The Hague **Centre for Strategic Studies • TNO**

Resources for our Future

Key Issues and Best Practices in Resource Efficiency

STRATEGY & CHANGE

RESOURCES FOR OUR FUTURE

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Key Issues and Best Practices in Resource Efficiency

The Hague Centre for Strategic Studies (HCSS) and TNO
within the context of the Strategy & Change-programme

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Foreword

The availability of critical resources for a competitive price is a fast-growing concern for business and industry but also for governments all over the world.

As the Dutch economy depends very heavily on the availability of many different resources, an early and sustainable response from business and industry is necessary. Companies can stepwise reduce their vulnerability by first analyzing their specific situation regarding critical resources, second by developing a resource strategy, and third by innovating. Innovation can result in more and further reuse or in developing alternatives for less readily available or expensive resources.

For our business and industry, these developments require knowledge and awareness about 'what's really going on in the resource business'.

With this excellent publication *Resources for our Future* TNO and HCSS explore the implications of recent developments and inspire entrepreneurs to start a journey in the world of resources. The publication gives practical examples of how entrepreneurs deal with issues of scarcity of raw materials, and how they make their businesses more economically sustainable. I support their ideas on how to tackle problems with security of supply of critical resources, and I commend their creative and innovative approach with new business models.

Let their innovative thinking be your inspiration!

Bernard Wientjes
President of the Dutch Confederations of Industry and Employers

Management summary

Natural resources, including minerals, water, energy and arable land, are the basis of human society. Throughout the 20th century, the growing population has led to an increase in the use of fossil fuels by a factor of 12, and to the extraction of 34 times more material resources. As a consequence, Earth's climate is changing, fish stocks and forests are shrinking, the prices of energy resources and critical materials are rising, and species are becoming extinct. If the population grows as expected and the mean per capita consumption doubles by the year 2050, it is most probable that humanity will experience the limits to growth.

Improving resource efficiency is about improving the quality of life while limiting environmental degradation by using resources more wisely and changing patterns of production and consumption. The main ambition is to enable prosperity for a growing population without exceeding planetary limits. In order to support economic growth with fewer resources we need to improve the efficiency of resource use, in terms of the economic value per unit of resources used. This is exactly what has been achieved in recent years: the world economy in 2005 extracted some 30% fewer resources to produce € 1 of GDP than it did in 1980. In absolute terms, however, global resource extraction is still rising. Population growth and economic growth have obviously outweighed the improvements in resource efficiency.

Key issues

Scarcity of natural resources is a largely a dynamic concept. The availability of natural resources is a function of current market conditions and technological means. The imbalance between booming demand and limited supply has resulted in high prices and increased competition between countries over access to natural resources. In July 2008, crude oil prices averaged 133 USD per barrel which represented a price increase of 94% from a year earlier. World food prices went from an all time low in 2002 to a record-high in 2008. Commodity prices have not only become higher but more volatile as well. At the same time, the international system is in transition. The relative power of the West is declining and the influence of emerging economies is growing. Slowly, we are moving away from a Western-dominated to a multipolar world order in which state capitalist tendencies are becoming more prominent, especially in the natural resources sector.

Countries with limited or no natural resource endowments are most vulnerable to the effects of high prices and supply disruptions. High prices and supply disruptions are a threat to economic security, as they may reduce a country's economic and innovative competitiveness and negatively affect national employment and prosperity. In some countries economic security is also important for social and political security. In China, for example, securing resources for economic growth is key to avoiding instability as a result of domestic opposition to the authoritarian regime. Some metals are also of strategic importance for military security, as they are used in high-tech defence technologies.

Supply disruptions may be accidental. For example, food supplies may be hampered by extreme weather event or wildfires that destroy harvests. Political instability increases the risk of supply disruptions. Congo for example, is the biggest producer of cobalt (25,000 tonnes in 2009) and holds the world's vastest cobalt reserves (3.4 million tonnes), but also one of the countries that scores high on political risk indicators. Supply disruptions, however, may also be intentional. The temporary freeze on rare earth exports from China to Japan is an example of the strategic use of minerals in international relations today. In September 2010 a Japanese coastguard patrol boat and a Chinese trawler collided near the Senkaku islands in the East China Sea. The Senkaku islands are the subject of a territorial dispute; both countries seek territorial sovereignty over the islands and possible nearby oil reserves. In retaliation for the capture of the Chinese trawler captain, China halted its rare earth exports to Japan until the diplomatic dispute was settled some weeks later on 24 September.

Securing resource supplies has thus become a priority for policy makers and companies. Import-dependent economies aim to secure their access to necessary resources for economic growth. In 2010, Japan gained access to Bolivia's lithium reserves in exchange for financial support and the construction of solar panels, energy plants and hospitals. China and other Asian and Middle East states, are actively purchasing and leasing land in Africa for food production.

Producing countries aim to reap the benefits of their natural resource endowments and rising prices through policy measures like increased taxation on extraction revenues (such as the super-profits tax in Australia), and export quotas (such as the Chinese export restrictions on rare earth elements). Governments are also increasingly limiting access to the domestic resource sector to foreign companies through licence fees, tariffs for mining and agricultural permits, making it more difficult for them to invest and gain access to resources in producing countries. In Canada, for example, the government ruled against the takeover of the Canadian potash producing company Potash of Saskatchewan by mining multinational BHP Billiton on the ground that the takeover was not in Canada's interest.

We observe an increasing prevalence of resource nationalism, which can also result in the creation of state-owned enterprises or the nationalization of an entire industry. In South Africa, for example, President Zuma launched a state-owned mining company, the African Exploration Mining and Finance Corporation (AEMFC), and started a debate on whether or not to fully nationalize its mining sector. These geopolitical developments, both in resource-rich countries and producer states where the state has traditionally played an important role, as well as in parts of the world that take a more liberal view of government interference with the market, may result in supply disruptions, export restrictions and price manipulations.

For resource-rich developing countries, sustainable resource management can catalyze economic growth and exports, and contribute to poverty reduction. In weak or failed states the potential economic growth is often not realized due to corruption, conflict, violence, human rights abuses and the lack of good governance. Many minerals used in consumer electronics, such as mobile phones and computers, are mined under dire social circumstances and working conditions or in areas controlled by warlords and militias. In the DR Congo, for example, the mining of gold, tin, tantalum and tungsten is controlled by warring factions, and the minerals are smuggled out of the country and traded illicitly. Money earned from the sale of these minerals is used for the personal profit of the militia leaders. The mining of these 'conflict minerals' contributes to the dire human rights situation and the protraction of the conflict.

The degree to which resource use causes environmental degradation depends not only on the amount of resources, but also on the types of resources and the ways they are used. The use of fossil energy resources may result in security of supply issues and may seriously impact the global climate. The demand for metal ores and industrial minerals is likely to rise steeply even under a business-as-usual scenario, while the quality of these resources is falling, and the related energy use and ecosystem degradation are likely to rise. Last but not least, the need to increase agricultural production and the rising use of biotic resources may cause depletion of arable land and clean water supplies and ecosystem degradation.

For private companies, making more efficient use of resources makes a lot of business sense, since it can help to improve profitability and competitiveness. The European Commission sees increasing resource efficiency as a way to generate economic opportunities, to boost employment and to improve Europe's global competitiveness. And for both companies and nations, improvements in resource efficiency should reduce their vulnerability to supply disruptions, a risk that is no longer negligible.

Resource strategies

Producers and consumers may contribute to the more sustainable use of natural resources using a wide range of strategies. These vary from measures to improve the efficiency of mining activities and existing manufacturing processes, to making radical changes in the design and use of products. Together, these strategies combine two lines of action: improving our present production and consumption patterns, and changing these patterns by addressing the underlying causes of overconsumption in society.

For most resource strategies the business case is far from obvious. Most of the strategies address more than one system level: materials, products, processes, the product chain, the product service system, the economic system, cultural values, etc. Each strategy that effectively impacts at one system level may result in additional costs and benefits at other system levels or somewhere along the product chain. Consequently, the costs and benefits of resource strategies are difficult to assess and in most cases are unevenly distributed across many stakeholders. With many actors and interests at stake, the challenge is to build coalitions between these actors that will enable a fair distribution of the costs and benefits along the value chain so that actions may be taken from which all may benefit.

Best practices

The second part of the book presents 21 inspiring examples of best practices in resource efficiency in a variety of industrial sectors. Based on a series of interviews with industrial pioneers, these chapters relate their experiences in improving resource efficiency. These business cases demonstrate that innovation and entrepreneurship can result in substantial improvements in resource efficiency.

Creating the built environment involves the use of substantial amounts of energy and construction minerals such as sand, gravel, lime, stone and clay. Best practices in the building industry have succeeded in reducing considerably the energy and material intensity. The business cases described in chapter 5 illustrate the virtue of know-how combined with creativity in the production, reuse and recycling of building materials. It is not only new technology, but the very concept of building that is changing. Building is conceived as a circular process in which building materials can be used and reused endlessly and in which the building itself is perceived as a 'materials bank'.

Feeding society impacts large areas of farmland and uses huge amounts of fertilizer, biotic resources (crops and livestock), water and energy. The business strategies described in chapter 6 have succeeded in improving resource efficiency throughout entire value chains. Key to their success are the inspiring new forms of cooperation developed between industrial sectors, and between industry and government. These new coalitions are developing interesting new business opportunities or are even creating entirely new business chains, as in the case of the introduction of insects as an alternative form of animal protein.

The chemical industry produces most of the ingredients, compounds and semi-products used in the majority of products manufactured in our society. Fossil fuels are traditionally the main resources used in the chemical process industry. Chapter 7 describes five surprising and convincing business ventures based on biotic resources such as straw, sugar beet and meat by-products, that demonstrate the potential of biotic resources as important alternative feedstocks. The bio-based economy is gradually becoming a reality as the value of bio-based products is rediscovered in new market applications.

High-tech devices such as computers, cars and coffee machines generally combine two types of material – plastics and metals – which traditionally have been dumped, burned or disposed of as waste at the end of their useful lives. Chapter 8 presents various examples of companies that are improving resource efficiency by optimizing their production processes and by recycling metals, plastics and other materials. Although there is as yet no positive business model for recycling many waste streams, these companies are striving to close several material loops in partnership with their suppliers and customers. They show the potential of new business models that gain value from waste or provide added value for customers and other stakeholders by offering a service instead of merely products.

Resource efficiency is an issue in the fashion and furnishing industries. Even the highest-quality products are disposed of as waste after a very limited time, and their production is energy and resource intensive or generates enormous volumes of waste water. Several best practices described in chapter 9 demonstrate that it is possible to design short-cycle products that can be 'reincarnated' at the end of their economic lifetimes into better than standard products. One of these is a revolutionary method of dyeing fabric that eliminates the need for vast amounts of fresh water and chemical dispersants, while radically reducing the use of energy and emissions of waste water.

Challenges ahead

We face the challenge of restructuring our industrialized economy from the present one based on an abundance of natural resources to a future economy that provides continuously improving goods and services for an increasing number of people, at prices they can afford, without unsustainable impacts and in ways that create jobs and true value. This truly represents a societal transition in which technological innovation goes hand in hand with the development of new business models, the building of new public–private partnerships, and the introduction of new and supportive governance structures.

Governments and international bodies could enhance this transition by:

- developing policies aimed at increasing transparency in the international trade regime for natural resources. The current situation of high price volatility is a negative sum game and benefits no one, with the possible exception of speculators;
- forging strategic bilateral partnerships between import-dependent economies, like the European Union, and politically stable suppliers of raw materials and semi-finished goods;
- enhancing international initiatives aimed at banning the trade in conflict minerals and at improving governance, transparency and sustainability in the extractive industries;

- encouraging true value pricing of natura l resources and monetizing the social and environmental impacts of pollution and emissions. This would discourage the overconsumption of resources and production beyond sufficient demand and would create an important stepping stone towards closing material loops;
- supporting the development of new coalitions that bring together companies, regulatory bodies, societal stakeholders and knowledge institutions in the joint implementation of best practices and in ground-breaking innovation programmes. Collaboration across traditional institutional boundaries is vital for enabling surprising new business opportunities to emerge within and beyond niche markets.

Substantial steps towards green growth need to be taken soon if we are to ensure the availability of resources for our future, and to enable prosperity for all without crossing planetary boundaries. Many of these measures would have to be coordinated on a European or an international level, although national approaches should not be overlooked. The industrial best practices presented in this book show that this societal transition will not only reduce resource vulnerability, but may also give rise to new and inspiring opportunities for business.

1 Introduction

Natural resources, including minerals, water, energy and arable land, are the basis of human society. However, the levels of consumption of these resources are rising rapidly. As a consequence, Earth's climate is changing, fish stocks and forests are shrinking, the prices of energy resources and critical materials are rising, and species are becoming extinct.

According to many scholars, population size and economic prosperity are the two main drivers of human impact on natural resources and ecosystems. Consider the following equation, originally presented by Ehrlich and Holdren (1971), which is often used to describe the relation between human impact and these drivers:

$$\text{Impact} = \text{Population} \times \text{Affluence} \times \text{Technology}$$

The equation suggests that if the world's population grows from the present 7 billion to some 9 billion in 2050, the impacts on natural resources and ecosystems are likely to increase considerably, especially if global economic growth results in a rise in the mean level of per capita consumption. Technological innovation may weaken the combined effects of population growth and economic growth if it enables the more efficient use of natural resources.

We should mention that the equation itself has engendered heated debate, especially regarding the relative importance of the three factors. Neo-Malthusians such as Paul Ehrlich believe that population is the number one problem. Ecological economists, like Herman Daly, believe that exponential population growth combined with increased consumption is the real culprit. Biologist Barry Commoner, however, focused on the amount of pollution resulting from economic growth, and concluded that population and affluence would contribute much less pollution than the technology of production (Commoner et al., 1971). Other commentators argue that economic growth is not the problem but the solution. One of them is Julian Simon (1980), who suggests that increasing populations and decreasing resources will boost technological innovation.

1.1. Drivers of resource use

Although opinions differ as to the precise relation between population, affluence and technology, the overall conclusion stands. Throughout the 20th century, the growing population has led to an increase in the use of fossil fuels by a factor of 12, and to the extraction of 34 times more material resources. If the population grows as expected and the mean per capita consumption doubles by the year 2050, it is most probable that humanity will experience the limits to growth.

The size and composition of the world's population will continue to change and increase the demand for natural resources. Although the rate of population growth has been slowing, the world population in absolute numbers will grow rapidly due to declining mortality rates in combination with a stable global fertility rate. According to the UN Population Fund, the world's population will exceed 9 billion by 2050 and will reach 10.1 billion by 2100 (UNPF, 2010). Most of this growth will take place in developing countries, in particular in cities (UN, 2011). Age structures are changing and the global median age is rising. As a result of improved sanitation and healthcare systems, and healthier and wealthier lifestyles, life expectancy is climbing in both developed and developing countries (de Spiegeleire et al., 2010). With population growth, the number of people leading resource-intensive lifestyles will increase (Hubacek et al., 2007). The FAO (2011) estimates that global food production will need to increase by 70% to meet demand by 2050.

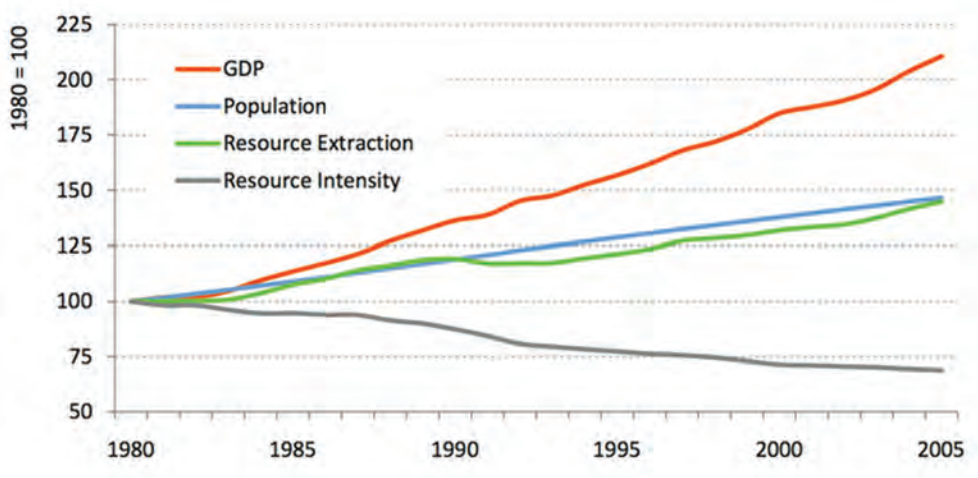
Economic growth is the second structural driver of resource use. Whereas much of the demand for natural resources has traditionally come from the consumption and production patterns and lifestyles associated with the developed world, it is now driven mainly by the accelerated economic growth of non-Western economies. Between 1990 and 2006, for example, energy use in high-income countries increased by 20%, compared with 40% in non-OECD countries (UN, 2010). Despite the negative effects of the recent economic crisis, the World Bank (2011) predicts that global GDP growth will continue in the coming years, with an average of 3.6% in 2013. In developing economies this percentage is even projected to be as high as 6.3%. If this rate of growth persists into the next decade, most of the increase in global demand for natural resources will come from low- and middle-income countries, in particular China, India and other emerging economies, the Middle East and Caspian Sea regions (EC, 2011a).

Economic growth also increases the demand for natural resources due to associated processes such as urbanization and changing consumption patterns. Continuing urbanization, and the growth of megacities with more than 10 million inhabitants, will spur the development of infrastructure for sanitation, water, transport and other public services that require energy, minerals and other resources (PRB, nd). Increasing prosperity will also change lifestyles. The rapidly growing middle class of emerging economies will increase the demand for luxury goods and services, such as cars, cell phones and travel. People are also moving up the food chain, wanting to eat more meat, eggs and dairy products (Brown, 2011).The production of luxury goods and services is resource intensive: food and drink have the highest ecological impact per dollar spent, followed by household equipment and transport (WWF, 2007). Worldwide, the middle class is expected to triple by 2030. In China the middle class is expected to increase fourfold between 2004 and 2025. By 2030, almost 80% of the world's population will be part of the middle class (WBCSD, 2008).

1.2. Decoupling

In managing our natural resources, the main challenge is to enable prosperity for a growing population without exceeding planetary limits. In order to support economic growth with fewer resources we need to improve the efficiency of resource use, in terms of economic value per unit of resources used. This is exactly what has been achieved in recent years. Figure 1.1 shows the development of GDP, population, resource extraction and resource intensity between 1980 and 2005. It is clear that we are improving in relative terms: the world economy in 2005 extracted some 30% fewer resources to produce € 1 of GDP than it did in 1980.

Figure 1.1 Relative decoupling of economic growth from resource use, 1980-2005. Source: FoE (2010)



In absolute terms, however, global resource extraction is still rising. Population growth and economic growth have obviously outweighed the improvements in resource efficiency. Measures need to be taken that will not only lead to improvements in the efficiency with which we use resources, but preferably do so in a way that will lead to 'absolute decoupling' – generating more prosperity for more people with fewer resources.

Returning to the formula above, one could argue that there is limited potential to influence population levels, and in many countries affluence still needs to grow significantly to provide a good quality of life for all. This leaves technology – or, in a broader sense, innovations that enable a more efficient use of natural resources – as the (main) factor that can lead to decoupling.[1]

For private companies the efficient use of resources makes a lot of business sense, since it can help to improve competitiveness and profitability. Similarly, the European Commission sees increasing resource efficiency as providing economic opportunities and as a way to boost employment. Generating more prosperity for more people with fewer resources is an integral part of the agenda to improve Europe's global competitiveness (EC, 2011b).

1.3. Global dimensions

For 200 years industrial development was based on cheap fossil energy and cheap raw materials. In recent years, the prices of raw materials and energy have already risen, due mainly to the increasing demand from emerging economies such as China. In the coming decades the availability of critical resources cannot be taken for granted. The succesful exploration and exploitation of resources will most likely not be able to keep pace with the steep increase in overall consumption, resulting in price fluctuations, speculation and scarcity.

Note, however, that the rates of exploitation and use of natural resources differ considerably from one country to another. Industrialized countries in Europe, North America, and also in Asia, export mostly manufactured products with high value added, while many developing countries continue to rely on exports of agricultural products and raw materials such as minerals and fossil fuels. Exporting manufactured goods is usually more profitable than exporting commodities.

Europe is to a very large extent dependent on imports of natural resources from the rest of the world, so that European industries are vulnerable to sudden supply shocks. Resource-rich countries such as China, in contrast, are able to give their industries an advantage over their international competitors. Faced with the prospect of increasing demand and tightening supplies of minerals used in critical applications, access to scarce minerals is increasingly being framed as an issue of vital interest or national security. China, the United States and Japan, for example, are all aggressively pursuing strategies that guarantee their high-tech industries' access to specific metals such as rare earths, a development that may come at the detriment of European interests (Kooroshy et al., 2010).

At present, the prices of many resources do not reflect the real costs of current levels of use to individuals and societies worldwide. For example, cheap oil has been the fuel for globalization and increasing international trade, without all the costs of its use – e.g. climate change, pollution and noise impacts of transport – being included in the price

1 Various authors have proposed formulas in which the 'T' factor is further decomposed; see e.g. de Bruyn (1998, 1999); Cleveland and Ruth (1999); Chertow (2000); Tukker and Tischner (2006).

(Collier, 2010). The environmental costs related to resources extraction and processing are high, and are borne mainly by resource-exporting countries, especially those with poorly developed environmental policies. The same goes for the social costs of resource exploitation. The role of valuable minerals such as diamonds, gold and coltan in stimulating national and international conflicts is well documented. In developing countries, resource abundance and political instability often go hand in hand.

1.4. Key issues and best practices

This book provides an analysis of the issues surrounding international resources and inspiring accounts of industrial best practices. The book consists of two distinct parts.

Part I: Key issues
The first part of the book brings together the results of years of research into the geopolitical, economic and ecological dimensions of material scarcity and resource efficiency.

Chapter 2 discusses the main challenges and constraints related to the use of energy resources, water and land, industrial and metallic minerals, construction minerals and biotic resources, including water use and ecosystem degradation. The chapter also addresses important linkages between these various resources.

Chapter 3 describes the international trends that are shaping the geopolitics of natural resources and looks at the implications for Europe and the Netherlands. The chapter presents an analysis of recent changes in the economic and political world order in which the trade in natural resources takes place.

Chapter 4 presents a wide range of strategies by which governments, producers and consumers may contribute to the more sustainable use of natural resources. These strategies include measures to improve existing mining activities, to optimize current manufacturing processes and to bring about radical changes in the design and use of products.

Part II: Best practices
The second part of the book describes 21 inspiring best practices in resource efficiency in a variety of industrial sectors. Based on a series of interviews with industrial pioneers, these chapters relate their first-hand experiences in improving resource efficiency. These business cases demonstrate that innovation and entrepreneurship can result in substantial improvements in resource efficiency.

Chapter 5 focuses on best practices in the built environment, where substantial amounts of energy and minerals are used. These construction minerals are not scarce, but producing building materials such as cement, asphalt and brick is very energy- and material intensive.

Chapter 6 presents four ambitious strategies to promote sustainable food production and consumption. The food industry produces most of the ingredients, products, meals and drinks we consume on a daily basis. Feeding society impacts large areas of farmland

and uses enormous quantities of fertilizer, biotic resources (crops and cattle), water and energy. With the world's population rapidly approaching 9 billion, food security is becoming an urgent issue.

Chapter 7 describes recent developments in the chemical process industry, which produces most of the ingredients, compounds and semi-products for the vast range of products used by society. Although the main resource for the chemical process industry has long been fossil oil, this chapter presents five surprising but convincing examples of new business opportunities based on biotic resources such as straw, sugar beet and meat by-products.

Chapter 8 provides four examples of the state-of-the-art in resource efficiency in the metal and high-tech industries. High-tech devices such as computers, cars and coffee machines generally combine two types of material – plastics and metals – which traditionally were dumped, burned or disposed of as waste at the end of their useful lives. This chapter presents four business cases highlighting the benefits of the efficient use and recycling of metals and plastics.

Chapter 9 focuses on the fashion and furnishing industries, where resource efficiency is an issue. Even the highest-quality products are disposed of as waste after a very limited time, and their production is energy- and resource intensive or generates enormous volumes of waste water. This chapter presents examples of companies in the fashion and home decoration sectors that have succeeded in closing the material loop.

Finally, chapter 10 relates the 21 best practices to the overview of resource efficiency strategies in chapter 4. It indicates where we stand today, and what we have learned in developing and applying these strategies. The chapter ends with some of the challenges that lie ahead in transforming the present economic system of exploitation and use of the world's resources into one that is more sustainable.

2 Resource constraints

The geopolitics of natural resources are shaped by the growing demand and the more slowly growing supplies. In recent decades the demand for fossil fuels, land and mineral resources has grown exponentially as a result of drivers such as population growth, industrialization and urbanization. According to the Organization of the Petroleum Exporting Countries (OPEC, 2011: 5-8), energy demand will increase by 51% by 2035, most of it from non-OECD countries. The UN Food and Agriculture Organization expects that food production will need to increase up to 70% by 2050 to meet the demand from the world's growing population (OECD/FAO, 2009). The demand for minerals is also expected to increase at a rate of 1% per year, and by 2050 will be 60% higher than it is today (Kesler, 2007).

The demand for natural resources fell temporarily in 2007 as a result of the financial crisis. Worsening economic conditions slowed the demand for energy resources. Lower energy prices also reduced the demand for biofuels and credit limitations reduced the trade in agricultural commodities. Nonetheless, demand has recovered more strongly than expected, especially from the rapidly developing emerging economies. Shortly after the worst dip, demand returned to pre-crisis levels. The resulting imbalance between demand and supply has led to tight mineral commodity markets and an unprecedented boom in the prices of both abiotic and biotic resources.[1]

2.1. A classification of challenges

The environmental and social challenges that face society at large and industry in particular can be classified in various ways. Here we use a categorization of resource-related challenges that has been inspired by two recent reports of the International Panel on the

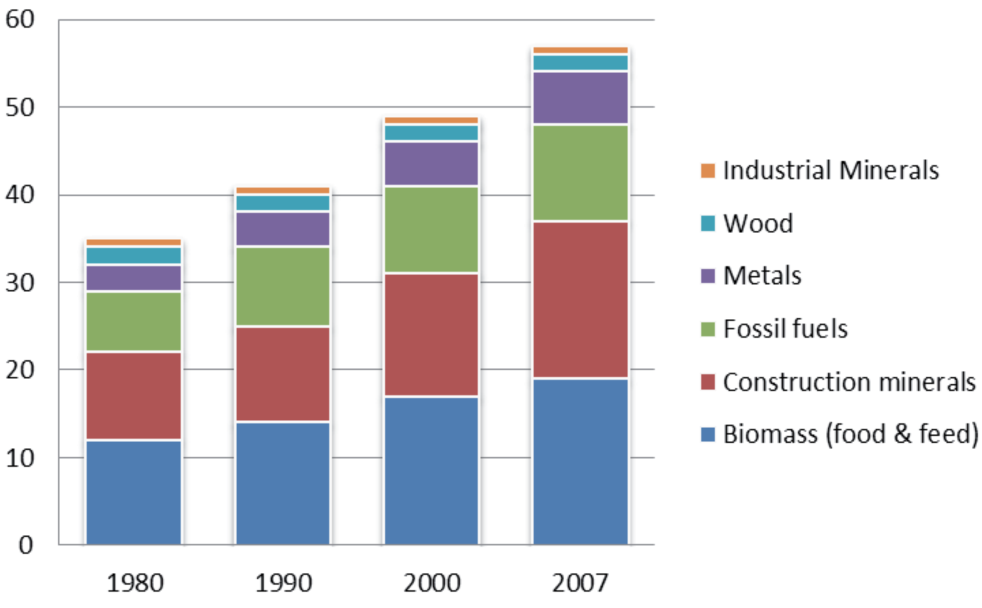
1 Biotic resources are obtained from living organisms such as plants and animals and include products from agriculture, forestry and fisheries. Abiotic resources are obtained from the physical environment and include minerals and metals.

Sustainable Use of Natural Resources (UNEP, 2010; 2011) and a set of indicators suggested by Giljum et al. (2009) for measuring eco-efficiency, which classifies resource uses and the related constraints according to the main categories identified in an economy-wide material flow analysis (MFA). From the recent trends in global resource extraction shown in Figure 2.1, it can be seen that biotic resources, construction minerals and fossil fuels now make up close to 80% of all materials extracted for human use, excluding water. Note that in this analysis, as well as the typical resources identified in the MFA, we also include water and land use.

This chapter discusses the challenges related to the following groups of resources:

- energy resources: security of supply and climate impacts;
- water and land: depletion and ecosystem degradation;
- abiotic resources:
  - industrial and metallic minerals: security of supply, energy use and ecosystem degradation;
  - construction minerals: energy use and ecosystem degradation; and
- biotic resources: water use and ecosystem degradation.

Figure 2.1 Global resource extraction, 1980-2007



Source: OECD (2008).

The chapter also addresses important linkages between these various resources. As the above list suggests, it may sometimes be possible to overcome the constraints with regard to one resource but at the expense of making significantly more use of another resource. It is therefore essential to apply a systemic view, in which all resource challenges are addressed in combination (Graedel and van der Voet, 2010; Meadows et al., 1972).

2.2. Energy resources: security of supply and climate impacts

In 2005, the world's total final energy consumption was 285 EJ[2], of which manufacturing industry accounted for 33% (including external energy supply from e.g. power plants; IEA, 2008), followed by transport and households. The most energy-intensive sectors include the steel, cement, chemicals and plastics, pulp and paper and aluminium industries.

For all of these industries, the main challenges include security of supply and energy prices. Competition over access to fossil fuels has already led to rising prices. Particularly for oil, a key 'portable' fuel that is essential for transport systems, newly discovered deposits tend to be smaller and require greater investments to access them. The International Energy Agency predicts that oil production will reach a plateau of 10.5 million barrels per day by 2017, after which it will no longer grow proportional with the economy or even decline slightly (IEA, 2011). New fossil energy resources such as tar sands require much more energy for their exploitation than conventional oil and gas. All of these trends indicate that energy is likely to become more expensive in the future; indeed, in its *World Energy Outlook 2011,* the IEA notes that 'Rising transport demand and upstream costs reconfirm the end of cheap oil'.

Another challenge is the concentration of ownership of energy supplies, which in the past has occasionally led to supply disruptions. Examples include the Arab oil embargo of the 1970s, and the dispute between the Russian Federation and the Ukraine over natural gas prices that began in 2005. With the phenomenal economic growth of China and India, where the demand for primary energy is expected to rise by at least one-third by 2035 (IEA, 2011), such problems are likely to become even greater. The challenges of security of supply and rising prices will hit industry in any case – there is no way that such costs can be externalized.

Climate change is another issue that will impact industry, but in quite different ways. In the absence of policies aimed at limiting carbon emissions, these impacts are externalized and there is no clear boundary within which industry has to operate. Although recent attempts to agree on global carbon emission reduction targets have been unsuccessful, it is probably naïve to assume that industry will not be affected by climate policies. The EU's Emissions Trading Scheme, which puts a price on carbon emissions, for example, has been operational since 2005.

Even institutes such as the IEA have provided clear warnings about climate change (IEA, 2011):

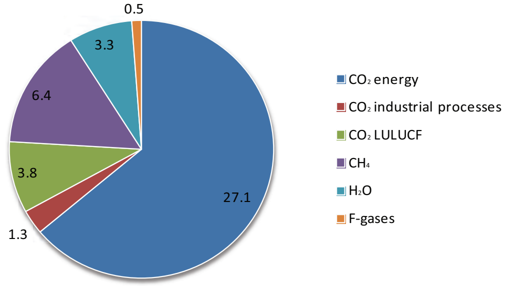
> We cannot afford to delay further action to tackle climate change if the long-term target of limiting the global average temperature increase to 2°C, as analysed in the 450 Scenario, is to be achieved at reasonable cost. In the New Policies Scenario, the world is on a trajectory that results in a level of emissions consistent with a long-term average temperature increase of more than 3.5°C. Without these new policies, we are on an even more dangerous track, for a temperature increase of 6°C or more.

