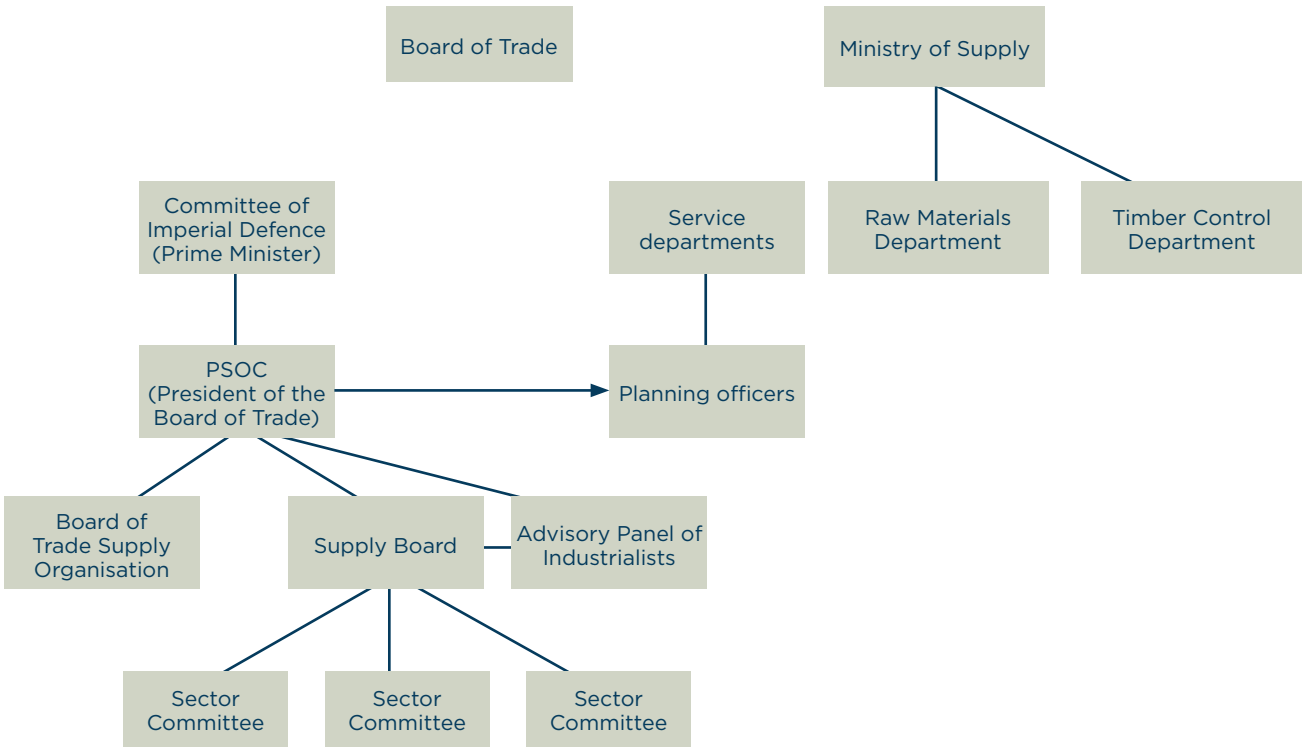



Figure 26 Organisation of different government institutions in Britain during WWII. Adapted from Miller, 2018.

to secure strategic supplies. It was assumed that the material demand in the first stages of war would be especially high, due to rearmament. A high demand combined with severely dislocated supplies because of a war in Europe and the fact that the United States was expected to adopt a neutral state and therefore no supplies from them could be expected, special precautions were necessary to survive this period. Therefore, the government decided to start building reserve stocks. Additionally, during the last year of peace, several schemes for reorganising materials supply were developed, taking into account the expected changes in international materials supply, the development of domestic supplies of timber and iron ore, the identification of scarce materials and the opportunities to substitute these with other materials. Production was based on a system of priorities, and the entire materials planning was deliberately kept flexible. About a month before the outbreak of the war, in August 1939, the Ministry of Supply and its Raw Materials Department were set up. On the 5th of September 1939, a Timber Control Department was set up under the Ministry of Supply, which ensured that all industrial consumers of wood obtained a licence to continue manufacturing. During the war, the Board of Trade commendably turned into a production department carrying out increasingly tight controls over many goods. The introduction of the utility schemes meant that the Board of Trade got involved in the planning of production by designating the allocation of raw materials and determining the designs of the output in many industries. Such extensive government control over resource distribution and supply and demand had never happened before. In the beginning, it was assumed that the challenges that would arise for the supply of materials would be responded to accordingly.

Therefore, no overarching single materials control policy was applied during this period. The government primarily used price controls, and conditions of material purchase, sale and use. The government used a company licensing system for controlling material use, which was primarily on a voluntary basis at this stage. However, the loose system of material priorities and price controls did not function correctly. It appeared inefficient and did not manage conflicts in material demand well. As a result, the government shifted to the system of allocations, which allowed for the assessment of the importance to war production for each material. Materials were allocated to government departments, based on quota that were determined for a period between a year and three months. Improved organisation of supply and demand caused the allocations system to function satisfactorily by April 1941. Allocations could be made to either a certain department, which could then further issue the supplies to contractors, or to the end use, which is the product to be manufactured. The system did not function perfectly, but no system would. (Hargreaves & Gowing, 1952; Peck, 2016; Postan, 1952; Zweiniger-Bargielowska, 2000)

Figure 26 provides an overview of the governmental structure that was in place to organise the planning and distribution of the supplies. The arrow indicates how, at the start of 1937, the work of the PSOC was taken over by the planning officers of the Service Departments. The chart also indicates the complexity of the government system and the number of departments involved in supply issues. It is, therefore, not surprising that conflicting priorities were not handled well since there was no overarching strategy. The governance system transitioned towards a new system of allocations which functioned satisfactorily.

Therefore, some form of transformation can be recognised in the British preparations for a time of material constraint. New departments specifically focused on supplies, such as the PSOC and the Ministry of Supply were set up during the planning phase. Once the war broke out, the government transitioned towards aligning interests through the allocations system. However, it was instead a top-down imposed alignment through the authority of the Board of Trade and the allocations system than an alignment of fundamental goals and values. The fact that such an alignment had not been undertaken during the planning years, probably required the top-down approach taken during the war, when there was no time to develop a long-term transformation process. Additionally, before and during the war there was no focus on developing the different roles of the government. The different roles were all present to some extent but were not further developed to accommodate the process of transformation.

The British government tried to include a diversity of societal actors in the transformation process. For the rearmament programme, private businesses had to apply for and execute orders for the production of war equipment. The Service Departments were in charge of arranging these orders. However, the distribution of orders did not always run perfectly smooth, and industrial parties could reach out to the Service Department with complaints. However, the complaints did not always receive the attention that they should and the Service Departments were sensitive to these complaints as they were sometimes perceived as accusations. Therefore, the Prime Minister set up an independent Industrial Advisory Panel – also called Advisory Panel of Industrialists – composed of six businessmen, who would receive and process any comment about delays, defects, or difficulties in supply or production with regards to the rearmament programme. Based on these complaints they would then propose remedial actions and general improvements to the programme based on frequently occurring issues. The panel was accessible to any industrial party, which could directly reach the highest level of government through their comments, as the panel reported directly to the Prime Minister. (Hansard, 12 December 1938 col 1613-8) Therefore, the panel allowed all kinds of businesses, from small to large, to influence the transformation process. However, their influence was limited to suggesting improvements to the existing system, if a part of the system would not function well. The industrial parties, as well as other societal parties such as individuals from the civilian society, knowledge institutions or other organisations, did not influence the development of goals and the system that was put in place to reach those goals.

(Hargreaves & Gowing, 1952; Peck, 2016; Reimer & Pinch, 2013)

Another advisory committee that was established was the Utility Furniture Advisory Committee (UFAC) which consisted of nine people of diverse societal backgrounds, including people from research and the industry. The committee was chaired by the designer Gordon Russell, and further consisted of the designers Ernest Clench, and John Gloag, who was also a writer in the fields of furniture design and architecture. Herman Lebus, the chairman and managing director of the Harris Lebus furniture factory, which produced utility furniture during the war, was also part of the committee. The consumer interest was represented by Mrs Elsie Winborn, who was a member of the Tenants' Committee of the Kensal House Estate. The members were selected to represent the furniture manufacturing industry, furniture designers, trade unions, housing specialists, and consumers. (Reimer & Pinch, 2013) This committee had a larger role than the Industrial Advisory Panel since its role was to determine which designs would be selected for the utility furniture programme. An attempt was made to gather a group of people with diverse backgrounds but included only one end user. However, it must be said that Mrs Elsie Winborn was likely a working-class woman with a modernist outlook since she lived in the Kensal House Estate. The Kensal House Estate was built in 1938 as part of a progressive, modernist housing scheme aimed at the working class rather than the intellectual middle class, which most modernist homes were aimed for at that time. (The Open University, 2001) Still, all the member of the committee were selected by the government, allowing the government to only select members with a preferred background and attitude.

In general, it can be said that the British government did not involve societal actors in defining the vision and goals for the transition. However, at some points, societal actors were involved in the execution of the plans, and when they were, an attempt was made to include a diversity of people in the process. The government did not attempt to adopt a networking role when defining the vision and goals. War is also an urgent situation which requires strong leadership and authority rather than a discussion between a variety of actors.

The primary goal or 'vision' of the British government was to fully control resource use to redirect as many resources as possible to the war effort and ultimately win the war. Additionally, there was the goal to maintain a basic standard of living for every person in the civilian society, in order to preserve the morale of the home front which was seen as essential to support the military, both physically in producing military supplies, and emotionally in supporting the army and enduring attacks such as the bombings. The economy and production were entirely controlled to support these goals. The government aimed to prevent inflation and to equally distribute the supplies that were available. Controlling prices was an important goal since war tends to tempt people into profiteering, which the government wanted to prevent. Technological development for the civilian society was aimed at reducing material use and substituting materials required for the war effort for materials that were not essential to the war in the production of new goods. The government also aimed for extending the lifetime of new and existing products. The goals that were defined by the government are specific to the local situation and provide direction to the measures that need to be taken. However, the goals are mainly aimed at the social system and do not take into account the ecological system. The level of direction is therefore rated as average.

Tools such as price regulation, taxes, the limiting of supply orders, concentrating production, issuing licences, and consumer rationing were used to control resource use and inflation, and prevent profiteering. These are all top-down regulations which needed to be observed, with the risk of receiving high fines or even imprisonment when not obeying the orders. There was little room for bottom-up innovation since the direction of research and development was also determined by the government. In many fields, companies did not have the freedom to develop and produce anything they would like but needed to produce the specified designs from the austerity and utility programmes such as utility furniture.

Still, the war provided a technological boost, since many war machines and related technologies needed to be developed. Similar developments on the side

of the enemy further accelerated these developments. Moreover, equipment was lost because of bombing and needed constant replacement. The equipment was made using a relatively small number of elements from the periodic table, which reduced the complexity of obtaining supplies or substitution to some extent. Additionally, the government encouraged batch production in large runs. The designs were also made in such a way that less skilled workers were needed for the production so that the higher skilled workers were available for the war effort. Even though there was lots of technological innovation during the war, true bottom-up social and technological innovation was not encouraged. The government applied a diverse range of social and technological innovations to achieve the goals. However, the room for bottom-up innovations was heavily restricted, since the government significantly extended its control. Individuals were encouraged to be creative in using the available resources, but businesses were often not allowed to develop their products which limited innovation. Additionally, the government did not attempt to create windows of opportunity in the governance system to allow bottom-up innovations to enter the mainstream market. Therefore, diversity, in this case, is rated as average.

The state introduced standardised designs through the austerity and utility schemes which reduced waste, avoided unnecessary material use, and reduced the requirement of (skilled) labour during production. All of the designs had a unique specification number, which was approved by the government. The government attached much value to ensuring that the furniture that was produced, though limited in quantity, was high in quality to increase durability and provide people with valuable furniture. The Board of Trade gave the items the CC41 Utility logo, in which CC stood for 'controlled commodity', which indicated that the item conformed to the government austerity regulations. After the utility scheme ended in 1952, manufacturers could still use the CC41 logo to indicate that it was an item of high quality. (Peck, 2016; Mills, 2008; Inner London Education Authority, 1974)

The material scarcity experienced in Britain was entirely caused by the effects of war. On the one hand, the loss of supplies due to the occupation of allied countries and the sinking of supply ships by U-boats, and on the other hand the diverging of the majority of available supplies towards the war effort. Only a small percentage of pre-war material supplies were available to the civilian society. Detailed planning, creativity, and especially making do with less proved essential to preserve the critical balance between civilian society and the military. The window of opportunity, in this case, was a crisis, the crisis of total war, which allowed change to happen. Social equality increased because of rationing, subsidies, price controls and the fair shares policy. The government also took the situation as an opportunity to introduce high quality, modern designs of good taste to the public.

During the war, the plans from the previous years were adopted and refined. Especially in the beginning, there was less focus on balancing supply between the military and the civilian society, however, after the first few months when the priority system proved not to function sufficiently, the allocation system was introduced which provided a more useful tool for balancing military and civilian demands. A lot was asked of people, as freedom was taken away in many ways, and the rationing and utility schemes provided an everyday struggle for housewives to obtain the necessary supplies. Consumer choices were significantly reduced, because of the limited amount of materials available and the specified designs by the utility schemes. In addition to the reduction in choice, the amount available was also significantly reduced since many products were only available upon specific needs or situations. At the same time, the extensive effort to support the war effort by restricting civilian material use also resulted in a stable societal situation. Unemployment virtually disappeared, providing steady earnings, and the high tax regime levelled income and increased equality. Rationing and utility schemes promoted equal distribution of the available goods and food rationing provided sufficient calories, and a relatively healthy diet compared to pre-war years. The government had also fixed the prices of furniture under the Utility Furniture Scheme which allowed all income groups to purchase furniture. In order to provide those who needed it most with furniture, buying permits were issued to people with high priority,

such as people who had been bombed out or were just married. People who received a buying permit gained access to a limited number of coupons which could then be used to purchase the furniture. Also, through the Utility Furniture Scheme, the government made high quality, modernist design furniture available to everyone. The fair shares policy contributed to the maintaining of morale even though supplies were significantly reduced. However, the system did not function perfectly, and problems with distribution did occur. A Consumer Needs Branch was established that served as a '*most useful two-way channel of information between the Board and its distributing and consuming public'* (Hargreaves & Gowing, 1952, p. 302) to address the problem. (Zweiniger-Bargielowska, 2000; Hargreaves & Gowing, 1952; Peck, 2016)

At the time of the war, environmental issues were barely a problem, as the most severe effects of the Industrial Revolution were yet to come. In the period, there was some attention to the preservation of the beauty of the British countryside, but this issue did not play a role with regards to the war or material supplies. On the contrary, since the import of timber had decreased so drastically, imported softwoods were substituted by locally grown hardwoods, and a sizeable amount of forests was cut down during the war. The consumption of home-grown softwood increased with 57 per cent and the consumption of home-grown hardwood increased with 114 per cent between 1940 and 1944, the year in which peak consumption of home-grown wood occurred (see Table D.5 in Appendix D). These the developments show that, especially with regards to hardwood use, the ability of future generations to meet their needs were deemed inferior to the need of the present generation to win the war. Which is a balancing act, since the future generations also benefit from the freedom they receive from winning the war, for which they are probably willing to pay the price of cutting down the forests. Moreover, wood is a renewable material source, and with the right management, the forests can grow back.

Regarding the economic situation, the government had a strong sense of equally distributing the available resources and applied a range of measures to ensure fair distribution. Additionally, the utility and austerity schemes did not only aim to save materials and provide a way to distribute the available furniture among those who needed it most. The scheme was also intended to provide people of all incomes, especially caring for the lower income classes, with affordable, high-quality designer furniture that would last them a lifetime. The situations around wood consumption is less clear-cut than the situation of mineral and metal consumption. The consumption of homegrown wood increased drastically, limiting future generations in the ability to meet their needs and therefore not equally distributing the disadvantages of the measure. Overall, the focus was primarily on the equal distribution among today's generation, and less attention was paid to equal distribution between generations. Therefore, distribution is rated as average.

### 4.2.4 Resilience to material constraint

As discussed in the previous paragraphs, the system was able to absorb large disturbances in the supply of materials while retaining its fundamental function and structure. The reduction in material supply to the society was severe, which shows that the system has considerable latitude. The system can absorb a sizeable maximum change. Second, the system showed high flexibility, as quite extreme measures, such as rationing, were applied while the system, in general, kept functioning. The high flexibility of the system contributes to a high resilience of the system and is therefore rated as high.

These first two indicators point towards high resilience of the system, however, the system itself did find itself close to its boundaries since it was pushed towards those boundaries to support the war effort in all aspects. Regarding society, the government carefully balanced the requirements of the war effort with the requirement of the civilian society. Ideally, all resources would be directed towards the war effort, but the civilian society required the provision of its basic needs, which was eventually beneficial to the war effort as well since a strong home front supported the military efforts. The environment was pushed to its limits to provide supplies that would have otherwise been imported, such as wood. The economy

was forced to under full government control to be able to use the available materials most efficiently and prevent profiteering. Moreover, technological innovation was pushed to do more with the available materials, regarding finding substitutes and for example using connection methods that did not require scarce materials. For example, the furniture was designed to be assembled without using screws.

Before the impacts of material constraint, Britain found itself in a relatively wealthy state with an extensive international network because of its Empire. It was also not as harmed by the crisis of the 1930s as other countries and therefore in a quite stable financial situation. Thus, Britain was far from any boundaries and precariousness is rated as high.

## 4.3 Material constraint in the Netherlands from 2008-2018

### 4.3.1 Case description

*Security of supply*

In 2008, the Dutch Prime Minister's Office (Cabinet) asked the Ministry of Housing, Spatial Planning and the Environment (VROM) and the Ministry of Foreign Affairs (BZ) to start a project group. Together with the other ministries, relevant Advisory Councils, the various planning agencies and other knowledge institutions, the project group developed knowledge on the subject of the global scarcity of essential resources such as food, water, energy, minerals and metals. The project was initiated because of the growing concern about the availability of resources. Already in 1972, the Club of Rome had warned about the exhaustion of natural resources. In the following years, this threat could be suspended every time because of the discovery of new sources or technological innovation. However, even though the consequences were not yet felt, the Dutch government realised that the earth's resources are not inexhaustible and that a consistent supply is never guaranteed. Additional issues are the growing world population and increasing prosperity, which require an increasing amount of resources while at the same time the extraction of these resources is detrimental to the environment, climate and biodiversity. At the same time, the government saw international relations change as economies became more intertwined because of globalisation and also the rise of emerging economies such as China, India and Brazil which increased the (experienced) dependency on the supply of essential resources by these countries. The specific request of the Cabinet for a report on the global scarcity of essential resources in April 2008 should also be seen in the light of the high energy and food prices, combined with the growing concern about the effects of climate change. (Bastein, Rietveld, & van Zyl, 2014; Projectgroep Schaarste & Transitie, 2009)

In November 2009, the project group *Schaarste & Transitie* (Scarcity & Transition) published their report, which formed the starting point of the actual research. The report contains three main knowledge issues with an explanation of why these issues are important and providing a starting point for further research. In the same month, Wouters and Bol of the Materials innovation institute (M2i) publishes a study, that was requested by TNO, on material scarcity which reaches the conclusion that material scarcity is a serious issue and that the best way forward includes increasing recycling and reuse, substituting materials, advocating a change of lifestyle among consumers and designing products for recycling. (Projectgroep Schaarste & Transitie, 2009; Wouters & Bol, 2009)

Additionally, in 2010, Statistics Netherlands (CBS) published an explorative study within the framework of the project *Duurzaam materialenbeheer* (Sustainable materials management). Together with TNO and the Institute of Environmental Sciences Leiden (CML), CBS researched the dependency of the Dutch economy on 44 materials upon request of the Ministry of Economic Affairs (EZ). The list of 44 materials consisted of the 41 materials researched by the Ad-hoc Working Group on defining critical raw materials, to determine the 2010 list of critical raw materials for Europe. Based on expert input, phosphorus, uranium and gold were added to this list to arrive at the number of 44 materials. The research indicated that the majority of the Dutch industries were

not highly dependent on critical materials. The industries that use the largest amounts of critical materials in the Netherlands appeared to be the manufacturing industries of transport equipment, basic metals and metal products, and machinery and equipment. (Statistics Netherlands, 2010)

Following these reports, and global as well as European developments in the field of resource supply, the observation that critical minerals and metals are essential for the sustainability of the Dutch economy and their supply is increasingly under the attention. Because of the increasing demand from emerging economies, and the export restrictions that China had already used as a power resource, the Cabinet was asked to develop a coherent policy on securing resource supply. The Cabinet delivered the *Grondstoffennotitie* (Policy Document on Raw Materials) in July of 2011. It was a time of worries about the security of supply, especially since China and Japan just argued about critical raw materials. The policy document states that the Dutch policy on raw materials would follow European policy where possible, and add national policy where needed. An important principle for the national policy on raw materials is that solutions are primarily the responsibility of the private sector and that the government will aid and facilitate where needed. According to the Policy Document on Raw Materials, the government would primarily commit to stimulating recycling and finding new supply routes, reducing the national demand and making it more sustainable, and making the use of resources in the Dutch economy more efficient and sustainable. Together with the Policy Document on Raw Materials, the first *Grondstoffengezant* (Special Envoy National Resources), Jaime de Bourbon de Parme, was appointed by the Ministry of Foreign Affairs with the special assignment to contribute to a socially, economically and ecologically sustainable access to, exploitation of, and use of natural resources. (Nicolaï & Ormel, 2010; Rosenthal, Verhagen, Atsma, Knapen, & Bleker, 2011)

On a European level, in 2008, the significance of access to raw materials and the need to form a common European approach resulted in the development of The European Raw Materials Initiative (RMI). The RMI aims to provide a just and sustainable supply of raw materials from international markets, as well as a sustainable supply of raw materials within the EU. It also promotes resource efficiency and aims to increase the supply of secondary raw materials through increasing the efficiency of recycling. (Commission of the European Communities, 2008) The European policy on raw materials was extended with the European Innovation Partnership (EIP) on Raw Materials, which reinforces the Raw Materials Initiative (2008) and plays a significant role in securing research and innovation funding. The Horizon 2020 programme is the largest EU research and innovation programme and runs from 2014 to 2020. It aims to research the possibilities to reach a smart and sustainable future with inclusive growth and jobs. Ad-hoc Working Group on Defining Critical Raw Materials of the European Union published its first report with a list of critical raw materials in 2010. For this list, 41 (groups of) raw materials were researched, and 14 were identified as critical. For the second list, 54 materials were analysed, and 20 were identified as critical, and for the 2017 list the assessment was conducted for 78 materials, and 27 ended up on the list. (European Commission, 2010; European Commission, 2014; European Commission, 2017)

### *The circular economy*

In September 2016, the government's attention for critical materials returned with the *Rijksbreed programma Circulaire Economie* (Government-wide programme for a Circular Economy), titled *Nederland circulair in 2050* (A Circular Economy in the Netherlands by 2050). With this programme, the focus shifted from security of supply to the circular economy, which is presented as a solution to both critical materials problems and sustainability issues. However, this is not the first policy related to the circular economy, since this government-wide programme was developed upon request of Çegerek and Dijkstra (2015) who had observed the presence of several policies and collaborations around the circular economy and asked the government to develop an overarching programme for the circular economy. The programme forms the starting point of the transition of the Netherlands towards a circular economy in 2050. The transition should reduce

the Dutch dependence on the import of critical raw materials and contributes to a cleaner environment. The programme builds on the existing green growth programmes *Van Afval Naar Grondstof* (VANG, From Waste To Resource) and the Biobased Economy. The primary goal of the transition towards a circular economy is to provide future generations with the access to material wealth. Therefore, the input of primary material should be drastically reduced (by 50 per cent in 2030) by increasing the reuse of materials at their end of life and reducing demand in general. At the same time, the government realises that a perfectly circular economy is not realistic and therefore also focuses on the sustainable extraction of raw materials. The specific activities of the government to accelerate the transition consist of reducing barriers by changing legislation, stimulating the economy, making funding available, stimulating knowledge and innovation and cooperating internationally; developing a *Nationaal Grondstoffenakkoord* (National Agreement on the Circular Economy) and developing transition agendas for the five priority industries (Rijksoverheid, 2016)

The National Agreement on the Circular Economy was presented in January 2017, signed by the National Government as well as several other parties. Any party who wishes to join the shared commitment to transition towards a circular economy has been welcome to join, and currently, the agreement has been signed more than 300 times (Programmabureau Nederland Circulair in 2050, n.d.). Besides creating commitment among companies and institutions to endeavour the transition towards a circular economy, the agreement also expresses the intention to develop the five transition agenda's mentioned previously. (Rijksoverheid, 2017)

In January 2018, the five transition agendas were presented. The transition agendas are intended to mark '*the end of the beginning*' (Meijer, Nelissen, Rakhorst, Keurentjes, & Kaanen, 2018, p. 4) and aid the start of going from words to deeds. The five themes of the transition agendas are Biomass & Food, Plastics, Manufacturing, Construction, and Consumer goods. The focus for Construction is on substituting the currently used materials as far as possible with biobased materials. For 'Consumer goods', the transition agenda encourages the minimisation of single-use items such as packaging and a service-based business model for the consumer goods with medium to long lifespans such as clothing or washing machines. The goal for 'Plastics' is to use solely recycled or renewable materials for their production. The 'Manufacturing industry', which is most vulnerable to critical materials problems, needs to become circular to remain competitive in the global market. (Meijer, Nelissen, Rakhorst, Keurentjes, & Kaanen, 2018; van Veldhoven - van der Meer & Wiebes, 2018)

Figure 27 provides an overview of the policy developments around material constraint in the Netherlands. Appendix E further describes the economic, technological, societal, and environmental context of the case.

