A RESOURCES PASSPORT FOR A CIRCULAR ECONOMY

An assessment of the possible content and format of a resources passport in order to successfully contribute to the achievement of the circular economy

Master Thesis

Maayke Aimée Damen

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"What should the content and format of a resources passport be, in order to successfully contribute to the achievement of the circular economy?"

Author: Maayke Aimée Damen
Student number: 3437671
Address: Eosstraat 386, 1076 D.T., Amsterdam
Email: maaykedamen@gmail.com
Telephone: 0623678160

Utrecht University, Faculty of Geosciences
Program: Sustainable Development, Environmental Governance
Number of ECTS to be obtained: 45

Supervisor Utrecht University: Prof. Dr. Walter Vermeulen
Supervisor De Groene Zaak: Ivo Bonajo
Second reviewer Utrecht University: Prof. Dr. Ernst Worrell

EXECUTIVE SUMMARY

Continued economic growth has steeply increased the demand for resources over the last decades. Pressure on resources further increases due to fewer and smaller mineral deposit discoveries, increased exploration expenses, and the high energy intensity of mining. Without a response these trends will result in the physical scarcity of twenty-two critical materials within a ten to fifty year timeframe. Additionally, due to among others unequal distribution of resources around the world and non-transparent markets, these trends can also result in scarcity of resources on an economic and political level.

Economies are directly and indirectly based on the use of resources. Scarcity of resources thus leaves the European and Dutch economies vulnerable. To be able to satisfy the still rising demand for raw materials, activities including changes in product design and increased reuse and recycling of resources are essential. One of the main barriers to seizing these opportunities is the lack of resource-related information exchange. The Dutch lobby organisation, De Groene Zaak, envisions a 'resources passport' on products as a viable instrument for creating a circular economy in the short- to medium term. The main question of this research is *What should the content and format of a resources passport be, in order to successfully contribute to the achievement of the circular economy?* This explorative and design-oriented research provides an unique academic assessment of the instrument resources passport. To answer this question, this research will go through five steps: 1. It explains the need for and necessity of creating a circular economy to address resource scarcity, 2. It identifies the scarcity-related roles and information needs of the different actors in the supply chain, 3. It investigates the extent to which current policies address resource scarcity, 4. It examines the practical experiences and information needs of circular economy frontrunner companies to address scarcity, and 5. It identifies and assesses the format aspects relevant for the development of information exchange systems like the resources passport.

Transforming the economy towards a circular economy is a way to prevent scarcity that currently receives much (policy) attention. Three schools of thought form the foundation of a circular economy namely: Industrial Ecology, Design for Environment, and Cradle to Cradle. A comparison and combination of the main tenets of these schools resulted in the identification of the four main principles of a circular economy:

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*
2. *The improvement and creation of end-of-life systems for flows of resources and products.*
3. *The creation of, preferably regional, networks of material exchange.*
4. *The collection, management and exchange of resource-related information.*

Preventing scarcity of resources is at the heart of the circular economy. Principle four of the circular economy - the collection, management and exchange of resource-related information - is a prerequisite for the achievement of the other three principles. However, very few information and material exchange instruments have been created, and the instruments that have been created mainly operate on a small-scale. This is because systems like this develop on a local scale. Growing from a local to a wider scale requires trust, increases the costs of coordination, and most often reduces the quality of the information. Only by exchanging information, companies can utilize the scarcity-related value creating levers, which relate to growth, return on capital and risk management.

Each actor in the supply chain only has a small piece of the information necessary to address scarcity. There is not a single actor that has the complete picture. In total, twenty-five unique information needs have been identified that specify what information needs to be gathered and exchanged to be able to address scarcity. Depending on their roles, each supply chain actor needs different information. Also, when addressing scarcity, supply chain actors sometimes have a different role than their traditional role. The information needs are depicted in the text box below. Category C contains all product-related information necessary to address scarcity via an instrument like the resource passport. The other categories provide generic and contextual information necessary to optimally use the product-related information.

An information exchange system develops and functions optimally if the costs of coordination and administration are kept as low as possible. Having a low-administrative burden is taken as a pre-requisite in the development of the design of the resources passport. European and Dutch policymakers have already developed and implemented various resource-related policies. These policies require information exchange. Although not combined in an instrument like the resources passport, information needed by the various actors in the supply chain, is potentially already present. Eleven directives and regulations, of which one Dutch, have been analysed by means of a policy document analysis[1]. Information can be disclosed through the fulfilment of legal obligations, and through the use of companies' privately used instruments. Through a document analysis seven of these instruments have been analysed on the resource-related information they gather and disclose[2].

Information necessary to address scarcity

A: General scarcity-related information needs

A1 Material scarcity in the short/ medium / long term
A2 Price and supply security/ dependence of materials
A3 Current and future scarcity-related legislative requirements

B: Mining-related information needs

B1 Mine site/ origin
B2 Mining data
B3 Local circumstances/ environment at the mine site

C: Product-related information needs

C1 Physical structure of the product
C2 Material content and composition of products
C3 Material characteristics and properties
C4 Production processes used, plus specification per material
C5 Initial lifetime of the product
C6 Product adaptations during usage
C7 Life extending possibilities
C8 End-of-life possibilities of the product
C9 Disassembly information

D: Company internal information needs

D1 Supply chain partners (including 2nd, 3th etc. tier)
D2 Position of scarcity on a strategic level within the company
D3 Market demand for products proactively addressing scarcity
D4 Product-related information of competitors products
D5 Guidelines for dealing with trade-offs resulting from substitution/ elimination of critical elements
D6 Where and how products are disposed of

E: Technology-related information needs

E1 Best available mining technologies
E2 Best available material manufacturing technologies
E3 Best available production technologies
E4 Best available technologies for end-of-life systems

Both analysis show that cross-cycle and cross-sector information exchange, which is necessary to address scarcity, is very complex. Little resource-related information is publicly disclosed. Only information needs C3, C7 and C8 are publicly disclosed through resource-related policies[3]. The voluntary, privately used instruments publicly disclose information needs C1, C2, C3, C4, C7 and C8[4]. The analysis further indicates that for the majority of the information needs, information is partially available, scattered or only available to a selected group. Many partial solutions are present, but there is no connection between the solutions. Moreover, little resource-related information is actually exchanged through the supply chain. Information gaps are mainly present for the mining-related information needs and the technology-related information needs. Also, none of the policies and privately used instruments have resource scarcity as their main aim.

Also, seven Dutch circular economy frontrunner companies: Ahrend, Desso, InterfaceFLOR, Philips, Van Gansewinkel, Van Houtum and VAR have been interviewed about their practical experiences and information needs to address scarcity. Their information needs are reflected in the twenty-five information needs in the text box above. It is concluded that the companies' internal resource-related information exchange takes place in a non-systemic manner, and as a consequence, available information is not used to its potential.

After comparing the results from the scientific literature study and empirical research, recommendations can be made regarding the content of a resources passport. In line with the distinction made between the information need categories, a distinction is made between the development of in-house servers and a general database. The in-house servers contain companies' own information like C2, and information that

[1] Eleven policies analysed: Eco-labelling Regulation (Eco-l), Energy Labelling Directive (En-l), Eco-Management and Audit Scheme Regulation (EMAS), Packaging and Packaging Waste Directive (PPWD), End-of-Life Vehicle Directive (ELV), Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), Waste Electrical and Electronic Equipment Directive (WEEE), Eco-design Directive (Eco-D), Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), Regulation on classification, labelling and packaging of chemical substances and mixtures (CLP) and the Landelijk Afvalbeheerplan 2009-2021 (LAP2).

[2] Bills-Of-Materials (BOM), Cradle to Cradle Certificate (C2C), Chemical Abstracts Service Registry (CAS), Environmental Product Declarations (EPD), Lifecycle Analysis (LCA), Material Safety Data Sheets (MSDS), and REACH database.

[3] Information needs C3 and C8 are disclosed through the REACH and CLP regulations. C7 is disclosed through the eco-label directive.

[4] BOM discloses information need C1. C3 is disclosed through CAS, MDSD and the REACH database. EPDs disclose information needs C1, C2, C4, C7 and C8.

does not immediately need to be exchanged like B2 and D2. When required, information can be send to the general database. The information in a resources passport forms a sub-part of this database that travels through the supply chain. The benefit of having all this information in one database is that it can much easier be analysed, compared and, if necessary, shared. Moreover it is easier to provide different, customized interfaces for different users.

It is recommended that the following eleven information needs be included initially in the development of the database and the resources passport.

A1: Scarcity prospects per material
A2: Dependency rate per material
A3: Legislation the product/ materials need to comply with
B1: The origin of the materials used in the product
C1: Description of the physical structure of the product
C2: Description of the material content and composition of a product
C3: Characteristics of the materials used and possible recyclability/ toxicity
C4: Specification of production processes used
C8: Description of the end-of-life possibilities of the product
C9: Information on how to disassemble the product
D1: Indication of the supply chain partners

For the resources passport to be effective, the fulfilment of five format aspects has been investigated by analysing scientific literature, similar information exchange systems and the practice of the seven companies. The five aspects are: provision, storage, access to, quality and presentation of the information.

Derived from this analysis it is recommended that the provision of the information that forms the content of the passport should be done by every actor in the supply chain. Moreover, the information should regularly be updated. The storage of all scarcity-related information should be online, on in-house servers that can provide the relevant information to a centralized database when requested. Confidentiality issues regarding access to information are one of the most important topics and certainly require further discussion. These discussions need to take the current advanced technological possibilities, to retrieve the detailed material content of any product within the span of days, into account. A suggestion is to start with a simple solution to reduce unnecessary administrative- and time burdens. However, discussions about and the development of more complex structures, like external certification or trustees, need to start immediately. In the process discussions about how to guarantee the quality of the information should be taken into account. Lastly, the resources passport should have a unified format. Such a format still enables customization of the information, for specific target groups by companies.

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LIST OF ACRONYMS

ATF	Authorized Treatment Facility
BAT	Best Available Techniques
BOL	Beginning-of-Life
BOM	Bills-of-Materials
C2C	Cradle to Cradle
CAS	Chemical Abstracts Service
CBS	Statistics Netherlands
CLP	Regulation on classification, labelling and packaging of chemical substances and mixtures
CO2	Carbon dioxide
CSR	Corporate Social Responsibility

EC	European Commission
ECHA	European Chemicals Agency
Eco-D	Eco-Design Directive
Eco-L	Eco-Labelling Directive
EEA	European Environment Agency
EEE	Electrical and Electronic Equipment
ELV	End-of-Life Vehicle (Directive)
EMAS	Eco-Management and Audit Scheme Regulation
EMF	Ellen McArthur Foundation
En-L	Energy Labelling Directive
EOL	End-of-Life
EPD	Environmental Product Declaration
ERP	Energy Related Products
EU	European Union
EUEB	EU Eco-labelling Board
EUP	Energy Using Products
FAO	Food and Agricultural Organisation
FSC	Forest Stewardship Council
GER	Generic Ecological Requirements
IMDS	International Material Data System
ISO	International Organization for Standardization
LAP	National Waste Management Plan
KAM	Company department for quality, labour and environmental issues
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
MDS	Material Data Sheets
MFA	Material Flow Analysis
MGI	McKinsey Global Institute
MOL	Middle-of-Life
MSDS	Material Safety Data Sheets
NVMP	Nederlandse Verwijdering Metalektro Producten
OECD	The Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PBL	Netherlands Environmental Assessment Agency
PCR	Product Category Rules
PGM	Platinum Group Metals
PPWD	Packaging and Packaging Waste Directive
REACH	Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals
REE	Rare Earth Element
RFID	Radio Frequency Identification
RoHS	Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment
SER	Specific Ecological Requirements
SERI	Sustainable Europe Research Institute
SFA	Substance Flow Analysis
SIEF	Substance Information Exchange Fora
SME	Small and Medium Enterprises
TNO	Dutch Organisation for Applied Scientific Research
UNEP	United Nations Environment Program
UNGHS	United Nations Globally Harmonized System
USGS	United Nations Geological Survey
VROM	Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer
WEEE	Waste Electrical and Electronic Equipment

CHAPTER 1
INTRODUCTION

1.1 Problem introduction

Demand for materials steeply increased over the last decades. The Sustainable Europe Research Institute (SERI) projected that in a business-as-usual scenario worldwide resource extraction of finite metals and minerals will grow from 19 billion tons in 1980 to 53.7 billion tons in 2030: a growth of over 180% in 50 years. It is estimated that the demand for food, feed and fibre will have increased by 70% in 2050. However, with 60% of the world's major ecosystems already degraded and used unsustainably, two planets would be needed to satisfy the estimated demand (European Commission, 2011). Pressure on resources further increases due to significant amounts of waste that are generated throughout the production process, from extraction to disposal (SERI, 2009; UNEP, 2011). Also, the discovery of fewer and smaller mineral deposits, increased exploration expenses and the high energy intensity of mining put pressure on the availability of resources. Without a response these trends result in physical scarcity of 22 critical materials within a 10 to 50 year timeframe (Diederen, 2010). Coupled with the unequal distribution of resources around the world these trends might also result in economic and political scarcity. In 2010, the EU identified 35 metals that are critical to the economy, meaning they are of high economic importance and have a high supply risk.

Scarcity of resources leaves the European and Dutch economy vulnerable. However, addressing scarcity is not the main aim of any of the European and Dutch directives and regulations. Although, exchange of resource-related information is vital in addressing scarcity issues, cross-cycle and cross-sector information exchange never took off or was overshadowed by other priorities like emission reductions. Recognizing the challenges of Europe's intensive use of resources the European Commission (EC) under its '*Europe 2020 Strategy*' initiated a policy guiding flagship initiative on '*A resource efficient Europe*' to fuel a "fundamental transformation within a generation – in energy, industry, agriculture, fisheries, and transport systems, and in producer and consumer behaviour" (European Commission, 2011:2). To identify long term objectives and means for achieving this transformation the EC published the '*Roadmap to a resource efficient Europe*' (2011). This roadmap identifies the circular economy as the overarching concept guiding the transformation in all areas and preventing large-scale resource scarcity. The Netherlands additionally supports the closing of the material loops and aims to create a so-called 'materials roundabout' (Dutch Cabinet, 2011). However, very few practical interpretations of this concept have been developed as of yet, while scarcity's impact on our society is increasing.

1.2 Problem definition

The European and Dutch economies are vulnerable to material scarcity due to their dependence on resources and the lack of mining sites on their own territory. The world's largest stock of material currently resides in the built environment, like infrastructure, houses, phones etc., especially in areas like the European Union. To be able to satisfy the still increasing demand for raw materials, changes in product design, exchange of materials and reuse and recycling of resources is essential. Nevertheless, reuse and recycling are opportunities not used to their full potential at the moment. A study conducted by the United Nations Environment Program (UNEP, 2011) calculated that worldwide less than 1% of Rare Earth Elements (REEs) are recycled. Economically these low recycling rates represent a missed opportunity. First of all, only by reusing and recycling resources future demand can be satisfied. Secondly, it is estimated that to mine one gram of gold, 5000 kilogram of virgin ore is needed, versus only 5 kilogram of mobile phones (Eurostat, Bio Intelligence Service, 2010). Besides, worldwide non-recycling means that annually $52 billion worth of solely copper is lost (EMF, 2011).

One of the main barriers to seizing these opportunities is the lack of information exchange (Reck & Gradel, 2012). In the Netherlands, (partners of) lobby platform 'De Groene Zaak'[5] have noticed the

[5] . 'De Groene Zaak', established early 2010, is complementary to the Dutch employer-organization VNO-NCW, whereby it represents and lobbies for the interests of companies specifically on the issue of sustainability. In that regard they have established a constructive dialogue with political parties, the government, and relevant stakeholders. The partners are convinced that a green economy and green businesses will have and define the

publication '*Roadmap to a resource efficient Europe*' and to them "resources and resource use conceptually serve as one of the most important links between the environment and economic activities" (UNEP, 2011, 2). Therefore they recently published a position paper on this topic[6]. De Groene Zaak envisions a 'resources passport' on products as a viable instrument for creating a circular economy in the short to medium term. The starting point of the circular economy is creating closed loop flows of materials. Closing these loops crosses the boundaries of individual enterprises. Therefore the main aim of the resources passport is to disclose product information related to scarcity, to close the resource-loops. The 130+ partners of De Groene Zaak have recently made the development and implementation of this resources passport a priority. However, the resources passport is a new instrument, so it is difficult to compare it with the development and workings of similar instruments.

Since the late 1970s, multiple research and policy areas have focussed on the importance of resource-related information exchange. However, for various reasons, comprehensive, systematic, publicly available, and supply chain wide information exchange has never evolved or gained ground. A supply chain here is defined as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer" (Mentzer et al., 2001: 4). Over the years instruments like Life Cycle Analysis (LCA) and Substance Flow Analysis (SFA) have been developed, yet none have the function of knowledge broker, which is essential in addressing scarcity and creating a circular economy (Lehtoranta, Nissinen, Mattila, & Melanen, 2011). Additionally, businesses internally conduct various kinds of reporting practices like Bills-of-Materials (BOM) and others that aren't publicly known or researched. As Lambert (2001) indicates, unification of methodology is indispensable within the manufacturing supply-chain approach. Concluding, given the need to address resource scarcity and the development of a circular economy, scientific literature and businesses indicate that there is a necessity for the development of an instrument functioning as a knowledge-broker.

1.3 Research context

The geographical focus of the research is the Netherlands. One of the reasons is that the EU in its roadmap emphasizes that it is the responsibility of the member states to measure, benchmark and improve the efficient use of resources, and to exploit industrial symbiosis (European Commission, 2011). Also, no other European country has expressed similar goals as De Groene Zaak. Nevertheless, a resources passport needs to be developed with the European context in mind. The ultimate aim is to use this instrument for cross-cycle and cross-sector implementation in Europe. An analysis of the needs and experiences of Dutch companies could prove the first, and a necessary step in that direction. The focus will be on the business perspective, in accordance with the extended producer responsibility principle and the viewpoint of the Dutch government that adequate supply of resources is primarily a company's private responsibility[7].

1.4 Research objectives

The overall aim of this explorative, and design-oriented, research is to define the content and format of a resources passport so it can be used as a tool to address resource scarcity and the creation of the circular economy. To achieve this aim five objectives have been identified:

I. Explain the need and necessity of addressing resource scarcity as the central element of the circular economy
II. Understand the roles and information needs of the different actors in the supply chain in addressing resource scarcity
III. Understand to what extent current policies address resource scarcity and understand the lack thereof
IV. Understand the experiences and information needs of circular economy frontrunner companies in addressing resource scarcity

future and that a solely a sustainable business model can be profitable. Together they work on the acceleration of the transition to a green economy and creation of a strong new economic basis, on which also next generations can build.

[6] De Groene Zaak (2011) Position Paper Grondstoffen. De winst van het tekort. Den Haag. http://www.degroenezaak.com/upload/files/position_paper_4_grondstoffen.pdf

[7] "Grondstoffenvoorzieningis in eerste instantie een eigen verantwoordelijkheid van bedrijven" (Aanbiedingsbrief van de ministers Rosenthal en Verhagen, en de staatssecretarissen Atsma en Knapen bij de Grondstoffennotitie van het Kabinet, 2011: 2) .

V. Understand which format aspects are relevant in the development of information exchange systems like the resources passport

1.5 Elaboration of research questions

In short, the problem definition is paraphrased into the main question of this research:

"What should the content and format of a resources passport be, in order to successfully contribute to the achievement of the circular economy?"

In order to answer the central question five sub-questions have been identified:

1. What is the need for and necessity of creating a circular economy in addressing resource scarcity?
2. What are the roles and information needs of the different actors in the supply chain in addressing resource scarcity?
3. To what extent do current European and Dutch policies address resource scarcity and the circular economy, plus how can the findings be explained?
4. What are the scarcity-related experiences and information needs of circular economy frontrunner companies in the Netherlands?
5. Which format aspects are relevant in the development of a resource passport?

1.6 Scientific and societal relevance

Scholars have stressed the need for uniform material information exchange instruments . A recent study by Koppius et al. (2011) also shows that extra-organizational information systems for closed loops supply chains create value for businesses in four different ways: sourcing value, environmental value, costumer value and information value, besides addressing scarcity issues. Yet, since scarcity has never before been such a pressing issue on such a large-scale, comprehensive and uniform scarcity-related information exchange never took off. The existing resource-related information exchange happens mostly on a voluntary basis, in an ad-hoc manner, not publicly accessible and does not provide a knowledge-broker function. The reasons for this vary widely, and include a lack of economic motives, trust and high costs. Consequently, there is no systematic overview of the roles of each of the supply chain actors in addressing scarcity, and no systemic knowledge about which information needs to be exchanged to address scarcity issues. It is also unclear which information is already known but not exchanged, and what the ideal format of such an information exchange instrument is. These questions are reflected in the research objectives of this study and hence fill part of the existing scientific knowledge gap.

Scarcity of resources can have profound consequences for the European and Dutch economy. For example, the impact of rising resource prices due to scarcity is illustrated by the billion euro increase of the resources bill of AkzoNobel in 2011. The resources bill of Unilever increased with 2,5 billion euros over the same year. Yet, the scope of the consequences is broader than just consequences for the European economy. The impact of resource scarcity on social cohesion has been illustrated by a UNEP (2009) report that states that currently already 40% of the intrastate conflicts and the majority of the international conflicts revolve around resources. This number is likely to increase in the future (ibid).

In 'Roadmap to a resource efficient Europe' the EU stresses the need to identify means for achieving the transformation towards a circular economy. Thereby they request country specific actions regarding benchmarking, measuring and industrial symbiosis. The perspective of the Dutch government is that agency is at the businesses themselves. This plus the anticipation of possible judicial and regulatory change[8], has led De Groene Zaak to make the development of a resources passport one of their priorities. This is reflected in the '*Position paper grondstoffen' (2011)*. Manufacturers and waste processers that are partners of De Groene Zaak have indicated that research like this is necessary. The results and recommendations of this research will directly be used by De Groene Zaak in their lobby efforts towards the government and by the partners of De Groene Zaak in the actual development and implementation of the resources passport.

[8] Like in the US where companies due to the Frank-Dodd act have to report on the use of conflict metals and minerals.

1.7 Research structure and reading guide

This qualitative research aims at defining the possible content and format of a resources passport in such a way that it addresses resource scarcity and enhances the creation of a circular economy. This thesis is structured in eight steps, as depicted in figure 1.1.

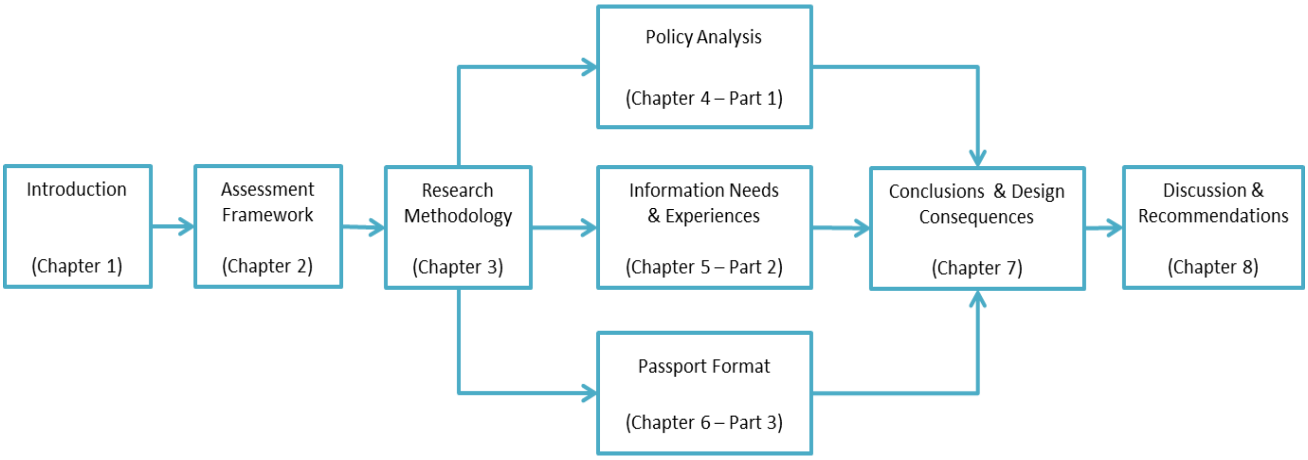

Figure 1.1 Graphical overview of thesis structure.

Chapter 1: Introduction. Introduces the main problem of this research, identifies the main research objectives, the central research question and the sub-questions. It also analyses the scientific and societal relevance of this research. *Chapter 2: Assessment Framework.* Presents the assessment framework used to identify the content and format of the resources passport based upon an extensive scientific literature research. *Chapter 3: Research Methodology.* Presents the methodological and technical research design used to attain the objectives of this research. *Chapter 4: Policy Analysis.* Part one of the empirical research analyses the extent to which current European and Dutch resource-related policies pursue the principles of the circular economy, and the consequences for information exchange. *Chapter 5: Information Needs & Experiences.* Part two of the empirical research identifies the scarcity-related experiences and information needs of circular economy frontrunner companies in the Netherlands. *Chapter 6: Passport Format.* Part three of the empirical research analyses which format aspects are relevant in the development of a resource passport. *Chapter 7: Conclusions & Design Consequences.* Sub-questions one to five are analysed, interpreted, compared to each other and to the literature, to answer the main research question regarding the identification of the content and format of a resources passport. *Chapter 8: Discussion & Recommendations.* This chapter reflects on the implications of this research, and concludes with recommendations for De Groene Zaak and further research.

CHAPTER 2

FRAMEWORK FOR THE ASSESSMENT OF THE CONTENT AND FORMAT OF A RESOURCES PASSPORT

2.1 Introduction

In this chapter the theoretical background and framework of analysis for this research will be provided. First of all, the theoretical background of resource scarcity and the current resource situation will be analysed (section 2.2). Second, the circular economy as a solution to the problem of scarcity will be presented, and the main principles of such an economy, that will guide the development of the resources passport, identified (section 2.3). Third, it is explained that many businesses already undertook action to address environmental issues, yet the focus on scarcity issues was minimal and there is a lack of scarcity-related information exchange throughout the supply chain (section 2.4). Next, the roles and information needs of relevant actors in the supply chain necessary to be able to address scarcity issues are examined. Together this forms the theoretical framework to analyse the content of a resource passport (section 2.5). Lastly, the characteristics of information exchange are examined in order to make recommendations for the passport format (section 2.6) Information exchange is here defined as the sharing of relevant, critical and/or proprietary information with one's supply chain partners (Monczka et al., 1998).

2.2 Resource scarcity

The literature presents two paradigms to interpret resource scarcity (Tilton, 2003; Wäger & Classen, 2006; Köhler et al., 2010). Resources are here defined as "natural assets deliberately extracted and modified by human activity for their utility to create economic value. They can be measured both in physical units (such as tons, joules or area), and in monetary terms expressing their economic value" (UNEP, 2011: 2). "Scarcity is the concept of finite resources in a world of infinite needs and wants" (PBL, 2011: 18). The first paradigm called '*finite stock*' believes that resource stocks are progressively depleted and humankind is going to run out of materials at a certain point in time. The other paradigm called '*opportunity cost*' believes that the existing stock of resources greatly exceeds human demand, and that extraction of resources is limited solely by economic factors and human ignorance. Market mechanisms will find a way to continuously balance supply and demand, and technological innovations will prevent scarcity (Köhler et al., 2010).

There is no consensus about which theory is right. However, as Köhler et al. (2010) state "uncertainty or incomplete knowledge regarding the determinants of material scarcity must not be a reason for ignoring a potentially severe and irreversible risk (ibid: 13). This risk is further explored in the next sections.

2.2.1 Dimensions of resource scarcity

Recent literature makes a distinction between three dimensions of scarcity: physical, economic and political. Physical scarcity relates to "the availability of resources as determined by physical and ecosystem characteristics" (PBL, 2011: 21). Economic scarcity focuses on the functioning of the market in satisfying demand: are resources available at the right time in the right quantities? Political scarcity comes forth from the uneven distribution of resources in the world. Import dependent countries are dependent on exporting countries who might politically misuse this dependency (ibid). Figure 2.1 provides an overview of the three dimensions of resource scarcity.

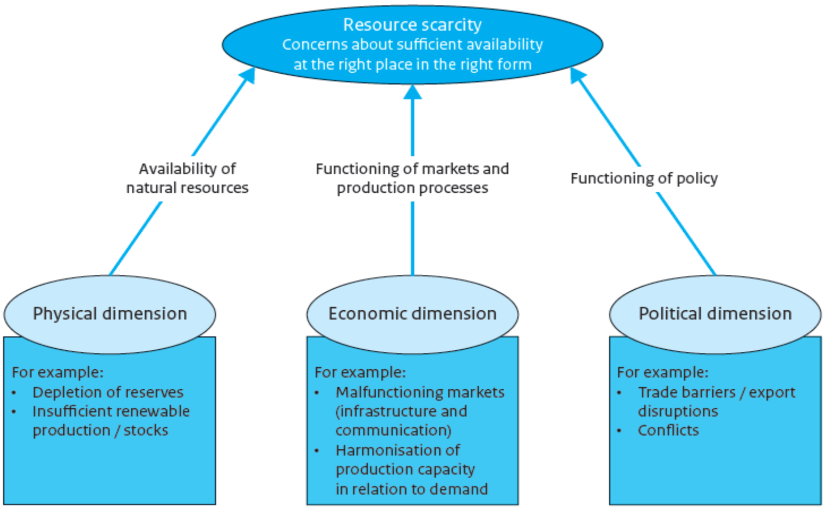

Figure 2.1 The dimensions of resource scarcity. Source: PBL, 2011: 21.

There are two kinds of resources: finite resources like oil, metal and minerals, that are non-renewable by definition, and renewable resources like water, wood and fish that have the ability to grow back after extraction. Regarding physical scarcity; there has always been uncertainty about the total quantity and quality of reserves of non-renewable resources still left in the earth's crust, the numbers change with progressing insight (see section 2.2.3). Currently, short-term physical scarcity is defined by comparing the known reserves (in the Earth's crust and/ or available for recycling) with another entity like consumption. Renewable resources can collapse due to, for example, overexploitation, which can possibly result in the extinction of species.

The economic dimension of scarcity addresses the satisfaction of needs by means of well-functioning markets. Bottlenecks can be insufficient production capacities, lack of information, infrastructural and transportation problems, and distributional problems at the end-user level. Other aspects of ill-functioning markets are speculation, which can create artificially high prices, and unfavourable exchange rates (ibid).

Since resources are unevenly distributed around the world, dependency can give rise to political scarcity by means of export quota or restrictions that can generate supply disruptions. These disruptions can occur suddenly and end equally abrupt. The reason for imposition of such restrictions might not be related to resource scarcity at all[9].

2.2.2 The resource intensive growth model

Doom scenarios regarding resources scarcity, like Malthus' 1798 '*An Essay on the Principle of Population*', Hardin's 1968 '*Tragedy of the Commons*´ and the 1972 '*Limits to Growth*' report by Meadows et al. are widely known. Nevertheless, the prevailing thesis of the 20th century was that the power of the market and technological innovations could solve any scarcity issue. So far, this thesis largely proved correct since the possibilities to extract resources greatly increased. This resulted in a decline of almost 50% of the commodity price index as measured by the McKinsey Global Institute (MGI, 2011). A remarkable development, because the world's population quadrupled during this period, and global economic output enlarged around 20 times, which caused the demand for various resources to increase with 600 to 2000% (Steinberger et al., 2010; MGI, 2011).

As a result of this increased demand, the extraction of resources grew steeply over the course of the 20th century. For example "the extraction of construction materials grew by a factor of 34, ores and minerals by a factor of 27, fossil fuels by a factor of 12, and biomass by a factor of 3.6" (UNEP, 2011, xiii). Besides, in the year 2000, Europe had a Total Material Requirement (absolute imports plus ecological rucksacks[10]) of which 89% consisted of non-renewable resources (Schütz, 2004). The Sustainable Europe Research Institute (SERI) projected that in a business-as-usual scenario worldwide resource extraction of metals and minerals would grow from 19 billion tons in 1980 to 53.7 billion tons in 2030: a growth of over 180% in 50 years

[9] An example was the sudden stop of the export of gas from Russia to the Ukraine in 2006 and 2009.
[10] Ecological rucksacks consist of the total quantity of materials moved from nature to create a product or service, minus the actual weight of the product (Schütz, 2004).

(SERI, 2009). In addition to this increased demand for many materials, the current industrial system also produces significant amounts of waste in the various stages of a products lifecycle:

- SERI estimates that annually 21 billion tons of materials are not physically incorporated in the manufacturing of products in OECD (Organisation for Economic Co-operation and Development) countries. These materials are for example overburden and parting from mining or by-catch from fishing (SERI, 2009).
- The resource intensive growth model is putting enormous stress on ecosystems and the services they provide (like the absorption of carbon dioxide and regulation of water tables). The Millennium Ecosystem Assessment (2005) investigated 24 ecosystems and found that 15 of them are used unsustainably and are being degraded. Humans are consuming more than the ecosystems can provide in a sustainable manner, so we are reducing the Earth's natural capital instead of living of its rent (ibid).
- Many materials are lost at the end of their functioning life. In 2010, 65 billion tons of materials entered the global economic system. In Europe, in the same year, 2,7 billion tons of waste were generated, but only 40% was reused, recycled, composed[11] or in some other form recovered. This European average is lower than the Dutch average of 80% recycling (Ministerie van Infrastructuur en Milieu, 2011). Nevertheless, much of this recycled material is 'down cycled', which means that the recycled materials are of lesser quality and functionality than the virgin input. Additionally, much recycled material is exported since the quality can't be guaranteed, due to a lack of (the exchange of) information (Flemish Parliament, 2010). Moreover, the recovery rates are only significant for particular waste streams, mainly those in large, fairly homogenous volumes. The global value of the annual lost volumes is indicated to range from 7 billion USD for silver, 15 billion USD for aluminium, 34 billion USD for gold and 52 billion USD for copper[12] (Ellen McArthur Foundation (EMF), 2011).
- Disposal of materials results in loss of its residual energy. The most energy intensive stages are extraction and conversion to a usable form. "Depending on the metal and the form of scrap, recycling can save as much as a factor of 10 or 20 in energy consumption" (Reck & Graedel, 2012: 691). With worldwide recycling rates of, for example, REEs[13] barely over 1%, much residual energy is lost (ibid; UNEP, 2011).

2.2.3 Recent disruptive resource developments

Although the current growth model results in high loss of materials, material scarcity has been postponed by means of new technological developments and the discovery of new ores. However, there are some recent developments that should be taken into account when addressing the resource challenge of the coming period.

First of all, there are varying projections of the dimension and severity of scarcity. One often-cited report by Diederen (2010) shows by means of United Nations Geological Survey (USGS) data, that with an annual economic growth rate of 2% the currently known reserves of 22 metals and minerals will be exhausted within 10 to 50 years. This means that they will become physically scarce. An overview of these metals and minerals is depicted in table 2.1.

Table 2.1 Metals and minerals availability. Source: Diederen, 2010.

Name	Years left	Name	Years left	Name	Years left
Antimony	11	Barium	20	Nickel	31
Silver	12	Cadmium	20	Niobium	32
Strontium	12	Zirconium	21	Bismuth	35
Zinc	14	Copper	27	Rhenium	35
Tin	15	Thallium	28	Tungsten	37

[11] Composting is defined as: "A biological process during which naturally occurring microorganisms (e.g., bacteria and fungi), insects, snails, and earthworms break down organic materials (such as leaves, grass clippings, garden debris, and certain food wastes) into a soil-like material called compost. Composting is a form of recycling, a natural way of returning biological nutrients to the soil" (EMF, 2012: 25).

[12] The calculation of these losses is based upon United States Geological Survey Data from the Minerals Information Database and "expected recovered volume of 2010 metal production, assuming today's recycling rates remaining constant until end-of-life of all product applications. The difference between recovered volume and hypothetically recoverable volumes under complete recycling, multiplied with today's market prices for secondary materials, gives monetary loss" (EMF, 2011: 16).

[13] "Rare earth element is a historical misnomer. Although actually more abundant than many familiar industrial metals, the REEs have much less tendency to become concentrated in exploitable ore deposits. Consequently, most of the world's supply comes from only a few sources" (PLB, 2011: 32).

Arsenic	17	Manganese	29	Yttrium	40
Gold	17	Mercury	29	Iron	46
Lead	18	Molybdenum	31		

Nevertheless, as the Netherlands Environmental Assessment Agency (from now on referred to as PBL, the Dutch abbreviation) states: "the total availability of non-renewables in the earth's crust is unknown and the enlargement of reserves is dependent on research and innovation" (PBL, 2011: 22). Moreover, the higher the price of the materials or the cheaper the energy necessary to mine the materials; the more materials can be exploited. Despite harmonizing attempts, there is no general definition of how to define resource reserves. The operationalization provided by McKelvey as depicted in figure 2.2, is often referred to. Here resource reserves are based upon the probability of being present and the economic extractability. Reserves are consequently defined as proved and economically exploitable.

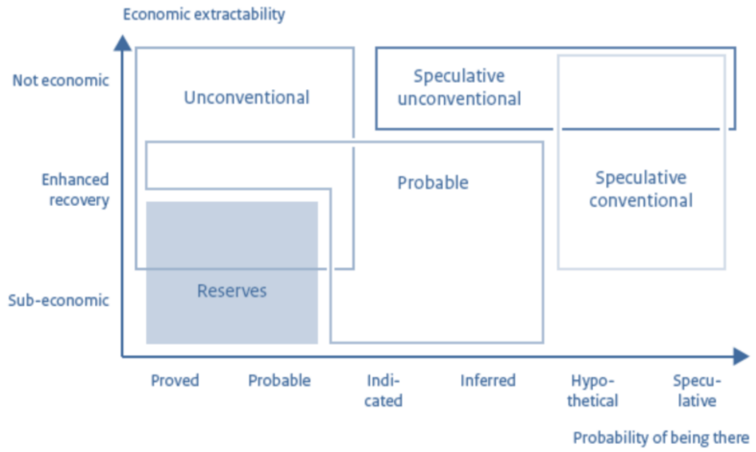

Figure 2.2 McKelvey Diagram[14]. Source: PBL, 2011: 22.

Thus, the projections of Diederen reflect the current knowledge. Yet, a significant degree of uncertainty remains. Resource depletion is not necessarily a problem of quantity, but mainly a problem of "how much of these quantities can be converted into production per unit of time and at what cost" (Diederen, 2010: 51). Most of the minerals on earth appear in quantities below the so-called 'mineralogical barrier', which means that the rock should chemically be taken apart to extract the metals. This is a very energy intensive undertaking. Above all, the looming metal scarcity reinforces the unfolding energy crisis, since "the energy required for extraction grows exponentially with lower ore grades" and the energy sector is the largest consumer of metals (Diederen, 2009: 5).

Since the 1990s there is a trend of fewer and smaller mineral deposit discoveries. Moreover, exploration expenses and energy intensity of mining have increased, as a result of lower ore grades and mining at remote locations (Ericsson, 2010). This trend is depicted in figure 2.3.

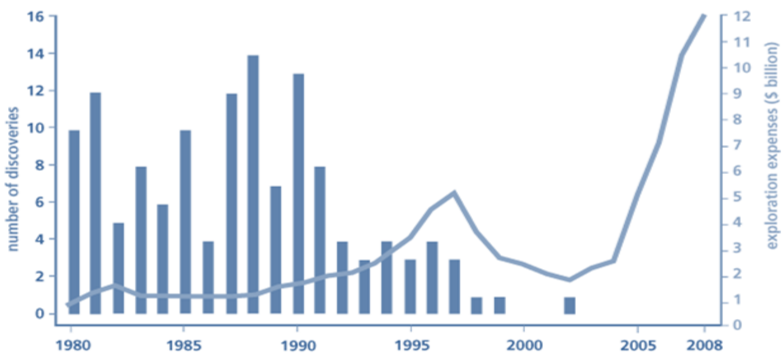

Figure 2.3 Major and world class mineral deposit discoveries and exploration expenses. The line indicates the exploration expenses. Source: based upon Raw Materials Group, 2008; Diederen, 2010; Ericsson, 2010.

[14] Named after Vincent McKelvey who was the former head of the United States Geological Survey (USGS).

The recent BP oil spill in the Gulf of Mexico exemplifies the risks of mining in remote locations. There has been a 100% increase in the average real costs per oil well (MGI, 2011). The supply curves in the short term have also become increasingly inelastic, which means that changes in demand can enhance price volatility. As Diederen (2010) states: the low hanging fruits in mining have been harvested. Additionally, water use intensity is rising, putting the supply of this resource under pressure as well. All factors mentioned above, together with the effects of climate change, like changed weather patterns, political shocks and innovation in financial markets (e.g. the development of exchange-traded funds), enhance price volatility. These trends also impact the projections on the scarcity of resources.

With an additional three billion middle class consumers, demand for some strategic metals like steel, is expected to grow by 80% within 20 years and demand for consumer goods like cars is expected to double in the same period. Besides the increased resource demand, the need for urban infrastructure, mainly in developing countries, will also escalate[15]. This will simultaneously impact the amount of arable land in the world negatively.

The current economic system could use resources basically for free. However in the process, it greatly deteriorated the environment that provides the natural resources necessary for production (EMF, 2011). The Food and Agricultural Organisation (FAO, 2010) estimated that almost 30% of the world's fish stocks are overexploited and over 50% fully exploited. Clear-cutting forests to satisfy timber demand affects rainfall patterns, which in turn impacts crop harvests (TEEB, 2009). Thus, the demand growth for natural resources drives the deterioration of the environment, which in turn increases the vulnerability of the supply of resources (MGI, 2011). It is estimated that the demand for food, feed and fibre will have increased by 70% in 2050. Yet, with 60% of the world's major ecosystems already degraded and used unsustainably, two planets would be needed to satisfy demand (European Commission, 2011). Furthermore, resource and price volatility have developed stronger linkages. This means that scarcity or volatility of one resource can have strong impacts on other resources, like how dropping ground table levels influences the higher energy intensity rate of water. Lastly, technical developments like the Internet and mobile phones increasingly enable the poor to raise their voice for an equal share in this world.

In addition, the declines in commodity prices during the 20th century have been erased by an increase in real commodity prices of 147% since 2000 (MGI, 2011). Rising prices of, among others, food have already pushed 44 million people into poverty (World Bank, 2011). Rising prices and its consequences have triggered the debate within countries on how to secure supply. The WTO stated that from October 2010 to April 2011, countries like China and Vietnam imposed at least 30 export restrictions on metals and mineral resources. As Diederen (2010) stresses, scarcity can thus also occur at low price levels, for example, when China put export quota on REEs. He emphasizes that absolute price levels are not solely sufficient indicators of scarcity. An absence in price stability, resulting in uncertainty when making investment decisions, can also have an impact on scarcity levels.

A large-scale survey among senior executives of leading global manufacturing companies from various industries, about metals and minerals scarcity, found that "the risk of scarcity is expected to rise significantly, leading to supply instability and potential disruptions in the next five years" (PwC, 2011: 5). The study also found that supply instability is already experienced in the renewable energy, automotive and energy & utilities sector. "For 84% of respondents the increase in demand is perceived as the main driver behind the issue of minerals and metals scarcity, followed by geopolitics (79%) and extraction shortage (73%)" (ibid: 16). This is followed by a low substitution rate, low re-use rates, over demand (supercycle), the running dry of reserves and insufficient research for development of alternatives (ibid). However, these companies do not see sufficient awareness of this topic among stakeholders, consumers and employees.

The data above indicate that scarcity is an issue and will continue to be an issue that society must acknowledge. The EU has returned scarcity of resources prominently on the agenda, ever since China cut the export quota of REEs, necessary to produce, among others, hybrid cars and mobile phones, with 72% in 2010. This action gravely affects industries in Europe since China controls 97% of the world's supply of REEs (Yu, 2010).

As a response, the EU conducted a study to get more insight into their dependence on these materials. The European Commission identified 35 materials critical for the European economy. The term 'critical' is defined as being of high economic importance and having a high supply risk. This means they have a high risk of becoming economically and/or politically scarce. Table 2.2 provides an alphabetically

[15] China for example will annually expand its floor space by 2,5 times the square footage of Chicago.

ordered overview of these 35 materials. This list is complemented with three materials added by the Netherlands, depicted in *italics* (CBS & TNO, 2010). The elements making up the REE group and the Platinum Group Metals (PGM) are individually mentioned. As can be seen there is some overlap between the list of materials that will become physically scarce and materials that have a high risk of becoming economically or politically scarce.

Table 2.2 Critical raw materials for the European Union and the Netherlands. Source: based upon CBS & TNO, 2010; European Commission, 2010.

Antimony	Gadolinium,	Lanthanum,	Platinum,	Terbium,
Beryllium	Gallium	Lutetium	Praseodymium,	Thulium,
Cerium	Germanium	Magnesium	Promethium,	Tungsten
Cobalt	*Gold*	Neodymium	Rhodium,	*Uranium*
Dysprosium,	Graphite	Niobium	Ruthenium	Ytterbium
Erbium,	Holmium,	Osmium.	Samarium,	Yttrium,
Europium,	Indium	Palladium,	Scandium,	
Fluorspar	Iridium	*Phosphorus*	Tantalum	

2.2.4 Consequences of resource scarcity

The consequences of the use of material resources can be studied from three perspectives:

1. *Economic perspective*. Management of resources affects “i) short-term costs and long-term economic sustainability; ii) the supply of strategically important materials; and iii) the productivity of economic activities and industrial sectors” (OECD, 2008: 11).
2. *Social perspective*. Extraction and use of resources affects people’s health, employment, recreational possibilities and cultural heritage. Moreover the equity aspect, like equal sharing of the profits, is part of this perspective (OECD, 2008).
3. *Environmental perspective*. The exploitation and use of resources affects “i) the rate of extraction and depletion of renewable and non-renewable resource stocks; ii) the extent of harvest and the reproductive capacity and natural productivity of renewable resources; and iii) the associated environmental burden and its effects on environmental services” (OECD, 2008: 11).

Europe’s economies are directly and indirectly based on the use of material resources. The resources underpinning the functioning of Europe include raw materials such as fuels, minerals and metals but also food, soil, water, air, biomass and ecosystems (European Commission, 2011). No comprehensive forecasting studies, that assess the effects that resource scarcity will have on the parameters mentioned previously, have yet been conducted. Therefore, the possible consequences of resource scarcity will be contextualized by analysing the resource situation in the EU and the Netherlands. The focus will be on non-renewable resources because a resources passport is mainly envisioned for these types of resources. Currently, much is known about biotic resources in food and feed due to among others, nutrition labels. Abiotic resources prominently figure in various certification schemes, roundtables and in the Dutch top-sectors.