2 1 EJ (exajoule) = 10^{18} J.

In 2005, total global CO_2 emissions were 28.4 Gt. Industry, in particular the energy-intensive industries mentioned above, was responsible for over 35% of these emissions, both direct and indirect (see Figures 2.2. and 2.3), followed by power plants, transport and the built environment. Agriculture and the food production system are responsible for almost one-third of greenhouse gas emissions via changes in land use and the methane (CH_4) produced by livestock (IPCC, 2007). From a final consumption perspective, housing, leisure, electrical appliances, transport, food and agriculture drive 80% of the life-cycle climate impacts (Tukker and Jansen, 2006; Hertwich, 2005). Significant transitions in all of these sectors and areas of consumption are essential if any policy aimed at limiting global warming to 2°C is to be effective.

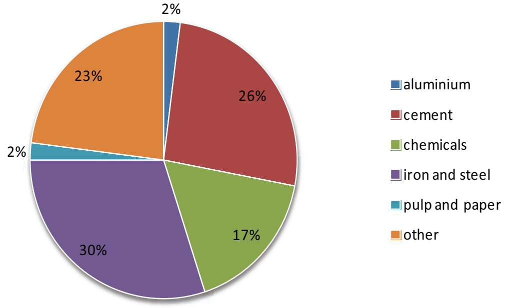
Unfortunately, a shift to alternative energy systems that could reduce security of supply problems and climate impacts is likely to involve trade-offs with other resource constraints. Even a modest switch to biofuels, for example, would create enormous pressures on land in many parts of the world (UNEP, 2009; Erb et al. 2009; Westhoek et al., 2011). A massive switch to renewable energy sources such as wind and solar power would need unprecedented amounts of critical raw materials such as Neodymium and Lithium that would soon exceed the known resource base (Kleijn, 2012).

Figure 2.2 Global anthropogenic greenhouse gas emissions by source, 2005



Source: IEA, 2009b. LULUCF = land use, land use change and forestry.

Figure 2.3 Global direct CO_2 emissions (7.2 Gt) by industry, 2006



Source: IEA, 2009a.

2.3. Water and land: ecological footprint

The growing scarcity of water and the availability of land will soon become significant factors that may constrain economic growth in the future. Forestry, agriculture and food production are responsible for some 90% of present (managed) land use. Industrial production or residential and infrastructural land use make up for the remaining 10% (UNEP, 2010). Additional pressure on land use and water use will be caused by the production of biomass for biofuels and biofeedstocks for industry (UNEP, 2009), as discussed above an issue related to energy use and climate change. In the agricultural sector the increasing use of fertilizers will cause further problems. The use of artificial nitrogen-based fertilizers leads to emissions of N_2O, a potent greenhouse gas, and to the eutrophication of lakes, while phosphorus-based fertilizers rely on natural phosphate deposits that are rapidly being depleted.

An interesting way of looking at land use is the 'ecological footprint' (WWF, 2010), an indicator that measures the land currently used for human purposes (for food production, buildings and infrastructure) but adds to it the land that would be needed to generate sustainable energy or to store CO_2 emissions from fossil fuels as biomass. It is then possible to compare the area of productive land available with the area that is needed – not surprisingly leading to the conclusion that there is an overshoot: more than one Earth is already needed to support the existing economic system.[3]

Both agriculture and industry face significant challenges with regard to water. Currently, the process water used by industry accounts for less than 10% of the volume used globally. By far the largest volume is used for agriculture (70%), followed by cooling water in the energy sector (10%) and drinking water (10%) (UNESCO, 2009). With the expected growth of industrial production, the demand for process water could grow to over 20% of global demand by 2030 (Water Resources Group, 2009; OECD, 2008). By that time, the demand for water is expected to exceed the maximum sustainable supply, leading to an absolute water shortfall of 40% at the global level (Water Resources Group, 2009). The extent of the shortfall will vary considerably at the regional and river basin levels (see Figure 2.4), as also will the extent to which industry drives water demand (see Figure 2.5; World Bank, 2008). Note that the above assessment focuses on quantitative estimates of water availability, but maintaining water quality is equally important. Again, there are likely to be enormous regional variations in water quality, but it is beyond the scope of this brief review to discuss them in detail. Finally, the use of water for cooling in power stations is of little concern as problems are related to the water temperature and not its quality.

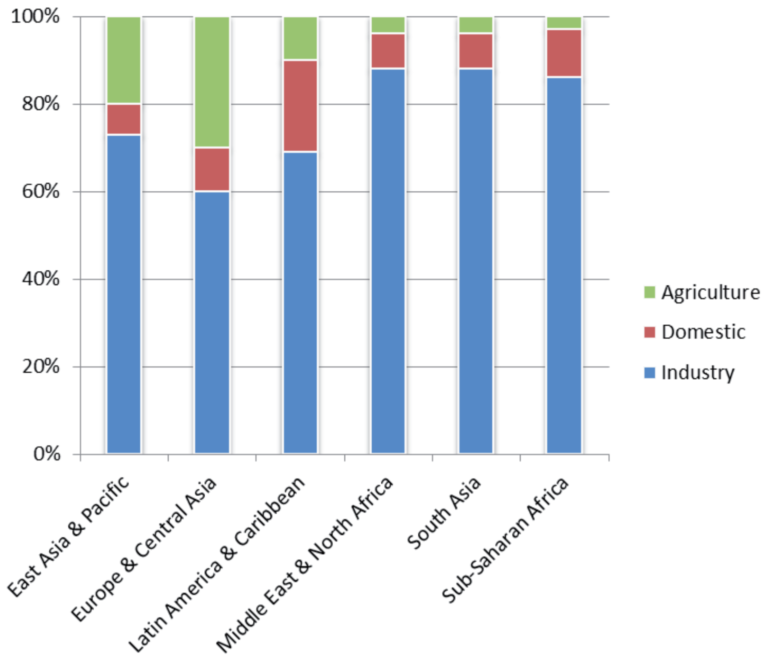
Millions of people in large parts of the developing world still have limited or no access to potable drinking water, leading to significant health problems (Griffioen, 2012). Problems with regard to the quality of waste water from mining and manufacturing industries are highly dependent on the water management practices they employ.

3 Although the 'ecological footprint' may be a persuasive concept that is easy to communicate, it has been criticized, in particular for expressing energy use in terms of land area.

Figure 2.4 Availability of renewable water supplies in 2025, in m³ per capita

Source: World Resources Institute, IUCN, IWMI, Ramsar (2003).

Figure 2.5 Water consumption by end use and region, 2008 (World Bank, 2008, table 3.5). Note that 'Industry' includes the electricity sector, whose use of water for cooling and other purposes accounts for more than half the consumption shown here



Source: UNESCO, 2009.

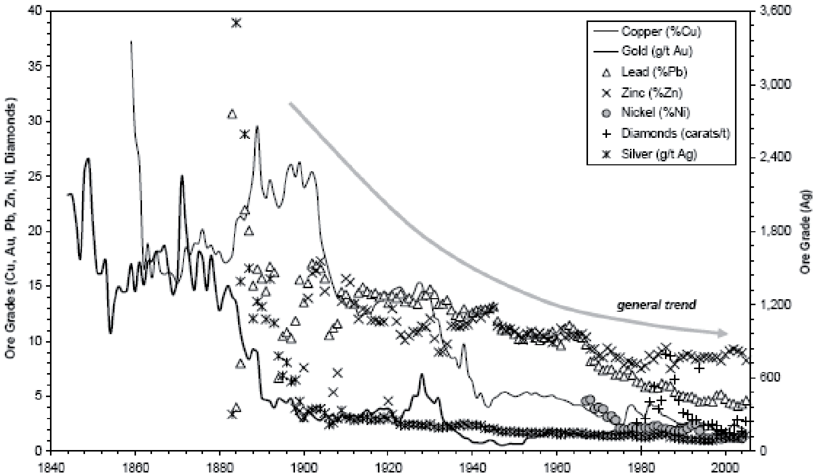
The growing scarcity of water has a number of obvious implications. Agriculture, the most important sector, will certainly need to change. Agricultural production must double by 2050 to meet the growing demands of populations that are becoming wealthier and so can afford diets rich in animal protein. Industries operating in regions where water systems are already under stress, and where industrial water demand is significant compared with other areas of demand, must dramatically improve their water use efficiency. This is particularly urgent for industries that use large volumes of water, such as pulp and paper, textiles and steel production, but less so for industries in regions where levels of water stress are lower, or where demand is dominated by sectors such as agriculture.

In addition to efficiency improvements to reduce the use of water, technical solutions such as desalination are available, but they are expensive and involve important trade-offs in terms of energy use and related greenhouse gas emissions (Water Resources Group, 2009; Graedel and van der Voet, 2010). Climate change, in turn, may have implications for the security of water supplies. Glaciers are expected to recede and become smaller. They will serve less as buffers for precipitation, which may imply certain river basins will be supplied less with water, or are supplied with the same amount in more concentrated time periods (IPCC, 2007).

2.4. Abiotic resources: metal ores and industrial minerals

Resource intensive industrial sectors face at least four challenges. First, emerging economies such as China are developing rapidly and their demand for resources is rising. Each year, China produces and consumes close to half of the global cement and over one third of steel. Competition for access to resources is likely to grow.

Figure 2.6 Grades of metal ores extracted from Australian mines, 1840-2005



Source: Mudd, 2009.

Second, as high-grade metal ores are gradually depleted (Figure 2.6), lower-grade deposits must be used that need much more energy to extract the useful metal component, in turn leading to higher costs and prices, and adding to climate change. Third, at the local level, resource extraction can have significant detrimental impacts on ecosystems, landscapes, watercourses, etc.

Fourth, there may be issues of security of supply. For some materials, the richest sources may be located in politically unstable areas, have been (partially) depleted, or are currently needed in such limited quantities that one or a few sources can supply them, potentially leading to monopolistic situations. China, for instance, is currently the main supplier of rare earth elements, but it needs most of its production for domestic use. The Chinese government has therefore restricted exports of these elements. This results in significant supply problems for non-Chinese users, although – according to the US Geological Survey – global reserves of rare earth elements are 800 times or more than current production (Graedel, 2011).

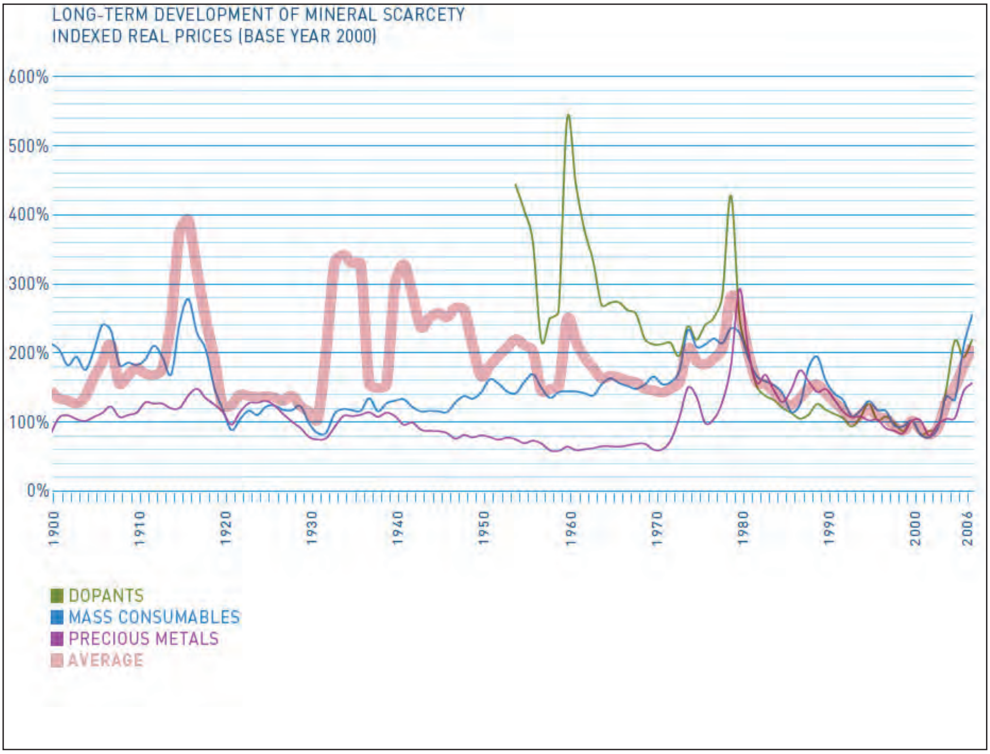
Not all industrial sectors will be equally affected by scarcity or security of supply issues, and not all materials are equally important in terms of their environmental impacts. Some fundamental challenges for the steel, aluminium and particularly electrical and electronics industries may be expected, however. The steel and aluminium industries are already responsible for some 5% of global energy consumption and the related carbon emissions. As high-grade ores become scarcer, they will have to be replaced by low-grade ores that are more difficult to extract and require more energy to refine. For some critical materials such as lithium and rare earths, used in the electrical and electronics industries, there are already problems with security of supply. If there were to be a significant transition to alternative (e.g. solar-based) energy systems and electric cars, the production of such critical materials would have to rise, leading to unprecedented levels of demand that would exceed the currently proven resource base (Kleijn, 2012).

Having said this, the prices of most materials still seem to be within their historical ranges (see Figure 2.7), so that suggestions of absolute scarcity are questionable or maybe relevant only to a particular set of critical materials (UNEP, 2010; EU, 2010). The jury is still out on whether this time the situation is different and that 'limits to growth' resource pessimists are indeed right, or whether, as reflected in the saying 'the Stone Age didn't end because we ran out of stones', humanity will once again be able to innovate itself out of these impending scarcity problems (Kleijn, 2012).

2.5. Abiotic resources: construction minerals

As shown in Figure 2.1, in terms of volume, construction minerals are much more important than industrial and metallic minerals – in fact, the former dominate global material use. At the same time, there is ample evidence that they may be the least problematic resources used by society, although there are some notable exceptions. Construction

Figure 2.7 Long-term trends in mineral prices, 1900-2006, base year 2000

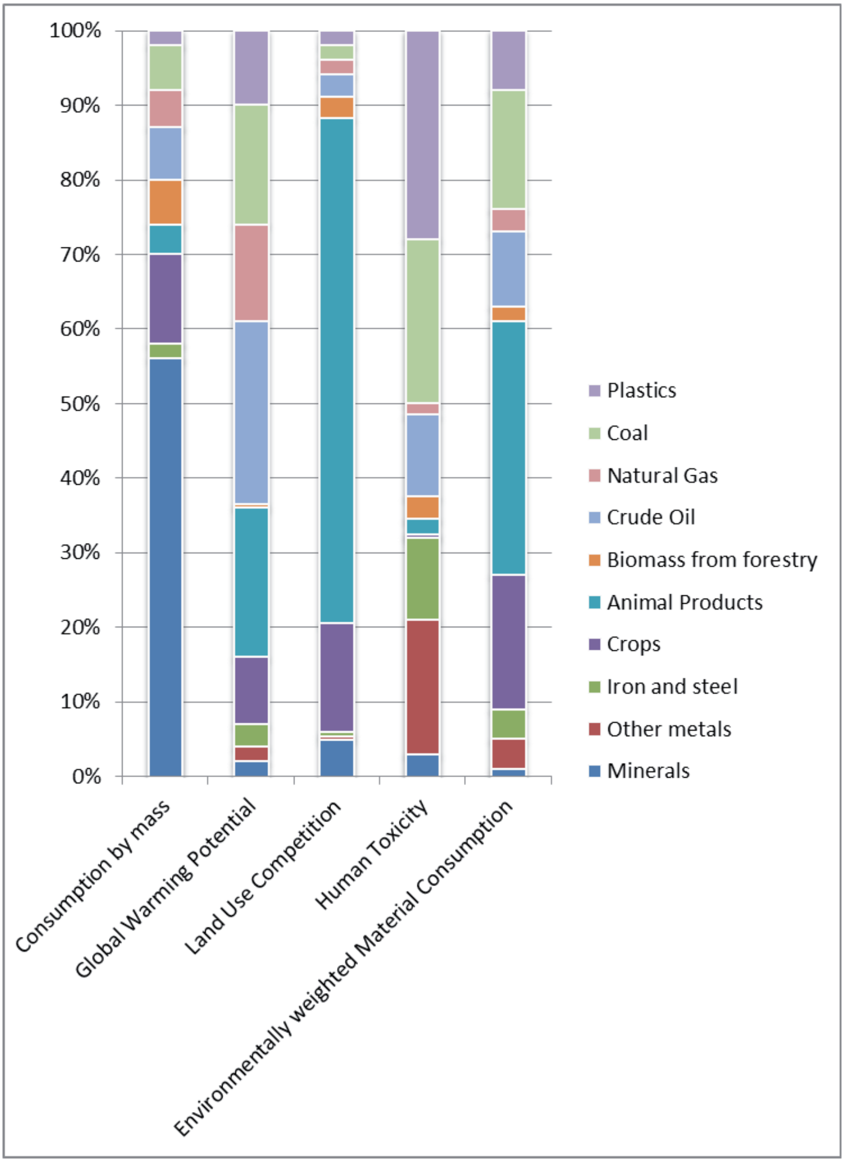


Source: Kooroshy et al., 2010.

minerals such as sand, gravel, stone, limestone and clay are not scarce; indeed, they can be found almost anywhere, and Europe is virtually self-sufficient (EU, 2010). It is only in small, densely populated countries such as the Netherlands that competition and trade-offs (e.g. between sand and gravel extraction and other forms of land use) may impose limits on extraction.

Also, in terms of their environmental impacts, construction minerals are not a priority problem. This can be seen in Figure 2.8, which combines information about the uses of these materials in Europe with their life-cycle environmental impacts per kilogram (UNEP, 2010). Whereas construction minerals dominate consumption by mass, they are of marginal importance in relation to global warming, toxicity to humans, land use, or integrated 'environmentally weighted material consumption'. The latter indicator combines volume of material use with the cradle-to-gate life-cycle impacts of that material (van der Voet, 2005). The main exceptions are construction minerals produced in high-temperature processes, most notably cement, steel and to a lesser extent glass and ceramics. As shown in section 2.2, such energy-intensive construction minerals contribute significantly to global warming impacts, and this is the main reason for limiting their use or changing production practices in the future.

Figure 2.8 Relative contributions of various materials to environmental problems, EU-27 + Turkey, 2000



Source: UNEP, 2010.

2.6. Biotic resources: HANPP and biodiversity problems

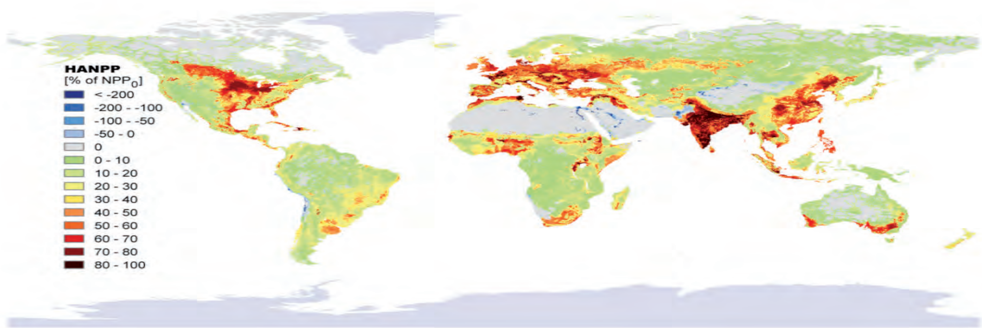
With regard to the use of biotic materials, the potential constraints can be derived from studies such the Millennium Ecosystem Assessment (MEA, 2005) and indicators such as the Human Appropriation of Net Primary Production (HANPP).

Produced by more than 1300 scientists from all parts of the world, the Millennium Ecosystem Assessment (MEA) is widely regarded as the most authoritative analysis of the status of global ecosystems. The MEA found that humans have changed ecosystems more rapidly and extensively over the past 50 years than at any other time in human history, largely to meet the growing demand for food, fresh water, timber, fibre and fuel. This has resulted in a substantial and largely irreversible loss of diversity of life on Earth. According to the MEA, the most significant causes of ecosystem degradation include:

- habitat changes (related to e.g. the conversion of natural areas to agricultural land, changes in water supply);
- pollution (particularly nitrogen and phosphorus);
- overexploitation of biotic resources such as fisheries and forests; and
- the spread of invasive species.

An alternative way to identify the potential limits on the use of biotic materials is the HANPP, an indicator that measures the percentage of the net primary production of biomass (or energy or carbon embodied in it) that is used by humans, by land conversion and biomass harvesting (e.g. Vitousek et al., 1986; Haberl et al., 2007). These authors estimate that humanity now appropriates around 30-40% of the net primary production of biomass (see Figure 2.9 for the regional distribution). A HANPP of 100% is obviously destructive since this would mean that all resources would be appropriated for human purposes, leaving none for other species (Haberl et al., 2004).

Figure 2.9 The global Human Appropriation of Net Primary Production (HANPP) in 2000 (from Haberl et al., 2007)



Both the MEA and the HANPP signal that there are important constraints that will limit the use of more biotic materials. It will be difficult to convert even more land for the production of biotic materials, since habitat change is a major factor leading to ecosystem degradation. Even the more intensive use of biotic materials will also soon reach its limits – the overexploitation of many fisheries and forests is already a reality. The HANPP points out that the current level of exploitation (30-40%) is dangerously close to the theoretical maximum (100%). Enhancing (agricultural) productivity is the only way out, but this will involve trade-offs with regard to the use of more water and energy-intensive products such as fertilizers (Graedel and van der Voet, 2010).

2.7. Linkages and trade-offs

As shown above, the growing scarcity of different resources will have different impacts and give rise to different problems. Or, as noted in the recent report of the working group on decoupling to the UNEP Resource Panel: 'The degree to which resource use causes detrimental environmental impacts depends not only on the amount of resources used, but also on the types of resources used and on the ways in which they are used' (UNEP, 2011).

Industry seems reluctant to accept 'one-size-fits-all' indicators and policy packages that do not acknowledge the crucial differences between resources (e.g. Euromines, undated). Based on the previous sections, Table 2.1 summarizes what constraints may arise, and Table 2.2 shows which sectors and areas of final consumption may be most affected (compare also Fischer-Kowalski et al., 2010). It should be noted that to a significant extent, consumption in Western countries drives resource extraction and impacts abroad. In other words, Western countries depend on resources from other countries for their wealth. This dependence has been demonstrated for energy use and climate impacts (Hertwich and Peters, 2009), for biodiversity impacts (Lenzen, 2012) and water use (Hoekstra and Chapagain, 2007). Studies by the EU's EXIOPOL[4] project have shown how enormous this dependence is (Tukker et al., 2013). European consumption depends for over 50% of the land use, 40% of the water use and 30% of the raw material use on other countries (see Table 2.3).

In formulating solutions to address these challenges, the potential trade-offs should not be underestimated. All resource constraints are interlinked, so that an approach that aims to resolve problems with regard to one resource may cause even worse problems for other resources. Some of the most prominent trade-offs may be between (Graedel and van der Voet, 2010):

- Energy/greenhouse gas emissions and land use: a significant switch to biomass-based energy may lead to a prohibitive level of demand for agricultural land, and increase water scarcity.
- Land use/biotic material use and water use plus energy/greenhouse gas emissions: the area of land required for the production of food, biofuel and biofeedstocks could

4 EXIOPOL – A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis – is an integrated project funded by the EU. www.feem-project.net/exiopol/

Table 2.1 Potential resource constraints

Type of resource	*Fraction of global mass of resources extracted*	*Basis for planetary limits*	*Potential limits*	*References*
Fossil fuels	20%	Absolute scarcity CO_2 emissions targets	EU targets 20% greenhouse gas emissions reduction by 2020 Scientific targets: >80% reduction by 2050	EC (2008, 2010); Meinshausen et al. (2009); IPCC (2007)
Biomass	30%	Maximum Human Appropriation of Net Primary Production (HANPP)	Currently, 30-35% of available biomass is extracted by humans. Target may be stabilization or minor growth	Vitousek et al. (1986); Haberl et al. (2007)
Metal ores and industrial minerals	10%	Absolute scarcity (different for each metal). The high levels of energy needed for refining most metal ores implies a 'linkage' to CO_2 emissions targets and energy constraints	Focus on 14 critical raw materials identified by the EU's Raw Materials Initiative. Changes in energy and transport infrastructures (solar cells, batteries) will determine future criticality	EU (2010) For linkages with energy use, see Graedel and van der Voet (2010)
Construction minerals	40%	Absolute scarcity not relevant, except in densely populated areas where space for sand, clay and gravel winning is limited	Implicit targets for construction minerals whose production requires high levels of energy (e.g. cement, ceramics)	
Land	Not expressed as mass	Available productive land, with areas reserved for nature (e.g. rainforests)	Conflicting information about remaining areas that can be converted to agricultural use	Erb et al. (2009); WWF (2010); OECD/FAO (2009)
Water	Usually not included in MFA	Renewable supply (varies by region); agriculture is dominant user	A global 'water gap' of 30% expected in 2030	Water Resources Group (2009); Hoekstra and Chapagain (2007)

Table 2.2 Priority industries and final consumption categories by type of resource (based on TNO analysis from EXIOBASE* and UNEP, 2010)

Type of resource	*Fraction of global mass of resources extracted*	*Most relevant intermediate industries (by NACE code**)*	*Most relevant categories of final consumption*
Fossil fuels	20%	Electrical energy, gas, steam and hot water Various industrial processes (steel, cement, chemicals) Land transport	Heating and cooling, personal transport, energy using products
Biomass	30%	Agriculture, forestry and fisheries, food products and beverages Construction work	Food, hotel and restaurant services, real estate
Metal ores and industrial minerals	10%	Basic iron and steel and ferro-alloys and first products thereof Aluminium and aluminium products Other non-ferrous metal products	Real estate, gross fixed capital formation (infrastructure). Energy using products
Construction minerals	40%	Ceramic goods Bricks, tiles and construction products, in baked clay Cement, lime and plaster Construction work	Real estate, gross fixed capital formation (infrastructure)
Land, water	p.m.	Agriculture	Food consumption

* EXIOBASE is the EU's Multi-regional Environmentally Extended Supply and Use/Input-Output database.
** The NACE code system is the European standard for industry classifications.

Table 2.3 Environmental impacts related to the final demand, and to imports and exports per capita in the EU, 2000.* For instance, the final demand of each European citizen required the extraction and use of 17 tonnes of primary materials, of which 6.5 tonnes were provided by non-EU countries. This figure is much higher than the 2.6 tonnes of primary materials embedded in European exports

Impact type	Unit	Final demand per capita	Imports per capita	Exports per capita
Land footprint	ha	1.7	1.0	0.1
Water consumption blue (ground- or surface water)	m^3	767	335	75
Water consumption green (rainwater)	m^3	4446	2301	367
Primary materials extracted/ used	Tonnes	17.0	6.5	2.6
Global warming potential	Tonnes of CO_2 equivalent	12.4	2.3	1.6

* Assuming an EU-27 population of 483 million in 2000 (Eurostat, 2009).

be reduced (significantly) by raising productivity. However, this usually involves a significant rise in the use of water for irrigation, artificial fertilizers produced in energy-intensive processes or practices such as production in greenhouses.

- Land use/biotic material use and non-renewable material use: biotic materials could in principle replace non-renewable materials, but again would involve the above-mentioned trade-offs between water use and energy use/greenhouse gas emissions.
- Energy/greenhouse gas emissions and water use: increasing water supplies by introducing desalination on a large scale would require prohibitive amounts of energy.
- Energy/greenhouse gas emissions and industrial mineral resource use: the resource base may be extended, often by using lower-grade ore, which in turn will require significantly more energy for mining and refining. Conversely, a switch to carbon-neutral energy and transport systems may require unprecedented amounts of critical materials such as platinum, neodymium and dysprosium that would exceed the known resource base.

These ‘linkages of sustainability’ indicate that preventive approaches are probably preferable, but that systemic prospective analyses of the impacts of proposed solutions and strategies are essential.

2.8. Conclusions

This chapter has sketched the potential resource constraints on the one hand, and the significant demand for resources due to drivers such as population growth and increasing wealth on the other. The resulting picture is worrying.

We are not the first to provide such a picture. Almost four decades ago, Meadows et al. (1972) did so in *The Limits to Growth,* and many others have done so since then. But until now true resource limits have not materialized and the global economy was doing remarkably well until the financial crisis of 2007. So the question is, to paraphrase the concluding chapter of René Kleijn's (2012) thesis on critical materials, why should it be different this time? Will the 'resource optimists' who point out that humankind has always managed to engineer itself out of problems be proved wrong?

On the emissions side, we would argue that the battle against climate change is close to being lost. Meinshausen et al. (2009) calculated that in order to limit global warming to 2°C, a maximum of 1000 Gt of CO_2 could be emitted between 2000 and 2050. But even by 2006 emissions had already reached 246 Gt, leaving only 750 Gt to emit. Davis et al. (2010) showed that if we use all existing energy and transport infrastructures to the end of their economic lives, they would account for as much as 500 Gt of this emissions budget. So even if we were to invest 100% in carbon-neutral energy systems from now on, we would still reach (almost) the maximum threshold. But the worst impacts of climate change will only become apparent over decades, and it is unclear whether policy makers will support strong measures to mitigate them in the near future.

With regard to resources, we would argue that even resource optimists must agree that significant efforts will be needed to engineer humankind out of these problems. Water and land constraints, in combination with the need to increase agricultural production, pose formidable challenges. The same applies to some metal ores and industrial minerals, for which demand is likely to rise steeply even under a business-as-usual scenario, while the quality of these resources is falling, and the energy and other costs of mining and refining them are likely to rise. It seems obvious that companies that become more efficient in their use of increasingly scarce resources, or are able to develop alternatives using more abundant raw materials, will have the competitive edge in the future.

3 The geopolitics of resources

Population growth, economic development and changing consumption patterns are putting tremendous pressure on the demand for natural resources. Whereas demand is growing rapidly, supply is growing much more slowly due to a complex mix of factors, such as technological challenges, financial barriers or hindering legislation. The imbalance between booming demand and limited supply has resulted in high prices and increased competition between countries over access to natural resources. At the same time, the international system is in transition. The relative power of the West is declining and the influence of emerging economies is growing. Slowly, the world is moving from a Western-dominated order to a multipolar world in which state capitalist tendencies are becoming prominent, especially in the natural resource sector. Concerns about mitigating climate change, depletion of fossil fuels, economic competitiveness and innovation have pushed governments around the world to formulate natural resource strategies. Securing resources has become a priority for policy makers and companies.

The policy measures countries take vary. Whereas import dependent countries, including some of the emerging economies, aim to secure the necessary resources for economic growth, producing countries aim to reap the benefits from their natural resource endowment and rising resource prices. Certain policy measures have negative effects on international trade in resources. Increasing protectionism and other trade barriers pose a real challenge for the European Union (EU), which is to a large degree dependent on imports, and for European companies.

This chapter describes the international trends that are shaping the geopolitics of natural resources and looks at the implications for Europe and the Netherlands. First, it looks at the position of Europe and the Netherlands in international trade flows of natural resources and the vulnerability associated with import dependence for certain resources, including energy, minerals and food commodities. Second, the chapter looks at the changes in the international system that are shaping the current economic and political world order in which trade in natural resources takes place. Third, the chapter identifies challenges and opportunities for the EU and the Netherlands.