### *Interviews*

The three interviews with Mattheüs van de Pol from the Ministry of Economic Affairs and Climate, Kees Veerman from the Ministry of Infrastructure and Water Management, and Dirk-Jan Koch from the Ministry of Foreign Affairs are coded in according to the methodology described in Chapter 3. After the precoding and the preliminary coding, three full rounds of coding were done to obtain the final codes. Between the coding rounds, the codebook has been updated to match the new code structure and develop the categorisation. During the process, the categorisation evolved towards the five categories of the theoretical framework: governance, economy, technology, society, and environment. Therefore, the codes are organised according to these categories. The codebook can be found in Appendix F. The following paragraphs provide a summary of the interview results. For each interview, the codes are labelled according to their main category, and the number of codes in each theme is counted. This way, graphs are made that display the prevalence of the categories in the different interviews (Appendix G).

### Governance

The results show first of all a high presence of governance-related statements, which is understandable since all three participants work for the government and the

interview questions were related to governance. However, Veerman has a notably lower score for *governance* compared to the other two participants and a relatively high score for *economy*.

Regarding government policy and international relations, export restrictions are a significant topic. Exporting countries increasingly resort to export restrictions to protect their markets. The WTO attempts to curb this development, but it remains problematic. According to Koch (personal communication, March 13, 2018), this development does not show that these countries are after weakening dependent countries, but export restrictions come more out of an effort to increase the value of materials before exporting them. Van de Pol (personal communication, February 19, 2018) states that manufacturers will primarily feel any consequences of severe disruptions in material supply in the Netherlands.

On a national level, developing ambitious goals as a government creates friction within the business community. For example, when developing the Government-wide programme, the goal of 50 per cent primary resource reduction in 2030 was included. However, during the following step in the process, the writing of the National Agreement on the Circular Economy, heavy lobbying from business organisations resulted in the disappearance of the 50 per cent resource reduction goal. The businesses did agree to the development of five specific transition agendas. The transition agendas were, first of all, delivered more than half a year later than promised, and second, are still far from concrete, which shows that there is still quite some resistance to change among businesses. At the same time, Koch indicates that businesses are also asking the government to determine a clear, long-term vision for the government policy and would like a more directive role of the government. An explicit government vision would allow them to develop long-term (sustainable) strategies, and plan for the future. It would also remove the competitive disadvantage of being the first one in an industry to operate more sustainably. Veerman (personal communication, February 21, 2018) notes that since Dutch manufacturers primarily import semi-finished products, there is not much awareness among businesses of the problems that are about to arrive.

Veerman describes that essentially, nationally – but also globally – the primary objective should be to reduce material use and also use the remaining materials smarter. Less and smarter use of materials will happen in the future as prices will go through the roof as serious supply issues occur, but the sooner, the better. Using less is an idea that is not fully accepted less, as it addresses the concept of continuous economic growth. Moreover, externalities are currently not represented in the prices of products. According to Veerman, including those externalities would result in entirely different consumption and production patterns and could even mean that economic growth decreases. The circular economy concept provides a solution to sustainability and supply issues that was welcomed by the government and businesses since it did not touch the principle of economic growth and even promised to contribute to economic development by generating new jobs and higher revenues. Veerman expects that a circular economy will not necessarily lead to the creation of additional jobs, but rather a shift in employment. He states that a circular economy needs to be accompanied by using less. Veerman also believes that it is not necessary to move towards a planning economy to manage critical materials problems, and states that especially globalisation forms a barrier towards forming a planning economy. Koch argues that a balance needs to be found where both the government and businesses take their responsibility and the government can take a leading role to stimulate businesses to take their responsibility. Governments should also aim to reduce as many barriers for the reuse of materials as possible, such as changing legislation around trading waste products.

### Economy

For all three interviews, *economy* stands out, with the highest score for van de Pol from the Ministry of EZK, which fits his role, working for the Ministry of Economic Affairs. At the same time, Veerman had the second highest score for *economy* and the lowest score for *planetary boundaries*, while the Ministry of Infrastructure and Water management is the ministry that is concerned

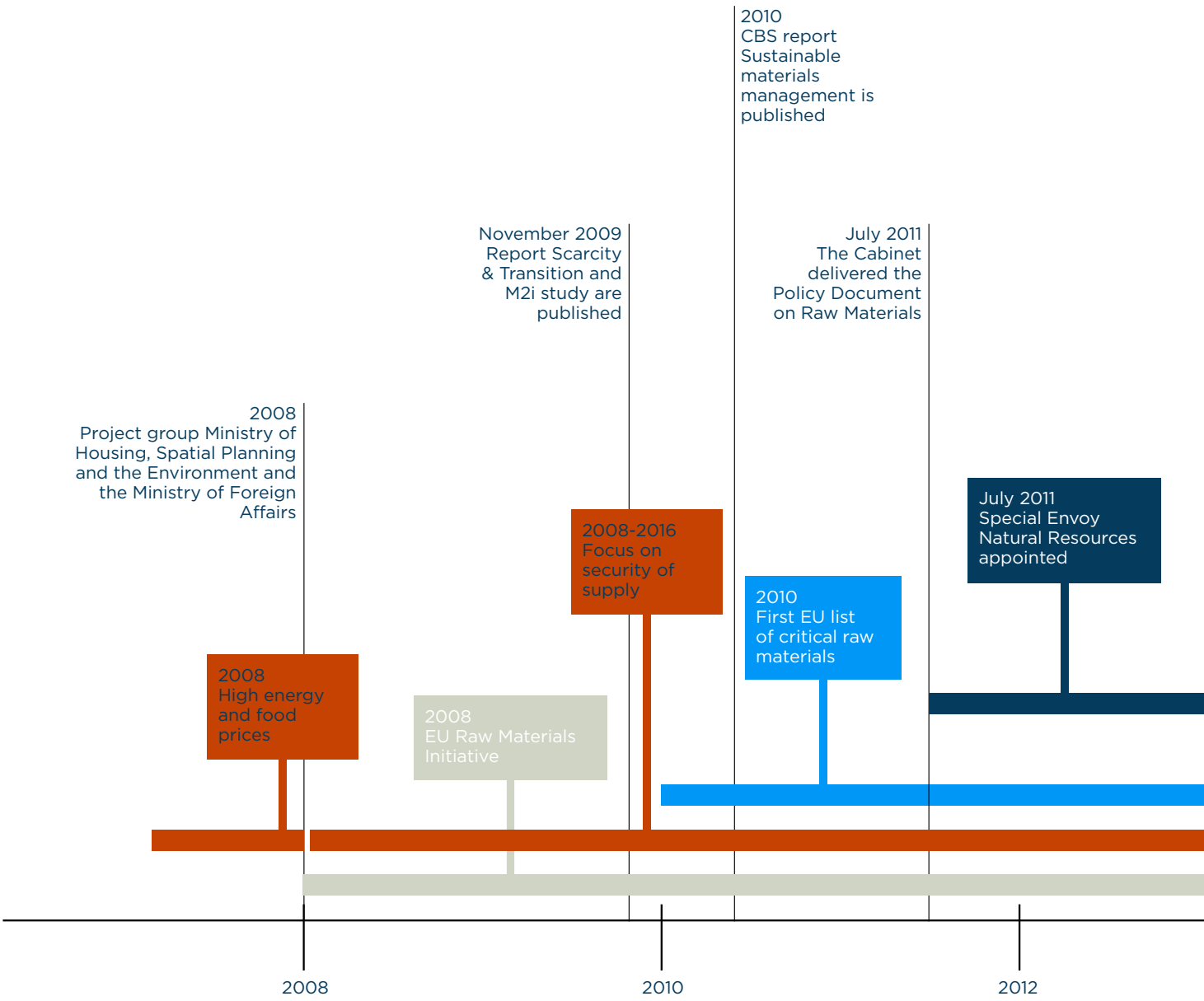
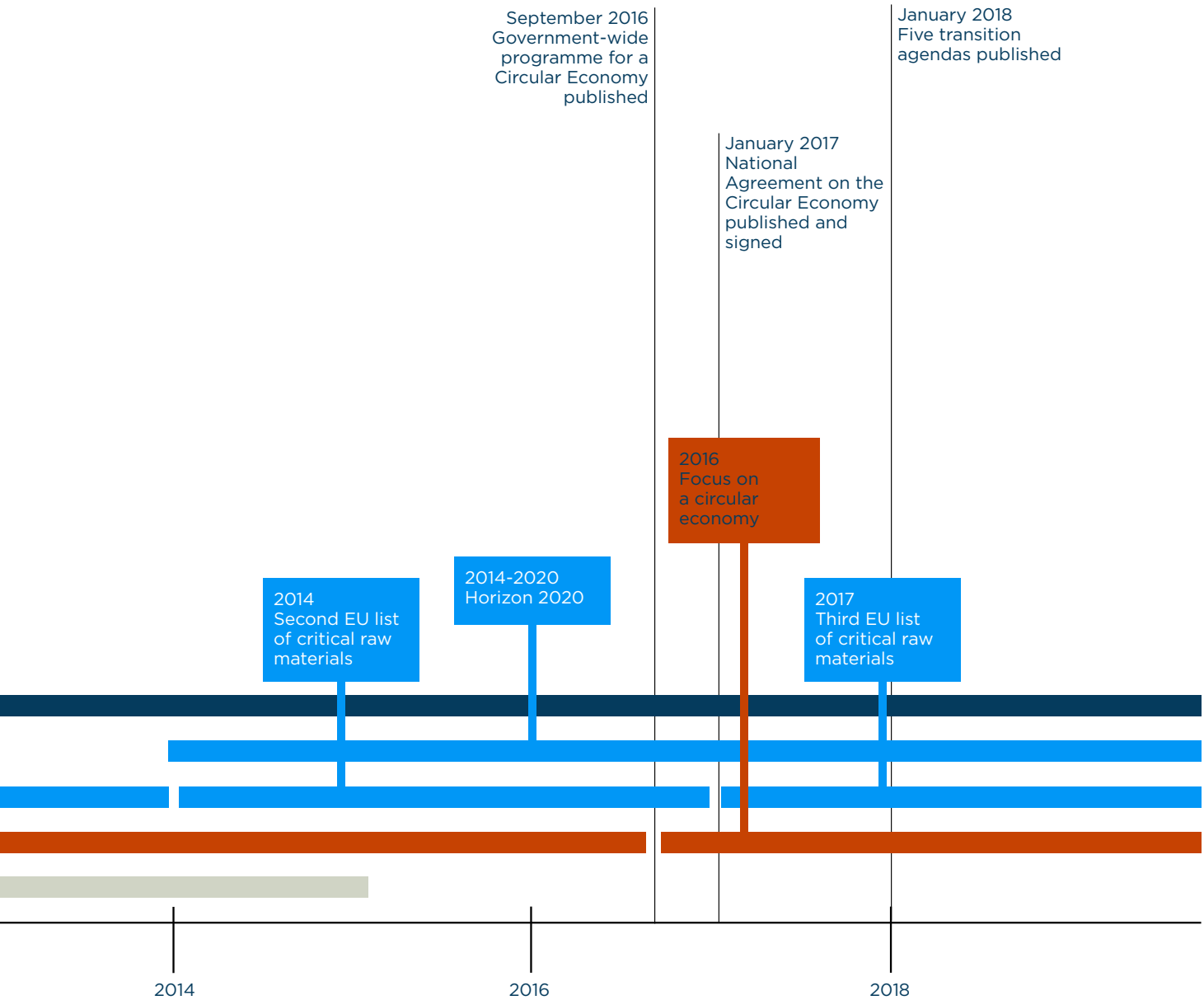



Figure 27 Home consumption of essential raw materials, monthly averages. Data from Central Statistical Office (1946).


September 2016
Government-wide programme for a Circular Economy published
January 2018
Five transition agendas published
January 2017
National Agreement on the Circular Economy published and signed
2016
Focus on a circular economy
2014
Second EU list of critical raw materials
2014-2020
Horizon 2020
2017
Third EU list of critical raw materials
2014
2016
2018

with resources, the environment and climate[1]. The high prevalence of economy-related codes for Veerman can be explained by the high level of attention for topics such as value chains, manufacturer responsibility and the circular economy.

According to Van de Pol, the circular economy shows a utopian image of an economy that allows businesses to produce goods and obtain revenue in a manner that is beneficial for the environment. However, there is not much proof that this could ever become a reality since there is a minimal number of examples of projects that managed to reach these goals. Nevertheless, the idea of making money through doing good is the only way towards a sustainable situation, since it is the only way to make the current 'old' form of economy disappear. Therefore, the concept of a circular economy is still the best option. Veerman identifies the need for a *versnellingshuis* (accelerator) where knowledge can be exchanged and connections are made.

As stated by Veerman, the current critical materials problems are primarily caused by a lack of transparency in the value chains which results in a lack of awareness of where materials come from with manufacturers. Additionally, the idea that the supply of raw materials is endless is still present among many producers. It is no simple task to get more insight into the supply chain of the complex products that are produced today. The government aims to implement extended manufacturer responsibility to demand a higher responsibility for their products from producers. Besides extending the existing manufacturer responsibility to other industries, the responsibilities themselves should also be extended to change the way products are designed and manufactured.

## Technology

Van de Pol scores relatively high on *technology* compared to the other two participants. The high score for technology is primarily caused by a focus on technological solutions or a technology push.

According to Van de Pol, the first problems with critical materials will be related to the materials that are required for the energy transition. Besides the materials needed for the sustainable energy technologies themselves, large amounts of critical materials are needed for ICT infrastructure, electric vehicles and smart energy systems as well.

In March 2018, the Ministry of Economic Affairs & Climate (EZK), together with FME and the Koninklijke Metaalunie, launched the *Grondstoffenscanner* (Commodity Scanner). The Commodity Scanner allows businesses to become aware of the critical raw materials in their components, semi-finished products or final products and the economic or social issues connected to these materials. The Commodity Scanner is part of the transition towards a circular economy and attempts to accelerate the transition by stimulating awareness among producers. As reported by Koch, the Netherlands lags behind more technologically advanced countries such as Japan, in developing a strategy for processing electronic waste and other household goods at their end-of-life within national boundaries. The current policy on reducing the shifting of waste products onto other countries such as Ghana is aimed at improving well-being in these countries and taking responsibility for the national waste. Nonetheless, this policy could be developed further to use this waste as an urban mine and further implement the circular economy principles.

According to Veerman, the circular economy gives direction to the solution to critical materials problems but is not a complete solution by itself. Losses always accompany recycling materials. Additionally, it is often not possible to make products out of entirely recycled material, so primary raw materials are needed as well. So it is inevitable to produce less and different products.

1 The term 'Climate' was added to the Ministry of Economic Affairs in 2017, which saw the addition of the transition towards sustainable energy technology and sustainable entrepreneurship added to their portfolio. The Ministry of Infrastructure and Water Management is still responsible for improving and managing the environmental space. The interviews were conducted in the first months of 2018, and all of the participants had been working several years at their current Ministry. Therefore, the previous situation is assumed to have primarily influenced their statements.

### Society

According to Koch, an essential aspect of obtaining resources for the Netherlands assuring well-being in the societies where the materials are extracted. This humanitarian aspect of importing resources contributes to increasing the security of supply. When these societies are doing well, there is a lower chance that they will obstruct or rebel against the extraction industry. Therefore, security of supply and responsible mining go hand in hand. One of the ways to contribute to responsible mining is legislation, such as the European Conflict Minerals Regulation. Apart from legislation, investments can also be used to promote well-being in these societies. Such as investing in the certification of mines to improve working conditions.

### Environment

Van de Pol sees environmental problems as the most significant driver for critical materials problems. Nonetheless, this is not motivating extracting countries to reduce their production, since they are too dependent on the revenues from export.

According to Veerman, the Ministry of IenW has had a leading role in the development of the Policy Document on Raw Materials from an environmental point of view, though they quickly involved the Ministries of EZK and BZ. However, generally, the environmental department has a relatively weak representation in the Cabinet which makes it a struggle to prioritise environmental issues.

## 4.3.2 Material supplies and price developments

Wouters and Bol (2009) have conducted an assessment of supply disruptions in the past decades and their effects on supplies and prices. The disruptions were caused by a variety of reasons, such as rebel invasions, floods, long-term maintenance, and export restrictions. In all situations, the prices rose rapidly, and in some cases, global shortages occurred. In this case, the worst case scenario would be a supply disruption that causes a high price increase and global shortage resulting in a 100 per cent supply reduction in the Netherlands. The full effect of such a situation on the actual supply shortage to the Dutch society is determined by the extent to which the circular economy principles have decreased the demand for primary material. That is to say, in an ideal situation the demand for primary material would have been decreased by 100 per cent and the global shortage of the material would have no effect on the Dutch society since all demand can be met by internal reuse and recycling of the products and materials that are already present in the economy.

Accordingly, the study by Wouters and Bol (2009) has concluded that material scarcity is a serious issue and that the best way forward includes increasing recycling and reuse, substituting materials, advocating a change of lifestyle among consumers and designing products for recycling. (Projectgroep Schaarste & Transitie, 2009; Wouters & Bol, 2009) The government has developed the idea further and has adopted the ambition of transitioning to a circular economy to solve material constraint problems. A circular economy should reduce the input of primary material by increasing the reuse of materials at their end of life and reducing demand in general. An intermediary goal of reducing the use of primary materials by 50 per cent in 2030 was defined. (Rijksoverheid, 2016) However, this goal was later removed due to lobbying from business organisations.
Figure 28 shows the use of minerals and metals from 2008-2016. The goals of transitioning towards a circular economy and reducing primary resource use by 50 per cent have been published in 2016, so it cannot be said whether material use is moving in the right direction yet. However, the figure does show a declining trend for mineral use, and the data shows that mineral use has decreased by 27 per cent. The use of metals stays steady.

Figure 29 shows the decrease in material use that needs to be achieved when aiming for a 50 per cent reduction by 2030 compared to 2016. For minerals, the trend is in line with the reduction that has been achieved between 2008 and 2016. However, the period of 2014 to 2016 does show an increase which needs to be reversed to achieve a trend of reduction. For metals, the curve appears quite smooth, especially, since a small decline has been achieved between 2014 and 2016. However, no notable

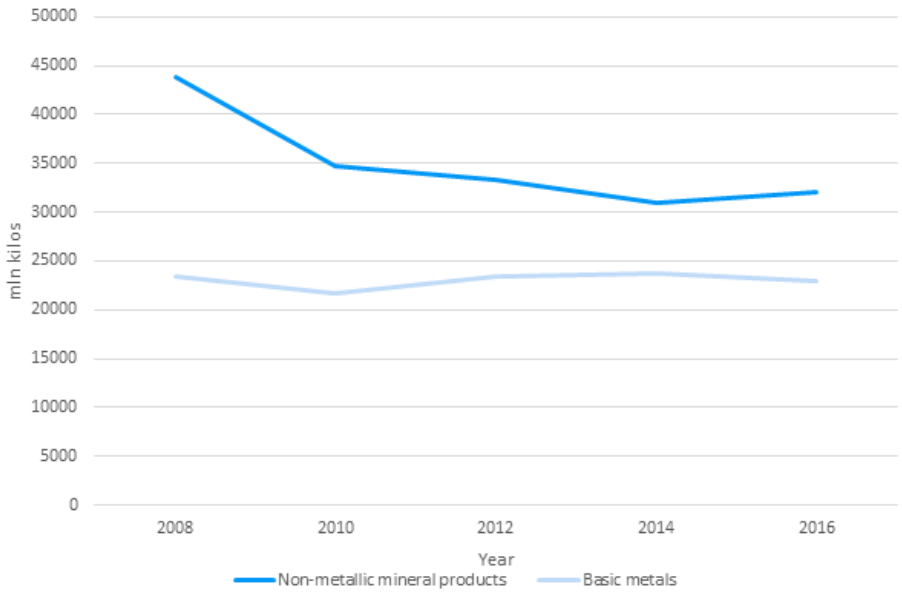



Figure 28 Mineral and metal use in the Netherlands. Data for 2008-2014 from Van de Pol-de Jongh, Keller, and Delahaye (2016), data for 2016 from Delahaye, Ganzevles, Hoekstra and Lijzen (2018).