2.2.4.1 Resource situation in the European Union

The EU is almost self-sufficient regarding its food supply (between 95%-100% for basic food products) and is one of the most important exporters of agricultural products. No prioritization has been made for biotic resources (Korteweg & De Ridder et al., 2011). Referring to abiotic resources Hagelüken (2007) states, that “after more than 1000 of years of mining, Europe has largely depleted its primary metal resources” (ibid: 10). This resulted in a large shift in resource extraction and processing, which impacts the environment the most during the lifecycle, away from the more industrialized countries (Giljum et al., 2008). Therefore the EU is characterized by large import dependence; however there are variations by country and resource. In 2010 the EU assessed their vulnerability for resources scarcity by looking at the economic importance and supply risk of materials. 35 materials were identified as critical for the European economy. The EU is the region in the world with the highest net imports. The import dependency for elements like REEs, antimony, cobalt, platinum and tantalum is even 100% (EC, 2008), for iron ores 83%, for bauxite 80%, and for copper 74% (Giljum et al., 2008). Especially the high-tech industry relies on a constant supply of REEs and other critical materials. When China in 2010 cut the export quota for REEs with 72%, the high-tech industry was confronted with a 40% reduction of available raw materials (Kooroshy et al., 2010). Angerer et al. (2009)

explain that shortages of these critical materials, which have specific properties essential for emerging green technologies like solar cells, wind turbines and fuel cells, may in the longer term hamper the spread of these technologies and impede other innovations. Figure 2.4 based upon the study of Angerer et al. analyses the demand for raw materials in 32 emerging technologies.

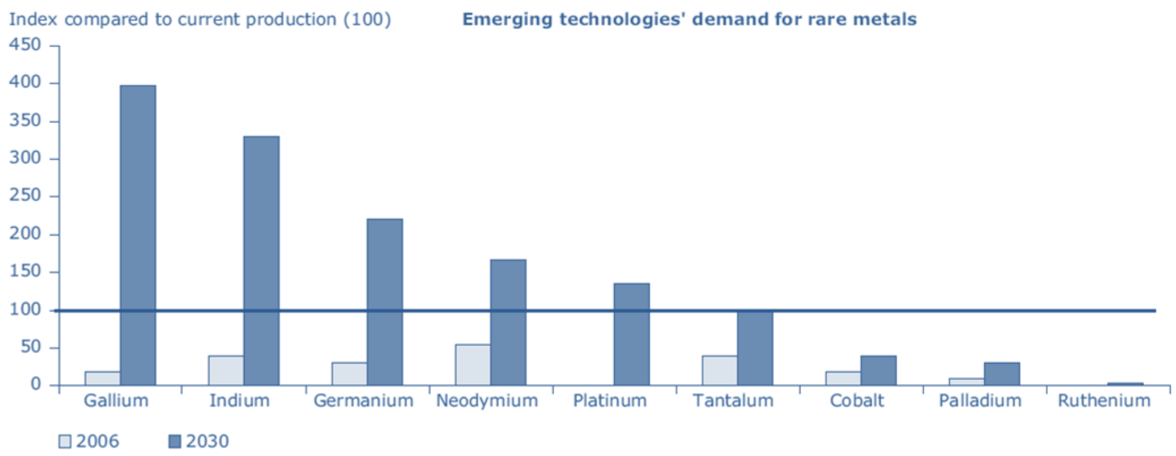

Figure 2.4 Global demand for raw materials by emerging technologies in 2006 and 2030 relative to global output of each material in 2006. Source: EEA, 2010: 22.

Annual demand for gallium in 2030 has risen with 397% compared to 2006. Demand for Indium is projected to rise with 329%, germanium with 220%, neodymium with 166% and platinum with 135%. A recent study by Alonso et al. (2012), based upon historic trends and the upper and lower bound projections for REE usage, estimate that the demand for dysprosium, another REE, could increase by 2600% over the next 25 years. Satisfying demand would require a steep increase in supply growth, historically unprecedented and challenging with the identified disruptive trends.

Data from the Eurobarometer (2011) shows that material costs for producing companies in the EU already account for around 40-45% of the gross production value. With a high import dependence and other resource disruptive development trends EU economies are vulnerable to scarcity.

2.2.4.2 Resource situation in the Netherlands

The overall picture described for the EU also holds true for the Netherlands, with some additions. A research conducted by Statistics Netherlands (referred to as CBS) and the Dutch Organisation for Applied Scientific Research (referred to as TNO) (2010) showed that the Netherlands imports almost all abiotic resources needed for its economy. Quantification of importance has been made based upon the role resources play in imports, added value creation, consumed end-products and export. Especially the product groups glass and construction materials, basic metals, metal products, machinery and equipment, office machinery and computers, electrical machinery, medical-, precision- and optical instruments, motor vehicles, other transport equipment and electricity and gas are dependent on these critical resources (CBS, TNO, 2010: 4). The Dutch government does use the list of critical materials as established by the EU, but has supplemented it with three other resources: gold, phosphor and uranium. No further detailed prioritization has been made, though the '*Grondstoffennotitie*' provides a first indication of the role of resources in the nine top sectors. The Netherlands does not have a large mining industry, yet is an important transit country of biotic as well as abiotic resources. Abiotic materials mainly enter the Netherlands as semi-manufactured goods or end-products. The distribution of the imported value in euros of the domestic import is respectively 9,3% for resources, 61,7% for semi-manufactured goods and 29% for end-products. A less open-market system could thus have direct negative consequences for the economy (Korteweg & de Ridder et al., 2011).

2.3 The circular economy

If we continue with the business-as-usual scenario outlined in section 2.2, there will soon be economic, political and/or physical scarcity of many raw materials (PBL, 2011). Transforming our economy towards a circular economy currently receives much policy attention in the EU, China, Japan and the United States, among others. Moreover for over two decades scientific attention for the concept circular economy has been extensive, although not under that name as will be explained below. There is no agreed definition or end-goal of the concept circular economy. Therefore, the theoretical foundation of a circular economy is analysed and its main principles are identified. These principles will serve as a guiding point in the development of the content and format of the resources passport.

2.3.1 From an open-ended economy to a circular economy

The concept circular economy shows the interlinkages between the economy and the environment by means of emphasizing four interconnected economic functions of the environment. Namely: the provision of amenity values, forming a resource base for human societies, being a sink for economic activities and being a life support system (Pearce & Turner, 1990). The concept is opposed to the conventional perception of the economic system as being linear and open-ended. Figure 2.5 is a schematic representation of the conventional linear economy.

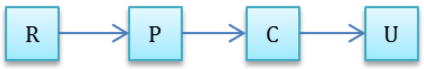

Figure 2.5 The conventional open-ended economy.
R (natural) resources, *P* production, *C* consumption, *U* utility. Source: adapted from Andersen, 2007: 134.

What stands out in Figure 2.5 is the absence of waste. However, waste is created in every stage of the production process and the natural environment is the ultimate repository of waste, like carbon dioxide ending up in the atmosphere and solid waste ending up in a landfill. The 'First Law of Thermodynamics' states that energy and matter can be converted and dissipated from one form to another, but cannot be created or destroyed: which means that waste should be incorporated. For example, the amount of coal consumption equals the amount of gasses, and solids produced. The idea of Earth as a closed system in which the economy and the environment are interlinked was visualized in Kenneth Boulding's essay `*The economics of the coming spaceship Earth*' from 1966. If the Earth would be a spaceship on a long journey it would only have the sun as an external source of energy. If the stock of resources present at boarding would be reduced, so would the lives of the people on board be shortened, unless ways are found to recycle and re-grow the diminished stock. If this knowledge that everything forms input for anything else is incorporated into the linear model, the following simplified model of the circular economy, as depicted in Figure 2.6, can be created. What stands out is that simply saying that the goal of the economy is to create utility is not enough. Within a closed system there are boundaries that have to be taken into account when aiming at the end goal of creating utility (Pearce & Turner, 1990).

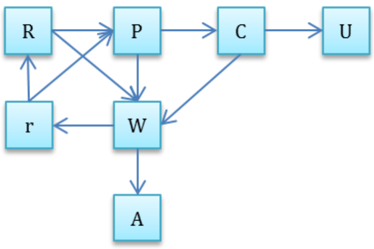

Figure 2.6 The simplified circular economy.
R (natural) resources, *P* production, *C* consumption, *U* utility, *r* recycling, *W* waste, *A* Assimilative capacity of the environment. Source: adapted from Andersen, 2007: 134.

As can be seen in Figure 2.6, not all waste is recycled, it also ends up back in the environment. The 'Second Law of Thermodynamics' dealing with entropy provides the reason for this. Most materials are used entropically, which means they dissipate throughout the system. For example, when burning fossil fuels: if the residue after combustion, in the form of carbon dioxide, is captured it does not (directly) form another fuel. Thus entropy forms another boundary in the economic system, together with the limited capacity of the environment to act as a waste sink. Lastly, a distinction should be made between non-renewable resources and recyclable resources, nevertheless both capable of collapse. When these last remarks are taken into account, a full picture of the circular economy is created, as can be seen in Figure 2.7.

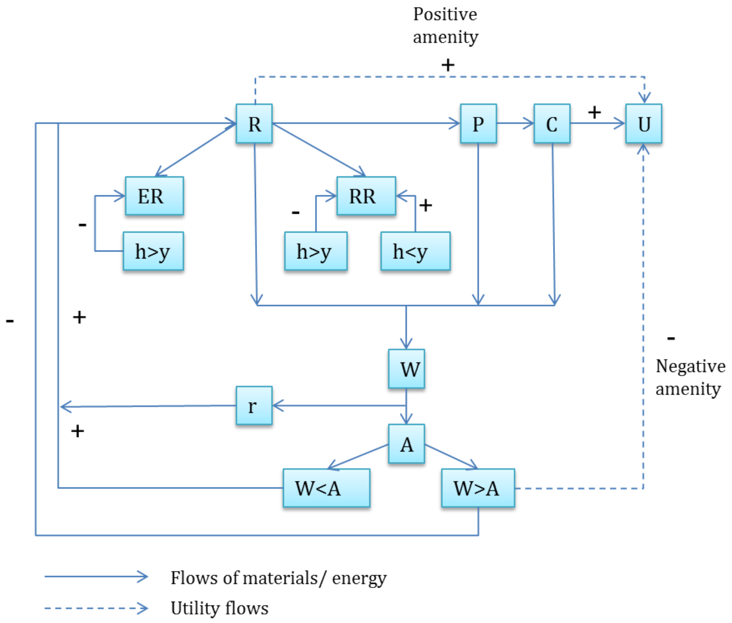

Figure 2.7 The circular economy.
R (natural) resources *P* production, *C* consumption, *U* utility, *ER* exhaustible resources, *RR* renewable resources, *A* assimilative capacity of the environment, *h* harvest, *y* yield. *W* waste, *r* recycling. Source: adapted from Andersen, 2007:136.

2.3.2 Foundations of the circular economy

The concept circular economy cannot be traced back to one author or publication. It gained public momentum in the late 1970s with the research report of Stahel and Reday '*The potential for substituting manpower for energy*' to the European Commission. There are various schools of thought that follow, partially overlap and reinforce each other in refining and developing the concept of the circular economy. Examples are Regenerative Design[16], Performance Economy[17], Industrial Ecology, Cradle to Cradle (C2C), Design for Environment or Ecodesign, and Biomimicry[18]. The most extensively researched and widespread schools of thought are Industrial Ecology, Design for Environment and C2C.

Industrial Ecology was firmly established as a school of thought in the late 1980s by Ayres, Frosch and Gallopolous. There is no standard definition of Industrial Ecology, however it focuses on the flows of materials and energy through industrial systems and the interaction with the biosphere. Subsequently, it studies how the industrial system can be made compatible with the local natural system, thereby taking global impacts into account. The aim is to create closed-loop processes and eliminate undesirable by-products, whereby the use of technology plays a crucial role (Erkman, 1997). Its principles have been applied to products, organisations and regions. A famous and extensively studied example of how these principles have been applied to practice is the Danish place Kalundborg.

Design for Environment originated in the 1980s and refers to the "systematic consideration of design performance with respect to environmental, health, safety, and sustainability objectives over the full product and process lifecycle" (Fiksel, 2009: 6). Since this concept addresses the whole lifecycle of a product, per stage the environmental, health and safety aspects need to be analysed. Gertsakis, Lewis and Ryan (1997) define 15 strategies that fall under the umbrella of Design for Environment, design for: resource conservation, -environmentally preferred materials, -cleaner production, -efficient distribution, -energy

[16] This school stems from American Professor John Lyle who in the 1970s gave students the assignment to come up with thoughts on how to create a society in which "daily activities were based on the value of living within the limits of available renewable resources without environmental degradation" (Lyle Centre for Regenerative Studies, 2012: History). The term regenerative design stems from his idea that the processes in every system generate the fuel they consume.
[17] This school is headed by Walter Stahel who wrote the report '*The potential for substituting manpower for energy*' to the European Commission in 1976. In this report he sketched a vision of a closed-loop economy and the impact thereof on employment, competitiveness, resource use and waste prevention. He argues that the circular economy is a coherent model that should be the response to the end of the era of cheap oil and material use. His Product-Life Institute stresses the importance of selling services instead of products.
[18] According to Janine Benyus who put biomimicry on the map it is a "discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems. Studying a leaf to invent a better solar cell is an example. I think of it as innovation inspired by nature" (Biomimicry Institute, 2012, About us). There are three leading principles: i) Nature as model, ii) Nature as measure, and iii) Nature as mentor (ibid).

efficiency, -water conservation, -minimal consumption, -low-impact use, -durability, -remanufacture, -re-use, -disassembly, -recycling, -degradability and -safe disposal. Moreover, Veerakamolmal and Gupta (2000) define the concept of Design for X, where X can be any design strategy like: compliance, disassembly, recycling, reliability, safety and liability, and testability. Much of these concepts provide life-extending strategies and overlap with each other. An often cited example is the eco-design strategy wheel developed by Van Hemel and Brezet (1997).

The C2C design concept as well as certification process has been developed by chemist Michael Braungart and Architect Bill McDonough throughout the 1990s. C2C moves from the perspective of incremental change and ‘doing more with less’ (eco-efficiency) towards the designing of industrial systems to be “commercially productive, socially beneficial and ecologically intelligent” (eco-effectiveness) (McDonough et al., 2003: 435). They perceive all materials as nutrients, either technical or biological, that can continuously be reutilized and recycled. Quality based material recycling is based on knowing exactly what the products are made of.

Although these schools of thought mainly emphasize their differences, they actually have much in common as seen in table 2.3, which provides an overview of the main tenets of each of these schools.

Table 2.3 Main tenets of Industrial Ecology, Design for Environment and Cradle to Cradle.

Industrial Ecology	Design for Environment	Cradle to Cradle
Analogue to the nutrient cycle in nature, industrial waste should function as input for industrial processes (Frosch & Gallopolous, 1989)	“Sustainability of natural resources—assurance that human consumption or use of natural resources does not threaten the availability of these resources for future generations” (Fiksel, 2009: 6).	Waste equals food: “Design products and materials to be benign to humans and the environment and to function perpetually in closed loop systems or metabolisms (McDonough et al., 2003).
Minimization of energy use, waste generation and the consumption of scarce materials (ibid).	“Environmental protection—assurance that air, water, soil, and ecological systems are not adversely affected due to the release of pollutants or toxic substances” (ibid).	Use current solar income: to not reduce the stock of resources present on the Earth, one has to rely on renewable sources of energy, like solar and wind (ibid).
System diversity and resilience are key when absorbing and recovering from shocks (ibid).	“Human health and safety—assurance that people are not exposed to safety hazards or chronic disease agents in their workplace environments or personal lives” (ibid).	Celebrate diversity: healthy ecosystems thrive on diversity of functions and connections , and are more resilient to shocks (ibid).

2.3.3 Principles of the circular economy

These various schools of thought all developed multiple lists of principles on how human society should be organized, to lower the pressure generated by industrial systems on human health and the environment. As stated in the central question, the resources passport should successfully contribute to the achievement of the circular economy. For all three schools addressed above, an exemplary and comprehensive list of principles is analysed and eventually synthesized, so as to identify the main principles of the circular economy.

There are several lists of principles of Industrial Ecology. A comprehensive one is developed by Vermeulen (2006). Based on extensive literature research he identifies six main types of changes in modes of production in the industrial ecology literature. Just like the other lists of guiding principles, these changes are formed by the definitions of the desired end goals of the paradigms. The six main principles are depicted in table 2.4.

Table 2.4 Six main principles of changes in modes of producing goods in society according to industrial ecology. Source: adopted from Vermeulen, 2006: 577.

No.	Description
1	The redesign of production processes into low- or zero-emission systems.
2	The redesign of the full lifecycle of products into minimal-impact human-needs-satisfying systems.
3	As a special field of principle 2: the redesign of the built environment into minimal-impact-producing infrastructures.
4	The creation of recycling systems for material flows after the use of resources or products.
5	The creation of regional networks of material exchange.
6	At the resource side: the redesign of society’s energy system into a system based on renewable resources with low impact.

Van Hemel and Brezet (1997) developed the often referenced to ‘eco-design strategy wheel’, based upon an extensive array of scientific literature. This strategy wheel specifies eight principles with various sub-principles that should be taken into account when designing a product in accordance with the eco-design philosophy. Table 2.5 provides an example of an ecodesign strategy wheel in which the eight principles are clearly marked and complemented with various sub-principles. These sub-principles can vary according to the desired end goal.

Table 2.5 The eco-design strategy wheel. Source: Van Hemel & Cramer, 2002: 441.

No.	Description
1	Selection of low impact materials. For example cleaner materials, renewable materials, lower energy content materials, recycled materials and recyclable materials.
2	Reduction of materials usage. For example: reduction in weight and reduction in (transport) volume.
3	Optimization of production techniques. For example: alternative production techniques, fewer production steps, lower/ cleaner energy consumption, less production waste and fewer/ cleaner production consumables
4	Optimization of distribution. For example: less/ cleaner/ reusable packaging, energy-efficient transport mode, energy efficient logistics.
5	Reduction of impact during use. For example: lower energy consumption, cleaner energy source, fewer consumables needed, cleaner consumables and no waste of energy /consumables.
6	Optimization of initial lifetime. For example: via reliability and durability, easier maintenance and repair, modular product structure, classic design and strong product-user relation.
7	Optimization of end-of-life system. For example: reuse of product, remanufacturing/ refurbishment, recycling of materials and safer incineration.
8	New Concept development. For example: dematerialization, shared use of the product, integration of functions and functional optimization of product (component).

Lastly, the developers of C2C formulated the "12 principles of green engineering". Table 2.6 provides an overview of these 12 principles.

Table 2.6 The 12 principles of green engineering. Source: McDonough et al., 2003: 437.

No.	Description
1	Designers need to strive to ensure that all material and energy inputs and outputs are as inherently non-hazardous as possible.
2	It is better to prevent waste than to treat or clean up waste after it is formed.
3	Separation and purification operations should be designed to minimize energy consumption and materials use.
4	Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.
5	Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.
6	Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse or beneficial disposition.
7	Targeted durability, not immortality, should be a design goal.
8	Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.
9	Material diversity in multi-component products should be minimized to promote disassembly and value retention.
10	Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
11	Products, processes and systems should be designed for performance in a commercial "afterlife".
12	Material and energy inputs should be renewable rather than depleting.

Synthesizing these three lists of principles results in identification of the following four main principles for a circular economy.

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

This is necessary to prevent large losses of materials as specified previously, plus reduce the large impact of current industrial systems on human health and the environment. This principle includes many aspects mentioned in the three lists, among which: the selection of low impact, abundantly available and non-hazardous materials: the reduction of material use, minimizing of the use of different materials and promotion of the use of modular design to better enable disassembly and reuse, prevention of waste during the production process, extended durability because the largest environmental impact is generated throughout the production process and this safes materials and energy, optimization of production techniques, and the use of renewable energy.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*
Many materials, especially in consumer products, currently operate in open loop systems resulting in a large loss of materials (Hagelüken, 2007). By creating more collection systems and making existing ones more user-friendly and easily accessible, and by including services like erasing all saved data on computers and mobile phones, the recollection rate can increase. Moreover, treatment and recycling systems should be improved, to better separate materials, prevent contamination and ensure a higher quality and quantity of recovered materials.

3. *The creation of, preferably regional, networks of material exchange.*
Material exchange enables actors in the supply chain to optimally use resources. For example, one actor's waste can be a vital ingredient for another actor. Also, cascading use of materials or products should be stimulated. Cascading use means that materials can consecutively be used in various product categories. For example, using cotton clothing in its second life as fibre fill for furniture and subsequently as insulation material before returning it to the biosphere. The regional aspect of material exchange is important, since transportation is currently still a resource intensive and polluting activity.

4. *The collection, management and exchange of resource-related information.*
To be able to achieve principle one to three, transparency plus traceability of information, and improved cooperation throughout the supply chain is essential. Without cross-sectors or supply chain wide sharing of information one cannot optimize principle one to three, plus one cannot make any predictions about the impact of scarcity of resources.

These four principles will be used as end-goals to which the resources passport needs to contribute and thus as guiding principles in the development of the content and format of the passport. Which information needs to be shared is explored in section 2.5.

2.4 Resource-related business practices

These four principles make clear that the circular economy revolves around resources and that preventing resource scarcity is a central aim of the circular economy. The lists of principles devised by the various schools of thoughts indicate that (mainly OECD countries) have given much attention to enabling sustainable development and reducing the harmful effects of economic growth on human health and ecosystems (CBS, PBL & Wageningen UR, 2008; Vermeulen, 2010; CBS, PBL & Wageningen UR, 2011; Eurostat, 2012).

Two trends are analysed. First of all, from all the possible environmental goals and actions to be achieved, scarcity was never the priority. Secondly, there is a need for, but lack of, information exchange or a particular information exchange mechanism related to addressing scarcity. These two will be addressed below in section 2.3.1 and 2.3.2.

2.4.1 Scarcity has never been the first priority

The main focus of this research is on the product manufacturing and waste processing industry. This is where an instrument like the resources passport on products can be used and useful immediately. One of the reasons that scarcity is a looming issue at the moment is that scarcity, until recently, never was a pressing issue and thus not at the forefront of design and recycling decision-making. Luttropp and Lagerstedt (2006) give an explanation related to the design phase. In most companies, the development of products means striking a balance between multifaceted demands such as safety, profits, competition, performance, aesthetics, legal requirements, environment etc. Given that many products consist of multiple materials combined in different components, this is a highly complex process. The principles in lists like those of Van Hemel and Brezet (1997) have to be related to all the other demands, without dominating the other also legitimate demands. Vermeulen (2006) explains that the competition between the various demands also takes place within the ecological agenda. Since companies have a limited amount of time and budget, not all eco-design principles will be given equal attention; instead choices will be made between, for example, recycling or applying abundantly available raw materials.

The same holds true for the recycling phase. Hagelüken (2007) identifies several reasons why scarce materials like Indium and REEs have a worldwide recycling percentage of around 1% (UNEP, 2011). Firstly, he concludes that design for recycling as a sub-strategy of Design for Environment has lost ground to the focus on energy consumption and exhaust of carbon dioxide (CO_2) emissions. In general, there is little to no dialogue between designers and the recycling industry, resulting in designs where scarce and hazardous substances are closely linked and therefore not retrievable. Secondly, he addresses weight based recycling quota, since this mainly promotes the recycling of the main constituent materials like steel and aluminium, which are not the most important materials from a scarcity and environmental perspective. Thirdly and most importantly, the average recycling percentage of scarce materials remains very low, even though there are adequate recycling techniques, plus legislative and economic incentives are increasing. That is the result of consumer products operating in an open loop system that leaks many valuable materials. This is due to a lack of information, cooperation, coordination, infrastructure, inappropriate recycling targets, collection targets and system boundaries, plus illegal shipments going abroad (Hagelüken, 2007; Reck & Graedel, 2012). Vermeulen also indicates that, in practice, the perception people have of recycling is often quite negative, focusing on the risks of contamination and loss of quality. This results in the perception of recycling as an unwanted risk instead of a solution (ibid).

Additionally, where the focus has been on addressing scarcity issues, there are some critical notes to make as well. The often used mitigation strategy of increased efficiency[19] is undermined by Jevon's Paradox. This paradox means that more efficient use of a resource via technological progress, increases instead of decreases the use of that resource. Thus, without large-scale control and recycling, material reserves are actually depleted faster (Blake, 2005).

Also dematerialization runs a risk of aggravating the problem by, for example, using thin layers or nano-technology as a solution. The production and recycling of those particles uses large amounts of energy and consumables in production and recycling, consequently hampering large-scale recycling (Diederen, 2010).

Although the amount of recycling in the EU has increased, recycling is a partial solution. "Even 100% recycling (which is virtually impossible) does not account for annual global demand" (Diederen, 2010: 89). This is partly explained by the fact that the growing EU economy accumulates materials in, for example, the construction or infrastructural sector, where they are stored for a longer period of time. Additionally there are some technological limitations, varying per material, which cause materials to not be recycled at all, or down cycled (EEA, 2010). As can be seen in figure 2.8, the maximum recycling potential for waste electrical and electronic equipment (WEEE), containing many critical materials, is only a fraction of the consumption. The same holds true for copper and aluminium.

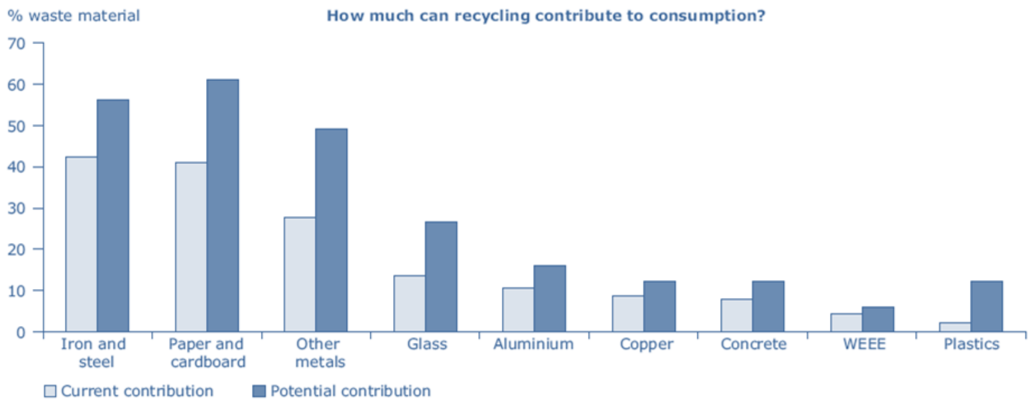

Figure 2.8 Current and potential contribution of recycling to meet EU demand for materials, 2006. Source: EEA, 2011: 19. (*) The current and potential contribution figures are both based on the infrastructure available in 2006. Future changes in collection rates, improved recycling structures and market conditions could significantly influence the potential contribution figures.

Besides, the EU also includes energy recovery under the category recycling. However, from the viewpoint of scarcity of materials, incinerating waste means losing the materials.

2.4.2 Scarcity related information exchange

Köhler et al. (2010) investigate material scarcity and possible solutions. They conclude that:

[1919] Efficiency is defined as doing the same task, or more, with less input of for example materials, energy or water and a smaller impact on, for example, the environment (Barbiroli, 2006).

“resource scarcity comprises a range of multidimensional complex problems, which are sometimes termed ‘wicked’ problems. Uncertainty prevails due to the fragmentation of the intelligence regarding the various aspects of scarcity. While relevant information might actually exist somewhere in society or industry it is hardly possible for practitioners to retrieve all relevant knowledge. From a single practitioners’ perspective these matters are simply too complicated and cannot be scrutinised ad infinitum. The situation can be interpreted as a sign of insufficient knowledge exchange” (ibid: 13).

Several scholars have analysed the need for information exchange to address scarcity issues. Some recent examples are Peck et al. (2010), who studied the response to uncertainty about, and severe scarcity of, resources during the Second World War in the United Kingdom. They conclude with several recommendations to prepare and deal with scarcity. Their most important conclusion is that “there needs to be a full appraisal of the consumption of material” (Peck et al., 2010: 26). Only by exactly knowing what is being used by whom, and what is being wasted by whom, adequate strategies can be formulated.

Lehtoranta et al. (2011) conducted a literature analysis on instruments that could enhance industrial symbioses, which refers to the cooperation between a group of local companies, communities, and other actors, who exchange energy, water, by-products, and waste (ibid: 1865). They identify the need for a person or an instrument to function as a knowledge broker. This knowledge-broker would exchange information about the created waste and the possibilities of reusing or recycling it.

Reck and Graedel (2012) and Köhler et al. (2010) state that designers have little awareness of the problem of scarcity, and have a lack of knowledge about the materials that make up their products. This is mostly because much of the product is outsourced. Producers buy many sub-components via a complex network of multiple and varying suppliers. This also results in a lack of knowledge on the routes the materials take during the lifecycle of a product. Moreover, designers have little knowledge about the technical substitution potential of materials. Hence, they propose a transparent knowledge database to support designers in their decision making. This database should host the following information:

- *“Application areas of critical elements and their functions.*
- *Inventory of products and product components and technologies that rely on critical elements.*
- *Information on recyclability and actual recycling rates of critical elements from waste, referring to the technical components they are contained in.*
- *Compendium of substitution potentials, e.g. alternative materials or components that can serve the same purpose and are less dependent on critical elements.*
- *Basic design guidelines for dealing with trade-offs that result from substitution or elimination of critical elements” (Köhler et al., 2010: 23).*

Lastly, Köhler et al. (2010) state that an abundance of sustainable design paradigms, like Eco-design and C2C have been developed, yet these paradigms all suffer from inadequate implementation by industries.

Hagelüken (2007) explains that material flows are currently extremely non-transparent. Even for large products like end-of-life vehicles, Germany cannot explain a statistical gap of two million vehicles. Besides a track and trace system to be able to recover scarce materials, Hagelüken emphasises that the cooperation between the stakeholders in the recycling chain needs to be improved. There are currently little to no interfaces between the various operators, hindering reuse and recycling. The large-scale survey of PwC (2011) showed that this supply chain wide exchange of information is important, since impacts of scarcity cause stress all along the supply chain and even tend to increase when one moves down the supply chain. Especially the risk of instability of supply is high because of the nature of metals production.

Thus, for decades multiple research and policy areas have focused on the importance of material information exchange for example within trade, economic and technological development policies, natural resource management policies and environmental policies. Although all areas claim that comprehensive material reporting is important, for various reasons comprehensive, systematic, transparent lifecycle or supply-chain material reporting has never evolved or gained ground.

One of the reasons, as explained in section 2.3.1, is that addressing scarcity via material reporting has lost ground to the focus on reporting about energy consumption and exhaust of CO_2 emissions. Since scarcity was never a priority, scarcity related information exchange was neither. Nevertheless, various instrument like Material Flow Analysis (MFA), Life Cycle Analysis (LCA) and Substance Flow Analysis (SFA) have been developed. Also standardization methods provided by the International Organization for Standardization (ISO) or certification schemes like C2C have been set up. Yet none of these tools function as a knowledge-broker between the various practitioners in need of this information. Additionally, businesses internally conduct various kinds of material reporting practices like Bills-of Materials (BOM) and others that aren't publicly known or researched. Like the other instruments, they do not function as a knowledge broker. Beijerse (2000) conducted research on the internal knowledge management in small and medium enterprises (SMEs). Within 12 companies he identified 79 different instruments to acquire, manage and share knowledge on an operational level. Despite this large number of instruments, he concludes that there is hardly any systematic knowledge management on a strategic and tactical level within SMEs. Knowledge exchange thus happens in a non-systemic manner and therefore available information is not used to its potential. Additionally, as Lambert (2001) indicates, although information is available, unification of methodology is indispensable given the manufacturing supply-chain approach.

As mentioned previously, the industrial symbiosis in Kalundborg since the 1980s, is one example of the principles of Industrial Ecology applied in practice. The comprehensive analysis of this case by scholars also provides clues regarding the lack of material information exchange. Industrial symbiosis can only take shape with the exchange of information about the use and waste of materials. Sterr and Ott (2004) provide an overview of lessons learned for creating industrial symbiosis by studying the Kalundborg-case and similar cases. They state that exchange of information and materials is much more likely when there is personal contact and mutual trust. This implies that industrial symbiosis is most likely to occur on a local level. In their study they find that after local cooperation has been established, eventually an information exchange system is developed to better manage the sharing of data. They also find that the presence of an adequate information exchange system enhances the exchange of information on a large-scale. Thus, large-scale information exchange more likely evolves when there is a system already in place. However, the need for such a system develops on a local scale. Their explanation:

> "*despite this potential, suitable instruments enabling the continuous discussion and exchange of data related to waste and secondary materials have not yet significantly developed. This is partly due to the traditional low-level of organization and diverse interests on the regional scale, but also to the fact that the number, the complexity, and the variety of actors rise sharply from the industrial site to the regional milieu. In addition, face-to-face contacts—which are unproblematic within a small industrial space—have to be (partially) replaced by indirect communication, which reduces the quality of information while at the same time increases the costs of coordination*" (ibid: 957).

To be able to use this potential they find that there is a large need for the development of a communication platform for the exchange of data, where high quality data are provided at minimal cost.

Another explanation for the lack of information exchange is provided by Sterr and Ott's (2004) conclusion that the industrial symbiosis in Kalundborg was driven by economical motives and not ecological ones. As analysed before, scarcity was never a first priority and the prices of resources only recently significantly rose. Therefore, economically the exchange of material information was not a priority.

2.5 Redesigning business practices to address resource scarcity

A resources passport should contribute to the achievement of a circular economy. Principle four of the circular economy: the collection, management and exchange of resource-related information, is a prerequisite for the achievement of the other three principles. However, each actor in the supply chain only has a small piece of information. There is not a single actor that has the complete picture. The exchange of resource-related information in order to address scarcity is a means to achieve an end. As Lee and Whang (1998) state "information sharing is only an enabler for better coordination and planning of the supply chain. Hence, companies must develop capabilities to utilize the shared information in an effective way" (ibid: 15). There are different end goals of addressing resource scarcity for companies. These various end goals, simultaneously forming the value creating levers for companies, are depicted in figure 2.9.

Figure 2.9 Value creating levers for companies in addressing resource scarcity (MGI, 2011: 20).

Hence, there are three broad categories of end goals: 1) growth, 2) return on capital and 3) risk management. The development of a resources passport should thus focus on addressing scarcity, by aiming at the adequate exchange of information between the stakeholders in the supply chain and preferably incorporate all value creating levers. All value creating levers require some level of transparency and internal or external information exchange. Since every supply chain actor has a different role and executes different actions, the information requirement of each actor is different. Before analysing the roles and information needs of the various supply chain actors in addressing scarcity, the flow of resources throughout the supply chain is described. Figure 2.10 provides an overview thereof. This overview is tailored to the goal of this research.

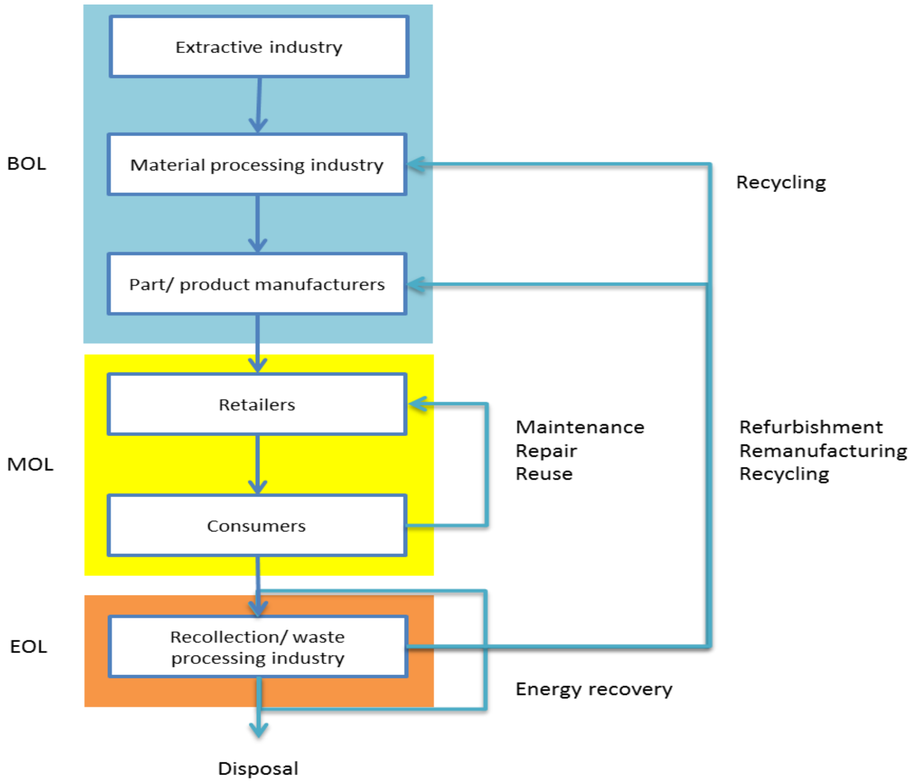

Figure 2.10 Supply chain actors and resource-related activities. Source: based upon Parlikad et al., 2003; Jun et al., 2007; Köhler et al., 2010; and EMF, 2011.

In general the lifecycle of a product consist of three stages:

1. Beginning-of-Life (BOL), which includes the extraction, product design and manufacturing of a product.
2. Middle-of-Life (MOL), which includes the retailers, use, maintenance and other life prolonging services.
3. End-of-Life (EOL) which refers to reverse logistics, and various recovery strategies (Jun et al., 2007).

Recovery strategies start at "the point in time when the product no longer satisfies the initial purchaser or first user. This allows for reuse and service in addition to recycling as possible end-of-life strategies" (Rose et al., 2002: 84).

First of all, materials are mined or harvested all over the world by the extractive industry. From the extractive industry, materials like metals, minerals, wood etc. are transported to the material processing industry. Material processers modify the raw materials into useful substances, for example, making plastics out of oil. These materials are bought by manufacturers who make a product out of it. The distributers step between producers and retailers has been left out of this supply chain model since their role in addressing scarcity in the context of this research is minimal. Next, the product is sold to a retailer who puts it in a store where consumers can buy it. From here on three recovery options can be applied, namely maintenance, repair and reuse. These options are described in more detail in table 2.7 below. When the product is not repairable anymore or no longer fulfils the desired function, the product is disposed of. It subsequently is distributed to waste processing companies who sort most materials and can opt for a process of remanufacturing, refurbishment or recycling of the disposed materials. The refurbished, remanufactured or recycled materials are then distributed to the product manufacturing industry. Recycled materials can also be distributed to the material processing industry. There the cycle starts all over again, thereby possibly competing with the supply of the extractive industry. Waste processers can also decide to dispose the materials with or without energy recovery.

Table 2.7 Description of recovery options.

Name	Definition
Maintenance	"Servicing of products with the goal of prolonging product lifecycle" (Mont, 2002: 241).
Repair	"The purpose of which is to return used products in working order. The quality of the repaired products could be less than that of the new products" (Parlikad et al., 2003: 5).
Reuse	"Reuse is the second hand trading of product for use as originally designed" (Rose et al., 2002: 84).
Refurbishment	"The purpose of which is to bring the quality of used products up to a specified level by disassembly to the module level, inspection and replacement of broken modules. Refurbishing could also involve technology upgrading by replacing outdated modules or components with technologically superior ones (Parlikad et al., 2003: 5).
Remanufacturing	"The purpose of which is to bring used products up to quality standards that are as rigorous as those for new products by complete disassembly down to the component level and extensive inspection and replacement of broken/outdated parts" (Parlikad et al., 2003: 5).
Recycling	"Recycling reclaims material streams useful for application in products. Disassembly into material fractions increases the value of the materials recycled by removing material contaminants, hazardous materials, or high value components. The components are separated mostly by manual disassembly methods." With recycling without disassembly the material is shredded to "reduce material size to facilitate sorting. The shredded material is separated using techniques based on magnetic, density or other properties" (Rose et al., 2002: 84)
Energy recovery	"The conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of so-called waste to-energy processes, including combustion, gasification, pyrolysis, anaerobic digestion, and landfill gas recovery" (EMF, 2011: 25).

Below, the roles of each supply chain actor and their information needs relevant to achieve principle four of the circular economy are analysed. This analysis will guide the remainder of this research. Five categories of information needs have been identified, based on scientific literature, the order of the supply chain, a distinction between generic and more specific information needs and internal and external information needs. Section A provides an overview of general scarcity-related information needs. This information needs to be publicly available, does not specifically address one actor in the supply chain and most likely needs to be gathered by combining currently fragmented information. Section B focuses on the mining-related information needs, that can solely be generated by the mining industry. Section C focuses on all the information about a product that needs to be available in order to address scarcity. This information needs to be gathered throughout the supply chain and needs to be accessible to multiple actors in and across supply chains. Where applicable, the information also addresses recycled materials. Section D lists information needs that are needed within companies. This information needs to be gathered throughout the supply chain or in cooperation with independent institutes or the government. It is currently fragmented and will be most useful within a company. Lastly, section E lists specific technological information needs. These are relevant for specific actors in the supply chain, however, they do require involvement of outside experts.

A: General scarcity-related information needs

A1 Material scarcity in the short/ medium / long term
A2 Price and supply security/ dependence of materials
A3 Current and future scarcity-related legislative requirements

B: Mining-related information needs

B1 Mine site/ origin
B2 Mining data
B3 Local circumstances/ environment at the mine site

C: Product-related information needs

C1 Physical structure of the product
C2 Material content and composition of products
C3 Material characteristics and properties
C4 Production processes used, plus specification on which material
C5 Initial lifetime of the product
C6 Product adaptations during usage
C7 Life extending possibilities
C8 End-of-life possibilities of the product
C9 Disassembly information

D: Company internal information needs

D1 Supply chain partners (including 2nd, 3th etc. tier)
D2 Position of scarcity on a strategic level within the company (goals, staff, time, budget)
D3 Market demand for products proactively addressing scarcity
D4 Product-related information of competitors products
D5 Guidelines for dealing with trade-offs that result from substitution or elimination of critical elements
D6 Where and how products are disposed of

E: Generic technology-related information needs

E1 Best available mining technologies
E2 Best available material manufacturing technologies
E3 Best available production technologies
E4 Best available technologies for end-of-life systems

Category C contains all product-related information necessary to address scarcity via an instrument like the resource passport. However, this information cannot be used to its full potential, without general scarcity-related information and contextual information, like company's internal information needs and technology-related information.

It should be noted that the roles and information needs in every step of the supply chain, potentially conflict with the traditional roles of these actors, when addressing scarcity. For example, procurement usually searches for the cheapest material available and the marketing department aims to achieve the highest market share for every product. Scarcity is not specifically addressed. The remainder of the paragraph will not mention these conflicts separately for every actor in the supply chain, but they are omnipresent (Hugos, 2011).

Five internal departments have been identified as relevant for all actors, except for the actor retailer and consumer, in the exchange of resource-related information in accordance with Brezet and Van Hemel (1997), Johansson (2002), and Crul and Diehl (2007). These are: management, research & design, procurement, marketing and environmental expert. Off course there are more departments, however, they are not relevant for this research. They are addressed under the part and product manufacturing stage, but equally hold true for the other actors. This division also makes the distinction between the suppliers of parts and in house production superfluous.

2.5.1 Extractive industry

The extractive industry satisfies the high demand for materials. In general, the aim is to extract as much as possible, as cheap and efficiently as possible. Their role in addressing scarcity of non-renewable resources mainly relates to extracting materials as efficiently and effectively[20] as possible, thus with little loss and maximum usage of ores. This poses challenges in some cases, like when critical materials such as germanium are extracted as by-products of other materials, in this case zinc (Azapagic, 2004). More indirectly, the role of the extractive industry is related to the environmental impacts of mining which affect the quantity and quality of other stocks of materials. This relates back to by-products but also neighbouring forests or fish stocks. When it aims for closure of the resource loops, the recycling industry will compete with the extractive industry. However, as new infrastructural and housing projects still store much resources it might take some time before the recycled supply can satisfy demand.

The information needs of the extractive industry related to addressing scarcity issues include having adequate knowledge of the demand for materials and the scarcity prospects in the short, medium and long term. The long lead-time for geological explorations to find ores, and the large investments needed make the system incapable of quickly responding to market demands (Köhler et al., 2010). Additionally, to extract resources as efficiently and effectively as possible, with a minimal environmental impact, it is important to have access to information about the best available techniques (BAT)[21] for mining. Moreover specific mining data regarding the specific ore grades and ore properties is necessary to enable more efficient and effective extraction. For all reasons above it is necessary to have knowledge about the current and future legislative demands. Internally research & design and environmental experts need to have knowledge about the position of scarcity on a strategic level within the company, to address scarcity as effectively as possible. Lastly, information about the local circumstances/ environment is necessary to prevent adverse impacts on neighbouring stocks of materials.

Table 2.8 Scarcity-related roles and information needs of the extractive industry.

Role in addressing scarcity	Information needs
• Increase extraction efficiency and effectiveness • Minimalize the impact and adverse effects on other stocks	• A1: Scarcity prospects in the short/ medium/ long term • A3: Current and future scarcity-related legislative requirements • B2: Mining data like ore grades, characteristics and properties • B3: Local circumstances/ environment • D2: Position of scarcity on a strategic level within the company • E1: Best available mining technologies

2.5.2 Material processing industry

The role of material processers in addressing scarcity is related to the production and reproduction of materials and the search for alternatives. The production of materials is linked to the demand from industry. By producing materials more efficiently and effectively, the industry needs less materials to produce the same quantity and quality. This is also relevant because over the years, a larger variety of materials needs to be manufactured from the same virgin ore. Moreover the environmental impact will decrease. Additionally, materials that have been recycled will be reprocessed to be used again. They can then be instrumental in the development of alternative materials for resource that are or will become scarce (Wouters & Bol, 2009).

The information needs of the material processing industry in addressing scarcity are related to a general awareness of which materials are scarce or will get scarce in the short, medium and long term future, and price and supply security/ dependence of these materials. This information can be used to tailor the production process to stimulate more effective and efficient production and can direct the search for alternative materials. The departments research & design and environmental experts need to have knowledge about the position of scarcity on a strategic level within the company, to address scarcity as effectively as possible. Information about the best available material manufacturing techniques is important to quickly optimize manufacturing and minimize waste. Also, information about end-of-life technologies is necessary to effectively reprocess recycled materials, and minimize pollution. To develop alternative materials knowledge about the specific characteristics and properties of materials like boiling point, strength, penetration of water etc. is necessary. This information must be complemented with information about material responses to mixture, hazard classifications, response to various production processes like welding,

[20] Effectiveness is defined as the extent to which an action or tools fulfills its intended purpose.
[21] Best available technology is defined as "the most effective and advanced stage in the development" (Integrated Pollution Prevention and Control Directive 96/61/EC). In this thesis it focuses on more than emissions.

and the ability to be recycled. To optimally use the opportunities related to the previous information needs knowledge about current and future legislative requirements is necessary.

Table 2.9 Scarcity-related roles and information needs of the material processing industry.