3.1. International trade flows of natural resources

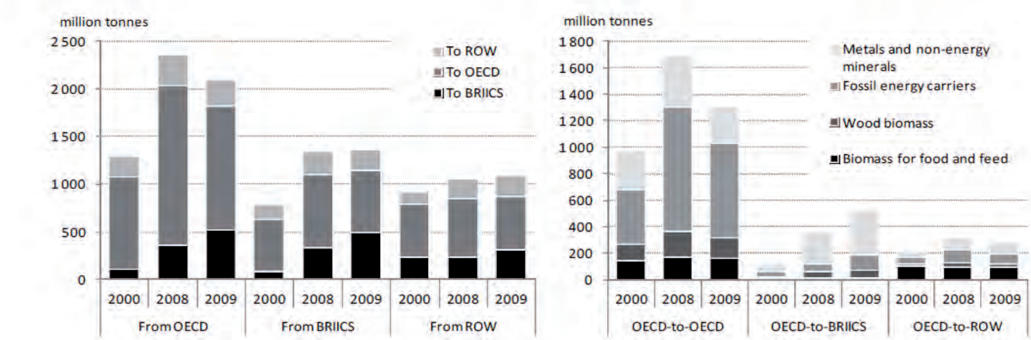
Natural resources are geographically unevenly distributed over the globe. Whereas some countries enjoy a rich resource endowment, others have limited or no domestic supplies. Trade has helped alleviate some of these disparities (OECD, 2011b). Trade in natural resources flows from production centres to consuming countries via countries in which one or more stages in the processing chain take place. Importing countries need resources as input to production processes and to maintain economic growth and well-being. For exporting countries, especially those with less diversified economies, the revenues from resource exports are an important source of income. This section shows the international trade flows for several important natural resources and highlights the important centres of production and consumption. The most significant trend in recent years has been the changing direction of international trade flows, with the centre of gravity shifting from the advanced economies of the OECD region to the emerging economies, represented by the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa). When observing international trade flows, one must bear in mind that countries are rarely 100% import dependent or fully self-sufficient. More often they are a combination of exporter of some and importer of other resources. After looking at the global picture, this section focuses on Europe's position in international trade flows.

Worldwide picture

Over the years, the trade in natural resources has grown due to globalization, the liberalization of trade and natural resource markets, and improvements in transportation technology, which have reduced the costs of shipping. These developments have increased the value, volume and range of trade flows of natural resources, which represent a growing share of international trade (IMO, 2012: 7). The value of global trade in raw materials, semi-finished and finished materials has grown faster than that of trade in manufactured goods, increasing from 13% to 17% between 2000 and 2008. Over the same period, in terms of the weight of goods loaded, the trade in raw materials, semi-finished and finished materials increased by 60%. These materials represent 50% of the weight of all goods traded, while fossil fuels alone account for 25%. Exports of natural gas and crude oil increased by 200% and 53%, respectively, between 2000 and 2008, as did exports of other materials, such as nickel (by 180%), iron and steel (74%), paper and paper products (60%) and coal (56%) (IMO, 2012).

Shifts in the global economy are also changing the direction of international trade flows in natural resources. The OECD economies were traditionally the largest consumers of natural resources, with the United States, Europe and Japan accounting for the majority of demand for raw materials. Now, however, demand is shifting from the advanced industrialized economies to the emerging economies. Economic development is a main driver of increased demand for raw materials and trade in these emerging economies. Economic growth in OECD countries is slower than in emerging economies such as the BRIICS. The economic crisis of 2008 was an important accelerator of the economic divide between the advanced and emerging economies. The OECD economies grew on average only by 2.1% per annum, whereas China, India and Russia showed growth rates of more than 8% of GDP (OECD, 2011b). According to data from the World Bank, between 2000 and 2008 China's consumption of metals, such as aluminium, copper, lead, nickel, tin and zinc, grew by an average of 16% per annum, whereas the demand for these metals in the rest of the world grew by an average of only 1% per annum (OECD, 2011b). The changing direction of trade flows can also be attributed to population growth and changes in consumption patterns. It is estimated that due to rising global prosperity and a growing middle class in the developing world, some 3 billon people are currently moving up the economic ladder (de Ridder, 2011b). This increase in wealth has resulted in less demand for staple foods and increased demand for meat, eggs and dairy products. Figure 3.1 shows the changing direction of trade flows.

Figure 3.1 Trade in raw, semi-finished and finished materials between the OECD, BRIICS and rest of the world (ROW) (2000-2009)



Source: OECD (2011b: 19).

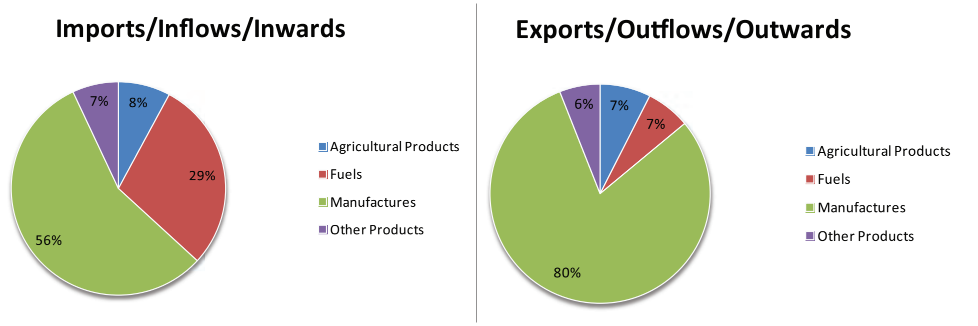
OECD countries remain important exporters and importers of natural resources. In 2008, half of the world's exports of raw materials, semi-finished and finished materials originated from OECD countries, compared with 30% from the BRIICS countries, and the remaining 20% from the rest of the world (OECD, 2011b). Of the exports from OECD countries, about 70% are to other OECD countries. Intra-regional trade within the OECD, however, has been declining due to increased export to the BRIICS countries and the economic crisis which significantly reduced demand for natural resources in OECD countries. Between 2000 and 2009 exports to the BRIICS countries increased from 8% to 25% of total OECD material exports (OECD, 2011b). Most of the expected economic growth in the near future will be driven by non-OECD countries and will be led by China, India and Indonesia (OECD, 2012: 12).

Within the OECD area, Australia, Canada and Norway are the major net exporters, followed by smaller net exporters such as Mexico, Sweden, New Zealand and Estonia. Canada and Norway export mainly fossil fuels and Australia's exports consist mainly of coal and metals. Between 1980 and 2008, their net exports quadrupled. Japan, the US, Korea, Germany, France, Italy, Spain and the UK are among the world's leading importing countries, accounting for 80% of total OECD imports in 2008. Among the BRIICS countries, China and India are the leading net importers. Their imports are dominated by fossil fuels and metals. Russia is a leading exporter of mainly fossil energy resources and saw its exports double between 1995 and 2008. Brazil exports mainly metals and biomass and increased its exports by factor of 9 between 1980 and 2008. Indonesia exports mainly fossil fuels and saw its exports quadruple in that same period. South Africa's exports are evenly divided between metals and fossil fuel energy resources (OECD, 2012: 52).

Position of the EU

At the global scale the EU is an important importer and exporter. Figure 3.2 shows that manufactured goods make up the majority of the EU's imports (and exports) of goods. Agricultural products, raw materials and fuels, however, also made up a significant share of the EU's imports in 2011 (EC, 2012e).

Figure 3.2 EU trade in goods



Source: EC (2012e).

Overall, the EU is a net importer of raw materials, including energy. In 2010, imports of raw materials, including energy, made up approximately one third of total EU imports. Non-energy industrial materials accounted for about 10% of EU imports on average over the last few years. In terms of value, the EU trade in raw materials in 2010 can be summarized as follows (EC, 2012c):

Table 3.1 EU exports and imports of raw materials

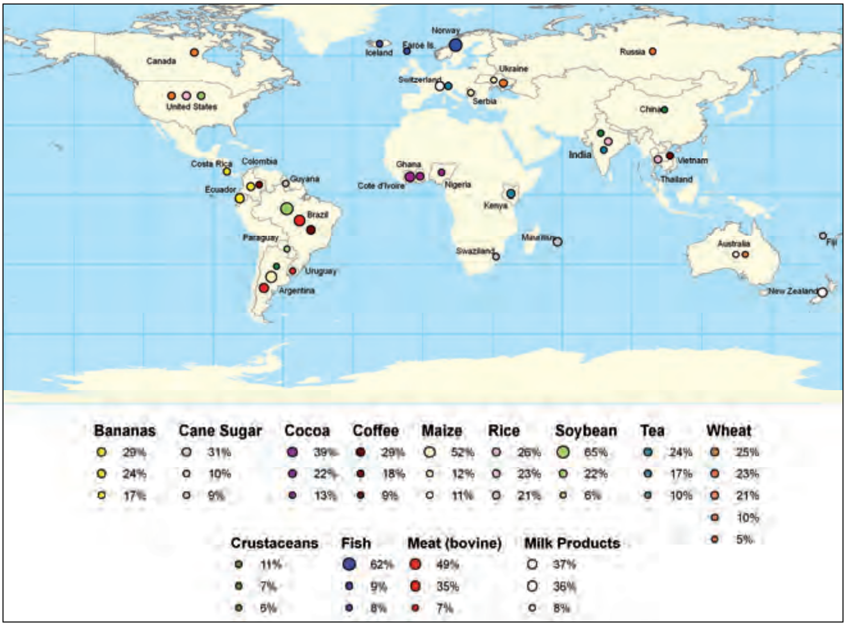
	Total EU exports	*Total EU imports*
Raw materials including energy	€ 181 billion	€ 528 billion
Non-energy raw materials	€ 100 billion	€ 142 billion

For many commodities, such as crude palm oil, bananas, cocoa, coffee and certain minerals, the EU accounts for more than 20% of total world imports (Dale, 2008: 27). For other commodities, such as maize and cotton, these shares are much smaller. There is a broad geographical spread of source countries and receiving countries although it is possible to identify a clear group of three to five leading source countries that account for most EU imports. For many commodities the top three source countries represent at least 50% of the total of EU imports. For minerals, metals and fossil fuels, this concentration is even greater. The countries featuring most regularly in the top three sources of EU imports of agricultural commodities (food and non-food), minerals and fossil fuels are Russia, US, Brazil, Norway, Canada, Australia and Ukraine. Price developments and high price volatility have caused significant changes in the import value from source countries (Dale, 2008: 28).

Agricultural and non-food agricultural commodities

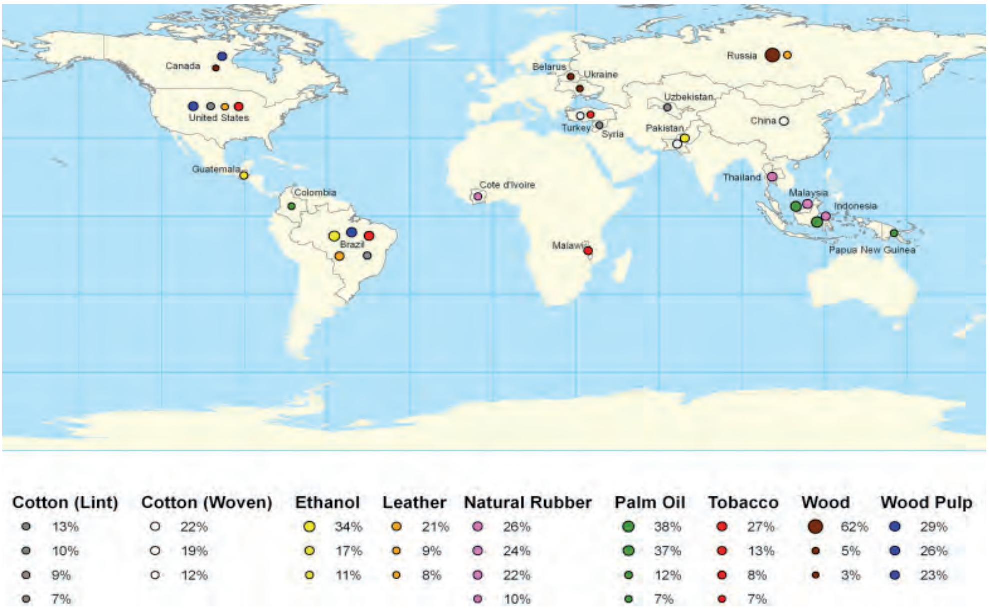
The EU is a major player on the world's agricultural markets, being the second biggest exporter of agricultural products and also the largest importer. The high import dependence for soy and vegetable oils, makes the EU a net importer. Figures 3.3 and 3.4 show

Figure 3.3 Main exporters of agricultural food products to the EU



Source: Dale (2008).

Figure 3.4 Main exporters of agricultural non-food products to the EU



Source: Dale (2008).

the trade flows to the EU for several agricultural food and non-food commodities, respectively. These maps show that there is a broad geographical spread of countries from which key EU imports of agricultural food and non-food products are sourced (Dale, 2008: 8). The maps also show a high concentration of source countries: for almost all commodities the top three countries present at least 50%, and in many case more than that, of total EU imports. For both groups of commodities the EU represents a major world market.

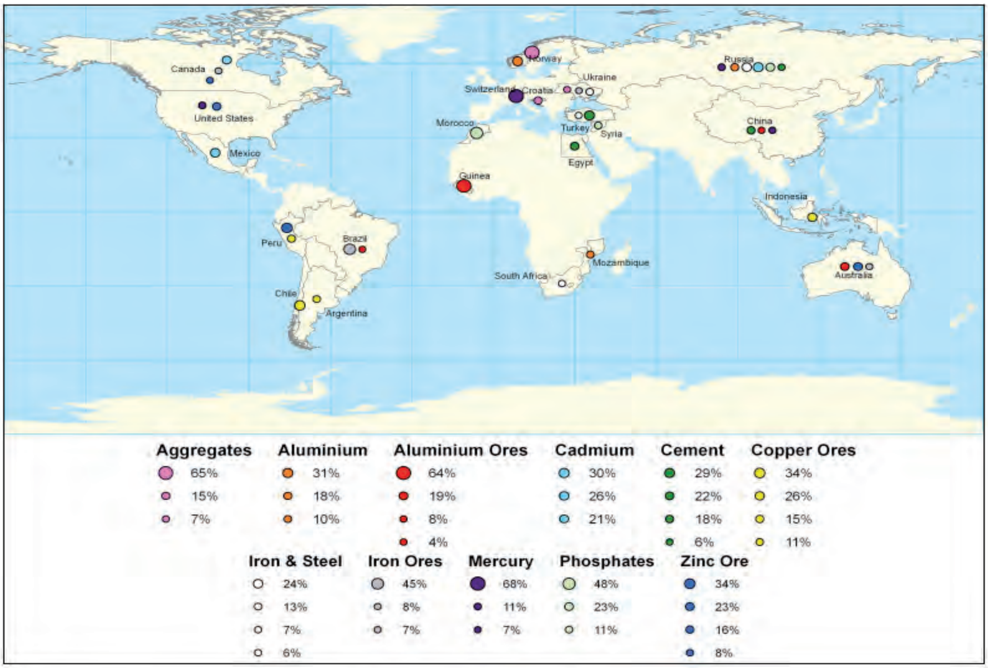
Minerals and metals

The EU has very limited domestic mining capacity and is highly dependent on imports of minerals and metals from non-EU sources. There is a domestic mining capacity for some metals in Austria (tungsten), Finland, Greece (bauxite, nickel), Ireland (zinc, lead), Norway (titanium), Poland (copper, silver, lead), Portugal (tungsten), Spain (gold), and Sweden (gold, lead, iron ore) (Mbendi.com, nd). For other metals, such as rare earths and platinum group metals but also base metals, it relies almost entirely on imports. In 2008, about 80% of zinc and aluminium ore and concentrates, 83% of iron ore and 74% of copper used in EU industries came from outside Europe (Dale, 2008: 20). EU policy aimed at improving resource efficiency and promoting recycling has reduced this dependency somewhat, but the EU's reliance on imports of minerals and metals remains high.

Although manufactured goods have the largest share in total EU imports when looking at the value of total imports (see Figure 3.2), the volume of trade in minerals is much greater than for manufactured commodities. In 2008, for example, the weight of EU imports of iron ore was four times greater than for iron and steel commodities while only a quarter of the value (Dale, 2008: 18).

Figure 3.5 shows that there is a regional spread when it comes to the source countries for EU imports of metals and minerals, but a concentration of top suppliers. For example, about 90% of imported aluminium ores and concentrates originated from three countries – Guinea (64%), Australia (19%) and Brazil (8%) (Dale, 2008: 21).

Figure 3.5 Main exporters of metals and minerals to the EU



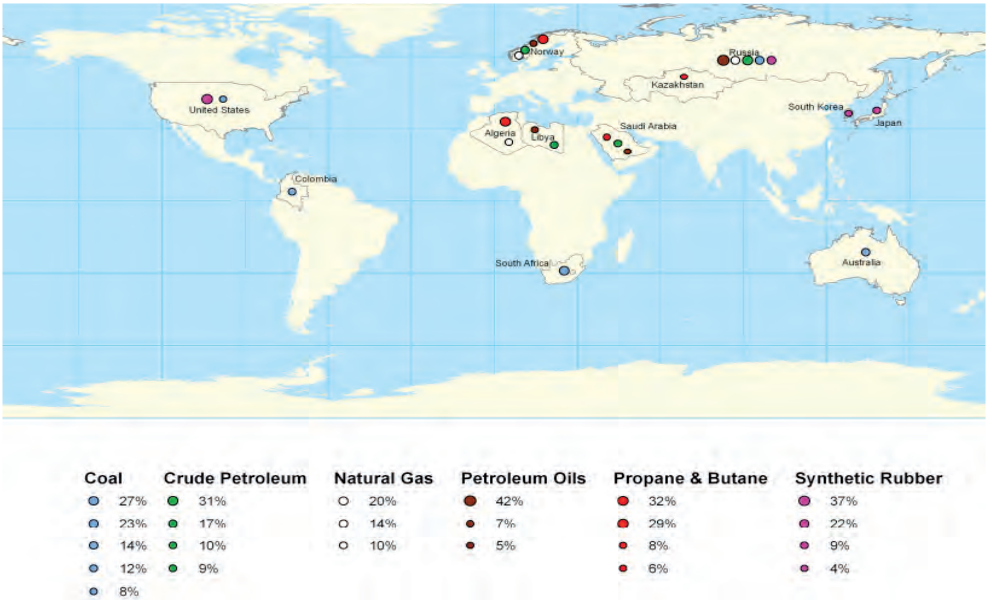
Source: Dale (2008).

Energy

There is limited domestic energy production in the EU. In 2009 the largest domestic energy producers were the UK, France, Germany, Poland and the Netherlands. Domestic energy production in the EU is falling due to the exhaustion of reserves and because exploitation of remaining resources is sometimes considered uneconomical. As a consequence, the EU is increasingly dependent on energy imports, particularly of oil and more recently also of gas. In 2009, more than half (53.9%) of the EU's energy consumption came from imported sources. The most populous member states are the largest net importers of energy, with the exception of the UK and Poland, which have domestic resources of oil, natural gas and coal (Eurostat, 2012).

Figure 3.6 shows that the geographical variance in the source countries of EU energy imports is smaller than for other commodities. Norway, Russia, Saudi Arabia, Libya and Algeria are among the most important exporters for many fossil fuel commodities to the EU. In 2009, 79.1% of the EU's imports of natural gas came from Russia, Norway and Algeria; 57.3% of crude oil imports came from Russia, Norway and Libya; and 77.5% of coal imports came from Russia, Colombia, South Africa and the US (Dale, 2008).

Figure 3.6 Main exporters of fossil fuels to the EU



Source: Dale (2008).

The geography of energy trade flows has shown some changes in recent years. First, Russia has become an ever more important supplier of energy to the EU. Not only has its dominance as a supplier of crude petroleum strengthened, but it has also become a more important supplier of forms of petroleum other than crude and of synthetic rubber (Dale, 2008: 23). Second, new suppliers are emerging. Hard coal imports from Indonesia, crude oil imports from Kazakhstan and Azerbaijan, and natural gas imports from Qatar, Libya, and Trinidad and Tobago are increasing (World Bank, 2009).

3.2. Price developments

The growing demand for and struggling supplies of resources have resulted in an unprecedented commodities price boom. According to the World Bank (2009), the commodity price spike between 2005 and 2008 was the highest and longest since 1900. The financial crisis brought down prices only temporarily as growth in the emerging economies picked up sooner than expected. Between 2003 and 2008, nominal prices of some abiotic resources increased by as much as 230%. In July 2008, crude oil averaged US$133 per barrel, which represented a price increase of 94% from a year earlier (Baffes and Haniotis, 2010). World food prices went from an all-time low in 2002 to a record high in 2008. The Food Price Index of the IMF shows a price increase of 90% since 2005. The UN Food and Agriculture Organization (FAO) warned that inflationary pressures will not abate any time soon (Blas, 2011). In their Agricultural Outlook 2012-2021, the OECD and the FAO announced that in the next decade agricultural commodity prices in real terms are likely to remain on a higher plateau compared to the previous decade (OECD-FAO, 2012). Cereal prices, for example, will be on average up to 20% higher and meat prices up to 30% higher compared with the previous decade (Farchy, 2011). In early 2012 commodities prices again reached an all-time high. As long as economic growth and other trends driving up demand persist, commodity prices will continue to remain high.

Commodity prices have not only become higher, but also more volatile. The IMF Food Price Index shows that the volatility for the most important traded commodities, wheat, corn and soybeans, is up by more than half since 2005 (FT.com, 2011). Some experts believe that increased speculation of non-commercial actors on commodities futures markets also has increased commodity prices and made them more volatile (de Ridder, 2011b). Financial firms are increasingly investing in commodities through futures contracts and other financial instruments, a process the FAO has labelled the 'financialization of commodities' (FAO, 2010). Although it is impossible to determine the exact impact of speculation on food prices, there are indications that prices and price volatility have increased due to investments by hedge funds and other investors during the past decade. Some research has shown that commodities that are not traded on futures markets show much less price volatility. Academic research, however, is not conclusive on the relationship between price volatility and the activity of financial institutions and non-commercial actors on commodities markets (Korteweg et al., 2011).

At a global scale, high commodity prices and high price volatility do not necessarily lead to a decrease of wealth as the loss of wealth in some parts of the world is balanced by those who benefit from the price increases. For people in low-income and resource-poor countries in the developing world, high prices and volatility are major issues of concern. Former World Bank president Robert Zoellick stated that 'We have been in a period of extraordinary volatility in food prices, which poses a real danger of irreparable harm to the most vulnerable nations' (Blas, 2011). Here, people spend as much as 70% of their income on food and often consume less processed food (FAO, 2010). As a consequence, rises and fluctuations in food prices are felt more strongly. Small-scale farmers in the developing world often lack insurance or savings to handle large income fluctuations caused by price volatility. But high prices and price volatility are also challenges for resource intensive industries in the developed world. In general, volatility becomes a problem when price fluctuations are large and cannot be anticipated, as they may delay investments and therefore slow production (FAO, 2010). On the other hand, high resource prices have also benefited some. The biggest winners are the resource-rich countries, companies in the energy and mining sectors, including state-owned enterprises, and producers of biofuels (Andrews-Speed et al., 2012).

Resource insecurity

Economic growth, and increases in population, income and health are fuelling an unprecedented demand for natural resources. Growing energy needs are contributing to the depletion of fossil fuels; the growing demand for raw materials is leading to skyrocketing mineral prices; and a growing demand for food is causing competition over land and biodiversity loss (Kooroshy et al., 2010a). Because of the interconnectivity between energy, minerals, food, water and land, scarcities in one system have impacts on the others (Qasem, 2010). Resource extraction, human-induced pollution and climate change are weakening ecosystems and contributing to land degradation and water scarcity. Environmental degradation can limit economic productivity and agricultural output, as the food system relies on ecosystem services and natural resources such as soils, water and biodiversity. These developments have raised fears of resource scarcity for both non-renewable and renewable resources, resulting in a Malthusian endgame scenario in which countries scramble to secure the scarce resources that are left and compete for control over remaining reserves (de Ridder, 2011c).

According to projections by the Worldwide Fund for Nature (WWF, 2008), global consumption may rise to 200% of global carrying capacity by 2030. If these projections are correct, the planet will not be able to regenerate our renewable resources (WWF, 2012). With regard to non-renewable resources such as oil, gas and minerals, fears about scarcity are based on the assumption that resource reserves are finite and are running out. According this so-called 'static paradigm', which is based the intuitive conception that growing demand is exhausting existing deposits, the speed of extraction and consumption determines the rate of reserve depletion (Kooroshy et al., 2010a). The most accessible reserves will be depleted first and supply will start struggling when new ones become more difficult to find. In this sense, the debate on mineral scarcity has been similar to that on peak oil.

According to the so-called 'dynamic-adaptive' paradigm, however, the total availability of reserves in the Earth's crust is less relevant. Under this paradigm, scarcity does not exist in an absolute sense as a linear equation of quantity and time, but as a relative economic function of supply and demand. Supply depends on whether deposits are profitable to extract using existing or future technologies and under current or future market conditions. The dynamic-adaptive paradigm takes into consideration that price fluctuations and imbalances between demand and supply are inherent to the dynamics of resource markets and are, as a result of market force equilibrium, likely to be corrected in the long term. Already, high prices and high price volatility have set in motion self-correcting mechanisms. For example, high fossil fuel prices have boosted the demand for renewable energy technologies and biofuel crops. High prices of abiotic resources have encouraged the exploitation of new mineral reserves, material substitution and recycling.

This does not mean that high resource prices and increased resource competition are not real concerns for governments. A stable and affordable supply of resources is necessary for economic growth and the innovative power and competitiveness of industries. When it comes to the security of supply, the issue is not always about availability of resources in the Earth's crust. For example, rare earth elements, a group of 17 minerals that are widely used in high-tech applications, are actually not rare and are found in many places, such as China, the US, Canada, India, Vietnam, Kazakhstan and Sweden. Their supply, however, is limited because under current market conditions and with current technology, only a small number of countries can mine these minerals profitably. China is the largest producer of rare earth elements, accounting for up to 97% of global production. This concentration of production in one area is the result of recent history (de Ridder, 2011d). China has systematically built up a monopoly on rare earth elements during the past decades. There used to be rare earth production capacity in other countries, but due to lower wages and less stringent environmental and health legislation in the Chinese mining sector, purchasing rare earth elements from China on the market became cheaper than maintaining domestic mining capacity. As a consequence, many countries, including the US, closed their domestic production of rare earth elements (Kooroshy et al., 2010b). A side effect of this development has been the loss of knowledge and hardware infrastructure in countries that were previously active in this field. Rebuilding a resource position is therefore far more complex and costly than just reopening mines. Besides rare earths, China is also the biggest or among the biggest producers of other minerals, such as tungsten, magnesium, molybdenum, vanadium, gallium, silver, tin, cadmium and indium.

The concentration of production of resources raises risks of supply disruption. Especially for highly import-dependent countries, supply disruptions can be an important threat to economic security and, indirectly, political stability and national security. Supply disruptions may be accidental or the result of political instability. For example, food supplies may be hampered by extreme weather events or wildfires that destroy harvests. Many minerals are produced in countries that score high on political risk indicators and where political instability increases the risk of supply disruption (Moss et al., 2011). Congo for example, is the biggest producer of cobalt (25,000 tonnes in 2009) and holds the world's vastest cobalt reserves (3.4 million tonnes; USGS, 2010). Supply disruptions, however, may also be intentional. The temporary freeze on rare earth exports from China to Japan is an example of the strategic use of minerals in international relations today. In September 2010 a Japanese coastguard patrol boat and a Chinese trawler collided near the Senkaku islands in the East China Sea. The Senkaku islands are the subject of a territorial dispute; both countries seek territorial sovereignty over the islands and possible nearby oil reserves. In retaliation for the capture of the Chinese trawler captain, China halted its rare earth exports to Japan until the diplomatic dispute was settled some weeks later on 24 September (Fackler, 2010).

As a consequence of these risks, governments are no longer solely relying on market forces but are interfering strategically on resource markets while responding to changes in the international system.

3.3. The emerging international system

The scarcity of resources is not unique in history. However, the present strain on the natural resource market is taking place at a time of global political and economic transition; i.e. the emergence of a multipolar world. This new global system has been particularly challenging for countries, as state capitalist tendencies have become more prominent in the natural resource sector.

Multipolarity

The international economic and political order was until recently dominated by the triad of powers, the US, Europe and Japan, of which the US was considerably the strongest (Gijsbers et al., 2010). Their power is in decline as economic and political power is shifting towards multiple emerging power centres. The most prominent new centres of power are the emerging economies, most notably Brazil, Russia, India and China. China and India in particular have shown impressive economic growth rates in recent years, leading some to refer to the 21st century as the Asian or Pacific century (Gijsbers et al., 2010).

The economic and financial crisis has accelerated this power shift from West to East and the transition to a multipolar world. The crisis hit the developed countries hardest, resulting in the depreciation of the dollar and the euro, a decline in GDP growth, mounting government debt and depleted national reserves. The federal debt crisis in the US has undermined its geopolitical muscle and has made the country dependent on foreign, mainly Chinese, creditors. Europe's position has been undermined by the euro crisis and the failure of its political leaders to resolve it. The crisis has highlighted the economic and political divisions that exist among EU member states, and threatens the continuation of the monetary union itself (de Ridder, 2011d).

The fiscal austerity measures that Western countries have been forced to take challenges their international commitments and leverage. The effect of the financial crisis on the growth of emerging economies was much less profound. The World Bank estimated that the global economy would grow by an average of 3.6% in 2012, but the emerging economies are expected to grow by almost twice that strong, by an estimated 6.2%. For China and India growth is expected to be even stronger, by 8.7% and 8.4%, respectively (World Bank, 2011). China is expected eventually to make the transition from an emerging to an 'emerged economy' (Hulbert, 2011).

Alongside these financial and economic changes, a paradigm shift has occurred at the international political level. Economic growth has encouraged the emerging economies to also bolster their political influence (Gijsbers et al., 2010). The BRIICS countries and other emerging economies such Turkey, are increasingly challenging the Western-dominated international order, including models of economic growth that were developed in the previous century. One such model is the Washington Consensus, a neoliberal programme for economic development prescribed to developing countries by the international financial institutions in Washington during the late 1980s and 1990s (Qasem et al., 2011b). This programme failed to bring economic growth in many parts of the developing world. The most recent economic and financial crisis has further undermined the credibility of neoliberal market democracy as a primary model for development.

State capitalist tendencies

China's economic successes have brought state capitalism to the fore as an alternative model for economic development. The Chinese model is based on state-led economic growth without political liberalization. As an authoritarian regime, China can do business with resource-rich developing countries much more quickly than liberal democracies, which often lack a long-term strategic vision and decisiveness, or international organizations (Qasem et al., 2011a). This point was illustrated by Senegalese President Abdoulaye Wade:

> If I wanted to do five kilometres of road with the World Bank, or one of the international financial institutions, it takes five years. One year of discussions. One year of back and forth. One year of I don't know what. With the Chinese it is a few days and I say yes or no, they send a team and we sign.[1]

China's quick way of doing business and its beneficial terms of trade, aid and investment make it an attractive economic partner for many resource-rich developing countries (de Ridder, 2011a). In addition, its pragmatic foreign policy, which is characterized by adherence to the principle of non-interference and its 'no (political) strings attached' development assistance policy, yields China a lot of political support from developing countries and less democratic regimes. As a result, China's state-owned enterprises have gained access to many natural resources reserves in the developing world, particularly in Africa. The incorporation of resource-rich developing countries into China's sphere of influence may reinforce the rise of state capitalism (de Ridder, 2011a).

The economic crisis also appears to have broken the taboo against economic government interference in liberal market democracies (Qasem et al., 2011c). Whereas government intervention in the resource sector has been widespread in non-democratic states for decades, leaders in the developed world are now also increasing state control over their economies. To deal with the economic crisis, measures of deregulation, privatization and trade and financial liberalization have been reduced, if not reversed.

Implications

What are the implications of the transition to a multipolar world and the rise of state capitalist tendencies for the geopolitics of natural resources? First, in a multipolar world countries tend to turn inwards, prioritizing their own national interest over cooperative policies on public good issues. This means that multilateral approaches and international institutions, such as the United Nations or the World Trade Organization (WTO), are

1 Comment by President Abdoulaye Wade at the EU-Africa summit in Lisbon, 8-9 December 2007; see Wallis and Bounds (2007).

weakened. In a multipolar world interests are diffuse rather than shared, which makes it more difficult to advance policy agendas that aim to benefit the international system as whole (Basha i Novosejt et al., 2010). Multipolarity also increases uncertainty and instability in international relations. In such a context the likelihood of international friction augments. Competition for resources makes the world more conflict prone and increases the likelihood of war between major powers, as securing access to resources becomes a national security interest that may even justify the use of military means (Qasem, 2010). The relationship between violence and the supply of vital resources has always been a persistent reality of international relations (Dalby, 2003).