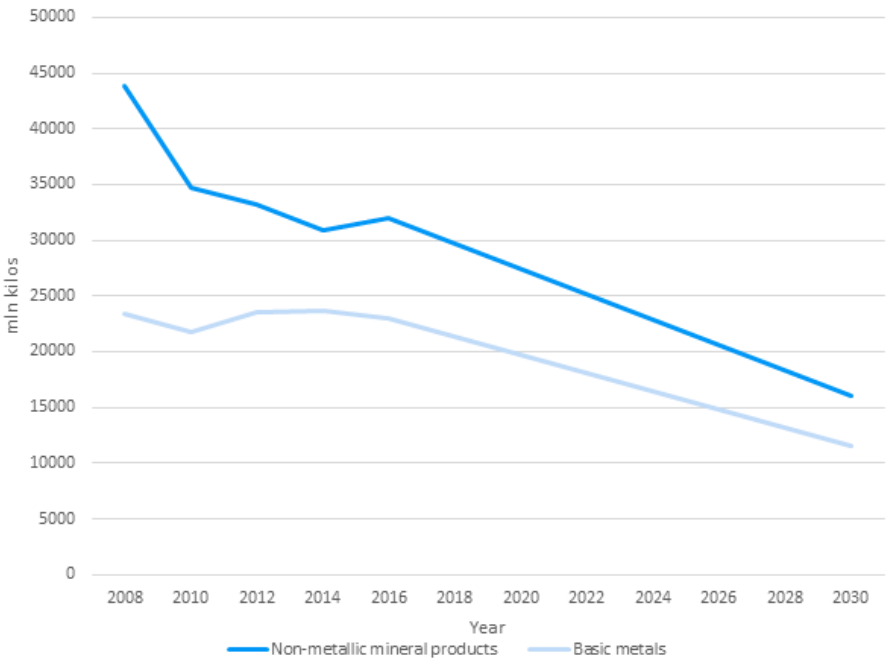



Figure 29 Achieving a 50 per cent reduction in primary material use in 2030. Adapted from Figure 26.

decrease in metal use has been achieved over the past years, so substantial systems changes will be needed to achieve the reduction.

The goal of achieving a 50 per cent reduction does not exist anymore and is, therefore, less likely to be achieved. For this study, it is therefore assumed that a 50 per cent reduction will not be reached, but that efforts towards this goal will be made and that the achieved reduction will lie between 26 and 50 per cent. Additionally, the research by André, Söderman, and Tillman (2016) shows that by using circular economy principles, reductions of critical materials of up to 60 per cent can be reached for specific metals, with an average of around 35 per cent. However, a reduction of the current critical material demand is likely to be answered by an increase in demand because of the material requirements of sustainable energy technologies and smart systems. Taking into account that demand will increase and that there are no plans to adopt the economic goal of degrowth, it is assumed that 50 per cent is the maximum reduction that can be achieved. However, it is likely that the achieved decrease will be significantly lower. Therefore, if a severe global supply shortage occurs, the effect of the shortage on the Dutch society will be halved since a maximum of 50 per cent of the national demand can be met by national supplies. The level of reduction in supply is therefore rated as average.

With regards to the prices of the materials, according to the metal-price index of The Economist, metal prices have seen an increase of 40 per cent between January 2015 and August 2017 (Figure 30). Still, it is 33 per cent below its peak which occurred a decade ago. The current rise can be explained by China's policy on fighting air pollution and the reformation of its industrial sector. However, the substantial increase in the metal-price index is mainly caused by the prices of aluminium and copper, which compose a large part of the metal trade. (The Economist, 2017) The price developments are relatively unpredictable, and it is not possible to know what will happen when an actual situation of material constraint occurs.

One example of what might happen in such a situation is demonstrated by the recent price developments of tungsten, a material that is classified as critical by the EU. In July and August of 2017, the price of tungsten rose more than 50 per cent (Figure 31). About 80 per cent of the metal comes from China, and export is restricted to a certain amount per year, though this limit is often exceeded. In June 2017, China's Ministry of Industry and Information Technology issued an edict in which they stated that producers needed to observe the quota's. The edict was a part of China's attempt to increase control over the production of tungsten, using environmental policy to legitimise the restricted export. In the same period, similar developments in China caused the prices of light rare earth metals and metals used in battery technologies to boom. For example, the price of neodymium increased by almost 100 per cent and the price of vanadium almost 140 per cent. (Biesheuvel, 2017; Bloomberg News, 2017; Biesheuvel & Burton, 2017)

Looking at these price developments caused by relatively minor disruptions, especially looking at how the prices of critical materials have responded to export restrictions from the Chinese government, price increases of more than 75 per cent can easily be achieved and is, therefore, rated as high.

### 4.3.3 Governance of change

According to the governance for resilience to material constraint framework, it is essential for the government to align its institutions and be able to work with all four roles of the government to accommodate a transformation. However, the results from the interviews indicate that the different institutions such as the ministries operate separately and towards individual goals. There is cooperation between the ministries on many topics, among which is the circular economy since the different ministries are responsible for different topics. (Veerman, personal communication, February 21, 2018) However, cooperation is not the same as alignment, and there is no indication that an effort is being made to increase alignment. Regarding the roles of the government, the Dutch government does use all of the four roles as described by the NSOB. The participants notice that the government, in general, is increasingly using


Figure 30 Metal price index from January 2016 to August 2017. Reprinted from The Economist, 2017.

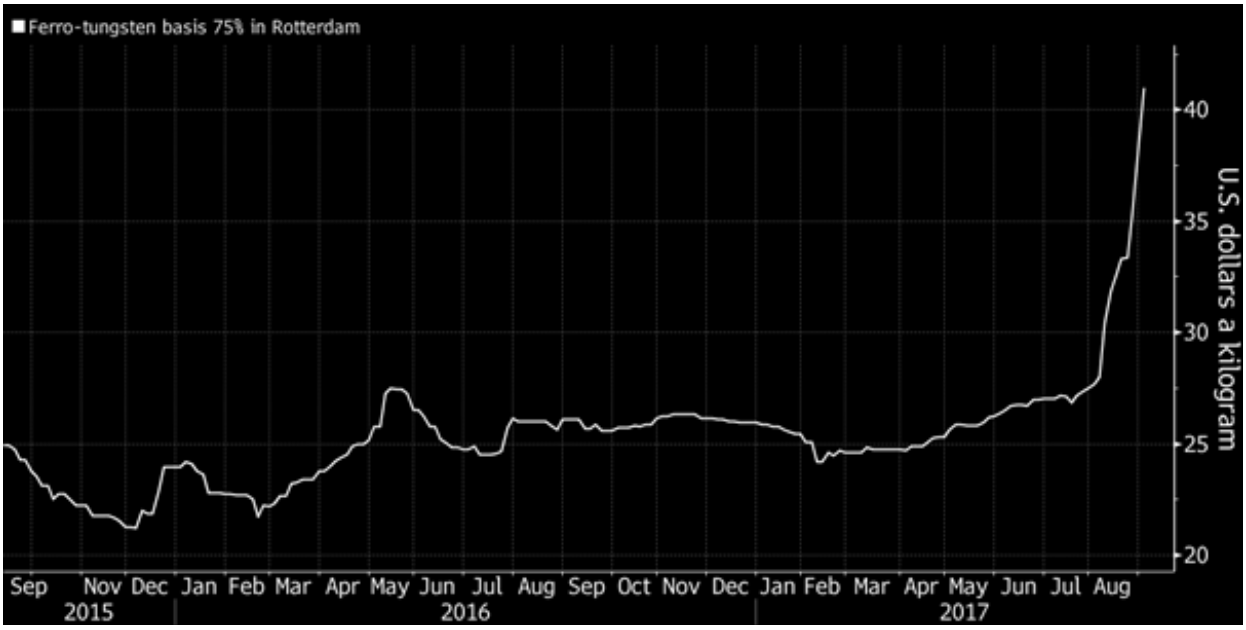



Figure 31 Price development of tungsten from September 2015 to August 2017. Reprinted from Biesheuvel, 2017.

the networking role because reducing funds steer the government towards using their networking power more. The participants or government documents do not indicate that the government is actively working on integrating all four roles in the way that is described by the NSOB (van der Steen, Scherpenisse, & van Twist, 2015). Regarding the transition towards a circular economy, the government has emphasised their networking role and incorporated a range of societal actors in the process. The National Agreement on the Circular Economy was presented in January 2017, and signed by the National Government as well as several other parties. Any party who wishes to join the shared commitment to transition towards a circular economy has been welcome to join, and currently, the agreement has been signed more than 300 times (Programmabureau Nederland Circulair in 2050, n.d.). Besides creating commitment among companies and institutions to endeavour the transition towards a circular economy, the agreement also expresses the intention to develop the five transition agendas mentioned previously. (Rijksoverheid, 2017)

The five transition agendas have been published at the beginning of 2018 and are written by a range of actors from the relevant industries, government, and knowledge institutions. However, social and environmental actors appear not to be included in the process, and the distribution seems limited. It is a not a development that invites all kinds of people and organisations to take part in the process, or that is open to suggestions from other parties. However, businesses do have a programme called Smart Regulation for Green Growth ($R^2G^2$) which allows them to let the government know whenever a law or regulation provides a barrier to sustainable innovation. The government then aims to find a solution together with the business.

Defining the goal of transitioning towards a circular economy has been made by the government, as a response to several developments related to the circular economy that were already running. The circular economy transition was supported by research and advise from the Social and Economic Council of the Netherlands (SER) and the Environmental and Sustainable Development Council (Rli), so it did have a social, economic, and environmental foundation. The circular economy that has been developed from this goal has been made using knowledge and suggestions from a diversity of societal parties, including local governments, social partners and civilians, who will be involved in the rest of the process as well. Therefore, the primary goal of moving to a circular economy seems to be a decision of authority, though based on developments in the society and supported by research, and the further development of the content of the plans and the specific actions is produced in cooperation with a diverse group of actors. The development of the transition agendas has also been a process of networking.

Three general goals for the transition towards the circular economy have been defined:

1. More efficient and high-quality use of raw materials in existing value chains.
2. Fossil, critical, and non-sustainable raw materials are replaced by sustainable, renewable, and commonly available materials.
3. New production methods, product designs and new ways of consuming are developed to transition towards new value chains.

(Rijksoverheid, 2016)

These goals are very similar to the circular economy principles and therefore not very specific to the local social and ecological situation. However, five main priorities of the transition towards a circular have been defined that are specific to the situation in the Netherlands. These priorities lie with biomass and food, plastics, the manufacturing industry, the construction sector, and consumer goods. For each of these fields, specific goals have been determined in the transition agendas. For example, for the manufacturing industry the following two goals have been defined:

- Reduce the ecological footprint of the Netherlands to one planet Earth by 2050 and honour the commitments of the Paris agreement.
- The manufacturing industry is still an essential foundation of the Dutch economy in 2050. Societal

welfare and well-being are maintained or increased. (Transitieteam Maakindustrie, 2018)

The first goal focuses on preserving ecological value and the second goal of preserving economic and social value.

For consumer goods, the following goals have been defined:

- The transition to a circular economy leads to the creation of value on a social, ecological, and economic levelling, in the Netherlands as well as in other countries.
- In 2030, wasteful products such as single-use packaging material should be used and produced less, and every new product that is brought to the market should be designed, produced, and used according to the circular economy principles.
- Products lifetimes should be extended, and only products that can be fully recycled should be produced.
- In 2030, products should be shared using service-based business models to use every existing product optimally.

The goals for consumer goods are still quite general, but the goals defined for the manufacturing industry are more specific than those for consumer goods. The other fields are outside the scope of this thesis and are, therefore, not included in this analysis. Overall, many goals have been defined, but they lack in specificity towards the local social and ecological situation. The direction is, therefore, rated as average.

One aspect of the Dutch national policy on raw materials is that solutions are primarily the responsibility of the private sector and that the government will aid and facilitate where needed. The National Agreement on the Circular Economy encourages companies to become involved in the transition. The government stimulates bottom-up innovation, especially technological innovation. The transition agendas provide a wealth of examples of innovative projects that contribute to the circular economy. The government stimulates the development of these projects through legislation, market incentives, subsidies, knowledge, and international cooperation. Examples are the R2G2 project which runs until 2020 and the efforts around developing a better definition of waste to make it easier to trade waste products. In the future, the Dutch government plans, among other things, to stimulate service-based business models, provide space for circular experiments, and expand producer responsibility to new product categories. The Dutch government has countless projects in the five different fields that should remove barriers and stimulate innovations. When looking at the diversity of these projects, the majority consists of financial or legislative measures aimed at economic and technological innovation. At the same time, the attention to social innovations is limited. Therefore, the diversity of the innovations is rated as average. (Rijksoverheid, 2016)

The government primarily uses economic stimulation in different shapes, for example, subsidies or taxes, to steer innovation towards circular solutions. For the effectiveness of these selective pressures, the government relies on the functioning of the market. Windows of opportunity are created through the same financial incentives as well. Removing legislative barriers through the $R^2G^2$ programme and other projects results in windows of opportunity as well.

The plans for transitioning towards a circular economy primarily focus on equal distribution of wealth between today's and future generations and people in other countries. The plan aims to bring the Dutch consumption back within the planetary boundaries. Achieving this would significantly relieve future generations and people in other countries today from the burden of the Dutch consumption pattern. However, less attention has been paid to the equal distribution of the advantages and disadvantages of the transition in the Dutch society. The current system results in an unfair distribution of wealth, and it is not clear how this will be different with a circular economy. Without active policy on reducing inequality, it is likely that the wealth that is derived from the new circular business models and product will go to a select few. At the same time, the disadvantages such as possible loss of jobs, loss of privacy and increased dependence because of a loss of ownership

will primarily impact the most vulnerable societal groups. In case of severe situations of material constraint, it depends on the resilience of the circular economy to such a situation to what extent these adverse effects are magnified. Therefore, the fairness of the distribution of the Dutch policy on transitioning towards a circular economy is rated as average.

### 4.3.4 Resilience to material constraint

It is quite difficult to review the resilience of the circular economy that the Dutch government is aiming for since the situation is still in the future. First, the latitude, which is the maximum change the system can endure before crossing a boundary. Considering that the economic system will not change fundamentally, and looking at the impact that minor supply disruptions of critical materials have on the system today and regarding the circular economy will probably reduce critical material use with a maximum of 50 per cent, latitude is rated as average. A similar observation applies to resistance. Flexibility to adapt to the new situation is essential to survive and be able to maintain the function of the system. Generally, preparation is an essential aspect of the ability to demonstrate flexibility when change is required. For the Netherlands, the results from the literature indicate that a circular economy alone is not sufficient in becoming independent from the import of CRMs. Therefore, planning for possible scenarios is essential to be flexible in times of crisis. However, planning, in the form of developing measures for different scenarios and calculating their effects is not yet done. Therefore, the level of flexibility is rated as average. Regarding the precariousness of the system when looking at material constraint problems, the circular economy will help to move away from the boundaries, since it will help to become more independent of imports of critical materials. However, the extent to which dependence can be reduced through the circular economy is limited, and since the Netherlands, as well as Europe, do not extract CRMs, a certain level of dependence will remain. Therefore, precariousness is rated as average.

## 4.4 Conclusion

This chapter aims to answer the second and third research questions. First, the second research question is answered: *What governance approaches to create resilience to situations of material constraint have been taken in the past?* In order to answer the question, the case of governance on material constraint in Britain during WWII has been analysed according to the methodology described in Chapter 3. For the case, the values of the independent variables material constraint and governance and the value of the dependent variable resilience have been determined according to the sub-variables. These outcomes can now be used to say something about the effectiveness of the government policies and regulations.

The civilian society in Britain during WWII was subject to severe levels of material constraint, an average decrease in the availability of supplies of 69 per cent was calculated, and therefore the level of supply reduction is rated as high. During this period, material prices rose considerably, with an average material price increase of 83 per cent. Therefore, the level of price increase in Britain is rated as high as well. Combining these values results in a high level of material constraint in Britain during WWII.

The governance process is rated according to the 3 Ds: the direction of goals, the diversity of innovations, and the distribution of advantages and disadvantages. The British government defined specific goals such as efficient resource use, maintaining a basic standard of living for the civilian society and prevent inflation. However, no goals related to the ecological system have been defined, and therefore direction is rated as average. Second, the government applied a diverse range of innovations to reach the goals. However, government control was extensive, and bottom-up innovation was not promoted. Additionally, the government focused on social, technological and economic innovation, but was not so much concerned with innovation related to the ecological system. The combination of these aspects results in an average rating of diversity. Third, the British government directed much effort towards an equal and just distribution. Price controls, rationing and a licensing

system, were implemented to prevent profiteering and ensure that the supplies that were available ended up with the people who needed it most. The government also attempted to include a range of societal groups in the process, for example through the Industrial Advisory Panel and the Utility Furniture Advisory Committee. However, again, the attempt was limited, and environmental aspects were not taken into account. Moreover, limited attention was paid to equal distribution between today's and future generations and the British society and foreign societies. Therefore, distribution is rated as average. Combining the ratings for direction, diversity, and distribution, Britain during WWII receives an average rating for its governance.

The dependent variable in this situation is resilience. The level of resilience is assessed using the sub-variables latitude, resistance, and precariousness. As discussed, the British society suffered severe supply reductions while being able to maintain its fundamental function. Therefore, latitude is rated as high. Second, the British society displayed great flexibility and therefore low resistance to change. The government had to implement rather extreme measures, but the society generally cooperated and adopted these new measures without significant problems. Flexibility is therefore rated as high. Finally, the British society was in a relatively wealthy state before the Second World War, with its supply restrictions, started. Therefore, the society was able to absorb the full length of the impacts and did not cross any definitive boundary that would cause it to lose its functioning. Therefore, precariousness receives a high rating, which in this model means that precariousness was low. The ratings for latitude, resistance, and precariousness, are combined to determine the level of resilience. Thus, the system has a high resilience to material constraint.

The results show that Britain was in a good starting position with high resilience to situations of material constraint. The level of material constraint that the British civilian society experienced during WWII was severe but did not push the social-ecological system beyond boundaries that would lead to a situation of no return to its fundamental state. The British government played an essential role in preventing an escalation of the situation which is primarily thanks to the extensive planning which was done in advance. Additionally, the government substantially increased its control and implemented a diverse range of solutions while aiming to ensure that the interests of all societal groups were served where possible. The most substantial gap in the British policy is the lack of attention for the ecological system and future generations. However, environmental issues were still a minor topic at the time, and the notion of caring for future generations is derived from the impact of environmental problems, it is therefore reasonable that limited attention was paid to the environment, especially in a situation of total war.

Table 5 shows a summary of the results for the case of governance on material constraint in Britain during WWII. A high supply reduction and a high price increase result in a high level of material constraint in society. Average direction, diversity, and distribution result in an average level of governance on material constraint. And a high latitude, high flexibility, and low precariousness (which contributes to a high resilience) result in a high resilience.

The second research question addressed in this chapter is: *What is the current governance approach to creating resilience in situations of material constraint in the Netherlands?* The current transition towards a circular economy in the Netherlands is analysed according to the same methodology that was used for the case of Britain during WWII. However, most of the variables that have been researched for this analysis will occur in the future, and estimations had to be made based on current developments.

First, the level of material constraint that could strike the Dutch society in the future due to export restrictions in other countries, natural disasters or other reasons. Assuming a maximum global supply shortage of 100 per cent and taking into account the circular economy goals that would make the Netherlands less dependent on imports of CRMs, an average impact of 50 per cent supply reduction is estimated, which results in a rating of average for supply reduction. Considering recent price developments of raw materials in general and especially CRMs experiencing supply disruptions, a severe disruption is expected to result in a high price rise

Table 5 Results governance on material constraint in Britain during WWII.

| Variable | Value | Variance description |
|---|---|---|
| **Material constraint in society** | Average of two sub-variables | Not present |
| | | Low |
| | | Average |
| | | High |
| • Supply reduction (%) | Negative reduction | Not present |
| | 0-25% | Low |
| | 26-50% | Average |
| | 51-100% | High |
| • Price increase (%) | Negative | Not present |
| | 0-25% | Low |
| | 26-75% | Average |
| | More than 75% | High |
| **Governance on material constraint** | Average of sub-variables | Weak |
| | | Average |
| | | Strong |
| • Direction | Limited definition of goals | Weak |
| | Definition of goals, but specificity is limited | Average |
| | Goals specific to social and ecological situation | Strong |
| • Diversity | No diversity | Weak |
| | Some diversity | Average |
| | Abundant diversity, and innovations specific to situation | Strong |
| • Distribution | Unfair distribution of advantages and disadvantages | Weak |
| | Some attention to equal distribution | Average |
| | Fair distribution of advantages and disadvantages | Strong |
| **Resilience of the new system** | Average of sub-variables | Low |
| | | Average |
| | | High |
| • Latitude | Small maximum change | Low |
| | Average maximum change | Average |
| | Large maximum change | High |
| • Resistance | Low flexibility | Low |
| | Average flexibility | Average |
| | High flexibility | High |
| • Precariousness | Close to a boundary | Low |
| | Halfway | Average |
| | Far from boundaries | High |

of far more than 75 per cent. The level of price increase caused by a possible supply disruption is therefore rated as high. A possible situation of material constraint has the potential to involve severe levels of constraint because of the high level of supply reduction and a high level of price increase that can be expected. Material constraint is, therefore, rated as high.

Regarding the governance of the transition towards a circular economy, the Dutch government has developed five transition agendas for specific fields that are relevant to the Dutch economy. Though these transition agendas are particular to these sectors, the goals that have been defined in these agendas are somewhat generic, depending on the transition agenda because some are more specific than others. Additionally, the goals are generally focused on the fields of technology and economy, with a little attention for the environment and almost no attention for the civilian society. Therefore, the direction of the goals is rated as average. A similar observation applies to the diversity of the innovations. There is a tremendous diversity of innovations, and bottom-up innovation is stimulated. However, the focus is again on technological and economic innovations, while social innovations are somewhat neglected. Therefore, diversity is rated as average. The transition towards a circular economy mainly focuses on an equal distribution of wealth and resources between today's and future generations. There is also attention for a fair distribution of welfare between the Dutch society and foreign societies today. However, less attention is being paid to a fair and just distribution of advantages and disadvantages within the Dutch society, as the circular economy goals, policies and actions do not address the increasingly unfair distribution of wealth. Therefore, the fairness of the distribution of the Dutch policy on transitioning towards a circular economy is rated as average. The combination of the ratings for direction, diversity, and distribution, results in a rating of the Dutch governance of change as average.