Role in addressing scarcity	Information needs
• Produce material more efficiently and effectively • Reprocess recycled materials • Be instrumental in the search for alternative materials/ mixtures	• A1: Material scarcity in the short/ medium / long term • A2: Price and supply security/ dependence of these materials • A3: Current and future scarcity-related legislative requirements • C3: Material characteristics and properties • D2: Position of scarcity on a strategic level within the company • E2: Best available material manufacturing technologies • E4: Best available end-of-life technologies

2.5.3 Part and product manufacturing

The main role of part and product manufacturers in addressing scarcity is efficient and effective part and product manufacturing to achieve a competitive advantage is (Riis, Johansen, Waehrens & Englyst, 2007).

The related information needs for part and product manufacturers are: having insight in material scarcity in the short, medium and long term. This is necessary to make strategic choices about, for example, which materials to use in production processes or what machines to buy. In order to produce as efficiently and effectively as possible, and to ensure a competitive advantage it is important to have knowledge about the current and future legislative requirements. That is why it is also important to have information about what the best available production technologies are. This also ensures minimal production waste (ibid).

Table 2.10 Scarcity-related roles and information needs of part/ product manufacturers.

Role in addressing scarcity	Information needs
• Efficient and effective manufacturing of parts and products	• A1: Material scarcity in the short/ medium / long term • A3: Current and future scarcity-related legislative requirements • E3: Best available production technologies

Management

The main role for management is making sure business can continue. This is an essential prerequisite to be able to address scarcity. Furthermore they decide on a strategic level what role scarcity of resources will play in their company. It should be determined what actions the company should take, and at which level. Management should communicate this throughout the company. For example: will scarcity issues be reflected in product design or new market development and to what extent and at what price? Will it be communicated externally? Management is in the position to identify clear goals and, depending on the size of the organisation, appoint staff to execute and supervise achievement of these goals, a timeframe, and a budget (Brezet & Van Hemel, 1997; Kolk, 2000; Crul & Diehl, 2007).

The information needs for management to address scarcity issues are related to 1) the overall strategy and goal, 2) resources available in money and people, and 3) timeframe. To make decisions about all three, management needs to have a general awareness of what materials are and will become scarce in the short, medium and long term. Also, they need to have knowledge about what materials their products are composed of, also about the ones purchased from suppliers. This simultaneously requires information about their supply chain partners, including the second, third etc. tier. Information about the price (forecast) of these materials, what the origin of the materials is, to assess how secure their supply of these materials is, and hence their dependence on these materials, is also necessary to fulfil their role. This information necessarily requires supply chain cooperation. On the other hand, management needs to have benchmark information about how the competition deals with scarcity issues, including product content, composition, lifetime and end-of-life strategies. Making strategic decisions includes having knowledge about the legislative requirements regarding resource scarcity for their own company or for other sectors, which indirectly affect the operations in their own sector. Lastly, management roles require knowledge about the demand from consumers and other sectors for products that proactively deal with scarcity issues.

Table 2.11 Scarcity-related roles and information needs of companies' management.

Role in addressing scarcity	Information needs
• Continuation of the business • Decide on a strategic level what role	• A1: Material scarcity in the short/ medium / long term • A2: Price and supply security/ dependence of these materials

scarcity will play in the company • Identify clear goals • Appoint staff to execute and supervise achievement of these goals • Set a timeframe • Designate a budget	• A3: Current and future scarcity-related legislative requirements • B1: Origin of the material • C2: Material content and composition of products (also from suppliers products) • D1: Supply chain partners (including 2nd, 3th etc. tier) • D3: Market demand for products proactively addressing scarcity • D4: Product-related information of competitors products • E3: Best available production technologies

Research & Design

It is the task of researchers and designers to balance the multifaceted demands related to product development, generate creative solutions for specific problems, like scarcity and develop alternative solutions (Luttrop & Lagersted, 2006). Researchers and designers influence the selection of materials and thus the demand for scarce or abundantly available materials. They can for example phase out the use of critical raw materials or materials that cannot be recycled. Also they can create new application areas for substitutes of scarce materials or use recycled materials to reduce the demand for virgin ores. For some materials there are no substitutes and then designers have a role to play in using less materials, and optimizing the initial life time and end-of-life system. Optimizing the product design includes: creating products that have a relatively long lifetime, are modular and can easily be maintained. To optimize the end-of-life system the products should be designed in such a way that they can easily be separated, refurbished or recycled. The further the design process and product has developed, the less freedom designers have to change the design. They can also determine the way in which products are used by the consumer, for how long and what the role of maintenance and refurbishment is. By neglecting their own role in the scarcity issue they also affect their own freedom of design since shortages in supply of materials hamper design possibilities (Köhler et al., 2010).

One of the information needs of researchers and designers to address scarcity is awareness about which materials are scarce in the short, medium and long term. This enables strategic decision making and anticipation on future scarcity issues. They also need information about the specific properties of materials, like strength, flammability, toxicity etc. to be able to assess whether the materials can be combined, so they can identify possible substitutes and take end-of-life possibilities into account. Information about the content and composition of the product components bought from suppliers is necessary to prevent contamination and optimize life prolonging and end-of-life possibilities. To be able to balance the multifaceted demands, designers need to be in close contact with management, in order to get an indication of what the priorities within the scarcity issue are, given a certain strategy, timeframe and budget. They need information about the costs of purchasing specific materials, about the accessibility and security of supply of materials. That information is most likely, and sometimes indirectly, provided by the procurement department. When balancing demands in general and when dealing with scarcity issues, it is important to know what consumer demands are and what they are willing to pay for certain kinds of products. The marketing department can provide this information. Designers also need to be in touch with internal or external sustainability experts, who can provide information about general scarcity related developments, like alternative materials, best available production and recycling techniques. Contact with waste processers is also important to gain insight in the most available separation and recycling technologies. An indication of the most available techniques enables designers to compose their product so it can be separated and recycled with that technique. To optimize the opportunities resulting from above mentioned roles and information needs, designers need to have knowledge about the current and future legislative requirements regarding resource scarcity which directly or indirectly affect their own product composition. Lastly, to make better informed decisions, designers need to have guidelines for dealing with trade-offs that result from substitution or elimination of critical elements, like increased water use or reduced recyclability.

Table 2.12 Scarcity-related roles and information needs of researchers and designers.

Role in addressing scarcity	Information needs
• Balance multifaceted product demands • Selection of materials • Reduction of materials • Optimize product design • Optimize initial lifetime • Optimize the end-of-life system	• A1: Material scarcity in the short/ medium / long term • A2: Price and supply security/ dependence of these materials • A3: Current and future scarcity-related legislative requirements • C2: Material content and composition of products (also from suppliers products) • C3: Material characteristics and properties • D2: Position of scarcity on a strategic level within the company • D3: Market demand for products proactively addressing scarcity

	• D5: Guidelines for dealing with trade-offs that result from substitution or elimination of critical elements • E3: Best available production technologies • E4: Best available technologies for end-of-life system

Procurement

The procurement department has three roles in addressing scarcity issues. Firstly, procurement tracks scarcity related developments in the world. Procurement has knowledge about where the materials or subcomponents are bought and at what price. Hence, they are able to assess the accessibility and general security of supply. Secondly, procurement is scoping for, and is in contact with, suppliers. When addressing scarcity suppliers are selected on their actions related to addressing scarcity. Lastly, the procurement department communicates scarcity or any other type of demand from the company to its suppliers upstream. They can, for example, search for a specific type of material quality. Their contact with the suppliers makes them simultaneously knowledgeable about scarcity-related changes at suppliers, which links back to their first role (Brezet & Van Hemel, 1997).

The information needs of the procurement department relate to what materials/components to look for and what materials/components to avoid. They need insight into the material content and composition (or function) of products, also the ones purchased from suppliers. This information guides the search among various suppliers, also of recycled materials or different quality of materials, since different functions require a different material purity. It also requires information about the supply chain partners, including second, third, etc. tier, themselves. The exact requirements on what materials to scope for depends on the requirements specified by management and the design department.

Table 2.13 Scarcity-related roles and information needs of the procurement department.

Role in addressing scarcity	Information needs
• Track scarcity related developments in the 'outside' world • Scoping for and contact with (possible) suppliers • Communicate demands towards suppliers	• A2: Price and supply security/ dependence of the materials used in their products • C2: Material content and composition of products • D1: Supply chain partners (including 2nd, 3th etc. tier) • D2: Position of scarcity on a strategic level within the company

Marketing

To address scarcity, the marketing department can track and report about the needs and wants for products, and about the general trends in the outside world. If there for example is a large demand for products that are completely compostable or recyclable they will internally communicate their advice. This advice will most likely influence decisions that are made on a strategic level and during the product design process. On the other hand, marketing via e.g. internal and external benchmarking can suggest areas and reasons where they lag behind in sales between their own products as opposed to the competition's supply. Plus they can act more proactively by internally suggesting directions to become frontrunner. Additionally, marketing is responsible for influencing the needs and wants of consumers by making the products provided commercially attractive. They can conduct explicit marketing on how they have addressed scarcity of materials. By informing consumers via marketing about issues like these, they can possibly change consumer's attitudes and raise awareness. Also, they can market the value of being more resource responsible (Brezet & Van Hemel, 1997; UNEP, 2005; Crul & Diehl, 2007).

The information needs of marketing in relation to scarcity are related to the needs and wants of consumers or other companies to scarcity issues. Marketing needs information about scarcity prospects in the short, medium and long term to guide positioning of the product on the market. For the same reason they need information related to the content and composition of their product, and how information about scarcity has been taken into account. Moreover, they need information about the initial lifetime and life extending possibilities, plus information about the end-of-life possibilities. All this information helps marketing to better position the product on the market. Lastly, to be able to benchmark and distinguish their product from a similar product of the competition, it is necessary to have insight into product-related information, like the content, composition, initial lifetime and end-of-life possibilities, of competing products. These information needs simultaneously address the possibility to market resource responsibility.

Table 2.14 Scarcity-related roles and information needs of the marketing department.

Role in addressing scarcity	Information needs
• Reporting about the needs and wants for products proactively addressing scarcity • Internally suggest areas of product improvement, new market development possibilities • Benchmark products opposed to competitors products • Influencing the needs and wants for products proactively addressing scarcity • Market 'resource responsibility'	• A1: Material scarcity in the short/ medium / long term • C2: Material content and composition of products • C5: Initial lifetime of the product • C8: End-of-life possibilities of the product • D3: Market demand for products proactively addressing scarcity • D4: Product-related information of competitors products

Environmental expert

Environmental experts play a role on two levels. First, on a more strategic level where they help determine how important scarcity is within the company and how scarcity issues can be integrated in the company's strategy and product development. Second, environmental experts provide the necessary and correct data and tools to ensure that environmental issues are carefully considered within a company's processes. Larger companies are likely to have these experts in house, while SMEs generally externally hire experts. Experts are working on establishing priorities within projects or design processes and in a later stage also measure progress, plus evaluate the extent to which the goals of for example becoming less vulnerable to scarcity are met (Brezet & Van Hemel, 1997; Crul & Diehl, 2007).

The information needs of environmental experts are related to awareness of the scarcity issue on the short, medium and longer term, and on how dependent the company is on scarce materials. They need knowledge about the material content and composition of the products, the initial lifetime, and end-of-life possibilities. Experts also need to have knowledge about other environmental issues to be able to assess which ones to address, given limited time and resources. Moreover to function on a strategic level, they need to have information about current and future legislative requirements and general scarcity-related developments in society. Examples are: material characteristics to find alternative materials for scarce resources and best available production and recycling techniques. Internally, environmental experts can use this information about best available techniques and scarcity related trends to suggest and provide evaluative indicators and measurement tools.

Table 2.15 Scarcity-related roles and information needs of environmental experts.

Role in addressing scarcity	Information needs
• On a more strategic level help determine the importance of scarcity in the company • Provide the necessary and correct data and tools to ensure that environmental issues are considered within the company's processes.	• A1: Material scarcity in the short/ medium / long term • A2: Price and supply security/ dependence of these materials • A3: Current and future scarcity-related legislative requirements • C2: Material content and composition of products • C3: Material characteristics and properties • C5: Initial lifetime of the product • C8: End-of-life possibilities of the product • D2: Position of scarcity on a strategic level within the company • E3: Best available production technologies • E4: Best available technologies for end-of-life system

2.5.4 Retailer

The role of retailers in addressing scarcity issues is in their ability to select products that are designed from abundantly available, non-polluted materials. Plus they can select products that can easily be maintained, separated and continuously recycled. In this case retailers fulfil a double function: first of all towards the producers and secondly towards the consumer. By only buying products that take scarcity issues into account, demands towards producers change, thereby possibly influencing product design. Simultaneously, product options consumers can choose from will change, possibly increasing their knowledge about and positively changing their attitude and behaviour towards scarcity issues (Jones et al., 2007). Studies of, for example, McGoldrick (2002) indicate that retailers are developing sophisticated marketing strategies towards consumers, resulting in a brand equity of retailers similar to that of leading manufacturers. Besides selecting and selling products that pro-actively address scarcity they can also market 'resource responsibility' to producers as well as consumers.

The information needs of retailers are guided by their potential roles. When selecting products the retailers will need to have information about the market demand for products proactively addressing scarcity.

Moreover they need information about the product content, composition, initial lifetime and end-of-life possibilities. It can even go as far as demanding that certain specifics have to be met, for example the absence of critical raw materials, toxic substance, or content that cannot be recycled. They require the same information as the marketing department for their relation with consumers: they also need information about the needs and wants of consumers related to scarcity issues, plus the products specifics like content, composition, lifetime and end-of-life possibilities. This information helps them to position themselves and the products. Lastly, to be able to distinguish products it is necessary to have general information about the present state of scarcity, plus product specifics of competitors' products. The information needs also address the role of marketing resource responsibility.

Table 2.16 Scarcity-related roles and information needs of retailers.

Role in addressing scarcity	Information needs
• Selection of products from manufacturers pro-actively addressing scarcity • Influence consumers by only selling products that pro-actively address scarcity • Market 'resource responsibility'	• A1: Material scarcity in the short/ medium / long term • C2: Material content and composition of products • C5: Initial lifetime of the product • C8: End-of-life possibilities of the product • C9: Disassembly information • D3: Market demand for products proactively addressing scarcity • D4: Product-related information of competitors products

2.5.5 Consumer

To address scarcity, the consumer has the purchasing power to buy only products that (proactively) deal with scarcity. Consumers also have a role to play in correctly maintaining and disposing products. For example repairing products, replacing certain parts, separating organic waste from other municipal waste, and separate glass, paper and chemical waste. These actions extent the lifetime of the product and/or increase the chances on quantitatively and qualitatively higher recovery of materials.

Further research is required on which factors influence the role of consumers in purchasing products containing less scarce materials and how consumers dispose of products. There is already an array of literature on factors that influence pro-environmental behaviour in general. Two ever-present approaches are found in the field of psychology and the field of socio-economics. The first approach focuses on factors that are motivators of behaviour from within the actor, for instance their attitudes, norms and perceived behavioural control (Azjen, 1991). The second mainly focuses on individual characteristics and factors that shape the actor's capacity to act, such as age, religion and income (Clark et al., 2003). Often these are referred to as internal and external factors. More and more it is argued that both approaches are necessary to explain pro-environmental behaviour (Kollmuss & Agyeman, 2002). Thereby external factors influence internal factors, the internal factor-behaviour relation and they directly influence behaviour itself. This means that external factors, that to a large extent cannot be influenced, still co-determine internal factors and behaviour. When companies want to influence behaviour they need to take the steering-effect of external factors into account and differentiate their strategies to influence internal factors in accordance with external factors specifics (ibid). Psychology literature recognizes that awareness, education, guilt, and persuasion are all significant tools for invoking behavioural change (Clark et al., 2003). Therefore it is assumed here that when more information is available, the possibility to influence consumption behaviour increases. Relevant here is information about material scarcity in the short, medium and long term, material content, composition, initial lifetime, life prolonging strategies, and end-of-life-possibilities of the product.

Table 2.17 Scarcity-related roles and information needs of consumers.

Role in addressing scarcity	Information needs
• Purchasing products that proactively address scarcity • Maintain and dispose of the products correctly	As much information as possible to increase the problem awareness: • A1: Material scarcity in the short/ medium / long term • C2: Material content and composition of products • C5: Initial lifetime of the product • C7: Life extending possibilities • C8: End-of-life possibilities of the product

2.5.6 Reverse logistics and waste processing industry

According to Jun et al. (2007) the material recovery process consists of two phases: reverse logistics, and the recovery process. Reverse logistics is defined as "the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal" (Jun et al., 2007: 863). In this phase as many products as possible should be recollected, to ensure high material recovery. The materials are separated as much as possible to prevent contamination and optimize the recovery process. After recollection and separation, inspection of the products and materials takes place so as to identify the best recovery option. This decision is mostly taken by making a comparison between the recovery costs and benefits of the recovered material. The aim in this phase is to recover quantitatively and qualitatively as many materials as possible.

The information needs for reverse logistics to address scarcity mainly focus on recollecting as many products as possible. Therefore, knowledge about where consumers and companies dispose which products and in what manner, is necessary to optimize and tailor the recollection process. When a product contains scarce or non-contaminated materials their recovery value will be quite high. Therefore it is important that these materials are recollected in a way that prevents contamination by e.g. hazardous materials. To set up an efficient and effective recollection process they need to have knowledge about the physical properties and content of the product. Moreover, to predict when products will be disposed of, it is important to have information about the initial lifetime of a product (Parlikad et al., 2003). Both reverse logistics as well as the waste processing industry need to have knowledge about the current and future scarcity-related legislative requirements to maximize opportunities. They also need to have knowledge about the position of scarcity on a strategic level within the company, to address scarcity as effectively as possible. The information needs of the waste processing industry are related to strategic decision making, the design and manufacturing of the product, initial lifetime, usage information and disassembly (Parlikad et al., 2003). To make strategic decisions about which materials to focus on, information about scarcity prospects, price and supply security and legislative requirements is necessary. Regarding the design of the product, information about the physical structure is necessary, such as the size, weight and shape of the product and of separate components. This information is used during disassembly to locate and recover reusable components. Plus, information about the size and weight identifies the possible value and determines the way in which the product should be collected and handled. Moreover, detailed information about the material content and composition, the way it is produced and can be disassembled, is necessary. Information about the content enables waste processers to decide for the best recovery option and focus on recovery of scarce materials. Besides they are also able to identify unwanted materials, like hazardous materials and they can prevent adverse consequences of mixing particular materials. Information about the production process is necessary since processes like forging or painting change the properties of materials and require special disassembly strategies. Almost every recovery option includes disassembly. For many processes like coating, forging or gluing, the disassembly process is not the same as the assembly process. Therefore to be able to recover as much scarce materials as possible, it is important to know how to actually disassemble the product. By knowing the initial lifetime of a product by describing the properties and functions of the product that determine the expected life of the components, the reusability can better be estimated. Lastly, regarding the usage information, Klausner et al. (1998) find that to ensure higher levels of material recovery, information about the product content and properties is essential. They explain this by stating that recovery options like repair and maintenance have a significant impact on the quality of the components at the end of their functional life. Therefore supply chain information regarding usage and adaptations is necessary.

Table 2.18 Scarcity-related roles and information needs of the waste processing industry.

Role in addressing scarcity	Information needs
• Recollect as much products as possible • Optimize the separation process • Recover as quantitatively and qualitatively as much materials, including scarce materials, as possible	• A1: Material scarcity in the short/ medium / long term • A2: Price and supply security/ dependence of these materials • A3: Current and future scarcity-related legislative requirements • C1: Physical structure of the product • C2: Material content and composition of products • C3: Material characteristics and properties • C4: Production processes used, plus specification on which material • C5: Initial lifetime of the product • C6: Product adaptations during usage • C9: Disassembly information • D2: Position of scarcity on a strategic level within the company • D6: Where and how products are disposed of • E4: Best available technologies for end-of-life systems

The information in this section is summarized in figure 2.11. This figure depicts all actors and the relevant internal departments. The header '*provide*' refers to what information the actors can possibly provide. What information do they work with and, hence can be provided to others. The header '*needs*' refers to which information is needed by the actors to be able to address scarcity in their work. As can be seen information can be spread out internally and externally. Many actors only hold a piece of the puzzle. For example. information from various departments needs to be combined to disclose information need A2. In some cases an independent organization or a government is necessary to coordinate, combine and manage the information.

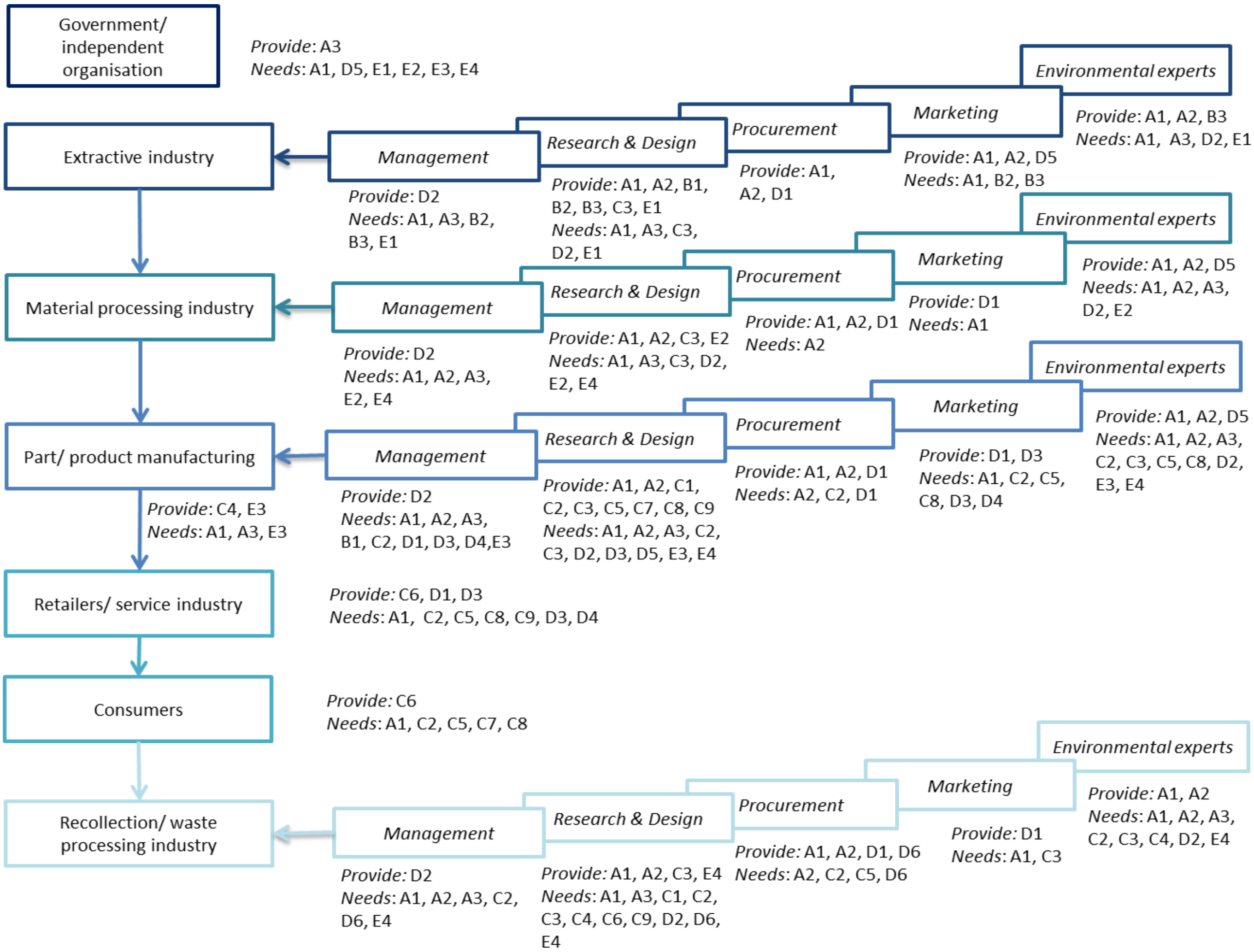

Figure 2.11 Information that supply chain actors can provide and need.

2.6 Characteristics of information exchange systems

Now it has been discussed what type of information is needed by whom, it can be discussed how this information can be exchanged. There has been extensive scientific modelling research and limited empirical research on the importance of information exchange in supply chains (Moberg et al., 2002; Li & Lin, 2006; Barratt & Adegoke, 2007). Empirical research showed that the following three factors greatly influence the sharing of information: a shared vision within the supply chain, trust within the supply chain, and supplier uncertainty (Li & Lin, 2006). Trust and a shared vision don't need additional explanation. Supplier uncertainty refers to unreliability of suppliers in sharing and managing information. This will negatively impact the whole supply chain. In order to reduce this uncertainty, partnerships will be build (ibid). These conclusions align with the conclusions in section 2.4.2.

However, there is no relevant scientific literature about which format elements define the success of an information sharing system. An information exchange system is defined as a set of principles or procedures according to which relevant, critical and/or proprietary information with one's partners is shared. Based upon the comprehensive study of the European Commission (2002) for evaluating the success of the Environmental Product Declaration Scheme, the empirical study of Li and Lin (2006), plus conversations with De Groene Zaak, its partners and prof. Vermeulen, the present author has identified the following five format elements as critical for the success of a resources passport.

1. Provision of the information

Information exchange throughout a supply chain requires someone that takes responsibility for the coordination of the exchange. However, there is no single authority that controls the supply chain partners. "Cooperation is through negotiation rather than central management and control" (Jain & Benyoucef 2008: 472). Mentzer et al. (2001) state that the information provision can be accomplished through "cross-functional teams, in-plant supplier personnel, and third party service providers" (ibid: 9). Cooper et al. (1997) state that the cooperation necessary to provide the information is not limited to involvement of solely top- and operational management levels. As among others Brezet and Van Hemel (1997) indicate, provision of for example scarcity-related information requires the involvement of many different departments in a company. Whether information should be transferred from one element to the next, downstream through the supply chain, or transferred to a third party or system that manages the whole supply chain depends on the goal of the instrument itself (Lee & Whang, 1998). Lastly, Cooper, Lambert, and Pagh (1997) and Mentzer et al. (2000) argue that more effective supply chain management is achieved when the information is frequently updated.

2. Storage of the information

Lee and Whang (1998) identify several trends in supply chain management. One is the globalisation of businesses. Companies extract and deploy resources globally to maximize the potential opportunities in the global community. This results in challenges like more complex logistics and increased cost of coordination. Currently, "significant investments are required to allow information to be shared across entities so that the activities and decisions throughout the supply chain can be coordinated" (ibid: 1). Yet development of cost-effective information technology and digitalization enable affordable optimization of the supply chain coordination (ibid; García-Dastugue & Lambert, 2003; Pramatari, 2007). The Internet facilitates sharing of information throughout a supply chain and connecting its members. Furthermore, "the emergence of new technologies such as radio frequency identification (RFID), is expected to revolutionize many of the supply chain operations, especially if the scope of implementation is extended from internal warehouse and distribution processes to supply-chain processes involving collaborating partners" (Pramatari, 2007: 211). Since each company is responsible for its own data, Bechini, Cimino, Marcelloni and Tomasi (2008) suggest to locally store the data within, for example, an in-house-server and transfer the data when necessary by means of a pull function of a centralized database or a third party.

3. Access to the information

Lee and Whang (2000) conducted a survey addressing the information sharing practices in supply chains and concluded that confidentiality issues regarding information sharing, especially in a competitive environment, form one of the major hurdles for supply chain wide information exchange. reflect upon dealing with confidentiality issues. Confidentiality of information means that information is secure from unauthorized disclosure (Smith et al., 2007). Smith et al. (2007) suggest that "there is a disincentive to share data due to ''information leakage'' and resulting strategic actions by competitors" (ibid: 2607). Bechini et al. (2008) suggest that in order to guarantee confidentiality, data is stored on in-house servers and others are only provided with traceability information. This requires a so-called 'intermediate data trustee'. "A data trustee is a private, third party intermediary among responsible actors and towards other entities: companies, government, individuals, or associated consumers. Each actor transfers its location and ownership data to a data trustee. The data trustee acts like an escrow agent, holding the actor's data until a legitimate investigation need arises" (ibid: 350). They envision multiple data trustees, so companies can chose who they trust their data to.

4. Quality of the information

Information quality is an important element in the supply chain management literature and refers to the "accuracy, timeliness, adequacy, and credibility of information exchanged" (Li & Lin, 2006: 1643). The study of Li and Lin (2006) concludes that information sharing and the quality of the information increases when there is a shared vision and trust in a supply chain. The quality of the information is negatively impacted by supplier uncertainty. They also state that the level of information quality is influenced by the length of the supply chain. If the supply chain is longer, the chance the information suffers delay and distortions increases. Partnerships are the proposed solution. Another solution is the usage of certification programmes like ISO 9000 (Tan, 2001). Within these certification programs independent validators regularly check compliance with the scheme. Jain and Benyoucef (2008) argue that business and selling products are becoming more web-based, resulting in improved quality.

5. Presentation of the information

Lambert (2001) states that unification of a method of reporting is indispensable since there is a need to understand the information in every stage of a supply chain. Jain and Benyoucef (2008) affirms this and state that "there is a need for unified approach for modeling and analyzing of long supply chain, which explicitly captures the interactions among enterprises and within departments of an enterprise" (ibid: 475). Unification enables integrated decision making and allows actors in the supply chain to quickly evaluate the information. Since there is no centralized planner in supply chain and decision making occurs in a decentralized mode, it is important that the information is presented in a unified but decentralized model (Sahin & Robinson, 2002).

Relating back to the three elements: the creation of a shared vision is what the development of the resources passport is all about. This research is the first step in that direction. Many more consultations will follow and therefore address this element. The building of trust and supplier uncertainty are addressed via the control over format elements three and four and to some extent also elements one and two.

2.7 Conclusion

Although scarcity of resources has been put on the international agenda decades ago, until recently no priority has been given to address this issue. Currently, scarcity of resources has become a serious threat to continued economic growth due to the continued economic growth itself and related rising demand for resources, great waste of resources during a products lifecycle, combined with recent disruptive development trends. A circular economy is devised to counter the disruptive consequences of resource scarcity. The concept circular economy comes forth from multiple already firmly established schools of thought. By means of synthesizing the main tenets of these schools of thought, four main principles of the circular economy are identified:

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*
2. *The improvement and creation of end-of-life systems for flows of resources and products.*
3. *The creation of, preferably regional, networks of material exchange.*
4. *The collection, management and exchange of resource-related information.*

Many environmental improvements have already taken place. However, scarcity was never the first priority and has never been at the forefront of business practices. Moreover to be able to address scarcity via a circular economy, large-scale exchange of information and materials is necessary. The lack of prioritization is one of the reasons that it never evolved. It can also be explained by the necessity for personal contact, a shared vision and trust for such a system to develop. Yet, development on a large-scale implies indirect communication and higher costs of coordination. Additionally, exchange of information and materials most likely takes off when there is an economic necessity. Until recently this has never been the case.

To be able to shape an instrument like the resources passport, it is necessary to identify which actors in the supply chain fulfil which roles in addressing scarcity and from there, which information needs they have (table 2.8). The roles and information needs differ substantially between and within supply chain elements. This overview enables identification of the content of a resources passport and will guide the remainder of this research.

In identifying the format of a resources passport for products, five format elements have been identified as important for its success. These elements are provision, storage, access, quality and the translation from complex to insightful presentation of the information. The theoretical insights gathered about these five elements are assessed in practice (and the findings presented in chapter 6).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

To recapitulate, the main research question of this research is: *what should the content and format of a resources passport be, in order to successfully contribute to the achievement of the circular economy?* This chapter elaborates on the methodological approach used to achieve the objectives of this research (section 1.3) and answer the main research question. An overview is given of the two research strategies used, namely: desk research and exploratory case study analysis (section 3.1). Next, the methodology applied for the attainment of each of the research objectives is explained (section 3.2). Lastly, a description of the research material used for this research is provided (section 3.3).

3.2 Research strategy

The research strategy concerns the decisions on the approach of the conduction of the research (see Verschuren & Doorewaard, 1999). The research strategies chosen for this research are desk research and exploratory case-study analysis.

3.2.1 Desk research

Desk research has been carried out to assess the need and necessity of a circular economy in addressing resource scarcity. It also guided the identification of the scarcity-related roles and information needs of supply chain actors. Moreover desk research has been conducted to analyse the extent to which European and Dutch policies address scarcity and contribute to the four principles of the circular economy. Next, the extent to which privately used, resource-related instruments contribute to the principles of the circular economy, has been assessed by means of desk research. Lastly, desk research has been used to analyse the format aspects of similar information exchange instruments.

3.2.2 Exploratory case study analysis

To determine the content and format of a resources passport, an exploratory and exemplary case study analysis was conducted. In this descriptive, design-oriented research, the focus is on getting an overview of the possible content and format of a resources passport. The exploratory nature of the case-study is aimed at generation of a variety of information. Consequently, the type of inferences made in this research are descriptive, qualitative and aimed at a comparison of the results (Verschuren & Doorewaard, 1999; Gerring, 2004).

For this research, the scarcity-related needs and experiences of seven Dutch circular economy frontrunner companies have been studied. Primary requirements in their selection were having knowledge about, and having an opportunity and need for the resources passport. Without these requirements the research would become arbitrary and suggestive. This particular knowledge is limited to a small group of partners of De Groene Zaak: the participants of the working group on resources. In accordance with the goal of developing a cross-cycle and cross-sector instrument, the cases represent different sectors and stages in the supply chain. The fact that the companies are frontrunners in contributing to a circular economy, better enables the analysis of available information that could possibly be used in the resources passport. An example is a company that produces Cradle to Cradle certified products. These products are already assessed on their environmental impact, manufacturing efficiency, material properties and recycling potential. After a literature analysis and discussion with experts at De Groene Zaak, it was found that the product manufacturing and waste processing stage are the most in need of a resources passport in the Netherlands. Plus they have a major influence on addressing scarcity. Therefore, they became the focus of this research. The following selection of producing companies is made from within the ranks of the working group on resources: Ahrend (furniture), InterfaceFLOR and Desso (carpets, although both use a different environmental strategy), and Van Houtum (paper). Additionally, after discussion with an informant Philips (electronics) appeared to have just concluded an internal analyses regarding the implementation of an instrument addressing scarcity. Philips is therefore added as the fifth case of producing companies. It must be noted that Philips is not a member of De Groene Zaak. Two waste processors, Van Gansewinkel and VAR, represent the end-of-life stage. A brief overview of these seven companies in alphabetical order is provided in table 3.1.

Table 3.1 Overview of the seven exemplary companies and their characteristics

Company	Product Group	Target market	Employees[22]
Ahrend	Office furniture	Multinational	>250
Desso	Flooring, mainly carpet	Multinational	<250 in NL
InterfaceFLOR	Flooring, carpet	Multinational	<250 in NL
Philips	Electric and electronic equipment	Multinational	>250
Van Gansewinkel	Waste treatment/ services	Multinational	>250
Van Houtum	Paper	Multinational[23]	<250
VAR	Waste treatment/ services	National	<250

A known weakness of this analysis is the limited empirical generalizability of the results. In this research, the companies are selected by specific characteristics, which inherently make it impossible to generalize the findings to the entire population from which the sample has been drawn. Nevertheless, theoretical generalizations can be made. This means that the results can be used as a starting point in generating new theoretical insights on the role of scarcity in business practices and the development of specific information exchange instruments. Moreover, they could be used to test existing theories on information exchange and business practices. Theoretical generalizations do not require a large N, yet the cases studied must have common features with those for which the theory was developed (ibid).

3.3 Research methodology

In order to attain research objective I, '*Explain the need for and necessity of addressing resource scarcity as the central element of the circular economy*', a literature analysis has been conducted. Scientific literature and documentation are used to identify the dimensions of scarcity, scarcity related trends and the consequences for Europe and the Netherlands of neglecting the associated risks. The circular economy is appointed as the envisioned solution. Scientific literature is used to identify the four main principles of a circular economy. Preventing scarcity proved to be at the heart of a circular economy.

To attain objective II '*Understand the roles and information needs of the different actors in the supply chain in addressing resource scarcity'* a scientific literature study is conducted. First of all the actors in the supply chain, relevant to address scarcity are identified. Subsequently, literature is used to identify their roles and corresponding information needs. The combination of this information results in an assessment framework used to attain the following two research objectives.

To assess which resource-related information is already out there and could possibly be used as content of a resources passport the following objective is analysed: III '*Understand to what extent current policies and policy tools address resource scarcity and understand the lack thereof*. To attain this objective, a policy (document) analysis is conducted. In recent years, resource-related policies have been formulated, including policies addressing the exchange of resource-related information. A detailed analysis of the legislative documents is executed to assess the contribution of these policies to the four principles of a circular economy. This also enables identification of which information needs are addressed. Lastly, a document analysis is conducted to explain the results of the policy analysis.

In order to attain objective IV '*Understand the experiences and information needs of circular economy frontrunner companies in addressing resource scarcity'* the following steps are taken. First of all, via interviews it is analysed which resource-related policies seven Dutch frontrunner companies abide to and hence which information needs are already knowledgeable. Secondly, interviews are used to assess which private instruments are employed to gather resource-related information. A document analysis is executed to assess which information needs are knowable via the use of these instruments. Thirdly, via interviews it is investigated how these seven companies manage and use the information gathered via fulfilment of legal requirements and the use of private instruments. Lastly, in depth interviews are conducted with the companies to analyse what they think should be the content of the resources passport. The outcomes of the various steps are compared to each other, enabling recommendations for the content of a resources passport.

[22] > 250 large company. <250, SME.
[23] http://www.vanhoutum.nl/98/mvo.html

After focusing on the content of a resources passport its format is addressed by attainment of objective V '*Understand which format aspects are relevant in the development of information exchange systems*.' A literature study combined with interviews led to the selection of the five relevant format aspects. Subsequently, via semi-structured interviews, it is analysed how the seven companies envision the format of the resources passport. Lastly, a document analysis assesses how three similar information exchange systems address these five format aspects.

3.4 Research material

There are five objectives in this research (section 1.3), for which information needs to be gathered. Therefore, three types of knowledge as identified by Verschuren and Doorewaard (1999) will be used, namely: scientific literature, policy documents and interviews. By using various types of information, triangulation of data becomes possible. Subsequently, a short description of each type of information used in the attainment of the research objectives is provided.

3.4.1 Scientific literature

Scientific literature has been used to analyse the need for and necessity of a circular economy, the roles and information needs of supply chain actors in addressing scarcity and to analyse the format aspects of information exchange instruments. Scientific articles and empirical studies on scarcity, the circular economy and resource-related information exchange instruments have been selected on the basis of their theoretical insights regarding the objectives of this research. Journals that have been used are, among others: *Journal of Cleaner Production, Oxford Review of Economic Policy, Environmental Science & Technology, Sustainable Development & World Ecology, Corporate Environmental Strategy and Practice* and the *International Journal of Production Research.*

3.4.2 Policy document analysis

Policy documents were used to identify and analyse the attainment of the four principles of the circular economy of European and Dutch resource-related policies. Documentation has also been used to analyse internal business practices, and similar information exchange instruments. The advantage of using documents is that they provide a rather objective source of information, and that they can supplement, support or verify the outcomes of interviews (Verschuren & Doorewaard, 1999). To avoid the disadvantage of mounting through a large amount of available policy documents at a European and Dutch policy level, communication has taken place with the Ministry of Foreign Affairs and the Ministry of Infrastructure and Environment. They provided several documents as starting points of the analysis.

3.4.3 Interviews

This research uses people as a source of information in two ways. The first is as 'informants': when people "provide data about other people or about situations, objects or processes" (Verschuren & Doorewaard, 1999: 116). Multiple informants have been used in the identification and analysis of resource-related policies, the policies' contribution to the attainment of the four principles of the circular economy, plus the analysis of similar information exchange instruments. The information has been gathered in an explorative and semi-structured fashion. The informants are professionals working with the specific objects analysed and therefore have comprehensive knowledge about the objects. In total eight informants have been interviewed, as depicted in annex I.

Secondly, people can act as 'suppliers of knowledge' in the form of experts (Verschuren & Doorewaard, 1999). Interviewing experts is a major and crucial part of this research, since they hold much private knowledge. Moreover, interviews allow for in-depth dialogue or discussion, plus rather quickly generate a wide diversity of knowledge, essential in explorative research. The experts interviewed are primarily selected on the basis of their knowledge about a resources passport and their role within the resource-related information exchange process. They have knowledge about the corporate strategy as well as information exchange. If experts would have been interviewed about the resources passport without knowing what it is supposed to entail, the research would have become suggestive. In total ten experts have been interviewed. This is depicted in annex II.

While both the resources passport as well as the resource-related information exchange process are very complex, the interviewees had a holistic perspective. This is in line with the objective of this research namely developing a cross-cycle and cross-sector instrument to exchange scarcity- related information. To gather comparable results the interviews were partially pre-structured and partially semi-structured. Annex III provides an overview of the questions asked to the interviewees.

CHAPTER 4 – PART 1

RESOURCE-RELATED POLICY ANALYSIS AND THE CONSEQUENCES FOR INFORMATION EXCHANGE

4.1 Introduction

Recapitulating, scientific literature and practical data show there is a need for supply chain wide information exchange related to scarcity. Now that the roles and information needs of supply chain actors are identified, the question remains whether this information is already disclosed. Sterr and Ott (2004) indicate that for an information exchange system to develop and function optimally, it is important to keep the costs of coordination and administration as low as possible. Various resource-related policies have already developed and been implemented. These policies require information exchange, which for the most part is mandatory. Information needed by the various actors in the supply chain to fulfil their roles in addressing scarcity, is thus potentially already present. This information can be used for the content of the resources passport.

This chapter is composed as followed: firstly it is analysed what resource related policies are already in place in the EU and the Netherlands (section 4.2). Subsequently it is analysed to what extent the four principles of the circular economy are pursued (section 4.3). Next, principle four of the circular economy and the scarcity-related information needs are assessed in more detail. Cross examination reveals which information is already available and to whom (section 4.4). Lastly, the lack of mandatory resource-related policy instruments is explained (section 4.5).

In this study, public policy making is defined as a "set of processes, including at least (1) the setting of an agenda, (2) the specification of alternatives from which a choice is to be made, (3) an authoritative choice among those specified alternatives, and (4) the implementation of a decision" (Kingdon, 1984:3). Policy instruments are defined as "everything policymakers use or can use to achieve behavioural change from societal actors that will contribute to the attainment of public policy goals" (Vermeulen et al., 2010: 24-25).

4.2 Resource related policies

In this section, the possible policy options for dealing with scarcity are presented. Next, resource-related policies in the EU and the Netherlands will be identified.

4.2.1 Policy options to address resource scarcity

The Netherlands Environmental Assessment Agency (PBL) classifies the various policy options to deal with scarcity in accordance with the three dimensions of resource scarcity. Table 4.1 provides an overview of these policy options. It is important to note that this research mainly focuses on the policy options as defined under the physical scarcity dimension, simultaneously reflected under the economic and political dimension.

Table 4.1 Policy options to deal with material resources scarcity (PBL, 2011: 38).

Scarcity dimension	Key policy options
Physical *Expand the resource base and reduce demand growth fundamentals*	• Build strategic reserves for critical minerals, e.g. rare earths, as a buffer against supply disruptions (long-term) • Open/reopen mines, invest in exploration (not an option for the Netherlands, but may be in other European countries) • Bilateral agreements with supplying parties, establish strategic partnerships with important producer countries • Improve recycling • Improve resource efficiency • Reduce resource intensity: encourage substitutes, focus R&D on substituting elements
Economic *Improve functioning of markets*	• Options under 'physical dimension' • Anti-trust legislation
Political *Prevent politically motivated supply disruptions and market*	• Options under 'physical dimension' and 'economic dimension' • Invest in global governance (liberalise world markets and collaborative governance,

distortions	stabilize tight markets, prevent conflicts) • Develop bilateral cooperation in the field of raw materials and work together on issues such as governance, infrastructure, investment and geological knowledge and skills • Invest in development cooperation (development aid, transparency, good governance) • Consider shaping a new EU-wide policy on foreign investment agreements to 'better protect EU investments in raw materials abroad' • Consider the merits of pursuing dispute settlement initiatives at WTO level 'to include in such initiatives more raw materials important for EU industry' • Proactive acquisition

It is interesting to note that circular economy principle one is reflected two times, principle two only one time and no attention is paid to circular economy principles three and four.

4.2.2 Resources related policies in the European Union and the Netherlands

The Dutch National Accounting Matrix with Environmental Accounts shows that the environmental impact of businesses on the environment is substantially larger than that of consumers (CBS, 2011). The same holds true for Europe. The reduction of the environmental impact of production processes in businesses has traditionally been the main subject of environmental policy. However, the role of the EU and national governments in this area is dual. On the one hand radical changes in production processes are a recurring requirement for businesses; changes that might come at the expense of companies' profits and continuity. On the other hand, there is the idea that the freedom of the market economy needs to be maintained, the innovative potential needs to be used in full, and businesses should be treated equally (Vermeulen, 2007).

The EU has a long policy tradition on resources. Resources like coal and steel were at the heart of the founding of the EU. In the early 1960s, the Common Agricultural Policy was set up to create income stability for farmers and prevent food shortages. Throughout the years especially biotic resources have been subject to policy making. As PBL (2011) states, only in 2005 did the European Commission develop an integrated natural resources policy called the '*Thematic strategy on the sustainable use of natural resources'*. It was not until 2008 that policy specifically addressing raw materials has been initiated in the form of the '*Raw Materials Initiative*'. Despite the only recent policy attention for scarcity, many policies addressing resources have been developed, especially since the 1990s.

From the 1990s onwards, the content of Dutch environmental policies is characterised by two shifts. The first shift is from separate emission requirements per type of emission to lifecycle approaches, in which methods like LCA combine environmental loads with the position in the lifecycle and effects of improvement options. The second shift is from grounding long terms goals on the national status of the environment and problems to placement in a context of international problems and justice (Vermeulen, 2007). Additionally, there has been a shift in process steering strategies. In the early years, environmental policies where mainly defined by a central management strategy of coercion via law and permit systems, and economical incentives like taxes. In the following years, this strategy proved to be ineffective, due to obsolete permit systems, poor enforcement, and lack of sanctions. In response, the steering strategy changed to a mixture of central management strategies, interactive strategies, and self-management. Thereby central management strategies are modernized via for example the generalization and streamlining of rules and greening of the tax system. In interactive strategies, the government closely cooperates with businesses in the definition of goals and targets such as energy efficiency and waste minimisation. They define long-term agreements together. Moreover, environmental management as well as annual environmental reporting are stimulated. Within self-management the initiative resides fully at the producers' side, in many cases in cooperation with NGO's. Examples are roundtables, private standards like the Forest Stewardship Council (FSC) and Corporate Social Responsibility (CSR) (ibid).