Second, the rise of state capitalist tendencies in a multipolar world leads to more government interference in the natural resource sector and to more resource nationalism. Resource nationalism refers to a situation in which control over natural resources shifts from foreign to domestic state-owned companies. It also means that governments align their natural resource policies more explicitly with the national interest (de Ridder, 2011d). In resource-producing and exporting countries, governments are putting increasing emphasis on maximizing revenues from the resource sector, which may result in access restrictions, trade barriers, export quotas and other manifestations of protectionism. In countries that rely on imports of natural resources, governments are primarily focused on the security of supplies, which may result in the proactive acquisition of resources abroad, trade restrictions and the creation of stockpiles (Korteweg et al., 2011).

Both the rise of state capitalist tendencies and the transition to a multipolar world are putting pressure on the rules and values that are in place to safeguard free trade in natural resources. The growing competition for natural resources and high prices are encouraging governments to assess their resource policies through a strategic lens. The policy measures, however, are based on national interests and are at times worsening the situation by contributing to market distortions that further drive up prices and increase price volatility (Korteweg et al., 2011).

3.4. Policy trends

Increased government interference is a response to growing competition for natural resources, but may in turn have an effect on natural resource markets and global trade. Trade barriers and other distortions of the free market may heighten resource scarcity, encourage price gouging, and possibly lead to increased international instability.[2]

Securing resources

Countries with a limited or no natural resource endowment are most vulnerable to the effects of high prices and supply disruptions. High prices and supply disruptions are

2 This section is adapted from the conceptual framework for understanding natural resource policy in a multipolar world, originally developed by Korteweg et al. (2011): 35-37.

a threat to economic security, as they may reduce a country's economic and innovative competitiveness and negatively affect national employment and prosperity. In some countries, economic security is also important for social and political security. In China, for example, securing resources for economic growth is key to avoiding instability as a result of domestic opposition to the authoritarian regime. Some metals are also of strategic importance for military security, as they are used in high-tech defence technologies. As a consequence, import-dependent countries show a tendency to securitize their policy.

The securitization trend is reflected in three categories of policy measures. First, import-dependent countries employ policy instruments aimed at securing stable and affordable supplies from abroad. These include, for example, concluding strategic bilateral agreements with producing countries, establishing joint ventures in resource-rich countries, pursuing upstream integration in value chains or the strategic use of development assistance. In 2010, Japan gained access to Bolivia's lithium reserves in exchange for financial support and the construction of solar panels, energy plants and hospitals (Chambers, 2010). Another example is that China, but also other Asian and Middle East states, are actively purchasing and leasing land in Africa for food production (Smith, 2009). Second, import-dependent countries adopt policy measures to reduce their import dependency by reducing domestic consumption, promoting reuse and recycling of materials, exploiting alternative domestic sources and developing substitutes. Import dependence can also be reduced by stockpiling strategic materials, like in South Korea and the US. Third, in the most extreme case, import-dependent countries may use their military capabilities to secure resources, as is happening in the Arctic region and in the South China Sea.

Maximizing the benefits of high prices

As a consequence of the relatively slower growth of production compared to consumption, resource markets transformed from buyers' markets into sellers' markets, in which the producing countries can determine market prices. It also implies that they can use their resource endowment as an asset to achieve their economic and political objectives, both domestically and internationally. The *de facto* power position of producing countries depends on their level of economic development, the size of the export flows and the extent to which a particular resource can be substituted.

The common characteristic of producing countries is their aim to maximize the economic and political benefits of their resources. Resources are generally considered state property and therefore some countries apply strict resource ownership rights. As many countries struggle with the consequences of the economic downturn, the commodity price boom has meant that the resource sector has become an important source of government revenue. This has led to the politicization of resource policy and increased resource nationalism. Resource nationalism has been a well-known policy in the oil and gas sector and has now spilled over to the mineral sector (Korteweg et al., 2011: 49).

Policy measures that governments enact in order to maximize profits from high prices include: increased taxation on extraction revenues (such as the super-profits tax in

Australia; Smith, 2010), and export quotas (such as the Chinese export restrictions on rare earth elements). Governments are also increasingly limiting access to the domestic resource sector to foreign companies through licence fees, tariffs for mining and agricultural permits, making it more difficult for them to invest and gain access to resources in producing countries. In Canada, for example, the government ruled against the takeover of the Canadian potash-producing company Potash of Saskatchewan by mining multinational BHP Billiton on the grounds that the takeover was not in Canada's interest (BBC, 2010). Resource nationalism can also result in the creation of state-owned enterprises or the nationalization of an entire industry. In South Africa, for example, President Zuma launched a state-owned mining company, the African Exploration Mining and Finance Corporation (AEMFC), and started a debate on whether or not to fully nationalize its mining sector (BBC, 2011).

To sum up, there is trend towards more government interference in both import-dependent and producing countries. It should be noted that the degree of government control over the resources sector varies. In state capitalist systems government control is stronger than in countries that have a market capitalist tradition. Nonetheless, the general trend towards more government interference has important implications for trade and the availability of resources on markets.

Impact on trade and investment

Increased government interference and protectionism have negative effects on the free trade of resources, which may result in reductions in global welfare. It is widely accepted that liberalized trade helps to lower prices and broadens the range and quantity of goods available on the market. Free trade facilitates competition and investment, and increases productivity.

The free trade in commodities has most prominently been distorted by export restrictions. The governance regime on export restrictions is weak. Export restrictions are often poorly motivated and lack transparency, and are generally prohibited under the WTO regulations. Several complaints have already been filed at the WTO against Chinese practices that are allegedly protectionist and do not comply with WTO rules. In one recent ruling, the WTO stated that China's export duties, quotas, and minimum export price of coke, fluorspar, manganese, zinc and other commodities are in conflict with WTO trade practices (The Street, 2011).

According to Article XI on the General Elimination of Quantitative Restrictions of the General Agreement on Tariffs and Trade (GATT), however, exceptions are allowed if export restrictions are applied to 'prevent or relieve critical shortages of foodstuffs or other products essential to the exporting contracting party.' The use of export restrictions during the food crisis of 2007-2009, however, exacerbated the crisis (FAO et al., 2011). After over 40 countries imposed various forms of export restrictions, food prices rose sharply (Korinek and Kim, 2010). Export restrictions contribute to higher prices for foreign consumer countries when producing countries divert material from export to the domestic market (OECD, 2010). Prices may rise further because export restrictions create uncertainty about future prices and consequently discourage investments in extracting and producing raw materials. Investments in the mining industry, for example, are long term and require large amounts of capital and know-how. The possibility of sharp fluctuations in world prices due to the imposition or sudden removal of export restrictions, or an outbreak of political instability, represents a significant risk for investors (Korinek and Kim, 2010). A lack of investment will reduce the overall supply of resources in the long term. The negative effects of export restrictions on the availability and price of resources are especially problematic since export restrictions of one country may lead to a spiral of restrictions by others that will further increase competition and fears of resource scarcity.

The disruption and fragmentation of the trade in resources will have a negative impact on global prosperity, which in turn will increase the likelihood of conflict. This is amplified by the tendency among import-dependent states to align their natural resource policy with other policy areas, such as development assistance and foreign policy, which means that countries risk having conflicting interests in a growing number of policy domains. Dealing with the risks and opportunities associated with volatile resource markets is a challenge the EU will have to tackle in the coming years.

Sustainability: the social and environmental dimension of resources

The negative consequences of the current patterns of production and consumption of natural resources have also resulted in increased attention to the social and environmental dimensions of sustainable resource management. Sustainability is about reconciling the objective of economic development with that of reducing the negative impacts of human activities on the biosphere (de Ridder, 2011c: 13). From a development perspective, it is seen as legitimate to exploit natural resources in order to promote economic growth, eradicate poverty and famine, and to improve access to modern consumer goods, but such efforts pose serious environmental challenges.

The impacts of human activities are determined by both our numbers and the way we use nature's resources. The growing demand for resources has caused serious negative environmental side effects, such as climate change, deforestation, pollution, loss of biodiversity, soil degradation, the depletion of fish stocks and other resources. Unsustainable farming methods and irresponsible management of agricultural land or mines can increase the scarcity of resources. Humanity is consuming resources more rapidly than they can be replenished (de Ridder, 2011c: 19).

The real challenge is to bridge the economic development gap between the developed and developing worlds without exceeding Earth's carrying capacity. An international policy agenda is emerging to address the environmental and social sustainability challenges associated with the growing demand for natural resources.

Environmental challenges

The environmental challenge is to reduce the negative environmental impacts of our resource production and consumption patterns. With each type of resource, there is a unique set of challenges relating to its extraction, use and consumption. The mining of minerals can contribute to air and water pollution; increase waste at operational sites and beyond; negatively affect the quality of landscapes; and decrease biodiversity. Mining and processing minerals also produce waste that contains substances that are hazardous for the environment, such as heavy metals, acids and other chemicals. In some instances, this process can even lead to increased levels of radioactivity at mining sites. In addition, these activities require massive amounts of water and energy as well as valuable resources that could be otherwise used in other crucial processes, such as farming. Oil and gas exploration can lead to pollution of extraction sites and the destruction of wildlife habitats. The large-scale use of fossil fuels in our economy is also causing emissions of greenhouse gases that are contributing to climate change (OECD, 2011b: 15). The use of fossil fuel derivatives, such as plastics and chemicals, can lead to waste, pollution and loss of biodiversity when these toxic substances enter the environment.

The production of biotic resources can also lead to a loss of biodiversity and the deterioration of land and watercourses. The production of food, animal feed and crops for biofuels can lead to soil degradation due to the depletion of mineral content and soil erosion. Intensive aquaculture and marine fisheries can reduce biodiversity (due to by-catches), damage ocean and sea floors, and contribute to water pollution. Unsustainable forest management can reduce the temperature buffers and carbon storage capacity of forests, which play an important role in mitigating climate change. The production of pulp, paper and wood fibre is also water and energy intensive (OECD, 2011b: 15).

Table 3.2 Environmental challenges related by resource type

Material Group	*Potential Environmental Impacts*
Biomass for food and feed	Intensification of land use, soil degradation, groundwater contamination, disintegration of nutrient cycles, food chain contamination through pesticides, acidification, loss of biodiversity, habitat loss, water use
Wood	Intensification of land use, soil erosion, loss of biodiversity, habitat alteration, carbon sink depletion, desertification, alteration of watersheds
Metals and metal ores	Resource avalability, entropy, habitat alteration, mining overburden, air emissions, water usage, tailings, radioactivity
Fossil energy carriers	Resource avalability, air pollutants, carbon dioxide emissions, habitat alteration, overburden, toxic chemicals for processing, water usage
Industrial minerals	Resource avalability, entropy, habitat alteration, mining overburden, air emissions, waste water, tailings
Construction minerals	Loss of biodiversity, habitat alteration, soil compaction, carbon dioxide emissions, (e.g. cement manufacturing)

Source: (OECD, 2011b).

Table 3.2 shows the potential negative environmental impacts that the extraction and production of resources may have on the environment. There are also negative environmental effects associated with later stages of the resource cycle that follow extraction and processing. Transportation of resources requires fuel and contributes to pollution and greenhouse gas emissions, and the post-consumption stage may lead to toxic waste or pollution if materials are not carefully managed at the end of their life cycle (OECD, 2011b: 16).

The increased awareness of the negative environmental impacts of natural resource production and consumption has attracted increased attention from policy makers and national initiatives to address these issues. As the consequences often extend beyond the borders of individual countries, an international policy agenda is required, with policy measures aimed at mitigating negative environmental effects in order to sustain economic growth, while preventing the depletion of resources and reducing the negative environmental effects.

Current policy efforts are focused on mitigating the local effects of resource extraction by improving governance in the extractive industries, on reducing demand by promoting recycling and the reuse of materials and reducing waste by closing the material cycle and by promoting the transition to a circular economy. Environmental regulations and guidelines to improve resource efficiency are key to reducing the negative environmental impacts of our resource consumption and production patterns.

Sometimes, however, policies aimed at solving negative externalities of natural resource use can have unintended negative consequences. For example, the introduction of subsidies to promote biofuel production as a measure to curb greenhouse gas emissions from fossil fuels had an adverse effect on the availability of food. The subsidies made it more lucrative for farmers to use land for biofuel crops and triggered a scarcity of land for food production, which in turn contributed to high food prices (de Ridder, 2011b). Another example is recycling. Recent studies by UNEP have pointed out that industrialized countries are sending large streams of used electrical and electronic equipment to developing countries, mainly in Africa, for recycling or disposal. Such equipment can contain heavy metals such as mercury and lead. When such hazardous substances are released during various dismantling and disposal operations this can pose serious risks to workers, public health and the environment. In 1994 the EU adopted the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. The UK is the dominant exporter of electronic and electrical equipment to West Africa, followed by France and Germany. In August 2012, the EU adopted new rules on electrical and electronic waste (e-waste) in order to combat more effectively the illegal export of waste to developing countries, and to ensure that resource recycling happens under favourable environmental, social and economic conditions (UNEP, 2012).

In the private sector, many companies have already integrated international sustainability norms into their business models under the influence of the corporate social responsibility (CSR) movement, which encourages companies to generate profit from business cases that contribute positively to people and the environment, a model known as the 'People, Planet and Profit' approach (de Ridder, 2011c). The World Business Council for Sustainable Development, for example, is a group of forward-thinking companies that aims to drive debate and policy change in favour of sustainable development solutions for business, society and the environment.

Social challenges

Sustainable resource management can catalyse economic growth and exports for resource-rich developing countries and contribute to poverty reduction. In June 2012, the UN Nations Conference on Sustainable Development (UNCSD), also referred to as the Rio+20 conference, focused on the management of resources in the context of sustainable development and poverty eradication. Unfortunately, the resource-rich countries have generally performed worse than those with no resources, due to the so called 'resource curse' (Stiglitz, 2012). In weak or failed states the potential economic growth is often not realized due to corruption, conflict, violence, human rights abuses and the lack of good governance. Many minerals used in consumer electronics, such as mobile phones and computers, are mined under dire social circumstances and working conditions or in areas controlled by warlords and militias. In the DR Congo, for example, the mining of gold, tin, tantalum and tungsten is controlled by warring factions, and the minerals are smuggled out of the country and traded illicitly. Money earned from the sale of these minerals is used for the personal profit of the militia leaders. The mining of these 'conflict minerals' contributes to the dire human rights situation and the protraction of the conflict.

Many countries have developed policies or support international policy initiatives aimed at banning the trade in conflict minerals and to increase good governance, transparency and sustainability in the extractive industries. A few examples:

- *The Dodd-Frank Wall Street Reform and Consumer Protection Act,* adopted on 21 July 2010, aims to increase transparency and accountability in the financial sector. It contains several disclosure provisions regarding natural resources in general and conflict minerals from the DR Congo in particular. Section 1502 on 'Conflict Minerals' requires persons to disclose whether any conflict minerals that are necessary to the functionality or production of a product originated in the DR Congo or an adjacent country. Section 1503 on 'Mine Safety' requires mine operators to disclose information related to violations of the act's health and safety rules. Section 1504 on 'Disclosure of Payments' requires companies engaged in the commercial development of oil, natural gas or minerals to disclose in an annual report payments made to the US or a foreign government (US SEC, 2012). In December 2011, the rules regarding mine safety were adopted, followed by the rules regarding the disclosure of 'conflict minerals' by resource extractors in August 2012.
- *The Kimberly Process* aims to stop the trade in 'conflict diamonds' and to ensure that diamond purchases are not financing violence by rebel movements. Since its launch in 2000 the Kimberly Process has resulted in an effective certification

scheme that has successfully curbed the flow of conflict diamonds and has contributed to peace and security.

- *The Regional Initiative against the Illegal Exploitation of Natural Resources (RINR),* an initiative of the International Conference on the Great Lakes Region, also aims to break the link between mineral revenues and the financing of rebel movements that destabilize the region.
- *The OECD's Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas* is intended to help multinational companies respect human rights and avoid contributing to conflict through their mineral or metal purchasing practices. The guidelines provide management recommendations for responsible global mineral supply chains (OECD, 2011a).
- *The Extractive Industries Transparency Initiative (EITI):* another example of a globally developed standard that aims to stop that citizens suffer from conflict and corruption related to natural resource extraction by promoting revenue transparency in the extraction industry at the local level.
- *The Natural Resource Charter* aims to improve knowledge about good resource management and the development of institutions that will enable resource-rich countries to harness their natural resource wealth effectively. The charter consists of a set of principles that can help guide governments and societies in their use of natural resources so that these economic opportunities result in maximum and sustained returns for citizens.
- *The Sustainable Trade Initiative* is a Dutch initiative that aims to promote fair and sustainable trade in biotic resources. By building impact-oriented coalitions of front-running multinationals, civil society organizations, governments and other stakeholders, the Initiative aims to make sustainable trade the new norm.

3.5. The EU: challenges and policy responses

The international dynamics of natural resources also affect the EU, although the challenges vary from country to country, depending on their natural resource endowment and their industrial and economic profile. The situation is also very different depending on whether one looks at biotic or abiotic resources.

Biotic resources

Overall, the EU is nearly self-sufficient when it comes to biotic resources. During the 1960s and 1970s the EU introduced agricultural policies that were aimed at ensuring food security in Europe by maintaining an agricultural sector large enough for self-sufficiency. The EU is a major player on the world's agriculture markets, being a producer of large quantities of a wide range of products. Globally, the EU is the second largest exporter of agricultural products but also the largest importer. The high dependence on soy and vegetable oils, which are essential to the European food industry, make the EU a net importer. The European Commission has identified climate change as a potential future threat to European food security in the long run, in addition to increasing water scarcities in Southern Europe. According to the Commission, the rising food prices in recent years have had a limited effect on the daily lives of European consumers. The share of household expenditure on food has been gradually declining and is currently estimated at around 14% of total expenditures. For Europe, the risks related to food insecurity are therefore limited.

Mineral supply disruption risks

The major issue of concern for the EU is the supply of abiotic resources. The EU is self-sufficient when it comes to several base metals and construction and industrial minerals. Minerals such as barytes, kaolin, potash, salt, silica and talc, which are used in a wide range of industries, are extracted within the EU. Europe is a major global producer of minerals such as magnesite, fluorspar, kaolin and potash (EC, 2012a), while its production of metallic minerals and high-tech metals, such as cobalt, platinum, rare earth elements and titanium (EC, 2008) amounts to just 3% of world output. For some strategic minerals the import dependence is as high as 100% (Gerdien Prins et al., 2011).

The EU has recently assessed the strategic importance of 41 abiotic resources for the European economy. Of this group, 14 materials or material groups were identified as critical due to their importance to European industries and the high risk of supply disruption. The group of critical materials includes, for example, rare earth elements. Europe is especially concerned with its dependence on imports of Chinese rare earth elements. Due to China's export restrictions on rare earth elements, world prices are now typically 20-40% higher than Chinese domestic prices, a price difference that is negatively affecting Europe's competitiveness.

Another issue of concern is the EU's dependence on phosphate imports. Phosphate is a crucial element in agricultural fertilizers, there is no substitute, and so far little is retrieved from waste flows. Phosphate reserves are located in a limited number of countries. Morocco, China, the US and Russia are among the most important producers. Political instability in the producing countries is a major threat to supplies of phosphate to the EU. For example, the EU used to import a significant share of its phosphate from Syria, but the supply has been disrupted due to the civil war and international sanctions against Syria's repressive regime. In Morocco, which currently produces about 70% of global phosphate supply, the resistance movement Polisario is claiming sovereignty over Western Sahara, a conflict that could potentially cause supply disruptions to the EU. In addition, China, the US and Russia have implemented trade restrictions on phosphate, such as high export tariffs, to protect their domestic reserves in light of the increased pressure on the phosphate market caused by the growing demand for food. This has resulted in price increases that negatively affect the EU's agricultural sector.

The EU's nuclear power industry is also highly dependent on imported uranium. In 2008, 25% of the uranium used in European nuclear power plants originated from Canada, 17% from Russia, and 16% from Australia.

Europe imports many of its minerals from politically or economically unstable regimes such as China, Russia and African states. The demand for minerals is projected to rise in the future, which means that the EU's dependence on these external suppliers will increase. Another obstacle to the security of supply is that some minerals are not traded on major exchanges, such as the London Metal Exchange, but through non-transparent long-term bilateral contracts based on prices negotiated between parties. Bilateral mineral trade fragments the market and may result in increased inflation, higher price volatility, lower investment levels and fuel fears about supply constraints (US DoE, 2011).

Security risks related to political instability

The international resource dynamics do not only pose direct economic risks for European countries and industries, such as increased supply disruptions and higher prices. They also bring about indirect security risks for Europe in the form of political instability elsewhere.

High prices or physical scarcity of resources may trigger social segmentation, migration, conflict and insurgencies, especially in countries where there is popular resentment about the political or institutional status quo. High food prices, for example, have major consequences for living standards and quality of life, especially in the developing world, where most households spend a high proportion of their income on food (Motaal, 2011). Particularly poor urban populations are disproportionately affected since they cannot grow their own food, which means that high prices have a direct impact on their consumption patterns. Rising food inflation is therefore not only an economic concern, forcing governments and central banks to tighten their monetary policies, but also a political one, as high food prices can trigger social unrest (Blas, 2011). The ongoing events in the Middle East, popularly known as the Arab Spring, are a recent example of how rising food prices can contribute to social unrest and regime change. The spread of revolutions in North Africa and the Middle East following the outbreak of protests in Tunisia in December 2010 has shown how food scarcity can have consequences for broader regional stability (de Ridder, 2011b).

In the context of high resource prices, corruption may also lead to instability. In producing countries, elites are often heavily involved in the resource sector and may be tempted to use resource revenues for personal purposes, which may increase inequality in society and sharpen social contrasts. Especially when the elites are affiliated with specific population groups, this can lead to social unrest and political instability in countries with strong ethnic divisions or with a history of ethnic conflict.

These shocks are not, however, confined to states where poor governance is the norm. Even states with strong institutions and rich traditions of good governance can slip into domestic disarray if policy measures are implemented by the national government that fail to consider the interests of regional governments. For example, tax increases on resource extraction may lead to intra-governmental friction, as the governments from resource-rich regions are less inclined to favour the redistribution of resource wealth to poorer regions.

In summary, high prices, price volatility and physical scarcity of natural resources may lead to economic stagnation, increase poverty and hunger, intensify domestic tensions and trigger migration. Local instability has the potential to spill over to neighbouring countries and amplify the security threat to the European Union.

EU policy

Many of the minerals for which the EU is import-dependent are of strategic relevance to high-tech industries, and the transition to a greener economy (Qasem, 2010). Securing these minerals is crucial for the success of a number of EU proposals to reduce the carbon footprints of the transport and energy sector, such as the Strategic Energy Technology (SET) Plan), the Trans-European Energy Networks and the Energy Efficiency Action Plan. As a result, the economic security perspective dominates European policy responses.

In response to the dynamics of international resource markets the European Commission has issued three major policy documents: the Raw Materials Initiative (RMI) I (2008) and II (2011), and a communiqué entitled 'A Resource Efficient Europe – Flagship initiative of the Europe 2020 Strategy'. The RMI focuses on three pillars:

- transparent and unhindered access to raw materials on the international market;
- fostering a sustainable supply of resources within the EU; and
- reducing consumption of resources within the EU by increasing resource efficiency and promoting recycling.

In 'A Resource Efficient Europe – Flagship initiative of the Europe 2020 Strategy', published in January 2011, the Commission addresses how resources can be used more efficiently in order to shift towards a resource-efficient, low-carbon economy and to achieve sustainable growth. The initiative provides a long-term framework for actions in policy areas, ranging from climate change, energy, transport, industry, raw materials, agriculture, fisheries, biodiversity and regional development. The underlying idea is that continuing current patterns of resource consumption is not an option and that increasing resource efficiency can bring about economic opportunities, improve productivity, boost competitiveness and create jobs (EC, 2011).

Transparent and unhindered access to raw materials

With regard to the first pillar of the RMI, the EU aims to promote the liberalization of trade in raw materials, for example in the OECD and the WTO. Together with the US and Mexico, the EU decided to file a complaint at the WTO against Chinese export restrictions on various resources. With regard to biotic resources, the Commission has also supported the request of the G20 for the World Bank and other relevant international agencies to develop joint regulations that would improve the provision of information on national and regional food stocks and food production processes.

Several EU member states are also stakeholders in the Extractive Industries Transparency Initiative (EITI), a voluntary global coalition of governments, companies, civil society groups, investors and international organizations that aim to improve efficient government and transparency of the mineral sector in resource-rich countries. The Commission values EITI for contributing to sustainable economic growth through strengthening state structures. It supports the initiative at a financial and a political level and promotes the implementation of EITI measures to developing countries.

The Commission aims to raise awareness of situations in which the revenues of resource extraction are used to finance wars and conflict, and promotes the implementation of European standards and codes of conduct for companies operating in developing countries. The Commission has proposed a system for Country-by-Country Reporting (CBCR), which is designed to increase transparency within the extractive and logging industries, and would apply to large, privately-owned European companies or firms listed in the EU that are active in the oil, gas, mining or logging sectors (EC, 2012d).

The Commission aims to establish strategic partnerships and maintain dialogue with resource-producing countries such as India, Brazil and Canada, as well as with countries that are rich in resources in Africa and Oceania. It seeks to cooperate with other import-dependent countries, such as Japan, to identify mutual interests and undertake joint initiatives to promote transparent and unhindered access to raw materials on the international market.

Sustainable supply of resources within the EU

To improve the sustainable supply of resources within the EU, the second pillar of the RMI, the Commission aims to promote the expansion of the domestic mining industry by creating favourable circumstances and a level playing field for the industry to warrant the industry's competitive power. The Commission also encourages the coordination and exchange of information between national geological services, which could lead to the discovery of new reserves, economies of scale and mutual projects, including harmonized European resource databases and yearbooks.

Resource efficiency and recycling

The EU has taken several steps to reduce its domestic consumption of resources by promoting resource efficiency and recycling, the third pillar of the RMI. Although recycling cannot meet the EU's needs for mineral resources, the Commission considers recycling and urban mining to be an important part of the strategy to reduce import dependence. European industries use large quantities of steel, aluminium and other metals that are valuable sources of supply. Recovering these resources requires less energy than processing ore and is therefore not only more resource efficient, but also saves on greenhouse gas emissions. In the RMI the Commission proposes measures aimed at improving recycling markets, including economic incentives for recycling (EC, 2012b).

The EU is also promoting resource efficiency at the international level, such as within the context of the Rio+20 Summit. International cooperation on resource efficiency could improve the sustainable supply of resources to Europe and contribute to reducing global demand as well as achieving climate goals.

3.6. The Netherlands

Disruptions in the supply of natural resources pose a serious risk to the Dutch economy. The Netherlands relies almost entirely on imports of strategic abiotic resources, most of which are semi-finished products. The Netherlands is a major exporter of agricultural products, and the sector is dependent on imports of phosphate. The production of meat and chocolate, for example, relies on imports of soy and cocoa beans. If the Netherlands can no longer import certain crucial inputs for commercial and industrial activities, this could damage the economy. Increased state capitalism, mercantilism and protectionism and high resource prices could also negatively affect its competitive position. The port of Rotterdam is an important gateway for goods being imported into the EU, including food, agricultural products, energy resources and semi-finished products. A weakening of the liberal trade regime would lead to economic losses for the Netherlands.

Policy focus

EU member states have a shared interest in ensuring the security of the resources they need, but have specific interests depending on their natural resource endowments and industries. Many countries are therefore complementing European policy with their own national resource strategies. Germany has been among the pioneers in developing a comprehensive resource strategy. The Netherlands, whose economy is closely tied to that of Germany, has followed its example in placing a resource security high on its policy agenda and has begun drafting a national resource strategy that will focus on strengthening market mechanisms and free trade at the international level (MFA, 2011). The Netherlands is seeking cooperation with other import-dependent countries, such as Japan and the US, in fighting anti-liberal trade practices through international institutions such as the WTO and OECD. The Netherlands has also appointed a Special Envoy for Natural Resources, charged with developing the international dimension of Dutch resource policy, such as forging strategic partnerships with resource-producing countries and those that supply semi-finished products. The Netherlands has a strategic interest in partnerships with West African countries for cocoa, South American countries for soy, Morocco for phosphate and Southeast Asian states such as Singapore for semi-finished products. Cooperation with European partners such as France, Germany and the UK is also part of the Dutch approach.

The Dutch strategy recognizes the importance of a strong EU policy focused on promoting free trade (MFA, 2011). If the EU aims to act at the same level as powers such as China and the US, this can only be achieved through joint European action. The strategy notes that the national policies being formulated by individual countries may jeopardize the EU strategy for resource security and weaken the position of the EU. If national strategies diverge, EU interests may not be sufficiently protected, even though this is crucial in a world that is moving towards a multipolar system. The European Commission has policy instruments that individual member states do not have, such as accumulated bargaining power in international forums such as the WTO. In many respects, the Netherlands is a small player that can benefit significantly from the collective action of the EU.

Opportunities for the Dutch economy

The Netherlands government recognizes that the growing resource scarcity is a risk, but that it also offers opportunities for economic growth and job creation while at the same time reducing the dependence on imports. Due to resource scarcity and high resource prices it may become economically feasible to start exploiting new reserves, to develop new extraction technologies or other technologies to collect resources, such as recycling, and technologies that improve the efficiency of resource use. The Netherlands has a competitive advantage to capitalize on such developments due to its unique geographical position in international lines of communication and its leading industries.

The government has identified nine economic domains in which the Netherlands already has leading industries or ones that could gain a strong competitive position internationally. These 'top sectors' include 'Agri-food' (food and non-food) and 'High-Tech Materials and Systems', which focuses on relatively small but strong technology companies that process semi-finished goods and abiotic resources into products of technological excellence. The government is supporting these sectors to enable them to remain competitive and innovative in a rapidly changing international environment.

Although the increasing costs of resources can be transferred to consumers and will also affect competitors in other countries, and are therefore not necessarily problematic for the top sectors, the decreasing security of supplies presents a considerable challenge. In order to increase its security of supply and to reduce domestic consumption of resources, the Netherlands needs to capitalize on its knowledge of sustainable innovation, the development of substitutes and sustainable governance of farmland and mining. With regard to biotic resources, the Agri-food sector could contribute knowledge of agriculture and land-use to enhance productivity, such as by emphasizing sustainable farming and improving degraded land in order to increase agricultural output.

Concerns about access to resources and stable supplies also present opportunities for the top sector 'Logistics'. The Netherlands has an excellent infrastructure that facilitates global trade flows. If the Netherlands can profile itself as a 'resource intersection', a hub for the supply and distribution of raw materials in Europe, this may create jobs and encourage growth. This requires that the government works with stakeholders in the private sector and foreign partners to connect even better with existing European infrastructure.

Innovation to reduce resource consumption is also a major driver of growth. The growing demand for renewable energy, for example, is important for the top sector 'Energy', where up to 40% of companies are already focused on innovation (Korteweg et al., 2011). The Netherlands has an innovative chemical industry. Growing emphasis on the recyclability and substitution of products can function as an important innovation trigger for the top sector 'Chemicals', especially in the development of specialty products based on biotic resources that can be used as substitutes for scarce materials.

One area that offers opportunities for the Netherlands and Dutch businesses is the transition to a circular economy in which material cycles are closed and so could reduce the resource intensity of many industries and the overall dependence on imports, and could lead to innovative products, processes and business models. Recycling is a key component of a circular economy, which is also characterized by enhanced maintenance and repairs, re-manufacturing, product-service systems and lease-multi-user models. At present, there is only limited pre- or post-consumer recycling of scarce materials in the Netherlands (Korteweg et al., 2011). This is thus where opportunities for the top sectors can be found. Promoting recycling and product design for post-consumer recycling can improve the security of supply for the Netherlands.

The Dutch private sector, NGOs and knowledge institutes can play an important role in enhancing resource security by reducing demand. The growing awareness of consumers about the need for more sustainable patterns of consumption and production is resulting in a growing market for sustainable products and services. By including resource efficiency and sustainable and fair production of resources in their purchasing decisions, Dutch companies can benefit from this growing market.