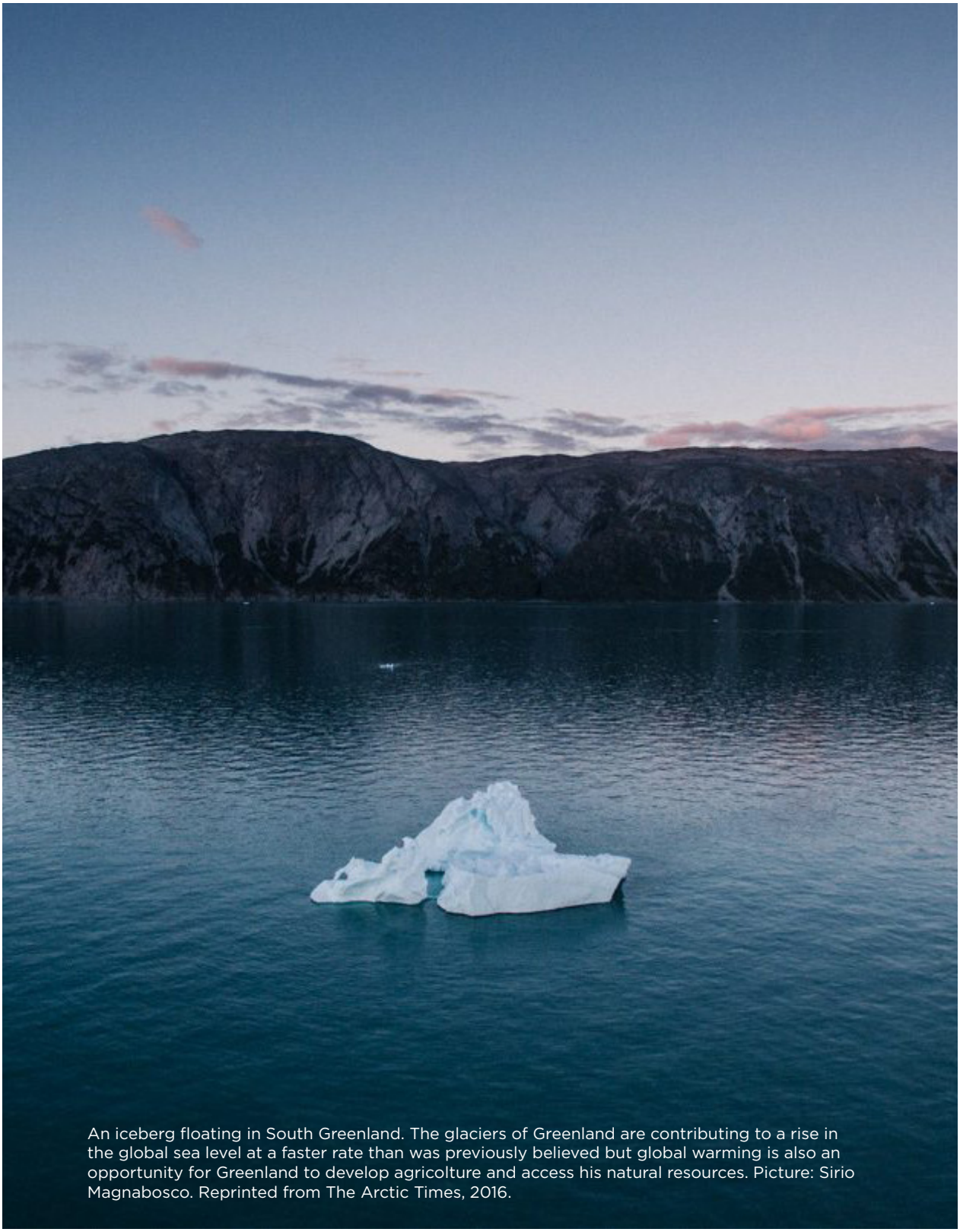
For resilience, the first sub-variable is latitude. Considering that the economic system will not change fundamentally, and looking at the impact that minor supply disruptions of critical materials have on the system today and regarding the circular economy will probably reduce critical material use with a maximum of 50 per cent, latitude is rated as average. The resistance to change is rated as average because of a lack of flexibility which stems from a lack of planning. The Netherlands is currently wholly dependent on imports for its CRMs which puts it in a precarious position. The circular economy could potentially reduce this dependence up to 50 per cent, which would reduce the precariousness of the system. Therefore, precariousness is rated as average. When combining the results for latitude, resistance, and precariousness, the level of resilience to material constraint that will be reached when following the current circular economy strategy is rated as average.

Table 6 shows a summary of the results for the case of governance on material constraint in the Netherlands from 2008-2018. An average supply reduction and a high price increase result in a high level of material constraint in society. Average direction, diversity, and distribution result in an average level of governance on material constraint. Third, an average latitude, average flexibility, and average precariousness result in an average resilience.

The results show that the Netherlands can expect severe material constraint situations in the future and that it is, therefore, imperative that the government has embarked on a transition towards a more resilient system. The results of the governance analysis show that the government addresses all three Ds in their approach, but that for every D some aspects are lacking. The resilience analysis indicates that the current circular economy approach is not sufficient to reach a high level of resilience. A transformation of the entire SES is essential, requiring economic and social reformation in addition to the technological innovations to reach such a high level of resilience to critical materials problems and stay within the planetary boundaries.

Table 6 Results governance on material constraint in the Netherlands from 2008-2018.

| Variable | Value | Variance description |
|---|---|---|
| **Material constraint in society** | Average of two sub-variables | Not present |
| | | Low |
| | | Average |
| | | High |
| • Supply reduction (%) | Negative reduction | Not present |
| | 0-25% | Low |
| | 26-50% | Average |
| | 51-100% | High |
| • Price increase (%) | Negative | Not present |
| | 0-25% | Low |
| | 26-75% | Average |
| | More than 75% | High |
| **Governance on material constraint** | Average of sub-variables | Weak |
| | | Average |
| | | Strong |
| • Direction | Limited definition of goals | Weak |
| | Definition of goals, but specificity is limited | Average |
| | Goals specific to social and ecological situation | Strong |
| • Diversity | No diversity | Weak |
| | Some diversity | Average |
| | Abundant diversity, and innovations specific to situation | Strong |
| • Distribution | Unfair distribution of advantages and disadvantages | Weak |
| | Some attention to equal distribution | Average |
| | Fair distribution of advantages and disadvantages | Strong |
| **Resilience of the new system** | Average of sub-variables | Low |
| | | Average |
| | | High |
| • Latitude | Small maximum change | Low |
| | Average maximum change | Average |
| | Large maximum change | High |
| • Resistance | Low flexibility | Low |
| | Average flexibility | Average |
| | High flexibility | High |
| • Precariousness | Close to a boundary | Low |
| | Halfway | Average |
| | Far from boundaries | High |



An iceberg floating in South Greenland. The glaciers of Greenland are contributing to a rise in the global sea level at a faster rate than was previously believed but global warming is also an opportunity for Greenland to develop agricolture and access his natural resources. Picture: Sirio Magnabosco. Reprinted from The Arctic Times, 2016.

# *Chapter 5*
# Conclusion and Discussion

## 5.1 Introduction

This chapter combines the answers to the three sub-questions to provide the answer to the primary research question. Two case studies were done, of which the results are presented in the previous chapter, to find the answers to the sub-questions. This chapter provides a discussion of the findings and provides practical recommendations as well as recommendations for further research.

## 5.2 Conclusion

The Netherlands is vulnerable to supply restrictions because of the importance of materials for economic development: materials are at the basis of the society since economic growth and material use are directly linked. Additionally, the aim of continuous GDP growth to ensure economic stability increases material demand and therefore the vulnerability to supply disruptions rises as well. The Dutch government has adopted the goal of having an entirely circular economy by 2050 to reduce the vulnerability of the economy to material constraint. However, the literature indicates that adopting a new economic model is not sufficient and that a sustainability transformation is essential. Furthermore, the way the circular economy as an economic model fails to reform the economic system which lies at the basis of material use, and therefore a degrowth model is suggested. According to literature, both a sustainability transformation and economic degrowth are essential to reach a situation of sustainable material use and therefore resilience to supply disruptions. Moreover, the literature emphasises that governance, and especially political leadership, is indispensable in achieving a successful transformation. This research, therefore, aimed to study how governance can bring about the desired sustainability transformation to reach a social and economic system that is resilient to situations of material constraint. Besides developing a framework for such a transformation from literature, policy on material constraint in Britain during WWII was analysed to gain insight into an actual case of governance to increase resilience to material constraint.

Moving to a resilient state requires a sustainability transformation that includes the entire social system (society, economy, and technology) as well as the ecological system (the environment). The transformation leads to a situation in which the environment and resources are used in such a way that every person, both today and in the future, can meet their needs. The transformation, therefore, involves the society, the economy, technology, and the environment.

Political leadership is essential to bring about the desired transformation. The theoretical framework that has been developed from the existing literature answered the first sub-question *What framework best describes governance for sustainability transformations to increase resilience to situations of material constraint?* According to the literature, the government needs to take the responsibility to transform itself first to align its organisations and departments and develop the ability to work with the four roles of the government. The government has a directive role in defining the vision and goals specific to the local situation. Then it needs to move towards a participating role to create an environment in which bottom-up innovation to reach resilience through diversity is enabled by applying selective pressures and creating windows of opportunity. Once the transformation is completed, the government needs to take the lead in building resilience of the new system through building trust. The theoretical framework shows that sustainability transformations can be brought about that provide social-ecological systems with resilience to material constraint. It shows that governance is essential to initiate and steer the process, but that the transformation itself is brought about by societal actors who develop social and technological innovations. The government has a vital role in guarding the direction, diversity and distribution of the process within the economic, societal, technological and environmental systems by applying selective pressures. The government provides windows of opportunity to allow successful innovations to enter the mainstream market fast.

The results from the historical case study of governance on materials constraint in Britain during WWII answer the second sub-question *How has governance for resilience to situations of material constraint been addressed in the past?* The case showed that Britain experienced severe levels of material constraint in the civilian society. Before the actual period of material constraint, Britain had a period of twenty years of planning in which the government system was adapted to accommodate the transformation by setting up dedicated departments. However, during the reformation phase, the government did not pay much attention to the alignment of vision and goals among the departments and focused primarily on identifying supply and demand flows while refraining from defining an overarching strategy. During the war, the realisation came that such a strategy was essential to achieve adequate distribution of supplies and a strategy was developed. Additionally, during the government reformation phase, no attention was paid to developing the four roles of the government as there was limited awareness of the necessity of such a development, which resulted in a primarily top-down approach. During the goal-setting phase, the government developed specific goals, though merely aimed at the social system while disregarding the ecological system. Regarding the innovations, a diversity of social and technological innovations were implemented to achieve the goals. However, the majority was top-down as there was little room for bottom-up innovation. Therefore, there was limited attention to creating windows of opportunity. However, the government did use a selective pressure to identify government-approved designs. They also paid much attention to the distribution of the advantages and disadvantages of the transformation among the civilian society, and aimed, to some extent, to include a range of societal groups in the process. However, the attention for enabling future generations or foreign societies to meet their needs was limited. The government process of planning and executing the transformation has resulted in a high resilience to the material constraint that emerged during the war. The government reinforced the transformation through building trust, in the form of ensuring the fair distribution of the available supplies and strong leadership and enforcement of the rules. Since the government had made extensive plans for such a situation and was therefore relatively well prepared, it could adequately respond to the situation. The government increased its control over the society and economy and imposed drastic measures to manage the situation. They employed a diverse range of social, economic, and technological solutions and aimed, to a certain extent, to include actors from all levels of society and business. Because of the preparations that were made during the planning phase, the leadership that the government displayed, and the diverse range of measures that were

taken, the government was able to prevent the system from moving beyond its boundaries.

The results of the contemporary case of policy on material constraint in the Netherlands from 2008 to today answer the third sub-question *What is the current situation with regards to a sustainability transformation for resilience to material constraint in the Netherlands?* The results showed that the Netherlands could expect situations of severe material constraint in the future. The government has a limited concern for transforming the governance system through aligning its institutions. Nonetheless, a government-wide programme on the circular economy has been developed. However, this was split up into five transition agendas which have been divided over the departments and are primarily the responsibility of private actors. There is cooperation between the different governmental organisations and ministries, but the alignment is limited. The four roles of the government are recognised, and some effort is being made to accommodate all four. The vision is defined by the government, and the goals are further developed in cooperation with a range of societal actors. The goals are divided over the five transition agendas, but it depends on the agenda how specific they are since the goals are generally somewhat generic circular economy goals. The Dutch government relies primarily on bottom-up innovations to bring about the transformation. Windows of opportunity are created through adapting legislation and providing subsidies. The subsidies and taxes also serve as selective pressures. The government aims to increase equality in the distribution of advantages and disadvantages between today's and future generations and between the Dutch society and foreign societies. The focus on the fair distribution among the national societal groups is not a priority. During the process, the government has emphasised their networking role and incorporated a range of societal actors in the process. The analysis indicates that the current circular economy transformation strategy leads to mediocre resilience to future situations of materials constraint since the approach does not sufficiently increase the latitude and flexibility of the social-ecological system and does not entirely move the system away from its boundaries. The results of the governance analysis show that the government addresses all three Ds in their approach, but that for every D some aspects are lacking. Including these missing aspects would result in a comprehensive approach that would be successful in achieving a sustainability transformation of the complete SES. The resilience analysis indicates that the current circular economy approach is not sufficient to reach a high level of resilience. A transformation of the entire SES is essential, requiring economic and social reformation in addition to the technological innovations to reach such a high level of resilience to critical materials problems and stay within the planetary boundaries.

The answers to the three sub-questions are used to answer the primary research question *How can governance bring about a sustainability transformation aimed at increasing resilience to critical materials problems in the Netherlands?* The theoretical framework is combined with the results of the historical case study and applied to the situation in the Netherlands. According to the framework and the historical case, the government needs to take the lead and initiate the transformation since societal actors are too restricted by the interlinked functioning of social, economic and ecological systems to initiate such a transformation of the entire system themselves. When the government recognises the need for a transformation and accepts the responsibility to start and guide the transformation, the government needs to start with evaluating its functioning and reform if needed to be able to accommodate the process. The analysis showed that this part of the process lacks with the Dutch government. Therefore, the Dutch government should first of all focus on aligning its organisations to work towards the same vision and goals. It is essential that all organisations have the same interest, know what the other organisations are doing, and operate in synergy. Additionally, the flexibility of the organisations should be increased so that they can work with all the four roles of the government simultaneously and can quickly switch between the roles. The case of Britain shows the effect of setting up a dedicated department concerned with material supply. This department can start to make an inventory of the requirements of all the firms in the

country and develop a range of scenarios of material constraint and the accompanying plans of what to do in these specific situations.

When the government itself functions in such a way that it can accommodate the transformation, the goal setting phase can be entered to develop the vision and the goals. The Dutch government has taken the lead in defining the overarching vision. However, the current circular economy vision is primarily focused on the technological system, which means that the vision needs to be extended to include economic, societal, and environmental aspects. The Dutch government cooperates with societal actors on defining the goals. However, both the literature and the British case suggest that it is desirable that the government defines the vision and the goals, and then apply a networking approach to develop how these goals will be reached. Additionally, the goals that currently exist for the Netherlands need to be more specific to the local social and ecological situation, and they need to be defined for all four aspects (economy, technology, society, and environment) equally. At all times, the specific goals need to achieve the overarching goals. Technology should adopt the principles of reduce, reuse, recycle, the use of the environment should stay within the planetary boundaries, every person in the Dutch society and foreign societies, today and in the future, should be able to live above the social baseline; and economic degrowth should be realised until a steady-state economy can be adopted. With regards to distribution, the Dutch government involves a range of societal actors in the process of defining the goals and developing action pathways. However, an equal distribution of the social actors involved can be achieved when opening up to actors that represent civilian society, industry, economic institutions and businesses, and environmental organisations, from all levels of society.

With regards to the creation of windows of opportunity and selective pressures, the Dutch government promotes top-down institutional change combined with bottom-up innovation. They create windows of opportunity and apply selective pressures to steer the innovations in the right direction. As shown by the British government, the system of windows of opportunities and selective pressures can be extended with a quality mark that is issued by the government. Such a mark indicates that the innovation is approved by the government and is, therefore, of high quality, does not use critical materials and meets the circular economy demands such as recyclability. Subsidies could be directed towards the products that have this mark so that they are affordable to people in every societal level. Additional measures might be necessary to prevent profiteering from such products. Additionally, the government should ensure that its windows of opportunity and selective pressures create opportunities for a diverse range of innovations. So, not only technological innovations but also societal, economic and environmental. They also need to guard that all the innovations that are allowed to enter the mainstream market contribute to the specific goals.

The current policy of the Dutch government focuses on measures that are aimed at equal distribution of the effects of the transition between the Dutch society and foreign societies by ending the shifting of externalities to developing countries. Additionally, the policy aims for equal distribution and between today's and future generations by limiting the pollution of the environment so that future generations also have access to the earth's life-giving ecosystems and natural resources. However, the focus for both the foreign societies and the future generations is on reducing the adverse environmental effects of today's behaviour but does not achieve an equal distribution of the benefits of the change among these groups. Additionally, there is no attention to the equal distribution of any other advantages or disadvantages within the fields of technology, economy, and society. Besides improving equality between the different societies, the government should also focus on equal distribution of positive and negative effects on the Dutch society today. It should be prevented that particular social groups bear more of the burdens than others or that specific societal groups primarily profit from the transformation while others do not. The government should make sure to cover equality and justice in all four aspects: economy, technology, society, and environment.

Once the transformation is brought about, the

resilience of the new system needs to be built, primarily through building trust. In the end, all the people in the social-ecological system are needed to bring about the transformation. The transformation will only be successful if the society can trust that it is in their best interest and that it is indispensable. Therefore, the government needs to include the 3 Ds, direction, diversity, and distribution in everything they do. Direction makes sure that the transformation and the selected innovations are targeted at the local social and ecological situation and will, therefore, enable the transformation to last and create true sustainability. Diversity ensures that a broad range of innovations is used to bring about the transformation and ensures that if one innovation fails the others can absorb the impact and allow the system to maintain its function and structure. Distribution ensures that the entire society is involved in the process of transformation and equally benefits from or is harmed by its implications. Equal distribution applies to impacts within the national society and impacts across geographical borders or time. Involving people from all social groups and equally distributing advantages and disadvantages will help people to understand what is happening and what is needed, without feeling that they are disadvantaged while others win. Additionally, communication is essential to build trust. Besides involving people in the process, the government needs to communicate the why, how, what, who and when of the transformation. Additionally, the government should not only send but be open to receiving as well. Therefore, people should have the possibility to report barriers, give suggestions or ask questions and receive adequate feedback on their requests.

By adopting all these points, the government can bring about a sustainability transformation towards a new social-ecological system, namely a system with a new function, which is providing its society with the basic needs for living, even in times of severe material constraint. It is a system that is balanced and diverse, and therefore far less dependent on economic growth or material supplies, which allows it to be flexible and resilient to a restricted supply of critical materials.

## 5.3 Discussion

### 5.3.1 Interpretation of results

This research contributes to the current knowledge about sustainability transformations and material constraint by combining approaches and frameworks from several fields into one overarching framework that describes the complete governance process. The analysis of the cases was based on the principles of the framework, and these proved useful to obtain in-depth insight into the cases. The use of case study research enabled the testing of the theoretical framework to provide more insight into the actual functioning of the principles of sustainability transformations. The analysis of the cases confirmed the structure and content of the framework. Both cases generally followed the transformation process of the framework, and the individual steps displayed the characteristics as described in the framework. No additional steps in the process or characteristics of the individual steps have been found that would require a revision of the theoretical framework. The results of this study, therefore, support the validity of the theoretical framework to serve as a basis for governance for sustainability transformations towards a social-ecological system that is resilient to situations of material constraint. Additionally, neither of the cases covered all of the steps in the framework entirely, and the framework proved to be helpful in identifying gaps in both of the cases.

A significant body of contemporary scientific literature on sustainability transformations and critical materials problems suggest that politics and political processes lie at the heart of governance for sustainability transformations and reducing vulnerability to critical materials problems. Governance includes the more traditional policy tools such as regulation, planning, and tax-based instruments. Both cases supported this theory. The case of Britain showed how extensive government control provided the direction and guidance necessary to pilot Britain through a situation of severe material constraint without any considerable breakdown of societal functions. The case of the Netherlands also confirms the importance of governance to initiate and

steer the transformation.

According to the literature, alignment of organisations and working with the four roles of the government is essential to accommodate the transformation process. The British case did not confirm that adopting the four roles of the government is essential. The government primarily made use of a directive role and did not attempt to adopt the other three roles as well. The directive way of government was continued throughout the stages of the process, from defining the goals to developing the innovations, resulting in a controlled process and effective management of supplies. The Dutch government, on the other hand, tends to focus on the participating and networking roles, incorporating societal actors in the goal-setting phase as well as the developing of innovations. Until now, the results are less immediate, structured, and effective. Therefore, the case studies appear to show that adopting all four roles of the government is not necessarily effective and that focusing on a directive role is desirable. However, the case of Britain was an emergency situation that did not allow for a transformation to occur gradually and naturally from the society itself. Full control over the society, the economy, and technology was essential to survive. Additionally, the change was of a temporary nature, after which the situation was expected to return to business as usual. In the Netherlands, there is a need and sufficient time for a gradual transformation in which the society is supposed to transform from the inside and completely, to be able to adapt to the global developments. The British emergency plan was in this sense not a complete transformation and therefore did not require the government to master and apply all four roles of the government in the appropriate situations, since a directive role was what was needed. The Dutch government is pursuing a complete transformation, which involves all roles of the government. Since the modern government tends to incline towards the networking and participating roles of the government, particular attention needs to be paid to ensuring the directive and performing are applied when appropriate as well. The Dutch government displays a significant focus on networking and appears to have adopted it as its primary role. The government aims to connect various actors to collaborate on bringing about the desired transition. Britain during the Second World War, on the other hand, showed more signs of a directive way of government with regards to its national policy. The directive way of government allowed the British Cabinet to make quick decisions without having to come to agreements with other actors. However, the British government was not ignorant of the opinions of the society and industry. The government conducted national surveys to determine public opinion on all kinds of governmental matters, and installed committees with members from relevant industries to consult them about policy development.

With regards to the alignment of the departments, in the British case, the individual departments were aligned to serve the goal of managing the available supplies. The separate departments had their individual, specific roles in achieving the common goal of winning the war. A primary aspect of this was obtaining, distributing, and effectively using material supplies since resources are the foundation of successful warfare. In the Netherlands, there is the goal of transitioning towards a circular economy. However, this goal does not have the power to align the departments to use their roles entirely to achieve this goal. One of the reasons that this goal lacks aligning power is probably the lack of urgency and the long timescale. Additionally, the goal only covers the technological system and therefore does not involve all the government departments equally. Also, even though the Dutch vision for a circular economy is long-term, the action plans are not. Mainly short-term plans in the form of projects of three to five years are executed and long-term planning related to developing legislation and stimulating knowledge is postponed. The Dutch government is reluctant to develop legislation with long-term effects since it is afraid that legislation will interfere with businesses in ways that are not desired and only hamper the process. The British government, however, was less afraid of adopting measures with long-term effects, but the controlled situation made it easier to control the outcome. Still, the case of Britain does demonstrate the value of subjecting every aspect of the government and the society to the goal or vision instead of

balancing between two worlds.

According to the theoretical framework, the definition of the vision and the goals is a task for politics, after which social actors can be included in the process of determining the actions that should lead to reaching the goals. The current vision for a circular economy primarily addresses the technological system since the circular economy is primarily concerned with how products and materials are used and reused. The vision can be further developed by adding the societal, economic, and environmental aspects. The Dutch government could envision 'a society in which wealth and harms are distributed in an equal and just way so that every person can thrive and live in connection with the environment and each other. While at the same time, our way of living allows us to stay within the planetary boundaries and generations today can meet their needs without compromising future generations to meet their own needs. The economic system serves the society by making products that add to people's well-being without harming the environment or exhausting the earth's natural resources'. The accompanying goals can consist of objectives such as the level of degrowth that needs to be achieved, the definition of a social baseline, or the level of distribution of benefits and harms that needs to be achieved. Other goals to consider are the specific local ecological boundaries that translate to the planetary boundaries, and the levels of reduction, reuse, and recycling that need to be achieved. The British case shows that the government indeed took charge of defining the goals as part of its directive role, which resulted in a set of goals that were specific to the local situation. In the Netherlands, the primary goal of moving towards a circular economy was set by the government, but the sub-goals defined in the transition agendas were defined in cooperation with all kinds of societal actors, which results in more generic goals and even the removal of the principal goal of reducing primary resource use by 50 per cent. Therefore, the case confirms that indeed the government should use its authority to define specific and ambitious goals that contribute to sustainable development. It could be argued that involving societal actors in the process of developing goals would lead to more engagement and dedication among the societal actors and goals that are more specific to the different industries. However, the results show that the goals become less specific when societal actors are included in the process. The general goals might be the result because actors have many interests that not always align with what is best for the country or the world. Therefore, they might be reluctant to oblige themselves to specific targets and would instead prefer a relatively vague goal. Involving them in developing pathways to reach the goals is useful since their specific knowledge of the functioning of the industry helps to develop useful pathways and actions. The framework also requires that the vision and the goals be defined for the economic, societal, technological, and environmental system. In Britain, no goals were defined for the environment, which demonstrates the lack of awareness of the necessity of protecting the environment, as well as the temporary nature of the transformation. In the Dutch situation, a permanent transformation is needed, since the goal is sustainability which inherently involves long timeframes and is mend to last. Since the environmental system inherently supports the societal system, which is in turn supported by the technological system and the economic system, environmental goals are crucial to a sustainability transformation. Goals for the other three systems are needed to make it possible to achieve the environmental goals.