Figure 4.1 provides a timeline of the relevant European and Dutch resource-related policies. Since Dutch policies do not operate in a vacuum, but are increasingly influenced by European Directives[24] or completely created on a European level in the form of regulations[25], this analysis starts on a European level and then narrows its scope to the Dutch situation. All the policies mentioned will be briefly explained in

[24] "EU directives lay down certain end results that must be achieved in every Member State. National authorities have to adapt their laws to meet these goals, but are free to decide how to do so. Directives may concern one or more Member States, or all of them." (European Commission, accessed January 13 2012, Application of EU law http://ec.europa.eu/eu_law/introduction/what_directive_en.htm)

[25] "Regulations are the most direct form of EU law - as soon as they are passed, they have binding legal force throughout every Member State, on a par with national laws. National governments do not have to take action themselves to implement EU regulations." (ibid)

more detail in Annex IV & V, the most relevant ones for this research will be explained in more detail in section 4.3.

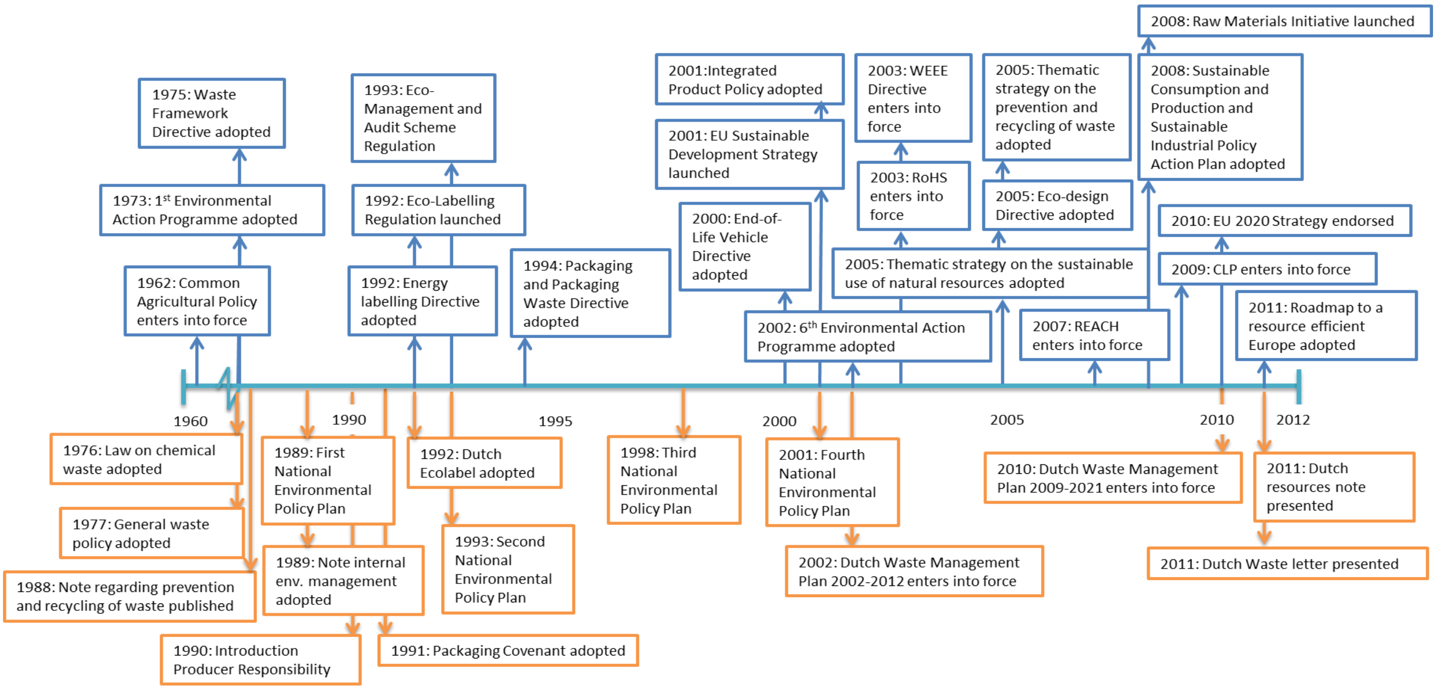

Figure 4.1 Timeline of most relevant European (blue) and Dutch (orange) resource-related policies.

As can be seen in figure 4.1 examples of Dutch policies equivalent to current European policies, yet developed earlier, are the Dutch Packaging Covenant established in 1991. It became abundant with the adoption of the European ‘Packaging and Packaging Waste’ directive in 1994. The Dutch Eco-label (‘Milieukeur’), developed in the same year as the European Eco-label, also immediately became the competent body of the Netherlands for the Eco-label directive. In general, most Dutch policies were adjusted or became abundant, after a European counterpart entered into force. Dutch policies that significantly differ from European policies have mainly been developed after 2000. Especially on the topic of waste, Dutch policies were frontrunners. These Dutch policies differ by, for example, applying more stringent targets or more detailed specifications as their European counterparts.

The focus of the resource-related policies, defined over time, has shifted from a mere environmental outlook to also include economic and political aspects, plus focus more on scarcity. Specifically that is the case with the recently published ‘EU 2020 Strategy’ in which the ‘Flagship Initiative for a resource efficient Europe’ is aimed at boosting Europe’s competitiveness, energy security and growth.

On a European level, since the early 2000s, there has been a shift from policies solely focussing on one stages of the products lifecycle towards a more holistic approach considering the whole lifecycle. The Integrated Product Policy Directive and Sustainable Consumption and Production and Sustainable Industrial Action Plan are examples of the first more cross-cutting, integrated and life-cycle focused policies. In the Netherlands this shift started about a decade earlier.

4.3 Principles of the circular economy pursued in resources-related policies

This section assesses to what extent the identified resource related policies pursue the four principles of the circular economy. Recapitulating, the principles are:

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*
2. *The improvement and creation of end-of-life systems for flows of resources and products.*
3. *The creation of, preferably regional, networks of material exchange.*
4. *The collection, management and exchange of resource-related information.*

The overarching strategies and thematic strategies as identified previously are not analysed in the following sections since companies do not directly have to deal with the ambitions set out in these documents. They provide direction and guidance for the development of directives and regulations. Only the directives and regulations that provide obligatory requirements are relevant in this research, since they contribute to the attainment of the circular economy and specifying information (exchange) requirements.

The following eleven directives and regulations are studied: the Eco-labelling Regulation (Eco-l), Energy Labelling Directive (En-l), Eco-Management and Audit Scheme Regulation (EMAS), Packaging and Packaging Waste Directive (PPWD), End-of-Life Vehicle Directive (ELV), Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), Waste Electrical and Electronic Equipment Directive (WEEE), Eco-design Directive (Eco-D), Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), Regulation on classification, labelling and packaging of chemical substances and mixtures (CLP) and the Landelijk Afvalbeheerplan 2009-2021 (LAP2). The LAP2 has been selected for it differs substantially from European legislation and provides binding targets for the processing and recycling of waste streams. The directives are analysed in a chronological order. In all cases, only the relevant information related to addressing the principles of the circular economy is analysed. More extensive information can be found in Annex VI.

4.3.1 Eco-labelling regulation

Eco-labelling regulation (EC) No 66/2010 intends to promote products with a high environmental performance, by setting special criteria per product group (currently 24, May 2012). It is a voluntary regulation, which means that producers can chose to apply for an eco-label for their products.

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

In developing the special criteria per product group, the regulation asks to focus on the most significant environmental impacts. In practice, these criteria are aimed at lowering the environmental impact of the product throughout its lifecycle, and not necessarily at reducing vulnerability to scarcity, or closed loop design.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

The eco-label and its criteria are not primarily aimed at generating improvements in, and the creation of end-of-life systems to recover resources. However, when found to be of significant importance, the improvement and creation of end-of-life systems can be turned into a requirement. In practice this rarely happens.

3. *The creation of, preferably regional, networks of material exchange.*

This regulation does not in any manner pursue the creation of networks of material exchange.

4. *The collection, management and exchange of resource-related information.*

Following a consultation with the EU Eco-labelling Board (EUEB), all stakeholders[26] may lead the development and revision of eco-label criteria. When producers apply for the Eco-label they have to fill out an application package specifying that they fulfil all the eco-design criteria, supported by test reports if necessary. This is different for each product group, however, producers do have to give many details of the product that could also be present in a resources passport. For example, characteristics and composition, the recycled content and reparability of a product (application pack notebook computers, 2012 version).

However, the information that producers are required to submit to the competent bodies in order to receive the eco-label is not publicly accessible, and may not be used by the competent bodies for any purpose other than assessing whether the eco-label can be granted. Moreover, the information is not systematically collected due to the voluntariness of the regulation (EC No 66/2010).

4.3.2 Energy-labelling directive

Energy labelling directive 2010/30/EU obliges the disclosure of information on a label, about the energy consumption and energy efficiency of products, that are likely to have a direct or indirect impact, on among others the consumption of energy, during the use of the product. The end goal is allowing end-users to choose more energy efficient products.

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

[26] Stakeholder groups consist of interested and concerned parties like industry and service providers, business organisations, trade unions, retailers, importers, environmental protection groups and consumer organisations. The regulation requires a balanced participation of these stakeholders in the development of the criteria.

This directive only indirectly influences the design of products. If consumers only buy appliances with the highest category energy label (currently A+++) that are cheaper in use, manufacturers might have to adjust their design to stay in the game. However, these design changes are solely related to reducing energy use, and not to closing the resource loops.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

The improvement and creation of end-of-life systems is not at any point addressed in this directive.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks of material exchange is not addressed nor pursued by this directive.

4. *The collection, management and exchange of resource-related information.*

The exchange of information from suppliers, via dealers to end-users by means of energy labels and fiches, is at the core of this directive. Manufacturers or, in this directive so-called suppliers, have to provide the dealers of the products with the labels and product information. Plus they have to provide a product fiche, that should be used in all brochures related to, or literature provided with, the product. Which information should be present on a product label or fiche is specified in the delegated acts provided by the Commission. The details differ per product. Currently none of the delegated acts requires suppliers to put scarcity related information on the label or fiche. Manufacturers are obliged to produce technical documentation, needed to assess the accuracy of the information presented on the label. In practice, this information is also not aimed at addressing scarcity. Furthermore, this information is initially only available to the supplier himself (directive 2010/30/EU).

4.3.3 EMAS: Environmental Management and Audit Scheme regulation

Voluntary regulation EMAS III (EC) No 1221/2009 aims at the improvement of organisations' environmental performance and to provide information related to that performance. Therefore, multiple criteria and aspects of an organisations performance are taken into account (Annex I-IV of the directive).

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

The redesign of products and production processes for resources to operate in closed loops is not specifically mentioned, and hence EMAS might only indirectly result in the pursuing of principle one.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

The indicators used to measure performance, form no obligatory targets or thresholds. Therefore EMAS only indirectly and non-systematically pursues principle two of the circular economy.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks of material exchange is not addressed nor pursued in this scheme.

4. *The collection, management and exchange of resource-related information.*

To apply to EMAS, organisations have to carry out an environmental review, develop an environmental management system, and carry out internal audits. This information is initially not aimed at addressing scarcity and solely insightful to a verifying body. When this information is verified, organisations have to produce periodic, publicly available environmental statements related to their environmental performance. This statement includes information about material efficiency and waste, however not specified on a product level or useful to enable the cascading use of materials. There are no specific, obligatory targets or thresholds to be met. To ensure these environmental reports are comparable, generic sector specific performance indicators, on a project and process basis, have been devised. The indicators in the reference document of the retail sector (one of the two documents available) focuses to a large extent on energy and CO_2 emissions (EC No 1221/2009).

4.3.4 Packaging and Packaging Waste Directive

Packaging and Packaging Waste Directive 94/62/EC aims at the prevention of waste and the reuse and recycling of packaging waste several rotations.

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

To prevent the generation of packaging waste, the directive specifies thresholds for the presence of certain hazardous materials in packaging materials. The aim is changing the design of packaging, to reduce its overall environmental impact. Also, packaging should be designed to be reused and recycled several rotations. To stimulate that, packaging material receives a mark. This directive thus pursues the first principle of the circular economy.

2. The improvement and creation of end-of-life systems for flows of resources and products.

To recycle and recover packaging waste, member states are required to set up return, collection and recovery systems. This directive also pursues the second principle of the circular economy.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks of material exchange is not mentioned nor pursued by this directive.

4. The collection, management and exchange of resource-related information.

Packaging placed on the market has to comply with requirements related to the use of lead, cadmium, mercury and hexavalent chromium, that cannot exceed a certain threshold. To monitor the implementation, member states are required to set up databases on packaging and packaging waste. These, publicly accessible databases, report on packaging and packaging waste flows on a national, aggregate level: thus not on a product level. The same holds true for the progress reports member states submit to the European Commission. Via the 'Dutch Normalisation Institute' standards that address, among others, criteria for a minimum content of recycled material and recycling methods, can be purchased. Member states provide information to the users of packaging about for example, the return, collection and recovery systems available to them, and their role in contributing to reuse, recovery and recycling of packaging and packaging waste (Directive 94/62/EC).

4.3.5 End-of-Life Vehicle directive

Directive 2000/53/EC addressing end-of-life vehicles (ELV) is subdivided into six parts with related goals namely: 1) prevention, 2) collection, 3) reuse and recovery targets, 4) treatment, 5) information gathering and dissemination, and 6) implementation (Konz, 2009).

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

The first goal is aimed at avoiding specific hazardous substances, and limiting the use of some others in the design of vehicles. The third goal is supported by two obligatory recovery and recycling targets to be taken into account at the design phase[27]. Demanding from Original Equipment Manufacturers (OEMs) that they recollect and recycle all domestically used motor vehicles, means asking them to close resource loops in an environmentally friendly manner.

2. The improvement and creation of end-of-life systems for flows of resources and products.

Consumers are obliged to take their end-of-life vehicle to an Authorized Treatment Facility (ATF), subjected to requirements like de-polluting of materials, focus on hazardous materials, and ensuring the reusability of components. Combined with the obligatory recovery and recycling targets, this resulted in boosting the creation and improvement of ELV end-of-life systems.

3. The creation of, preferably regional, networks of material exchange.

The directive does not request the creation of networks of material exchange as such.

4. The collection, management and exchange of resource-related information.

Much information relevant in addressing scarcity is collected, managed and exchanged with selectively chosen actors in the supply chain. Among others, vehicle manufacturers need to provide the recycling industry and ATFs with "all requisite dismantling information, in particular for hazardous materials" (directive 2000/53/EC: 35). Moreover, they need to use component and material coding standards, which enable better recovery (ibid). Lastly, they need to adhere to the recycling and recovery target. To comply with all these provisions, manufacturers need to know exactly which materials are used in their product and what their properties are. How these materials are processed/ what their functions are and what the composition of the materials is. They need to have information about the quantity and quality of the materials, and whether they are potentially reusable and recyclable, plus information about end-of-life systems. Much of the detailed information is only available to upstream suppliers, OEMS and ATFs. Competing OEMs and consumers do not have insight in this information. To ensure convenient information exchange and rightful access to this information, the IMDS has been established (see section 6.3.2). Public authorities need to submit a report about the progress on implementing the directive. This publicly accessible information is presented on an aggregate, national or European level. Consumers receive information about

[27] "All domestically used motor vehicles should have a reusable and recovery rate of 95% in 2015; and a reuse and recycling rate of 85% in 2015" (Article 7, Directive 2000/53/EC).

the recycling and recovery targets and about where to dispose the vehicle. This information is available on the website of producers (Directive 2000/53/EC).

4.3.6 RoHS: Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment

RoHS Directive 2002/95/EC aims at protecting human health and environmentally sound recovery and disposal of waste electrical and electronic equipment (WEEE) by means of restricting the use of six hazardous substances in electrical and electronic equipment (EEE). The scope of the directive is restricted to the eight out of ten categories (excluding category eight and nine) of WEEE as defined in the WEEE directive.

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

Products put on the market from July 1, 2006 onwards may not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls or polybrominated diphenyl ethers above a certain maximum level. This directive thus (possibly) requires design changes and increases profitability of recycling. However, these changes are of limited scope, applied to a limited range of products and not guided by resource scarcity issues.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

This directive does not create or improve end-of-life systems as such.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks for the exchange of materials is not addressed in this directive.

4. *The collection, management and exchange of resource-related information.*

Very little information relevant for addressing scarcity is collected, and almost none exchanged. The detailed information that is actually exchanged is not publicly accessible. Manufacturers of EEE need to assess whether their products fulfil the RoHS obligations. As of yet, there is no official RoHS conformity label. Producers ask their suppliers to confirm their compliance with the RoHS directive. However, no detailed information is exchanged, solely compliance is confirmed. Each Member State has a designated body with executive and monitoring competences. In the Netherlands that body is the 'VROM Inspectie'. However, the EU directive does not specify how manufactures should prove conformity. Consequently, there is no databank with national conformity data (Directive 2002/95/EC).

4.3.7 WEEE: Waste Electrical and Electronic Equipment Directive

Directive 2002/96/EC mainly aims at the prevention of waste electrical and electronic equipment (WEEE), and at the reduction of the disposal of waste, via reuse, recycling and other forms of recovery. The directive covers ten categories of electrical and electronic equipment (EEE).

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

Member states shall encourage design changes which take into account and facilitate decomposition, reuse and recycling of materials. This is supported by the fact that producers are required to finance the future end-of-life costs of their own products. When a product can be better maintained, decomposed and recycled, the end-of-life treatment costs will be significantly lower. However, scarcity not necessarily has to be the aim of the design changes.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

Member states are required to increase the separate collection of WEEE from municipal waste and the division of take-back points, free of charge for the consumer. By specifying minimum requirements, the quantity and quality of recovered WEEE increases. The directive also sets recovery targets specified per category of EEE[28]. Moreover, the directive aims at increasing the environmental performance of waste processers. End-of-life systems are hence improved and created.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks of material exchange is not pursued by this directive.

[28] General targets are: "the rate of recovery shall be increased to a minimum of 80% by an average weight per appliance, and, component, material and substance reuse and recycling shall be increased to a minimum of 75% by an average weight per appliance" (ibid: article 7).

4. The collection, management and exchange of resource-related information.

Producers need to provide reuse and treatment information for each type of new EEE put on the market. "This information shall identify the different EEE components and materials, as well as the location of dangerous substances and preparations in EEE. It shall be made available to reuse centres, treatment and recycling facilities by producers of EEE in the form of manuals or by means of electronic media" (directive 2002/96/EC: article 11). Member States shall establish a register that gathers and manages information about EEE put on the market, and WEEE collected and treated. In the Netherlands this information is generally not provided by the individual companies, but by NVMP (Nederlandse Verwijdering Metalektro Producten) and 'ICT Milieu', who report for around 1500 companies to the Dutch Ministry of Infrastructure and Environment (VROM Inspectie, 2010). This information is highly classified and not even accessible to all employees of NVMP and ICT Milieu. On a two-year basis, member states transmit this transcribed information, provided on an aggregate, national level, to the European Commission. These reports are publicly accessible in Eurostat's Environmental Datacentre on Waste. The treatment facilities are inspected at least once a year. This information is not publicly accessible. Lastly, member states should provide information to consumers about among others where to dispose of WEEE (Directive 2002/96/EC).

4.3.8 Eco-design directive

The Eco-design directive 2009/125/EC, is specifically aimed at changing the design of products to address adverse environmental impacts a product has throughout its lifecycle. The so-called 'implementing measures' of the eco-design directive are legally binding for the producers of Energy Using Products[29] (EUPs) and Energy Related Products[30] (ERPs).

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

In theory, much attention is paid to closing the resource loops by looking at all phases of the lifecycle of a product, in the design phase. Nevertheless, in practice, the implementing measures focus mainly on the use of energy and not on addressing scarcity.

2. The improvement and creation of end-of-life systems for flows of resources and products.

This directive is primarily aimed at changing design of products, not at creating end-of-life systems. Nevertheless, the framework directive states that if necessary, producers are required to provide information regarding the end-of-life phase of the product. However, in practice in the implementing measures, producers have not been obliged to provide this information.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks of materials exchange is not part of the directive at the moment. However, a recent motion for a European Parliament resolution "calls on the Commission to ensure policies drive cascading use of natural raw materials and favouring highest value-added and resource-efficient products over energy generation, taking into account in particular greenhouse gas mitigation potential" (Gerbrandy, 2012: 9). Thus the scope might be extended, yet, the focus is still more on emissions than on scarcity.

4. The collection, management and exchange of resource-related information.

Based on the eco-design parameters mentioned in Annex I of the directive, significant environmental aspects of the product throughout its lifecycle are identified. This is collectively done in a European context on the basis of the data of a standard product, for example a television, and then holds true for all televisions. Subsequently minimum ecological requirements are adopted through the comitology procedure[31] which defines specific implementing measures for each product group included in the scope of the Directive. Currently, 12 implementing measures have been adopted[32]. Information in implementing measures consists among others of: Generic- and Specific Ecological Requirements. Generic Ecological Requirements (GERs)

[29] "Energy-using products use, generate, transfer or measure energy (electricity, gas, fossil fuel), such as boilers, computers, televisions, transformers, industrial fans, industrial furnaces etc." (European Commission, accessed May 6, 2012, Ecodesign: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/index_en.htm

[30] "Energy related products do not use energy but have an impact on energy and can therefore contribute to saving energy, such as windows, insulation material, shower heads, taps etc."(ibid).

[31] Comitology is EU jargon for "a procedure that allows the European Commission tob e assisted by a Comitology Committee when using its implementing powers". There are three types of committees: advisory, management and regulatory (Lobby Planet, accessed May 7, 2012) EU Law. http://www.lobbyplanet.eu/wiki/when/legislative-procedures/eu-law/).

[32] Implementing measures have been adopted for these twelve product groups: Air Conditioners and Comfort Fans, Household Dishwashers, Household washing machines, Domestic refrigeration, Circulators, Electric motors, Televisions, External Power Supplies, Lighting Products in the Domestic and Tertiary Sectors, Simple Set-Top Boxes (which convert digital input from e.g. antennas to analogue output signals on e.g. a television), and Standby and off Mode Electric Power Consumption of Household and Office Equipment.

aim at improvement of the overall environmental performance. Specific Ecological Requirements (SERs) are thresholds for selected environmental aspects with a significant adverse impact on the environment. Information availability depends on the specifications of the implementing measure. In practice, the implementing measures do not address scarcity. Producers are obliged to compile a technical documentation that can be requested by the verifying body to assess the product conformity with the requirements in implementing measures. This data is not publicly accessible and the verifying body in not allowed to publish the content. Concluding, much information possibly useful for the resources passport is gathered, yet only for a standard product and not publicly accessible. Additionally, the implementing measures, so far, do not reflect scarcity issues and the scope of the directive is limited (Directive 2009/125/EC).

4.3.9 REACH: Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals

REACH Regulation EC/1907/2006 addresses the design of products by assessing and reporting about the risk of the substances used in the product.

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

If the risks of a substance are found to be unmanageable, the use of these substances can be restricted, subjected to prior authorisation, or banned. The end goal is replacing hazardous substances with benign or less hazardous substances. However, this directive is primarily aimed at reducing the human health and environmental risk of substances used.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

Material Safety Data Sheets (MSDS) provide information about recycling and methods of disposal, which enable better recycling of substances. However, the improvement and creation of end-of-life systems is not a specific goal under the REACH regulation.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks of material exchange is not a goal in itself, however, REACH does enhance the free circulation of substances on the European market. This indirectly benefits the creation of networks of material exchange. Possibilities for cascading use are not addressed.

4. *The collection, management and exchange of resource-related information.*

All producers and importers of substances used in volumes of 1 tonne or more annually, must register them with the European Chemicals Agency (ECHA). Registration means submitting a technical dossier, for substances in quantities of 1 tonne or more per year and additionally a chemical safety report for substances that are used in quantities of 10 tonnes or more annually. There is a gradual increase in information requirements, the higher the tonnage of the substance. Information exchange under REACH takes place among all producers and importers of a substance in Europe, cross-sector and cross-cycle, since companies are required to jointly register a substance. However, the information exchange is primarily aimed at identifying the human health and environmental risks of a substance, plus the prevention of unnecessary animal testing. The information is thus not aimed at addressing scarcity, products or end-of-life systems. The exchange of information to downstream users is aimed at safe handling of the substances. Although after registration information about a substance is publicly accessible, it is not directly communicated to distributors or consumers. They are informed about the health and environmental hazards of a substance via the CLP regulation. Yet, also this information is not aimed at addressing scarcity in any way (Regulation EC/1907/2006).

4.3.10 CLP: Regulation on classification, labelling and packaging of chemical substances and mixtures

Regulation EC/1272/2008 on the classification, labelling and packaging of chemical substances, aims at the protection of the environment and human health via communicating the hazards of chemicals to workers and users of chemicals. The directive is complementary to the REACH regulation.

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

To attain its goal, substances are classified and labelled according to the United Nations Globally Harmonized System (UNGHS). This communication of hazards is aimed at the safe usage, not at the prevention of scarcity or the closing of the resource loops via design changes.

2. The improvement and creation of end-of-life systems for flows of resources and products.

The improvement and creation of end-of-life systems is not pursued in this regulation.

3. The creation of, preferably regional, networks of material exchange.

The creation of, regional, networks of material exchange is not addressed nor pursued in this regulation.

4. The collection, management and exchange of resource-related information.

Manufacturers, importers, and downstream users are required to self-classify substances and mixtures placed on the market. Therefore they need to identify whether the substances entail a physical, health or environmental hazard. If substances fulfil the criteria of Annex I of the directive, they have to be labelled before placement on the market, or notified to ECHA when not placed on the market. These labels are used as a communication tool to consumers. They do not address scarcity of resources in any way. Material Safety Data Sheets (MSDS) are used to communicate the hazards of chemicals within the supply chain. They include information about among others the properties and the composition of the ingredients, recycling and methods of disposal for the public. Member states should ensure that all substances and mixtures placed upon the European market comply with this regulation. Therefore, every five years they have to submit a report to ECHA with the results and possible additional enforcement measures. This report contains aggregate, national data. Concluding, information collection, management and exchange are one of the main aims of the CLP regulation. However, the collection and exchange mainly addresses the environmental and human health hazards. Limited information can be used to address scarcity of resources (Regulation EC/1272/2008).

4.3.11 LAP: Landelijk Afvalbeheerplan 2009-2021

The National Waste Management plan 2009-2021 (Landelijk Afvalbeheer Plan 2, from now on referred to as LAP2), aims at the prevention of waste, limitation of the environmental pressure of the activity 'waste management' and limiting the environmental pressure of products' supply chains by means of supply chain oriented waste management policies[33].

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

The main focus of the LAP2 is on waste management. Prevention of waste is only a minor part of this policy. Thus, the LAP2 itself is not pursuing principle one of the circular economy.

2. The improvement and creation of end-of-life systems for flows of resources and products.

The LAP2 defines several quantitative and qualitative aims that both enhance principle two of the circular economy. The quantitative aims, among others, set a target for the prevention of waste: not more than 68 Mt in 2015, the increase of the useful application of municipal waste to 60% in 2015, the phasing out of land-filling of combustible waste, and reduction of the environmental pressure for the seven priority waste streams[34]. The qualitative aims refer to, among others, the use of Cradle to Cradle (C2C) as a source of inspiration for the attainment of the goals related to these seven waste streams. Moreover it defines minimum standards for specific waste streams. These minimum standards define the minimal quality of processing to prevent lower-grade processing. The LAP2 does not provide a detailed specification on how these aims should be achieved. The execution is left to the municipalities and waste processers themselves. Moreover the improvement and creation of end-of-life system is mainly aimed at reducing the overall environmental pressure, referring to emissions, and not specifically at reducing vulnerability to resource scarcity. The much stimulated 'useful application' of resource also includes incineration with energy recovery, which still results in the loss of the resources.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks of material exchange is solely referred to in the context of C2C, which is seen as an inspirational source rather than an obligatory requirement.

4. The collection, management and exchange of resource-related information.

[33] "Dit algemene milieudoel betekent dat het afvalstoffenbeleid zich richt op het beperken van het ontstaan van afvalstoffen, het beperken van de milieudruk van de activiteit 'afvalbeheer' en het vanuit ketengericht afvalbeleid beperken van de milieudruk van productketens" (VROM, 2010:15).

[34] These seven streams are paper & cardboard, textile, construction and demolition waste, organic waste, aluminium, PVC and large municipal waste.

The policy does not devise specific information collection by municipalities or waste processors. However, the government does monitor the progress on the attainment of the quantitative and qualitative goals devised and general implementation of the policy. These figures are publicly accessible on the database called '*Afval Monitor*'. This database reports mainly about the total waste collection and the separation rates. The minimum standards, part of the qualitative goals, are developed based on so-called 'BREFs' which stands for Best Available Technology Reference documents. The BREFs identify the best available technology based upon the amount of pollution, mainly air pollution. There are no BREFs related to resource use. Part of the goal of prevention of waste, the LAP2 refers to another database called 'Environmental Measures' or in Dutch '*Milieumaatregelen'*. This database reports about various preventive environmental measures and practical examples on waste, energy etc. The database does not specify any detailed product information, however the available information does enhance the application of best available technologies by businesses. The appendix, which specifies end-of-life possibilities of various waste streams, is useful when recycling, but is not defined on a product level. Consumers are informed about how to dispose of their waste mainly via AgentschapNL. This organization simultaneously gathers information about waste disposal and separation by consumers and indirectly also of companies. This information is used to monitor progress, benchmark and conduct research. However, mainly national and generic information is publicly available (National Waste Management plan 2009-2021).

4.4 Information needs addressed by the resource-related policies

The assessment of the attainment of the four principles of the circular economy, combined with the information needs as assessed in chapter two, are analysed in more detail in this section.

Based upon the previously gathered information table 4.2 is created. It provides an overview of which information is already available due to legislative requirements and to whom in the supply chain this information is available.

The extent to which the policies attain principle one, two and three of the circular economy is translated in the following four category scale. It is important to explicitly mention that all of the directives and regulations solely apply to specific industries, product groups, or materials. This is indicated with symbols. Besides the eco-labelling directive and EMAS, all the private instruments are voluntary in use.

1	pursues the principle of the circular economy
2	largely pursues the principle of the circular economy
3	slightly pursues the principle of the circular economy
4	does not pursue the principle of the circular economy

#	Directive addressing specific product group
*	Directive addressing specific industry
^	Voluntary directive

Additionally, the following legend has been created to visually depict the vast amount of information presented in table 4.2. In the legend the colour orange indicates that the information disclosed within the directives is only partially available (which can also mean that it is scattered) or that the information is available yet only visible to a selected group of people. Green indicates that the information is publicly discloses by the directive regarding the subject of that directive. It also must be noted that the availability of information in the Eco-labelling directive an only be analysed via application packs. The information in table 4.2 is based upon the application pack for notebook computers, randomly chosen from the most recent application packages (Ecolabel, 2012).

(red)	no information available
(orange)	information only partially available, and/ or visible for a selected group of people e.g. producers / designated authorities
(green)	information publicly available

Table 4.2 Information needs addressed by resource-related policies.

Circular economy-related information

	# ^	#	^	#	*	#	#	#	#	#	#
	Eco-L	En-L	EMAS	PPWD	ELV	RoHS	WEEE	Eco-D	REACH	CLP	LAP2
Circular economy principle 1	2	4	4	1	1	3	2	1	3	4	4

Circular economy principle 2	3	4	3	1	1	4	1	3	4	4	2
Circular economy principle 3	4	4	4	4	1	4	4	4	3	4	4

A: General scarcity-related information needs

Companies need information about:		Eco-l	En-l	EMAS	PPWD	ELV	RoHS	WEEE	Eco-D	REACH	CLP	LAP2
A1	Material scarcity in the short/ medium / long term											
A2	Price and supply security/ dependence of materials											
A3	Current and future scarcity-related legislative requirements											

B: Mining-related information needs

Companies need information about:		Eco-l	En-l	EMAS	PPWD	ELV	RoHS	WEEE	Eco-D	REACH	CLP	LAP2
B1	Mine site/ origin											
B2	Mining data											
B3	Local circumstances/ environment at the mine site											

C: Product-related information needs

Companies need information about:		Eco-l	En-l	EMAS	PPWD	ELV	RoHS	WEEE	Eco-D	REACH	CLP	LAP2
C1	Physical structure of the product											
C2	Material content and composition of products											
C3	Material characteristics and properties											
C4	Production processes used, plus specification on which material											
C5	Initial lifetime of the product											
C6	Product adaptations during usage											
C7	Life extending possibilities											
C8	End-of-life possibilities of the product											
C9	Disassembly information											

D: Company internal information needs

Companies need information about:		Eco-l	En-l	EMAS	PPWD	ELV	RoHS	WEEE	Eco-D	REACH	CLP	LAP2
D1	Supply chain partners (incl. 2nd, 3th etc. tier)											
D2	Position of scarcity on a strategic level within the company (goals, staff, time, budget)											
D3	Market demand for products proactively addressing scarcity											
D4	Product-related information of competitors products											
D5	Guidelines for dealing with trade-offs that result from substitution or elimination of critical elements											
D6	Where and how products are disposed of											

E: Technology-related information needs

Companies need information about:	Eco-l	En-l	EMAS	PPWD	ELV	RoHS	WEEE	Eco-D	REACH	CLP	LAP2

E1	Best available mining technologies											
E2	Best available material manufacturing technologies											
E3	Best available production technology											
E4	Best available technologies for end-of-life systems											

The information for C3 and C8 regarding the REACH and CLP regulations can be found online on the website of ECHA[35]. The information for C7 of the Eco-label directive can be found on page 16 of the application pack of notebook computers[36]. As stated before, it is not possible to analyse information disclosure via the directive itself. It must be stressed that the information disclosure identified in table 4.2 only holds true for this specific application pack. Element C8 for the Packaging and packaging waste directive can be found in Article 13 in the legislative text[37]. The information for the same element, C8 for the WEEE directive can be found in Article 10 in the legislative document[38].

The information from table 4.2 can be summed up in figure 4.2 depicting which specific elements of the supply chain are addressed by the information that is already gathered to fulfil legislative requirements, whether or not the information is publicly available. This means that the subjects coloured green and orange are depicted. It is also indicated whether the information that is disclosed, is only available for a specific industry, product group or voluntarily disclosed.

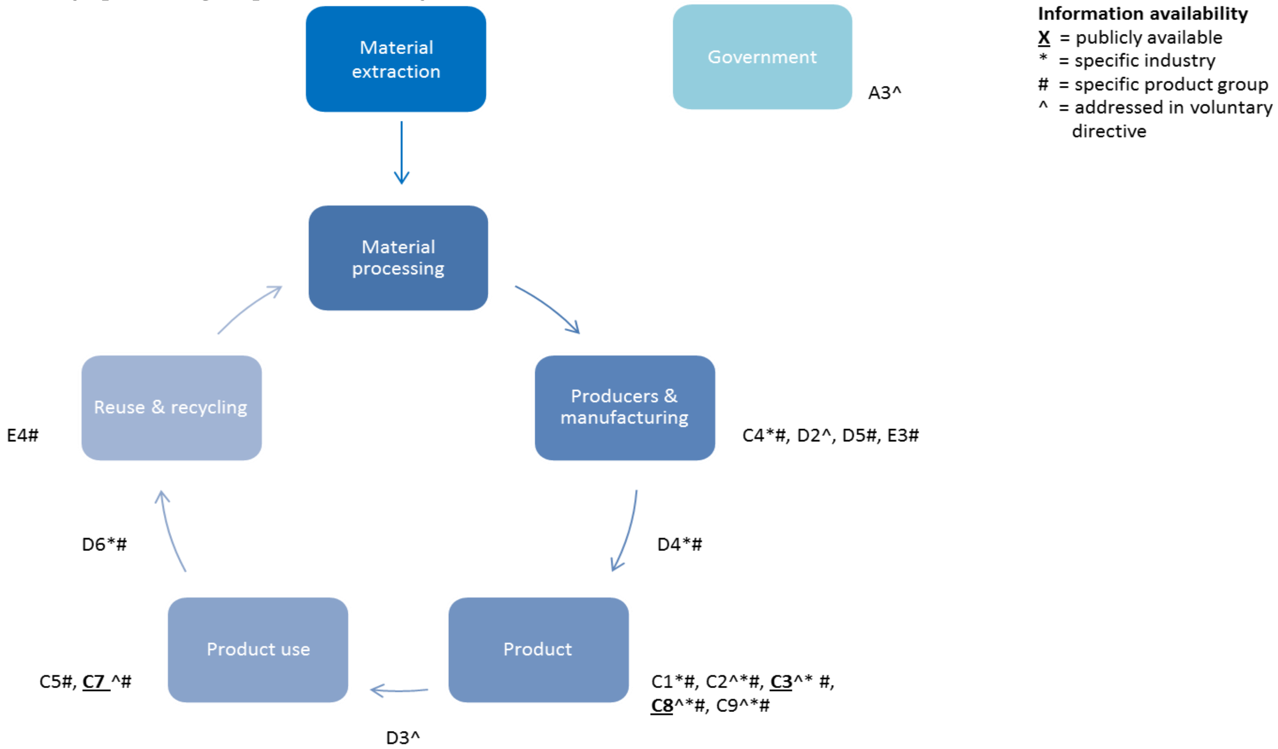

Figure 4.2 Elements of the supply chain addressed by information disclosed by legislative requirements.

As can be seen from figure 4.2, the following information needs are missing: A1, A2, C6, B1, B2, B3, E1, E2. The policies do not address the material extraction, the material processing stage and the transitions from and to the material processing stage. Also, little information is required, and thus little is available about the reuse and recycling stage.

4.5 Explanations for the lack of focus on resource scarcity in policies

It can be concluded that addressing scarcity is not the aim on any of the resource-related policies studied. However, much of the scarcity-related information needs are somehow addressed, although the majority of the information is not publicly available. An interesting fact is that in the EU as well as in the Netherlands no

[35] http://echa.europa.eu/information-on-chemicals
[36] http://ec.europa.eu/environment/ecolabel/documents/app_form_pcs.pdf
[37] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1994:365:0010:0023: EN:PDF
[38] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003: 037:0024:0038:en:PDF

information gathering tools regarding the use or management of resources are made mandatory by the policies. Subsequently, it will be investigated why scarcity-related policies or tools are not obligatory.

First of all, as can be analysed from the timeline in figure 4.1, prevention of scarcity via the management of abiotic resources has just very recently been put on the policy agenda of the EU and the Netherlands. Moreover, resource scarcity has for years been approached mainly from the physical point of view. As became clear in 2010 with the export restriction of REEs in China, economic and political scarcity are as much of a threat, or even more so, than physical scarcity. Consequently, policy attention shifted to also include these perspectives in the EU 2020 flagship initiative (2010) and roadmap (2011). Still, reporting on the use of resources within products is not at the core of this approach and policy.

Another reason, as analysed in the MGI (2011) and EMF (2011) reports, there has never been an economic, political or physical need for closing the resource loops, hence information required to do that has never been gathered on a large-scale. Additionally, up until recently there has never been a political or economic need to disclose information about resource management and use within businesses. Likewise, for businesses there has never been a political or economic need to gather this information. This, as opposed to the information requirements surrounding the prevention of adverse health impacts from the use of certain substances.

Due to the large differences between EU member states in economic performance, industrial profiles, resource needs and stocks, plus perspectives on the role of the government and the EU, little action is taken at an EU level at the moment. Consequently, mandatory policy making and tool setting is a difficult process (Smeets, 2012, personal communication).

In the Netherlands, the focus is on self-management, since the Dutch government believes that agency to address scarcity resides at the businesses themselves (Rosenthal et al., 2011). Besides, disclosing information about the specific content of a product might negatively affect competitiveness issues. Therefore, the framing of such an idea within the linear economy was never positive.

4.6 Conclusion

For an information exchange system to develop and function optimally, it is important to keep the costs of coordination and administration as low as possible. This chapter analysed which European and Dutch resource-related policies have already been implemented. The analysis assessed which information needs necessary to address scarcity, and for creating a circular economy, are already disclosed and exchanged via policies. It has been analysed that many of the Dutch resource-related policies developed some time before their European equivalents did. However, most of the Dutch policies have been replaced by more recent European equivalents. In total eleven directives and regulations, of which one Dutch, have been analysed on their attainment of the circular economy and addressing of the information needs as identified in chapter two. It is analysed that only one directive, the End-of-Life Vehicles Directive, attains the first three principles of the circular economy. Moreover, many of the information needs are already addressed, yet the information is still fragmented or not publicly available. Three information needs are publicly accessible, namely C3 material characteristics and properties, C7 life extending possibilities, and C8 end-of-life possibilities of the product. Eight information needs are not addressed by any of the eleven policy, A1 material scarcity in the short/ medium / long term, A2 price and supply security/ dependence of materials, B1 mine site/ origin, B2 mining data, B3 local circumstances/ environment at the mine site,C6 product adaptations during usage, E1 best available mining technologies, and E2 best available material manufacturing technologies.

Even though 17 of the information needs are addressed by the policies, none of the policies addresses resources scarcity as its main aim and the majority of this information is still scattered and not publicly available. Explanations are that political and economic scarcity have only recently been placed on the European and Dutch policy agenda. Moreover up until recently there has never been a political or economic need to address scarcity.

CHAPTER 5 – PART 2

FRONTRUNNER COMPANIES' INFORMATION NEEDS AND EXPERIENCES

5.1 Introduction

To be able to make recommendations for the content and format of a resources passport, it is necessary to understand the experiences of circular economy frontrunner companies in their dealings with information required to address resource scarcity. Besides through fulfilment of legal obligations, the information needed, can also be disclosed through the use of companies' privately used instruments. To analyse the possible contribution of the use of these instruments to disclosing information, and companies' internal management of the information, the experiences of seven circular economy frontrunner companies in the Netherlands are examined.

First of all, per company, the information needs satisfied through fulfilment of legal obligations are analysed (section 5.2). Subsequently, it is investigated which resource-related information is gathered by the companies themselves via privately used instruments. The information gathered via these instruments is also compared with the information needs as identified in chapter two (section 5.3). After that, it is analysed how these seven cases manage and use the information gathered to comply with legislative requirements and the additionally gathered information to satisfy their resource-related information needs (section 5.4). Next, it is investigated which resource-related information needs these seven companies have, that should be included in the content of the resources passport (section 5.5). Lastly, a comparison is made between the results from the various analysis conducted in this chapter (section 5.6).

5.2 Companies information needs satisfied via legislative requirements

Recapitulating, chapter four has analysed that part of the identified information needs, necessary to address scarcity, are already being satisfied by means of legislative requirements. However, much of the information is not publicly accessible. This means that the information is still mainly utilized internally by companies. Moreover, currently none of the policies are aimed at addressing scarcity. To get an insight in companies experiences and information needs related to scarcity, seven frontrunner companies have been interviewed.

Firstly, it is fair to assume that companies fully comply with their legislative requirements. This implies that, in practice, they already have part of their information needs satisfied. However, the requirements differ per company and its position in the supply chain. The first step in this analysis is to assess which information is already being gathered by these companies in order to fulfil their legislative obligations. The eleven directives and regulations, identified as the most relevant ones for this research, are taken as a starting point.

In every company the persons in the position where they have an overview of the company's overall strategy, plus the resource-related information needs are interviewed. Additionally, the interviewees have knowledge about the resources passport to prevent the interview from becoming suggestive.

Table 5.1 provides an overview of which companies comply with which legislative requirements dealing with resources. Since none of the companies deal with vehicles or end-of-life vehicles, that directive has been left out of this analysis.

Table 5.1 Overview of the legislative requirements of the seven companies

	Eco-l	En-l	EMAS	PPWD	RoHS	WEEE	Eco-D	REACH	CLP	LAP2
Ahrend	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Desso	Yes	No	No	Yes	No	No	No	Yes	No	Yes
InterfaceFLOR	No	No	No	No	No	No	No	Yes	No	Yes
Philips	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Van Gansewinkel	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Van Houtum	Yes	No	No	Yes	No	No	No	Yes	No	Yes

VAR	No	No	No	No	No	No	No	No	No	Yes

Table 5.1 shows that, even though the Eco-labelling and EMAS directives are voluntary regulations, more companies comply with the Eco-labelling directive. Desso, InterfaceFLOR and Philips explained that they opted for ISO14001 instead of EMAS, since ISO14001 is an internationally recognized certificate and not only confined to the EU. Moreover, this table shows that for some product groups there is more legislation than for others. The majority of the resource-related legislation targets electrical and electronic products. Additionally, VAR and Van Gansewinkel, although both waste processing companies, due to the different nature of the waste they collect, comply with different regulations.

By means of comparing the information needs as identified in chapter two with the regulations companies comply with, an overview is created that shows what information is already accessible to the seven frontrunner companies. Table 5.2 depicts this comparison. The green boxes imply that information is available, the red shaded boxes that information is not. It must be noted that information that was only partially available or visible to a selected group has also been classified as information being available.

red (shaded)	no information available
green	information publicly available, information partially available and/or visible for a selected group of people

Table 5.2 Availability of information for frontrunner companies, in practice.

		Ahrend	Desso	Interface FLOR	Philips	Van Gansewinkel	Van Houtum	VAR
A1	Material scarcity in the short/ medium / long term	red	red	red	red	red	red	red
A2	Price and supply security/ dependence of materials	red	red	red	red	red	red	red
A3	Current and future scarcity-related legislative requirements	green	red	red	red	green	red	red
B1	Mine site/ origin	red	red	red	red	red	red	red
B2	Mining data	red	red	red	red	red	red	red
B3	Local circumstances/ environment at the mine site	red	red	red	red	red	red	red
C1	Physical structure of the product	red	red	red	green	green	red	red
C2	Material content and composition of products	green	green	green	green	green	green	red
C3	Material characteristics and properties (including recyclability and toxicity)	green	green	green	green	green	green	red
C4	Production processes used, plus specification on which material	green	green	green	green	green	green	red
C5	Initial lifetime of the product	red	red	red	green	green	red	red
C6	Product adaptations during usage	red	red	red	red	red	red	red
C7	Life extending possibilities	green	green	red	green	green	green	red
C8	End-of-life possibilities of the product	green	green	green	green	green	green	green
C9	Disassembly information	green	green	green	green	green	green	red
D1	Supply chain partners (incl. 2nd, 3th tier)	red	green	green	green	green	green	red
D2	Position of scarcity on a strategic level within the company (goals, staff, time, budget)	green	red	red	red	green	red	red
D3	Market demand for products proactively addressing scarcity	green	red	red	red	green	red	red
D4	Product-related information of competitors products	green	green	green	green	green	green	red
D5	Guidelines for dealing with trade-offs that result from substitution or elimination of critical elements	red	red	red	green	green	red	red
D6	Where and how products are disposed of	green	green	red	green	green	green	green
E1	Best available mining technologies	red	red	red	red	red	red	red
E2	Best available material manufacturing technologies	red	red	red	red	red	red	red
E3	Best available production technology	green	green	green	green	green	green	green
E4	Best available technologies for end-of-life systems	green	green	green	green	green	green	green

Table 5.2 shows that the available information is similar for many companies. This means that it is hard for companies to complement each other. Eight specific gaps can be identified, namely A1, A2, B1, B2, B3, C6, E1, and E2[39]. One explanation of these specific mining-related gaps is that the Netherlands and Europe are not self-sufficient in metals and minerals mining, and have very little actual mining going on (Hagelüken, 2007).