3.7. Conclusions

Current consumption and production patterns and trade in international resources have major impacts on our prosperity and wellbeing, our environment, biodiversity and the carrying capacity of the planet, and also affect international relations, peace and security. In the near future, the world will be characterized by tight markets and competition for natural resources, due to the underlying drivers of demand and supply of natural resources, such as demographic shifts, changing consumption patterns, economic growth and climate change. Scarcity of natural resources is a largely a dynamic concept. The availability of natural resources is a function of current market conditions and technological means. Nonetheless, the risks of physical scarcity are not negligible due to geopolitical developments and the risks of supply disruptions, export restrictions and price developments, all of which pose real challenges to economic growth and competitiveness.

One such development is the increasing prevalence of resource nationalism, both in resource-rich countries and producer states where the state has traditionally played an important role, as well as in parts of the world that take a more liberal view of government interference with the market. The emergence of state capitalist tendencies and resource nationalism means that the Netherlands needs to respond strategically and may have to adjust its view of the role of government with regard to natural resources.

The Netherlands must work within the European framework to address the challenges related to increased resource competition. Only if EU member states act together and form a united front can the EU act as a countervailing power on the international playing field. The Netherlands and Europe need to adopt a two-pronged approach. On the one hand, the approach should be aimed at increasing transparency and strengthening the liberal free trade regime for natural resources. This would entail making clear to other countries that the current situation of high price volatility is a negative sum game and benefits no one, with the possible exception of speculators. On the other hand, the Netherlands and the EU need to forge strategic bilateral partnerships with important suppliers of raw materials and semi-finished goods. At the same time, the Netherlands and the EU should focus on the opportunities that scarcity offers and invest in innovation, recycling and the development of substitutes that could contribute to economic growth and competitiveness.

4 Resource strategies

Improving resource efficiency is about improving the quality of life while limiting environmental degradation, using resources more wisely and changing patterns of production and consumption. In a world that is reaching the physical limits of consumption, ensuring the more efficient use of natural resources is essential. The fact that resource efficiency is one of the flagship elements of the European Union's framework programme Horizon 2020 is evidence of the increasing awareness of the urgent need to improve resource efficiency.

In the 30-year update to *The Limits to Growth*, Meadows et al. (2004: 236) call for action along two lines: improving the eco-efficiency of our present production and consumption patterns, and changing these patterns by influencing the underlying causes of overconsumption in society.

This chapter discusses a variety of strategies that could contribute significantly to improving overall resource efficiency, as indicated in Table 4.1. They range from steps that can be taken on the basis of current societal, economic and technological models and know-how, to more radical steps that may only be possible under new and different economic, political and societal structures.

Table 4.1 Resource efficiency and sufficiency strategies

	Production side				*Consumption side*	
	Efficiency strategies			Sufficiency strategies		
Step in production-consumption chain	Mining	Manufacturing	Products and services	Use of products and services	Expenditure mix	Quality of life realized
Strategies	Sustainable mining	Process optimization Materials recycling	Radical redesign Substitution	Intensifying the use of products Reuse	Shifting expenditures to low-impact activities	Improving quality of life without spending money
Section	4.1	4.2 4.3	4.4 4.5	4.6	4.7	4.8

4.1. Mining primary resources

For most natural resources the patterns are similar: the demand for commodities has increased sharply over the last three decades. The increase has been particularly spectacular for some specific minor elements, such as the rare earth elements that are used in high-tech applications such as cellphones and batteries. Although one might expect increased demand to lead to higher resource prices, thus providing an incentive for mining companies to intensify their output, this has evidently not happened. In relation to the mining of metals, there are a number of complicating factors:

- The costs of extraction have increased over the years as sources have become smaller, more remote and less concentrated, requiring more energy, time and capital to develop.
- Many metals are obtained as by-products of the extraction of other materials. An increase in the demand for a by-product therefore does not necessarily lead to increased supply, as this will depend on the market dynamics of the primary product. Mining companies are often not inclined to extract small quantities of minor elements from mining waste.
- Commodity markets are often concentrated in a few countries and/or companies, leading to non-transparent price formation, and in turn to volatile prices that discourage investors in view of the high economic risks involved. Another consequence of this concentration is that skills and intellectual capital are monopolized by just a few players, making it difficult for new companies to enter the market.
- Unlike other product markets, the supply responsiveness of many mineral resources is slow. This is due to the amount of time required to reopen former mines or to develop new ones. Geopolitical tensions and regulatory (trade) barriers may slow down supply responsiveness even further.

Although many of these factors are beyond the reach of many individual mining companies, research organizations or even resource-poor countries, at least three sustainable mining strategies could help them to overcome some of the problems related to the increasing scarcity of primary mineral resources.

First, mining companies might consider introducing environmentally 'clean' technologies to reduce the amounts of water and energy used in their operations, especially in regions where water shortages are already a problem. In Morocco, Tunisia and Jordan, for example, where the mining of primary rock phosphate is concentrated, water shortages might lead to political tensions and increase the risk of resource supply disruptions. The introduction of environmentally clean technologies might even open up new areas for exploration in dry regions.

Second, countries could encourage greater transparency in the mining sector by supporting good governance structures worldwide, especially in conflict areas. Many countries have already developed policy initiatives to encourage good governance, transparency and sustainability in the extractive industries. In the United States, for example, the Dodd-Frank Wall Street Reform and Consumer Protection Act was signed into law on 21

July 2010. This act contains several specific provisions aimed at promoting transparency regarding the origin of natural resources, health and safety conditions and the related financial transactions in the mining sector in general, and conflict minerals from the Democratic Republic of Congo in particular.

Last but not least, 'urban mining', or the recycling of materials in the end-of-life phase of products, is now an important strategy that has been adopted in many countries. Increased commodity prices generally cause a 'natural' stimulus for recycling activities, and the resulting flow of secondary resources may dampen the demand for primary resources. We will return to the subject of materials recycling in section 4.3.

4.2. Process optimization

A basic resource strategy is to optimize production and manufacturing processes in order to reduce the use of water, energy and other (primary) resources. New or improved technologies may generate less waste and use fewer raw materials for identical or similar functionalities. Given that in a competitive environment, most industries keep an active eye on their bill of materials – all the parts and assemblies required to build a complete and shippable product – and efficient processing is the first and most often implemented industrial policy. Typical examples of such measures include:

- implementing improved process control;
- introducing (radically) improved production technology (e.g. more efficient layer deposition for the production of photovoltaic cells);
- recycling production waste as secondary raw materials.

This resource efficiency strategy has been successfully applied in the field of emissions reductions. A good example concerns projected emissions from vehicles in the European Union (EU-15[1]) between 1990 and 2020. The introduction of effective policy measures and the subsequent development and implementation of new technologies led to absolute reductions in vehicle emissions (of some minor pollutants) despite a considerable increase in vehicle use (see Table 4.2). For major pollutants such as CO_2, process optimization is not sufficient to accomplish absolute emission reductions. Obviously, these 'end of pipe' decoupling strategies have their limits.

The same is true for more mature technologies. Given that thermodynamic barriers exist in the production of steel and cement, for example, there are limits to the strategies to improve the efficiency of these processes, and further improvements will lead to decreased added value (see Figures 4.1 and 4.2). The International Energy Agency (OECD/IEA, 2008) estimates that sectors that apply the best available technologies (BATs) are likely to reduce the emissions and energy use by only about 25%.

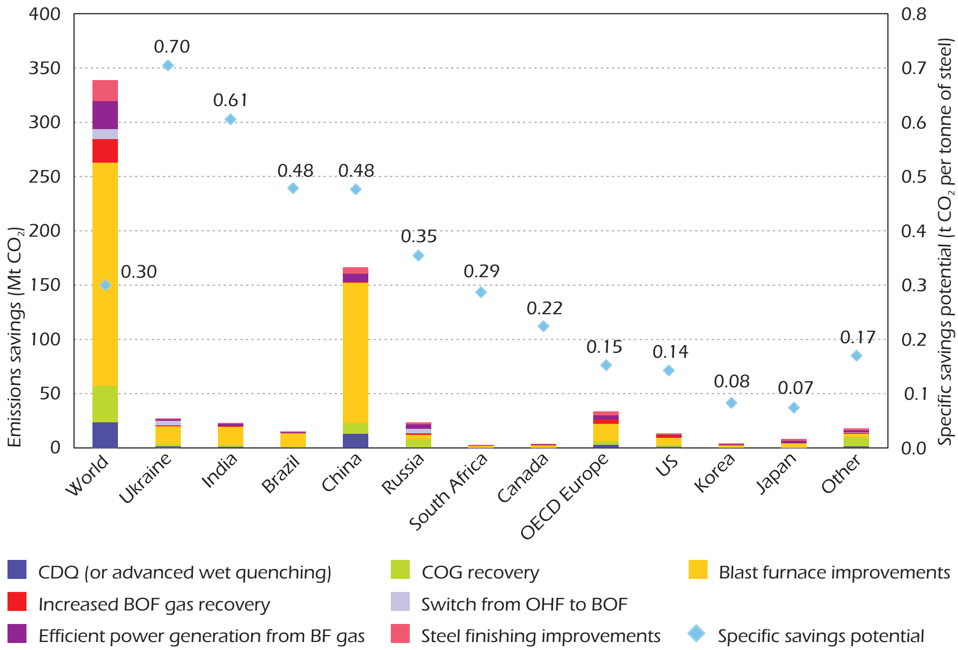
1 The 15 EU member states prior to the accession of 10 candidate countries in 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the UK.

Table 4.2 Estimated vehicle emissions in the EU-15, 1990-2020

Substance	Emissions, EU-15 (million tonnes, Mt)		
	1990	2000	2020
Km	2150 Billion	2700 Billion	3400 Billion
CO_2	570 Mt	710 Mt	900 Mt
NO_x	5.5 Mt	3.8 Mt	1.1 Mt
CO	19 Mt	17.5 Mt	5 Mt
Volatile organic compounds (VOCs)	3.5 Mt	2 Mt	0.5 Mt

Source: Adapted from Ntziachristos et al. (2002).

Figure 4.1 CO_2 emission savings in the iron and steel industry in 2005, based on BATs. Total CO_2 emissions in 2005 were 2.6 Gt

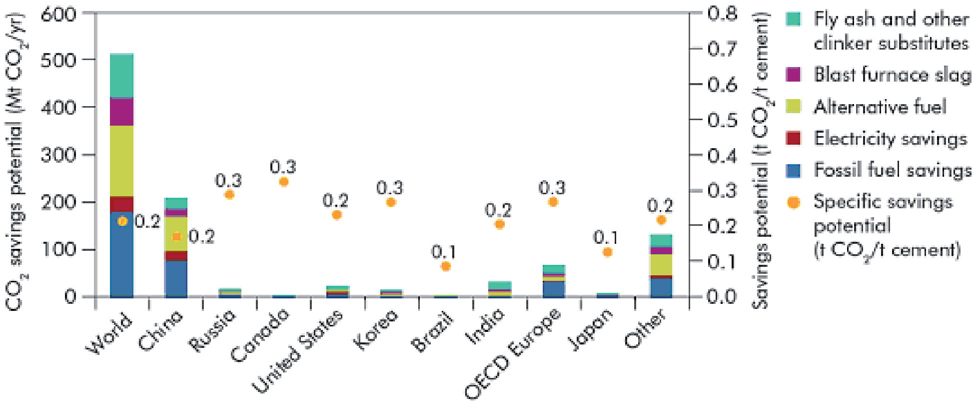


Source: OECD/IEA (2008). Figure reproduced with permission from: Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis. © OECD/International Energy Agency 2008, Figure 3.2, p.32.

In the cement industry, companies such as Calera have experimented with some novel processes and types of cement that have the potential to achieve radical reductions in energy consumption (OECD/IEA, 2009). And even less radical measures like combined heat and power generation can achieve significant reductions in energy consumption in the region of 50%, since heat is no longer wasted. But for materials such as steel and some chemicals it is unlikely that radical reductions can be realized.

The potential to improve the efficiency of a given process can be estimated using the 'learning curves' of various technologies. Without going into the details of specific technologies, it is a fact that the efficiency of each process improves (in a log-log fashion) as new capacity is installed and the amount of installed processes increases. Apart from more fundamental considerations (such as thermodynamic aspects of the process under consideration), these learning curves provide insights into the value for money of an incentive to improve the efficiency of a given process.

Figure 4.2 CO_2 emission savings in the cement industry in 2006, based on BATs. Total CO_2 emissions in 2006 were 1.9 Gt



Source: OECD/IEA (2009). Figure reproduced with permission from: Energy Technology Transitions for Industry: Strategies for the Next Industrial Revolution. © OECD/International Energy Agency 2009, Figure 3.5, p.87.

To carry out a proper analysis of measures that have led to more efficient processes, it is essential to asses all aspects of an industrial process. Methodologies such as life cycle assessments (LCAs) or the analysis of the total cost of ownership (TCO), which is used in the field of semiconductors, show the impact of each step in a production process on aspects like cost, yield, loss of raw material, and inputs of energy and fresh water. Such analyses therefore indicate where and how large the improvement potential is, what benefits it brings in economic terms (which also imply reduced losses, improved throughput and uptime, reduced use of consumables, etc.). The improvement potential may be limited by practical considerations (the cost and availability of a technology, its importance relative to total price, the way in which added costs are transferred to customers), as well as by more fundamental considerations (often related to thermodynamic barriers of the process).

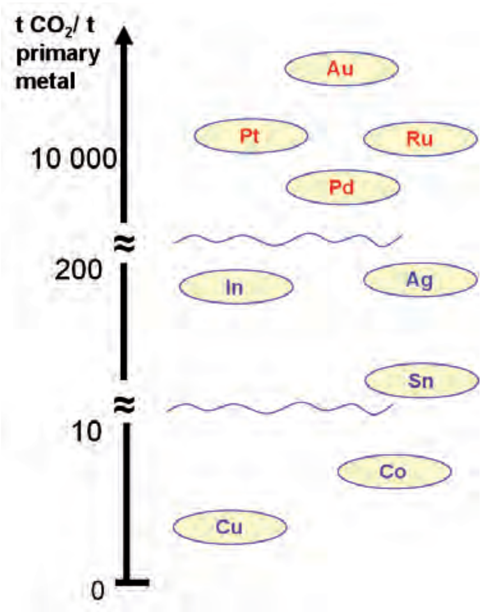
Efficient processing also has its downsides. Consider a printed circuit board (PCB), a well-known element of most electric and electronic appliances. A PCB consists of numerous electronic parts interconnected through wires of a conductive material such as copper. Process development has led to enormous performance improvements over the years, and also to reductions in material contents. However, it is conceivable that at the end of life of a PCB, the miniaturization of components and connections has led to products that can no longer be economically or technologically recycled. What seems to have been a sensible improvement for PCB producers has led to efficient resource use at first sight, but to potentially less resource efficiency in the long run. Such holistic problems can be adequately resolved only by building chains of stakeholders that share a common interest in optimizing the materials chain at a systems level.

4.3. Materials recycling

The term ‘reuse’ is generally used to refer to the use of (components of) an obsolete product in an unchanged form. In this section we focus on recycling, which refers to a process in which materials are liberated from their matrix in a used (end-of-life) product and are then employed in a production process to create a new product.

Recycling of materials is a long-established industrial activity, driven by a combination of sound business cases (governed by the costs of the total operation and the expected commodity prices) and implemented policies (establishing targets for minimal recycling grades, often inspired by environmental concerns). From a resource efficiency point of view, recycling offers the opportunity to reduce substantially the total carbon footprint of a material. Umicore, a large metal recycler in Hoboken, Belgium, for example, estimates that the production of 70,000 tonnes of metal from scrap (on an annual basis) can save the equivalent of 1 million tonnes of CO_2 emissions from primary sources (see Figure 4.3).

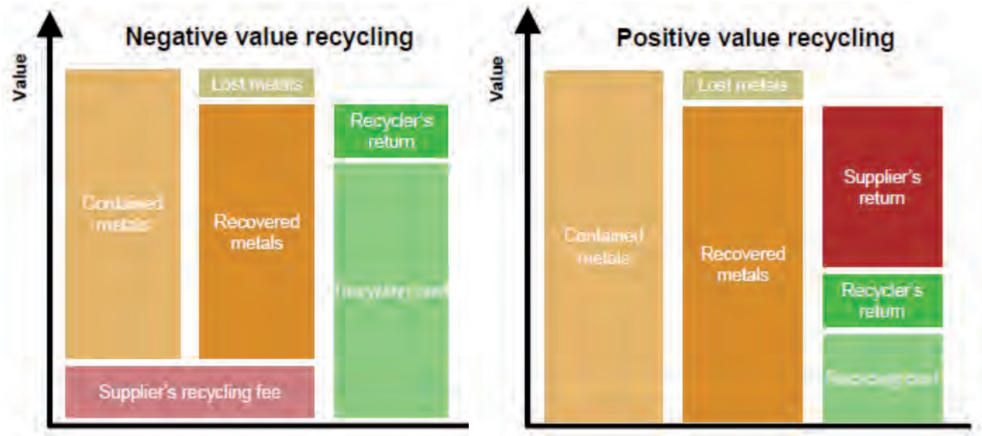
Figure 4.3 Umicore recycling of critical elements



Recycling has received renewed attention for two reasons. The first is the observation that the rising costs of a wide range of raw materials has opened up new recycling routes that were previously uneconomic. The second reason is the concern that the security of supply may be at risk for some materials, especially those for which only a few source countries are known (increasing the risk of supply disruptions) or where urgent scarcity issues are suspected.

Recycling may provide another source of raw materials, thereby reducing the dependence on monopolistic source countries. Yet, in order for a sound and robust recycling system to develop, the business case for all stakeholders involved should make sense. This business case thinking is reflected in Figure 4.4, which shows two strategies, positive and negative value recycling, used by Umicore.

Figure 4.4 Umicore: recycling strategies



In positive value recycling, the cost of the material makes up for the required supplier's and recycler's return, but in negative value recycling this is not the case. Examples of the positive business case include printed circuit boards, catalysts, indium tin oxide (ITO) sputter targets and copper indium gallium selenide (CIGS) production waste, while examples of the negative business case include (in 2011): rechargeable batteries, silver in radio-frequency identification devices (RFIDs), photovoltaic modules and liquid crystal displays (LCDs).

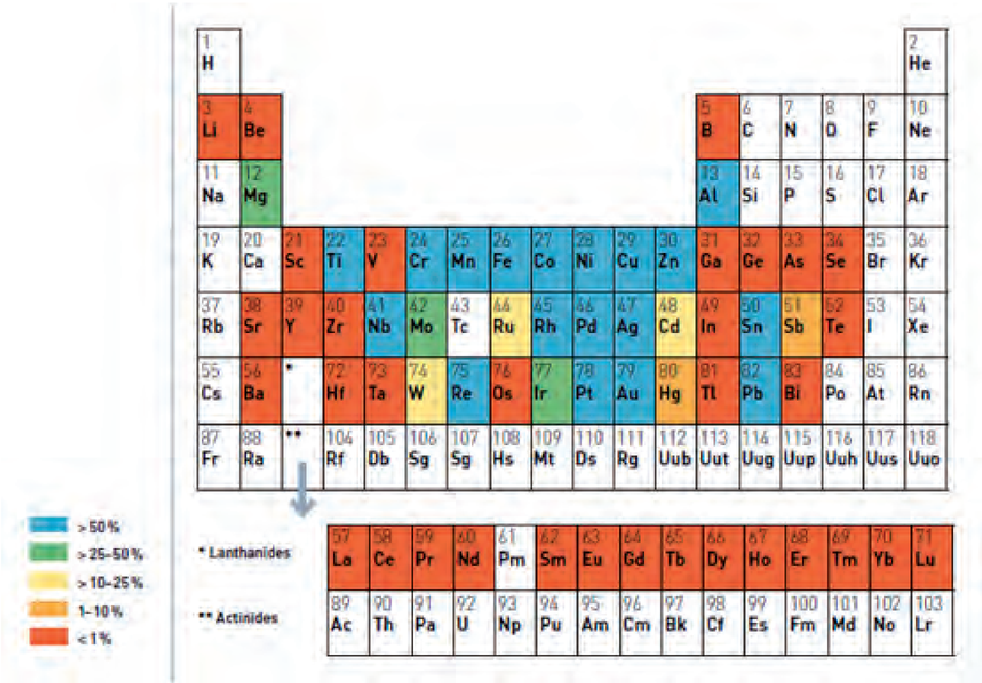
In the public debate, recycling is often embraced as a cure for many of our concerns about raw materials. However, a long list of challenges makes it clear that recycling will only constitute a part of any solution.

With regard to the recycling of metals, the UN Environment Programme (UNEP, 2011) recently published a number of papers describing the status of recycling technology for all the elements in the periodic table. The findings of those papers are summarized in Figure 4.5.

Given that recycling is not a new concept, the low level of recycling of a significant proportion of elements in the periodic table is indeed an indication of the difficulties that need to be overcome. For example:

- Many consumer goods have become extremely complex over the last decades. Not only have the numbers of chemical elements used in products such as computers and mobile phones increased, but their concentrations have often decreased and their interconnections have become more compact. Much of the material cannot be easily separated, preventing effective recycling.

Figure 4.5 Status of recycling technology



Source: UNEP (2011).

- The concentration of many of the elements used in consumer products is low, making it very complex and costly in terms of both collection and disassembly as a process technology to separate materials in an economically feasible way.
- The chemistry of waste streams determines to what extent high-grade products can be recycled. From a thermodynamic point of view, some material combinations cannot be separated with current process technology. If such material combinations appear in the waste stream that a recycling plant needs to treat, no optimal result can be achieved (the materials remain impure or rest streams end up in slag). Obviously, the disassembly step is crucial in separating components to such an extent that subsequent processes lead to higher yields. As well as appropriate

policy measures (such as subsidies for manual sorting), design strategies can have an important influence on the ultimate efficiency of the disassembly step.

- The collection efficiency of many products is very low often because of the lack of habit and infrastructure, but also because of the low perceived urgency and sense of high value of goods (e.g. mobile phones or small electrical appliances). Thus, even in societies with established recycling infrastructures, many appliances end up in general waste streams or 'hibernate' in drawers.
- A peculiar aspect of many metals is that they are mined in combination. Germanium, for example, is mined as a by-product of zinc. One the one hand, this prevents price elasticity playing a significant role, since the production capacity of the minor by-product cannot grow unless that of the major element grows as well. On the other, it may imply that a reduction in the demand for a major metal, perhaps because of a significant increase in recycling efficiency, may lead to the unwanted side effect of reducing the supply of the minor by-product.
- The volatility in the (often not transparent) commodities markets means that investments in recycling are often risky. In the case of rare earth elements, there has been an enormous increase in exploration activities because of the high perceived need for rare earths for high-tech applications. The potential effect of these activities on price development in an already very small market means that rare earth recycling is a very insecure investment.

In section 4.1 we introduced the notion of 'urban mining', a term that refers to urbanization. In 2012 more than 50% of the world's population was living in cities, and the urban population is increasing by some 200,000 people each day. It is expected that by 2050, some 6 billion people will be living in an urban environment. Potentially, this could provide a strong incentive for recycling goods, buildings and waste materials. For instance, it may well be that in terms of organization and costs related to the collection, separation and transportation of waste materials, recycling in urban areas may lead to a better business case than recycling in rural areas. However, the transportation costs do not always play a dominant role in the business case. Spatial concentration is important, but not always decisive. Other factors may also be significant, such as the labour costs of (manual) disassembly of used products and components, so that it may still be worthwhile to ship used electronic goods from the industrialized to developing nations for further disassembly.

All in all, material recycling is an important strategy for resource efficiency, but it has its limits: recycling can only provide a fraction of the total demand for a given material. Especially for materials whose consumption increases as new technologies are developed, it is clear that recycling can meet only a small fraction of the demand. Several important steps need to be taken:

- Ensure sound business cases, creating partnerships between partners along the value chain. Within these value chains, ensure that the costs and benefits are transparent and shared, ensure that stable and guaranteed supplies of waste and raw materials are established and ensure a stable demand and price for the recycled material.

- Improve collection and disassembly steps of the recycling chain; redesign can ease disassembly (through more complete sorting at early stages) to such an extent that more effective recycling processes can take place;
- Understand the 'whereabouts' of products in their overall lifecycle, including the materials of which they are made (through extensive material flow analysis). Such knowledge is essential for building the sound business cases and policies required for more fruitful recycling.

4.4. Radical redesign of products

There is a huge potential to improve the resource efficiency of products by radically changing their design, while maintaining or even improving their functionality and quality. One of the key concepts here is the ground-breaking 'Factor Four' concept, which asserts that by using natural resources efficiently it is possible to halve our use of resources while doubling living standards (von Weizsäcker et al., 1997; Weaver et al., 2000; Pauli, 2010).

In recent decades many products have been redesigned for application in a wide variety of sectors, from housing to food and transport. Examples include *Passivhauses* (passive houses) that need no energy for cooling or heating, and fuel-efficient cars that use only 3 litres of gasoline per 100 km are already on the market.

Although many of these radical improvements were introduced into the market years ago, most of them have not yet been widely adopted. Their wide implementation seems to be hindered. Radical changes in the design of products may demand similarly radical changes in consumer behaviour. Companies may need to invest in new competences and technologies in order to manufacture the redesigned products. New technologies may generate new risks that need to be assessed, regulated and accepted. And finally, the introduction of radically redesigned products on the market may affect vested interests in society, which may actively obstruct their introduction. For these and other reasons, radically redesigned products may promise radical jumps in resource efficiency, but their market penetration will take time.

4.5. Substitution: easier said than done

Substitution is the replacement of a substance, process, product or service by another that maintains the same functionality. As such it is a broad and complex 'solution' to raw materials scarcity and resource efficiency. As with recycling, policy documents frequently assume that substitution is a solution to these problems.

In terms of mitigating the effects of the increasing scarcity of many raw materials, substitution becomes very powerful in those cases where a potentially scarce and critical raw material can be substituted by an abundant one (an 'element of hope'), by a new technology or by a smarter product approach. A robust substitution does not mean exchanging one rare metal for another one. Currently, substitution is mainly initiated as a strategy to alleviate undesirable dependencies.[2]

A substitution strategy does not necessarily mean a new production process would consume less energy and water, so that any suggestion that a substitution strategy would contribute to resource efficiency should be tested in a systems approach. For each application of a particular raw material, a different substitution approach may be required. In the framework of this chapter, substitution is considered only in cases where an improvement in resource efficiency or mitigation of materials scarcity is the basis for the initiative (and not any other type of alternative process or product development). Some examples of substitution include the following:

- *Substituting one substance for another:* Polyethylene terephthalate (PET) has replaced glass as the material for soft drinks containers. This has dramatically reduced the weight of packaging and the associated transport emissions.
- *Substituting one process for another:* Caustic soda and chlorine were originally produced by the electrolysis of brine in Castner-Kellner cells using a mercury cathode. The process has now been superseded by one that uses membrane cells that do not require the use of mercury.
- *Substituting a new technology for a substance:* A different solution or service may provide the same benefits as the chemical substance being replaced, or a technology supporting the implementation of one of the other strategies. For example,
  - platinum electrodes in fuel cells have been replaced by biocatalysts (in microbial fuel cells);
  - lanthanum and cerium in nickel-metal hydride (NiMH) batteries have been replaced by lithium ion batteries (in electric vehicles);
  - permanent magnet-based motors (using rare earths) in electric and hybrid vehicles have been replaced with new hybrid ‘rare-earth-free’ motors.

One could imagine that substituting products for services could also be included here. However, since this involves different thinking about business models, we discuss this ‘substitution’ route in section 4.6.

The results of a recent survey conducted by TNO and the Materials Innovations Institute (M2I), on behalf of the Dutch high-tech industry association (FME), revealed that many companies are experiencing supply disruptions. Although most companies interviewed had responded by trying to make their supply chains more robust (identifying second suppliers, entering into long-term agreements, creating stockpiles), some of them were also looking for alternative solutions to particular technologies or materials. Although in some cases they had indeed succeeded, the substitutes appeared to be viable alternatives but were felt to be less than ideal. As soon as supply disruptions were re-

2 A recent report by HCSS and TNO (2012) “Samenwerken aan Zeldzame Aarden” gives an overview of Japanese research efforts in the field of substitution.

solved, the companies returned to their original designs. These substitution technologies have an important function: they make a company's future more robust and give a signal to suppliers that pressure cannot be exerted at all costs. It is clear that such activities will have only a marginal effect on resource efficiency at a global scale. The example of introducing terephthalate as a packaging material, however, shows that there may be significant benefits at a systems level.

4.6. Intensifying the use of products and services

A very different resource strategy is to enhance the intensity of use of products. Consequently, changing consumer behaviour is part of this strategy. Examples include:

- wider application of the concept of leasing;
- the introduction of services enabling the sharing and pooling of consumer products that consumers need only occasionally;
- repair services combined with the reuse of components to enhance the technical lifetimes of products and components; and
- designing for reuse of products, enhancing their economic lifetimes.

A good example is the rise of car-sharing systems. The work of Meijkamp (2000) and Mont (2004) has shown that such measures can typically lead to a reduction in the ecological footprint by a factor of 2. One of the main problems with this strategy is that in societies where people are becoming richer, more individualistic lifestyles tend to emerge, which puts a market premium on offering individualized rather than shared products and services (Tukker and Tischner, 2006; Pine and Gilmore, 1999).

A specific form of both changing and intensifying the use of goods, and enabling a stepwise change in recycling and a circular economy, is to introduce the use and purchase of services rather than the purchase of the products with which those services are obtained. An excellent example is the concept of Turntoo introduced by Dutch architect Thomas Rau.[3] The concept is based on consumers who hire a service provided by a product, while the producer retains ownership of the product. At the end of its useful life, the product – the used product, its components and raw materials – is returned to the producer. The product cycle is closed and the resources remain available for making future products. The claimed benefits of this idea include:

- performance-based consumption: consumers pay for the function of the product and not for its component raw materials;
- resource management: producers continue to own their resources and become less dependent on commodity markets; and
- closing the life cycle: valuable resources are no longer lost.

3 For additional information, see www.turntoo.com/en

Turntoo and similar concepts of performance-based consumption represent an important systemic change for both consumers and producers. Consumers are invited to rethink the actual purpose of a purchase: do they want the product itself or the service it provides? Producers, besides owning the material system and retrieving all of its contents after use, may then radically rethink their design philosophy. They may decide to create products containing better quality materials and components, thus extending their lifetimes. They may design products that are more easily disassembled for reuse or ultimate recycling to a large extent, or they may rethink the product so that they can deliver the service more efficiently. Philips recently adopted the Turntoo concept in its 'Pay per Lux' service,[4] whereby the customer contracts to pay for the installation and use of a lighting system in the workplace, while Philips retains ownership of and responsibility for maintaining the system.

Another example (although not based on the Turntoo concept) is Interface, an American company that used to sell carpet tiles but has recently embraced the idea of providing carpets as a service. Customers no longer buy the carpet tiles but, for an annual fee, the company guarantees to provide floor covering of specified quality. In other words, in this case the producer is again no longer simply selling a product (carpet tiles) but is selling what the carpet tiles do. Following this change of business model the company has developed a new range of carpet tiles that are more durable and more easily recycled.

4.7. Shifting expenditures to low-impact products and services

The next resource strategy aims to shift expenditures to low-impact products and services; in short, to encourage spending with less impact. It requires consumers to shift their expenditure from material to non-material value components. Such non-material value is created when customers attribute added value to elements such as:

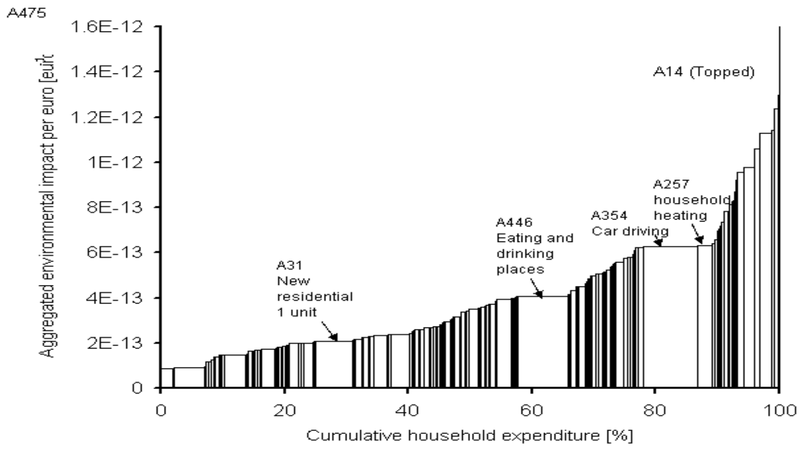
- experience and atmosphere;
- brand names, image and lifestyle;
- intellectual property rights, such as copyrights and patents; and
- 'clean' and 'fair' products.