Furthermore, the theory suggests a combination of top-down institutional change with bottom-up social and technological innovation. However, the British case was utterly top-down since there was no room for bottom-up innovation. Full government control was probably the best option in this situation. Despite the years of planning, the war happened sooner than expected and there were only 2.5 years for the actual planning phase. Therefore, there was no time to let innovation emerge naturally, change needed to be forced by the government. Indeed, this strategy proved to be successful in leading to efficient use of the available materials. The Dutch government, on the contrary, does follow the theory and creates space for bottom-up innovation to emerge. The difference between a top-down and bottom-up approach brings us to a substantial difference between the two cases. In Britain,

the intention was not to move from one social-ecological system to another. The primary objective was to increase the resilience to material constraint of the current system, aimed at a relatively short period of war. The government developed a comprehensive plan of the measures it should take in a period of material constraint caused by war. Once a war occurred, it could implement these plans, improve them along the way, and survive, keeping in mind that all the measures would only be temporary. Therefore, Britain did not go through a sustainability transformation, since it did not aim to reach a sustainable situation. The temporary nature of the British case also explains the lack of attention to environmental issues. At the same time, the government did have a compelling long-term vision for the social aspect of its policy. Britain did not experience a transformation at all; it only saw a limited governance transformation with the setting up of the departments dedicated to managing supply and demand. What was studied, was a change within a system, a change that was necessary to adapt to the shocks and disturbances of the supply disruptions and displayed the flexibility of the system to retain its fundamental function. The situation in the Netherlands is different since it is focused on a transformation to reach long-term sustainability and resilience. What was analysed was the transformation process initiated to reach a society that does not need extensive planning or severe measures to respond to the shocks and disturbances of material constraint. The goal for the Netherlands is to reach a society that is inherently resilient to such as situation. Therefore, the two cases show indicate that top-down measures might be needed in times of crisis, but that bottom-up innovation contributes to a sustainable transformation of the entire society. However, when the sustainability transformation needs to be accelerated, a combination of the two could be most effective. When thinking about innovations, one generally primarily thinks of technological innovations. However, the theory describes the need for both technological and social innovations aimed at the four systems. Since innovation is the introduction of something new, the majority of the measures applied by the British government can be described as innovations, both technological and social. The innovations that are being developed in the Netherlands are primarily technological. The range of innovations that have been displayed in the British case can inspire the Dutch government to stimulate or even develop social innovations to influence the way products and materials are used. That innovations describe anything new that is introduced in the SES, shows that innovations, in the broadest sense of the word, are indeed the way to bring about a transformation. When not introducing anything new, nothing is changed, and therefore the system will not transform.

Since innovations are elementary to transforming the SES, it is crucial that any innovation that influences the system contribute to the sustainability transformation to prevent any undesired transformation from happening. Considering that innovations naturally occur in the SES, the theory recommends the application of selective pressures and the creation of windows of opportunity to increase the chance that desired innovations reach the mainstream market whereas undesired innovations will not. The notion of naturally appearing innovations also explains the balance between top-down institutional change and bottom-up innovation. This division is about using the strengths of the SES and the government optimally and assumes that the innovations required for the transformation are already present but only need support to gain the power that is needed to transform the system. It also provides direction for the government in determining when top-down innovation is needed, which is when bottom-up innovation is not sufficient to bring about the desired transformation, especially when short timeframes are involved. However, in a typical situation, the government focuses on supporting desired innovations. In the case of Britain, windows of opportunity and selective pressures were limited because the majority of the innovations was top-down because of the short timeframe and the idea that the goal was not a complete systems transformation. Nonetheless, the British government did apply a quality mark which could have served as a selective pressure in a less government-controlled situation. The Dutch government aims to create windows of opportunity and applies selective pressures to stimulate innovations. These tools can be used to direct change, but also to accelerate change, depending on the

extent to which they are applied. Besides selecting the desired innovations, the windows of opportunity and selective pressures should also promote a diversity of innovations in all parts of the SES. In the Netherlands, the windows of opportunities and selective pressures that are present are primarily aimed at technological innovations. Developing additional opportunities and pressures for social innovations would help to accelerate and direct the transformation.

Likewise, the literature indicates that the opportunities and pressures should be designed in such a way that they enable an equal distribution of the advantages and disadvantages of the innovations. This distribution needs to be present on many levels, within the society and between societies, and within the current generation and between today's and future generations. Both cases address distribution but oppositely. Britain pays an extraordinary amount of attention to distribution within its society within the generation, while the Netherlands focuses on distribution between societies and between generations. The difference can be traced back to the origin of the material constraint in both cases. In Britain, the material constraint is caused by war, and therefore of a temporary nature, in the Netherlands, material constraint can arise due to critical materials problems which is a long-term problem. However, both are important in a sustainability transformation. Long-term distribution across borders is the foundation of the sustainability part of the transformation, while distribution within the society in the current generation is the foundation of the transformation itself because it helps to build the trust that is necessary to build the resilience of the new system. The question arises whether resilience is built solely by building trust as the literature suggests, or whether it is established through building trust at all. The case of Britain, in which high resilience was displayed, provides more insight into the role of building trust. In Britain, the government was devoted to ensuring that all social groups would have access to the necessary supplies and that the limited supplies that were available were equally distributed. Therefore, people could trust that the government would take care of their basic needs and therefore trusted the system. When people trust the system, they are likely to cooperate which enables the government to apply the necessary measures. As long as people trust the system, the system can maintain its fundamental function, even when being exposed to severe shocks and disturbances. The alternative to building trust is using force, which is not desirable nor useful in the long run.

When looking at the resilience in the case of Britain, a high level of resilience was observed, because the society was able to endure large shocks, was flexible to adapt to the new situation and was in a relatively comfortable starting position. For the Netherlands, there are two types of resilience present in the case. First, the resilience of the old system. The total resilience of the system consists of a range of specific types of resilience, among which is resilience to material constraint. The resilience to situations of material constraint in the Netherlands is relatively low in the old system, which is the reason why the Dutch government wants to transition to a circular economy. However, when going towards an entirely new system, the resilience of the old system needs to be dismantled to be able to change, after which the resilience of the new system has to be built again. The Dutch government seems to be doubting whether a full transformation is needed since the current strategy will not bring about a complete sustainability transformation. However, a complete transformation is essential to achieve long-term resilience and a truly sustainable system. Currently, transformation in the fields of economy, society, and environment are missing to result in a complete transformation.

The comparison of the British case to the framework has brought to the light that Britain did not experience a sustainability transformation, but instead a case of strong resilience to material constraint. While the British case cannot provide insight into the transformation process, it does show what resilience looks like. It also shows that there is sometimes no time for a complete transformation process, and in such a case planning is crucial for the level of resilience of a system. Detailed plans for a range of possible material constraint scenarios provide the government with a set of measures that can be used to manage the situation. Until

the sustainability transformation is complete, planning remains indispensable.

Finally, let us return to the start: the aim of the Dutch government to transition to a circular economy to increase resilience to critical materials problems. The theory, as well as the British case, have shown the necessity for a broader transition, including all aspects of the SES. Literature has also demonstrated that the concept of a circular economy does not entail an economic transformation, but a transformation of the industrial system. For the economic system, a period of degrowth was suggested. However, other authors have stated that achieving a decrease in GDP is not possible without implementing draconian state interventions such as rationing. This question cannot be answered wholly based on the results of this research. In Britain during WWII, the amount of capital involved in the civilian society drastically dropped, caused by both the material constraint itself and the government measures such as rationing. Therefore, the case supports the statement that degrowth cannot be brought about naturally. However, the war was an exceptional situation in which there was no other choice. Still, it is evident that state interventions are needed to curb consumption, though it is not known which types of interventions would lead to sustainable degrowth. Literature suggests that social interventions such stimulating an equal distribution of wealth and promoting immaterial wellbeing would help to encourage sustainable consumption patterns.

This research provides a comprehensive framework of the separate frameworks that exist in the fields of both industrial ecology and classic ecology and the related scientific fields. The field of industrial ecology is concerned with the issue of critical materials and is beginning to develop frameworks for sustainable materials use. The ecology field has an advanced and extensively peer-reviewed body of work on sustainability transformations, which has not been applied to the field of critical materials problems yet. This work combines the two fields in a new Governance for resilience to material constraint framework that has been tested using case study research, and the findings have been applied to the case of policy on material constraint in the Netherlands. The results show that a broad approach, including the entire SES, is essential and that the government can use selective pressures and windows of opportunity to steer and accelerate the transformation. The case study of policy on material constraint in Britain underlined the importance of planning besides the transformation. Additionally, the research has uncovered trust, and therefore the importance of equal and just distribution, as the foundation of resilience.

The Dutch government is in the best position to influence the sustainability of the social-ecological system of the Netherlands. The government is the only actor in the system that can represent the interests of all societal groups and should, therefore, take the responsibility to use its authority and define a sharp vision and goals for the sustainability transformation. If diversity and distribution are valued during the transformation process, the Netherlands is in the position to achieve a high level of resilience to critical materials problems. Resilience does not mean that situations of material constraint will not occur, or that they will not affect the society, but it does mean that the Dutch social-ecological system will be flexible enough to change according to the new situation while maintaining its function.

### 5.3.2 Limitations of research

The study has primarily been limited by the selection of the case study. First, only one historical case was used because of limitations in time. However, the consequence is that the theoretical framework could be tested using only one case, while different results could have been developed when a different case would have been selected. Therefore, the use of multiple historical cases would have added to the value of this research. Additionally, the case of Britain that was selected eventually appeared not to be a case of sustainability transformation, which reduced the extent to which the case could be used to test the framework.

Additionally, a general limitation of case study research is that it involves a high level of interpretation. Therefore, the same research could lead to a different outcome if it was conducted by another researcher, even though a

structured methodology was used to reduce the influence of personal interpretation bias.

### 5.3.3 Recommendations

Valuable research that could be done to build on this work would be to conduct a similar analysis with a different case, such as the period of resource constraint in the 1970s. Additionally, further research could be done into the different phases of the framework, such as a study of the transformation phase. A study into the transformation phase could discover aspects such as how many innovations and what level of innovations are needed to complete a transformation. It is also interesting to find out at what point a government should decide to aid the transformation by applying top-down innovations, and what the effect of a combination of top-down and bottom-up innovations would be. Additionally, further research could show what kind of selective pressures and windows of opportunity would ensure diversity and distribution. Furthermore, research into how governments can bring about sustainable degrowth would be valuable.
In a practical sense, this theoretical framework that has been developed in this research can be used by government officials to test its usefulness in helping to develop a transition pathway for the government, including a timeline.

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# *Appendix A*
# Dutch interview questions

## Interview afstuderen

Ik doe onderzoek naar overheidsbeleid in tijden van een tekort aan grondstoffen en dan toegespitst op de problemen rond kritieke materialen voor Nederland. Daarvoor vergelijk ik de situatie in Engeland tijdens de Tweede Wereldoorlog met de circulaire economie nu, om daar hopelijk lessen uit te halen voor de huidige situatie.

1. Zou u kort willen vertellen wat u precies doet als secretaris van de Nederlandse grondstoffenstrategie?
2. Op welke manier denkt u dat Nederland te maken heeft en/of krijgt met een tekort aan grondstoffen?
3. Wat is de invloed van schaarste aan grondstoffen op de maatschappij?
4. Op welke manier draagt de huidige maatschappij bij aan deze problemen?
5. Hoe kan voorkomen worden dat Nederland grote problemen krijgt met kritieke materialen en een tekort aan grondstoffen?
6. Hoe kijkt u daarin aan tegen economische groei? Is het nodig om minder of helemaal niet meer te groeien met het oog op grondstoffengebruik? Is het mogelijk om minder harde/helemaal geen economische groei te hebben?
7. Hoe urgent is het probleem met kritieke materialen voor de overheid?
8. Wat is de rol van de overheid in het oplossen van deze problemen?
9. Is de overheid eventueel geïnteresseerd in de resultaten van mijn onderzoek?

# *Appendix B*
# *A priori* codebook

Table B.1 *A priori* codebook.

| Code | Description |
|---|---|
| **Material constraint** | Not able to access sufficient material for the demand |
| • Critical materials | List of materials that are at high risk of becoming, or already are, hard to access because of high risk of supply disruption or a high importance for the economy or both |
| • Geopolitical tensions | Tensions between countries that can result in reduced exchange of resources, etc. |
| • Export restrictions | When countries choose to reduce export of certain resources to protect their own market |
| • Environment | The ecosystem of our planet which is affected by the extraction of resources |
| **Societal transitions** | Moving from one paradigm to another as a society |
| • Production | The processes, usually undertaken by businesses, to change resources into products |
| • Consumption | Buying those products for personal use by consumers |
| • Economic growth | Or GDP growth, the most important measure for the economic welfare of a company or country |
| **Role of the government** | The role that a government adopts lead a country |
| • Social | Increased control |
| • Liberal | Small government, less interference, market will balance itself |
| **Solutions** | Solutions that can be adopted to anticipate on (future) critical materials issues |
| • Circular economy | An economy where all materials go in cycles through the economy, which is also emission and toxin free, improves the environment and runs completely on renewable energy |
| • Framing of the circular economy | The circular economy is framed as a solution to, amongst other things, supply issues, which is only partially true |
| • Reuse | Reuse materials at their end-of-life as much as possible and at the highest level possible to reduce the need for primary material |
| • Stockpiling | Create large stocks in advance to reduce the effect of reduced supply of materials |
| • Technology | Technological innovations could help to move to a less material intensive economy, so the same economic value can be achieved with less material |

# *Appendix C*
# Material use in Britain during WWII

*Economy*

By the late 1920s, the economic situation of Britain stabilised, but it already fell behind the United States. Churchill put Britain back on the gold standard in 1925, which probably, combined with inflationary effects of the World War and supply-side shocks caused by reduced working hours after the war, caused the mediocre performance of the economy. The Great Depression in the 1930's fortunately impacted Britain less severely than other major nations, though there were times of long-term unemployment and hardship, especially in the mining districts. The impact was less hard because Britain had not seen the boom that other countries had gone through in the twenties. Still, Britain's world trade fell in half, and the output of heavy industry fell by a third. Employment and profits plunged in nearly all sectors, reaching its lowest point in the summer of 1932. Depression in the shipbuilding industry, while it had been dominating world trade for over the past hundred years (in 1914 42 per cent of the world steam and motor tonnage sailed under the British flag). (Postan, 1952; Greaves, 2007)

During and after the First World War, steel production had been expanded significantly, which caused excess capacity during the 1920s. The output was mainly plain steel, made from phosphoric ores from the East Midlands. However, the output of iron ore declined in the rest of the country, leading to a general decrease in iron ore output. Since imports of iron ore could not be increased, the increased steel production was made possible by increasing the use of scrap iron. Exports of coal and steel halved by 1939 and the business community was slow to adopt new labour and management principles from the US. (Solomou & Vartis, 2005; Broadberry & Howlett, 2014)

In June 1936, a new policy was accepted, and the building-up of reserves of some raw materials had begun. The building of reserves applied only to essential materials of which standard stocks in the country were small, which concerned only a limited number of materials. At the beginning of 1939, as the war was approaching, the issue of sufficient raw material stocks was reconsidered, and in the end, in July 1939 moderate amounts of American cotton, iron ore, pit-props, phosphate rock, copper and hemp were bought. Additionally, in October 1939, lead, zinc and wool were bought in bulk from Empire producers. Also, plans were made to substitute commodities such as timber, iron ore and flax with home supplies and the use of scarce materials by more common ones, but these plans were not executed until later during the war. (Postan, 1952; Peck, 2016)

In March 1938, the assumption that rearmament should not impede the course of regular trade was cancelled, mainly because of the aircraft industry which

pointed out that it would not be able to complete the rearmament programme by 1939, but that it would take up to two years longer. From that point onwards, the rearmament programme had the priority in the nation's efforts. However, in the beginning the government established nothing more than a generic system of priorities, which encouraged producers to take on rearmament orders, but manufacturers often chose not to do so for reasons of profit and civilian production continued to compete with military production. (Postan, 1952; Peck, 2016)

It became clear that if there were to be a war in five years, the height of peacetime orders would not be sufficient to train and equip factories to provide the amount required during wartime. Therefore, the government invested in 'educational orders' and the erection of distinct factories. (Postan, 1952)
About a month before the outbreak of the war, in August 1939, the Ministry of Supply and its Raw Materials Department were set up, and a group of 'essential' commodities were placed under control. In the later stages of the war, more and more materials were placed under control.

Britain was a relatively wealthy country in the first half of the twentieth century so that devoting nearly 50 per cent of national expenditure to the war resulted in a formidable war effort. GDP, just like during the First World War, GDP rose significantly during WWII. GDP growth reached a peak of 27 per cent above the pre-war level. This growth of GDP during wartime was an essential aspect of the financing of the war effort. Britain saw a sudden expansion of government expenditure, especially in the first two years of war. (Broadberry & Howlett, 2014)

Regarding consumer expenditure, during the inter-war years, it had seen a rapid increase (Figure C.1). When the war began, it significantly decreased again. In 1942, consumer expenditure had fallen by about 15 per cent. Additionally, a shift towards goods and service with a low resource content was observed. Household goods sales decreased by 25-75 per cent since many of the goods were regulated under the utility and austerity schemes. Such a reduction in consumption – in both magnitude and duration – had never happened before in Britain. As Dow describes it, '*the wartime system of controls was interlocking, self-reinforcing and, in total, almost all-extensive: demand that was not stopped at one point was stopped at another*' (Dow, 1964, p. 146). One of the reasons for the implementation of the extensive system of controls by rationing, austerity and the utility schemes, was to curb inflation which rose since unemployment was eradicated due to the war effort. How the ever, in the first place, it was essential because of the need to economise on raw materials, labour and shipping space and to achieve a balanced distribution of resources between military and civilian requirements since it was essential to maintain civilian efficiency. (Zweiniger-Bargielowska, 2000)

The need to control the production of war goods as well as civilian goods meant an inevitable extension of state power and therefore, of state control of the economy. The government had control over imports, production, distribution, and prices of consumer goods, resulting in an exceptional degree of regulation of production and a massive reduction in consumption. Food, clothing and petrol were rationed, but the rationing only applied to a certain number of goods within these categories. For the category of household goods, all goods became subject to extensive regulations, made possible by emergency legislation and a vast bureaucracy. As a result of the intensive rationing and controls regulations, private consumption of food, clothing, miscellaneous household goods, and private motoring was significantly reduced as economic resources were directed towards the war effort. The combined effect of rationing, price controls and subsidies tied with zero unemployment and high taxes did not only reduce consumption but also resulted in a more uniform distribution of goods between income groups. During the period of scarcity, the regular price mechanism did not function, and allocation was determined by a combination of price controls, rationing and the black market. As with regards to the price controls, these were an integral part of Britain's war economy from the start. They were mainly implemented to maintain morale, prevent economic derangement at a time of war, prevent post-war economic disturbances, controlling government expenditure, and preventing certain societal classes of enriching themselves at the cost of others. Therefore, the

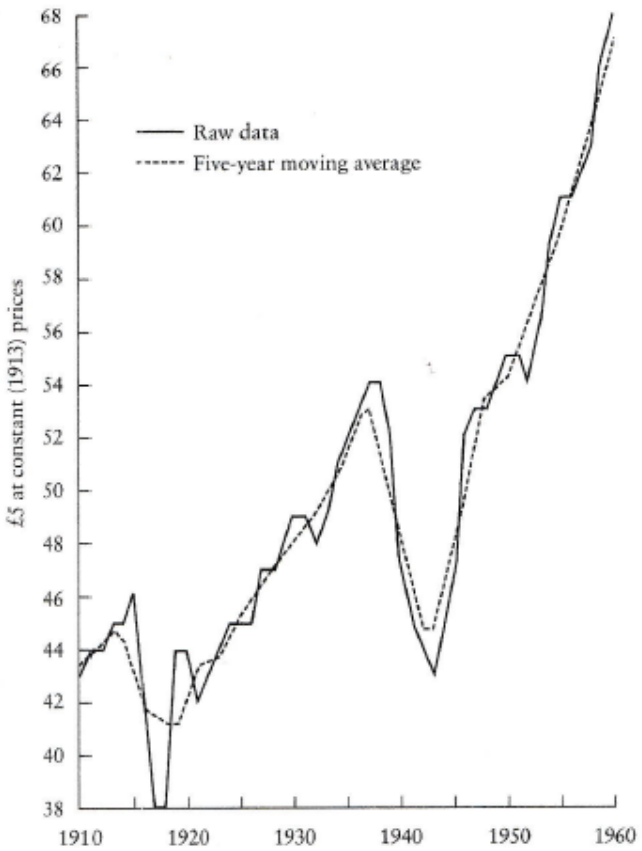


Figure C.1 Metal price index from January 2016 to August 2017. Reprinted from The Economist, 2017. Consumers' expenditure per capita at constant (1913) prices, 1910-1960. Reprinted from Zweiniger-Bargielowska, 2000.

government adopted two main goals: minimising the increase of the general British price level and controlling the prices of specific goods to prevent corrupt profits. The three most important agencies that were involved with price control were the Ministry of Supply, the Ministry of Food, and the Board of Trade. The Ministry of Supply determines the price of industrial raw materials, both for civilian and military use; the Ministry of Food determines the price of all food-related goods; and the Board of Trade controls the prices of consumer goods, by the Prices of Goods Act and the Goods and Services Act. The Treasury is responsible for assuring uniformity in the price policies of the different agencies. (Marwick, 1968; Zweiniger-Bargielowska, 2000; Earley & Lacy, 1942)

The Ministry of Supply was created after the Ministry of Supply Act was accepted in July 1939 and had the task to congregate supplies of industrial raw materials for civilian and military use, and, once collected, to distribute those supplies through the industrial system. Therefore, the Ministry is divided into two departments: the Raw Materials Department and the group of Directors General. Each of the five Directors General is in charge of the production of a military good. The Raw Materials Department is divided into sections which are all responsible for one or more raw materials. Each section has a complementary Control Board, composed

of representatives from the industry. To determine the prices of raw materials, the Raw Material Department consults with the Finance Department, industrial advisory committees and the Treasury. (Earley & Lacy, 1942)

The activities of the Board of Trade, related to price controls are to control the prices of consumer goods and services, regulate civilian industry using its licensing power and the Limitations of Supplies Orders, and determine the import-export policy. The Board of Trade was charged with the administration of the Prices of Goods Act and the Goods and Services (Price Control) Act, which served as an addition to the previous act. The Prices of Goods Act, established in 1939, allowed the regulation of prices by requiring that a good shall not be sold at a higher price than the basic price plus a permitted increase. In July 1941, the Goods and Services (Price Control) Act was passed as a supplement to the Prices of Goods Act. The new act allowed the Board of Trade to fix maximum prices, to minimise the activities of unnecessary intermediaries, and to establish an official price control organisation. The Board of Trade selected a Central Price Regulation Committee that was responsible for its price regulation activities. (Earley & Lacy, 1942)

One of the major aims of the price control programme was to restrict profits to a reasonable level. Prices were initially set very near the prices from immediately before the start of the war and were reviewed from time to time to be adjusted according to the current imports and costs. However, the policy showed that the fixing of prices based on costs and profits is not able to solve the problems faced by a price regulation authority in modern war. The one who fixes the prices inherently has the task to fully manage the supply and the consumption of the goods under control. Otherwise, the price needs to be fixed at the same level the market would have determined. The price that appears reasonable to provide the industry with basic profits will almost certainly provide insufficient profit to sustain adequate supply and restrain consumption within the limits of available supply. (Earley & Lacy, 1942)

Another measure that was taken to prevent large price increases by maximising supply was to purchase large supplies of essential commodities in advance, in addition to increasing national production. Additionally, 'cost-equalisation' schemes were used to balance national production and imports of commodities such as steel by imposing a levy on domestic production and using the fund to subsidise the import of the material. (Earley & Lacy, 1942)

Thirdly, British policy on price control during WWII has shown that extensive regulation of the process of distribution is essential to successful control of prices. Lastly, the experience of Britain, as well as all other countries shows that in total war, the supplies of goods cannot be made sufficient to meet both civilian and military demands at constant prices. However, through the use of priorities, allocation and rationing, in addition to conserving scarce goods and services for the war effort, the British authorities have significantly contributed to stabilising prices.