5.3 Resource-related information gathered via privately used instruments

Companies themselves also have resource-related information needs that are not fulfilled through compliance with legislative requirements. For example, information necessary for market-research in the quest to enter new markets. By means of semi-structured interviews, it has been assessed what other instruments are used by the seven companies to gather resource-related information that could be useful in providing content for the resources passport. Subsequently, it is assessed which information needs, as specified in chapter two, are satisfied by these privately used instruments.

5.3.1 Companies privately used instruments

Table 5.3 provides an overview of the resource-related instruments used by the seven companies that could provide data for the content of the resources passport. It simultaneously indicates which instruments are suggested by the companies themselves to provide input for the content of the resources passport. The names of the instruments are alphabetically ordered. It should be noted that to be able to get a good overview of the possibilities regarding material reporting, the companies interviewed for this research have been selected on the criteria that they are frontrunners in this area. Therefore the representation of usage of these instruments here cannot be generalized to all businesses in the Netherlands or anywhere else. During discussions with De Groene Zaak and the interviews, remarks were made that every company can extract information as long as they are willing to pay for it and that having a standardized system is important. Therefore, internal processes like green procurement requirements or non-standardized measurements of weight of recycled products have not been taken into account (Lambert, 2001).

Table 5.3 Suggested and used instruments to provide content for the resources passport.

Name	Description	Used by	Suggested by
BOM: Bills-of-Materials	"The 'recipe' listing the materials (including quantities) needed to make a product" (Monk & Wagner, 2007: 237). BOMs are obligatory for every producer.	Ahrend, Desso, InterfaceFLOR, Philips, Van Houtum	Desso, Philips
C2C: Cradle to Cradle Certificate	Design process in which "materials are applied with respect for their intrinsic value and their useful afterlife in recycled or even "upcycled" products, which have value and technological sophistication that may be higher than that of their original use" (EPEA, 2012: EPEA GmbH).	Ahrend, Desso, Van Gansewinkel, Van Houtum	Ahrend
CAS: Chemical Abstracts Service registry	"A unique numeric identifier, designates only one substance, has no chemical significance, and is a link to a wealth of information about a specific chemical substance" (CAS, 2012: CASRNs)	Ahrend, Desso, InterfaceFLOR, Philips, Van Gansewinkel, Van Houtum	Van Gansewinkel
EPD: Environmental Product Declarations	"Quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information" (DG Environment, 2002: 18)	Desso, InterfaceFLOR	InterfaceFLOR, Van Gansewinkel
LCA: Life Cycle Assessment	"Compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its lifecycle" (Guinée et al., 2001: 3).	Ahrend, Desso, InterfaceFLOR, Philips	Ahrend, InterfaceFLOR
MSDS: Material Safety Data Sheets	Provides workers and personnel with guidance on the safe handling of a substance, plus information on physical data, data on toxicity, storage, disposal etc. (European Parliament and Council, 2006). MSDSs are mandatory under the REACH and WEEE Directives.	Ahrend, Desso, InterfaceFLOR, Philips, Van Gansewinke, Van Houtum, VAR	Ahrend, Van Houtum
REACH	"Manufacturers and importers are required to gather	Desso, InterfaceFLOR,	Philips, Van

[39] A1 material scarcity in the short, medium & long term, A2 price and supply security/ dependence of materials, B1 mine site/ origin, B2 mining data, B3 local circumstances/ environment at the mine site, C6 product adaptations during usage, E1 best available mining technologies, and E2 best available material manufacturing technologies.

-database	information on the properties of their chemical substances, which will allow their safe handling, and to register the information in a central database run by ECHA" (European Commission, 2012, REACH).	Philips, Van Gansewinkel, Van Houtum	Gansewinkel, VAR

5.3.2 Information needs addressed by privately used instruments

Since the instruments suggested and used by the companies are mainly plain, single issue instruments it is not relevant to assess to what extent these methods pursue the first three principles of the circular economy. It will solely be assessed which information needs as identified in chapter two are met by these instruments.

It is important to explicitly mention that the colour orange indicates two categories, namely that the information is only partially available or that the information is available yet only visible to a selected group of people.

red	no information available
orange	information only partially available and/or visible for a selected group of people e.g. producer/ designated authorities
green	information publicly available

Table 5.4 Information needs addressed by companies' privately used instruments.

A: General scarcity-related information needs

		BOM[40]	C2C[41]	CAS	EPD[42]	LCA[43]	REACHdb	MSDS[44]
A1	Material scarcity in the short/ medium / long term	red	red	red	orange	orange	red	red
A2	Price and supply security/ dependence of materials	orange	red	red	red	red	red	red
A3	Current and future scarcity-related legislative requirements	red	red	red	red	orange	red	red

B: Mining-related information needs

		BOM	C2C	CAS	EPD	LCA	REACHdb	MSDS
B1	Mine site/ origin	red	red	orange	orange	orange	red	red
B2	Mining data	red	red	red	red	red	red	red
B3	Local circumstances/ environment at the mine site	red	red	red	red	red	red	red

C: Product-related information needs

		BOM	C2C	CAS	EPD	LCA	REACHdb	MSDS
C1	Physical structure of the product	green	orange	red	green	orange	red	red
C2	Material content and composition of products	orange	orange	red	green	orange	red	orange
C3	Material characteristics and properties (including recyclability and toxicity)	red	orange	green	orange	orange	green	green
C4	Production processes used, plus specification on which material	red	orange	red	green	orange	red	orange
C5	Initial lifetime of the product	red	red	red	red	orange	red	red
C6	Product adaptations during usage	red	red	red	red	red	red	red

[40] Based upon the following example: http://www.billofmaterials.net/example.php
[41] Based upon the official certification website: http://www.mbdc.com/detail.aspx?linkid=2&sublink=9/ http://www.mbdc.com/images/V2_criteria_matrix-C2CPII_03-20-2012%20Sheet1.pdf
[42] Based upon the EPD of InterfaceFLOR called 'Microtuft modular carpet' provided by the Institut Bauen und Umwelt e.V.
[43] Based upon the ILCD Handbook: http://lct.jrc.ec.europa.eu/pdf-directory/ILCD-Handbook-General-guide-for-LCA-DETAIL-online-12March2010.pdf and ESU Services: http://www.esu-services.ch/projects/ubp06/
[44] Based upon the guidelines as specified in REACH Annex II http://www.reach-compliance.eu/english/REACH-ME/engine/sources/reach-annexes/launch-annex02.html

		BOM	C2C	CAS	EPD	LCA	REACHdb	MSDS
C7	Life extending possibilities							
C8	End-of-life possibilities of the product							
C9	Disassembly information							

D: Company internal information needs

		BOM	C2C	CAS	EPD	LCA	REACHdb	MSDS
D1	Supply chain partners (including 2nd, 3th etc. tier)							
D2	Position of scarcity on a strategic level within the company (goals, staff, time, budget)							
D3	Market demand for products proactively addressing scarcity							
D4	Product-related information of competitors products							
D5	Guidelines for dealing with trade-offs that result from substitution or elimination of critical elements							
D6	Where and how products are disposed of							

E: Technology-related information needs

		BOM	C2C	CAS	EPD	LCA	REACHdb	MSDS
E1	Best available mining technologies							
E2	Best available material manufacturing technologies							
E3	Best available production technology							
E4	Best available technologies for end-of-life systems							

Information need C1 is disclosed by a BOM[45]. CAS discloses information need C3[46]. The EPD publishes information needs C1, C2, C4, C7 and C8[47]. The REACH database discloses information need C3[48]. Lastly, MSDS also address information need C3 as specific in Annex II of the REACH directive[49].

Summarizing, the seven instruments do provide information necessary to address companies information needs relating to resource scarcity. The focus of these instruments is mainly on product-related information, where quite a bit of publicly accessible information is available. This coincides with the results from the information disclosed by the eleven policies. The instrument LCA satisfies most of the information needs[50].

The information from table 5.4 can be summarized in figure 5.1, depicting which specific elements of the supply chain are addressed by the information that the privately used instruments of companies gather. The information needs depicted represent the orange and green coloured aspects of table 5.4.

Figure 5.1 Elements of the supply chain addressed by information disclosed by privately used instruments

As can be seen from figure 5.1, companies' privately used instruments, as opposed to legislative requirements, do address the material extraction and material processing stage. Although only a fraction of the information gathered by the instruments addresses these stages. The transitions from and to the material

[45] An example thereof is http://www.billofmaterials.net /example.php
[46] http://www.cas.org/content/chemical-substances
[47] An example of an EPD in which this information is disclosed: http://bau-umwelt.de/download/CY6978 d166X128144 04465XY4402/EPD_IFF_2010111_E.pdf?ITServ=CY21f5c25dX13a1c244405XY658
[48] http://echa.europa.eu/information-on-chemicals
[49] . An example of an MSDS is http://www.generalpaint.com/content/GeneralPaint/Html/General/Pages/for_ your_business/technical_info/MSDS/52-216M.pdf
[50] It must be noted that implementation costs of these instruments are not taken into account in this analysis.

processing stage are still not addressed. Besides the product stage, little information about the other stages is gathered. Missing information needs are: C6, B2, B3, D2, D3, D5, D6, E1, E3.

By means of comparing the information needs as identified in chapter two with the instruments that are used per company, an overview is created that shows what information is already accessible to the seven frontrunner companies. Table 5.5 depicts this comparison. The green boxes imply that information is available, the red shaded boxes that the information is not. It must be noted that information that was only partially available or visible for a selected group has also been classified as information being available.

red	no information available
green	information publicly available, information partially available and/or visible for a selected group of people

Table 5.5 Information needs per company satisfied by the use of private resource-related instruments.

		Ahrend	Desso	InterfaceFLOR	Philips	Van Gansewinkel	Van Houtum	VAR
A1	Material scarcity in the short/ medium / long term	green	green	green	green	red	red	red
A2	Price and supply security/ dependence of materials	green	green	green	green	red	green	red
A3	Current and future scarcity-related legislative requirements	green	green	green	green	red	red	red
B1	Mine site/ origin	green	green	green	green	green	green	red
B2	Mining data	red	red	red	red	red	red	red
B3	Local circumstances/ environment at the mine site	red	red	red	red	red	red	red
C1	Physical structure of the product	green	green	green	green	green	green	red
C2	Material content and composition of products	green	green	green	green	green	green	green
C3	Material characteristics and properties (including recyclability and toxicity)	green	green	green	green	green	green	green
C4	Production processes used, plus specification on which material	green	green	green	green	green	green	green
C5	Initial lifetime of the product	green	green	green	green	green	red	red
C6	Product adaptations during usage	red	red	red	red	red	red	red
C7	Life extending possibilities	green	green	green	green	green	green	red
C8	End-of-life possibilities of the product	green	green	green	green	green	green	green
C9	Disassembly information	green	green	green	green	green	green	red
D1	Supply chain partners (incl. 2nd, 3th tier)	green	green	green	green	green	green	red
D2	Position of scarcity on a strategic level within the company (goals, staff, time, budget)	red	red	red	red	red	red	red
D3	Market demand for products proactively addressing scarcity	red	red	red	red	red	red	red
D4	Product-related information of competitors products	red	green	green	red	red	red	red
D5	Guidelines for dealing with trade-offs that result from substitution or elimination of critical elements	red	red	red	red	red	red	red
D6	Where and how products are disposed of	red	red	red	red	red	red	red
E1	Best available mining technologies	red	red	red	red	red	red	red
E2	Best available material manufacturing technologies	green	green	green	green	green	green	red
E3	Best available production technology	red	red	red	red	red	red	red
E4	Best available technologies for end-of-life systems	red	green	green	red	red	red	red

Similar to the results of table 5.2, table 5.5 shows that only specific information needs are met. Hence, companies cannot complement each other. The instruments are thus focused on gathering specific types of information. The specific gaps here partially overlap with those identified in table 5.2. Only four gaps (written below in *italics*) are not addressed by regulations or private instruments. The others are addressed in one or the other and hence information exchange might be a possibility. The ten specific gaps are: *B2 mining data*, *B3 Local circumstances/ environment at the mine site*, *C6 product adaptations during usage*, D2 position of scarcity on a strategic level within the company (goals, staff, time, budget), D3 market demand for products proactively addressing scarcity, D5 guidelines for dealing with trade-offs that result from substitution or elimination of critical elements, D6 where and how products are disposed of, *E1 best available mining technologies*, and E3 best available production technology.

5.4 Management and use of gathered information

In this section it is analysed how the information gathered through fulfilment of legislative requirements and the use of private instruments is managed and used within these seven companies.

First of all, it is assessed whether there exist internally used comprehensive databases that store all resource-related data gathered by the various departments. As of this moment, none of the companies interviewed have a central database that stores all the different pieces of information gathered to comply with different directives or to satisfy other needs. This information is scattered across various databases and departments. However, InterfaceFLOR, Van Houtum and VAR indicate that all their legislative information is gathered into one database. Philips is currently working on setting up a new IT system that should converge all different data streams. Systems that are currently used are, among others SAP, Lotus Notes, ISO and RDMG. The companies state that the information is being entered by different departments, mainly procurement and the department for quality, labour and environmental issues (abbreviated as KAM in Dutch). More operational activities are being managed by the designated officials.

Secondly, it is analysed who has access to this resource-related information. Ahrend, Desso, InterfaceFLOR, Philips and Van Houtum state that all the information in theory is accessible. However, much information is scattered over various databases and management systems, plus information is gathered under non-disclosure agreements. In practice, information is not accessible. Additionally, as Van Gansewinkel states the information is foremost accessible to the departmental officials.

Lastly, it is analysed whether and to what extent all the information gathered is used for other purposes than fulfilling legal requirements and internal information needs. Asides VAR, all companies state that they use some of the information for other purposes. For example, Philips states that data to comply with the WEEE directive and packaging and packaging waste directive is used for other purposes than legal compliance. These purposes are: annual environmental reports, the Global Reporting Initiative, Cradle to Cradle reports and assessment of market and business opportunities. The same holds true for the other companies. Ahrend states that they sometimes use the information to respond to consumer demands. However, this does often requires a translation from technical to language that is easier to understand. These other purposes as defined here are mostly confined to existing schemes and reporting frameworks and are not exploratory in nature, or actively in search of new solutions for the coming scarcity issues.

Concluding, resource-related information is scattered over various databases and departments of a company. In theory this information is accessible to anyone. However, non-disclosure agreements and the fact that the data itself is scattered, in practice, make that the data is hard to access. Moreover, the data is used for other purposes, yet these purposes do not actively and innovatively contribute to solving the coming scarcity problem. Departments do not actively reach out for the information of other departments in an attempt to compare the data.

5.5 Resource-related information needs of companies

As analysed in chapter four and foregoing sections of this chapter, information is gathered via fulfilment of policy obligations and the use of resource-related private instruments. However, there are still information gaps, there is a lack of information exchange and an internal overview is lacking. This section assesses the resource-related information needs of the seven frontrunner companies.

5.5.1 Companies' value creating levers

First it is assessed what the seven frontrunner companies identify as the problems the resources passport should address and hence what its goal should be. These data have been gathered via interviews and have been used to identify companies' main value creating levers (section 2.5). This information is depicted in table 5.6.

Table 5.6 Perceptions on the value creating levers of addressing scarcity

Company	Problem(s) to be addressed	Goal of the resources passport	Value creating levers
Ahrend	Resources are: 1. nobodies responsibility/ no owner 2. economically worthless 3. therefore they are not recycled	1. separate clean and polluted streams of resources 2. cleaning of polluted streams of resources 3. prevention of creation of polluted streams of resources	Sustainable value chains, operational risk management, innovation and new products.
Desso	It is an opportunity, there is no	Enhance the circular economy and	New markets, operational risk

	problem. Recycling will help offset the future problem of the Netherlands not having any resources of their own.	resource metabolism, so that resources can freely circulate between sectors and applications.	management, innovation and new products.
InterfaceFLOR	Lack of control over the use and management of resources, especially related to the ecological impact.	Create transparency about resources in the supply chain, thereby enabling producers and consumers to make better choices based on the sustainability of a product.	Sustainable value chains, green sales and marketing, innovation and new products.
Philips	Lack of resource-related supply chain transparency.	Get insight in the materials used in a product and at which level/ tier.	Sustainable value chains, operational risk management, composition of business portfolio.
Van Gansewinkel	Waste of valuable resources by not recycling them.	Identify, interpret and modify resources so as to be able to reuse and recycle them. Not necessarily done on a product level, substance level is sufficient.	Sustainable value chains, innovation and new products, new markets.
Van Houtum	The exponential growth of the demand for paper. Raise consumer awareness about the environmental footprint of products.	Get insight into the origin and supply chain of the materials used.	Green sales and marketing, reputation management.
VAR	Waste is provided in such a way that it is hard to be recycled (often polluted or wet).	Raising consumer awareness about the value of materials in their end-of-life phase, plus a tool to ease recycling of resources.	Sustainable value chains, innovation and new products, new markets.

As can be seen in table 5.6, the seven companies identify a large variety of problems and goals for the resources passport. Especially the perspective of Van Gansewinkel differs from the others. They focus more on the characteristics and quality of the individual resources, as opposed to the combination of resources in products. Nevertheless, all cases agree that cross-cycle and cross-sector transparency is necessary and that joint implementation is required. This table shows no significant inconsistencies between the problems to be addressed and the envisioned goal. There are some minor mismatches. For example, for Van Houtum getting insight in the origin and supply chain of resources, does not necessarily address or counter the exponential growth of paper use. However, these are likely to be explained by means of the envisioned content of the passport.

Regarding the value creating levers that are derived from the companies answers, the levers innovation and new products, and sustainable value chains have been mentioned most often: five times. The resources passport is important for both. Related to the former, one needs to have knowledge of the current status quo within ones supply chain and what the people downstream in the supply chain demand and how they act. Since for this research frontrunner companies were interviewed, the fact that this lever is an important goal for many is not surprising. Nevertheless, these results cannot be generalized. A resources passport is also necessary to utilize the latter lever, since without knowledge of what happens in your supply chain you cannot create a sustainable supply chain. The levers operational risk management, and new markets are each mentioned by three companies. In order to manage both, companies need to have knowledge of what happens upstream and downstream in their supply chain. The more international the company, the more complex it is to manage both levers. No-one mentions the value creating lever regulatory management. This can be explained, since the resources passport is initiated to go beyond current legislative requirements. Also no-one mentions the value creating lever sustainable operations. This can be explained by the fact that companies do not need supply chain transparency or a resources passport to address this value creating lever.

5.5.2 Companies resource-related information needs

Subsequently it is analysed what information should be incorporated into the resources passport according to the seven companies. Table 5.7 provides an overview of the proposed elements of the content of a resources passport. Some companies anticipated a phased implementation of the resources passport. When this occurred, this is specified in the last column.

Table 5.7 Resource-related information needs, to be used in a resources passport, according to companies.

Element	Corresp. inf. need	Description	Reason	Supported by
Critical raw materials	A1	Identification whether there are materials that are on the list of (currently) 35 materials that are critical to the EU economy.	To assess whether materials used are susceptible to supply risks and price volatility.	Philips
Origin of the materials	B1	The country or place where the materials are mined or extracted otherwise.	To assess how secure the supply of these materials is.	Van Houtum
Conflict minerals	B1 & B3	Whether the materials used are mined under conflict conditions or human rights violation.	To assess whether materials are used to fuel conflict. Use is prohibited under US law (Frank-Dodd Act) and soon may also be forbidden in the EU.	Philips
Basic product information	C1	Description of the product and its function, for example an office chair. Plus the product number.	To identify to which product the passport belongs and which general function the materials currently have.	Desso, InterfaceFLOR, Philips, VAR
Material information	C2 & C3	Information about the materials present in the product or used to create a material in the product, can be based on CAS number (section 5.2).	To be able to better reuse and recycle the materials (see section 6.2 for a more detailed discussion).	Ahrend, Desso InterfaceFLOR, Philips, Van Gansewinkel, Van Houtum, VAR
Recycling gradient	C3a	To what extent the product consists of recyclable and non-recyclable or down-cyclable materials (see section 8.2 for discussion).	Various reasons, among others achievement of clean streams, lowering of environmental impact, indicator of effectiveness and efficiency of design (see section 8.2 for discussion).	Ahrend, Desso, InterfaceFLOR, VAR
Toxicity	C3b	Identification of the hazard class as e.g. identified by the EU like substances of very high concern.	To assess how sustainable a product is. (Ahrend states that if you know what material is used, you also know whether or not it is toxic).	Van Houtum. Future element: Philips, VAR
Handling and storage	C3 & C7	How the materials in a product should be stored and handled by workers with the materials and consumers.	Enhances safer recycling of the product.	Van Houtum
Function and location of materials, and disassembly information	C4 & C9	An indication of the reason why a material is used, for example as pigment and in which component This is useful when separate treatment is needed. If possible to detach a description how to detach it from the product.	To enable better disassembly and hence recycling.	Ahrend, Philips, Van Gansewinkel, VAR, Van Houtum
Product durability	C5	The minimal lifespan of a product, in which all functions are maintained.	To assess how sustainable a product is. Without fully closed loops: the longer the lifespan the better.	InterfaceFLOR
Address of recyclers or producer	C8	Name and contact information of waste management companies that are able to recycle the product or of the producer of the product itself.	Mainly for consumers to know where to dispose the product.	Recycler: Ahrend, Philips Producer: Ahrend, InterfaceFLOR
Producer / Original Equipment Manufacturer	D1a	Name of the brand or company that put the product on the market.	To be able to contact them about take back and/ or recycling issues.	Ahrend, Desso, InterfaceFLOR , VAR
Supply chain information	D1b	The names of all the suppliers of components of a product.	To enable/ enhance transparency and responsibility in the supply chain.	Ahrend
Best Available Technique	E4	Identification of the best available recycling technique for the product. Possibly in combination with the name and contact details of the recycler that provides this technique.	To ensure the materials are reused/ recycled in the most efficient manner and stimulate competition to create the best BAT.	Desso
The environmental impact/	N.A.	The environmental impact of a product measured by energy use, water use, toxicity, greenhouse	This indicates how sustainable a product is, the implications of material choices are made visible and	LCA: InterfaceFLOR, MSDS: Van

footprint of a product		potential etc.	benefits can be claimed. VAR: Opposed to the initial element here it is seen as an extra element in deciding which material to use, to achieve clean material streams.	Houtum, Future element: VAR
Benefits beyond system boundaries	N.A.	Additional information that producers would like to add but that is not categorized in the passport, like social impacts of extraction and production.	To enable the mentioning of extra information, used as a marketing tool, or enable better design and recycling.	InterfaceFLOR

The information from table 5.6 can be summarized in the following figure, depicting which specific elements of the supply chain are addressed by the information that the companies suggest should form the content of the resources passport.

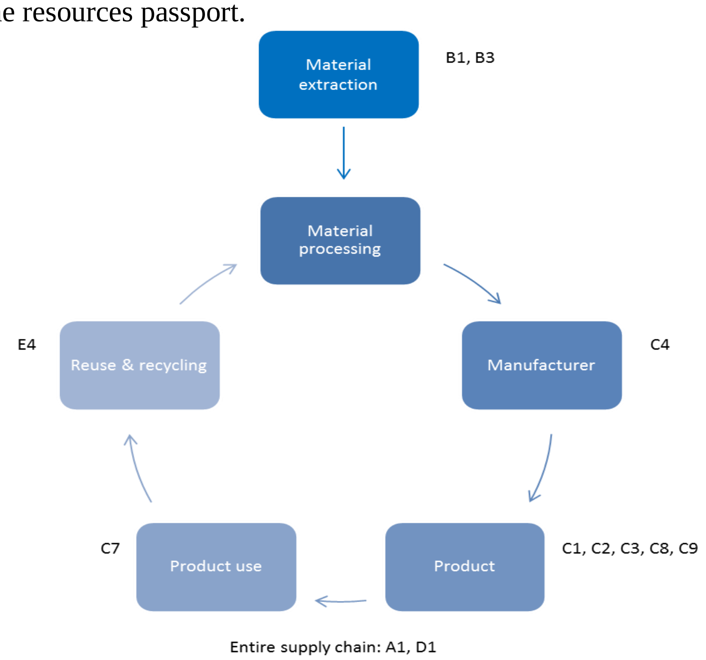

Figure 5.2 The specific elements of the supply chain that are addressed by the additional resource-related information needs of companies.

As can be seen in figure 5.2, information needs related to the material processing step in the supply chain have not been mentioned. This coincides with the results from the analysis of the information gathered by legislative compliance as depicted in figure 4.2. Most of the information needs concentrate around the product itself, again similar to figure 4.2.

5.6 Comparison

In this section it is analysed whether and how much of the suggestions made by the companies for the content of the resources passport are already met through fulfilment of legal obligations and private instruments. Since all companies fulfil different legislative requirements, this analysis is conducted per company. Table 5.8 depicts the comparison of companies' suggestion of elements with information already available through legal compliance. Table 5.9 depicts the comparison of companies' suggestion of elements with information already available through the use of privately used instruments. In both tables, 'V' means that these companies have suggested this element as component of the content of the resources passport. The green colour indicates that the information is available to them, whereas red indicates that the information is not available. Moreover, number 9 (the environmental impact) and number 16 (benefits beyond system boundaries), as information needs suggested by the companies are not immediately relevant in the addressing of scarcity issues and are therefore not incorporated in the analysis.

(red)	no information available
(green)	information publicly available, information partially available and/or visible for a selected group of people
V	Information needs suggested by company

Table 5.8 Suggestions for the resources passport versus information available via legislative compliance.

Information needs	Ahrend	Desso	Interface FLOR	Philips	Van Gansewinkel	Van Houtum	VAR
A1				V			
B1						V	
B1& B3				V			
C1		V	V	V			V
C2 & C3	V	V	V	V	V	V	V
C3a	V	V	V				V
C3b				V		V	V
C3 & C7			(only C3)			V	
C4 & C9	V			V	V	V	V
C5			V				
C8	V		V	V			
D1a	V	V	V				V
D1b	V						
E4		V					

It can be analysed that quite a few of the companies' suggestions are met through legislative compliance. A gap can be analysed related to identifying critical raw materials, conflict minerals and the origin of the materials. Moreover, especially VAR has multiple knowledge gaps.

Table 5.9 Suggestions for the resources passport versus information available via privately used instruments.

Information needs	Ahrend	Desso	Interface FLOR	Philips	Van Gansewinkel	Van Houtum	VAR
A1				V			
B1						V	
B1 & B3	(only B1)	(only B1)	(only B1)	V (only B1)	(only B1)	(only B1)	
C1		V	V	V			V
C2 & C3	V	V	V	V	V	V	V
C3a	V	V	V				V
C3b				V		V	V
C3 & C7						V	(only C3)
C4 & C9	V			V	V	V	V (only C4)
C5			V				
C8	V		V	V			
D1a	V	V	V				V
D1b	V						
E4		V					

It can be analysed that almost all of the information needs as suggested by the companies are already met via the use of private instruments. Similar to table 5.8, VAR has multiple knowledge gaps.

5.7 Conclusion

In this chapter it is analysed what the experiences and information needs are of seven circular economy frontrunner companies in their dealings with resources and upcoming scarcity. It is assessed with which resource-related policies these Dutch companies comply. Concluded is that the legislative requirements differ extensively per industry, with the majority of the burden on electric and electronic products. Moreover, there are eight specific knowledge gaps regarding information that is necessary to address scarcity, namely A1, A2, B1, B2, B3, C6, E1, and E2[51].

The usage of private instruments to gather resource-related information is also analysed. Seven relevant instruments have been identified based upon a usage and suggestion selection: Bills-Of-Materials, Cradle to Cradle Certificate, Chemical Abstracts Service Registry, Environmental Product Declarations, Lifecycle Analysis, Material Safety Data Sheets and the REACH database. Of these seven, lifecycle

[51] A1 material scarcity in the short, medium & long term, A2 price and supply security/ dependence of materials, B1 mine site/ origin, B2 mining data, B3 local circumstances/ environment at the mine site, C6 product adaptations during usage, E1 best available mining technologies, and E2 best available material manufacturing technologies.

analysis' provide the most information necessary to address scarcity. The information that is gathered by these instruments, combined with what is gathered via legislative compliance leaves four information needs completely uncovered: B2, B3, C6, and E1[52].

The management and use of the information gathered through fulfilment of legislative requirements and the use of private instruments is assessed. It is concluded that resource-related information is scattered over the various databases and departments of a company. In theory this information is accessible to anyone, yet in practice the data is hard to access. Additionally, resource- related information is rarely used to search for innovate solutions.

Following, the value creating levers for companies in addressing scarcity are identified. For all the levers selected by the companies the resources passport would be a necessary enabling tool. Next, the information that should be incorporated into the resources passport according to the seven frontrunner companies is identified. Sixteen elements, ranging from recycled content to toxicity, are identified. Most elements consist of information that is already gathered through fulfilment of legal obligations and the use of private instruments. The analysis shows that cross-cycle and cross-sector information exchange, which is necessary for addressing scarcity, is very complex. Although little resource-related information is publicly disclosed, more information is available than initially expected. For the majority of the information needs, information is partially available, scattered or only available to a selected group. Many partial solutions are present, but there is no connection between the solutions. Nevertheless, there are many opportunities to address scarcity of resources via a resources passport.

[52] B2 mining data, B3 local circumstances/ environment at the mine site, C6 product adaptations during usage, and E1 best available mining technologies.

CHAPTER 6 – PART 3

FORMAT OF A RESOURCES PASSPORT

6.1 Introduction

This chapter assesses which format aspects are relevant in the development of a resources passport. To meet this objective, function is translated to form, by assessing how the seven frontrunner companies in the Netherlands think the five format aspects, as identified in chapter two, should be addressed in the resources passport (section 6.2). Subsequently, it is assessed how three similar information exchange systems address these five format aspects (section 6.3). Lastly, a comparison is made between the data gathered in the different section of this chapter (section 6.4).

6.2 Format requirements according to frontrunner companies

In this section it is analysed how the seven frontrunner companies in the Netherlands deem that the five format aspects, as identified in chapter two, should be addressed in the resources passport. Their perspective and practical expertise are both necessary to adequately translate function to format.

Even though the feasibility and implementation of the resources passport were outside of the scope of this research, they have indirectly been taken into account since they shape the perceptions of the seven frontrunner companies regarding the format of a resources passport. Aspects that were most important are the administrative burden and the costs related to implementation. All companies agree that both should be kept to a minimum.

1. Provision of the information

All seven companies agree that the manufacturer of a product or component is responsible for filling out the information as required by the resources passport. As Ahrend reports: anybody that adds something to a component or product should report about it, and take responsibility for it. Every step, like soldering or coating, should be reported about by the one responsible for that act. It is deemed important that there is total transparency from the beginning to the end of the supply chain. This has not been achieved anywhere in the world yet, not even in the FCS 'chain of custody'. Philips too stresses the importance of transparency of information in the supply chain, also regarding information from indirect suppliers.

Desso believes producers should retrieve the information from their supply chain necessary to fill out the resource passport themselves. They state that other companies only want what Desso is already doing, namely retrieving the information from their supply chain themselves, by only requesting products that fulfil the C2C criteria. Desso argues that companies are responsible for the affairs in their own supply chain and they see it as companies' own responsibility to have suppliers fill out a resources passport. When a resources passport would be obligatory for all, their perspective on this matter changes.

Important for the format of the resources passport is whether the information in the passport should be static or dynamic. This choice will influence the kind of information that needs to be gathered. Ahrend, Desso, InterfaceFLOR, Philips and VAR state that the information provided in the resources passport should be dynamic. Thereby InterfaceFLOR states that when the material composition of the products changes the products properties, the resources passport should be updated. The other companies also believe that whenever the material composition changes, the resources passport has to be altered and a distinction has to be made between the former and the latter version of the passport.

Van Gansewinkel envisions the development of a separate passport for each material used. This means the passport does not address products, but addresses separate resources. Therefore they state that the information in a resources passport is static. When the composition of a material changes, the material itself becomes a different material and thus requires a different resources passport. Van Houtum does not have an opinion in this matter.

2. Storage of the information

All seven companies agree that information should be registered digitally and be accessible via a comprehensive and comprehensible database. Producers should be able to register their information directly in this database. Whether this should be done through an online database or an in-house server, is not specified. Philips specifies that it should be done on a component base. Many producers use the same component in multiple products, hence, in this manner they can easily generate a resources passport for several products.

Ahrend believes that there should also be a physical version of the resources passport. The fact that they envision a physical version attached to a product in stores could possibly conflict with the believe that information should be dynamic. Desso, for example, states that if the component 'Best Available Technology' is present on a passport, it is inherently complicated to keep it up-to-date on a physical document, especially when it is a slow-moving consumer good. Desso also argues that it is most likely that consumers will lose this physical document and therefore it does not serve the purpose regarding information provision on the most effective recycling. Ahrend believes the resources passport should play a role during purchasing decisions. Currently, Ahrend has trouble recollecting their products at the end of their life, due to ownership issues. They believe that the consumer mentally is not part of the chain, and does not feel responsibility to return the products at the end of their life. To be able to close the resource loops, consumers should be aware of what they buy and how to dispose of the product, following the information provided in the resources passport.

3. Access to the information

Ahrend, Desso, Philips and VAR state that the information in a resources passport should be open and accessible to everyone, to be able to serve its purpose of closing resource loops. InterfaceFLOR, Van Gansewinkel and Van Houtum believe the resources passport's added value is mostly in business-to-business relations. Access to the information should therefore be limited to business relations.

However, Philips, Van Gansewinkel and VAR see confidentiality of material composition as a possible barrier to development and implementation of the passport. On the other hand, Van Gansewinkel states that without that information, there is no added value to usage of the passport. "What is a passport without a picture?" (Van Gansewinkel, 2012, interview).

Several suggestions are made to circumvent the confidentiality issue. Philips and Desso argue that it is important to keep the first step of the implementation process simple. One can think about only implementing a subset of the whole resources passport. This subset will not touch upon proprietary information. Slowly, the information in the passport can be extended.

Ahrend suggests implementing a treasury. This treasury functions as an intermediary between company A and B. Company B needs the material information of a component from company A, yet two mixtures within the component are confidential. Then company A discloses this information to the treasury, who checks whether the mixtures are in accordance with the requirements of company B. If this is the case, the classified information will receive approval and company B can continue with the component. The disadvantage of this system is that there need to be multiple treasuries to handle requests from the same sector. Plus it is time consuming and has a high administrative burden.

Desso has another proposal to circumvent disclosure of the composition of specific proprietary mixtures. They suggest reporting on a composite level, instead of detailed material reporting. Another suggestion is the provision of a description of the function of the mixture, and suggestions for what it could be used for. In that case, interested parties can contact the producer via the information on the passport, if they want more information about the mixtures, its functions and applications.

InterfaceFLOR adds that currently every producer can already discover the material content and composition of their own products or those of the competitor by sending the product to a specialized lab.

4. Quality of the information

One concern all companies have is that producers filling out the information themselves makes the system susceptible to fraud. To prevent that, all companies agree that the information entered into the system should be subjected to an independent control or check. This independent check generates credibility to the passport by adding a layer of objectiveness. The companies suggest that this independent check could be executed by an already existing independent organization conducting similar tasks. This prevents overlap between organizations and results in a better learning curve. Suggestions mentioned are Agentschap NL, Euroflower, Milieukeur, or sector specific organisations like the Institut Bauen und Umwelt and GUT for flooring.

On the contrary, an independent validation of the information makes the whole process less decisive, more bureaucratic, and more expensive. This might clash with the ambition of creating a dynamic passport. A suggestion by Desso is to, in line with GUT, not check every product, but regularly take several samples from the market.

5. Presentation of the information

As stated under element one, the information in a resources passport needs to be filled out by the producers of that product or component. Philips, for example, manufactures hundred thousands of products composed of over three million components bought from over tens of thousands of suppliers, who source from over thousands of suppliers. The composition of the components and the suppliers of Philips and their own suppliers vary continuously. Streamlining information exchange, keeping it comprehensible and up-to-date, is a daunting task. The seven companies agree that suppliers will need to provide similar information to multiple costumers. If there is no standardized format for all supply chains, this will cause confusion, an enormous administrative and financial burden, and be impossible to manage. A format that keeps the administrative burden as low as possible is thus a requirement. By making sure that everyone operates by the same standardized format, everybody deals with an equal burden and the system will be manageable.

As already mentioned, Ahrend, Desso, Philips and VAR state that the information in a resources passport should be open and accessible to everyone. InterfaceFLOR, Van Gansewinkel and Van Houtum believe the resources passport's added value is mostly in business-to-business relations. This means that detailed material information is not something of interest to consumers. Yet, they believe the information should be disclosed when asked.

InterfaceFLOR and Philips remark that it might be necessary to present the information for consumers in a different format than the information for businesses. Philips suggests disclosing the supply chain information on a business-to-business level, while consumers that have interest should be directed to information on the standard product website. This, as opposed to Ahrend, Desso and VAR who believe the passport should be the same format for consumers as well as for businesses. However, Ahrend suggests that to improve the readability, on top of the (physical) resources passport one sheet is added that provides a summary with all basic information of interest to consumers.

Desso, although having no problems with disclosing information to anyone, is opposed to usage of the resources passport as a marketing tool. They want to prevent it from solely being a label that could be used as another Unique Selling Point for products.

6.3 Format of similar information exchange systems

In this section three information exchange systems are analysed on how they address the five format elements. These three systems have been selected on the following criteria: addressing resources, dealing with information sharing throughout the supply chain and dealing with various types of users. The analysis is conducted from the perspective of companies using the scheme.

6.3.1 Environmental Product Declarations (EPD)

Contextualization

An Environmental Product Declaration (EPD) is defined as "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information" (DG Environment, 2002: 18). The overall goal of EPDs is "through communication of verifiable and accurate information, that is not misleading, on environmental aspects of products and services, to encourage the demand for and supply of those products and services that cause less stress on the environment, thereby stimulating the potential for market-driven continuous environmental improvement" (Manzini et al., 2006: 122). The intent is to enable fair comparison of products based on their environmental performance. This enables any product to be accompanied by an EPD, also products that are not the best in their class (Magerholm Fet, Skaar & Michelsen, 2009).

The demand from the business sector and society for quantified environmental information about products increased over the last decades. Additionally, there was a need for simplified environmental information exchange used in purchasing and procurement by businesses as well as consumers. Also, companies themselves needed the environmental information to support the product-related work they conduct, like eco-design, energy efficiency improvement etc. Since the 1980s coordinated and uncoordinated environmental labelling programmes took off in several countries, resulting in a growing diffusion of these instruments. These documents were mostly unverified, incomparable, selective and incomprehensible. This necessitated the need for rules and has forced among others the International Organisation for Standardization (ISO) to develop specific standards. The idea for EPDs was first proposed in 1994 by a member of the US Delegation to the ISO Technical Committee 207, Sub Committee 3 (TC207/SC3) (DG Environment, 2002). At that time the aim was to provide consumers with environmental product information in the form of unweighted lifecycle inventory data. Over the years this resulted in the development of Environmental Product Declarations Type III in the ISO 14025 standard released in 2006. Up until now, EPDs are voluntary instruments. Companies can go to an independent national or international EPD scheme that offers a program to develop and communicate EPDs. There is no estimated about the total number of EPDs created.

Creating an EPD that complies with the ISO 14025 standard must meet the following three criteria/ steps (InterfaceFLOR, 2012):
1. Use Product Category Rules (PCR) for the relevant product type
2. Be based on a Product Life Cycle Assessment (LCA) according to ISO 14040 standards
3. Provide an EPD Report certified and signed by an outside expert
When assessing the five format aspects for EPDs, these three steps will be recurring.

1. Provision of the information

Regarding step one: a "PCR is a set of specific rules, requirement and guidelines for developing the EPD for one or more products that can fulfil equivalent functions – called the product category. A PCR provides information about the functional unit, system boundaries, impact categories and data quality and other parameters for the underlying LCA" (Meissner Schau & Magerholm Fet, 2007: 256). Examples are PCRs for books in print and machine-tools for drilling or milling metal (IEPDS, 2012). All manufacturers of carpet tiles, when creating an EPD, will have to comply with the PCR for carpet tiles and the specified predefined parameters. The use of PCRs ensures consistency regarding methodology, data and calculations, which enables comparison of EPDs. It is recommended by ISO that all PCR documents are drafted in an open and participatory consultation process, to ensure the use of product specific knowledge. Contributors to the development of a PCR are companies, research institutes or official organisations (ibid). So a company wanting to create an EPD either searches for the relevant PCR or contacts the EPD program operator to develop one for their product group.

Step two constitutes the conduction of an LCA. The PCR provides the common format per product category in which the LCA data is presented. LCAs requires extensive data and therefore are time intensive and thus costly (IVM, 2012). Moreover, the quite complicated procedure of conducting an LCA requires expertise, either in-house or external (ibid). To ease the conduction of an LCA, general databases have been established, like Ecoinvent, that provides transparent life cycle inventory (LCI) data and LCA data (Magerholm Fet, Skaar, and Michelsen, 2009).

The third step consists of producing a certified EPD Report signed by an outside expert. The compilation of the report is done by experts within the company, either with or without external help. There are various certified validators, that can be hired to conduct the external validation of the EPD report.

The information within an EPD holds true for a single product or service. EPDs are characterised by limited validity, mostly three years. After this time period the EPD has to be revised if the validity is to be extended.

2. Storage of the information

Firstly, PCRs are stored and accessible online in databases among others on the ISO and various EPD Scheme websites. To ease the conduction of LCA's, especially for SMEs, specific online databases, like Ecoinvent, have been created. The standard LCA data applied to calculate the environmental consequences of a company's product from cradle to grave, is stored internally on in-house servers. The main results from the LCA are eventually published in the EPD report.

The EPD report itself is publicly accessible on the website of the specific EPD Scheme that has registered the EPD and the website of the company itself. These reports can also be printed and attached to the physical product as desired.

3. Access to the information

Firstly, PCRs are publicly accessible to anyone interested. Although the development process is open to various stakeholders, information is not accessible to any layman, only the results are.

The general LCI/LCA data gathered in the databases is publicly accessible. However, the application of this data to a specific product or service is not publicly accessible. Only the main results required for the EPD are accessible in the externally validated EPD report. The EPD report itself is publicly accessible to anyone interested. The report contains detailed material composition data, some classified as proprietary. An example is depicted in table 6.1.

Table 6.1 Example of detailed report on the material content in an EPD. Source: IBU, 2011: 6.

Table 4: Composition and characteristics

Construction Layer	Material	Mass [%]			Renewable Ressource	Availa-bility	Origin
		LC1	LC2	LC4			
Total Pile layer	Solution dyed polyamide 6	12,6	17,3	22,1	no	limited	Europe
Carrier	Polyester/ polyamide, nonwoven	2,2	0,7	1,9	no	limited	Europe
	Polyester nonwoven **post-**consumer recycled	–	1,5	–	no	abundant	Europe
Precoat Bonding Layer	SBR				no	limited	Europe
	Limestone	5,0	13,8	4,1	no	abundant	Europe
	Antistaticum				no	limited	Europe
	ATH	–		–	no	limited	Europe
	Limestone, pre-consumer recycled	14,0	1,5	11,2	no	abundant	Europe
Structural Graphlex® Backing	Bitumen				no	limited	Europe
	SBR	21,2	34,4	19,5	no	limited	Europe
	Limestone				no	abundant	Europe
	Limestone, pre-consumer recycled	43,1	28,9	39,5	no	abundant	Europe
	Glassfleece	0,8	0,7	0,7	no	limited	Europe
	Polypropylene, nonwoven	1,1	1,1	1,1	no	limited	Europe

4. Quality of the information

Before a PCR is officially approved, a review procedure is conducted by the Technical Committee of the international EPD system, consisting of PCR, LCA, and EPD experts from different working fields. Besides the necessity of official approval the validity of PCRs is specified to a pre-determined time period, after which it is re-assessed and if deemed necessary adjusted.

Before the EPD report can be published, the LCA data en the data handling presented in the background report, have to be subjected to an independent verification and registration. This verification process can be conducted by either an individual expert, certification body, or an organisation licensed for an "EPD® process certification" by a certification body (IEPDS, 2012). As a last step, the EPD needs to be officially registered at the EPD scheme, after which the applier receives a registration number and the EPD can be published.

5. Presentation of the information

Several countries have developed national EPD schemes, of which most do comply with the ISO 14025 standard (DG Environment, 2002). There is one international EPD scheme provided by the Swedish Environmental Management Council. Other national schemes complying with ISO 14025 are the Building Research Establishment or BRE operating from the United Kingdom, EPD Norge: the Norwegian EPD foundation, Institut Bauen und Umwelt or IBU, operating from Germany, and the French EPD Scheme called Fiches de Déclaration Environnementales et Sanitaires, in short FDES.

Even though there are strict rules laid out in ISO 14040 and 14025 that must be followed when creating an EPD, these rules still leave many aspects of the PCR and EPD format up to individual EPD schemes. Some of the differences between the schemes result in considerable variation in the results of EPDs. This is mainly due to differences in the scope, boundaries and underlying assumptions of the PCRs. Table 6.2 provides an example of the difference between four larger schemes for building materials.

Table 6.2 Comparison of the differences between four large schemes on building materials. Source: PE International, 2012, what are EPDs.

	UK	France	Germany	Sweden
Scheme	BRE Environmental Profiles	Fiche de Declaration Environmentale et Sanitaire (FDES)	IBU EPD	International EPD® system (Environdec)
Scope	Cradle to Grave, including 60 year study period	Cradle to Grave, including study period (normally 50 years)	Cradle to Site plus optionally transport use and/or End of Life (EOL) stage	Cradle to Gate plus optionally transport use and/or End of Life (EOL) stage
Declared Unit (DU) or Functional Unit (FU)	FU: product in 1 m² building element over 60 year study period	DU: Product (e.g. m³/kg) over study period	DU: Product (e.g. kg/m³)	DU: Product (e.g. kg/m³)
End of Life recycling	Allocation from primary to recycled based on primary to scrap value	System boundary at stockpile. No allocation over system boundary	EOL modelled based on impact of disposal and any recycling, plus benefits of recycling	Waste processing / recycling included until waste has a value.
Verification	BRE Global verify LCA. Manufacturer data is audited and certified by BRE/BBA	From 2012, independent third party verification by verifiers certified by AFNOR required	Independent third party verification by verifiers appointed by IBU	Independent third party verification. Manufacturer can select from a list of approved verifiers

As table 6.2 shows, only when the same PCR has been used and all relevant lifecycle stages are included, can an EPD be compared. Moreover, comparison is only possible when functionality and use are considered. The functional unit has to be identical. For example: an EPD for 1m^3 of cement cannot be compared with an EPD for 1 kg of concrete (PE International, 2012).