The basic assumption is that consumers are willing to pay more for added value and, more specifically, for products and services with relatively low life-cycle impacts. There has been broad optimism about this strategy, which assumes there will be growth in terms of 'quality' (e.g. VROM Raad, 2002), although it is questionable whether this optimism is justified.[5] This can be illustrated with Figure 4.6.

4 See www.lighting.philips.com/main/projects/rau.wpd [this is the same article in English]

5 For instance, much domestic 'amusement' consists of watching TV and plasma screen TVs, which compete with fridges as major electricity users and are now penetrating fast in the Western world.

Figure 4.6 Environmental impact of products and services per euro versus total expenditures on 280 expenditure categories, EU-25



Source: Tukker et al. (2006). Figure kindly provided by Arjan de Koning of the Institute of Environmental Sciences (CML), Leiden University.

Figure 4.6 shows the life cycle environmental impacts per euro of the total final consumption expenditures in the EU-25, divided into 280 expenditure categories (Tukker et al., 2006; Huppes et al., 2006).[6] In theory, shifting expenditure from the high to the low impact per euro categories would reduce the total impact. Yet, the flexibility to make this shift is limited. The top 5% of expenditures are on foodstuffs, and one cannot expect humanity to stop eating.[7] The bottom 5% consist of services such as insurance, but these are in fact often bought in relation to other, high-impact expenditure categories (e.g. driving a car and housing). Neglecting these top and bottom 5%, the difference in impact per euro between the 'dirtiest' and 'cleanest' categories is at most a factor of 4. Even if massive expenditure shifts from the 'dirtier' to 'cleaner' categories were possible, this would at best give a net improvement in environmental impact by a factor of 2. The conclusion seems clear: shifts in expenditure alone, with no technical improvements, will not lead to drastic reductions in the impacts of final consumption expenditures.

4.8. Improving quality of life without spending money

The final strategy discussed in this chapter aims to get more quality of life per euro spent. This strategy focuses on two elements:

6 The environmental impacts in the figure are an aggregation of well-known life-cycle impact assessment categories such as global warming potential, acidification and eutrophication. For further information, see Tukker et al. (2006).

7 Meat scores higher than most other foodstuffs, of course, and a shift to diets with less meat is of course not an impossible option, but it is not easy to encourage radical shifts in diet (Tukker et al., 2009).

- *Reducing 'obligatory needs' by creating 'no-need' contexts.* This means creating living conditions where people simply need fewer material artefacts in order to achieve the same result (e.g. a spatial policy planning that succeeds in reducing the need for commuting). Or, as a negative example, a society that is not too concerned about working conditions may see relatively high expenditures on healthcare. Neighbourhood security, which most European countries could take for granted 40 years ago, now requires continuous surveillance via closed-circuit TV systems, more intensive police patrols, and burglar-proof windows and doors.
- *Enhancing non-market-related quality of life factors.* Sometimes, 'economic growth' involves little more than attaching a price tag to a 'service' that used to be available for free. Child care, formerly provided at home by a parent who was not involved in the formal economy, is now outsourced to a kindergarten.[8] The same applies to care of the elderly, or the functioning of social networks (which now often need a lot of material stuff to be maintained). And in the case of neighbourhood security mentioned above, despite all these measures, the 'quality' experience still may be reduced.

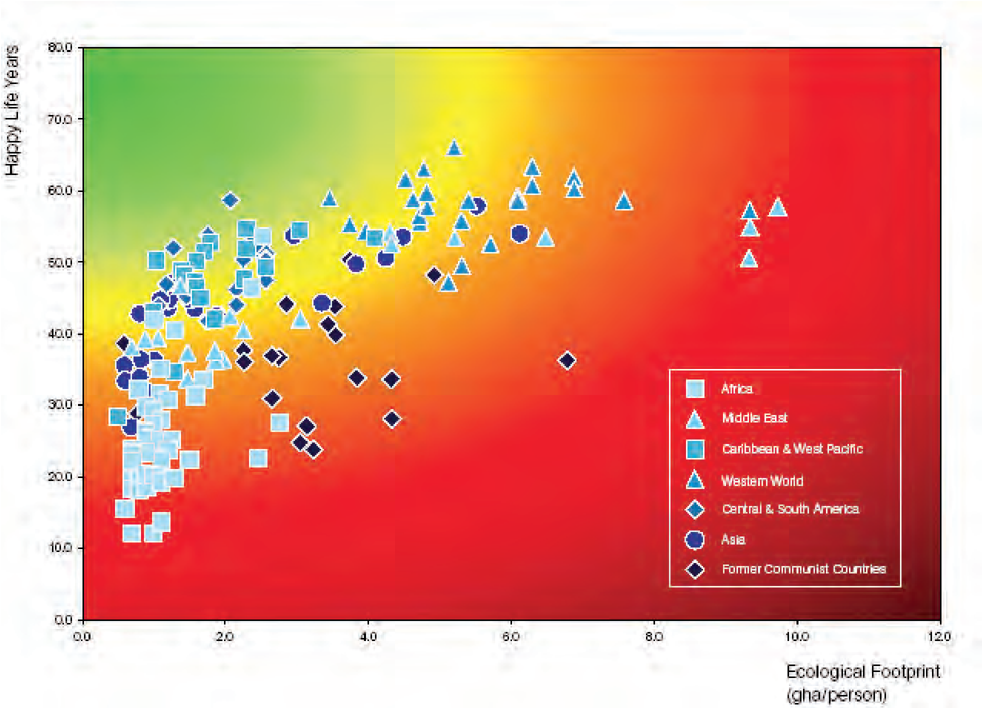
Various studies have plotted the happiness of people (assessed via surveys) against income (e.g. between different countries or as change over time). These studies have shown a rather surprising result: once a certain income threshold is exceeded, any additional income has no influence on happiness (Veenhoven, undated). There is also a considerable body of literature that suggests in modern society, the fulfilment of basic needs is only possible using many material artefacts (Segal, 1999). So, though the Japanese national income grew by a factor of 5 between 1959 and 1991, the increase in happiness was close to zero (Hofstetter and Ozawa, 2004). This suggests – at least – that the efficiency of income to create quality of life shows considerable room for improvement (Jackson et al., 2004; Jackson, 2004). An illustrative example is given in the 'Happy Planet Index' compiled by the New Economics Foundation. According to Abdallah et al. (2009), the index 'measures the ecological efficiency with which, country by country, people achieve long and happy lives. In doing so, it strips our view of the economy back to its absolute basics: what goes in (natural resources – measured as the ecological footprint of consumption), and what comes out (human lives of different length and happiness).'

Figure 4.7 suggests that a large ecological footprint (related to high consumption per capita and high GDP) is not a precondition for a high quality of life. One could even go so far as to say that having a very high GDP (and hence a large footprint) per capita is not a sign of progress, but rather a sign of inefficiency in providing what truly matters: the ecological footprints of countries with equal quality of life and life years may differ by up to a factor of 4.

8 In their otherwise very inspiring book, *The Experience Economy*, Pine and Gilmore (1999: 97) make the rather depressing observation: 'The history of economic progress consists of charging a fee for something that once was free'.

This observation points to the importance of thinking through what kind of a society economic development should lead to: a materialistic, consumerist society where economic growth becomes a goal in itself and material goods provide a kind of surrogate for creating meaning in life, or a society where economic activities are used as means to provide harmony and well-being, which is pursued as the ultimate goal (Jackson, 2009).

Figure 4.7 Happy life years versus the ecological footprint for 143 countries



Source: from Abdallah et al. (2009: 26); reprinted with kind permission of the authors.

4.9. Conclusions

This chapter has discussed a wide range of strategies by which producers and consumers may contribute to the more sustainable use of natural resources. These strategies vary from measures to improve the efficiency of existing manufacturing processes to radical changes in the design and use of products, and from improving mining activities to the introduction of performance-based consumption. Together, these strategies combine two lines of action: improving our present production and consumption patterns and changing these patterns by addressing the underlying causes of our overconsumption in society.

Table 4.3 The scope of resource strategies discussed in this chapter

	Production side					*Consumption side*
	Efficiency strategies			Sufficiency strategies		
Step in production-consumption chain	Mining	Manufacturing	Products and services	Use of products and services	Expenditure mix	Quality of life realized
Strategies	Sustainable mining	Process optimization Materials recycling	Radical redesign Substitution	Intensifying use Reuse	Spending money on low-impact activities	Improving quality of life without spending money
Type of innovation	Optimization	Optimization	Product redesign	Product system innovation	Pricing non-monetary values	Redefining needs and aspirations

The resource strategies summarized in Table 4.3 range from incremental innovations that can be taken on the basis of current societal, economic and technological models and know-how, to more radical innovations that may only be possible under new and different economic, political and societal structures. Experience has shown that although the overall impact of incremental innovations is limited, they are generally easier to implement than it would be to introduce and upscale more demanding, radical innovations.

For most resource strategies the business case is far from obvious. Most of the strategies mentioned here address more than one system level: materials, products, processes, the product chain, the product service system, the economic system, cultural values, etc. Each strategy that effectively impacts at one system level may result in additional costs and benefits at other system levels or somewhere along the product chain. Consequently, the costs and benefits of the resource strategies are difficult to assess and in most cases are unevenly distributed across many stakeholders. With many actors and interests at stake, the challenge is to build coalitions between these actors that will enable a fair distribution of the costs and benefits along the value chain, so that actions may be taken from which all may benefit.

5 Resource efficiency in the built environment

The built environment uses a substantial amount of energy and minerals. In terms of volume, construction minerals are much more important than industrial and metallic minerals. Construction minerals are not scarce: sand, gravel, stone, lime and clay can be found almost everywhere. However, producing building materials such as cement, asphalt and brick from these construction minerals is energy and material intensive. The actual use of buildings also affects overall energy use and CO_2 emissions in the built environment. Technological innovations, awareness programmes and urban planning have all been deployed to reduce the consumption of fossil-based energy by residents of houses and offices. And we are making considerable progress: the zero-energy building is now within reach.

The production, reuse and recycling of building materials are creating inspiring innovations. This chapter will present three successful business cases that illustrate the virtue of know-how combined with creativity. One example is the ClickBrick®, which eliminates the need to use cement and enables bricks to be used over and over again. Another example is ASCEM, which produces cement from fly ash and other secondary materials, substantially reducing the use of virgin materials as well as CO_2 emissions. And last but not least, there is the Highly Ecological Recycling Asphalt System (HERA), which makes it possible to produce higher quality asphalt using less energy and creating fewer emissions while re-using up to 100% used asphalt.

It is not only new technology that is making breakthroughs in resource efficiency in the built environment possible. Indeed, the very concept of building is also changing. Essentially, building is a circular process in which building materials can be used and reused endlessly. However, the traditional business case in the building sector is a linear one. Each link in the chain of materials production, assembly, and the use and demolition of buildings has its own costs and benefits. Park 20/20, a business estate near Amsterdam Schiphol Airport in the Netherlands, is an example of a circular business case, in which the building is perceived as a 'materials bank'.

5.1. Bricks outlive their buildings
Gert Jan den Daas, Daas Baksteen

Gert Jan den Daas graduated from Nyenrode Business University and completed an MBA in the United States. On his return to the Netherlands he started working for General Electric there and later also in Pittsfield, Massachusetts in the United States. In 1988 he followed in his father's footsteps and became the fourth-generation owner and managing director of Daas Baksteen.

As some 6000-year old ruins illustrate, bricks can long outlive the buildings in which they were originally used. Still, reusing bricks is cumbersome because they are cemented together. Any demolition of the walls and cracking or chipping of the cement damages them. The ClickBrick®, a patented and cradle to cradle[1] certified invention by Daas Baksteen, can be used over and over again in an endless cycle of buildings.

When Gert Jan den Daas opens the door to the machine hall, we are greeted by the deafening noise of a 10-metre-long grinding machine. The machine makes the grooves in the raw ClickBrick® and grinds them to their specified height and length, with an accuracy of 0.1 mm and 1.0 mm, respectively. 'When cement is used to pile up bricks in traditional building methods,' says Den Daas, 'the exact size of the brick is not a critical detail, because you can compensate for minor differences by making the joints smaller or wider. ClickBrick® walls don't have joints, however, so you can't compensate for differences. Therefore the height of the brick has to be exactly right. The length and width have a little bit more tolerance.'

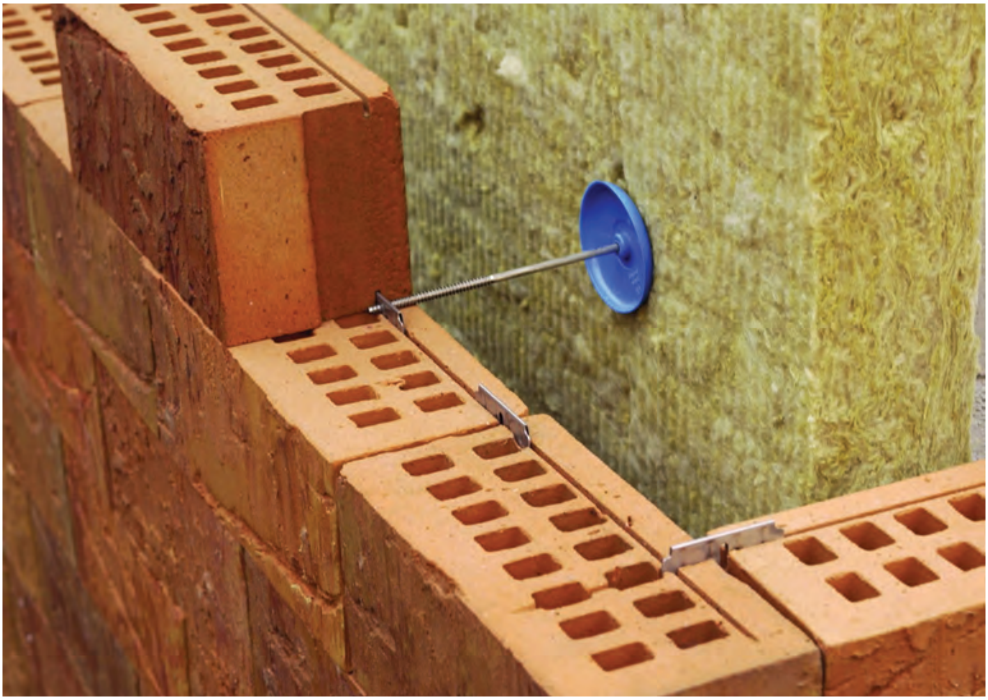
Family business

Gert Jan den Daas is the fourth-generation owner and managing director of Daas Baksteen, a medium-sized brick manufacturer with a staff of 90 spread over two locations in the eastern part of the Netherlands near the German border. They are suitable locations because half of the company's bricks are exported to Germany. Most of these bricks are made to order in a wide variety for architects and contractors. 'In my father's time we produced two types of bricks. Now we make 250.'

A little over 10 years ago Den Daas developed several ideas for making jointless façades, partly for aesthetic reasons, but also to find ways to reuse bricks over and over again. In fact, Den Daas was using a cradle to cradle approach even before the term was coined by German chemist Michael Braungart and American architect William McDonough. Meanwhile the ClickBrick® has received cradle to cradle certification, which means the product meets minimum criteria in five categories: material health, materi-

1 Cradle to Cradle® is a registered trademark of MBDC, LLC. Cradle to Cradle Certified^CM is a certification mark licensed by the Cradle to Cradle Products Innovation Institute™. See http://mbdc.com/images/MBDC%20C2C%20Certified.pdf

Figure 5.1 The ClickBrick®



al reutilization, renewable energy use, water stewardship and social responsibility. 'We even have Silver certification',[2] says Den Daas proudly.

Renewable feedstock

The reason for developing a reusable brick was not so much a shortage of raw materials. 'Enough clay can be mined in an area with a radius of 60 km to 70 km to last us for ages,' says Den Daas. 'In fact the Dutch research institute Deltares views clay as a renewable feedstock. Every year the rivers deposit far more clay than we can ever use.'

A more important reason to develop a reusable brick is the enormous amount of energy that is used in its production. Energy is used to transport the clay to the brickworks (mostly by environmentally friendly barge, by the way), but most of all, the energy is used to make a brick. To turn a hunc of clay into a dry ceramic brick, it has to move at a rate of 1.5 metres per hour through a 150-metre-long gas-heated oven that reaches a temperature of approximately 1150 degrees Celsius.

Stainless steel clips

The development of a reusable brick started with a groove and tongue system, resembling floor planks. 'That didn't work out because it was too complicated', says Den Daas. 'Eventually I discovered it was much easier to use a stainless steel clip to keep the bricks

2 There are four levels of cradle to cradle certification: Basic, Silver, Gold and Platinum.

in place. Together with my brother Bert, my technical director Hans Nijkamp and building consultant Harrie Vekemans, we further developed the idea of the ClickBrick® and patented it in 2001.'

To go from an idea to producing the first batch of bricks for commercial use was a big step for a medium-sized company like Daas Baksteen. 'We had to develop and actually build a special grinding machine to make the grooves and grind the brick to its specifications,' says Den Daas. 'We did it together with the machine-builder, but still it was a large investment – over a million euros – which is quite a lot of money for us. It was a leap of faith, and we only pulled it off because we believed so strongly in it. Some support from the government would have been nice – a soft loan, for example – but we didn't meet the criteria of the existing subsidy schemes.'

Smooth surface

The first batch of ClickBricks® consisted of 8,000 bricks, ground with hand tools. They were used in the wall of a building in the town of Velp, near Arnhem. Since the commercial introduction of the ClickBrick® in 2003, more than 300 buildings, including houses and offices, have been built with ClickBrick® façades. 'Architects like the smooth surface and the absence of cement joints,' says Den Daas. 'It gives the building a distinctive appearance. The fact that the bricks come in a range of colours helps too. The only drawback for architects is that they have to work within certain dimensions based on the size of the ClickBrick®, because you cannot cut it. We have people to help architects work out these details.'

Although the architects like the look of ClickBrick® façades, it took quite a while for the building industry to accept the system. 'People were sceptical, because it is a new system and by nature the building industry is rather conservative. That is of course understandable, because its products have to last 50 years or more,' says Den Daas.

It took a few years, but the ClickBrick® is now fully accepted among architects and others in the Dutch building industry and in neighbouring countries. 'Its success has given us the reputation of being an innovative firm, which is great,' says Den Daas. 'It helps to pave the way for other innovations, such as our DuecoBrick.' The DuecoBrick is a lightweight hollow brick with either a smooth or a rough, rock-like appearance. Production of this hollow brick uses 55% less energy and raw material than regular brick. 'Because it is lighter than traditional brick the load-bearing parts of the building have to carry less weight and can be made lighter, which also saves raw material.'

Raincoat

Back to the ClickBrick®. According to Den Daas, its acceptance was certainly helped by the fact that it dovetailed with traditional building methods: builders still have to pile up bricks. The only difference is that steel clips are used to bond the bricks instead of cement. In fact the ClickBrick® system is far easier to process than traditional bricks and mortar.

'You don't have to train people how to do it,' says Den Daas, 'which is an advantage, because there are fewer and fewer skilled masons around. It is important that the first layer of bricks is perfectly horizontal. Only the two layers of bricks beneath window frames and cornices have to be glued together to prevent people stealing a row of bricks.'

In the Netherlands brick walls are mainly used in the façades of houses and buildings and not in load-bearing constructions. That role has been taken over for a number of years now by limestone and sandstone (calcium silicate brick) and, of course, concrete. Even inner walls are not made of brick any more in the Netherlands, unlike in Germany and Belgium, but of limestone and sandstone or cellular concrete. 'So the traditional load-bearing harness has become a raincoat', as Den Daas puts it. As many as 90% of all new houses and 50% of office buildings have brick façades.'

Except for the wind and their own weight, brick walls no longer bear any load in modern buildings. The ClickBrick® has small recesses for placing wall ties that transfer the wind load to the load-bearing construction. Like any brick façade, the ClickBrick® is an open system. The vertical joints are left open for ventilation. As no cement is used it cannot accidentally fill the vertical joints. Another advantage of the ventilation in ClickBrick® walls is that they are not marred by the efflorescence that is spoiling many newly built brick façades.

Lease

The greatest advantage of the ClickBrick®, however, is its reusability. When a building nears the end of its lifetime, Daas Baksteen will take back the bricks. 'We have so much faith in our product that we are certain that we can resell used ClickBricks. As a matter of fact we promised to take back the bricks that are now in the façade of a specialized hospital. We might have to clean them, but they will have acquired a certain patina over time, which may be of great interest to architects. Come to think of it, we might even start leasing our bricks instead of selling them.'

5.2. Reducing carbon dioxide by reusing secondary materials
Hans Wiercx, BTE and Anja Buchwald, ASCEM

Hans Wiercx studied civil engineering at Delft University of Technology and worked until 2007 as technical director of Romein Beton, one of BTE's subsidiary companies. When Wiercx joined BTE he became project manager of R&D, a position that also made him managing director of ASCEM.

Anja Buchwald studied the science of building materials at Bauhaus-Universität Weimar in Germany and did a PhD on salt transport in building materials at the same university. Afterwards she worked as a scientist, doing research on the chemistry of binders. She has been working as deputy director of ASCEM since 2009 and is responsible for R&D for ASCEM cement.

As global demand for cement rises, so are carbon dioxide emissions. 'We have developed an alternative binder that reduces CO_2 emissions from cement production by half – or more', says Hans Wiercx, project manager at BTE, a group of companies specializing in concrete products. 'As it can be made from fly ash and other secondary materials it preserves some of our valuable natural resources', adds Anja Buchwald, researcher at ASCEM, a research centre for building materials.

The development of ASCEM cement goes back to the 1980s. Confronted with the perspective of a growing mountain of fly ash from coal-fired power stations, several initiatives were taken – both in Belgium and the Netherlands – to turn fly ash into something useful. One of these initiatives was the setting up of a research company named PBI, a forerunner of ASCEM. Together with the regional power company of the Province of Limburg, this research company built a pilot plant to turn fly ash into cement.

'At some point, though, it became clear that fly ash could be used just as a filler in concrete', says Wiercx from BTE, a group of companies specialising in concrete products. Then the production of cement out of fly ash hit rock bottom, at least in Western Europe. In the ensuing years ASCEM put tremendous effort into trying to produce cement that had large deposits of fly ash in India and China, but that did not work out either.

Change

'In the meantime something had changed in Europe', says Anja Buchwald, who has conducted research on binders for years and who recently joined ASCEM from the Bauhaus-Universität Weimar in Germany. 'At the turn of the century people became more and more aware of the possible effects of carbon dioxide on climate change. The production of Ordinary Portland Cement is responsible for more than 5% of total global CO_2 emissions. This prompted architects and builders to start looking for other binders. ASCEM cement is certainly a promising alternative. Its carbon footprint is less than half of that of Portland cement.'

Portland cement is made from limestone (calcium carbonate) mixed with less than 10% of other constituents, such as clay. By heating it in a kiln to a temperature of 1,450 degrees Celsius, the calcium carbonate decomposes into calcium oxide and carbon dioxide. Every kilogram of cement that is produced generates 0.5 kilograms of CO_2. And the fuel used for the kiln produces another 0.3 kilograms of CO_2 per kilogram of cement.

'Apart from less CO_2 per kilogram of cement, ASCEM has other environmental benefits', continues Buchwald. 'For every kilogram of cement produced, 25% less raw material is needed. In other words, more cement can be produced from the same amount of raw material. Moreover, about 20% less energy is needed for each kilogram of cement produced. Another interesting feature is that ASCEM cement has a 10% lower density. So the same volume of cement weighs 10% less than regular cement. It is not really a lightweight material, but it can make a difference during building.'

Influence

To make cement out of fly ash or other mineral raw materials, such as metallurgical slag, the material is melted in a furnace at about 1,450 degrees Celsius. This produces a reactive alumino-silicate glass, which, after quickly being cooled and milled, is mixed with a dry alkaline activator and a filler material. The result is a cement-like powder. The properties of this powder, such as its hardening time and strength development, are comparable to Portland cement.

'The interesting thing about ASCEM cement is that its composition and hence its strength and other characteristics essentially depend on the size and structure of the raw materials you start with, and on the curing time, the temperature and the activator,' says Wiercx. 'Depending on the application you want, you can control the quality of the cement. There are no limitations on the filler material you can use either. Thanks to the way it is produced (alkali activation), the interface between cement and filler is better than with Portland cement.'

The special properties of ASCEM cement should arouse the interest of architects and builders. 'For about five years now the market, at least in industrialised countries, has leaned towards the diversification of cement types, depending on their application. While Portland cement can be described as "one size fits all", ASCEM cement can be produced in a range of varieties. It becomes a design variable, which is a feature our clients welcome. But I have to admit that we still need to do some serious research to be able to optimise all properties of the end product.'

Hands-on experience

In 2011 ASCEM cement was put to a critical test. Two prefab concrete products were made from ASCEM cement in two of BTE's different precast concrete plants. De Meteoor BV in Rheden, near Arnhem, used the new material to make Stelcon slabs for paving industrial terrains, and De Hamer BV in Alphen aan den Rijn, between Leiden and Utrecht, made standard concrete sewage pipes. The batch of ASCEM cement needed for these tests was made in an industrial furnace in the south of Europe. 'It was a critical test of the material', says Wiercx. 'The furnace had been designed for another type of material, so a small change in temperature could have led the mass to solidify too early.'

The production of Stelcon slabs and sewage pipes gave those involved hands-on experience with the material. It turned out that using ASCEM cement did not pose any special problems, neither for the people who were making the products nor for the machinery that was used. The mixing characteristics and workability of the cement are comparable to those of Portland cement. 'The people who actually made the concrete products were rather positive,' says Wiercx. 'The material dovetailed with their routines.'

The quality of the end product was measured as well. It turned out that ASCEM cement had a high resistance to liquid penetration thanks to its very dense structure. 'In general ASCEM cement's performance in real-life applications was good', says Buchwald. 'It performed so well that we think it may even serve as an alternative to Portland cement in the most demanding application of concrete, namely in construction elements – but first we have to successfully produce a self-compacting variety.'

Trust

A new material can be as good as or even better than a traditional one, but that does not mean that it will supplant the old one overnight. 'It takes time to build up trust,' says Wiercx. 'The key issue is "durability". Will it live up to its specifications in 50 or 100 years, because that is the time frame in the building industry?'

'At the moment there is no standardized test for this type of material,' adds Buchwald. Recently, in 2012, the International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM) set up a technical committee to test the durability of alkali-activated materials. Its primary aim is to come up with recommendations for appropriate testing methodologies and protocols for bonders, mortars and concretes. Until now the vast majority of durability testing methods have been developed specifically for the application of Portland cement binder systems.

RILEM's recommendations are generally adopted by national bodies and institutes when creating new standards.

Production

Even standardized testing methods are not enough to develop a market for a new product like ASCEM cement, according to Wiercx. 'You have to produce it in quantities that are large enough so that precast concrete plants can test the material themselves. In the near future we hope to build a small cement plant that produces between 50,000 and 100,000 tonnes of cement per year. The plant will preferably be in Germany or the Netherlands, although the market for cement in Western Europe is difficult, to put it mildly. We think we can pull it off, however, because we are part of a group of companies that specialize in precast concrete. There is a lot of interest in the market, especially because ASCEM cement has a significantly lower carbon footprint.'

5.3. No need to barbecue secondary asphalt

Chris Grootendorst, Asfaltcentrale Rotterdam

Chris Grootendorst studied civil engineering at the school for secondary technical education and worked in road building until 1989, when he became an asphalt engineer. He is now manager of ACR, which produces 300,000 tonnes of asphalt per year, one third of which is made from secondary asphalt

'We don't barbecue it – we put it in a wok', says Chris Grootendorst, manager of ACR, an asphalt plant in Rotterdam, the Netherlands, which produces the Highly Ecological Recycling Asphalt System (HERA). 'The HERA System produces a higher quality asphalt using less energy and creating fewer emissions, but we can use as much as 100% used asphalt.'

Driving through an industrial landscape of refineries, chemical plants and harbours, you cannot help but notice the huge mountains of broken asphalt, sand and gravel around

Figure 5.2 The HERA system for recycling asphalt

a relatively modest plant. Lorries drive back and forth, either loaded with sand and gravel or hot bitumen, or with ready-to-use asphalt on its way to roadworks in the vicinity. This all takes place within a radius of 50 km.

This rough exterior conceals a hi-tech manufacturing process. On the site of ACR, an asphalt plant in Rotterdam, the Netherlands, there is a large tank, the size of a road tanker, lying on its side on a very large table. The tank is the heart of the HERA System for recycling asphalt, developed by VolkerWessels, one of ACR's parent companies. Inside the tank seven cylinders slowly turn around a central axis, while they are heated by hot gases. Inside the cylinders large chunks of secondary asphalt are melting at temperatures of around 160 degrees Celsius, like a phoenix regaining a new life.

Cooked through

Traditionally secondary asphalt is heated directly while it passes through a cylindrical drum mixer, meeting the flames head-on, like a cauliflower on a barbecue. In the HERA System it is heated indirectly, like vegetables in a wok. 'Like the vegetables the asphalt is heated evenly and retains its taste and smell, whereas on a barbecue your cauliflower would get burnt on the outside and stay raw on the inside,' says Chris Grootendorst, manager of ACR.

Apart from producing higher quality asphalt, the HERA System has other benefits as well. CO_2 emissions are reduced by 75% compared to traditional drum mixers. This is partly the result of less natural gas being used, since heat is being reused. And it is partly the result of less transport being needed for the supply of raw materials such as sand, gravel and bitumen. 'The HERA System recycles up to 100% of secondary asphalt,' says Grootendorst. 'Most other recycling plants need to add virgin raw materials to the process, which make up 40% to 50% of the total material used in producing the total end product.'

Mountains

The development of the HERA System began when Grootendorst became more and more annoyed with the fact that he could only recycle 45% to 50% of secondary asphalt. 'I saw mountains of secondary asphalt on the site, and they kept getting larger while the prices of virgin raw materials also kept increasing. I said to myself, "I have all the raw materials, but I can only use a small part of them." So I started talking with Cas van de Ven, a researcher at KWS, a subsidiary of VolkerWessels.'

Van de Ven had been thinking about indirect heating (the wok method) for quite some time. Someone had already tried to use a microwave. The method was tested at the pilot plant, also in the Rotterdam area, and it worked fine. The only drawback was that they had to warn the power company when they got started because the plant used a lot of electricity. 'If we hadn't warned them,' says Grootendorst, with a smile, 'all the lights in the Rotterdam area would have started to flicker.'

Polybatcher

In 2004 they started experimenting with a polybatcher, a mixer with gas burners on the outside of the drum. In the United Kingdom and elsewhere it is often used for small road repairs on asphalt. 'We experimented a bit and found out that the indirect heating technique showed a lot of potential, even on this small scale. I personally wanted to press on and build a full-scale plant, but the management considered that premature. So we continued with the medium-scale pilot plant.'

The plant had a directly heated drum mixer with a volume of six cubic metres and a diameter of two metres that had become obsolete. 'We converted it for direct heating by attaching several gas burners to the outside of the drum,' says Grootendorst. 'We also developed and built an automated control system, so ultimately it became a pretty advanced installation. After experimenting for several years we were able to produce good asphalt using less energy and producing fewer emissions. What's more, we also showed that we could handle all kinds of secondary asphalt, even the more critical mixtures from the top layer, which are course-grained or polymer modified.'

Risk of rutting

Indirect heating also has a positive effect on the quality of the end product. Direct heating overheats and thus burns or chars part of the bitumen of the recycled asphalt, which reduces the quality of the secondary asphalt. This reduces the penetration of bitumen – the so-called pen value. In new asphalt the pen value is around 45, but every time you recycle, the pen value is reduced by 25 percentage points.