The impact of the war on the civilian economy increased gradually and especially during the first nine months of the war, the average standard of living was sustained. A state of affairs that rapidly changed after the fall of France. The limitation of Supplies Orders, introduced in 1940, restricted the permitted sales of household goods to a fraction of the pre-war level. By Spring 1941, the supply of miscellaneous consumer goods was reduced by 30-75 per cent, also causing severe shortages of the more necessary commodities. During 1941 and 1942, improvements were made to the system, especially with the introduction of the Goods and Services (Price Control) Act in July of 1941. Additionally, the limitation of Supplies Orders did not suffice since it did not distinguish between essential and non-essential goods. The Board of Trade had to be careful to maintain morale among the citizens. From 1941 onwards, tableware was only produced under licences and according to approved specifications. In 1942, this policy was extended to a wide range of consumer goods. For furniture production, the Utility Furniture Scheme was introduced in 1943 to control quality, price and address supply shortages. The furniture was freed from tax responsibility, and the profits for producers and retailers were fixed. (Zweiniger-Bargielowska, 2000; Peck, 2016)

The policy measures related to the field of

economy that have been applied are:

| | |
|---|---|
| 1927 | watch stocks of raw material and maintain a list of contractors |
| 1933 | appoint an advisory group of leading people from the industry who produced an assessment of the resources that manufacturing needed for the production of armaments |
| 1936 | [June] a new policy on the building-up of reserves of some raw materials is accepted |
| 1937 | detailed planning of production, firm by firm, including a thorough understanding of the company material requirements |
| 1938 | cancellation of the assumption that rearmament should not impede the course of regular trade, priority of the nation's efforts to the rearmament programme |
| 1939 | investment in educational orders and the erection of distinct factories |
| 1939 | [July] moderate amounts of American cotton, iron ore, pit-props, phosphate rock, copper and hemp are bought |
| 1939 | [August] setting up of the Ministry of Supply and its Raw Materials Department<br>the first group of essential commodities is placed under the control |
| 1939 | [October] lead, zinc and wool are bought in bulk from Empire producers<br>Plans are made to substitute commodities such as timber, iron ore and flax with home supplies and the use of scarce materials by more common ones |
| 1939 | [November] introduction of the Prices of Goods Act |
| 1940 | Limitation of Supplies Orders introduced |
| 1940 | [July] all timber supplies for domestic furniture are withdrawn |
| 1941 | Utility Ceramics Scheme |
| 1941 | [February] Standard Emergency Furniture |
| 1941 | [July] introduction of the Goods and Service (Price Control) Act |
| 1943 | Utility Furniture Scheme |

### *Technology*

With regards to the technological situation of Britain in the interwar years, Edgerton notes that Britain was a technologically advanced and eager to innovate. If having a small domestic agricultural sector is a measure for modernity, then Britain was by far the most modern large nation in the world. Britain's shipping fleet was also the biggest merchant marine in the world, making up over a third of the world's ocean-going gross registered tonnage. The ships themselves were also unique in the world, especially the refrigerated liner, which carried all kinds of chilled and frozen products from the southern hemisphere to Britain. All around the world British technical experts were vital to the operation of British-owned facilities. (Edgerton, 2011) Vital industries to the war were the navy, the air force and arms. By 1939 about a quarter of the world fleet was powered by diesel engines.

At the time of the start of the war, the principal materials were bauxite, zinc concentrates, wool, flax and rubber. Other essential commodities such as iron and steel, some non-ferrous metals, wool, leather, timber, hemp, flax, jute, paper and aluminium, that were scarce or were in danger of becoming scarce were placed under full control. The war resulted in a range of material shortages, which all had to be dealt with differently. One strategy was to find a domestic substitute, mainly for wood and iron ore. However, changing towards production using these substitutes often caused problems for manufacturers. For example, the iron ore mined in Britain was of a lower grade and iron content than imported ores, increasing the energy demand for steel production. For wood, imported softwoods were substituted by domestic hardwood, which caused problems for, for example, furniture production, since some of the designs were based on softwood. (Postan, 1952; Peck, 2016)

During the war, the supply of materials for both civilian and military purposes was essential to British success. Therefore, several technology-related policy measures were implemented to reduce material use. In 1943, the Utility Furniture Scheme was introduced to control the production and distribution of furniture. Besides controlling, how much was produced, the Utility Scheme also aimed to reduce power, labour and material

used during production. Therefore, detailed recordings and inspections of all stages of the supply chain were kept. Producers needed a licence to produce furniture, and licences were provided strategically since the production was allocated geographically to reduce transportation distances. Specific designs were specified, and it was strictly forbidden to produce anything else than these designs. All of the designs had a unique specification number, which was approved by the government. The government encouraged batch production in large runs. The designs were also made in such a way that less skilled workers were needed for the production so that the higher skilled workers were available for the war effort. The government attached much value to ensuring that the furniture that was produced, though limited in quantity, was high in quality to increase durability and provide people with valuable furniture. The Board of Trade gave the items the CC41 Utility logo, in which CC stood for *controlled commodity*, which indicated that the item conformed to the government austerity regulations. After the utility scheme ended in 1952, manufacturers could still use the CC41 logo to indicate that it was an item of high quality. Additionally, it was important that the items were easy to repair and did not have any features that wasted material, such as additional style elements like carvings. Utility furniture had wooden handles instead of plastic ones and solutions were sought to reduce the need for steel screws. (Peck, 2016; Mills, 2008)

The government encouraged people to reduce, repair and reuse by providing information in the 'Make Do and Mend' campaign, which was explicitly aimed at housewives and gave them advice on how to give clothes a longer life and be creative with the materials that were available. For example, people were encouraged to use parts of old items to repair items that can still be used. Some products could just not be produced because of the vast number of scarce materials required, such as a three-piece upholstered suite. (Mills, 2008; British Ministry of Information, 1943)

The policy with regards to technology, engineering, and materials that has been applied is:

1942 [autumn] The Make Do and Mend scheme is given official support by the Board of Trade
1943 the pamphlet 'Make Do and Mend' is issued

*Society*

The interwar period is a period of peace and relative economic stagnation. The British society had become more egalitarian after the First World War. Power was removed from the landed aristocrats towards the lesser businessmen. The working class had a strengthened role in the market, and therefore their wages and living standards rose. Additionally, their participation in activities and decisions increased which resulted in a stronger political and industrial organisation, mainly through the process of legislation. The new power of the working class resulted in the quick organisation of the Labour Party and acceleration of social reform. The average income of all working-class families rose by 100 per cent between 1914 and 1920, while after 1920, prices fell while the new income levels remained stable, which further increased the welfare of the working class. The taste of affluence, afforded to some workers during the war, significantly accelerated that quest for a higher standard of living which in itself has proved so potent an agent of continuing social change. Unemployment because of the dislocations of war. New social construction of education, health provision and housing to repair the wastage caused by the war. Destruction of inefficient institutions and transforming less efficient mechanisms into more efficient ones (i.e. economic liberalism, the Liberal party and the rapid development of science and technology). After 1918 Britain became a political democracy. Stimulus to the arts in Britain. Many conversions to socialism or away from orthodoxies. (Marwick, 1968)

Because of the economic crisis of the early 1930s, there were severe pockets of long-term unemployment, but apart from those pockets, Britain was generally prosperous. Prices fell sharply while income rose and over 4,000,000 new houses were built. The number of cars on the expanding road network grew from 110,000 to 2,300,000. Industrial and urban development was accelerating. Land, labour and materials were cheap. Many people from the middle class could buy telephones,

beautiful suites, electric cookers and vacuum cleaners. In Britain, the depression spawned a consumer boom. (Brendon, 2008; Sims, 2016)

Business as usual went on until March 1938, when the government realised the rearmament programme needed higher priority as the outbreak of war was expected soon. Even though 'business as usual' was over at this point, 'life as usual' could go on since the supply of material to civilian businesses was not yet restricted. (Peck, 2016)

The policy with regards to the societal aspects that has been applied is:

1941 Utility Ceramics Scheme
1941 [February] Standard Emergency Furniture
1943 Utility Furniture Scheme

*Environment*

As the environmental consequences of the Industrial Revolution became evident, organised environmentalism arose as people sensed that the process of industrialisation was not going to end. Already before the First World War, in 1895, the National Trust was founded, an organisation that cares for historic properties and beautiful countryside. In 1912, the Society for the Promotion of Nature Reserves (now called The Wildlife Trusts) was founded, which aimed to purchase land to protect it as nature reserves. A few years later, in 1926, the Council for the Preservation of Rural England was established to protect and shape the English countryside. More than a century after the start of the industrial revolution, people started to become disillusioned with Western progress and wanted to go 'back to the land' or 'back to nature'. The British middle class withdrew to '*the rustic and nostalgic myth of an "English way of life"* ' (Sims, 2016, p. 17), which has been said to have led to the British falling behind economically from the 20th century onwards, but was also the start of environmental practices. (Sims, 2016)

In the inter-war period, Matless (2016) notes an emergence of a planner-preservationist movement. The preservationism sought to protect the countryside while encouraging the continuation of well-planned urban and industrial development, using expert knowledge. Preservationism was a central topic at that time, for example around the development of a national electricity grid between 1927 and 1934 where some saw this new power source as a transformative power for society, while others felt the network of pylons threatened the rural landscape. Overall, a sense of balancing planning and preservationism was present throughout the inter-war period in the broader political community when it came to protecting the environment, though, mainly aimed at preserving the aesthetic qualities of the land and providing access to clean outdoor space to impoverished workers. The desire for National Parks, following the example of national parks in the USA, arose and the government encountered campaigns to convince them to do so. (Sims, 2016)

In 1929, the government established the National Park Committee chaired by the former Minister of Health, following two decades of discussion and investigation into establishing national parks. The goal of this committee was to

> *'consider and report if it is desirable and feasible to establish one or more National Parks in Great Britain with a view to the preservation of natural characteristics including flora and fauna, and to the improvement of recreational facilities for the people.'*
>
> (National Park Committee, 1931, p. 1)

The committee published its report in 1931, with the recommendation to create a network of National Parks in Britain. They realised that Britain is a relatively small country compared to the USA and that it would, therefore, be impossible to separate large pieces of land and to keep them virtually untouched by humans. In Britain, every acre of land was already used for economic purposes to some extent, which also contributed to the beauty of the land. It would be necessary to keep working on this land to preserve its qualities. However, the committee did recommend to establish the network of National Parks to plan these areas in such a way that it would help to preserve the beautiful and wild countryside in England

and Wales to some extent.

In 1932, the National government passed the first Town and Country Planning Act. The wartime coalition passed additional acts in 1944 and the Labour government in 1947. This first town and country planning legislation provided the principle of 'amenity', which served as a term to describe the satisfactory quality of the surroundings that should be considered when planning for the development of urban and rural land.

At the end of WWII, the Labour government set up a second National Parks Committee. Their primary focus was on health and recreation for people living in urban areas. They published their report in 1947, which provided the foundation for the legislation of 1949. In that year, the National Parks and access to the Countryside Act was passed, which provided the framework for the creation of National Parks. (Sims, 2016)

During the inter-war period, concern over the status of the countryside and natural beauty grew more intense and became enshrined in law with the legislative measures of the 1940s. The legislation of the 1940s coincided with the extension of governmental authority into other areas of national life, and the willingness of both main parties to use state power in the interests of public welfare would help to shape the development of environmental politics in subsequent decades. (Sims, 2016)

Even though town and country planning and the National Parks were designed to protect the landscape, it was not an expression against development, but rather a balancing of the two. (Sims, 2016)
Ultimately, this desire for balance was answered by the creation of the National Parks. Only after the smog disaster of December 1952, legislation with regards to pollution came into sight with the 1956 Clean Air Act. (Sims, 2016)

With regards to energy, Figure C.2, Figure C.3, and Figure C.4 show a trend of decreasing coal production and consumption (after a mild increase at the start of the war), and a substantial increase of gas and electricity production. These figures indicate a shift away from coal. At the time of the Second World War, 90 per cent of the electricity was produced from coal, and Figure C.4 shows a substantial increase in electricity use. Figure C.5 confirms the increase in the use of coal for electricity consumption but shows that this increase was compensated by a decrease in coal use for domestic and industrial purposes. These developments indicate the start of the transition away from coal, towards cleaner energy sources which would be less detrimental to the ability of present and future generations to meet their needs. Still, this transition was primarily caused by economic developments and was not necessarily born out of concerns for the environment.

The policy with regards to the environment that has been applied is:

| | |
|---|---|
| 1929 | The government establishes the first National Park Committee |
| 1932 | The National government passes the first Town and Country Planning Act |
| 1944 | The wartime coalition passes additional acts |
| 1945 | The second National Parks Committee is set up |

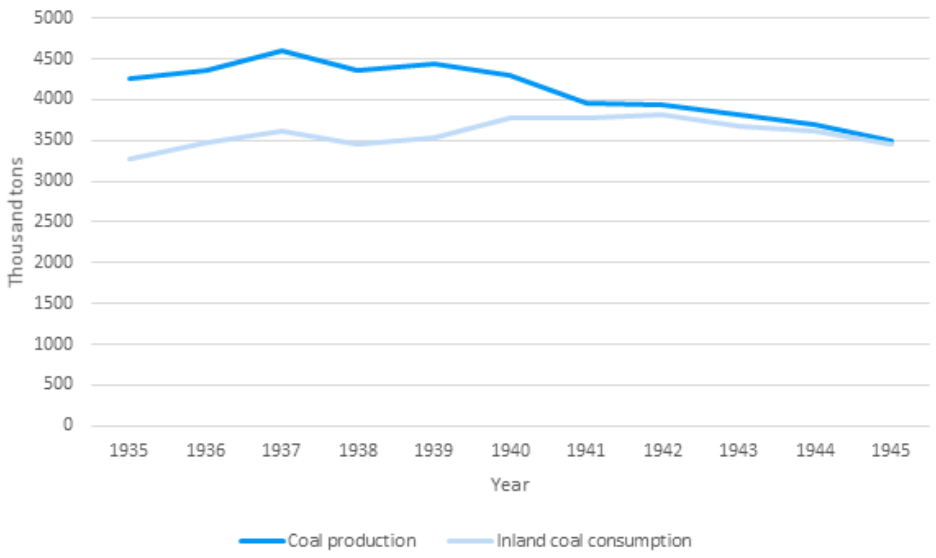


Figure C.2 Production and consumption of coal, weekly averages. Data from Central Statistical Office (1946).

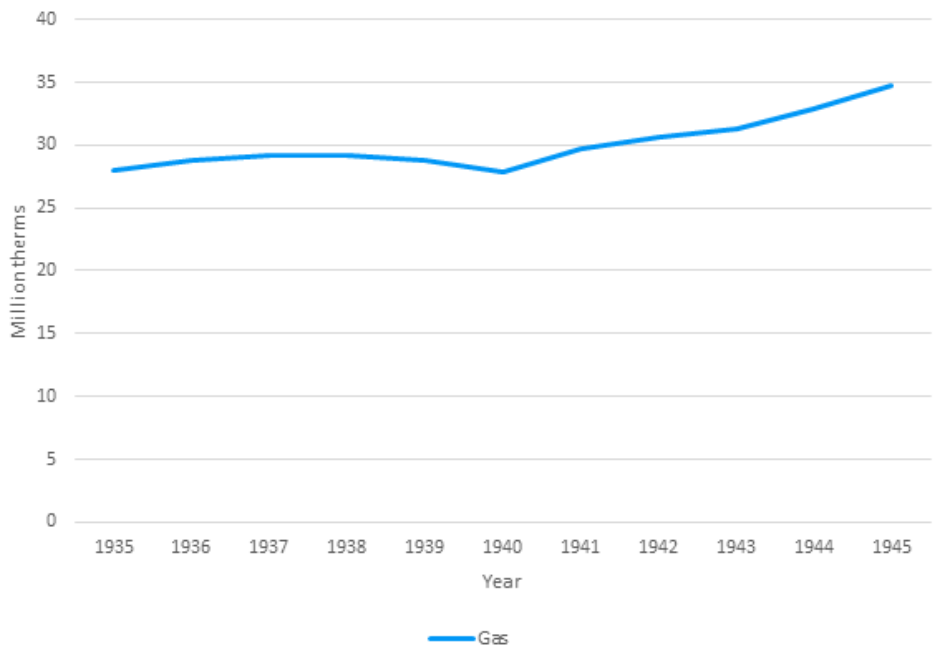


Figure C.3 Production of gas in Great Britain, weekly averages. Data from Central Statistical Office (1946).

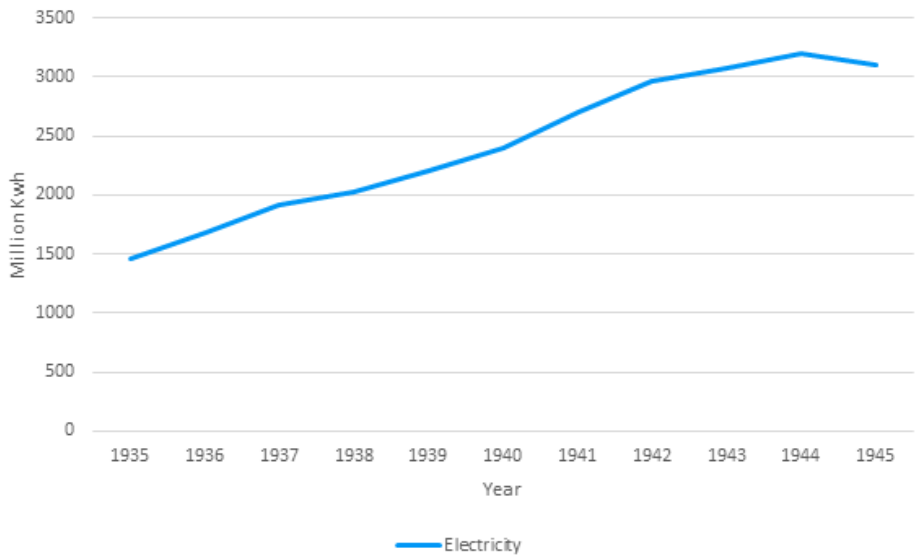


Figure C.4 Electricity generated in Great Britain, monthly averages. Data from Central Statistical Office (1946).

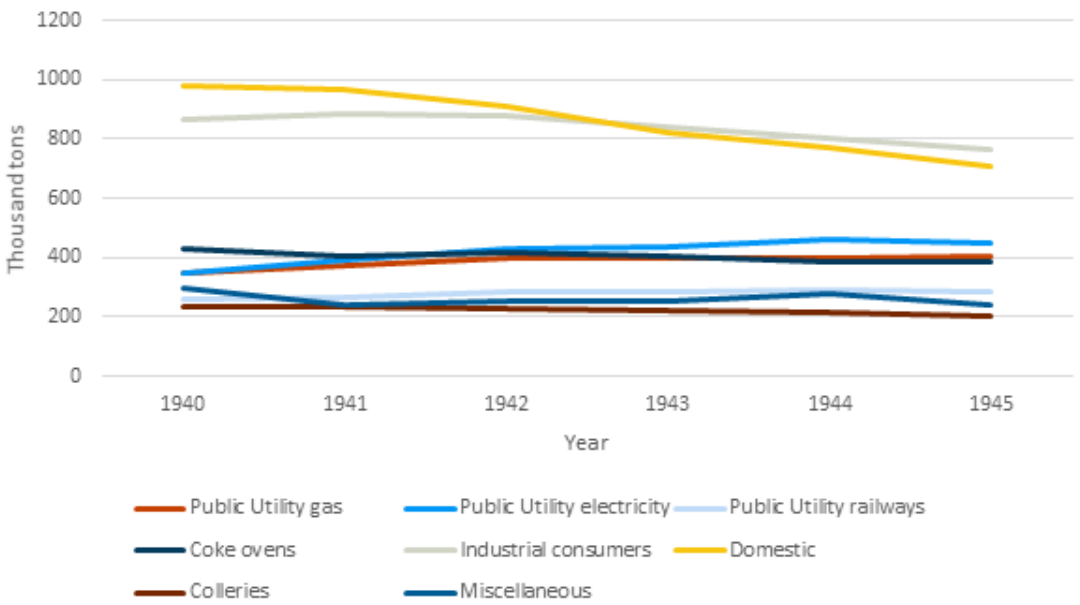


Figure C.5 Inland consumption of coal divided by category, weekly averages. Data from Central Statistical Office (1946).

# *Appendix D*
# Material consumption in Britain

Table D.1 Consumption of several industrial raw materials. Data from Central Statistical Office (1946).

*Thousand tons, monthly averages*

| *Year* | Scrap consumption iron | Virgin aluminium consumption | Magnesium | Bauxite | Copper | Zinc | Lead | Tin |
|---|---|---|---|---|---|---|---|---|
| 1935 | 452 | 2,8 | | | 20 | 17 | 29,2 | 1,79 |
| 1936 | 532 | 3,2 | | | 21,5 | 17,3 | 29,5 | 1,82 |
| 1937 | 576 | 3,3 | | | 25,1 | 17,4 | 28,8 | 2,16 |
| 1938 | 472 | 3,7 | | | 21,5 | 15,4 | 27 | 1,52 |
| 1939 | 568 | 6,5 | | | 24,4 | 18,6 | 28 | 2,27 |
| 1940 | 552 | 8,5 | 0,67 | | 37,2 | 21,7 | 21,1 | 2,65 |
| 1941 | 532 | 9,7 | 1,15 | 13,7 | 37,5 | 21 | 17,9 | 2,93 |
| 1942 | 576 | 16,3 | 1,73 | 14 | 40,9 | 20,6 | 20,5 | 2,24 |
| 1943 | 612 | 17,3 | 3,01 | 18,6 | 36,9 | 18,6 | 17,7 | 1,47 |
| 1944 | 568 | 12,5 | 3,01 | 17,9 | 29 | 15,4 | 18,4 | 1,54 |
| 1945 | 552 | 8,5 | 0,8 | 12,9 | 24,6 | 15,8 | 19,9 | 1,44 |
| Average 1935-1939 | 520 | 3,9 | - | - | 22,5 | 17,1 | 28,5 | 1,91 |
| Average 1949-1945 | 565 | 12,1 | 1,73 | 15,4 | 34,3 | 18,9 | 19,3 | 2,05 |
| Average increase (%) | 9 | 211,0 | - | - | 52,7 | 10,0 | -32,5 | 6,99 |

The average increase in consumption of industrial raw materials is 37 per cent.