6.3.2 International Material Data System (IMDS)

Contextualization

The IMDS is a database which permits Original Equipment Manufacturers (OEMs) to identify, archive and maintain all materials used for the production of motor vehicles plus identify the original manufacturer of the materials and components of which the vehicle is composed. Hence, IMDS is a practical implementation of a business-to-business material declaration for the automotive industry (Schischke et al., 2005).

Annually, end-of-life vehicles generate around 9 million tonnes of waste in the EU. To be able to better manage this waste stream in 2000 the EU adopted the End-of-Life Vehicle Directive (ELV). By legally demanding from OEMs that they recollect and recycle all domestically used motor vehicles, the EU, via the ELV Directive, is asking the automotive industry to close the loops on the manufacturing of motor vehicles and asks them to rethink design in a more environmentally friendly manner (Crotty, 2006). To be able to do that, the OEMs need to know exactly what a product is composed of and how it is put together. Compliance with both regulatory targets requires manufactures to calculate and disclose the recycling ratio and recycling implementation ratio[53]. Both need to be approved and certified. Moreover, the use of hazardous substances needs approval. Concluding, enormous amounts of data need to be collected. However, OEMs are primarily engaged in the assembly of finished components. Although involved in the design of the vehicle, they subcontract the manufacturing of the individual components to a diverse chain of suppliers. Therefore, without involving the supply chain, OEMs will never be able to oblige to the requirements set out in the ELV Directive. If the OEMs would individually develop a system to fulfil the requirements, there would be large variations in the information disclosure requests send to component or sub-assembly

[53] "The recyclable ratio is the portion of vehicle weight for which there is a possibility of recycling (theoretical value). The recycling implementation ratio is the portion of weight actually recycled by the automobile manufacturer from vehicles taken back" (Iishi et al., 2003: 46).

manufacturers, creating confusion if these would supply various OEMs, plus it would require considerable expenses for the development and maintenance of similar systems. Therefore, in the late 1990s, eight American and European automotive manufacturers, namely: Audi, BMW, DaimlerChrysler, Ford Motor Company, Opel, Porsche, Volvo and VW, in conjunction with the German company EDS (who provided the development and operation of the system, now called HP) decided to jointly create a system for this sector. A system that can be used throughout the world, in which this kind of information and possibly more can be gathered in the same format and with equal burden. Currently, over 100.000 component suppliers and OEMs use the IMDS (HP, 2012: Engage)

The three goals in establishing the IMDS are: 1) limiting the use of hazardous substances throughout the lifecycle of vehicles plus avoidance of four specified substances; 2) Design vehicles in such a manner that they can easily be recycled; and 3) Increase the amount of recycled materials in vehicles (Ishii et al., 2003).

1. Provision of the information

To identify which materials are present OEMs need Material Data Sheets (MDS) from suppliers who have supplied components that make up the end-product. An MDS is “a logical data unit and constitutes a complete information package for a part” (IMDS, 2012, user manual: 23). “Every component, subcomponent, semi-component or material has its own MDS. Each data sheet is built for the specific item and the material it is composed of” (Jahn, 2009: 7). Each MDS has its own particular identifier, corresponding to the roof-company number and version number. All MDS are built in accordance with a predefined tree structure. To create an MDS one generally starts with defining the various components as specified in the BOM.

As Ishii (2003) specifies, about 30 items per component have to be registered, and for full featured products this requires tabulation of information of about 1500 parts. Large-scale investigation regarding material information on pre-existing and new parts is conducted, thereby generating collaboration between the various departments, like design, and procurement, of companies. Whenever components change the MDS needs to be updated.

Recently the possibility to send an MDS request to suppliers has been added to the IMDS system, so as to gradually move from a ‘push’ to a ‘pull’ process. Hence, suppliers need to log in regularly to see which data they are required to submit.

2. Storage of the information

When a company fills out MDS’ within the IMDS system they needs to register their company online; free of charge. With their unique identity number they get access to the protected servers at HP where they can create MDS and exchange information. When exchanging information, the data never leaves the servers of HP, but access is granted.

Some tier 1 companies (direct suppliers to OEMs) and OEMs purchase a basic license. This enables them to download IMDS to an in-house system which helps manage the large amount of data and analyses the product lifecycle.

3. Access to the information

Each so-called ‘roof’ company receives its own ID. The roof company can be comprised of many organizational units[54] which have their own ID corresponding with the roof company ID. As long as the MDS is not released for internal use or sent to other companies, no other person or company can access the data. When a MDS is created and ready to be sent to a costumer, it first needs to be internally released, to a self-selected group of people. Next, the most common action is to ‘send’ the MDS to the costumer, who can accept or refuse the MDS, in case information is missing. Another option is to ‘publish’ the MDS, which means the information will be accessible to every IMDS user. Most companies do not accept published data, since published data does not have an ‘accept’ option. This means that companies cannot reject the data when flawed or incomplete. The majority of the MDS is hence not publicly accessible.

HP created a system in which the data never actually leaves the protected server area, but links are established to be able to view the data, only for viewers selected by the creator of the MDS.

[54] “An Organizational Unit (Org Unit) is an entity that facilitates data management in the company” (http://www.mdsystem.com/html/data/OrganizationalUnitsDecoded.pdf) These can thus be various division or locations of the same company.

To deal with confidentiality issues, there also is a possibility to flag substances as confidential or proprietary on the MDS. These substances can only be viewed by others that are identified as 'trust users'. Not more than 10% of the substances that comprise a product can be flagged as confidential nor can legally prohibited substances.

When an MDS of, for example, a second tier company is attached to the MDS of the first tier company who sends it to their costumer, the costumer will be able to see the tree structure but not the supplier data (IMDS, 2012, user manual).

4. *Quality of the information*

When a MDS is created and ready to be sent to a costumer, it first needs to be internally released. Besides a double-check within the company, the system will check for anomalies in the MDS, calculation mistakes etc. Moreover HP developed the Integrated Corporate Material Management System (icm2) which enables automatic integration of data from various existing systems and results in higher quality data input (ibid).

5. *Presentation of the information*

The IMDS is a business-to-business tool that does not have a special interface for consumers. The database has a unified format.

6.3.3 Registration, Evaluation and Authorisation of Chemicals (REACH)

Contextualization

"REACH is a landmark in European chemicals regulation as it shifts the burden of evidence from public institutions (Member States or EU agencies) to the producing or importing companies" (IMV, 2007: 11). In the White Paper '*Strategy for a Future Chemicals Policy*´, published February 2001 the European Commission calls for the development of a system that deals with new and existing chemicals[55]. In 2003, a comprehensive plan to reform the existing chemicals policy under REACH (Registration, Evaluation and Authorisation of Chemicals) legislation was put forth by the European Commission (EC). As opposed to existing policy REACH provided a harmonised approach and eliminated the differential treatment between new and existing chemicals. The existing legislation applied different, more stringent testing standards to 'new' chemicals. Yet, this resulted in a very slow pace of risk assessment of 'existing' chemicals. Only 27 existing chemicals had a completed risk assessment in 2004, while around 30.000 existing chemicals would be subjected to the REACH legislation. Contrary, approximately 4000 new chemicals were introduced in the EU (Hester et al., 2005; EC, 2007).

Additionally, the former system was thought to hamper research and innovation, thereby negatively affecting the competitive advantage the EU had previously had over the US and Japan (European Commission, 2007). This was due to the fact that new chemicals had to be notified and tested from volumes over 10kg annually, while this was not necessary for existing chemicals. Consequently, this policy resulted in favouring the use and development of existing substances over new ones. Moreover, harmonization would reduce the scope of trade and investment distortions, plus would make it cheaper for exporters to the EU to comply with regulatory requirements.

Lastly, since the existing chemicals account for a large portion of the chemicals used in the EU, better management would result in significant health benefits. The EC estimated that by reducing the disease burden by 0.1 per cent the public health benefits of REACH could be around € 50 billion in a 30 year period (ibid).

Eventually, REACH came into force June 1, 2007. The aim of REACH is to "ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of substances, as well as the free circulation of substances on the internal market while enhancing competitiveness and innovation" (European Parliament & Council, 2006: 47). Thereby REACH covers "all substances whether manufactured, imported, used as intermediates or placed on the market, either on their own, in preparations or in articles, unless they are radioactive, subject to customs supervision, or are non-isolated intermediates" (European Commission, 2007: 6). REACH will gradually come into force up until 2018.

[55] Existing chemicals are "chemicals that were already on the market before new EU legislation on chemicals came into force 18 September 1981". New chemicals were marketed after that date (Combes et al. 2003: 7).

For industry to be held responsible that chemicals on the European market do not negatively affect human health or the environment, requires knowledge regarding the properties and risks of the substances used (European Commission, 2007).

1. Provision of the information

Since the section on REACH in chapter four already provides a brief explanation of the workings of REACH, the explanatory content is kept to a minimum. All producers and importers of chemicals used in volumes of 1 tonne or more annually, must register them with the European Chemicals Agency (ECHA). The number of substances that fulfil the criteria is around 30.000. Thereby it is important to note that only substances, not the actual preparations or finished products, are subject to registration (ECHA, 2012).

Registration requires the submission of a technical dossier, for substances in quantities of 1 tonne or more per year. Additionally, a chemical safety report has to be submitted for substances that are used in quantities of 10 tonnes or more annually[56]. This information needs to be communicated to EACH in the form of a registration dossier containing the substance's hazard information, possible health or environmental risks and possible controls (ibid).

Relevant for the provision of the data is the aspect of 'data sharing' within the registration requirements of REACH in accordance with the "one substance, one registration" principle. Importers and manufacturers of the same substance need to jointly register that substance at ECHA in order to reduce animal testing and compliance costs for the industry. This is done by means of obligatory participation in Substance Information Exchange Fora (SIEFs). When the data to fulfil the registration requirements is not available, registrants need to submit specific testing proposals, that need to be approved by ECHA, before testing can take place (ibid). This means that new registration dossiers need to be made only when new substances are imported, manufactured or the legislative requirements tighten.

2. Storage of the information

There is no specific IT system available to support the information exchange that takes place in the SIEFs. The completed registration dossiers per substance need to be electronically submitted to ECHA via REACH IT Portal and are stored on their servers (ECHA, 2012).

3. Access to the information

The focus is on substances, thus not on the specific composition of substances in products. However, the composition of substances can also be confidential. Via the SIEFs data sharing occurs directly between the manufacturers and importers of the substances. An inquiry to ECHA forms an indirect route to direct exchange of data. This information is only accessible to the companies and organizations involved in the SIEFs. Data sharing from manufacturers and importers to distributers and users, mainly occurs via the use of material safety data sheets (MSDS), that also include relevant Exposure Scenario's developed in the chemical safety report. These MSDS are publicly accessible, yet they only report on a fraction of the information present in the registration dossiers (ECHA, 2012).

ECHA is obliged, in accordance with Article 2 of the REACH regulation, to publish the information submitted via the registration dossiers online, free of charge (EC/1907/2006). Companies are allowed to register substances separately due to confidentiality reasons or exceptionally high costs. Registrants may also request ECHA to keep certain pieces of information confidential[57] for a certain price. ECHA decides whether or not to grant permission. As already stated in chapter four, no proprietary information is publicly available (ECHA, 2012).

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[56] The technical dossier includes the following information: "substance identity, physicochemical properties, mammalian toxicity, ecotoxicity, environmental fate, including abiotic and biotic degradation and, information on manufacture and uses as well as risk management measures" (ECHA, 2012: information requirements). There is a gradual increase in information requirements the higher the tonnage of the substance. These requirements are set out in Annexes VI to XI. The chemical safety report documents include the following steps: "(1) Collection and generation of information on intrinsic properties of the substance, (2) Human health hazard assessment, (3) Physicochemical hazard assessment, (4) Environmental hazard assessment, (5) Persistent, Bioaccumulative and Toxic (PBT) and very Persistent and very Bioaccumulative (vPvB) assessment". If, after these steps, the conclusion is that the substance is hazardous, the following steps are also needed: (6) Exposure assessment and (7) Risk characterization (ibid).

[57] Detailed rules regarding confidentiality are set out in Regulation (EC) No 1049/2001 of the European Parliament and the Council of 30 May 2001.

4. *Quality of the information*

When the registration dossiers are submitted to ECHA there are three types of evaluations that can be carried out:

1. Compliance check of the submitted dossiers by registrants: ECHA tests whether the registrants have fulfilled the requirements laid down in the REACH regulation (ECHA, 2012).
2. Substance evaluation: ECHA in cooperation with the Competent Authorities of Member States evaluate whether substances pose a risk to human health or the environment. An approved information request will be send towards the registrants if concern arises. The evaluation may conclude that the risks are under control, or may lead to an EU-wide proposal for risk management measures (ibid).
3. Examination of testing proposals submitted by registrants: ECHA checks the proposals so as to prevent unnecessary animal testing, repetition of existing tests, and poor quality tests (EC, 2007). Third parties, like universities, are also invited to provide information that could prevent unnecessary testing.

5. *Presentation of the information*

ECHA specifies that the format of all registration dossiers must be in accordance with the International Uniform Chemical Information Database (ECHA, 2012). Companies are free to use any tool in drafting the registration dossier. To communicate the risks to distributers and users, Material Safety Data Sheets (MSDS) are employed, that also all have the same format. There is no information exchange format or instrument to send information from distributers and end-users to manufacturers and importers.

6.4 Comparison of interpretations of format aspects

Table 6.3 provides an overview of the opinion of the seven Dutch frontrunner companies about the five format aspects. Table 6.4 provides an overview of the practical interpretation of the same aspects by three selected information exchange systems: EPD, IMDS and REACH.

Table 6.3 Companies' opinions about the interpretation of the five format aspects.

Company	Provision & update	Storage	Access	Quality	Presentation
Ahrend	Every step of the supply chain, when composition of product changes	Online and physical document	Public, with possibility for confidentiality	Independent validation of data	Same format for every user (also consumers)
Desso	End-producer, when composition of product changes	Online	Public, with possibility for confidentiality	Independent validation of data	Same format for every user (also consumers)
InterfaceFLOR	Every step of the supply chain, when composition of product changes	Online	Restricted to business relations	Independent validation of data	Different format consumers
Philips	Every step of the supply chain, when composition of product changes	Online	Public, with possibility for confidentiality	Independent validation of data	Different format consumers
Van Gansewinkel	Manufacturer, when composition of substances change	Online	Restricted to business relations	Independent validation of data	Same format
Van Houtum	Every step of the supply chain, no opinion	Online	Restricted to business relations	Independent validation of data	Same format
VAR	Every step of the supply chain, when composition of product changes	Online	Public, with possibility for confidentiality	Independent validation of data	Same format for every user (also consumers)

Table 6.4 Practical interpretation of five format aspects by similar exchange systems.

System	Provision & update	Storage	Access	Quality	Presentation
EPD	End-producer, 3 year revision of EPD	Online	Public, except for LCA calculations	Extensive independent validation of every step of the process	No single format

IMDS	Every step of the supply chain, revised at least once a year	Online on secured server of HP	Restricted to a selected group	Internal quality check	Same format for every user
REACH	Supply chain, when composition of substances change	Online	Once submitted public, unless otherwise decided by ECHA	Dossier quality and substance evaluation by ECHA	Same format for every user

This comparison shows that the majority of the interpretations of the format aspects are very similar. For the provision of information most companies think that it should be provided at each step of the supply chain. Two schemes do provide information in this manner. Desso only supports this option when it is obligatory for everybody. Otherwise competitors can free-ride on Desso’s efforts. Since the EPD is not obligatory, the information gathering to complete an EPD is initiated by the end-producer. Scientific literature confirms that, by lack of a central authority in the supply chain, cooperation should be negotiated and depending on the goal of the instrument, information should be pushed upstream or pulled downstream (Lee & Whang, 1998). Moreover, all companies argue for, and similar systems have a regular update of the information. This similarly aligns with the scientific literature that states that frequent updating of information leads to more effective supply chain management (Mentzer et al., 2000).

Regarding the storage of the information, only Ahrend wants a physical version of the passport. They see an added value in involving the costumer in the return collection process at the procurement stage. Keeping the physical version up to date is a challenge. The literature affirms that information technologies and digitization enable more efficient supply chain information exchange. With each actor being responsible for its own data, Bechini et al. (2008) suggest to store the information on in-house servers and only pull the relevant information to a centralized database when requested.

The format aspect ‘access to information’ has the most diverse answers. Confidentiality issues are seen as one of the most important barriers to implementation of the resources passport. However, there are ways to circumvent this issue, as reflected in the answers of the companies and the manners in which the EPD, IMDS and REACH deal with it. Literature on this issue also mentions confidentiality of information as one of the major hurdles to information exchange (Lee & Whang, 2000; Smith et al., 2007). One of the suggestions to overcome this hurdle, done by Bechini et al. (2008), aligns with the suggestion of Ahrend to set up a data trustee or treasury.

All companies mention some form of quality assessment, most of them opt for an independent quality assessment. The IMDS is the only system with solely an internal quality assessment, yet automated and build into the system. The literature states that quality of information increases with the use of information technologies and digitization. A shared vision and trust in a supply chain also enhance information quality. The most common quality checks are conducted via partnership agreements or the usage of externally validated certification schemes (Li & Lin, 2006; Jain & Benyoucef, 2008).

Regarding the presentation of the information, only the EPD does not have a unified format. Otherwise all companies envision, and the other two similar systems have a unified format for every user, with some exception for a different format for consumers depending on how one intends to use the passport. The literature affirms this by arguing in favour of a unified format, with the possibility of presenting it in a decentralized model, adjusted to the needs of specific supply chain elements (Lambert, 2001; Sahin & Robinson, 2002).

6.5 Conclusion

In this chapter seven Dutch frontrunner companies: Ahrend, Desso, InterfaceFLOR, Philips, Van Gansewinkel, Van Houtum and VAR reflect on five format aspects relevant for the development of a resources passport. These aspects are: provision, storage, access, quality, and presentation of information. Also, the practical interpretation of these five format aspects by three similar information exchange systems is analysed. The outcomes have been juxtaposed with the scientific literature on these topics and the following conclusions are drawn: without a central supply chain manager there are various options on how to coordinate information provision. The selection of options depends on the reason of the information exchange. All companies think, and the three systems do regularly update the information. All envision or do store the information digitally, partially on in-house servers and partially in a connected centralized database. Confidentiality issues are one of the main obstacles to implementation of an information exchange instrument. Working with traceability information or data trustees are viable options to circumvent this issue.

The quality of the information can be guaranteed in various ways, trust and a shared vision are two of them. Independent quality checks can form the third. Lastly, all companies envision and the similar systems do present the information in a unified format. This still leaves the possibility to customize the information for different users.

CHAPTER 7

CONCLUSIONS AND CONSEQUENCES FOR THE DESIGN OF A RESOURCES PASSPORT

7.1 Introduction

In this chapter the results of the sub-questions addressed in chapters four to six are compared to each other and to the analytical framework established in chapter two. The outcomes of the empirical research are used to answer the main question of this research:

What should the content and format of a resources passport be, in order to successfully contribute to the achievement of the circular economy?

By addressing all sub-questions, one by one, a comprehensive answer to this central question is given. The chapter starts with a reflection on the need for and necessity of creating a circular economy in addressing resource scarcity (section 7.2). Subsequently, the roles and information needs of different actors in the supply chain in addressing scarcity are examined (section 7.3). After that, an overview is given of the extent to which Dutch and European policies address the circular economy (section 7.4). Following, an overview is provided of the scarcity-related needs and experiences of Dutch frontrunner companies in the circular economy (section 7.5). Next, an analysis is made of the relevant format aspects in the development of a resources passport (section 7.6). After that the content and format of a resources passport are identified (section 7.7 and 7.8). The chapter concludes with a brief reflection on the data (section 7.9).

7.2 Reflection on the need and necessity of a circular economy

This section reflects on sub-question one:

What is the need for and necessity of creating a circular economy in addressing resource scarcity?

In chapter two, consultation of scientific literature resulted in a framework for the description and assessment of the extent to which Dutch and European policies contribute to the circular economy and what the experiences and needs of Dutch circular economy frontrunner companies are. The data collection leads to several conclusions regarding the need for and necessity of a circular economy.

Research shows that resources will become more and more scarce in the coming decades. This is due to continued economic growth coupled with steeply rising demand for materials, with extensive material waste during a product's lifecycle, and with the lack of reuse and recycling of materials (SERI, 2009; Diederen, 2010; Ericson, 2010; MGI, 2011; UNEP, 2011; Reck & Graedel, 2012).

Europe and the Netherlands are characterised by large-scale import dependence on many critical metals and minerals. Scarcity, economic, political or physical, will in the longer term hamper economic growth, the spread of clean technologies and impede other innovations (Angerer et al., 2009).

The coming scarcity and its economic, political and societal consequences, have put addressing scarcity at the centre of attention in the political arena and within businesses (OECD, 2008; DGZ, 2011; European Commission, 2011). Currently, uncertainty or incomplete information about the specific determinants of scarcity do not form reasons anymore to ignore the irreversible risks of scarcity (Köhler et al., 2010).

In many arenas a circular economy, is the proposed solution to address scarcity of resources (European Commission, 2011; DGZ, 2011). Three schools of thought, form the foundation of a circular economy: Industrial Ecology, Design for Environment and Cradle to Cradle. Comparison and combination of the main tenets of these schools resulted in the identification of the four main principles of a circular economy:

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*
2. *The improvement and creation of end-of-life systems for flows of resources and products.*
3. *The creation of, preferably regional, networks of material exchange.*
4. *The collection, management and exchange of resource-related information.*

Preventing scarcity of resources is thus at the heart of a circular economy. The fourth principle forms a prerequisite for the attainment of the other three principles. These four principles have guided the research to assess the achievement of the circular economy in European and Dutch resource-related policies and in addressing the information needs satisfied via legislative compliance and privately used resource-related instruments.

In order to achieve these four principles large-scale exchange of information and materials is necessary. However, very few information and material exchange instruments have been created, and mainly on a small-scale. An explanation is that large-scale information exchange is more likely to evolve when there is a system already in place. However, the need for such a system develops on a local scale. Growing from a local to a larger scale requires trust, increases the costs of coordination, and often reduces the quality of the information (Li & Lin, 2006; Köhler et al., 2010). Yet, even companies' internal information exchange takes place in a non-systemic manner, and as a consequence, available information is not used to its potential (Beijerse, 2000).

Furthermore, it is important to note that information exchange is mainly driven by economic motives. Because recent price developments impacted the European and Dutch industries, economic motives are getting stronger. Only by exchanging information, companies can utilize the scarcity-related value creating levers, which relate to growth, return on capital and risk management (Sterr & Ott, 2004; MGI, 2011).

Most information gathered and exchanged does not focus on scarcity. Also, scarcity, until recently, never was a priority in the design or end-of-life phase of products (Luttropp & Lagerstedt, 2006; Vermeulen, 2006; Hagelüken, 2007). Within the environmental agenda, the focus has been on energy consumption and exhaust of CO_2 emissions.

With increased scarcity of resources the need for and necessity of a circular economy is an economic, social and environmental reality.

7.3 Reflection upon the role and information needs of supply chain actors

Principle four of the circular economy: the collection, management and exchange of resource-related information, is a prerequisite for the achievement of the other three principles. However, each actor in the supply chain only has a small piece of information. What information is needed by which supply chain actor is subject of analysis of the following sub-question:

What are the roles and information needs of the different actors in the supply chain in addressing resource scarcity?

To answer this sub-question, a scientific literature study has been conducted in chapter two. The results have been used to attain objectives III: understand to what extent current policies address resource scarcity and understand the lack thereof, and IV: understand the experiences and information needs of circular economy frontrunner companies in addressing resource scarcity. The following section describes the conclusions on the basis of that study.

Six supply chain actors have been identified as relevant for this research. These actors and the flow of resources through the supply chain are depicted in figure 7.1 (Parlikad et al., 2003; Jun et al., 2007; Köhler et al., 2010; EMF, 2011). The lifecycle of a product consist of three stages, namely BOL: Beginning-of-Life, MOL: Middle-of-Life, and EOL: End-of-Life.

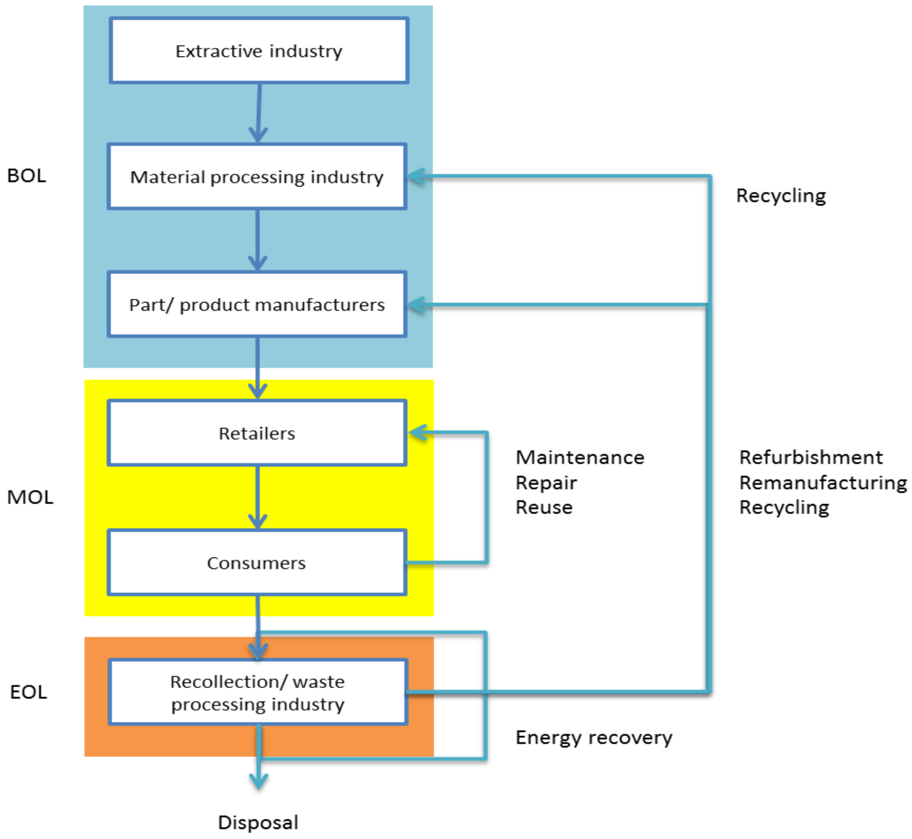

Figure 7. 1 Supply chain actors and resource-related activities. Source: based upon Parlikad et al., 2003; Jun et al., 2007; Köhler et al., 2010; and EMF, 2011.

When addressing scarcity, supply chain actors sometimes have a different role than their traditional role. For example, the procurement department usually searches for the cheapest materials available instead of tracking scarcity related developments, and communicating these demands to suppliers. Hence, the related information needs differ from the information actors traditionally gather and communicate (Hugos, 2011).

For the actors, extractive industry, material manufacturing industry, part and product manufacturing and recollection and waste processing industry, five internal departments have been identified as relevant in the exchange of information. These are management, research and design, procurement, marketing and environmental experts (Brezet & Van Hemel, 1997; Johansson, 2002; Crul & Diehl, 2007).

In total twenty-five unique information needs have been identified as necessary to address scarcity. These information needs are:

A: General scarcity-related information needs

A1 Material scarcity in the short/ medium / long term
A2 Price and supply security/ dependence of materials
A3 Current and future scarcity-related legislative requirements

B: Mining-related information needs

B1 Mine site/ origin
B2 Mining data
B3 Local circumstances/ environment at the mine site

C: Product-related information needs

C1 Physical structure of the product
C2 Material content and composition of products
C3 Material characteristics and properties
C4 Production processes used, plus specification on which material
C5 Initial lifetime of the product
C6 Product adaptations during usage
C7 Life extending possibilities

C8 End-of-life possibilities of the product
C9 Disassembly information

D: Company internal information needs

D1 Supply chain partners (including 2nd, 3th etc. tier)
D2 Position of scarcity on a strategic level within the company (goals, staff, time, budget)
D3 Market demand for products proactively addressing scarcity
D4 Product-related information of competitors products
D5 Guidelines for dealing with trade-offs resulting from substitution/ elimination of critical elements
D6 Where and how products are disposed of

E: Technology-related information needs

E1 Best available mining technologies
E2 Best available material manufacturing technologies
E3 Best available production technologies
E4 Best available technologies for end-of-life systems

A distinction is made between category C, and the other categories. The product-related information specifically provides the product information envisioned in a resources passport. The other categories provide generic and contextual information necessary to optimally use the product-related information. Each actor and internal department needs different kinds of information to address scarcity in their role. Figure 7.2 depicts which information actors can provide and need.

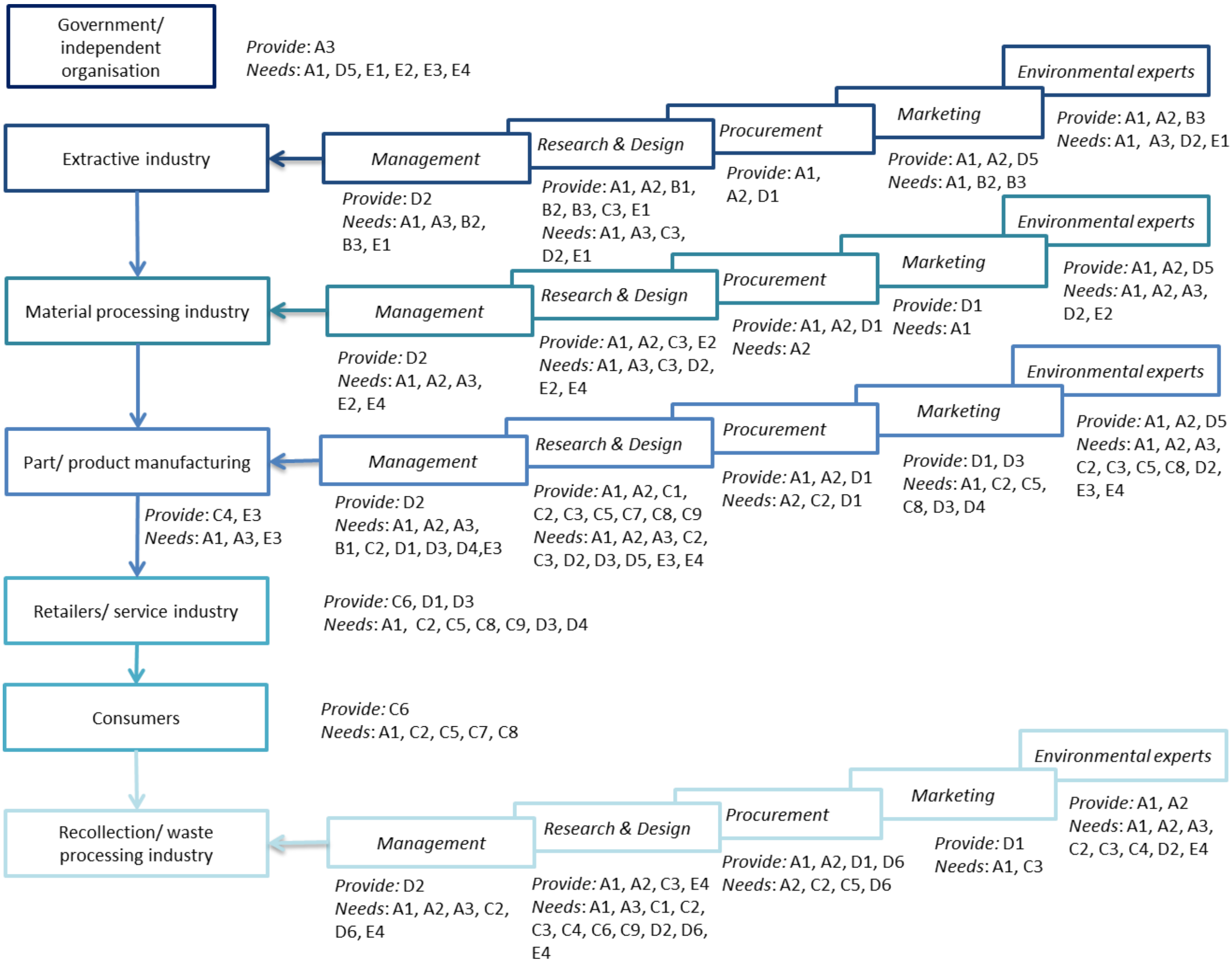

Figure 7.2 Information that supply chain actors can provide and need.

The actors in need of a specific type of information do not necessarily have this information themselves. The information could be present internally, but for example not exchanged between the design department and the marketing department. Furthermore, various internal departments could need the same information. Also, information in the hands of the extractive industry might not be known, yet wanted, by manufacturers. Hence, the exchange of information internally and through the supply chain is crucial for the achievement of a circular economy and the utilization of scarcity-related value creating levers by businesses. A government or independent organization is necessary to manage and coordinate the information exchange of some information needs.

7.4 Dutch and European policies addressing the circular economy

Now the roles and information needs of supply chain actors are identified, it is assessed if these information needs are already disclosed. When information is already known, the burden on companies to fill out the resources passport is lighter. This was an important prerequisite by De Groene Zaak in the development of the resources passport. European and Dutch policies require information exchange, for the most part mandatory. Already disclosed information can easily be part of the content of a resources passport. Therefore the following sub-question is:

To what extent do current European and Dutch policies address resource scarcity and the circular economy, plus how can the findings be explained?

This sub-question, addressed in chapter four, was answered by conducting a policy/document analysis. The framework built by answering sub-questions one and two, helped describe and assess the extent to which Dutch and European policies contribute to the circular economy, and satisfy the information needs identified as part of circular economy principle four.

An historical overview of resource-related policies shows that scarcity by itself has only recently been put on the policy agenda. This is mainly done in thematic strategies and action plans, which are less mandatory by nature. This confirms that scarcity has not been the main priority for a long period of time, also not within the environmental agenda (Luttropp & Lagerstedt, 2006; Vermeulen, 2006; Hagelüken; 2007, European Commission, 2011).

Current policy options to deal with material resources scarcity, as identified by the PBL (2011), focus mainly on circular economy principle one: the redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health. This is also reflected in table 4.2 about the contribution of European and Dutch resource-related policies to a circular economy.

One Dutch and ten European resource-related policies have been identified as possibly disclosing information about the twenty-five information needs. These are, in alphabetical order: the Eco-labelling Regulation (Eco-L), Energy Labelling Directive (En-L), Eco-Management and Audit Scheme Regulation (EMAS), Packaging and Packaging Waste Directive (PPWD), End-of-Life Vehicle Directive (ELV), Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), Waste Electrical and Electronic Equipment Directive (WEEE), Eco-design Directive (Eco-D), Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), Regulation on classification, labelling and packaging of chemical substances and mixtures (CLP) and the Landelijk Afvalbeheerplan 2009-2021 (LAP2). Eco-L and EMAS are voluntary regulations, the others are mandatory.

Only the ELV directive fully contributes to circular economy principles one to three. The fulfilment of these three principles by the other policies varies, with the Energy-labelling directive and CLP directive at the other end of the spectrum.

Disclosing information needs under principle four is characterized by publicly accessible information for three information needs: C3, C7 and C8[58]. C3 and C8 are disclosed via the REACH and CLP directives on the website of ECHA[59]. C8 is also disclosed via the PPWD[60] and the WEEE directive[61]. The information

[58] C3: Material characteristics and properties, C7: Life-extending possibilities, and C8: End-of-life possibilities.
[59] http://echa.europa.eu/information-on-chemicals
[60] http://eur-lex. europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L: 1994:365:0010:0023:EN:PDF
[61] http://eur-lex.europa.eu/LexUriServ /LexUriServ.do?uri=OJ:L:2003:037:0024:0038:en:PDF

for C7 is disclosed in application packs of the Eco-label directive, and can be found on page 16 of the application pack of notebook computers[62]. This only holds true for this specific application pack.

Complete information gaps exist for the following eight information needs: A1, A2, B1, B2, B3, C6, E1, and E2[63]. The information addressing the remaining 14 information needs, A3, C1, C2, C4, C5, C9, D1, D2, D3, D4, D5, D6, E3, and E4[64], is either partially satisfied, fragmented or only available to a selected group. Most of the information available is product-related. Thereby it must be noted that all of the directives and regulations solely apply to specific industries, product groups, or materials. For example, the (W)EEE sector is subject to more resource-related legislation, than industries producing non-electric products. The Eco-labelling directive and EMAS are mandatory in use.

The fact that many policies do not actively contribute to the creation of a circular economy, and that the majority of the information needs are only partially met, or not met at all, can be explained by the lack of an economic, political and/or physical necessity for closing the resource loops. Hence, resource-related information has never been gathered and obligated on a large-scale. Little action is currently taken at an EU level, due to the large differences between EU member states in economic performance, industrial profiles, resource needs and stocks, plus perspectives on the role of the government.

7.5 Scarcity-related experiences and information needs of companies

Besides via the fulfilment of legal obligations, information can also be disclosed via the use of companies' privately used instruments. Also, the content of a resources passport should align with the experiences and needs of companies that will eventually use the instrument. This section deals with the following sub-question:

What are the scarcity-related experiences and information needs of circular economy frontrunner companies in the Netherlands?

This sub-question, addressed in chapter five, has been answered by conducting a document analysis and interviews with representatives of seven Dutch circular economy frontrunner companies: Ahrend, Desso, InterfaceFLOR, Philips, Van Gansewinkel, Van Houtum and VAR . The four principles of the circular economy and twenty-five specific information needs as defined under principle four are used to describe and assess the experiences and information needs of these companies which lead to various conclusions.

Assessment of which laws the seven companies comply with, combined with the results from chapter four, reveals which information is already available to these companies in practice. The same information gaps as identified in section 7.4 apply here. Moreover, the data in table 5.2 illustrates the fact that legislation is industry and product-group specific. Philips and Van Gansewinkel comply with the most directives: ten out of eleven.

Seven privately used instruments have been identified as possibly disclosing information relevant to address resource scarcity. These voluntarily used instruments are: BOM, C2C, CAS, EPD, LCA, MSDS, and the REACH database. Analysis in accordance with the fourth principle of the circular economy (principles one to three are not relevant since these are single issue instruments) reveals that publicly accessible information is available for six information needs: C1, C2, C3, C4, C7, and C8[65]. A BOM presents information need C1[66]. CAS discloses information need C3 on their website[67]. An EPD publishes

[62] http://ec.europa.eu/environment/ecolabel/documents/ app_form_pcs.pdf

[63] A1: Material scarcity in the short/ medium / long term, A2: Price and supply security/ dependence of materials, B1: Mine site/ origin, B2: Mining data, B3: Local circumstances/ environment at the mine site, C6: Product adaptations during usage, E1: Best available mining technologies, and E2: Best available material manufacturing technologies.

[64] A3: Current and future scarcity-related legislative requirements, C1: Physical structure of the product, C2: Material content and composition of products, C4: Production processes used, plus specification on which material, C5: Initial lifetime of the product, C9: Disassembly information, D1: Supply chain partners (incl. 2nd, 3th etc. tier), D2: Position of scarcity on a strategic level within the company, D3: Market demand for products proactively addressing scarcity, D4: Detailed product-related information of competitors products, D5: Guidelines for dealing with trade-offs resulting from substitution/ elimination of critical elements, D6: Where and how products are disposed of, E3: Best available production technologies, and D4: Detailed product-related information of competitors products.

[65] C1: Physical structure of the product, C2: Material content and composition of products, C3: Material characteristics and properties, C4: Production processes used, plus specification on which material, C7: Life extending possibilities, C8: End-of-life possibilities of the product.

[66] An example thereof is http://www.billofmaterials.net /example.php

[67] http://www.cas.org/content/chemical-substances

information needs C1, C2, C4, C7 and C8[68]. The REACH database discloses information need C3[69]. Lastly, MSDS also address information need C3 as specific in Annex II of the REACH directive[70].

Information gaps are identified for nine needs: B2, B3, C6, D2, D3, D5, D6, E1 and E3[71]. For the remaining ten information needs, A1, A2, A3, B1, C5, C9, D1, D4, E2, and E4[72], information is either only partially available or available to a selected group.

Interviews with the seven companies about the management and use of the gathered resource-related data show an internal knowledge-broker is lacking. This is in accordance with the findings of the research of among others, Beijerse (2000). Non-disclosure agreements and the fact that the data itself is scattered over different databases or departments make the data hard to access within a company. The data is used for other purposes, but these purposes do not actively and innovatively contribute to addressing scarcity.

To ensure that an instrument like the resources passport is consistent with the practice of companies, the information needs of the seven frontrunners are examined. When the companies' suggestions of information needs (table 5.7) are compared to the information they already have access to via legislative compliance (table 5.8), and the use of private instruments (table 5.9), it shows that many suggestions are already covered. However, for most of the information needs covered, only partial information is available or available for a selected group. Moreover, most of the suggested needs are disclosed via privately used instruments, which confirms the fact that these seven companies are frontrunners and their experiences cannot be generalized. Additional measures need to be taken to fill the remaining gaps.

Table 7.1 combines all the data gathered in chapter two, four and five. It is important to explicitly mention that all of the directives and regulations solely apply to specific industries, product groups, or materials. The eco-labelling directive, EMAS and all the private instruments are voluntary in use. The colour orange (also underscored) indicates that only partial/ scattered information is available or available for a selected group. The colour green (also *italics*) indicates that the information is publicly disclosed by the directive regarding the subject of that directive. The numbers in the table indicate the number of directives disclosing information out of the total examined. For example, 4/9 means that four out of the total of nine directive disclose that information.

Table 7.1 Comparison of disclosure of scarcity-related information needs.

A. General scarcity-related information needs

		Disclosed by mandatory legislation	Disclosed by voluntary legislation	Disclosed by privately used instruments	Suggested by companies as part resources passport
A1	Material scarcity in the short/ medium / long term	No	No	2/7 (EPD, LCA)	Yes
A2	Price and supply security/ dependence of materials	No	No	1/7 (BOM)	No
A3	Current and future scarcity-related legislative requirements	No	1/2 (EMAS)	1/7 (LCA)	No

B: Mining-related information needs

		Disclosed by mandatory legislation	Disclosed by voluntary legislation	Disclosed by privately used instruments	Suggested by companies as part resources passport
B1	Mine site/ origin	No	No	3/7 (CAS, EPD, LCA)	No
B2	Mining data	No	No	No	No
B3	Local circumstances/ environment	No	No	No	No

[68] An example of an EPD in which this information is disclosed: http://bau-umwelt.de/download/CY6978 d166X128144 04465XY4402/EPD_IFF_2010111_E.pdf?ITServ=CY21f5c25dX13a1c244405XY658
[69] http://echa.europa.eu/information-on-chemicals
[70] An example of an MSDS is http://www.generalpaint.com/content/GeneralPaint/Html/General/Pages/for_your _business/technical_info/MSDS/52-216M.pdf.
[71] B2: Mining data, B3: Local circumstances/ environment at the mine site, C6: Product adaptations during usage, D2: Position of scarcity on a strategic level within the company, D3: Market demand for products proactively addressing scarcity, D5: Guidelines for dealing with trade-offs resulting from substitution/ elimination of critical elements, D6: Where and how products are disposed of, E1: Best available mining technologies and E3: Best available production technologies.
[72] A1: Material scarcity in the short/ medium / long term, A2: Price and supply security/ dependence of materials, A3: Current and future scarcity-related legislative requirements, B1: Mine site/origin, C5: Initial lifetime of the product, C9: Disassembly information D1: Supply chain partners, D4: Detailed product-related information of competitors products, E2: best available material manufacturing technologies, and E4: Best available technologies for end-of-life systems.

	at the mine site				

C: Product-related information needs

		Disclosed by mandatory legislation	Disclosed by voluntary legislation	Disclosed by privately used instruments	Suggested by companies as part resources passport
C1	Physical structure of the product	4/9 (En-L, ELV, WEEE, Eco-D)	No	4/7 (*BOM*, C2C, *EPD*, LCA)	Yes
C2	Material content and composition of products	7/9 (PPWD, ELV, RoHS, WEEE, Eco-D, REACH, CLP)	2/2 (Eco-L, EMAS)	5/7 (BOM, C2C, *EPD*, LCA, MSDS)	Yes
C3	Material characteristics and properties (including recyclability and toxicity)	5/9 (ELV, WEEE, Eco-D, *REACH*, *CLP*)	2/2 (Eco-L, EMAS)	6/7 (C2C, *CAS*, EPD, LCA, *REACHdb*, *MSDS*)	Yes
C4	Production processes used, plus specification on which material	5/9 (ELV, WEEE, Eco-D, REACH, CLP)	No	4/7 (C2C, *EPD*, LCA, MSDS)	Yes
C5	Initial lifetime of the product	1/9 (Eco-D)	No	1/7 (LCA)	Yes
C6	Product adaptations during usage	No	No	No	No
C7	Life extending possibilities	1/9 (Eco-D)	2/2 (*Eco-L*, EMAS)	3/7 (C2C, *EPD*, LCA)	No
C8	End-of-life possibilities of the product	7/9 (*PPWD*, ELV, *WEEE*, Eco-D, *REACH*, *CLP*, LAP2)	1/2 (EMAS)	4/7 (C2C, *EPD*, LCA, MSDS)	Yes
C9	Disassembly information	5/9 (ELV, WEEE, Eco-D, REACH, CLP)	1/2 (Eco-L)	2/7 (C2C, LCA)	Yes

D: Company internal information needs

		Disclosed by mandatory legislation	Disclosed by voluntary legislation	Disclosed by privately used instruments	Suggested by companies as part resources passport
D1	Supply chain partners (incl. 2nd, 3th etc. tier)	7/9 (En-L, ELV, RoHS, WEEE, Eco-D, REACH, CLP)	2/2 (Eco-L, EMAS)	3/7 (BOM, C2C, LCA)	Yes
D2	Position of scarcity on a strategic level within the company (goals, staff, time, budget)	No	1/2 (EMAS)	No	No
D3	Market demand for products proactively addressing scarcity	No	1/2 (EMAS)	No	No
D4	Detailed product-related information of competitors products	2/9 (ELV, REACH)	No	1/7 (EPD)	No
D5	Guidelines for dealing with trade-offs that result from substitution or elimination of critical elements	1/9 (Eco-D)	No	No	No
D6	Where and how products are disposed of	4/9 (PPWD, ELV, WEEE, LAP2)	No	No	No

E: Technology-related information needs

		Disclosed by mandatory legislation	Disclosed by voluntary legislation	Disclosed by privately used instruments	Suggested by companies as part resources passport
E1	Best available mining technologies	No	No	No	No
E2	Best available material manufacturing technologies	No	No	1/7 (CAS)	No
E3	Best available production technology	2/9 (Eco-D, LAP2)	No	No	Indirectly via the environmental footprint
E4	Best available technologies for end-of-life systems	3/9 (PPWD, WEEE, LAP2)	No	1/7 (EPD)	Yes

Information mentioned by companies, not reflected in information needs

	Suggested by	Relevance in addressing scarcity
Environmental impact/ footprint of a product	InterfaceFLOR, Van Houtum, VAR	Only relevant when used to assess the scarcity of a material. For example when energy use to extract a resource is high, high energy prices might result in scarcity. Otherwise not relevant.
Benefits beyond system boundaries	InterfaceFLOR	To unspecified to be relevant. Up to the manufacturers to include.