'A soft bitumen is added to the mixture to forestall this lower penetration,' explains Grootendorst, 'so that the combination of old and new bitumen produces the desired penetration. This could lead to partial blending, however. According to the "black rock" theory heating can harden bitumen so much that the soft new bitumen and the secondary bitumen will barely mix. What you then get is a hard lump in soft bitumen and a serious risk of rutting.'

It has been shown that with indirect heating the penetration factor diminishes by five percentage points every time the asphalt is recycled. 'So we can recycle indirectly heated asphalt three to five times more often than directly heated asphalt,' says Grootendorst. 'Bitumen that is up to about 70% softer can be added as a fresh material during the recycling process in order to obtain the required penetration value of the combined old and new bitumen. No fresh binder is added for 100% recycling; however, the harder older binder can be softened by using "rejuvenating oil", a blend of natural resins that improves the rheological properties of the bitumen. The HERA System gives us the freedom to try out all kinds of percentages of recycled materials in the mix, depending on the requirements of the newly produced asphalt and the availability of materials.'

Commercialization

Building asphalt mixers is not KWS's core business, so the company struck up a partnership with Ammann, a Swiss company and the largest builder of asphalt mixers in the world, to develop the HERA System. 'At first they were not very interested', says Grootendorst, 'mainly because they had developed their own mixer for up to 100% recycled asphalt. But when they saw the results produced at our medium-scale pilot plant they were blown away. They simply could not believe that our hydrocarbon emissions were close to zero, because we feed them back into the flame. And because our burner temperature is low, the emission of nitrogen oxides is also very low.'

Ammann is planning to sell the HERA System worldwide. Expectations are not too high at this moment, because there is not much pressure yet to reuse secondary asphalt outside the Netherlands. Emission standards in the Netherlands are far stricter than anywhere else in the world. 'Nevertheless, the interest in the HERA System will grow in the future', thinks Grootendorst. 'The price of raw materials, especially of bitumen, which is an oil-product, will probably increase in the near future, while environmental regulations are sure to become stricter in the meantime.'

Slow acceptance

Another possible barrier is the slow acceptance of secondary asphalt in the market. 'We supply our asphalt to road builders, but their clients – mostly governments – have a large say in the material they use. For them 50% secondary asphalt is perfectly acceptable, but they hesitate once it is 70% or more. Acceptance is improving though, because more and more often construction specifications are based on functional requirements. In such cases, the composition of the asphalt does not matter anymore, as long as it lives up to its specifications. I have no doubts about our secondary asphalt for that matter.'

5.4. Building a business model on borrowed materials
Coert Zachariasse, Delta Development

Coert Zachariasse studied accountancy at Erasmus University Rotterdam, the Netherlands and worked for 10 years as a registered accountant. In 1995, while considering an offer to become partner at the accountancy firm where he worked, his father asked him to take over Delta Development, and in 2001 he became owner of the company.

'The focus in the building industry is on actual buildings and their use. But buildings are a circular process: eventually most of them will be demolished. If we want to close the materials loop, we will have to develop a business model that puts value on waste materials.'

With the help of William McDonough, one of the godfathers of the cradle to cradle approach, Coert Zachariasse, CEO of the Delta Development Group, together with partners VolkerWessels and Reggeborgh, is developing a business model in Park 20/20, a new business estate near Amsterdam Schiphol Airport in the Netherlands. For the development of the site he got in touch with McDonough. '"I want the complete site cradle to cradle", I said to him.'

They agreed to meet in Charlottesville, Virginia in the United States, McDonough's home base, and together with Michael Braungart, the other godfather of the approach, they created a master plan for the area. 'At a certain point, I wanted them to become more concrete, because eventually I would have to deliver results. Then Bill said to me – rather apologetically – "What you want has never been done before. If we do this it will be a long journey through unknown territory".'

Break through routines

Gradually a few things became clear, according to Zachariasse. 'The first thing is that technology is not a restriction. We can build sustainably if we can make it economically viable and if we can overcome the fear of change. People tend to stick to their routines. Often I have heard people say "This can't be done" or "We always did it this way". In my view these phrases betray a fear of change. The only effect they have on me is to make me even more stubborn.'

Another thing that Zachariasse discovered was that the term sustainable almost always refers to reducing CO_2 emissions, i.e. energy use. Most certification schemes for 'green buildings' even see energy use as the main criteria. 'Of course it is good to reduce energy use, but the real problem we are facing is a shortage of materials. We get more energy from the Sun every day than we can use in a year, but apart from a meteorite once in a while there is no material coming into the system. So I think our focus should be on materials and their circulation.'

Circular

With circulation in mind, Zachariasse decided to start at the 'end' of the pipeline: the demolition and processing of waste. He asked representatives from demolition companies and waste processers what architects can do to make it easier to demolish buildings and increase the value of the residues. Together with an architect, a contractor and a waste processer, he developed a materials passport describing not only the chemical composition of all materials used, but also how much these materials were used and where, and what their residual value was estimated to be after demolition. 'In my cradle to cradle business model of Park 20/20 I see a building not only as a place to work in, but also as a materials bank containing capital that derives its value from its future reuse. So instead of writing it off I can put the estimated economic value of that capital on the balance sheet of the project.'

Residual value

If you consider the building as a materials bank, it is important to increase your capital by creating as much residual value as possible. This can be achieved in part by designing for disassembly, making it easier to 'mine' the materials. And it can also be done in part by striving for the highest quality of materials. 'Traditionally you put out a tender and go for the lowest quote,' says Zachariasse. 'But this often sets a miserable chain of events into motion, where contractors squeeze the last bit of money out of their subcontractors, and subcontractors squeeze the last penny out of their suppliers. The result is poor quality.'

To break this chain Zachariasse decide to strike up a partnership with his preferred contractor on the basis of an open budget. That means x amount for personnel, x amount for materials and transport, and a fixed amount for general costs and a fixed profit. The subcontractors were also asked to be transparent about their books and honest about the discounts they usually get from their suppliers. 'It was one strike and you're out. We told them that if we discovered that they were withholding information about discounts it was end of story for them.'

Certification

To increase the economic value of his material capital – more specifically the residual economic value – Zachariasse and his preferred contractor also visited more than 70 suppliers of building materials and asked them which materials they thought were good quality and potential candidates for a cradle to cradle lifecycle, which meant that they could be recycled after use and turned into an even better material or put back into the ecological cycle.

The data of over 300 products were collected and scanned for cradle to cradle potential at the McDonough Braungart Design Chemistry centre, and the promising ones were selected. The suppliers of these promising materials were then asked if they were willing to invest in research to improve their products and start a cradle to cradle certification procedure.

'If they were willing to get their product certified,' says Zachariasse 'then we promised to make them a preferred supplier for the Park 20/20 development project. On top of that, our contractor – one of the largest in the Netherlands – also promised to become their preferred supplier for other projects. By late 2012, 33 companies had joined our partnering programme. When we started we had three cradle to cradle certified products – a chair, a carpet tile and a window frame. The 33 potential producers of certified products do not supply all the materials we need, but it is quite an improvement compared to the three we started with.'

Reverse logistics

Another initiative to increase the residual value of the materials used is what Zachariasse calls 'reverse logistics', i.e., the best way to return the material to its supplier. 'The materials passport gives an excellent description of the kind of materials that have been used and how they have been used. We are also building for disassembly to recuperate the materials in pristine condition. We think therefore that our buildings are an excellent source of materials. Even better than virgin materials, because you don't have to spend money and energy on mining and ore processing.'

'The problem', continues Zachariasse, 'is the logistics. How do you keep track of materials for a period of 30 years or more? Shaw carpet tiles, for example, have a phone number on the back you can call, but other products are much more difficult to track. A possible solution is to lease the products and the materials they are made of instead of buying them. For example, we have come to an agreement to lease our lighting.'

Higher rent

Building a cradle to cradle office park is more expensive than building it the traditional way. According to Zachariasse the extra cost is on average about 300 euros per square meter, so 1,300 euros instead of 1,000 euros. Part of the extra building cost can – possibly – be made up for by the residual value of the material: the building as a 'materials' bank. But for now the extra cost has to be made up by rental revenue. 'To make up for a cradle to cradle design the rent has to go up by 20 euros.'

Are tenants willing to pay rent that amounts to about 10% above the average price? 'They are', confirms Zachariasse, 'as long as you can explain that they are actually earning money. When it comes to housing we always talk about the cost, but I tell my potential customers that the building is an investment in their workforce. If your employees feel comfortable, can have a nice lunch and can have their hair done and car washed, their productivity increases. Studies in lighting and interior air quality, for example, show tangible increases in worker productivity.'

'Let me give you an example. Say, you have 500 people working in the building. That will cost you about 37 million euros in salary. If the quality of the building and the materials you use helps you to reduce absenteeism or increase productivity by 1%, then you will have earned back the extra rent in no time.'

'Apart from the fact that being in a sustainable office creates a positive image for a company, it also is a means by which an employer can attract talented and motivated staff. Sustainable buildings show that you are taking responsibility and, of course, this is exactly what sustainability is all about: taking responsibility.'

6 Resource efficiency in the food sector

The food industry produces most of the food ingredients, food products, meals and drinks we consume on a day-to-day basis. This industry has organized our food chain in such a professional way that it has become perfectly normal to buy food at the supermarket. Most of the harvesting and production, refining and preparation has been done for us, enabling us to enjoy the final product, without wondering where it came from and whether it will be available for us tomorrow or the day after tomorrow.

Feeding society impacts large areas of farming land and uses huge amounts of fertilizer, biotic resources (crops and cattle), water and energy. With the world population expected to reach 9 billion people by 2050, food security is becoming a serious issue. At the present rate, the overall ecological footprint of food production and consumption will go beyond sustainable levels. In looking for solutions, small, medium and large companies are starting to collaborate on sustainability initiatives and generate value chain innovations. A group of eight large Dutch multinationals in particular, called the Dutch Sustainable Growth Coalition, has made it very clear how important sustainability is for companies who still want to be in business five years from now.

This chapter presents four ambitious strategies towards sustainable food production and consumption. The example of HEINEKEN breweries shows the radical steps that the company took to improve the efficiency of water and energy use throughout the entire value chain, including packaging and transport. The brewery is a front runner, not only by virtue of its water strategy – it reduced its water footprint by 25% in 2020 – but also because it encourages farmers both in the Netherlands and abroad to practice sustainable malting barley farming.

The FrieslandCampina example teaches us that a sustainable business strategy is 'actually a way of making the business model robust against all the global challenges we are facing, such as the scarcity of natural resources and the high cost of fossil fuels.' In close cooperation with farmers, employees and customers, the company takes a leading role in safeguarding sustainability throughout the entire dairy chain, providing a basis for interesting new business opportunities.

Inspiring new forms of cooperation between industrial sectors, and between industry and government, are key to the success of the Dutch Phosphate Value Chain Agreement. Phosphate is an important fertilizer for farmers all over the world. It is a vital resource for maintaining or even increasing present food production levels. However, the recoverable reserves of primary phosphate are limited and mining is using up a great deal of water in countries that are already suffering from water shortages. The Dutch Phosphate Value Chain Agreement has generated a host of new initiatives for recovering secondary phosphate from saturated soils, wastewater and manure.

The final example illustrates how substituting scarce resources with less scarce ones can create entirely new business chains. The Dutch insect industry is an example. It is introducing insects as an alternative for animal protein. The efficiency of protein conversion has become increasingly important as there are more mouths to feed. Crickets are 12 times more efficient at converting food than cattle, which is one of the main reasons why rearing bugs, crickets, mealworms, locusts and maggots for food production is commercially promising and encourages sustainability in our food chain.

6.1. Brewing a better future
Jan Kempers, HEINEKEN Nederland Supply

Jan Kempers studied chemical engineering at Delft University of Technology and started his career as a yeast physiologist at HEINEKEN Research in 1985. Since then, he has worked for HEINEKEN in various positions in research and quality assurance. He was manager of the Technology Department of the HEINEKEN Brewery in Zoeterwoude, and has been manager of sustainable development at HEINEKEN Nederland Supply since 2009.

HEINEKEN has created an ambitious comprehensive sustainability programme, which has become an integral part of its business plan. 'We work with a whole team on new ways to reduce our carbon and water footprint and to empower communities with our brewing operations,' says Jan Kempers, Manager Sustainable Development at HEINEKEN Nederland Supply. 'As an important economic factor we can easily bring parties together and act as the catalyst for sustainable investments.'

The HEINEKEN brewery in Zoeterwoude in the Netherlands is one of the three most efficient breweries in the world. It is Europe's largest brewery. Every day, millions of bottles filled with beer leave the site and are shipped all over the world. HEINEKEN beer is traded worldwide and produced in more than 70 countries. 'Since we operate worldwide, we need to compete on a global scale in terms of cost per hectolitre of our product. That includes the costs for raw materials, energy, water and labour,' says Jan Kempers. He was specially appointed to forge alliances and encourage people to take steps towards using resources more sustainably. 'The availability of our ingredients and packaging materials will decrease in the future, and inevitably prices will rise. If you want your business to stay healthy in the long term, then it's important to make strategic choices now concerning scarce natural resources and look for solutions where problems are anticipated.'

Energy mix

'Our "Brewing a Better Future" programme takes the entire value chain into account and quantifies specific targets. More than 50 professionals work on the programme. They have a wide variety of expertise, ranging from packaging and energy to infrastructure development in Africa,' Kempers says. 'Energy is one of our areas of focus. We want to reduce our carbon footprint by 40%. To do this, we need to reduce our energy use and add renewables to our energy mix.'

HEINEKEN has been using cogeneration – the simultaneous generation of heat and electricity – at its brewery in Zoeterwoude, and is one of the first breweries in the Netherlands to do so. 'In addition to that, we are going to build four large wind turbines that are going to deliver 24 million kWh. That is a third of the electricity we need at this site.' Kempers is also looking into biogas as an option. 'We want to form alliances with farmers who want to invest in their own biogas installations. Our goal is to bring stability to the off-take market and give a guarantee that we will use the gas the first 20 years. Our size and brand name helps to bring people together quite easily and get things started.'

From road to water

Besides the brewing itself, transport and logistics use up energy as well. Petrol is expensive and clogged roads can cause problems. HEINEKEN came up with an environmentally friendly solution: the company set up its 'own port'. Since 2010, 95% of the container movements between Zoeterwoude and Rotterdam were by water. Before that, trucks drove 50,000 containers a year back and forth between Zoeterwoude and the Rotterdam and Antwerp ports. Now they drive to a nearby container terminal in Alphen aan den Rijn, where the containers are transported by ship to Rotterdam and Antwerp. 'It is more efficient and cuts down on costs and emissions,' says Kempers. 'In addition it is strategically important since it makes us less vulnerable to rising fuel prices.'

The project took 12 years to realize. HEINEKEN initiated it, and other parties such as the Port of Rotterdam, the province of South Holland and the Van Uden Group built and operate it. 'We are the launching customer and have thereby justified the investment. The entire region will profit from it. For example, Electrolux in Alphen aan den Rijn uses Alpherium for their containers with products,' explains Kempers. 'We are always trying to find ways to streamline production and simultaneously create job opportunities in the region. As soon as you become an important economic factor in a region, you have responsibilities there.'

Packaging

Together with an environmental consultancy agency, HEINEKEN built a tool – based on life-cycle assessment protocols – to calculate the environmental impact of its supply chain activities, both upstream and downstream. 'This Carbon Footprint Model enables us to identify key areas of improvement. Packaging, for example, accounts for about 45% of the supply chain's carbon footprint, which is mainly energy use,' Kempers explains. 'We are starting to talk about this issue with our suppliers. Some of them produce up to 90% of their goods for us. It is therefore in the interest of both to initiate projects together. If we can install wind turbines, why would that not be an option for a bottle factory?'

Cooling installations on customers' premises, such as draught beer installations and fridges, consume also a lot of energy. Some years ago HEINEKEN looked for partners to improve the energy efficiency of refrigerators. 'They had to get in line. Within no time, energy consumption had halved.'

Water use

Water is both an important ingredient for beer and a scarce and finite resource. Therefore HEINEKEN is developing a comprehensive water strategy to cover all the steps in the brewing process, from barley to bar. The company's target is to reduce its water footprint by 25% by 2020. 'Opportunities were for the picking here as well,' says Kempers. 'Optimizing the bottle rinsing and evaporation process in the brewery is an example. That not only saves water but a great deal of energy as well.'

Reusing wastewater in many grey water applications could be another big step forward. Wastewater treatment is also on Kempers' list of research projects – not traditional wastewater treatment but a new approach to recycling substances such as phosphate, which is becoming scarce. Together with Wageningen University's Applied Plant Research, HEINEKEN has installed algae bioreactors to investigate the purification efficiency and the value of the biomass.

Sustainable farming

Beer is brewed from malted barleys, so HEINEKEN depends on the barley supply. Malting barley is grown as part of a crop rotation scheme in arable farming. 'We started to look for sustainable barley just after the turn of the century, and this led to the establishment of the Skylark Foundation in the Netherlands, at a time when sustainable farming was not known yet. Together with farmers, agronomists and a rotating group of industrial partners such as Unilever, Suiker Unie and McCain, we have developed a successful practice that has become the standard for sustainable arable farming in the Netherlands,' says Kempers.

The focus is on soil fertility. Making healthy soil a priority also improves the soil's capacity to drain or store water and retain nutrients. This leads to a healthier crop. 'In order to encourage farmers to adopt this practice we have started a supply chain project, and anyone who wants to discover the joy of sustainable farming can join this project and become a member of the Skylark Foundation.'

Farmers write and implement their own sustainability plans. They are free to set their own priorities, based on the type of farm they want, their financial situation and personal preferences. They are supported by agronomists who were trained (and received ac-

Figure 6.1 Sustainable farming

creditation) in sustainable farming at Dronten Agricultural College. Sustainable farming is an attitude, a continuous search for improvements with respect to nature, people and the economy.

'Our brewery in Zoeterwoude needs approximately 280,000 tonnes of malting barley a year. The Netherlands produces around 150,000 tonnes, which means that we always have to turn to sources abroad. Our experience "playing this game" has turned us into a leader in other areas where barley is sourced outside my country,' Kempers says.

Biodiversity

HEINEKEN is situated on a beautiful site, one hundred acres large, next to the Dutch 'ecological main structure', a network of areas in which nature is the main priority. So it is anything but a typical industrial site. 'But we never gave much thought to how we could contribute to biodiversity,' says Kempers. 'We have about 50 types of host plants in the countryside around us, for example. Host plants have a particular function in the ecosystem because they feed specific insects. Other projects in the region have taught us that there are potentially 250 domestic species that can support our regional ecosystem.'

Together with Alterra, a research institute of Wageningen University, Kempers is going to make an inventory on the site and develop a plan to improve the brewery's own ecosystem. 'Some may think that the global impact of such a project is small, but what it will do is make biodiversity a tangible and comprehensible topic for our employees. And anyway, we Dutch feel comfortable in a landscape full of flowers. You could say it's in our genes.' The Skylark farmers have coloured their fields with flowers in order to improve natural pest regulation. The insects enjoy disturbing the huge mono-cultures of modern farming. They eat aphids, and as a result farmers use less pesticide.

'Pleasant societies don't drop out of the sky. It's something we need to build for our children: a society in which we live off the daily sunlight and produce all our goods in closed cycles.'

6.2. Making a business case of sustainability

Frank van Ooijen and Ton van Hengstum, FrieslandCampina

Frank van Ooijen studied political science and international relations at Radboud University Nijmegen. He has held a number of positions in communications management at the Netherlands Ministry of Foreign Affairs, Unilever and Laurus since 1992. From 2002 onwards, he worked as director of corporate communication and corporate social responsibility at Nutreco and later at the Rabobank Group. Since 2010, he has been working as director of communication and sustainability at FrieslandCampina.

Tom van Hengstum studied chemical engineering at Delft University of Technology. After completing his PhD at Twente University of Technology he started working at AkzoNobel as a researcher. In 2002 he switched to the food sector and started working as manager of Friesland Campina Research's Process Technology Department.

'We have made sustainability one of the foundations of our new business strategy, called *route2020*. This has firmly integrated the principle of sustainability into our company,' says Frank van Ooijen, director of communication and sustainability at FrieslandCampina. 'We only started implementing this strategy about a year ago, but our strong commitment has already enabled us to forge new partnerships to promote innovation and sustainability.'

FrieslandCampina is a cooperative with over 14,000 member dairy farms in the Netherlands, Germany and Belgium, and 80 facilities in 26 countries around the world. These facilities produce a range of dairy-based products from beverages, infant and toddler nutrition, cheese, butter, cream and desserts, to functional dairy-based ingredients. 'After the merger between Friesland Food and Campina in 2009, sustainability consciously became an important part of our new business strategy, *route2020*, for the successful growth of our company. This was commitment, pure and simple,' says Frank van Ooijen, director of communication and sustainability at FrieslandCampina. 'That stopped people from talking about why the company should take the path towards sustainability and it allowed us to focus on the how and what: which issues are important for us and our stakeholders, the member dairy farms.'

Van Ooijen is responsible for the development and implementation of the sustainability programme that addresses four priority areas: 'nutrition and health', 'efficient and sustainable production chains', 'dairy development in Asia and Africa' and 'sustainable dairy farming'. Key performance indicators (KPIs) and action plans have been developed in each of these areas that reflect how FrieslandCampina wants to achieve its goals and contribute to a more sustainable future that ensures a supply of food and nutrition.

Facing food security

It is important that leaders of the company implement the strategy with conviction and enthusiasm – something that Cees 't Hart, CEO of Royal FrieslandCampina, is doing with fervour. In later 2012, he gave the keynote speech at the International Dairy Federation's World Dairy Summit in Cape Town, South Africa. Food supply is a hot topic in a world that is expecting to see its population rise to 9 billion people by 2050. Food or nutrient security will be a major challenge. Analysis shows that in 30 to 40 years, two times as much food will need to be produced using half of the amount of natural resources. Food is becoming a scarce commodity. 'In his speech, 't Hart clarified why it's important to work on and invest in sustainability for the future of both society and the dairy industry. It's actually a way of making your business model robust against the global challenges we are facing, such as the scarcity of natural resources and the high cost of fossil fuels,' says Van Ooijen. 'The speech was very well received.'

Saving energy and water in milk processing

Tom van Hengstum is head of FrieslandCampina's Process Technology Department and responsible for the long-term research on energy and water efficiency at the corporate level. 'Large steps forward were made in energy savings in the past by modifying and improving our production processes. The first 10% was relatively easy. But the further you get, the more complicated things become,' Van Hengstum says. 'Our goal is to reach the point where we can boast 2% energy savings a year in the dairy chain until 2020.'

Van Hengstum's department focuses on the processing of milk, which arrives daily from the member-farmers at the factory. The production of milk and whey powder is a particularly energy-intensive process, as is the manufacture of concentrates. 'A large part of our milk and whey is converted into powder. So we evaporate enormous amounts of water, and that uses up a lot of energy,' says Van Hengstum. 'Removing water in evaporators, the first step in milk powder production, is a rather efficient process. The second step, spray drying, is a different story. A dairy concentrate consisting of 40%-50% dry matter has to be converted into powder that consists of 95%-98% dry matter. The removal of water by spray drying is not very efficient. So a great deal of effort has been devoted to saving and reusing energy. However, there is still a lot of low-quality residual heat, which can't be reused at this point.' Innovations in high-temperature heat pump technology should create solutions that will enable us to use this energy in an efficient and economical way as well.

Removing and reusing water

Van Hengstum's team is running several projects to streamline the process of water removal. Unfortunately, most new techniques are not robust enough to be used commercially. It is more or less standard practice to use membrane systems to remove part of the water by reverse osmosis before the dairy concentrate passes the evaporation units. That is off-the-shelf technology. If you look at the cost per kilogram of water evaporated, then the membrane system is most cost efficient. Evaporation is next best, followed by spray drying. The rule of thumb is that every additional step increases the cost by a factor of 10 per kilogram of water removed. This means that water removal has to take place as early in the process as possible, creating challenges in the processing of more concentrated liquids during reverse osmosis, as well as evaporation and spray drying.

In addition to saving energy, saving water is another important part of Van Hengstum's sustainability programme. The production facilities have extensive programmes that stipulate how to reduce water use and increase water reuse. 'Every day, milk, which consists mainly of water (around 87%), enters our factory and to a large extent leaves our site as powder. Parts of the processing operation, such as cooling, steam production and washing, use up large amounts of additional water. A 20% reduction target by 2020 has been agreed upon as well for water use.' The main challenge in terms of water reuse is to convert water removed by reverse osmosis and evaporation into high-quality water that is safe to use in contact with products.

Throughout the chain

There is more to the story than just showing strong commitment, according to Van Ooijen. Since he rolled out the sustainability programme in January 2011, he and his team have been working hard to gain the support of FrieslandCampina's member-farmers, managers and employees, and explain to them why this programme is so important and what they can do to make it a success. 'We are in a unique position in that we control the whole dairy chain, from our member-farmers, who deliver the milk, to the products that end up on shelves. That means we can safeguard sustainability throughout the entire dairy chain,' Van Ooijen says. 'We are currently the second-largest dairy cooperative in the world, so it is our duty to take the lead on issues such as sustainability. That's why we became a member of the Dutch Sustainable Growth Coalition, a group of eight Dutch multinationals that promotes sustainability, including Unilever, Shell and AkzoNobel.'

Gaining support

Van Ooijen and his team engaged in an intensive dialogue with their dairy farmers for a full year to get a buy-in for their ambitious sustainable farming programme. 'That was a real challenge, because we essentially told them that there were ways they could be more sustainable on their farms. We held 140 meetings with 6,500 member-farmers and worked in small groups to gain a better understanding of what sustainability had to offer them.'

In late December 2011, the farmers agreed to give it their full support. So in January 2012, Van Ooijen and his team started to integrate the sustainable farming programme into the existing quality managementprogramme for farmers. 'At that point, there was no turning back, because the farmers' income depended on how many sustainability points they gained,' he explains.

Sustainable dairy farms

The sustainability programme for the dairy farm contains several points on animal health and animal care, such as outdoor grazing, a 50% reduction in the use of antibiotics and bringing clinical mastitis and clinical lameness down to natural levels. It also looks at the nutrient management and how to regain valuable phosphate from manure. 'We already buy sustainable soybean for cattle feed and hope that by 2015 100% of our cattle feed will be sustainable soybean. Furthermore, we want our 1990 levels of greenhouse gas emissions to be reduced by 30% by 2020. We now are at 18%.'

FrieslandCampina is also progressing in its use of green energy. The company uses solar energy, wind energy and biomass on its farms. As much as 30% of the electricity needed at the company's Dutch production facilities is green power generated by its own member-farmers. 'We want our electricity to be 100% green as well in our 25 large facilities in the Netherlands. From now on, we want our companies and our dairy farms in North-western Europe to work together on energy consumption and production. Our German farmers have invested massively in green energy.'

Imbedded goals

The trick to making the programme a success is to build a business case for sustainability, according to Van Ooijen. 'What makes our case different is that our sustainability targets are embedded in our management systems and reward structures, and handed over to our executive and supply chain managers. They and their teams are responsible for achieving the targets. So our targets become ingrained in our daily business processes.'

At the same time, Van Ooijen tries to inspire everyone to work on the programme's points. FrieslandCampina has struck up a partnership with the Red Cross for health and nutrition, for example, which is the programme's first focal area. 'The Red Cross addresses the problem of global malnutrition. We can help to develop products that they can use to help refugees in shelters and victims of natural disasters. And we can help them with fundraising.' This is one of the reasons why FrieslandCampina has become one of the partners that supports 3FM Serious Request, an annual Dutch fundraising initiative by radio station 3FM to collect money for Red Cross initiatives.

Strong brand

All these sustainability issues create a strong brand proposition: climate-neutral production processes using renewable energy. That provides a basis for interesting business opportunities, according to Van Ooijen. FrieslandCampina and its large industrial customer Unilever recently announced that they are going to work closely together on sustainability and innovations in the dairy sector to reduce carbon emissions, cost and waste. ‘This initiative is mainly the result of our firm commitment to sustainability. Large customers such as Danone and Unilever are very open to our efforts to produce sustainable milk. It also shows that we are on the right track and picked the right issues to focus on. Our stakeholders recognize and support that, and as a result we have managed to make good progress and involve our farmers and staff in the process. Even politicians are starting to take notice and mention us as an example of best practice,’ says Van Ooijen. ‘It is time to abandon the idea that sustainability is a kind of luxury that you should be able to afford as an organization. It is an essential adjustment that will enrich your business. More than that, it is a necessity if you still want to be in business in five years’ time.’

6.3. ‘Green Deal’ turns Holland into net exporter of phosphate
Arnoud Passenier, Ministry of Infrastructure & Environment

Arnoud Passenier studied political science and international relations at Leiden University before starting to work in 1990 for what is now the Ministry of Infrastructure and the Environment. From 2003 to 2009 he was head of the Ministry’s Strategic Planning Unit, and since 2009 he has been special advisor on the scarcity of resources and sustainable transitions. Since the beginning of 2012 he has represented the government in the Nutrient Platform as director of the implementation of the Phosphate Value Chain Agreement.

Although poor in mineral resources, the Netherlands can become a net exporter of secondary phosphate – that is, if the Phosphate Value Chain Agreement, which 20 parties signed in 2011, achieves its aim. Arnoud Passenier, a senior civil servant at the Dutch Ministry of Infrastructure and the Environment, is the godfather of this so-called Green Deal. ‘The important thing is to DO, DO, DO! Getting everyone to start moving fuels enthusiasm, which in turn releases a lot of creative energy.’

In 2008 China reduced its export of phosphate, an important fertilizer. In the panic that followed, the price of rock phosphate spiked from less than US$50 a tonne to more than US$400 a tonne. Less than a year later a report was published in the Netherlands predicting the end of the recoverable reserves of rock phosphate within 100 years.

‘Since that first panic it has become clear that rock phosphate reserves will last us quite a bit longer than that,’ says Passenier. ‘Still, there are a lot of good reasons to reduce the demand for primary phosphate and replace it by secondary phosphate. One of them is that phosphate mining uses a lot of water. As a lot of these mines are located in countries that are not blessed with much rainfall, such as Morocco, Tunisia and Jordan, you can imagine that water shortages might increase tensions in these regions and therefore risk disrupting the supply for European food production.’

Oligopoly

Another reason to turn to secondary phosphates – at least partially – is the geopolitical reality that rock phosphate reserves are concentrated in few countries, of which China and Morocco are the most important. 'It is not a free market, but an oligopoly like OPEC,' says Passenier. 'As China has reduced its export of phosphate once already, there is definitely a risk of price spikes and supply disruptions, which would threaten the future of European agriculture. The EU might think it is self-sufficient in its food supply, but phosphate is a weak spot.'

The third reason, though perhaps not the most important one, is certainly the most practical one: the Netherlands has an enormous reserve of secondary phosphate. Originally it was imported as a raw material for fertilizer and as an agricultural product that was processed into food and feed. As a result, the soil in large areas of the country is saturated with phosphate that has been used as mineral fertilizer and manure from the millions of cows, pigs and chickens that are farmed in the Netherlands. Until now, excess phosphate from the soil has often leaked into rivers and lakes, causing large-scale algae blooms.

Water plants

'We cannot actually mine phosphate reserves in saturated soils,' says Passenier. 'Concentrations are too low to make it economically feasible. What can be done is to apply less phosphate as a fertilizer, so that the plants will actually mine the phosphate. But that will take a long time.'

There are three sources of secondary phosphates that can be mined, so to speak. The first source is the phosphate that has leaked into rivers and lakes. Growing, harvesting and eventually fermenting water plants, and burning the remaining sludge, produces ashes that contain enough secondary phosphate to replace rock phosphate.

Passenier does not expect much phosphate to be produced from the ashes of water plants because harvesting and processing the plants is expensive. Still, it might be a good way of getting rid of excess phosphate in our rivers and lakes. In 2012 a small experiment was launched in a small lake in the south-west of the Netherlands, but there are no results yet.