Table D.2 Supplies of household appliances for the home civilian market per month. Data from Central Statistical Office (1946).

*Number of products (thousands)*

| *Year* | Electric fires | Electric irons | Electric vacuum cleaners | Electric kettles | Radio sets | Domestic sewing machines | Prams, etc. | Cycles | Travel goods |
|---|---|---|---|---|---|---|---|---|---|
| 1935 | 100 | 100 | 33 | 30 | 150 | 8 | 50 | 140 | 700 |
| 1942 | | | | | | 2,8 | 27 | 40,4 | 108 |
| 1943 | 4,3 | 7,6 | 0,03 | 2,4 | 14 | 1,7 | 34,2 | 44,7 | 71 |
| 1944 | 3,9 | 14,8 | 0,08 | 5,4 | 15 | 1,5 | 40,6 | 36,6 | 66 |
| 1945 | 25,9 | 44,8 | 5,93 | 11,4 | 20,2 | 1,55 | 45,3 | 47,5 | 99 |
| Average 1942-1945 | 11 | 22 | 2 | 6 | 16 | 2 | 37 | 42 | 86 |
| Decrease (%) | 89 | 78 | 94 | 79 | 89 | 76 | 26 | 70 | 88 |

The average decrease in the supply of household appliances for the home civilian market is 76 per cent.

Table D.3 Supplies of miscellaneous goods for the home civilian market. Data from Central Statistical Office (1946).

*Number of products (thousands)*

| *Year* | Table cutlery | Spoons and forks | House-hold brushes | Tooth brushes | Other toilet brushes | Clocks | Watches | Fountain pens | Pencils | Matches (millions) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1935 | 2000 | 4700 | 5000 | 2100 | 1400 | 400 | 540 | 750 | 12500 | 229 |
| 1942 | 526 | 1474 | 3054 | 1487 | 786 | | | 180 | 7918 | 149 |
| 1943 | 358 | 482 | 2876 | 1208 | 643 | 34 | 23 | 158 | 8936 | 140 |
| 1944 | 419 | 630 | 2701 | 1328 | 714 | 67 | 22 | 156 | 8665 | 143 |
| 1945 | 473 | 1110 | 2854 | 1548 | 748 | 57 | 39 | 170 | 8509 | 140 |
| Average 1942-1945 | 444 | 924 | 2871 | 1393 | 723 | 53 | 28 | 166 | 8507 | 143 |
| Decrease (%) | 78 | 80 | 43 | 34 | 48 | 87 | 95 | 78 | 32 | 38 |

The average decrease in the supply of miscellaneous goods for the home civilian market is 61 per ce

Table D.4 Industrial materials prices. Data from Central Statistical Office (1946). Supplies of household appliances for the home civilian market per month. Data from Central Statistical Office (1946).

*Price index – August 1939 = 100*

| *Year* | Basic materials | Intermediates | Manufactures | Building materials |
|---|---|---|---|---|
| 1935 | 93,4 | 84,3 | 87,3 | 90,1 |
| 1936 | 104,7 | 89,7 | 90,3 | 92,9 |
| 1937 | 130,1 | 104,7 | 102,5 | 100,1 |
| 1938 | 98,3 | 100,5 | 103,1 | 100 |
| 1939 | 105,5 | 102,4 | 102,4 | 100,7 |
| 1940 | 155,9 | 139,4 | 123 | 117 |
| 1941 | 176,4 | 158,8 | 136,5 | 133,9 |
| 1942 | 178,7 | 162,5 | 140 | 139,2 |
| 1943 | 184 | 164,7 | 142,5 | 143,8 |
| 1944 | 194,9 | 168,3 | 145,9 | 147,3 |
| 1945 | 198,7 | 173,7 | 147,7 | 150,3 |
| Average 1935-1939 | 106,4 | 96,3 | 97,1 | 96,8 |
| Average1940-1945 | 181,4 | 161,2 | 139,3 | 138,6 |
| Price increase (%) | 70,1 | 87,9 | 86,4 | 87,1 |

The average increase in industrial materials prices is 82.9 per cent.

Table D.5 Consumption of home grown and imported hardwood and softwood. Data from Central Statistical Office (1946).

*Softwood in thousand standards and hardwood in million cubic feet (multiplied by 10)*

| *Year* | Home grown softwood | Home grown hardwood | Imported softwood | Imported hardwood |
|---|---|---|---|---|
| 1940 | 13,45 | 18,4 | 59,1 | 21,2 |
| 1941 | 18,71 | 21,7 | 52,52 | 16,1 |
| 1942 | 23,3 | 32,1 | 39,86 | 13,6 |
| 1943 | 20,74 | 37,5 | 35,8 | 10,9 |
| 1944 | 21,08 | 39,4 | 50,41 | 9,3 |
| 1945 | 14,48 | 38,2 | 52,41 | 11,8 |
| Increase between 1940 and 1944 (%) | 56,73 | 114,1 | -14,70 | -56,1 |

# *Appendix E*
# Material constraint in the Netherlands from 2008-2018

*Economy*

Like other European countries, the Netherlands depends strongly on the import of primary material from other nations. Currently, the Netherlands imports 68 per cent of all primary materials used from abroad. However, not only the supply of primary materials poses a risk, but other steps in the value chain as well (e.g. components, sub-assemblies or products). It is often assumed that the Netherlands primarily imports intermediates and components and less primary resources. Research by TNO (Bastein, Rietveld, & van Zyl, 2014) shows that of the critical materials under research, all are primarily imported as primary material. Figure E.1 shows the proportions of primary material (blue), intermediates (red) and final products (green). The results are displayed as percentages of total yearly global production. The main trade partners for the import of primary materials are China, Germany and the US. The same research also shows that the Netherlands mainly exports parts (46.3 per cent) and final products (53.7 per cent), which means production using primary resources does take place. More than 80% of these products are exported to other European countries. If the majority of these products is not further exported to countries outside of Europe, these numbers indicate that many of the (critical) materials used in those products are accumulating in Europe, opening the way for urban mining. (Bastein, Rietveld, & van Zyl, 2014)

Especially the manufacturing industry in sectors such as the machinery and systems industry, electronics and sustainable energy use an increasing amount of (critical) raw materials. According to Mattheüs van de Pol (personal communication, February 2, 2018), the manufacturing industry uses primarily semi-finished products and will encounter a growing number of problems with the supply of these products and any raw materials needed. Currently, the circular economy is presented by the government as the best economic solution, which is only partly right according to van de Pol. Questions about how to reach a recycling rate close to 100%, how to power the circular economy only using renewable energy, and how to avoid a rebound effect remain. Therefore, the circular economy cannot be applied as the ultimate solution yet, but instead functions as a stimulant to promote a more sustainable way of production and consumption. (Rijksoverheid, 2016)

The way production and consumption functions today makes it clear that finding new ways for production and consumption is essential for sustainable development. Every year, over 30,000 new consumer products are brought to the market globally, of which a remarkable 90 per cent fails. Companies have made a great effort to change commodities into fast moving consumer goods by making them subject to trends and providing lower quality. Especially the possibility

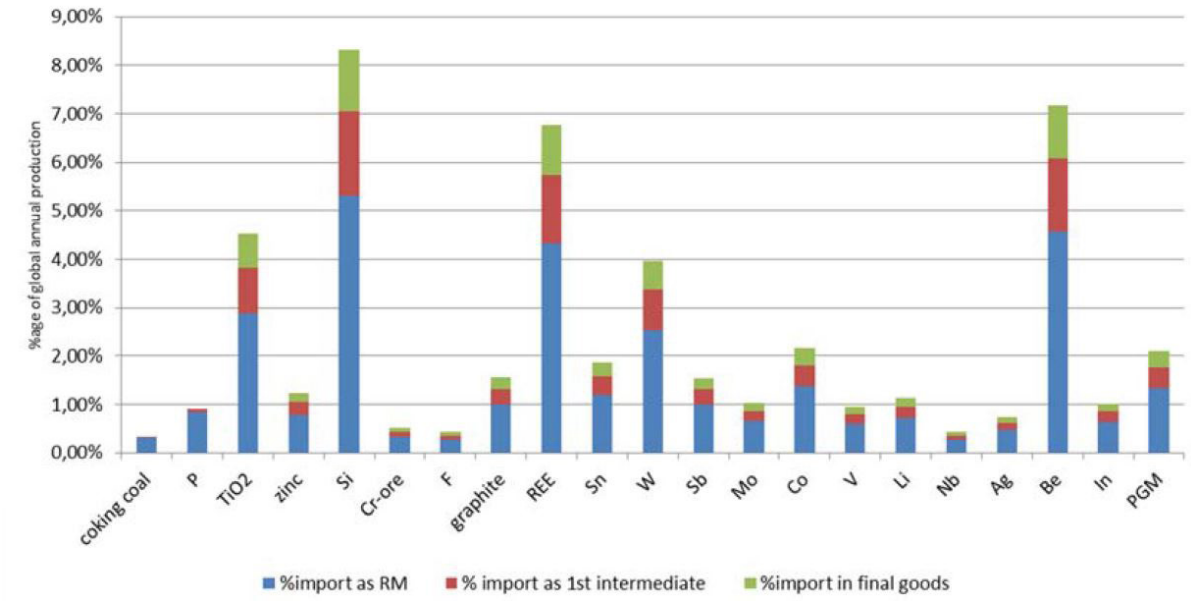


Figure E.1 Imported materials as percentages of yearly global production. Reprinted from Bastein, Rietveld and van Zyl, 2014.

to produce plastic products using cheap labour has accelerated this development. In the first place, these products replaced the kinds of products that were already commonly used, but soon many new products were brought to the market, products that would probably have never existed would it not be for globalisation and cheap labour. The movement towards fast moving consumer goods is a global trend, but also very well present in the Netherlands, most visible in stores such as the Action. (Milanovic, 2016a; VPRO, 2017; Muñoz & Marselis, 2016)

The primary goal of companies operating in the current global market is to fulfil any demand of anyone who can afford to buy what is wanted. The method of the market is to buy or to sell ready-made products at whatever price one can get. The system in which companies operate is usually referred to as the 'free market', but McMurtry (2013) argues that it is instead a corporate system that shows characteristics quite the opposite to the classic definition of a free market. The most significant differences are listed in Table E.1. (McMurtry, 1998)

According to Baumol, Litan and Schramm (2007), four different types of capitalism can be identified in the current capitalist economies. These are state-guided capitalism, oligarchic capitalism, big-firm capitalism and entrepreneurial capitalism. Baumol, Litan and Schramm state that not all types of capitalism yield the same results, some lead to growth and some to stagnation. A notion that indicates that not all capitalist economies have to be based on growth. Their research indicates that entrepreneurial capitalism with a right amount of big-firm capitalism leads to growth and a state-guided or oligarchic type of capitalism generally leads to stagnation. The current situation in Western consumer economies, such as the Netherlands, resemble the growth-based type. This growth-based system of consumer capitalism as it could be described works circularly. Companies use labour and capital to produce goods and services for the consumer. Both goods that they need and that they desire through a created or stimulated want. People, at their turn, offer up their labour in return for income. This income they

Table E.1 The free market space and the corporate system: structural contrasts. Reprinted from McMurtry, 1998.

| | Free market space | Corporate system |
|---|---|---|
| Investor | Direct producer | Money investor |
| Product | Organic food and handicrafts | Any commodity that sells |
| Labour contribution | Labour of those who own and sell | Purchased labour of unrelated others |
| Methods of production | Skill-intensive integrated labour | Machine-intensive division of labour |
| Seller | Producer and/or associates | Separate retailer |
| Buyer | Local individuals | Global mass market |
| Product information | Personal knowledge | Media commercial |
| Medium of exchange | Cash or promise | Bill payment |
| Source of packaging | Recycled wrapping | Extraction of natural resources |
| Nature of demand | Natural need | Stimulated want |
| Price determination | Local negotiation | Fixed by external decision |
| The relation between producer and buyer | Face to face | Non-existent |
| Site of transaction | An open community meeting place | Segregated private property |
| Relation to local culture | Expression of its climate or arts | Normally none |
| Surplus value recipient | Principally producer | Non-producing stakeholder |
| Expenditure of revenues | In local community | By corporate head office |

then partly spend on new consumer goods or savings, the saving is then invested back into the companies. (Jackson, 2009)

For companies, the ability to adapt and to innovate – to design, produce and market not just cheaper products but newer and more exciting ones – is essential to survive. Firms who fail in this process will fall behind. The process of continuous innovation, where the success of new products destroys the old ones, is called creative destruction and is happening in ever more frequent cycles. Companies are often forced to join this race to stay relevant and do not lose sales, like what happened to companies such as Kodak and Xerox which did not adapt to new technologies quickly enough. The race is unusually intense for listed companies that need to satisfy shareholders with ever-increasing profit. Pleasing the shareholders with increasing profits is essential to attract capital, needed to keep improving the company's efficiency and drive innovation. (Jackson, 2009)

The process of creative destruction puts pressure on material demand since 'old' products become obsolete whenever the updated version becomes available and are thrown away. Moreover, humans have turned out to have an enormous appetite for novelty, not only out of interest but most importantly to seek status. This results in a great driver of growth, ceaselessly extracting materials from their natural resources.

The government, on their part, is also caught in the pursuit of growth and stimulates growth seeking behaviour among its citizens. Generally, the wellbeing of a country is measured by its gross domestic product (GDP) and specifically increase of GDP per capita. The

GDP of a country consists of the total market value of all products and services produced in a certain period (e.g. a year) and is used to determine the economic performance of the nation. Rising GDP generally means rising income, which is translated to increased prosperity and therefore GDP is often used as a measure for a country's well-being. The focus on prosperity in the form of economic growth results in governments being narrowly framed to obtain resources. Additionally, most Western countries, as well as the Netherlands aim for individual consumer and market freedom in their policies. Implementation of these ideas has led to deregulation. Interesting to see here is the effect that what is measured becomes the goal. In most countries, GDP is measured as an indicator of well-being, and therefore the goal becomes to increase GDP. However, measuring another indicator of wellbeing, for example, the number of divorces or suicides could result in very different goals and strategies. (Jackson, 2009; Rutherford, 2008a; Sibbel & Smit, 2017)

However, governments keep measuring GDP and growth remains their primary goal, afraid to lose votes or even risk economic instability when growth stays away for too long. To maintain the growth, governments encourage people to increase consumption, however, creating more and more debt at the same time. However, this debt can become – and has become – unstable in itself. (Schinkel, 2017)

Over the past decades, globalisation has been on a significant rise. Policies have generally followed this trend, while globalisation fundamentally reduces the field of feasible economic policies. Therefore, economic policies are becoming more and more similar. Globalisation does result in economic growth, but unfortunately, the economic gains are not evenly distributed. For example, if an affluent person gains 1200 euros and an impoverished person loses 200 euros, the average gain is still 500 euro. However, the person of affluence obtains even more wealth, while the impoverished person loses from the small amount he already has. Contrary to what is often believed, the wealth of the wealthiest people does not 'trickle down' to the lower classes. Moreover, for the Netherlands, there are signs that income inequality has not decreased or stabilised as is sometimes suggested (Frederik, 2016). Milanovic (2016b), poses that governments should pay more attention to aspects such as workers' rights and quality of education to reduce inequality.

In 2005, the concept of Green Growth was introduced on a global level and adopted by institutions such as the OECD, UNEP and the World Bank and in 2013, the Dutch Cabinet published its proposition on how it would contribute to green growth in the Netherlands. Green growth generally means government subsidies and investments for green technologies that should accelerate the transition towards an economy that is powered by sustainable energy sources and uses 'green technologies'. (Kamp & Mansveld, 2013; CPB, 2016; OECD, 2015) As part of the Green Growth programme, the Ministries of Economic Affairs and Infrastructure and the Environment developed *Ruimte in Regels voor Groene Groei* (Smart Regulation for Green Growth), where companies that feel limited by certain regulations in moving forward in sustainable innovation, can mention these issues after which the government will attempt to remove the regulatory barriers. (Rijksoverheid)

Additionally, from 2011 onwards, the government has started the Green Deals programme, which also has become part of the Green Growth strategy. Green Deals are agreements between the government and companies or other parties in the civil society, where all parties commit to actively contribute to a certain sustainable goal, related to topics such as energy, climate, resources or the environment. In 2016, 185 of these Green Deals had been made, of which 91 had been completed successfully.

From 2016, the transition towards the goal of a circular economy was officially made with the publishing of the programme *A Circular Economy in the Netherlands by 2050*. Apart from solving environmental and resource issues, a circular economy has been said to increase employment opportunities, especially in the green sectors. However, the transition will simultaneously cause a reduction in employment opportunities in the grey sectors, and therefore it is not clear yet whether the net change in employment opportunities will be positive. (PBL/CPB/SCP, 2018)

Recently, the Dutch government has widened

its vision on well-being, and requested an exploration of well-being, which has resulted in the *Monitor Brede Welvaart* (Monitor of Well-being: a broader picture). Besides material well-being, it includes aspects such as health, education, environment, political freedom, social cohesion, and safety. Additionally, these aspects are not only reviewed for the Dutch society today, but also considers foreign and future societies. (PBL/CPB/SCP, 2018)

Lastly, the development towards the ambition for a circular economy, via green growth, was generally born – in respect of recent historical development – around the year 2009, when the Netherlands experienced the effects of the credit crisis. At the same time the prices of natural resources boomed (Figure E.2 and Figure E.3) and, according to Dirk-Jan Koch (personal communication, March 13, 2018), this price increase, together with China's policy to prioritise the supply of raw materials to its industry which started around 2010, concerns about the supply of materials grew. Additionally, China is actively purchasing large supplies of raw materials from other countries to build strategic stocks. (CPB, 2008; Transitieteam Maakindustrie, 2018)

Another policy that is applied is Extended Producer Responsibility which was implemented for the first time in 1995. Extended Producer Responsibility means that manufacturers remain responsible for the products that they have brought to the market and that reach their end of life. The manufacturer is responsible for both the organisational and the financial aspects of taking care of the waste streams. The regulation applies to a specific set of products, such as batteries, electronic appliances, and cars. (Ministry of VROM, 2007)

The policy with regards to the economy that has been applied is:

| | |
|---|---|
| | Extended Producer Responsibility (from 1995) |
| 2011 | Green Deals |
| 2013 | [March] Green growth policy |
| 2014 | Smart Regulation for Green Growth |
| 2016 | Rijksbreed programma Circulaire Economie |
| 2018 | Monitor Brede Welvaart |

*Technology*

In the Netherlands, the manufacturing industry with sectors such as '*electronics, machinery and systems industry, electronic transport, aerospace, and sustainable energy technologies'* (Rijksoverheid, 2016) is the primary user of raw materials. Developments in these sectors and the transition towards sustainable energy technologies are expected to greatly increase the demand for specific raw materials such as cadmium, indium, and gallium for solar panels and neodymium and dysprosium for wind turbines. Especially dysprosium will cause problems in the future since the demand is estimated to increase 26-fold over the coming 25 years (Figure E.4). The transitions towards a more digital society, smart systems and electric cars, developments that are also connected to the transition towards a circular economy, require additional raw materials. A significant innovation in the automotive industry is that of self-driving cars, which should decrease the demand for cars (and car batteries) to dampen the effect of increased demand to some extent. (Transitieteam Maakindustrie, 2018)

In 2007, the Ministries of VROM, EZ, and Infrastructure and Water Management (IenW) wrote a document with the government vision of a Bio-based Economy (BBE). The desire for a Bio-based Economy arose from the increasing geopolitical tensions, primarily related to China and India, which put much pressure on the supply of resources. The Bio-based Economy policy started with a focus on bio-based alternatives for fossil fuel but included all kinds of materials could also be replaced by bio-based alternatives (e.g. bio-based plastics). In 2012, an additional document was published by the Cabinet, describing the middle- to the long-term vision of the Dutch government on the Bio-based Economy in the Netherlands, including the policy measures that the government would adopt. The policy ambitions mainly include promoting networking between private players. (Ministry of VROM/Ministry of EZ/Ministry of IenW, 2007)

Figure E.5 provides an overview of the elements that were identified as critical by the European Commission in 2017. The Netherlands is for the most of the supply of critical raw materials dependent on the import from other countries. It is shown that the

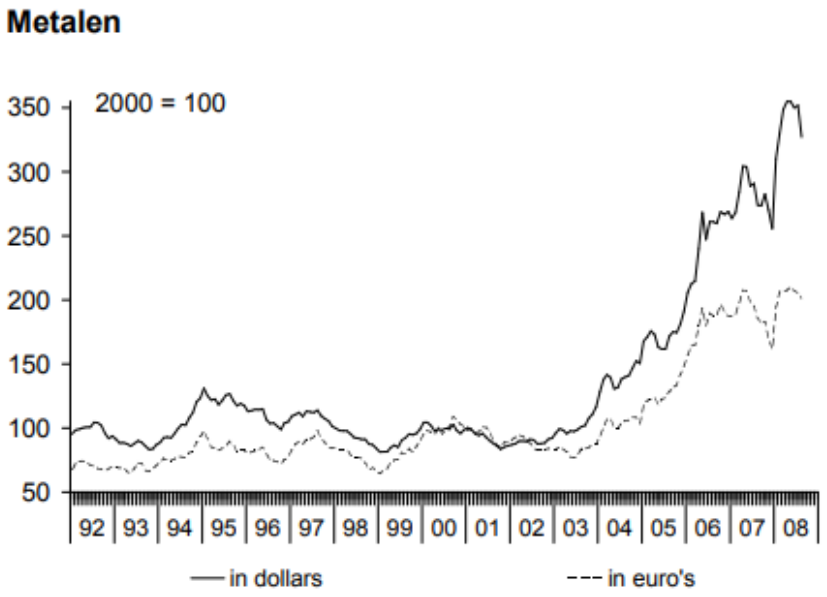


Figure E.2 Commodity prices HWWI-Index and global trade volume metals, 1992-2008. Reprinted from CPB, 2008.

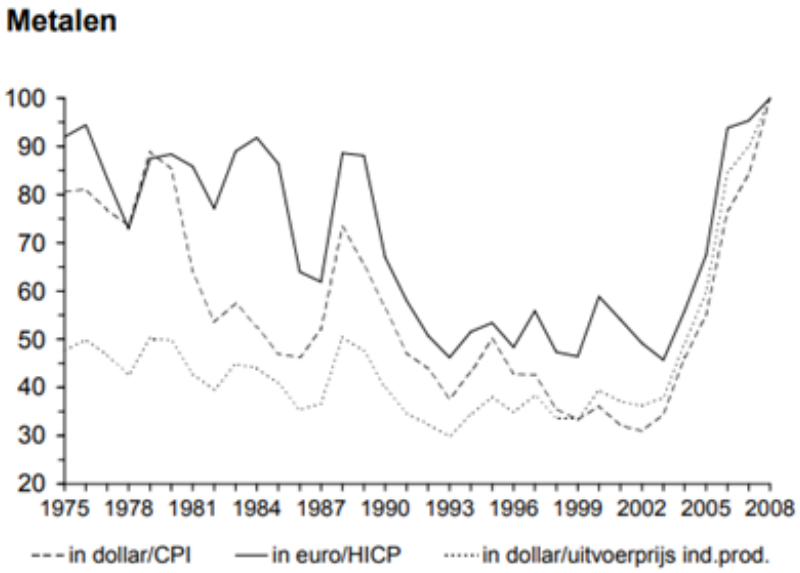


Figure E.3 Real commodity prices HWWI-Index Metals, 1992-2008. Reprinted from CPB, 2008.