7.6 Format aspects relevant for the resources passport

Apart from an analysis of the possible content of a resources passport, an analysis of the format aspects that enable the resource passport to be effective is required. The following sub-question addresses this matter:

Which format aspects are relevant in the development of a resource passport?

To answer this sub-question, five relevant format aspects have been identified: provision, storage, access, quality and presentation of the information. These elements are analysed by means of scientific literature, a document analysis of three similar information exchange systems, and interviews with the seven companies. The findings are reported in the following section. Both the analysis of similar systems as well as the interviews enable and support a translation from theory to practice.

A complete comparison of the data gathered in chapter six shows that the majority of the interpretations of the format aspects is similar. Scientific literature, as well as the majority of the answers (from the interviews and analysis of similar systems), state that information should be provided at every step of the supply chain, and pushed up- or downstream from there (Lee & Whang, 1998). Also, theory and practice align regarding the regular updating of the information provided. This leads to more effective supply chain management (Mentzer et al., 2000).

The literature affirms the practical findings regarding the storage of information. This should be conducted online, preferably on in-house servers, that only provide the relevant information to a centralized database when requested (Bechini et al., 2008).

Confidentiality issues, addressed under the format aspect 'access to information', are seen as one of the most important barriers to implementation of the resources passport (Lee & Whang, 2000; Smith et al., 2007). Each similar information exchange system has found its own way to circumvent the issue. Companies also present a variety of solutions on how to deal with it. One similarity between the literature and practice is the solution of setting up a data trustee or a treasury (Bechini et al., 2008).

All companies mention some form of independent quality assessment, and all similar systems have some form of quality check embedded. The most common quality checks are conducted via partnership agreements or the usage of externally validated certification schemes (Li & Lin, 2006; Jain & Benyoucef, 2008).

All answers of companies and the majority of the similar information exchange systems reflect the need for a unified format for the presentation of a resources passport. Such a format still enables customization of the information, for a specific target group, by companies. The literature affirms this by arguing in favour of a unified format, with the possibility of presenting it in a decentralized model adjusted to the needs of specific supply chain actors (Lambert, 2001; Sahin & Robinson, 2002).

7.7 The content of a resources passport

Now that the results have been presented recommendations can be made regarding the content of the resources passport. Ideally all information needs should be disclosed and exchanged to address scarcity. However, there is a difference in the nature of the information needs, already reflected in the division into five categories (A-E). Category C: product-related information, forms the initial content of a resources passport for products. This category contains all product-related information, necessary to address scarcity via an instrument like the resource passport. However, this information without general scarcity-related information, companies internal information needs and technology-related information cannot be used to its full potential. Therefore, and in line with the results of the format aspect 'provision of information', a general database that pulls together companies' own data from in-house servers is recommended. The in-house servers contain companies' own information, which is send to a central hub of the database when required. The information in a resources passport forms a sub-part of this database that travels through the supply chain. Information needs like a company's strategy will be stored in this in-house database but will not be sent through the supply chain. The benefit of having all this information in one database is that it is easier to analyse, compare and, if necessary, share it. Moreover it is easier to provide different, customized interfaces for different users.

Starting with implementation of all information needs at once is unrealistic. The majority of the information needs is only partially available, non-disclosed or non-aggregated. This research specifically focused on the manufacturing, and the recollection, and waste processing industries. Their information needs are thus at the forefront of addressing resource scarcity. Figure 7.2 shows that five information needs are not initially relevant for the manufacturing and waste processing industries. These information needs are B2, B3, C7, E1, and E2[73]. These elements should not be left out, but they should not be part of the initial content.

Sterr and Ott (2004) state that for an information exchange system to develop and function optimally, it is important to keep the costs of coordination and administration as low as possible, while the quality of the information should be as high as possible. Therefore it is logical that the initial content of the database, including the resources passport, is formed by information that is already available. Information gathered to fulfil legal obligations is taken as the starting point. Voluntary legislation and instruments are not preferable, exactly because they are voluntary.

A: General scarcity-related information needs

A1 material scarcity in the short/ medium / long term, and A2 price and supply security/ dependence of materials, are not fulfilled by legislative requirements. They can be satisfied by combining data of several supply chain actors. Since the EU and the Dutch government have made a start with this analysis it only seems sequacious to build upon their efforts and include the information that is already available. Reports to build upon are '*Critical Raw Materials for the EU'* (European Commission, 2010) and *´Critical materials in the Dutch economy'* (CBS & TNO, 2010). These two information needs are necessary to contextualize the information presented in the product category. The involvement of an independent organization or the government in providing information need A1 could be beneficial to streamline the data and guarantee objectivity. Information need A3 current and future scarcity-related legislative requirements, is scattered over European and Dutch government pages. With minimal effort the information can be combined and included in the initial database.

B: Mining-related information needs

As discussed previously, only B1 mine site/ origin would be included initially. This information need is not disclosed by legislation. However, with the implementation of the Frank-Dodd Act in the United States the demand for this information increases. The instruments CAS, EPD and LCA already indicate the origin of the material on a more general, country or regional level. The heart of the circular economy is formed by the sharing of information and materials through a supply chain. Having knowledge about the supply chain is thus not an element that can be addressed later. It is recommended that element B1 is initially included on a general, country or region-wide level.

C: Product-related information needs

C1 the physical structure of the product, is described in four out of nine directives. However, the information is only partially or not publicly available. Yet, based on a BOM, this information is easy to retrieve. Therefore C1 should be included. Elements C2, C3 and C4 are the most rudimentary pieces of information necessary to achieve a circular economy via a resources passport. For C2, the material content and composition of products, seven out of nine obligatory directives touch upon this information need. Both the voluntary instruments touch upon it and the EPD even publicly discloses this information. Although it will not be easy for every sector to gather this information (also depending on the level of detail), it is nevertheless essential and should therefore be included. Discussions about the level of detail need to take place, and these discussions will also define the additional effort that is required to gather this data. C3 material characteristics and properties, is publicly available via the REACH and the CLP directive, and is therefore included. Similarly to C2, discussions about the level of detail need to take place, that will define

[73] B2 mining data, B3 local circumstances/ environment at the mine site, C7 life extending possibilities, E1 best available mining technologies, and E2 best available material manufacturing technologies.

the additional effort that is required to gather this data. C4 about the production processes used, plus specification on which material, just like C2 and C3 is important to be touched upon. Five out of nine directives address it and the EPD publicly discloses the information. Similarly to C2, it will not be easy for each sector to gather this information, however, a start should be made with collecting and sharing this information. Not much information is disclosed about C5, initial lifetime of a product, all the more since this touches upon the broader issue of business models build around the 'throwaway society'. The broader discussion about sustainable business models should be started, but it is recommended that this element should not be incorporated initially. The information for C6 product adaptations during usage, is not available, and it is therefore recommended to not initially include this element. C8, end-of-life possibilities of the product, is publicly disclosed in four directives: PPWD, WEEE, REACH, and CLP. The EPD also discloses this information and it should therefore be incorporated in the initial version of the passport. C9 disassembly information, is not only relevant for waste processers but also for the repair and reuse of a product. The information is not publicly disclosed by law or private instruments but is partially available in five out of nine mandatory directives. Since the element is also requested by the companies it should be included. In a pilot study the recommendation for initial inclusion of this need could be evaluated.

D: Company internal information needs

D1, supply chain partners, should be incorporated in the initial version. Incorporation also enables the sharing of information. Moreover, by including this element, companies are required to contact their up- and downstream suppliers and in this manner the information can be retrieved. The elements D2, D3, D4, D5 and D6 are not recommended to be included initially. D2, about the position of scarcity on a strategic level within the company, can be reported upon by the company itself in their annual report, and stored on the in-house servers. D3, regarding market demand for products proactively addressing scarcity, can also be reported upon internally. Disclosing this information now is irrelevant and would run into all kinds of competition and confidentiality issues that need to be addressed first. D4, product-related information of competitors products, is satisfied when a resources passport plus database is put in place. This element can thus only be disclosed in time. The discussion about D5, guidelines for dealing with trade-offs has only just started and is currently only relevant within companies. Moreover, objectivity of information is relevant and therefore a third party could be invited to help coordinate the data. This element is not included. D6, where and how products are disposed of, is currently only known in aggregates in the automotive sector. The efforts to include this element are even larger than to include elements like C2 and C4. Moreover, the applicability of this information is not as broad, and hence it should not be included initially.

E: Technology-related information needs

These information needs are not immediately relevant in the development of a resources passport, but more as contextualization. E3, best available production technologies, is partially available in two directives. Besides only partially being available, the information is mainly aimed at preventing pollution and not at addressing scarcity. The same holds true for element E4, best available technologies for end-of-life systems. Therefore, before these two elements can be taken up into a resources passport, an additional effort needs to be made. A suggestions could be for the government or an independent organisation to coordinate data gathering in cooperation with the specific industries. These discussions can start immediately.

Concluding, the following eleven information needs are initially included in the development of the database and the resources passport.

A1: Scarcity prospects per material
A2: Dependency rate per material
A3: Legislation the product/ materials need to comply with
B1: The origin of the materials used in the product
C1: Description of the physical structure of a product
C2: Description of the material content and composition of a product
C3: Characteristics of the materials used and possible recyclability/ toxicity
C4: Specification of production processes used
C8: Description of the end-of-life possibilities of the product
C9: Information on how to disassemble the product

D1: Indication of the supply chain partners

Discussion about how to address and include different information needs should start as soon as possible. Besides the exact formulation of initial content elements, discussion about, for example, measurement of product adaptations during usage, guidelines for dealing with trade-offs and where and how products are disposed of, should be initiated. Additionally, discussions between experts, industries and an independent third party are necessary to come to an objective and comprehensive overview of best available technologies.

7.8 The format of a resources passport

Based on a scientific literature analysis, similar information exchange system analysis and interviews, this research recommends the following:

The provision of the information that forms the content of the passport should be done by every actor in the supply chain. Actors themselves are responsible for management and exchange of their information and should push it up or down the supply chain when requested. Moreover, the information should regularly be updated. The definition of regularly depends on the specific information that needs to be provided.

Because companies are responsible for the management of their own information, the storage of the information should be online, on in-house servers that can provide the relevant information to a centralized database when requested. These in-house servers and the centralized database can be set up in line with the IMDS database. This means they are developed by the stakeholders, but operated and managed by an independent third party. This division between in-house servers and a central database also enables easy customization of the information within a company and to third parties.

Confidentiality issues regarding access to information are most certainly a topic that requires further discussion. Especially with the current advanced technological possibilities to retrieve the detailed material content of any product within the span of days. The initial focus of the passport will also guide the development of confidentiality guarantees. A suggestion would be to start with a simple solution to reduce unnecessary administrative- and time burdens. For example, disclosure only to a select group or person. However, discussions about and the development of more complex structures, like external certification or trustees, can start immediately. In this process discussions about how to guarantee the quality of the information should be taken into account.

Lastly, the resources passport should have a unified format. Such a format still enables customization of the information by companies. For example, if desired, communication of the information to consumers could take place via a one page summary. This summary can also be printed and attached to the product, if required.

7.9 Reflection on the data

This chapter provides the main results of this research. As stated previously, the focus has been on the information needs and experiences of Dutch frontrunner companies in the manufacturing and waste processing industry. This has been a deliberate choice since their experiences as frontrunners better enables the analysis of data availability. Moreover, their knowledge about the concept of a resources passport prevents the research from getting suggestive. Empirical generalization of these companies experiences in the Netherlands or Europe is not possible. Their experiences can however form a starting point for the development of a resources passport.

Furthermore, theoretical generalization of the outcomes of this research is legitimate. They align with the outcomes of previous research and can contribute to the further legitimization of these theories. Nevertheless, it is vital that more research regarding all aspects of a resources passport is conducted in order to make more robust statements.

CHAPTER 8
DISCUSSION AND RECOMMENDATIONS

8.1 Introduction

The main results of this research have been presented in the previous chapter. This chapter will reflect upon the following discussion points: the limitations of this research, recycling gradients, technological developments, and the role of the government (section 8.2). The final section of this chapter will provide recommendations about a pilot study and further research (section 8.3).

8.2 Discussion points

In this section the following four discussion points are reflected upon: the limitations of this research, recycling gradients, technological developments, and the role of the government.

8.2.1 Limitations of this research

The first discussion point is about the limitations of this research. It was a personal desire to produce an academic report with high practical application. The discussion about the development of a resources passport, at De Groene Zaak, started about a year ago. Therefore, this research is inherently explorative in nature. This means that, within a limited amount of time and space, a broad overview of the topic is created. Specialist knowledge from various areas is gathered to enable making design-oriented recommendations. Information from scientific literature, a policy analysis, an analysis of similar information exchange systems, and interviews with circular economy frontrunner companies have been conducted. As far as known, this research will be the first academic report addressing a resources passport. The explorative and design-oriented nature provide a solid foundation for further research and possible pilot studies.

The explorative nature of this research simultaneously implies that the investigated policies have not been analysed regarding their practical functioning and implications. This research assumed that the policy theory is one on one translated to practice. Also, it is assumed that everyone complies with the law. Although this aspect was outside of the scope of this study, the findings can still be relevant for the design of a resources passport. The same holds true for the analysis of the scarcity-related experiences and information needs of frontrunner companies. Circular economy frontrunners have been selected, because they have valuable knowledge about how to address scarcity. They gather more resource-related information than average companies, which provides a better overview of where information is disclosed. However, the findings in this report cannot be generalized to all companies within the Netherlands or Europe. Also, the three similar information exchange systems have not been analysed on their efficiency and effectiveness. It has been assumed that the optimal format to achieve its goal has been chosen.

8.2.2 Recycling gradients

During the interviews, a discussion about the interpretation of a recycling gradient developed between Ahrend, Desso, InterfaceFLOR and VAR. This discussion is part of elements C2 and C3[74]. InterfaceFLOR states that the definition should be '*recycled content*' which implies the percentage of weight of the product that consist of recycled material. This is relevant since, in general, the higher the recycled content, the lower the environmental impact. Ahrend and Desso prefer '*defined recycled content*' which refers to the percentage of weight of the product or materials that are recycled and can be used for any application, thus not 'polluted'. In this concept, defined means it is valuable and 'clean' recycled content, which is much more important than recycling for its own sake. Desso, InterfaceFLOR and VAR are also interested in the category '*recycle potential*' which means the percentage of the weight of the product or materials that is potentially recyclable. Yet not every recycler has the right technique to maximize this potential and some materials cannot be recycled at all. This element thus indicates the percentage of materials that can be recycled, when the content is recycled optimally. The companies state that this stimulates innovation to achieve 100%

[74] C2: Material content and composition of products, and C3: material characteristics and properties.

recycling. The same companies also plea for the element '*effectively recyclable content*'. This is the percentage of weight of a product that can be recycled or upcycled with the techniques available at the moment. To enlarge this percentage producers have to either change design or recyclers have to develop new techniques. This indicates how effectively products are designed or recycled with the current technologies. Ahrend suggests the following two elements: '*down-cyclable content*' and '*non-recyclable content*'. The former refers to the materials in a product that are only down-cyclable and the latter to the materials in a product that are non-recyclable. Since Ahrend wants clean streams only, these elements indicate how good the design is and which materials should be replaced. Hagelüken (2007) argues that weight based recycling quota alone are not sufficient. These mainly promote the recycling of the main constituent materials, like steel and aluminium, which are not the most important materials from a scarcity perspective. The ELV directive, which scores highest on attainment of the circular economy, makes a distinction between two types of recycling targets: a reuse and recycling rate of 85%, and a reusable and recovery rate of 95% in 2015for all domestically used motor vehicles (directive 2000/53/EC)[75].

Which interpretation of the recycling gradient is used, should be based upon scientific literature and practical examples. To ease implementation, the availability of information should be taken into account. It is assumed that similar discussions will evolve during the development and implementation of the passport. To guide these conversations, this discussion has been show-cased here.

8.2.3 Technological developments

With the current technological developments it is possible to disclose the detailed content of a product within days or less. These developments, like electron microscopes, will only speed up and develop further in the coming decades. This could have positive effects, also on the mitigation of scarcity. However, such developments also require a discussion about the perspective on confidentiality issues. Privacy will get a whole new dimension with progressing digitization and the possibility to easily replicate structures and mixtures. The solution that will be chosen to ensure confidentiality, within the resources passport and the wider database, should reflect the exponential developments in this arena.

8.2.4 Role of the government

De Groene Zaak represents and lobbies for the interests of companies on the issue of sustainability, specifically towards the government. A recurring topic during interviews, is the possible role of the government in development and implementation of a resources passport. All companies expressed the need for the government to amend laws and regulations that frustrate the large-scale reuse and recycling of resources. Additionally, Ahrend, Desso, Van Gansewinkel and VAR explicitly state that the resources passport itself does not have to become obligatory. The status of the passport should be created naturally by being economically attractive. Van Gansewinkel and Van Houtum think that it should be embedded in a legal framework to create widespread support for the passport. Philips does envision a more obligatory character for the resources passport. They see the role of the government as leading the discussions for EU wide implementation within the European Council. The government should be involved in reaching agreement about the content of the passport and thereby function as an arbiter to balance the interests of the stakeholders. Desso suggests that the government should use the resources passport to tax the –percentage of- resources in a product that cannot be reused or recycled. VAR suggests that the government could use the resources passport, plus stimulate its goal, in reviewing the LAP2. The next LAP should focus more on specific materials instead of waste streams. Furthermore, the government can urge others to use the instrument. Ahrend emphasizes that the government is also part of the supply chain and therefore could, for example, stimulate the closing of the loops via using the passport as a prerequisite and guiding principle for public procurement. Moreover, Ahrend believes that financial incentives, provided by the government, are necessary to speed up this process of closing the resource loops.

8.3 Recommendations

In this section recommendations are made regarding the conduction of a pilot study, communication, and further research.

[75] In the ELV directive the recycling target is defined as reusing the recycled material for the same or a similar purpose. The recovery target also includes the incineration of materials for energy generation. The difference between the two targets thus relates to the percentage of a vehicle that goes to a waste incineration facility.

8.3.1 Recommendations for a pilot study

Building onto the recommendations for the content and format of a resources passport (sections 7.7 and 7.8), it is recommended that a pilot study with this content and format is conducted. This pilot study could be conducted among the partners of De Groene Zaak, including the companies that participated in this research. The participating companies can start by gathering the required information and sharing it among each other. Thereby it is recommended that the pilot is not limited to a specific sector, since the enabling of cross-sector information exchange is at the heart, and one of the key challenges in the development and implementation of a resources passport. It is recognized that implementation in some sectors is easier than in other sectors, due to the larger availability of information as a result of stricter legislative requirements. After a cross-cycle and cross-sector pilot is conducted, implementation itself could start in sectors or industries that are already subject to legislation requiring the gathering and/or disclosure of resource-related information. The experiences in the pilot study can only improve cross-sector implementation. Specifically the sector electrical and electronic equipment is subject to more resource-related legislation.

A pilot among the members of De Groene Zaak can identify challenges related to all content and format aspects. It can be used to identify the most suitable framing of the information needs. How should the information be specified in order it to be useful for each step in the supply chain. It can be helpful in identifying where exactly in the supply chain information is withhold and why. An indication thereof is useful in identifying a tailored solution to deal with confidentiality issues. The early inclusion of a third party organization that can function as an independent trustee or provide an independent quality check is valuable. Suggestions are organisations like AgentschapNL and Milieukeur. The pilot can moreover be used to start quantifying and qualifying the benefits of the use of such an instrument for companies and the economy in general. Additionally, a pilot study can include communication and reflection on companies' internal knowledge management. Suggestions how to unify and streamline the management of resource-related information could be valuable for many companies.

8.3.2 Recommendations for communication

Development and implementation of a cross-cycle and cross-sector instrument like the resources passport would benefit from an approach that includes different industries and societal organizations. The position of De Groene Zaak as lobby organization can be very beneficial in this regard. Early communication about this passport can generate broad discussions, which could be used to improve the content and format of the passport. The extensive network of De Groene Zaak can speed up the execution of a pilot project. Plus it could contribute to the framing of the passport and possibly easy and speed up implementation.

A more specific communication related recommendation is about the use of the term Homogeneous Composite Material (in Dutch Homogeen Samengesteld Materiaal[76]). During discussions of the working groups at De Groene Zaak and the interviews with the companies the term was often used. However, the seven companies do not agree on the definition of the term. Desso and De Groene Zaak itself, define it as material which is useless to mechanically decompose if it can be reused in the same composite, like a carpet backing or an alloy. Other companies do not agree that this is homogeneous, because this carpet backing or alloy consists of many materials blended together. None of the companies see the added value of the concept at the moment, and think it confuses and distracts from establishing a resources passport. It is recommended to not use the concept.

8.3.3 Recommendations for further research

Further research should address the limitations of this research. One of them is that it has not been investigated how policies translate into practice. Also, the effectiveness of the similar information exchange instruments has not been taken into account. Moreover, the experiences and information needs of non-frontrunner companies in the Netherlands and Europe should be investigated: what scarcity-related information do they have and need? Cooperation with the EU could be sought to investigate all these points.

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[76] "Indien aangetoond kan worden dat het, vanwege zeer kleine afmetingen of andere beperkingen, onmogelijk is om mechanisch een bepaalde component of onderdeel te demonteren, en analyse van individuele homogene materialen onmogelijk is, moet deze component of dit onderdeel worden beschouwd als één homogeen materiaal. In deze gevallen, kan het gebruik van homogeniserende technieken voor componenten en onderdelen die zijn samengesteld uit twee of meer homogene materialen in overweging worden genomen." http://www.lap2.nl/sn_documents/downloads/03%20Wet-%20en%20regelgeving/Overig/Richtsnoer%20Handhaving%20RoHS-Richtlijn.pdf

A resources passport would be most efficient and effective when used worldwide. A first start could be made in the Netherlands. Yet, it is important that in the development and implementation of the passport the international perspective is taken into account. Hence, research regarding the international perspective of all aspects of the resources passport and the database is necessary. Cooperation with the EU or OECD could be relevant. Also, further research should focus on the quantification and qualification of the costs and benefits of an instrument like the resources passport and the database. What are the costs and benefits for companies, national economies, and the EU. Also the effects on society and the environmental should be analysed.

Part of this research focused on identifying the possible content of a resources passport. The analysis of policies and privately used instruments was on the availability of information needs. Availability lowers the initial time and administrative burden of implementing a resources passport. Scientific literature and De Groene Zaak indicated this as one of the most important aspects in the development and implementation of such an instrument (Sterr & Ott, 2004). The next step in this analysis is identifying where in the supply chain the information is withhold and why. This information is necessary to tailor the passport, possible legislation, start focus groups and direct the pilot project.

Research should also focus on the discussion point about the recycling gradient. As shown by literature, weight based recycling statements result in completely different incentives than scarcity-related statements. How to translate the information needs into workable definitions, that provide the right incentives, is the next step in the development of the passport.

Another recommendation is to conduct research about the implementation of the resources passport. Which aspects will hamper implementation, which aspects will accelerate implementation and how can these aspects either be circumvented or embraced. Related to that, companies have mentioned multiple times that policies which frustrate the closing and cascading of the resource loops should be phased out. The previously discussed note about material use of the Flemish Parliament (2010) provides an excellent starting point in that regard. It identifies multiple policies frustrating a circular economy and also comes with some solutions. Related to that, research could focus on adequate framing of such an instrument.

Also, further research should focus on the identification of which information needs are essential to include when implementing the resources passport. This research has identified 25 information needs, however, it did not attempt to quantify one information need as more important than another information need.

8.4 Conclusion

The list of recommendations presented above is diverse. It reflects the difference between product-related information that should be incorporated in a resources passport, and the more general and contextual information needs, necessary to address scarcity and optimally use the resource-related information. This explorative, design-oriented research only forms a foundation and much further research is necessary. A pilot study is advised to speed up the development of a passport, and work towards a circular economy.

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ANNEXES

Annex I Informants

Informant	Function
Jaime de Bourbon de Parme	Special Envoy Natural Resources at Ministry of Foreign Affairs
Julius Langendorff	European Commission, DG Environment: Sustainable Production and Consumption
Ilse Maas	Staff advisor Sustainability and Coach at Ministry of Infrastructure and Environment
Davide Minotti	European Commission, DG Environment: Sustainable Production and Consumption
Tammo Oegema	Principal en senior advisor at IMSA
Nienke Smeets	First Embassy Secretary at The Netherlands Permanent Representation to the European Union
Frans Vollenbroek	European Commission, DG Environment: Sustainable Production and Consumption
Doutzen Wagenaars	Permanent Representation of the Netherlands to the EU via Ministry of Economic Affairs, Agriculture and Innovation

Annex II Experts

Company	Expert	Title
Ahrend	Roel van der Palen Diana Seijs	Manager Business Development Coordinator MVO and Sustainability
Desso	Rudi Daelmans	Director Sustainability
InterfaceFLOR	Geanne van Arkel Paul Bruinenberg	Sustainability & Corporate Communication Manager European Quality Supply Chain Manager
Philips	Eelco Smit	Senior Manager Sustainability
Van Gansewinkel	Geert Visser	Manager Concepts and Innovations, and Manager Waste
Van Houtum	Nick op den Buijsch	Concept manager Corporate Social Responsibility
VAR	Richard Broekhof Michiel de Boer	Manager Government and Manager Business Development Manager KAM (quality, labour and environment)

Annex III Interview questions

Because the interviews were conducted in Dutch the questionnaire is also in Dutch. The questionnaire is structured in two parts. One part is about privately used instruments and internal management of data. The other part addresses the content and format of a resources passport.

Onderdeel I: Bedrijfsinterne praktijken

Het gebruik van bestaande meetmethoden:

1. Op welke huidige bekende additionele meetmethoden kan/ moet de inhoud van het grondstoffenpaspoort gebaseerd worden volgens u?
2. Welke meetmethoden om 1) gebruik van materialen te registreren, 2) de efficiëntie van gebruik inzichtelijk te maken, 3) herkomst, 4) milieu- impact en/of 5) gebruik in eigen in het bedrijf vast te stellen, gebruikt uw bedrijf?
3. Hieronder heb ik een lijstje van wetten waar uw bedrijf mogelijk mee te maken heeft. Kunt u met een ja of nee achter de wet aangeven of uw bedrijf aan deze wet moet voldoen?(lijst met wetten per bedrijf)

Intern management van information:

4. Is er intern een overzicht (of database) van al de informatie die wordt verzameld om aan de wetgeving, en gebruik van de additionele meetmethoden te voldoen? Zo niet hoe is de informatie dan georganiseerd?

5. Heeft iedereen op elke afdeling, zoals management, inkoop, design, marketing, sustainability toegang tot al deze informatie?
6. Wordt de informatie die wordt verzameld om aan de wetgeving te voldoen en bij de additionele instrumenten wordt verzameld ook gebruikt voor andere doeleinden, zoals het adresseren van schaarste?

Onderdeel II: Het grondstoffenpaspoort

Relevantie van een grondstoffen paspoort:

1. Welke huidige problemen moet het grondstoffenpaspoort aanpakken?
2. Wat zou het doel van het grondstoffenpaspoort moeten zijn?
3. Welke functies moet het grondstoffenpaspoort hebben?
4. Wat is de relevantie van het 'gezamenlijke' volgens u?

De inhoud van een grondstoffen paspoort:

5. Welke elementen moeten in het grondstoffenpaspoort staan?
6. Met welke elementen kan het paspoort op termijn uitgebreid worden?

Technische vastlegging:

7. Wie gaat het grondstoffenpaspoort invullen?
8. Waar zouden de uitkomsten precies geregistreerd moeten worden?
9. Voor wie is de data toegankelijk?
10. Hoe wordt tegen concurrentiegevoeligheid van het openbaren van deze informatie aangekeken?
11. Hoe moet de kwaliteit van de data gewaarborgd worden?
12. Hoe moeten de resultaten gepresenteerd worden?
13. Hoe en hoe vaak zou de informatie herzien moeten worden?

Annex IV Resource-related policies in the European Union

Figure 4.1. provides a timeline of European (blue) and Dutch (orange) resource related policies. In this annex, in a chronological order the various European policies, their goals and link to resources will be briefly described. The ones that are addressed in chapter four itself are not addressed in this annex.

The Waste Framework Directive (WFD) was firstly adopted in 1975 and lastly revised 2008 because of implementation of the thematic strategy on waste that required streamlining and clarification of existing legislation. Most importantly, the WDF sets the basic concepts and definitions related to waste management, like end-of-waste criteria, lays down basic waste principles and extends producer responsibility for waste generation. It states that countries waste policies should be aimed at reducing the use of resources. It also defines a recycling and recovery targets: "by 2020, the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight"; and "by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight" (European Parliament and Council, 2008: 13).

The voluntary Eco-label scheme was first established in 1992 and had a recast in 2000 and 2009. "The scheme is intended to promote those products which have a high level of environmental performance through the use of the EU Ecolabel." (European Parliament and Council, 2009: 1). The recast focused on indicator development based on scientific data and environmental impacts and synergy with other labels.

The Energy labelling Directive originally adopted in 1992 had recast in 2010 thereby extending the scope to include energy related products and commercial and industrial products. The Directive "establishes a framework for the harmonisation of national measures on end-user information, particularly by means of labelling and standard product information, on the consumption of energy and where relevant of other essential resources during use, and supplementary information concerning energy-related products, thereby allowing end-users to choose more efficient products" (European Parliament and Council, 2010:3).

The first Eco-Management and Audit Scheme Regulation (EMAS) was developed in 1993. The EMAS III Regulation entered into force in 2010. EMAS is a voluntary management tool to help companies and organisations evaluate, report and improve their environmental performance including the use of resources (European Parliament and Council 2009). The three key elements are performance, credibility and transparency. ISO 14001 forms an integral element of EMAS III, yet EMAS III also includes additional elements for the improvement of environmental performance.

The Packaging and Packaging Waste Directive adopted in 1994 and last amended in 2009, aims at harmonising national measures to prevent and reduce the environmental impact of packaging and packaging waste and to ensure and to enhance the functioning of the Internal market. It contains provisions on the recovery of packaging waste. It also establishes recycling targets for materials used in packaging waste and regarding the composition and reusability of packaging and packaging waste.

The End-of-Life Vehicle Directive adopted in 2000 aims at the "prevention of waste from vehicles and, in addition, at the reuse, recycling and other forms of recovery of end-of life vehicles and their components so as to reduce the disposal of waste, as well as at the improvement in the environmental performance of all of the economic operators involved in the lifecycle of vehicles" (European Parliament & Council, 2000: 36). It compels all Original Equipment Manufacturers (OEMs) to recollect and dismantle all motor vehicles at the end of their life. Ultimately all domestically used motor vehicles should have a reusable and recoverable percentage of 95% in 2015 (currently 85%) and should be for reusable and recyclable for 85% (currently 80%).

The European Union Sustainable Development Strategy (EU SDS) was developed in 2001, renewed in 2006 and reviewed in 2009. It has defined seven key challenges including 'sustainable consumption and production' and 'conservation and management of natural resources'. At the review in 2009 it was decided that the EU SDS continues to provide a long term vision and overarching policy framework for all other EU policies and strategies (European Commission, 2009). In line with the EU SDS the Netherlands developed a national sustainable development strategy. However, this was not the first environmental strategy developed in the Netherlands, as the first National Environmental Policy Plan was developed in 1989. Yet, this is a specific strategy related to the EU SDS.

The Green Paper on Integrated Product Policy (IPP) was adopted in 2001 and it is an "approach which seeks to reduce the life cycle environmental impacts of products from the mining of raw materials to production, distribution, use, and waste management. The driving idea is that integration of environmental impacts at each stage of the lifecycle of the product is essential and should be reflected in decisions of stakeholders" (European Commission,. 2001: 5). Since the lifecycle of a product knows many actors and a variety of produce, no simple policy measure is available. Therefore IPP consists of a toolbox of voluntary and mandatory tools.

The 6th Environmental Action Programme (EAP) is an overarching strategy, adopted in 2002 for the period 2002-2012. It provides a framework for environmental policy making and one of the four priority areas is natural resources and waste (European Parliament and Council, 2002). It aims to pursue its objective via ten strategic approaches and calls for the development of seven thematic strategies, of which the two relevant ones will be discussed below. Thematic strategies consider the available range op instruments and options to tackle specific issues, and propose actions. The first Environmental Action Programme was adopted in 1973, yet did not specifically address scarcity of resources.

The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), is in force since 2003 and aims to "approximate the laws of the Member States on the restrictions of the use of hazardous substances in electrical and electronic equipment (EEE) and to contribute to the protection of human health and the environmentally sound recovery and disposal of waste electrical and electronic equipment"(European Parliament and Council, 2003: 20). The six restricted substances are: Lead, Mercury, Cadmium, Hexavalent chromium, Polybrominated biphenyls, and Polybrominated diphenyl ether. RoHS applies to eight categories of EEE. In 2011 the RoHS was revised and will become law in 2013. Two major changes are the expansion of the concept EEE and the inclusion of three more categories of EEE.

The Waste Electrical and Electronic Equipment (WEEE) Directive entered into force in 2003 and aims at the prevention of WEEE, the reduction of the disposal of waste via reuse, recycling, and other forms of recovery and the improved environmental performance of operators in the lifecycle of EEE (European Parliament and Council, 2003). It defines the (financial) responsibilities of EEE producers in the collection and recycling of waste. The WEEE is closely linked to, and applies to the same range of products as the RoHS, thus. Moreover it is currently being revised.

The Thematic Strategy on the prevention and recycling of waste adopted in 2005 and reviewed in 2011 sets a long term goal for the EU namely; becoming a "recycling society, that seeks to avoid waste and uses waste as a resource" (European Commission, 2005: 6).Thereby the reduction of the environmental impacts of waste also plays an important role by means of for example the Eco-design Directive. Promotion of recycling is done by regulations on specific waste streams like batteries and waste oil. This strategy complements the thematic strategy on resource use and the Integrated Product Policy Directive.

The Thematic Strategy on the sustainable use of natural resources also adopted in 2005 concerns the framework of action for the next 25 years to reduce impacts from the use of resources and a growing economy. Therefore a lifecycle approach is envisioned, whereby the aim is to integrate this into all environmental policies. One of the four actions defined to achieve the objective is to "develop tools to monitor and report progress in the EU, Member States and economic sectors" (European Commission, 2005: 5).The Integrated Product Policy directive is complementary is this regard. One specific proposal has resulted in the creation of the Environmental Data Centre on Natural Resources and Products. However, it is not designed to be used by businesses. It instead provides macro and aggregate data mainly used by the Directorate General Environment of the EU. Most of the recommendations of this strategy are reflected in the new Europe 2020 Strategy.

The initial Eco-design Directive was adopted in 2005, yet a recast took place in 2009 thereby extending the scope from Energy Using Products (EUPs) to also include Energy Related Products (ERPs). It "provides for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market and/or put into service. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply" (European Parliament and Council, 2009:14).

REACH (Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals) entered into force in 2007 and aims "to ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of substances, as well as the free circulation of substances on the internal market while enhancing competitiveness and innovation" (European Parliament and Council, 2006: 18). Industries become responsible to identify and manage the risk related to chemicals and this information has to be shared with importers as well as down-stream users.

The Sustainable Consumption and Production and Sustainable Industrial Policy (SCP-SIP) Action Plan is part of the EU SDS and contains proposals for the revision of the Ecodesign, Ecolabelling, Energylabelling and EMAS Directives. "The core of the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan is a dynamic framework to improve the energy and environmental performance of products and foster their uptake by consumers. This includes setting ambitious standards throughout the Internal Market, ensuring that products are improved using a systematic approach to incentives and procurement, and reinforcing information to consumers through a more coherent and simplified labelling framework, so that demand can underpin this policy" (European Commission, 2008: 2-3).

The 'Raw Materials Initiative' adopted in 2008 is the first communication that suggests that more coherent EU policy, specifically on raw materials, is necessary. This resulted in a strategy document adopted in 2011. Its three pillars are "ensuring a level playing field in access to resources in third countries; fostering sustainable supply of raw materials from European sources, and boosting resource efficiency and promoting recycling" (European Commission, 2011: 11). The 2011 communication positions raw materials scarcity in the broader context of politics, finances, trade and industry. Many of the objectives defined in this strategy document are incorporated in the 'Flagship Initiative for a Resource Efficient Europe' (2010) and its roadmap (2011), part of the EU 2020 strategy (2010). The focus is mainly on investment in and knowledge about Europe's own extractive industry.

The Regulation on classification, labelling and packaging of chemical substances and mixtures (CLP) entered into force in 2009 and aligns existing EU legislation to the United Nations Globally Harmonised System (GHS). The CLP regulation uses internationally agreed classification and labelling elements aimed at facilitating trade and protecting the environment and humans from harmful effects of chemicals. Via standard statements and pictograms on labels and Safety Data Sheets the hazards of chemicals in a product are communicated to workers and consumers. It complements REACH in its aim (European parliament & Council, 2008).

The EU 2020 Strategy, proposed in 2010 is the successor the Lisbon Strategy. It identifies three main long term priorities: smart, sustainable and inclusive growth. To address these priorities seven Flagship Initiatives have been created, called: Digital agenda for Europe, Innovation Union, Youth on the move, Resource efficient Europe, An industrial policy for the globalisation era, An agenda for new skills and jobs, and European platform against poverty. One of the challenges is pressure on natural resources, which is addressed in the '*Flagship Initiative for a resource efficient Europe*'. Its aim is "to decouple our economic growth from resource and energy use, reduce CO2 emissions, enhance competitiveness and promote greater energy security" (European Commission, 2010: 14). Thereby a "fundamental transformation within a generation – in energy, industry, agriculture, fisheries and transport systems, and in producer and consumer behaviour" is envisioned (European Commission, 2011:2). To identify long term objectives and means for achieving this transformation a '*Roadmap to a resource efficient Europe*' was published in 2011. This roadmap identifies the circular economy as the overarching concept guiding the transformation in all areas. Especially relevant for the development of the resources passport are the milestones formulated in the areas of sustainable production & consumption, and waste. However, as stated in the roadmap, there are still many uncertainties regarding the scope and effects of resource scarcity and appropriate policies to address this issue (ibid).

At the moment the European Commission is working on the development of a harmonised methodology for the calculation of the environmental footprint (including carbon) of products, as specified as an action in the Roadmap. The analysis of the pilot that is currently conducted will be published at the end of 2012. If successful, this might also provide information requested by the resources passport.

Annex V Resource-related policies in the Netherlands

Initially, from about 1970 to 1983 the focus in Dutch policy was upon the improvement of health by cleaning up of stocks of resources like water and air. Policy was implemented top-down via European and national legislation and stakeholders were not involved. Problems with this type of central management were the lack of shared responsibility, and a general problem in the beginning of the establishment of the ecological arena with policy entity being characterized by a lack of policy coherence (Keijzers, 2000). The law on chemical waste (in Dutch 'Wet chemische afvalstoffen') was adopted in 1976 and aimed at efficient removal of chemical waste. The general law on waste (in Dutch 'afvalstoffenwet') was adopted in 1977 and aimed at the efficient removal of waste, other than chemical waste (Van Bergen, 2009:18). Both laws have been adapted multiple times and are currently integrated into chapter ten of the overarching law on environmental management (in Dutch 'Wet milieubeheer').

From around 1984-1989 the scope of environmental policies widened from cleaning up to also include the prevention of pollution, thus from reactive to more proactive policy making. Plus it widened to include stakeholders in the development and implementation of policies. Exemplary is the in 1988 adopted note regarding the prevention and recycling of waste materials (in Dutch notitie inzake preventie en hergebruik van afvalstoffen[77]). This policy specified targets for the prevention and recycling of 29 waste streams.

The policy aim followed the same path, from a focus on the protection of human health, to also include protection of ecosystems. This more interactive management strategy required new instruments like Environmental Impact Assessments (EIA) and financial incentives. Combined with the continued economic growth, the importance of setting long-term goals became apparent (ibid).

The adoption of 'Indicative Environmental Multi-year Programs' in the 1980s eventually led to the development of the First National Environmental Policy Plan (from now on referred to with the Dutch abbreviation NMP1) in 1989. The policy scope again widened to incorporate global environmental issues like climate change and acidification, plus the long term perspective was incorporated. This was done by drawing attention to the depletion of stocks of resources. In that regard NMP1 offered three principles: i) the closing of material cycles, ii) improvement of the quality of production processes and products, iii) energy efficiency and the use of sustainable sources of energy. The objectives set in the NMP1 were also reflected in the second NMP (1993) and third NMP (1998). Gradually, the objectives set in the NMP's became guiding instruments and more freedom was given to local authorities and stakeholders.

From the mid-1990s, local authorities were formally entitled to set environmental standards themselves. This increased flexibility and autonomy resulted in more flexible forms of design and implementation aimed at, and defined by specific target groups and their problems. New instruments like covenants and negotiated agreements between the government and businesses were promoted. Environmental management systems and voluntary agreements also proved successful. This started with the 1989 note on companies internal environmental management (in Dutch 'notitie bedrijfsinterne milieuzorg'). Internal environmental management refers to the efforts and activities of a company regarding the understanding, managing and where possible, reducing the effects of its operations on the environment[78]. In 1990 this lead to the introduction of the concept producer responsibility[79] in a letter from the minister of Housing, spatial planning and environment to the House of Representatives. The in 1992 developed Dutch Ecolabel is one of the more publicly visible policies that gives exposure to the concept of producer responsibility.

However, this success was mainly in the area of large companies. Less progress was made with small and medium sized enterprises (SME's) and consumers, however general rules for these groups were developed. At the end of the 1990s the focus on pollution prevention had not yet resulted in large-scale energy efficiency. Moreover the depletion of world-wide stocks of resources continued (Keijzers, 2000; Smith & Kern, 2009).

In 2001 the Fourth NMP was released with a scope until 2030. NMP4 revolves around a transitions approach, by means of decoupling, to address the continued environmental pressure generated by economic growth. One of the environmental problems that require a transitions approach is the unsustainable use of natural resources. The focus shifts towards improved management of natural resources stocks, nationally as well as internationally, plus at the decoupling of growth and environmental pressures by limiting the use of natural resources. Emphasis is placed on integration of economic, social and environmental interests and the formulation of joint objectives by the various stakeholders. This integrated approach changes the role of the government to a facilitator, aimed at cooperation. (New) instruments like setting incentives for producers, consumers, extended producer responsibility, stimulation of technological innovations and eliminating price distortions are stimulated. Moreover long term goals are formulated. Nevertheless scarcity of abiotic resources was not on the agenda when NMP4 was developed, and is therefore not addressed.

Policies particularly on resource scarcity were put on the Dutch policy agenda in 2008, as a response to the energy and food crisis. In November of that year, Dutch Parliament asked government "to initiate, nationally and internationally, the development of scenarios for integrated policy responses to the multiple crises the world population is presently facing" (Eerste Kamer, 2008). There are three resource related policies that distinctly differ from the European policies the Netherlands already has to comply with (Maas, 2012, personal communication). These three policies are the

[77] Kamerstukken II 1988/89, 20 877, nr. 2.
[78] Dutch tekst: "Alle inspanningen en activiteiten van een bedrijf met betrekking tot het inzicht krijgen in, het beheersen van en het waar mogelijk verminderen van de effecten van de bedrijfsvoering op het milieu."
[79] Tweede Kamer, 90-91, 21137 nr. 49.

National waste plan (‘Landelijk Afvalbeheerplan 2009-2021’) the resources note (´Grondstoffennotitie’) (2011) and the so-called Waste Letter (‘Afvalbrief’) (2011).

The first policy that differs from EU policies is the Landelijk Afvalbeheerplan (LAP2) 2009-2021, which specifies policies regarding the treatment of waste streams addressed in the law on environmental management (wet milieubeheer). Additionally the LAP2 addresses waste scenarios, monitoring and compliance. Most relevant in this research is that it aims at creating a material chain approach regarding waste and prioritizes the following waste streams: 1. Paper and carton, 2. Textile, 3. Construction and demolition waste, 4. Organical/ food waste, 5. Aluminium, 6. PVC, 7. Large domestic waste. It furthermore prioritizes the preferred manner of waste disposal in accordance with the so-called ‘Ladder van Lansink’. Thereby disposal by means of land filling is the least preferred option and prevention the most preferred option. Burning waste is specific cases also seen as useful application of waste (VROM, 2010).

With the formulation of the Grondstoffennotitie (2011) and the Afvalbrief (2011) the Dutch policy agenda broadened from merely focusing on CO_2 emission to also include scarcity of abiotic resources. The Grondstoffennotitie published in the summer of 2011 forms the kick-off of an integral policy response to scarcity of abiotic resources in the Netherlands. It builds upon the recommendations given in the European Raw Materials Initiative. Its three focal points are addressing supply security, reducing demand and stimulating efficient and sustainable use of resources. Relevant for the resources passport is the following action point: assess the possibilities to use market instruments to discourage the use of unsustainably produced products. No follow-up has been given yet (Maas, 2012, personal communication). Other relevant action points might be the intention to increase transparency of supply via for example the Extractive Industries Transparency Initiative (EITI). Moreover the government intends to develop supply chain agreements regarding product design, re-use of waste stream and support leasing business models over traditional business models.

The Afvalbrief, published just after the Grondstoffennotitie, aims at creating more value from waste. It specifies several action areas, most importantly: raising awareness among consumers, reducing waste and disposal of waste, and recycle more. Different from the EU, the Netherlands specifies minimum standards at which waste should be processed. These standards prevent processing at a lower level than desirable and possible. When defining these standards the environmental impacts of processing the waste are investigated by means of an LCA. The note also states that almost 95% of the Dutch waste is processed by private companies. Since the Netherlands is an important transit country of materials the government aims at creating a materials round-a-bout, meaning “waste streams ‘drive’ onto the roundabout and after processing they leave as raw materials for the manufacture of products” (Van de Wiel, 2011:2). This ambition, that reflects the principles of a circular economy, would benefit the Dutch economy and make use of the knowledge and expertise the Netherlands already has on these issues. For PVC the government specifically aims at the development of a quality criterion that stimulates the use of recycled PVC. By knowing exactly what the quality of the recycled PVC is, buyers know which PVC they can / cannot use in their products.

Annex VI Principles of the circular economy pursued in resources-related policies

4.3.1 Eco-labelling regulation

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

Regulation (EC) No 66/2010 intends to promote products with a high environmental performance, by setting special criteria per product group (currently 24, May 2012). In developing these special criteria, the regulation asks to focus on the most significant environmental impacts and suggests taking into account the impact of the product on resource consumption, non-hazardous materials or designs, the products durability, and reusability as options one can think about. Following these requires however, design changes only when found to be of significant importance. Moreover, these criteria are aimed at lowering the environmental impact of the product throughout its lifecycle and not necessarily at reducing vulnerability to scarcity or closed loop recycling. However, this differs per product. For example, the application pack for notebook computers requires, among others, the following related to design for disassembly “All plastic materials in covers/housing shall have no surface coatings incompatible with recycling or reuse” (Ecolabel, 2012: 25). Lastly, the eco-labelling regulation is a voluntary scheme, which means that producers can themselves chose to apply for an eco-label for their products.

2. The improvement and creation of end-of-life systems for flows of resources and products.

The eco-label and its criteria are not primarily aimed at creating and improving end-of-life systems to recover resources. However, when found to be of significant importance, the improvement and creation of end-of-life systems can be turned into a requirement. For example, the application pack for notebook computers requires the following: “the external plastic case of the system unit, monitor and keyboard shall have a recycled content of not less than 10% by mass” (Ecolabel, 2012: 23). Yet, for example the application pack for light sources does not include any reuse or recycling requirements.

3. The creation of, preferably regional, networks of material exchange.

This regulation does not in any manner pursue the creation of networks of material exchange.

4. The collection, management and exchange of resource-related information.

There are five relevant stakeholders, namely: (1) the EU Eco-labelling Board (EUEB); they contribute to the development and revision of the eco-label criteria or the regulation. (2) European Commission; it is their task to ensure that the regulation is correctly implemented on an EU level. Moreover, they adopt the criteria for each product group as 'commission decision'. (3) Competent Bodies; these are national bodies charged with the national implementation of the regulation. They are also responsible for assessing and verifying the eco-label applications. (4) Stakeholder groups consist of interested and concerned parties like industry and service providers, business organisations, trade unions, retailers, importers, environmental protection groups and consumer organisations. The regulation requires a balanced participation of these stakeholders in the development of the criteria. (5) Consumers. The only information consumers receive is the label being present on a product. This label is just a picture of the logo of eco-label and does not specify the eco-requirements the product fulfils.

The regulation aims to develop criteria that reduce the environmental impact of a product over its entire lifecycle. For optimal results eco-labelling criteria are tailored to specific product groups and are revised every four years to incorporate technical innovations and market changes.

Following a consultation with the EUEB, all stakeholders, except for consumers, may lead the development and revision of eco-label criteria. The regulation states that the "criteria should be market-oriented and limited to the most significant environmental impacts of products during their whole lifecycle" (European Parliament & Council Regulation, 2009: 1). In determining the criteria, seven principles have to be taken into account, among which: "(a) the most significant environmental impacts, in particular the impact on climate change, the impact on nature and biodiversity, energy and resource consumption, generation of waste, emissions to all environmental media, pollution through physical effects and use and release of hazardous substances; (b) the substitution of hazardous substances by safer substances, as such or via the use of alternative materials or designs, wherever it is technically feasible; and (c) the potential to reduce environmental impacts due to durability and reusability of products" (ibid: 3-4).

Producers have to fill out an application package specifying that they fulfil all the eco-design criteria, supported by test reports if necessary. This is different for each product group. However, producers have to give many details of the product that could also be present in a resources passport. For example, the application pack for notebook computers (2012 version) requires producers to provide information on among others: the main characteristics and composition, energy savings, the presence of heavy metals and flame retardants, substances used, the recycled content, reparability, Design for Disassembly, and Lifetime extension. The criteria for textile floor coverings demand a specification of the raw materials used and the substances used in the production process. The application pack of textiles even demands upstream supplier information.

The national competent bodies receive the applications, yet, as article 10.6 states: "The competent body which has awarded the EU Ecolabel to the product shall not disclose, or use for any purpose unconnected with the award for use of the EU Ecolabel, information to which it has gained access in the course of assessing the compliance by a user of the EU Ecolabel". This implies that the detailed product information is not transparent, also not to the EUEB or the European Commission. The eco-label itself, visible for the consumer on the product, does not specify any of the above mentioned information.

Concluding, much information possibly useful for the resources passport is collected by producers applying for the Eco-label directive. However, the information that producers are required to submit to the competent bodies in order to receive the eco-label is not publicly accessible, and may not be used by the competent bodies for any purpose other than assessing whether the eco-label can be granted. Moreover the information is not systematically collected due to the voluntariness of the regulation. Also the information does not contribute to the achievement of circular economy principle three.

4.3.2 Energy-labelling directive

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

Directive 2010/30/EU obliges the disclosure of information about the energy consumption and energy efficiency of products, that are likely to have a direct or indirect impact on among others the consumption of energy during the use of the product, on a label. The end goal, as specified in Article 1 of the directive is allowing end-users to choose more energy efficient products. This aim does not directly influence the design of products. Yet, indirectly, the design of products is influenced, because if consumers only buy appliances with the highest category energy label (currently A+++) which are cheaper in use, manufacturers will have to adjust design to stay in the game. However, these design changes are solely related to reducing energy use and not to closing the resource loops. The use of more efficient green technologies and nanotechnology may even result in an increased usage of REEs.

2. The improvement and creation of end-of-life systems for flows of resources and products.

The improvement and creation of end-of-life systems is not at any point addressed in this directive.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks of material exchange is not addressed or pursued by this directive.

4. The collection, management and exchange of resource-related information.

The energy-labelling directive is an obligatory directive which requires products, that have a direct or indirect impact on the consumption of energy and other potential resources during use, when placed on the market, to have a label containing the information regarding its energy consumption, electric or other forms.

There are four relevant parties in the exchange of information in this directive, namely: manufacturers of products, dealers, member states and consumers.

Manufacturers or, in this directive so-called suppliers, have to provide the dealers of the products with the labels and product information free of charge. Plus they have to provide a product fiche, that should be used in all brochures related to, or literature provided with the product. Which information should be present on a product label or fiche is specified in the delegated acts provided by the Commission. The details differ per product. Currently none of the delegated acts requires suppliers to put scarcity related information on the label or fiche. Information that is present relates to energy consumption, efficiency and, where relevant, water consumption and noise.

Moreover, manufacturers are obliged by Article 5 to produce technical documentation, needed to assess the accuracy of the information presented on the label. This information should be available "for a period ending five years after the last product concerned was manufactured" (European Parliament and Council, 2010: 5). The technical documentation should disclose the following information: "(i) a general description of the product; (ii) where relevant, the results of design calculations carried out; (iii) test reports, where available, including those carried out by relevant notified organisations as defined under other Union legislation; (iv) where values are used for similar models, the references allowing identification of those models" (ibid). When given a notice, the supplier should provide this documentation to the public authorities of the member state. The specific technical documentation requirements vary per product group. For example, the one on vacuum cleaners only provides a general description of the product and states the dust removal ability[80]. Furthermore, this information is initially only available for the supplier himself, written down in the technical documentation.

The role of dealers in this directive is minimal. They receive the label and fiche from the suppliers and are responsible for the affixation of the energy label on the product; visible and legible.

The role of Member states is to ensure that suppliers and dealers provide the specified information. Moreover, the introduction of the system of labels and fiches should be accompanied by educational and promotional information for the consumer. Lastly, every four years, the Member States have to submit a report to the Commission providing information about enforcement and compliance of the directive in the member state. If Member states suspect that suppliers present incorrect information, they can request them to provide evidence, mainly in the form of the technical document.

Concluding, the exchange of information from suppliers, via dealers to end-users by means of energy labels and fiches, is at the core of this directive. Yet, this information does not address any principle of the circular economy.

4.3.3 EMAS: Environmental Management and Audit Scheme regulation

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

Voluntary regulation EMAS III (EC) No 1221/2009 aims at the improvement of organisations' environmental performance and to provide information related to that performance. Therefore, multiple criteria and aspects of an organisation's performance are considered (Annex I-IV). The redesign of products and production processes for resources to operate in closed loops is not specifically mentioned and hence EMAS might only indirectly result in the pursuing of principle one.

2. The improvement and creation of end-of-life systems for flows of resources and products.

As holds true for the first principle of the circular economy, the environmental performance of an organisation is defined by multiple criteria. Waste is one of the criteria that should be taken into account when conducting an environmental review. Moreover, in the first sector-specific reference document for the retail sector, the improvement and creation of end-of-life systems is specifically mentioned as an indicator for the environmental performance. However, indicators are used to measure performance, there are no obligatory targets or thresholds. Therefore EMAS only indirectly and non-systematically pursues principle two of the circular economy.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks of material exchange is not addressed nor pursued in this scheme.

4. The collection, management and exchange of resource-related information.

To comply with this scheme organisations have to produce periodic, publicly available environmental statements/ -reports related to their environmental performance and in compliance with legal environmental requirements.

Designated competent bodies in the member states are responsible for the processing of applications for participation in the scheme. If organisations want to apply they have to carry out: (a) "an environmental review of all environmental aspects of the organisation in accordance with the requirements set out in Annex I and in point A.3.1 of Annex II" (ibid: article 4). Annex I mentions a list of direct and indirect environmental aspects that the organisation

[80] http://www.ebpg.bam.de/de/ebpg_medien/tren17/017_workd_11-08_label.pdf

should consider when conducting the review. This list includes the use of natural resources and raw materials (including energy), and the lifecycle of products including design and recovery. (b) "In the light of the results of the environmental review, develop and implement an environmental management system covering all the requirements referred to in Annex II" (ibid). (c) "Carry out an internal audit in accordance with the requirements set out in point A.5.5 of Annex II and Annex III" (ibid). (d) "Prepare an environmental statement, in accordance with Annex IV" (ibid). The statement includes a brief description of the environmental management system, environmental performance and environmental impact. Moreover, material efficiency, defined as "concerning the 'annual mass-flow of different materials used' (excluding energy carriers and water), expressed in tonnes" is one of the core indicators, and the only one referring to material use (ibid: Annex IV). The total generation of waste and especially the generation of hazardous waste is also addressed. The organisation has to demonstrate to the verifier that the information in the environmental statement is freely and easily accessible to anyone interested. There are no specific, obligatory targets or thresholds to be met.

The information mentioned above has to be verified and validated by special environmental verifiers. Subsequently the declaration of verification, the environmental statement, and payment details are send to the competent body that checks the validity of this verification process. After some formal procedures, organisations become listed as participants of EMAS. The competent bodies have a register of participating organisations, and environmental statement are publicly available on their website. The environmental review, management system and internal audit are thus not publicly available, but only to the verifying body. Only the environmental statement/report is publicly accessible.

To ensure these environmental reports are comparable; generic, sector specific performance indicators have been devised, on a project and process basis. If sector or cross-sector reference documents are available they need to be taken into account when analysing the environmental performance. These documents, developed by the commission in conjunction with the member states and other relevant stakeholders, include: "(a) best environmental management practice; (b) environmental performance indicators for specific sectors; (c) where appropriate, benchmarks of excellence and rating systems identifying environmental performance levels" (ibid: article 46). So far only the final draft of a reference document for the retail sector has been presented (JRC, IPTS, 2011). The sector-specific reference documents for the construction and tourism sector are being developed. The indicators in the reference document of the retail sector focus to a large extent on energy and CO2 emissions, yet also on the tracking and improvement of sustainability practices in the supply chain, the recycling and reuse of packaging material, the reduction of food waste and the implementation of a product take back system. The category materials management solely focuses on the use of less, and certified paper. Waste management is also part of the best practices section.

The role of the Commission is small, namely to maintain and disclose, among others: "(a) a register of environmental verifiers and registered organisations; (b) a database of environmental statements in electronic format; (c) a database of best practices on EMAS, including, inter alia, effective tools for EMAS promotion and examples of technical support to organisations" (ibid: article 42).

Concluding, the most resource-relevant information in this case, presented in an environmental review, management system and internal environmental audit, is solely insightful to verifying bodies. Only the environmental report is publicly accessible. This includes information about material efficiency and waste, however not specified on a product level, or useful to enable the cascading use of materials.

4.3.4 Packaging and Packaging Waste Directive

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

One of the goals of directive 94/62/EC is the prevention of waste. Therefore, the directive specifies thresholds for the presence of certain hazardous materials in packaging materials. The aim is changing the design of packaging, thereby reducing the overall environmental impact of packaging. Moreover packaging should be designed to be reused and recycled several rotations. The other goal is the recycling and recovery of packaging waste. Therefore packaging material receives a mark which better enables the recycling and recovery of packaging waste. This marking system, adopted in 1997, is described in Commission Decision 97/129/EC. This directive thus pursues the first principle of the circular economy.

2. The improvement and creation of end-of-life systems for flows of resources and products.

Besides the prevention of waste via changes in the design, the directive also aims at the recycling and recovery of packaging waste. This is done by requiring member states to set up return, collection and recovery systems. Moreover, the use of these systems is necessary to achieve the recycling and recovery targets as set out in article 6. Although the marking on the packaging is very general, by means of abbreviations for categories like steel, cotton and wood, this enhances the recycling and recovery of packaging waste. This directive thus also pursues the second principle of the circular economy.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks of material exchange is not mentioned or pursued by this directive.

4. The collection, management and exchange of resource-related information.

Article 4 requires member states to implement measures to prevent packaging waste. This can be programmes, projects etc. Packaging placed on the market has to comply with requirements related to the use of lead, cadmium, mercury and hexavalent chromium, that cannot exceed a certain threshold. Article 11 of the directive 94/62/EC, and Annex II specify (a) "requirements specific to the manufacturing and composition of packaging", among others, "packaging shall be designed, produced and commercialized in such a way as to permit its reuse or recovery, including recycling" (ibid; Annex II), (b) "requirements specific to the reusable nature of packaging", like "the physical properties and characteristics of the packaging shall enable a number of trips or rotations in normally predictable conditions of use" and (c) "requirements specific to the recoverable nature of packaging" such as "packaging must be manufactured in such a way as to enable the recycling of a certain percentage by weight of the materials used into the manufacture of marketable products" (ibid).

To monitor the implementation of the directive, article 12 sets out the role of the member states therein. They are required to set up databases on packaging and packaging waste. These "databases shall provide in particular information on the magnitude, characteristics and evolution of the packaging and packaging waste flows (including information on the toxicity or danger of packaging materials and components used for their manufacture) at the level of individual Member States" (ibid: Article 12). Annex III specifies the data that member states should send to the commission: "(1) For primary, secondary and tertiary packaging: (a) quantities, for each broad category of material, of packaging consumed within the country (produced + imported − exported); (b) quantities reused. (2) For household and non-household packaging waste: (a) quantities for each broad category of material, recovered and disposed of within the country (produced + imported − exported); (b) quantities recycled and quantities recovered for each broad category of material" (ibid: Annex III). This information is publicly available, yet specified on a national, aggregate level and not on a product level.

Regarding the recycling and recovery of packaging waste, article 6 sets specified targets that member states should meet at a certain point in time. For example: "no later than 31 December 2008 between 55% as a minimum and 80% as a maximum by weight of packaging waste will be recycled, and no later than 31 December 2008 the following minimum recycling targets for materials contained in packaging waste will be attained" (ibid: article 6). The same article requests member states to present a report to the European Commission in which the implementation of this article is monitored and possible suggestions for alterations mentioned. This data is also presented on an aggregate, national level.

Article 10 specifies another part of the role of the European Commission, namely the preparation of standards relating to, among others, "criteria and methodologies for life-cycle analysis of packaging, criteria for a minimum content of recycled material in packaging for appropriate types of packaging and criteria for recycling methods" (ibid: article 10). These standards have been developed and are accessible, yet have to be purchased, in the Dutch case at the NEN.

Article 13 ensures that member states provide information to the users of packaging about among others, the return, collection and recovery systems available to them, and their role in contributing to reuse, recovery and recycling of packaging and packaging waste.

Concluding, the relevant the information in this directive is publicly accessible yet collected on a national, aggregated level. Consumers are provided with information on where to dispose of the product and their role in recycling.

4.3.5 End-of-Life Vehicle directive

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

Directive 2000/53/EC is subdivided into six parts namely: (1) prevention, (2) collection, (3) reuse and recovery targets, (4) treatment, (5) information gathering and dissemination, and (6) implementation (Konz, 2009). The first goal is aimed at avoiding specific hazardous substances and limiting the use of some others in the design of vehicles. The third goal, as specified in article 7 of directive 2000/53/EC, is supported by two obligatory targets to be taken into account at the design phase: all domestically used motor vehicles should have a reusable and recovery rate of 95% in 2015; and a reuse and recycling rate of 85% in 2015. Demanding from Original Equipment Manufacturers (OEMs) that they recollect and recycle all domestically used motor vehicles, means asking them to close resource loops in an environmentally friendly manner.

2. The improvement and creation of end-of-life systems for flows of resources and products.

Consumers are obliged in article 5 to take their ELV to an Authorized Treatment Facility (ATF), subjected to requirements as specified in article 6 regarding environmentally sound storage, stripping before treatment, de-polluting of materials, focus on hazardous materials, and ensuring the reusability of components. Combined with the reuse, recycling and recovery targets, this resulted in boosting the creation and improvement of ELV end-of-life systems.

3. The creation of, preferably regional, networks of material exchange.

The directive does not request the creation of networks of material exchange as such, yet article 4 states that manufacturers, in liaison with material and equipment manufacturers, are required to use recycled materials in their products, “in order to develop the markets for recycled materials” (ibid: 36). This does create new networks from recyclers to manufacturers, however most likely not specifically regional.

4. The collection, management and exchange of resource-related information.

The fifth goal specifically addresses the gathering and dissemination of information. Article 8 states that producers should provide coding standards and dismantling information to facilitate identification of components and materials suitable for reuse and recovery. Article 9 instructs Member States to require relevant economic operators to publish information regarding “(1) the design of vehicles and their components with a view to their recoverability and recyclability, (2) the environmentally sound treatment of end-of life vehicles, in particular the removal of all fluids and dismantling, (3) the development and optimisation of ways to reuse, recycle and recover end-of life vehicles and their components, (4) the progress achieved with regard to recovery and recycling to reduce the waste to be disposed of and to increase the recovery and recycling rates” (ibid: article 9). The producer is obliged to publish this information to prospective buyers via e.g. promotional literature. Member States themselves also have to report about the implementation of the directive. For producers to better be able to gather and share relevant information, several leading companies have established the International Material Data System (IMDS), now widely used.

The requirements as specified in the ELV directive, are obligatory for the four stakeholders, namely: vehicle manufacturers, the recycling industry, public authorities, and the owner of the vehicle. The vehicle manufacturers, when designing products are required “take into full account and facilitate the dismantling, reuse and recovery, in particular the recycling, of end-of life vehicles, their components and materials”, plus “integrate an increasing quantity of recycled material in vehicles and other products, in order to develop the markets for recycled materials. Additionally they need to provide the recycling industry and ATFs with “all requisite dismantling information, in particular for hazardous materials” (directive 2000/53/EC: 35). Moreover, they need to use component and material coding standards, which enable better recovery (ibid). Lastly, they need to adhere to the recycling and recovery target. To comply with all these provisions, manufacturers need to know exactly which materials are used in their product and what their properties are. How these materials are processed/what their functions are and what the composition of the materials is. They need to have information about the quantity and quality of the materials and whether they are potentially reusable and recyclable, plus information about end-of-life systems. Much of the detailed information is only available to suppliers down the supply chain, OEMS and ATFs. Competing OEMs and consumers do not have insight in this information. To ensure convenient information exchange and rightful access to this information, the IMDS has been established.

The ATFs need to make sure the two recycling and recovery targets are met. Therefore they receive information about the material content, composition and dismantling information free of charge from the producer. A certificate of destruction is needed as a condition for deregistration of the ELV. This certificate is only provided when the vehicle is taken to a licensed treatment facility. This ensures optimal recollection of the ELVs and also optimal recovery. A treatment facility is only authorized when it complies with the ELV directive. There are publicly available list of ATFs in every member state.

The public authorities need to submit a report about the progress of implementing the directive. The directive states that the report shall contain “relevant information on possible changes in the structure of motor vehicle dealing and of the collection, dismantling, shredding, recovery and recycling industries, leading to any distortion of competition between or within Member States”(ibid: 39). This information is provided by the producers. The European Commission synthesizes these reports and subsequently publicly publishes an assessment of the current state of implementation of the ELV directive. This publicly accessible information is on an aggregate, national or European level.

Lastly, the directive states that consumers need adequate environmental information to make informed decisions. The owner of the vehicle needs to have information about where to dispose the vehicle, like the nearest ATF. This information should be made available by producers, for example on their website. This means the information is publicly accessible. It is not specified how much environmental information should be disclosed, yet at least information regarding the two targets will be shown.

Concluding, much information relevant for addressing scarcity is collected, managed and exchanged with selectively chosen elements in the supply chain.

4.3.6 RoHS: Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

Directive 2002/95/EC aims at protecting human health and environmentally sound recovery and disposal of waste electrical and electronic equipment (WEEE) by means of restricting the use of six hazardous substances in electrical and electronic equipment (EEE). The scope of the directive is restricted to the eight out of ten categories (excluding category eight and nine) of WEEE as defined in the WEEE directive. Products put on the market from July 1, 2006 onwards may not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls or polybrominated diphenyl ethers above a certain maximum level. Exemptions from this rule are specified in Annex I. This directive thus possibly requires design changes and, by restricting the use of these six substances, also limits the health and environmental impact during recycling of a product, plus increases profitability of recycling. However, these changes are of limited scope, applied to a limited range of products and not guided by resources scarcity issues.

2. The improvement and creation of end-of-life systems for flows of resources and products.

By restricting the use of these six substances in EEE, recycling of WEEE becomes more profitable and the environmental and human health impact is limited. This directive however does not create or improve end-of-life systems as such.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks for the exchange of materials is not addressed in this directive.

4. The collection, management and exchange of resource-related information.

The manufacturers of EEE are the ones that need to assess whether their products fulfil the RoHS obligations. As of yet, there is no official RoHS conformity label. Only when components have some other label it can be easily assessed whether they comply with the regulation. This results in producers developing their own labels; all plain pictures without additional information. Moreover, as part of their compliance program, producers ask their suppliers to confirm their compliance with the RoHS directive. However, no detailed information is exchanged, solely compliance is confirmed.

Each Member State has a designated body with executive and monitoring competences, in the Netherlands that body is the 'VROM Inspectie'. When they suspect non-compliance they can ask the manufacturer to provide evidence of compliance. The EU directive does not specify how manufactures should prove conformity. This data can include purchasing policies, test reports and the total sales numbers (VROM Inspectie, 2010). Consequently, there is no databank with national conformity data.

Concluding, very little information relevant to addressing scarcity is collected and almost none exchanged. The detailed information that is actually exchanged is not publicly accessible.

4.3.7 WEEE: Waste Electrical and Electronic Equipment Directive

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

One goal of the WEEE Directive focuses on the prevention of WEEE by addressing the design of products. Article 4 of directive 2002/96/EC states that member states shall encourage design changes which take into account and facilitate decomposition, reuse and recycling of materials. This is supported by the fact that producers are required to finance the future end-of-life costs of their own products. When a product can be better maintained, decomposed and recycled, the end-of-life treatment costs will be significantly lower. However, scarcity not necessarily has to be the aim of the design changes. The other goals are "the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste", plus, "improve the environmental performance of all operators involved in the lifecycle of electrical and electronic equipment" (European Parliament and Council, 2003: 26).

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

The directive directly aims at the reduction of the disposal of waste via reuse, recycling and other forms of recovery. Therefore Article 5 requests the increase of separate collection of WEEE from municipal waste and the division of take-back points, free of charge for the consumer. Article 6, Annex II and III make demands on the treatment of WEEE and of the sites where WEEE is treated. By specifying minimum requirements, the quantity and quality of recovered WEEE increases. Article 7 sets recovery targets specified per category of EEE. General targets are: "the rate of recovery shall be increased to a minimum of 80% by an average weight per appliance, and, component, material and substance reuse and recycling shall be increased to a minimum of 75% by an average weight per appliance" (ibid: article 7). Moreover, the environmental performance of especially waste processers increases. End-of-life systems are hence improved and created.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks of material exchange is not pursued by this directive.

4. *The collection, management and exchange of resource-related information.*

The mandatory directive covers ten categories of EEE as specified in Annex IA. There are five parties involved in the exchange of information, namely producers and importers, retailers, waste processers, the member states, and consumers.

Producers and importers of materials in accordance with article 11 "provide reuse and treatment information for each type of new EEE put on the market within one year after the equipment is put on the market. As far as it is needed by reuse centres, treatment and recycling facilities in order to comply with the provisions of this Directive, this information shall identify the different EEE components and materials, as well as the location of dangerous substances and preparations in EEE. It shall be made available to reuse centres, treatment and recycling facilities by producers of EEE in the form of manuals or by means of electronic media (e.g. CD-ROM)" (ibid: article 11). Moreover, producers are obliged to depict the WEEE symbol on EEE products if they fall within the scope of the directive and placed on the market after August 13, 2005.

Additionally, since producers are required to finance the future end-of-life costs of their products they are stimulated to alter the design of products. They are however not required to disclose specific information in this regard.

Article 12 of the directive specifies that Member States "shall draw up a register of producers and collect information, including substantiated estimates, on an annual basis on the quantities and categories of electrical and electronic equipment put on their market, collected through all routes, reused, recycled and recovered within the Member States, and on collected waste exported, by weight or, if this is not possible, by numbers" (ibid: article 12). This information is also used to check compliance with the recovery targets as specified under article 7. In the Netherlands this information is generally not provided by the individual companies, but by the NVMP (Nederlandse Verwijdering Metalektro Producten) and 'ICT Milieu', who report for around 1500 companies to the Dutch Ministry of Infrastructure and Environment (VROM Inspectie, 2010). On the basis of a product list, members report about the numbers, weight and brands of the products. This information is highly classified and not even accessible for all employees of NVMP and ICT Milieu. This information is used to compose a report towards the Dutch government. In accordance with the format, this report provides information on the total quantity of EEE put on the market, recollected WEEE and quantity of WEEE being reused in tons, or having a useful application, also in tons (NVMP, 2009). On a two-year basis, member states transmit this information to the European Commission. The information is provided on an aggregate, national level and is available and made publicly accessible in Eurostat's Environmental Datacentre on Waste. In accordance with the 2002 version, the member states used this information to check compliance with the minimum collection target of 4 kg per annum per inhabitant for WEEE from households. Recently, the European Parliament proposed a collection rate of 85%[81].

The requirements for treatment facilities as specified in article 6, Annex II and III are checked by the member states. The treatment facilities are inspected at least once a year and the inspectors verify: (a) the type and quantities of waste to be treated; (b) the general technical requirements to be complied with; (c) the safety precautions to be taken. This information is not publicly accessible. Moreover, as article 0.17 states "Best available treatment, recovery and recycling techniques should be used provided that they ensure human health and high environmental protection. Best available treatment, recovery and recycling techniques may be further defined in accordance with the procedures of Directive 96/61/EC, the Integrated Pollution Prevention and Control Directive. More information about this directive can be found in section 4.2.11.

Lastly, Article 10 specifies the information member states should provide to consumers. Namely: (a) the requirement not to dispose of WEEE as unsorted municipal waste and to collect such WEEE separately; (b) the return and collection systems available to them; (c) their role in contributing to reuse, recycling and other forms of recovery of WEEE; (d) the potential effects on the environment and human health as a result of the presence of hazardous substances in electrical and electronic equipment; and (e) the meaning of the symbol shown in Annex IV.

4.3.8 Eco-design directive

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

Directive 2009/125/EC, is specifically aimed at changing the design of products to address adverse environmental impacts a product has throughout its lifecycle. When assessing the eco-design parameters to identify significant environmental aspects that should be changed by design to following is addressed: the use and choice of materials, the initial lifetime and the recovery of materials in end-of-life systems. If necessary, manufacturers are required to provide information about the manufacturing process and information for treatment facilities regarding disassembly, recycling, or disposal at end-of-life. Thus, in theory, much attention is paid to closing the loops by looking at all phases of the lifecycle of a product in the design phase. Nevertheless, in practice, the implementing measures focus mainly on the use of energy and not on addressing scarcity. Principle 4 provides more information about the implementing measures.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

This directive is primarily aimed at changing design of products, not at creating end-of-life systems. Nevertheless, the framework directive states that if necessary producers are required to provide information regarding the end-of-life phase of the product, for example on how to maintain the product, how and where to dispose of the product and disassembly information for waste processers. This information would stimulate the improvement of end-of-life systems. However, in practice in the implementing measures, producers have not been obliged to provide this information.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks of materials exchange is not part of the directive at the moment. However, a recent motion for a European Parliament resolution "Calls on the Commission to ensure policies drive cascading use of natural raw materials and favouring highest value-added and resource-efficient products over energy generation, taking into account in particular greenhouse gas mitigation potential;" (Gerbrandy, 2012: 9). Thus the scope might be extended; however the focus is still more on emissions than on scarcity.

[81] http://www.europarl.europa.eu/news/en/headlines/content/20110131FCS12843/007/html/MEPs-demand-better-e-waste-management

4. The collection, management and exchange of resource-related information.

The implementing measures of the eco-design directive are legally binding for the producers of Energy Using Products[82] (EUPs) and Energy Related Products[83] (ERPs), and are implemented with a transitional period. Manufacturers that are not part of the scope of the directive can also voluntarily comply with the implementing measures.

Based on the eco-design parameters mentioned in Annex I of the directive, significant environmental aspects of the product throughout its lifecycle are identified. These parameters include predicted consumption of materials, expected generation of waste material, and possibilities for reuse, recycling and recovery of materials and/or of energy. To evaluate the potential for improving the environmental aspects, the following parameters must be used: "(a) weight and volume of the product; (b) use of materials issued from recycling activities; (c) consumption of energy, water and other resources throughout the lifecycle; (d) use of substances classified as hazardous to health and/or the environment; (e) quantity and nature of consumables needed for proper use and maintenance; (f) ease for reuse and recycling as expressed through: number of materials and components used, use of standard components, time necessary for disassembly, complexity of tools necessary for disassembly, use of component and material coding standards for the identification of components and materials suitable for reuse and recycling (including marking of plastic parts in accordance with ISO standards), use of easily recyclable materials, easy access to valuable and other recyclable components and materials; easy access to components and materials containing hazardous substances; (g) incorporation of used components; (h) avoidance of technical solutions detrimental to reuse and recycling of components and whole appliances; (i) extension of lifetime as expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability; (j) amounts of waste generated and amounts of hazardous waste generated; (k) emissions to air (l) emissions to water and; (m) emissions to soil" (European Commission & Parliament, 2009: 23-24). However, this is collectively done in a European context on the basis of the data of a standard product, for example a television, and then holds true for all televisions. This method does not take into account the large variety of production methods and product designs, fulfilling a similar function.

Subsequently minimum ecological requirements are adopted through the comitology procedure[84] which defines specific implementing measures for each product group included in the scope of the Directive. "Implementing measures are proposed for products which: (a) "represent a significant volume of sales and trade, indicatively more than 200.000 units a year within the Community; (b) have a significant environmental impact within the Community; and (c) present significant potential for improvement in terms of its environmental impact without entailing excessive costs" (European Commission & Parliament, 2009: 20). Currently, 12 implementing measures have been taken for the following product groups: Air Conditioners and Comfort Fans, Household Dishwashers, Household washing machines, Domestic refrigeration, Circulators, Electric motors, Televisions, External Power Supplies, Lighting Products in the Domestic and Tertiary Sectors, Simple Set-Top Boxes (which convert digital input from e.g. antennas to analogue output signals on e.g. a television), and Standby and off Mode Electric Power Consumption of Household and Office Equipment.

Information in implementing measures consists among others of: Generic- and Specific Ecological Requirements and Information requirements. Generic Ecological Requirements (GERs) aim at the improving of the overall environmental performance, focusing on environmental aspects identified in the implementing measure. Specific Ecological Requirements (SERs) are thresholds for selected environmental aspects with a significant adverse impact on the environment. Implementing measures may also include information requirements to be supplied by the producer regarding: (a) information from the designer relating to the manufacturing process; (b) information for consumers on the significant environmental characteristics and performance of a product, accompanying the product when it is placed on the market to allow consumers to compare these aspects of the products; (c) information for consumers on how to install, use and maintain the product in order to minimise its impact on the environment and to ensure optimal life expectancy, as well as on how to return the product at end-of-life, and, where appropriate, information on the period of availability of spare parts and the possibilities of upgrading products; and (d) information for treatment facilities concerning disassembly, recycling, or disposal at end-of-life.

The information is thus available depending on the specifications of the implementing measure. As an example the GERs and SERs of household washing machines and televisions have been studied. The GERs and SERs of washing machines only address energy consumption via the Energy Efficiency Index, the washing capacity via the Washing Efficiency Index and water consumption. Scarcity of materials in any phase of the products lifecycle is not addressed in this implementing measure. Benchmark information describing the best available standards on the market is included (European Commission, 2010). The GERs and SERs of televisions mainly revolve around energy

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[82] "Energy-using products use, generate, transfer or measure energy (electricity, gas, fossil fuel), such as boilers, computers, televisions, transformers, industrial fans, industrial furnaces etc." (European Commission, accessed May 6, 2012, Ecodesign: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/index_en.htm

[83] "Energy related products do not use energy but have an impact on energy and can therefore contribute to saving energy, such as windows, insulation material, shower heads, taps etc."(ibid).

[84] Comitology is EU jargon for "a procedure that allows the European Commission tob e assisted by a Comitology Committee when using its implementing powers". There are three types of committees: advisory, management and regulatory (Lobby Planet, accessed May 7, 2012) EU Law. http://www.lobbyplanet.eu/wiki/when/legislative-procedures/eu-law/).

consumption when the power is on and in standby modus. Moreover, it specifies that manufacturers are required to specify whether mercury or lead is present in the television (European Commission, 2009).

Producers are obliged to compile technical documentation that can be requested by the verifying body to assess the product conformity with the requirements in implementing measures. This data is not publicly accessible and the verifying body in not allowed to publish the content.

A motion of May 8, 2012 for a European Parliament resolution calls for the extension of "the scope of the eco-design directive to non-energy related products and to come forward with additional eco-design requirements on the performance of products, including recycled content, durability and reusability, in order to improve their environmental impact and promote recycling markets;" (Gerbrandy, 2012: 5).

Since the implementation measures are obligatory for producers, each member state designates a body "that presents the necessary guarantees for impartiality and availability of technical expertise for carrying out a verification of the product with regard to its compliance with the applicable implementing measures" (European Commission & Parliament, 2009: 13). In the Netherlands the 'Inspectie Leefomgeving en Transport' has since 2010 been designated by the public authorities to fulfil this task. It is also their task to act in response to reports of possible non-compliance. Moreover, the Directive states that "the exchange of information on environmental lifecycle performance and on the achievements of design solutions should be facilitated" (ibid). However, in practice this does not occur, and scarcity proved not to be a priority yet. This information also won't enable cascading use of materials.

Concluding, much information possibly useful for the resources passport is gathered, yet only for a standard product and not publicly accessible. Additionally, the implementing measures, so far, do not reflect scarcity issues and the scope of the directive is limited.

4.3.9 REACH: Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

REACH Regulation EC/1907/2006 addresses the design of products by assessing and reporting about the risk of the substances used in the product. If these risks are found to be unmanageable, the use of these substances can be restricted, subjected to prior authorisation which is only granted under specific circumstances, or they can be banned. The end goal is replacing hazardous substances with benign or less hazardous substances. Although the usage of non-hazardous substances and information about substance properties enhance design changes, better enabling the closure of resource loops, this directive is primarily aimed at reducing the human health and environmental risk of substances used. The analysis is on the level of substances, not products.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

Safety Data Sheets provide information about recycling and methods of disposal, which enable better recycling of substances. However, the improvement and creation of end-of-life systems is not a specific goal under the REACH regulation.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of networks of material exchange is not a goal in itself, however, REACH does enhance the free circulation of substances on the European market. This indirectly benefits the creation of networks of material exchange. Possibilities for cascading use are not addressed either.

4. *The collection, management and exchange of resource-related information.*

REACH is a legally binding directive that in principle applies to all chemical substances. There are several stakeholders: producers or importers of materials, downstream users, member states and ECHA.

"REACH places the burden of proof on companies. To comply with the regulation, companies must identify and manage the risks linked to the substances they manufacture and market in the EU" (ECHA, 2012, understanding REACH). All producers and importers of substances, used in volumes of 1 tonne or more annually, must register them with ECHA. There are additional requirements for substances in finished products. Registration means submitting a technical dossier for substances in quantities of 1 tonne or more per year and additionally a chemical safety report for substances that are used in quantities of 10 tonnes or more annually. There is a gradual increase in information requirements, as the tonnage of the substance increases. These requirements are set out in Annexes VI to XI. The technical dossiers report about the substance identity; this includes CAS numbers, weight, composition and other properties. Furthermore, information about physicochemical properties, mammalian toxicity, eco-toxicity, environmental fate, including abiotic and biotic degradation, information on manufacture and uses as well as risk management measures have to be reported (ECHA, 2012: information requirements). As specified in Annex I, a chemical safety report assesses above mentioned features. When substances have been found hazardous, an exposure assessment and risk characterisation have to be made (ibid).

To gather all this information about the specific characteristics of a substance, as laid out in the technical- and chemical safety report specific substances, companies that use the same substance are required to jointly register the substance. This also prevents duplication of studies and unnecessary animal testing. Third parties like citizens, organisations, academics etc., may provide information on a testing proposal involving vertebrate animals. After registration, information about a substance is publicly accessible on the website of ECHA.

Safety Data Sheets, and if necessary exposure scenarios developed in the chemical safety report, are used to communicate information for manufacturers or importers to downstream users, who use the substance, in the course of their activities. As specified in Annex II of the directive, Safety Data Sheets provide information on the properties and the composition of the ingredients, hazardous materials upon decomposition of the product, handling and storage information, recycling and methods of disposal for industry and for the public, toxicity information etc. Distributors and consumers are not classified as downstream users. They are informed about the risks of certain substances via the CLP regulation.

After registration, ECHA and the member states have a different role. ECHA is in charge of evaluating the compliance of the registrations. The member states evaluate substances for their effect on human health and the environment. If the risks of a particular substance are found to be unmanageable, the member states can subject it to prior authorization, restrict the use or ban it completely.

Concluding, information exchange under REACH takes place among all producers and importers of a substance in Europe, cross-sector and cross-cycle, since they are required to jointly register a substance. However, the information exchange is primarily aimed at identifying the human health and environmental risks of a substance, plus the prevention of unnecessary animal testing. The information is thus not aimed at addressing scarcity, products or end-of-life systems. The exchange of information to downstream users is aimed at safe handling of the substances. Although after registration information about a substance is publicly accessible, it is not directly communicated to distributors or consumers. They are informed about the health and environmental hazards of a substance via the CLP regulation. Yet, also this information is not aimed at addressing scarcity in any way.

4.3.10 CLP: Regulation on classification, labelling and packaging of chemical substances and mixtures

1. *The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.*

Regulation EC/1272/2008 on the classification, labelling and packaging of chemical substances, aims at the protection of the environment and human health via communicating the hazards of chemicals to workers and users of chemicals. Therefore substances are classified and labelled according to the UN (Globally Harmonized System) GHS. This communication of hazards is aimed at the safe usage, not at the prevention of scarcity or the closing of the resource loops via design changes. Therefore, this regulation does not pursue principle one of the circular economy.

2. *The improvement and creation of end-of-life systems for flows of resources and products.*

The Safety Data Sheets provide information about recycling and methods of disposal, which enable better recycling of substances. However, the improvement and creation of end-of-life systems is not a specific goal under the CLP regulation and is therefore not pursued.

3. *The creation of, preferably regional, networks of material exchange.*

The creation of, regional, networks of material exchange is not addressed nor pursued in this regulation.

4. *The collection, management and exchange of resource-related information.*

This directive complements the REACH regulation. The regulation ensures that workers with and consumers of chemicals are informed about the hazards of chemicals by means of classification and labelling of chemicals. First of all, manufacturers, importers, and downstream users are required to self-classify substances and mixtures placed on the market. Therefore they need to identify whether the substances entail a physical, health, or environmental hazard. This procedure is set out in Annex I. Information that, among others, needs to be gathered is "(a) scientifically sound data (article 8(3)), (b) epidemiological data and experience on the effects on humans, such as occupational data and data from accident databases; (c) any new scientific information" (ibid: article 5). The information manufacturers, importers and downstream users gather for the self-classification should be kept available for a period of at least 10 years after the substance of mixture was last supplied (article 49).

If substances fulfil the criteria of Annex I, they have to be labelled before placement on the market or notified to ECHA when not placed on the market. Labelling is done in accordance with a standardised system, the GHS, so that workers and consumers know about their effects before they handle them. These labels consist of standard statements and pictograms on the labels and safety data sheets.

Article 17 presents the general rules of the content of such a label: "(a) the name, address and telephone number of the supplier(s); (b) the nominal quantity of the substance or mixture in the package made available to the general public; (c) product identifiers as specified in Article 18; (d) where applicable, hazard pictograms in accordance with Article 19; (e) where applicable, signal words in accordance with Article 20; (f) where applicable, hazard statements in accordance with Article 21; (g) where applicable, the appropriate precautionary statements in accordance with Article 22. This precautionary statement includes information about the disposal of the substance or mixture; (h) where applicable, a section for supplemental information in accordance with Article 25" (ibid: article 17). These labels are used as a communication tool to consumers.

Safety data sheets are the other communication tool, solely used to communicate the hazards of chemicals within the supply chain. As specified under REACH, safety data sheets contain information about the properties and the composition of the ingredients, hazardous materials upon decomposition of the product, handling and storage information, recycling and methods of disposal for industry and for the public, toxicity information etc.

The creation of a classification and labelling inventory is another obligation as specified in the directive. This database, publicly accessible on the website of ECHA, contains the following information (article 42) on the notified and registered substances: "the name in the IUPAC Nomenclature for substances classified with certain hazard classes or categories set out in Article 119(1)(a), without prejudice to Article 119(2)(f) and (g) of REACH, the name of the substance as given in EINECS, if applicable, and other numerical identifiers as appropriate and available, and the classification and labelling of the substance" (ECHA, 2012, Classification & Labelling Inventory).

This information has been provided to ECHA by companies who submit their classification and labelling notifications or registration dossiers. ECHA does not verify the accuracy of the information.

Article 46 specifies the role of member states, namely: ensuring that all substances and mixtures placed upon the European market comply with this regulation. Therefore, every five years they have to submit a report to ECHA with the results and possible additional enforcement measures. This report contains aggregate, national data.

Concluding, information collection, management and exchange are one of the main aims of the CLP regulation. However, the collection and exchange mainly addresses the environmental and human health hazards. Limited information can be used to address scarcity of resources.

4.3.11 LAP: Landelijk Afvalbeheerplan 2009-2021'

1. The redesign of products and production processes so they can operate in closed loops with a minimal- or zero impact on the environment and human health.

The National Waste Management plan 2009-2021 ('*Landelijk afvalbeheer plan 2*'; from now on referred to as LAP2, the Dutch abbreviation), is the interpretation of the '*Wet Milieubeheer*' which obliges the Dutch ministry of Infrastructure and Environment to determine a waste management plan. As stated in article 10.14 of the Wet Milieubeheer, the LAP2 is horizontally and vertically binding for governments in the Netherlands. The fact that local governments are also bound by the LAP2, and have to use the LAP2 as a reference to their own plans, is rare in Dutch environmental policies.

Its goal is the prevention of waste, limitation of the environmental pressure of the activity 'waste management' and limiting the environmental pressure of products' supply chains by means of supply chain oriented waste management policies[85]. The main focus is on waste management. Prevention of waste is only a minor part of this policy. The Eco-design directive is the sole design oriented aspect referred to. It is seen as a useful instrument in the attainment of the supply chain oriented waste management. Concluding, the LAP2 itself is not pursuing principle one of the circular economy.

2. The improvement and creation of end-of-life systems for flows of resources and products.

The LAP2 defines several quantitative and qualitative aims that both enhance principle two of the circular economy. The quantitative aims among others set a target for the prevention of waste; not more than 68 Mt in 2015, the increase of the useful application of municipal waste to 60% in 2015, the phasing out of land-filling of combustible waste, and reduction of the environmental pressure for the seven priority waste streams (paper and cardboard, textile, construction and demolition waste, organic waste, aluminium, PVC and large municipal waste.

The qualitative aims refer to among others the use of C2C as a source of inspiration for the attainment of the goals related to these seven waste streams. Moreover it defines minimum standards for specific waste streams. These minimum standards define the minimal quality of processing to prevent lower-grade processing. For example the minimum standard can be landfilling, incineration or useful application.

The LAP2 does not provide a detailed specification on how these aims should be achieved. The execution is left to the municipalities and waste processers themselves. Moreover the improvement and creation of end-of-life system is mainly aimed at reducing the overall environmental pressure, referring to emissions, and not specifically at reducing vulnerability to resource scarcity. The much stimulated 'useful application' of resource also includes incineration with energy recovery, which still results in the loss of the resources.

3. The creation of, preferably regional, networks of material exchange.

The creation of networks of material exchange is solely referred to in the context of C2C, that is seen as an inspirational source rather than a obligatory requirement.

4. The collection, management and exchange of resource-related information.

The policy does not devise specific information collection by municipalities or waste processors. However the government does monitor the progress on the attainment of the quantitative and qualitative goals devised and general implementation of the policy. Annually PBL and CBS publish an integral report. The facts and figures presented in the report are gathered throughout the year by governments, branch organisations, companies etc. The organization 'Agentschap NL' is responsible for the coordination of the gathered material. These figures are publicly accessible on

[85] "Dit algemene milieudoel betekent dat het afvalstoffenbeleid zich richt op het beperken van het ontstaan van afvalstoffen, het beperken van de milieudruk van de activiteit 'afvalbeheer' en het vanuit ketengericht afvalbeleid beperken van de milieudruk van productketens" (VROM, 2010:15).

the specially designed database called '*Afval Monitor*'. This database reports mainly about the total waste collection and the separation rates.

The minimum standards, part of the qualitative goals, are developed based on so-called 'BREFs' which stands for Best Available Technology Reference documents. These documents are developed in accordance with the Integrated Pollution Prevention and Control Directive of the EU. That directive aims at preventing and controlling the pollution stemming from large companies by means of requiring them to have a permit based upon the use of best available technologies. The BREFs identify the best available technology based upon the amount of pollution, mainly air pollution. There are no BREFs related to resource use.

Part of the goal of prevention of waste, the LAP2 refers to another database called 'Environmental Measures' or in Dutch '*Milieumaatregelen'*. This database reports about various preventive environmental measures and practical examples on waste, water, energy etc. The database does not specify any detailed product information, however the available information does enhance the application of best available technologies by businesses.

Other relevant information is provided in the appendix, which specifies end-of-life possibilities of various waste streams. This is thus not defined on a product level, however useful when reusing and recycling. Consumers are informed about how to dispose of their waste mainly via AgentschapNL. This organization simultaneously gathers information about waste disposal and separation by consumers and indirectly also of companies. This information is used to monitor progress, benchmark and conduct research. However, mainly national and generic information is publicly available.