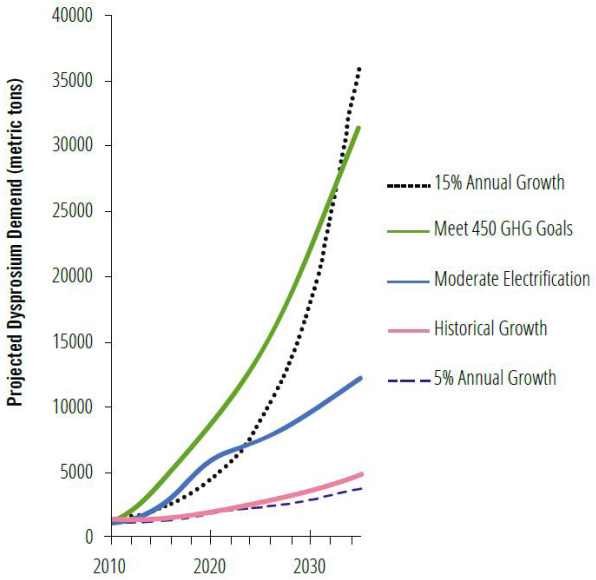


Figure E.4 Projected dysprosium demand. Reprinted from Transitieteam Maakindustrie, 2018)

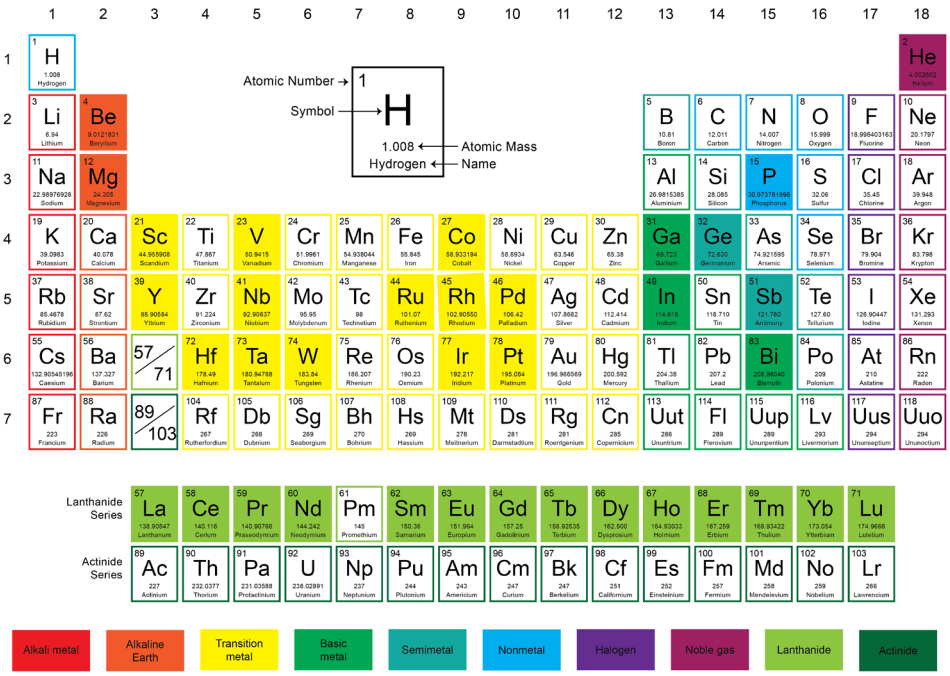


Figure E.5 Overview of the elements defined as critical for the EU according to the EU 2017 list. The list also includes baryte, borate, coking coal, fluorspar, natural graphite, natural rubber, phosphate rock, and silicon metal. (European Commission, 2018)

majority of the critical raw materials used in the Dutch manufacturing industry are imported in the form of components or semi-finished products, according to van de Pol (personal communication, February 19, 2018). The majority of manufacturing work in the Netherlands consists of the assembly of separate parts to add value to the value chain.

The document *De transitie naar een circulaire economie voor de maakindustrie* (The transition towards a circular economy for the manufacturing industry), which is the transition agenda for the manufacturing industry on how to reach a circular economy by 2050, was published in 2018. Numerous parties from the industry and the government, as well as different knowledge institutions, have cooperated to develop an agenda for the coming years. The tasks for the government mainly consist of initiating and facilitating research and standardisation and participating as an active stakeholder in circular procurement. (Transitieteam Maakindustrie, 2018)

The policy with regards to technology that has been applied is:

| | |
|---|---|
| 2007 | Bio-based Economy |
| 2018 | [January] Transition agenda manufacturing industry |
| | Transition agenda Consumer goods |
| 2018 | [March] Commodity Scanner |
| 2018 | [July] Proof of concept circular procurement (e.g. infrastructure or ICT hardware) |

### *Society*

In daily life, the regular Dutch person mostly encounters and interacts with finished consumer goods. This section, therefore, focusses on consumer behaviour and other related societal trends. Consumers are the most important and most abundant group of people that form the society. In fact, they are the same people as the employees and owners of companies and join politics to give a voice to their opinions, so every single person is a consumer. Consumer purchases represent about 60 per cent of the world's GDP, in the Netherlands, this is 45 per cent. These numbers indicate the influence consumers have on production, material use and the costs. At the same time, research shows that consumers only have restricted control over their buying behaviour. The decision-making process is never optimal because of limited time and information. People also rather avoid decision making entirely by resorting to habits, educated guesses and copying others. Also, people tend to choose their interest over that of the group, imitate others, make choices that affirm the image created by past decisions, do not like to change, prefer instant gratification and are sensitive to marketing. (Muñoz & Marselis, 2016)

At the same time, the largest group of Dutch consumers, the middle class, is among the group of disadvantaged of the modern society. According to Branko Milanovic (2016a; 2016b), formerly a World Bank lead economist, people with average to low incomes from the rich countries (a group that consists of about 50 per cent of the people in those countries) are in the same or a worse position than 25 years ago. Compared to all the other societal groups, they have gained the least (Figure E.6). While in 1980, one full-time income was enough to maintain a family, this is not the case anymore. Three leading causes are globalisation, technological change and economic policies.

At the same time, companies are focussed on making a profit and are well aware of the weaknesses of human decision making. They market a luxurious lifestyle and promote the impression that the latest version of their products is required for a successful and happy life. However, while this lifestyle was once achievable for the middle class of the most developed countries, it is not anymore. People want to shop without feeling the pain of the purchase; everything needs to be on sale. The result for this group is that the lifestyle that fits their social class is no longer affordable and they have to resort to cheaper products to maintain a sense of their social class. Low-quality, often plastic, products fill the pain or hole created by the lack of social support. The desire for new products is strongly linked to the symbolic role that these products play in our lives. This does not only include the status that comes with owning the products but goes much further. Material artefacts together create a powerful 'language of goods', used to communicate with each other. It is about expressing identity, values and even feelings for each other

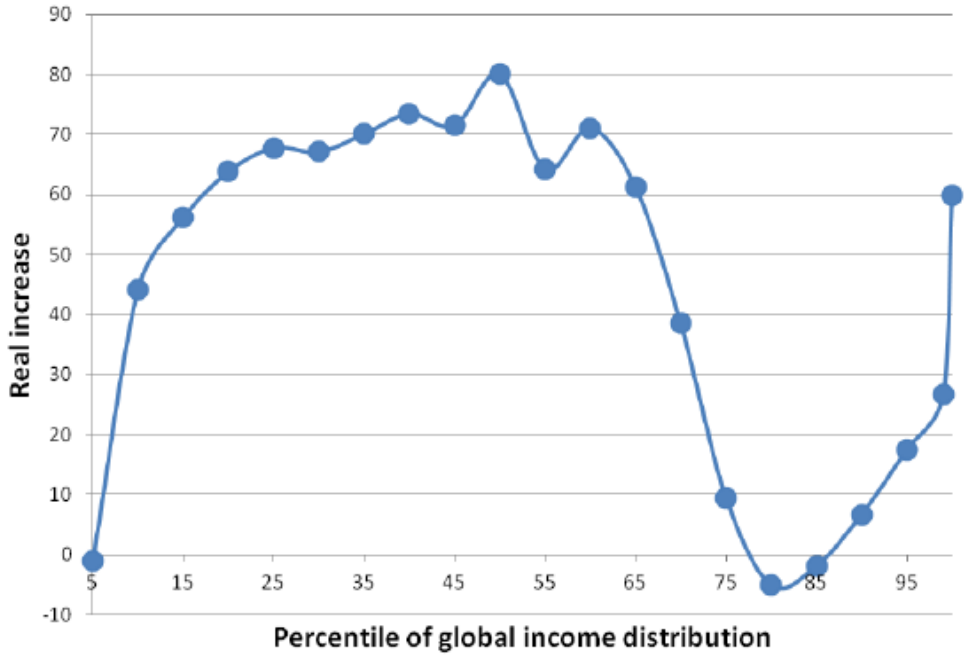


Figure E.6 'Elephant chart' depicting the change in real income between 1988 and 2008 at various percentiles of the global income distribution. The vertical axis shows the percentage change in real income, measured in constant international dollars. The horizontal axis shows the percentile position in the global income distribution. The percentile positions run from 5 to 95, in increments of five, while the top 5% are divided into two groups: the top 1% and those between 95$^{th}$ and 99$^{th}$ percentiles. Reprinted from Milanovic, 2012.

through giving and receiving gifts. They even, and maybe ultimately, express the hopes and dreams we have for a good life. (VPRO, 2017; Milanovic, 2016a; Jackson, 2009)

It is also interesting to note that the group that is generally seen as a sensitive measure of the wellbeing of a society, adolescents and children, indicate a 'social recession'. Researchers have observed a sharp increase in mental health issues in children from the UK compared between 1974, 1986 and 1999. Emotional problems, including depression, anxiety and hyperactivity increased by 70 per cent. The researchers were not able to explain the cause of this increase but did notice a coincidence with improved economic circumstances. (Rutherford, 2008b) This research gives a notion that increased economic wealth is probably not the way towards emotional well-being, on the contrary, the research indicates that it does not only halt the increase of emotional wellbeing like the Easterlin paradox suggests but even depreciates it. Therefore, prosperity does not consist of increased GDP, but of the ability to flourish as human beings. Something that is not possible when crossing the ecological limits of a finite planet, since this means people will start to suffer, generally the weakest groups first. It is therefore of utmost urgency to create a society with the conditions in which it is possible for every human being to flourish. (Jackson, 2009)

Interestingly enough, the rise of the current capitalist society was supported by the 'liberation-ethic'

of individual self-expression, being emotionally in tune with the world and personal pursuit of pleasure which started to emerge during the 1960s. This culture, focusing on personal development and well-being fit perfectly with the neo-liberal economic ideology which promoted free market competition without state interference as the highest good. The same hang towards individualism and self-expression resulted in the rise of aesthetics, personal leisure and fashion markets. (Rutherford, 2008a)

At the same time, research shows that there is a movement among consumers towards a more socially conscious consumption pattern. This can be seen as 'politics at the checkout lane', where people deliberately choose not to buy certain items (which are for example produced with child labour) and do buy other items (e.g. environmentally friendly products). However, this movement is still small and assumedly coincides with the top incomes, but is spreading among a bigger group of consumers. Currently, an estimated 5% of the Dutch population actively employs a socially aware consumption pattern and a group between 40% and 70% displays this behaviour on a more occasional basis. (Schyns, 2016)

According to the Netherlands Environmental Assessment Agency (PBL), a central, controlling role for the government is not effective when aiming for sustainable development. A controlling government tends to hinder the development of sustainable initiatives among citizens. A more effective role for the government would be to set clear goals, but then step back and facilitate the 'dynamic society' by eliminating obstructive legislation and other barriers. Rotmans (2012) argues that the Netherlands finds itself in a transition phase which makes the society vulnerable to disruptions, but also open to radical change. According to Rotmans, it is essential for the government to release control and allow for bottom-up change.

In 2017, the Cabinet requested a new kind of societal well-being research with the CBS, which resulted in the 'Monitor Brede Welvaart' (Monitor Broad Prosperity). 'Broad prosperity' is viewed as the present quality of life and the extent to which this quality of life comes at the expense of future generations or societies in other parts of the planet. In general, the Monitor concludes that the level of well-being 'here and now' increases or stays the same and is relatively high compared to other countries. However, this high level of well-being appears to come at a cost for future generations and people elsewhere. Consequences for future generations in the Netherlands are, amongst others, degrading of natural resources, individual health and quality of education. The costs for other societies of the growing Dutch well-being is the increasing pressure on natural resources because of the high exports to the Dutch economy, on the other hand, the Netherlands give a relatively high amount of development aid.

The policy with regards to society that has been applied is:

2018 Monitor Brede Welvaart

*Environment*

In 1989, the Dutch government presented the first National Environmental Policy Plan (NMP) with which included ambition goals for emission reduction and indeed gave way to a new era of effective environmental policy. PBL concluded 25 years later that '*air, water and soil are relatively clean, especially compared to 25 years ago, when the first NMP appeared (...)*' (PBL, 2014, p. 16). Today, most visible contamination has disappeared, and the quality of water, air and soil safely falls within the norms. However, at the same time, many of the environmental goals that the government had set for itself to reach by 2010 have not been attained yet, and the PBL notices a dwindling effect. The shift from polluting industries to services has resulted in cleaner production methods, but also lower production costs and cheaper products. Therefore, pollution per production unit has decreased, while more products were produced and sold, so the net environmental pressure due to production (slightly) decreased while production grew. A changing economic landscape needs adjusted environmental policy, but the goals can be adjusted as well. Over the past years, the government has extensively adapted policy measures and regulations, but also the formal goals. Overall, a trend of declining ambition among the Dutch government and society can be observed, and European

and global developments predominantly determine the environmental policy. (Hoogervorst & Dietz, 2015)

More recently, the environmental policy appears to be integrated into economic policy, such as Green Growth and the Circular Economy, as discussed in the economic section or needs to come from European legislation or international agreements. On the 12 December 2015, an agreement on limiting the global average temperature increase to 2°C – and preferably 1.5°C – was reached and signed by 195 United Nations Framework Convention on Climate Change (UNFCCC) members. The Netherlands signed the agreement as well, and soon a *Klimaatwet* (Climate Act) was proposed. However the Act was said to be controversial, and the discussion was ended.

Furthermore, protecting the environment was included in the Government-wide programme for a Circular Economy. The ambition of a circular economy should use resources more efficiently and therefore result in less harm to the environment, such as less environmental pollution, fewer greenhouse gas emissions and a reduction in biodiversity loss. (PBL/CPB/SCP, 2018)

The policy with regards to environment that has been applied is:

2015 [December] Paris Agreement
2016 [January] Sustainable Development Goals
2016 [September] Klimaatwet proposal
2016 Government-wide programme for a Circular Economy

# *Appendix F*
# Codebook

Table F.1 The free market space and the corporate system: structural contrasts. Reprinted from McMurtry, 1998.

| ***Category*** | Code | Description |
|---|---|---|
| **Governance** | DUTCH POLICY ON RESOURCES | Any policy from the Dutch government on supply, distribution or use of resources |
| | SECURITY OF SUPPLY | Ensuring the supply of materials essential to the economy |
| | CRITICAL MATERIALS | List of materials that are at high risk of becoming, or already are, hard to access because of high risk of supply disruption or a high importance for the economy or both |
| | STRATEGIC STOCKPILING | Create large stocks in advance to reduce the effect of reduced supply of materials |
| | COOPERATION | Cooperation between government institutions, or between the government and any external actor |
| | PLANNING | Planning for times of material constraint |
| | NATIONAL LEVEL | Any form of governance or government interaction on a national level |
| | EUROPEAN LEVEL | Any form of governance or government interaction or relationship on a European level |

| | | |
|---|---|---|
| | INTERNATIONAL LEVEL | Any form of governance or government interaction or relationship on an international level |
| | ROLE OF THE GOVERNMENT | The role that a government adopts to lead a country, multiple roles can be adopted simultaneously for different situations |
| | LEARNING | Government reflecting on and learning from the past |
| | GEOPOLITICAL TENSIONS | Tensions between countries that can result in reduced exchange of resources, etc. |
| **Economy** | PRODUCTION | The processes, usually undertaken by businesses, to change resources into products |
| | MANUFACTURING INDUSTRY | The most significant production industry in the Netherlands |
| | CONSUMPTION | Buying those products for personal use by consumers |
| | PROSPERITY | The level of economic welfare, however, not dependent on economic growth |
| | REBOUND EFFECT | Increased efficiency (e.g. energy or material use efficiency) often leads to increased consumption which off-sets the gain |
| | MATERIALS | Are at the basis of the economy, together with other primary resources such as fuel |
| | VALUE CHAINS | The chain of companies and/or industries that comprise the different steps of the production process, from raw material to finished good |
| | MARKET | The virtual or real place where materials, goods, and anything in between is traded |
| | ECONOMIC GROWTH | Or GDP growth, the most important measure for the economic welfare of a company or country |
| | CIRCULAR ECONOMY | An economy where all materials go in cycles through the economy, which is also emission and toxin free, improves the environment and runs completely on renewable energy |
| **Technology** | MINING | The process of extracting raw minerals and metals |

| | | |
|---|---|---|
| | COMPLEXITY | Refers to the increasing material and product complexity that we find today, which is due to technological developments |
| | TECHNOLOGY PUSH | Refers to the technological innovation boost that is required/ expected to solve many of today's problems, as well as problems with the circular economy. Usually entails digitalisation |
| | SUBSTITUTION | Replacing a critical material by a more available material, however this could mean compromises in quality and functionality |
| **Society** | LONG-TERM VISION | A vision of how the society would ideally be shaped and functioning in the future |
| | SOCIETAL TRANSITION | Moving from one paradigm to another as a society |
| | SHORT-TERM PROJECTS | Projects running for three to five years, as opposed to a long-term vision or strategy |
| | AWARENESS | Awareness among people involved in the shift towards renewable energy that this shift demands large amounts of (critical) materials, as well as general awareness of the need for a societal transition among society |
| | WELL-BEING | Societal well-being, independent of economic welfare |
| | POPULATION GROWTH | A societal issue related to critical materials since population growth contributes to increasing material demand |
| **Environment** | PLANETARY BOUNDARIES | The boundaries ecosystem of our planet which is affected by the extraction of resources. Exceeding those boundaries has detrimental effects on the life-giving ecosystems of the planet |
| | SUSTAINABLE DEVELOPMENT GOALS | Seventeen global sustainability goals |
| | ENERGY TRANSITION | From (fossil) fuel based to product based energy, |

# *Appendix G*
# Counting of categories

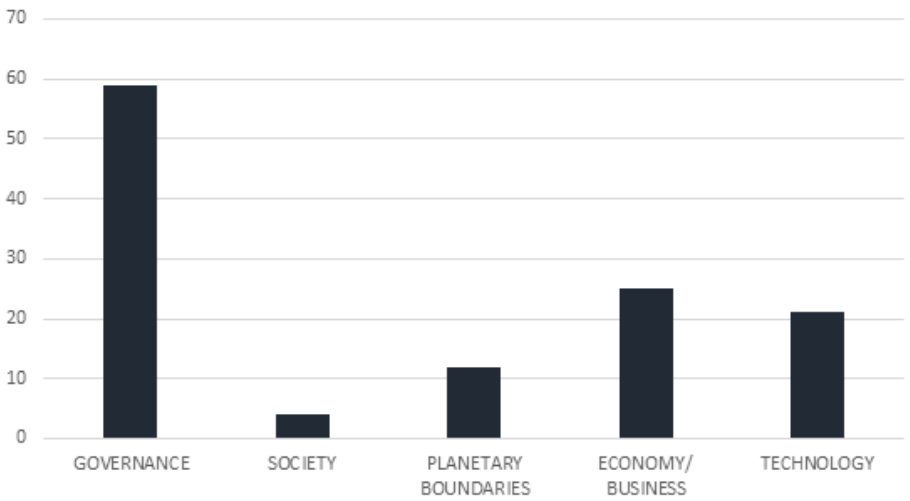


Figure G.1 Prevalence of categories - Ministry of Economic Affairs and Climate.

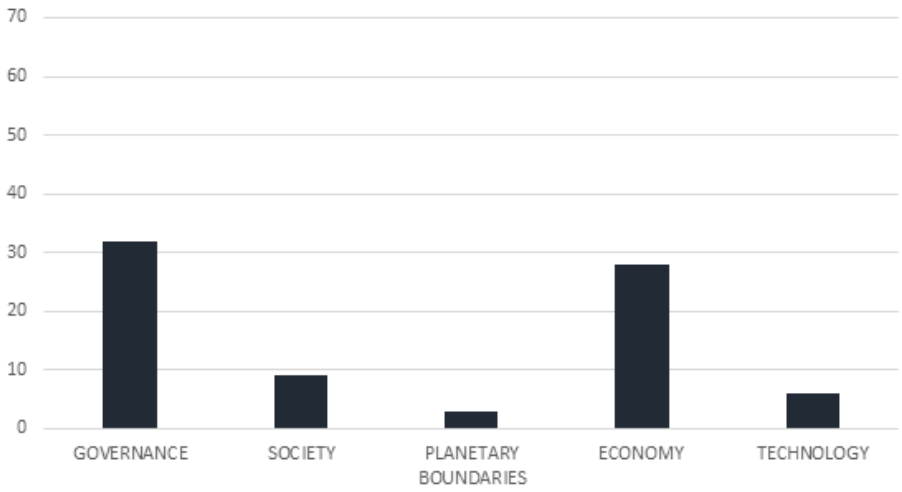


Figure G.2 Prevalence of categories - Ministry of Infrastructure and Water Management.

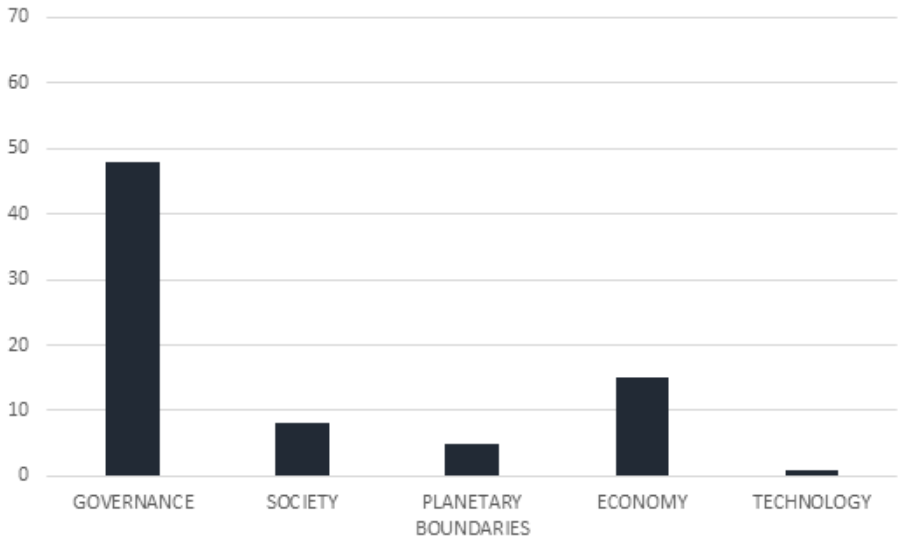


Figure G.3 Prevalence of categories - Ministry of Foreign Affairs.