Manure

Two larger and more important sources of secondary phosphate are manure and wastewater from households and the agricultural processing industry. As in the case of the water plants, the remaining sludge after wastewater treatment can be incinerated, producing ashes rich in phosphate, which can be used again by the fertilizer and chemical industry. The other option is to ferment the sludge during wastewater treatment and add magnesium salts to form a phosphate precipitate such as struvite, a phosphate-rich mineral that also contains ammonium and can be used as a fertilizer as well. The third source is animal manure, which is the Netherlands' largest source of phosphate-rich waste. The same incineration and fermentation processes can be used to recover phosphorus from the manure.

Platform

'Technically all these processes are feasible,' says Passenier. 'However, turning wastewater and manure into an exploitable source of phosphate requires the cooperation of several partners that normally do not work together. In 2011 most of them were not even aware of each other yet. But that year the Nutrient Platform was launched, and it brought together parties from the phosphate-producing industry to the district water boards responsible for wastewater treatment to the farmers' organization. I was also involved, representing the national government.'

In one of its first meetings the Nutrient Platform concluded that the only viable solution for our excessive organic waste – keeping in mind the expected shortage of rock phosphate – was to create a European market for secondary phosphate and eventually turn the Netherlands into an exporting country. 'Shortly after we came to that conclusion,' says Passenier, 'an opportunity arose to make a "Green Deal" and sign it at a national meeting. At that time the "Green Deal" was a new policy instrument of the national government, intended to bring different parties together in joint initiatives to promote the transition to sustainable energy. We used the opportunity to facilitate an agreement between parties throughout the phosphate value chain to formalise their commitment to develop a market for secondary phosphate together.'

Scepticism

According to Passenier, it took a lot of effort to make sure that the Green Deal was more than just a symbolic gesture. 'Several stakeholders were still a bit sceptical', he remembers. 'So we asked them all to state their ambitions and what specific goals they wanted to reach at what time. They also had to make clear what their (economic) interest was in the deal and how much effort they would put in. I found it important to use their energy to achieve concrete results instead of dictating, as a government representative, what should be done. The main thing was that they could depend upon each other when making plans and appointments for the production and use of secondary phosphate sources.' Trust and transparency between the stakeholders are essential for an evolving market like this one.

'We also asked them what they wanted from the national government, keeping in mind there were no subsidies available. What we were able to offer was help in overcoming national and European regulations that were hindering the production and use of secondary phosphate sources. It turned out that they were in abundance. For instance, struvite is still not allowed to be used as a fertilizer in the Netherlands, so most of it is exported to Germany nowadays. But we are working on changing the regulations, not only nationally but also at the EU level.'

Win-lose

The Phosphate Value Chain Agreement did not only create win-win situations. Some parties might end up profiting more than others from the deal. For instance, sewage sludge incineration companies are afraid that their profits will be threatened because wastewater treatment plants are opting to use struvite, which will reduce the concentration of phosphate in sewage sludge. Leftover sludge from manure fermentation, on the other hand, could be dried and used directly as a fertilizer. Competition will arise when different techniques and processing routes are developed.

As a government representative, Passenier had a special role in these situations. 'Because I have no financial stake in any of the projects I can play the role of mediator and broker between the parties involved in real or potential conflicts and bring them down to a level where it is easier to negotiate. My involvement is not as an outsider, but as a committed partner, albeit with a focus on the public interest.'

New initiatives

The Phosphate Value Chain Agreement has led to a range of new initiatives, thanks to new forms of cooperation between the different sectors in question. Passenier has persuaded the MARS company in Veghel, the largest cacao-producing facility in Europe, to work together with a Dutch water board and Ghanaian waste management company to see if it is possible to create a closed phosphorus cycle in Ghana as well. By connecting sanitation, water treatment and agriculture, the Ghanaian farmers will depend less on the import of expensive chemical fertilizers, and the soil can be restored so farmers can ensure the future supply of cacao beans.

District water boards in the Netherlands are cooperating closely with farmers to see if they can join forces to generate the investment needed to build fermentation plants in the region. The plants could be built on the same sites as the water treatment plants. Not only would that be cheaper, but it would also provide an opportunity to build faster, because it would be easier to get building and environmental permits. Farmers are interested in this idea because they have to dispose of manure. Farmers are obliged to treat manure as European environmental regulations limit the direct use of manure as a fertilizer on Dutch soil.

Another initiative is taking place in the phosphate industry, which will be affected by the European Commission's plans to revise European fertilizer regulations. Among other things, the Commission wants to limit the content of cadmium – a naturally occurring component of rock phosphate. By using secondary phosphate, fertilizer companies can keep the cadmium content of their resources and their fertilizers within the new limits.

'The nice thing is that every party involved has its own reasons for taking part in the agreement,' says Passenier. 'Bringing together parties with different interests has boosted efforts to recover the enormous amount of secondary phosphate that is available in the Netherlands.'

6.4. Insects as new raw material and protein source
Marian Peters, Venik, the Dutch Association of Insect Breeders

Marian Peters studied domestic science at Wageningen University, and worked as a senior consultant on project development of employability projects. She continued in this field for the local authority of Amsterdam and later for the government of the province of North Holland, while including economy, innovation and sustainability to her portfolio. Now she initiates collaborations for the Dutch Insect Industry, such as Venik and InsectCentre. Recently Peters earned an MBA degree in Business Creation Food & Health.

'Eighty per cent of the world's population already eats bugs regularly. So why aren't we? That would solve the problem of the increasing demand for protein,' says Marian Peters of Venik, the Dutch Association of Insect Breeders. 'Insects are a good alternative for animal protein, and more sustainable. If we want we can feed the world with proteins from insects.'

'Everyone we work with believes that eating bugs is necessary, and that is the most important thing,' says Marian Peters. Venik takes care of the insect industry's collective interests by providing information and encouraging the necessary research and product development. 'It is also the way we talk about it. The insect industry is expected to grow rapidly in the near future, so we have been taking measures to prepare for that. It is just a matter of reasoning backwards.'

Protein transition

The facts speak for themselves. The world population is increasing, as is prosperity. It is well known, according to Peters, that the more money people have, the more meat they are going to eat. 'Look at restaurant menus. They are completely built around meat, not vegetables. There is no doubt that we have to change our eating habits. We will reach a point where we have to produce two times more protein, but with half the input. The only way to achieve that is by using insects,' Peters says. 'I hardly have to explain that anymore.'

Cows, pigs and even chicken convert their food very inefficiently and need more input than insects. To produce one kilo of 'edible meat', crickets need 2.1 kg of feed, whereas poultry needs 4.5 kg, pigs 9.1 kg and cows 25 kg. So crickets are 12 times more efficient at converting food than cattle. An advantage of insects is that they are cold-blooded and can convert feed more efficiently to body mass. For that reason they also produce less greenhouse gases. A recent study conducted by researchers at Wageningen University confirmed that rearing insects is more sustainable than conventional meat production. Insects' nutritional value is comparable to conventional meats such as beef or pork. In addition to large amounts of essential amino acids, they also contain healthy unsaturated fatty acids, vitamins and minerals.

Face the truth

Peters knows that what people are willing to eat is culturally bound: some people may find it difficult to put something in their mouths that they used to kill because it was a nuisance. But the same obstacles were overcome with shrimps and snails, so why not with mealworms or locusts? 'When I started this endeavour in 2007, I was laughed at,' Peters clearly remembers. '"You will never succeed", was the common reaction. But people are no longer laughing at the idea, and we have the wind in our sails now.'

Indeed, protein transition is high on the Dutch government's agenda, which has initiated a dialogue on the transition to a consumption pattern centred less on animals and more on plants. Society has made significant progress as well. When Peters started, the Food and Agriculture Organization had just published its 2006 report, *Livestock's Long Shadow*, on the implications of agricultural practices at the time, and Al Gore released his 2007 film, *An Inconvenient Truth*, about our consumption behaviour and global warming. In the Netherlands this was followed by a movie about the effects of excessive meat consumption, *Meat the Truth*, presented by the leader of the Dutch political party, the Party for the Animals.

To address a whole chain straight from the beginning was a smart first move, Peters recalls. From start to finish, the insects are grown according to the standards of the European General Food Law, including tracking and tracing, and guaranteed clean rearing practices. 'From that moment on we had a working prototype.'

The first bite

In America locusts are referred to as 'land shrimp' on menus, and they actually taste like crunchy shrimp. Freeze-dried insects have a unique, nutty taste. A tasty experience will generally help consumers take that first step towards crossing the psychological barrier. 'Therefore we are grinding the bugs in flour and processing that into all kinds of products,' says Peters. We have already made Bugnuggets, Bugsticks and Buqadillas.' Recently entomologists from Wageningen University presented an insect cookbook filled with recipes, which has now been translated into English by Columbia University Press.

More than 1900 insect species are eaten worldwide, including caterpillars, grasshoppers, beetles, termites, ants, bees and wasps. This mostly occurs in the tropics, where people harvest the product directly from nature as a seasonal product. Only a fraction of these bugs can be reared. The most interesting insect species for large-scale production are black soldier flies, houseflies, crickets and yellow mealworms. These insect species have short reproductive cycles, and they can efficiently convert low-value organic residual streams into high quality protein.

Rearing bugs

Insects clean up organic waste in nature from flora, fauna and humans, so organic waste streams can serve as their feed in large-scale rearing factories. Dry organic material is feed for mealworms and grass-eaters such as locusts. Organic household waste is the housefly's favourite feed. Black soldier flies convert manure and are 'self-harvesting'.

'Once the maggots are big enough, they crawl away from their food source. If you guide them in the right direction they walk straight in the processing machine. This is pure science,' Peters says. 'Luckily we have companies in the Netherlands that can make the rearing of bugs work. You have to understand the behaviour of the bugs and how they mate, to be able to scale up production. You have to think out of the box and believe that it is possible to rear bugs.'

Green deals

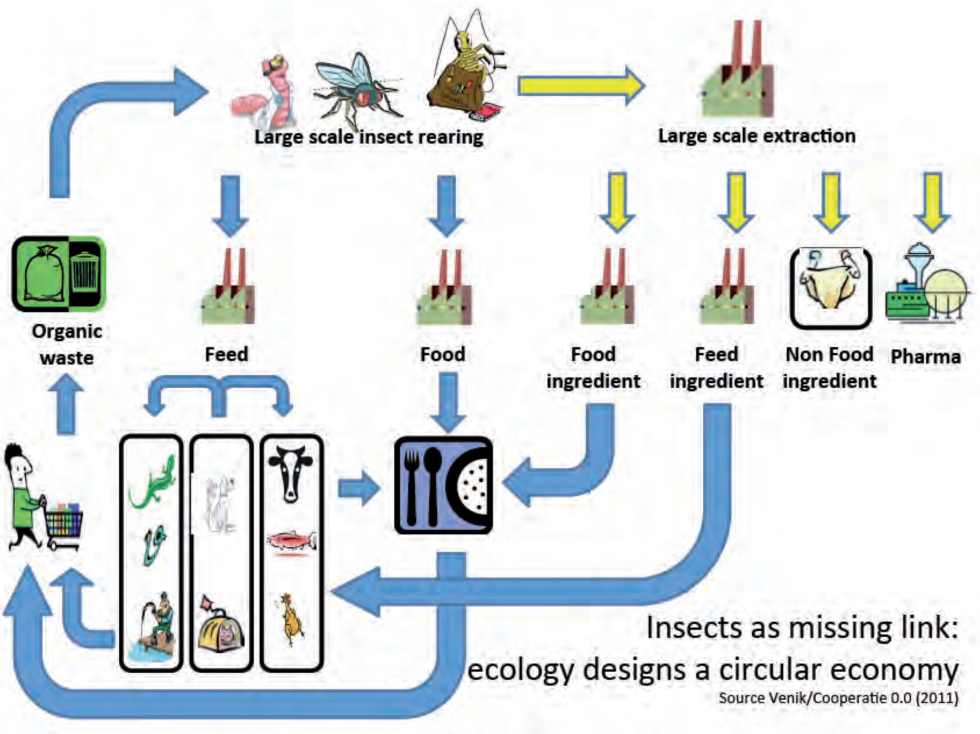
According to Peters the main obstacle to rearing insects on large-scale residual flows and then processing and marketing them is a lack of legislation and regulation. 'Insects are always seen as a "pest" or "contaminant", never as bulk raw material for feed or food. Indeed, TSE regulation for preventing mad cow disease does not even allow insects to be used for feed. Moreover, extracted insect protein would be considered a novel food and therefore need to meet food standard requirements. Fortunately the Dutch government has a policy programme called Green Deal, in which it removes some of the regulatory barriers for new sustainable, innovative projects. The government has given our "Insects for Feed, Food and Pharma" proposal Green Deal status.' On their part, Venik and the chain partners are committed to identifying the specific bottlenecks in laws and regulations. To make it easier for them to deal with this, Peters is working with the Netherlands Food and Consumer Product Safety Authority, the National Institute for Public Health (NVWA) and the Environment (RIVM), and RIKILT, a Wageningen University research institute specialized in food safety. 'We have to build up a market entry for this new sector. That has never happened before,' realizes Peters. 'If we manage to overcome the regulatory obstacles, then we can start to make real progress. Investors will join us and we can open the market for Europe.'

Scaling up production and bio-refinery

In order to be competitive with other protein sources, prices have to go down first. Currently the production volume of insects at rearing companies in the Netherlands is low. It is done manually and on a small scale to supply crickets, mealworms, locusts, fruit flies and cockroaches, for example, to zoos and pet shops as feed for birds, reptiles and amphibians. Prices will only go down if there is large-scale and automated production of insects. 'We need to develop all kinds of new technologies to scale up insect rearing. For instance, sensors that measure ammonia, a signal that the feed of mealworms is finished, which prompts them to start breaking down their own proteins.'

The next step will be to build a bio-refinery to divide the insects into their different components, such as proteins, unsaturated fatty acids and chitin, which is present in exoskeletons. 'Insects can have many different uses. They are a good alternative for fishmeal because they contain omega-3 fatty acids. Or a welcome addition to the diet of pigs and poultry. Chitin and its derivative chitosan reportedly have immuno-enhancing properties and show antimicrobial activity, so that suggests that it may be possible to reduce the use of antibiotics in animal husbandry. Of course more research is needed on

Figure 6.2 Large scale insect rearing for food, feed and pharma



things like feeding value, the functional properties of ingredients, animal welfare, safety and so on.'

Food, feed and pharma

In the beginning Peters wanted to expand the niche for bugs in the mass market for human nutrition. The way the entire plan is evolving has broadened the scope to include animal feed and pharma. She is convinced that within five years, the first large-scale insect-rearing factories will have been built in the Netherlands. 'We can feed the world with insects,' predicts Peters. 'But we're not worth our salt if we keep the knowledge to ourselves.' She is referring to ongoing projects in Laos, Kenya and Uganda. In Kenya and Uganda 4,000 small cricket farms have been set up as part of the Flying Food project, a collaborative effort including TNO and supported by the Dutch Ministry of Foreign Affairs. The project not only transfers knowledge about rearing, but will also help to process cricket-based food products and will structure the whole value chain from breeding to consumption. This project provides local people with revenue and tackles malnutrition. 'These kinds of projects keep you passionate,' Peters says. If it were up to her, the theme of the Food and Agricultural Organization Congress in 2014 in the Netherlands would be insects for food, feed and pharma. 'That would firmly position the Netherlands as a centre of innovation, leading the way.'

7 Biotic resources in the process industry

The chemical industry produces most of the ingredients, compounds and semi-products used in the majority of products manufactured in our society. Fossil fuels are traditionally the main resource used in the chemical process industry. However, this means that the security of oil supplies and oil prices are a major concern. Competition for access to fossil energy carriers has already caused energy prices to rise. In its 2011 World Energy Outlook the International Energy Agency states that 'rising transport demand and upstream costs reconfirm the end of cheap oil.' In addition, the concentration of supplies is sometimes causing supply chain disruptions – the oil embargo by the Organization of the Petroleum Exporting Countries in the mid-1970s is a classic example, while the Russia-Ukraine gas disputes over the price of natural gas and its transit to countries beyond the Ukraine are a more recent example. Another important issue related to the use of fossil fuels is climate change.

Biotic resources such as timber, straw, rapeseed, manure and organic waste streams from food production and food consumption are gradually becoming an important feedstock for energy production and chemistry. Climate policy strongly supports their use as sources of energy. The fermentation, gasification and burning of these organic resources produce heat, electricity, biogas and biocrude oil, which can be used in applications where fossil fuels were traditionally used. In the process industry these biotic resources are not being used for energy production. The characteristics of natural fibres, proteins, starch and other ingredients have proven to be extremely valuable in the manufacture of a wide range of products, from medicines to construction materials and from fine chemicals to ethanol. As more and more companies discover or rediscover the added value of biotic resources, the mobilizing concept of a biobased economy is gradually becoming reality. Some are calling it the third industrial revolution.

This chapter presents four compelling and convincing examples of new business opportunities based on biotic resources such as straw, sugar beet and meat by-products. 'Nature does not produce waste,' as Jalal Laham, president of Teeuwissen Group, says.

The examples illustrate that we are rediscovering the value of bio-based products in new market applications.

7.1. Clutching at straws to make paper
Henk Hoevers, Smurfit Kappa

Henk Hoevers studied chemical engineering at the Enschede Polytechnic in the Netherlands and started working for Smurfit Kappa in 1987. He has been vice-president of technology at the company's European Paper Division since 2005. The 12 members of the paper production technology group are responsible for R&D ('a small r and a large D') for all 27 of Smurfit Kappa's paper and board mills in Europe.

The demand for recovered paper in China is growing rapidly. This could put tremendous pressure on the paper industry's supply of recovered paper – the ultimate recycling success – in the not too distant future. That is why Smurfit Kappa, a major producer of paper-based packaging, is exploring alternative sources of fibre. One of these is straw, a by-product of cereal cultivation.

Making paper in one of Smurfit Kappa's huge factories does not differ so much from how paper is made at fairs, where traditional handicrafts are still practised. 'It is still a craft,' says Henk Hoevers, vice-president of technology at Smurfit Kappa's European division. 'We have rationalized production as much as we can, but in the end the quality of the product still depends a lot on the craftsmanship of the papermaker.'

The process starts with fibres from wood and recovered paper (textiles are hardly used anymore) that are suspended in water. After that the water is removed, first mechanically by gravity, vacuum, and press and then thermally by evaporation. Adding starch improves the mechanical properties of the paper. 'The main difference,' Hoevers says, 'is that you can only produce a few sheets of paper a day by hand, whereas our machines produce paper at a speed of 1 km per minute, 24/7.'

Water

There are other differences as well. The modern paper industry, for instance, uses water much more efficiently than traditional papermakers. 'Our factory in Roermond, which produces fluting, the paper inside corrugated cardboard, uses four litres of water to produce 1 kg of paper. One of the four litres evaporates, while the rest is discharged into a river. The Roermond factory has its own biological wastewater treatment plant that pays for itself because it also produces biogas for energy. The sludge that is produced, and which contains a high percentage of calcium carbonate, is used as filler in our paper products.'

The effluent from the wastewater treatment plant could be reused, but it is clean enough to be discharged into the river. 'We reuse the water from the treatment process,' explains Hoevers, 'when there is a water supply or water discharge problem. There is no shortage of water in Roermond, however, so we discharge the water into the river Meuse.

We have designed and built a paper mill that does not discharge any water at all. But there we need to use a lot more chemicals to overcome problems during paper production. So for practical and economic reasons, and environmental sustainability, we aim to discharge about three litres of water for each kilogram of paper produced.'

Energy

Although paper mills use large amounts of water, the cost of that pales in comparison with the cost of energy from heat and electricity. To produce 600,000 tonnes of paper a year, for example, the Roermond mill uses approximately 180 million kWh of electricity, or 300 kWh per tonne of paper produced. The mill has four gas turbines to produce heat and power with a total installed capacity of 20 MW, with the same amount as a backup in a regional utility. Heat is used to dry the paper, while electricity is necessary to pump water and operate the vacuum pumps and presses that dewater the pulp mechanically.

'You can imagine,' says Hoevers, 'what a huge effort it is to reduce our energy consumption. Apart from the obvious ways, like fitting our chimneys with heat recovery systems, we also try to optimize the dewatering of the suspension. If you can increase the dry matter yield mechanically from 50% to 52%, then you will need a lot less steam for drying. With the enormous quantities of energy we use, I can assure you that reducing our energy consumption is a top priority on everyone's agenda.'

Fibres

With regard to raw materials, Smurfit Kappa Europe uses two sources of fibre: wood and recovered paper. 'Five of our 27 paper mills in Europe,' says Hoevers 'are integrated with a kraft pulp factory, which is essentially a huge chemical plant where wood chips are boiled together with chemicals. During this process the wood breaks down into long cellulose fibres that we use to make paper. The remaining components of wood, lignin and hemicelluloses are dissolved in the spent cooking liquor, or "black liquor", and used as fuel. The chemicals are recovered from the ashes of the "black liquor" and reused in the pulping process.'

The five paper mills only make virgin fibres from certified wood. All the other paper mills in Europe, including all the mills in the Netherlands, use recovered paper as a raw material that is collected in regional depots, transported and cleaned by Smurfit Kappa. Fibres in recovered paper get a little bit shorter each time they are recycled. The paper industry is able to maintain the high quality of its products thanks to a recycling rate of approximately 75%-80% in Europe and the virgin fibre input that is needed in the system to make up for the quality loss of recovered fibre.

Recovered paper is contaminated with paper clips, staples, plastic and other 'non-paper' materials. 'About 5% or, in the case of Roermond, 30,000 tonnes of the paper that is brought in, is reject material,' says Hoevers. 'We have to remove it in order to make new paper. Part of this material can only be used for landfill or ends up in a waste incinerator. A large part, though, is combustible material like fabric fibre, plastic, wood and rope and can be converted into fuel. About 10 years ago Smurfit Kappa's paper mill in Roermond developed Rofire to make solid fuel pellets, which are sold as a sustainable alternative fuel for combustion in cement kilns, for example.'

Straw

Approximately 75%-80% of the paper in the European Union is recycled, so clearly recovered paper is an important source of fibre for Smurfit Kappa – not to mention for other paper mills in Europe. 'The amount collected is not decreasing, but we are noticing that a lot of recovered paper is going to China nowadays,' says Hoevers. 'To prepare ourselves for a possible shortage of recovered paper in the not too distant future we are now exploring alternative sources of fibre.'

Straw is a promising candidate. What is not left on the land as a soil improver can be partly used as cattle feed or as a soft cover for concrete stable floors or as fuel. 'We consider straw to be an interesting source of fibre,' Hoevers. 'It has been done before. Until 20 or 30 years ago it was used to make strawboard, but the pulping process at the time caused tremendous pollution. Stricter anti-pollution laws, which required manufacturers to invest in costly installations, meant the end of the strawboard industry in the Netherlands and the rest of Europe. Nowadays straw is only used on a very small scale for papermaking.'

Together with TNO, the Netherlands Organization for Applied Scientific Research and other partners, Smurfit Kappa is now developing new, more environmentally friendly ways – whether chemical, thermal, mechanical or a combination of these methods – to free the cellulose fibres in straw. To make the process economically feasible, Smurfit Kappa is also looking for ways to market the by-products, more specifically lignin.

Cascading system

Using all the compounds in straw is an example of a bio-refinery resource cascading system. 'A cascading system means creating the highest added value from a raw material by looking for the highest added value of each by-product. So you start with straw, extract the cellulose fibres for papermaking, and then use the remaining lignin as a source of phenolic compounds. The by-products of that process can potentially be used in some other product or as a fuel. The ashes can be reused as a source of inorganic compound, perhaps for fertilizer.'

To use raw materials effectively, you need these resource cascading systems, according to Hoevers. 'Right now wood is being used as a green fuel in power stations. There are also research projects exploring the possibility of using wood as a source of dimethyl ether, an alternative for diesel. I'm afraid that by doing that, however, we are not using our raw materials in the most effective or respectful way.'

'In my view it is much better to use wood for timber and paper, and use wood leftovers, such as the stumps and small branches, but also the lignin, to produce useful chemicals and fuel. After the wood has been burned the ashes can be used as a soil improver. This allows you to keep your materials in a technological cycle as long as possible until they can be safely transferred to the biological cycle.'

7.2. Beet thick juice is naphtha to bio-based economy
Frank van Noord, Suiker Unie

Frank van Noord studied food technology at Wageningen University in the Netherlands and started his career as a process engineer at Meneba cereal products. He has held several positions at Suiker Unie since 1991 and is now vice-president of R&D at the company's central office in Dinteloord in the province of North Brabant, the Netherlands.

What naphtha is to the petrochemical industry – a versatile feedstock – thick juice, a water solution that is 70% sugar, is to the bio-based economy. 'Thick juice is an important intermediate for all kinds of synthesis routes, either through fermentation or catalysis', says Frank van Noord, Director of R&D at Suiker Unie, one of the largest sugar refineries in Europe.

It is visible from afar when one travels down the two-lane road through the flat and fertile lands of the western part of the Dutch province of North Brabant: a huge silver-coloured tank containing 60,000 cubic meters of concentrated thick juice. Just across the road is the large Dinteloord complex, one of the remaining two sugar refineries of Suiker Unie, a subsidiary of Royal Cosun.

Royal Cosun is a cooperative with 10,000 farmer-members. Every year, 5.5 million tonnes of beet and a 100,000 tonnes of imported sugar cane are processed into granulated sugar for all kinds of food applications, such as bakery products and soft drinks. At least, that has been the case for about the last hundred years, since this cooperative refinery was established.

Nowadays sugar beets are considered a feedstock for a whole range of products, from specialty chemicals such as the amino acid glycine betaine, which is used as a medicine, to bulk products like ethanol and methane and everything in between, from polymers such as polylactic acid to platform molecules such as succinic acid.

Live off the land

The transformation of the sugar beet into a feedstock for the bio-based economy is driven by the need to find alternatives for oil and gas, according to Frank van Noord. 'It might take 50 years or maybe even a century, but eventually our fossil fuel feedstock is going to run dry and force us to live off the land again, as we did before 1850.'

Sugar beet seems like a good alternative for fossil fuel as a chemical feedstock. Over the last 60 years sugar beet production has more than doubled, with sugar production increasing from 6,000 kg per hectare to 13,000. Yields will increase even further by 2020, to around 20,000 kg per hectare, thanks to classical breeding techniques and im-

Figure 7.1 The sugar beet

proved farm management. 'We now produce more sugar per hectare with beet than Brazil does with sugar cane,' says Van Noord.

Increased yields have been accompanied by lower processing costs. 'In 2006 the European Union introduced a new quota system,' explains Van Noord, 'limiting sugar production for use in food to 13.3 million tonnes a year, thus opening up the EU market for sugar from abroad. The production of sugar for non-food applications was not limited. The new policy shook up the sugar industry, and only the most efficient producers survived. Thanks to economies of scale and innovation the cost per tonne of sugar fell sharply, opening up new possibilities for non-food applications of sugar.'

Right intermediates

'We are now witnessing the beginning of a new era for sugar beet as a green feedstock,' Van Noord continues. 'Our challenge as a refinery is to find the right intermediates for possible applications.'

Granulated sugar and thick juice might be the most important sources of feedstock at the moment, but they are not the only ones. Another option is to use beet mush, i.e. mashed beet that has been treated with enzymes, such as cellulase and pectinase. The resulting liquid contains sugar but also other nutrients, and can be a cheap and effective alternative as a feedstock for fermentation processes.

Traditionally beets are cut and then the sugar-containing juice is extracted. This 'raw' juice, a 16% sugar solution, can be used as a feedstock for the production of ethanol. 'As ethanol evaporates from the liquid,' says Van Noord, 'it does not matter if the feedstock contains impurities. So it is cheaper to use the "raw" juice instead of the crystallized sugar. On the other hand, there are also chemical or fermentation processes in which the product remains in the solution. In those cases it is often better to use granulated sugar so purification is less complicated.'

Energy

Beet pulp is the residue left after the sugar has been extracted from the beet. Every tonne of sugar produces a tonne of pulp. Traditionally about half of the pulp is sold fresh to farmers as animal feed. The other half is force-dried and sold during the year. Drying the pulp uses a lot of energy. 'That is why we developed an alternative,' says Van Noord. 'Instead of using energy to dry the pulp we now produce energy from the pulp and other green leftover materials.'

A massive 'digester' was built next to the Dinteloord factory in 2011. It produces and modifies biogas so it can be injected into the national gas grid. It produced 10 million m^3 of green gas in 2012, enough to supply 9,000 households. 'With this digester, and our other ones in our factories in Vierverlaten in the north of the Netherlands and Anklam in Germany, we aim to become a leading player in the green gas market in the Netherlands. We hope to produce 25 million m^3 of gas a year, enough to supply more than 15,000 households. We also use the green gas as fuel for our trucks and cars, which reduces our carbon footprint even further.'

Feedstock

Raw juice is purified and boiled into a syrup that is 65%-70% sugar. This syrup can be stored in large tanks to be further processed, either into granulated sugar through crystallization or into a whole range of other products, such as biopolymers and specialty chemicals. 'The great advantage is that syrup does not spoil, because of its high sugar concentration. That makes it an ideal intermediate for all kinds of food or non-food applications. Eventually a quarter of our yearly production, i.e. 240,000 m^3, will be stored as syrup.'

Indeed, syrup can become the naphtha for the bio-based economy. Earlier initiatives in the 1930s and 1980s to push the chemical industry to move away from fossil fuels to renewable sources failed because the price of fossil fuel feedstocks dropped. This could happen again. In the United States the abundant supply of shale gas has already led to a sharp decrease in the price of gas, making shale gas a 'game-changer' for the chemical industry.

Van Noord is not too worried about these developments. 'The gas price will fluctuate in the coming decades, but in the end gas remains a finite resource. The worldwide increase in both population and prosperity means that eventually there will be no other alternative but to revert to renewable feedstocks.'

Combine capacities

To meet the challenge of finding the right intermediates for possible applications, Suiker Unie is working with existing and potential customers. 'We have more than a century of experience processing green feedstock, mostly for food applications. The chemical industry has been working for a hundred years or more with fossil fuel feedstocks, first coal, and later oil and gas. Our experience mostly involves the technology of separating and isolating substances in liquid solutions. The chemical industry has a lot of experience in the technology of synthesizing and modifying materials, using mostly solvents. In my view we should not be trying to copy each other's strengths but cooperating to combine our different capacities.'

Through its parent company, Royal Cosun, Suiker Unie is an active partner in the Green Chemistry Campus in the south-west of the Netherlands (see also the interview with Wim Sederel, initiator of the Green Chemistry Campus). Suiker Unie is also involved in several related initiatives for developing a bio-based economy in the western region of Brabant and in Zeeland, where 'agro meets chemistry'.

'Co-operation is extremely important to make this a successful encounter,' says Van Noord. 'As a producer of feedstock for the chemical and pharmaceutical industries we have to be very aware of customer specification demands in the future. On the other hand, the chemical industry has to be aware that using green feedstock is different from using gas or oil. One harvest differs from the other both in quantity and in quality. It is quite a challenge, but it is also very exciting. In fact we are on the verge of a third industrial revolution.'

7.3. YXY platform molecule – the green 'Intel Inside'
Ed de Jong, Avantium Technologies

Ed de Jong studied food technology and did his PhD on lignocelluloses degradation at Wageningen University, the Netherlands. After his research at the University of British Columbia in Vancouver, Canada, he became head of the Department of Fibre and Paper Technology of Agrotechnology & Food at the Wageningen University & Research Centre in 1997. In 2007 he became director of catalytic biomass conversion at Avantium Technologies. Since 2009 he has been vice-president of development at Avantium Chemicals.

'We developed a new catalytic process to convert sugars extracted from biomass into new green, recyclable building blocks called YXY. YXY has superior barrier and thermal properties, making it ideal for the packaging of beverages, fruit, food and non-food products. 'The bio-based Coca-Cola bottle made from polyethylene furanoate,' says Ed de Jong, vice-president of development at Avantium Technologies, 'is probably one of our most imaginative innovations.'

In December 2011 Avantium officially opened its pilot plant on the Chemelot Campus, a former site of the chemical company DSM in Geleen, in the Dutch province of Limburg. The pilot plant aimed to demonstrate its technology on a larger scale before taking it to larger commercial plants. The facility can produce 40 tonnes of product per year.

Geleen is a long ride from Avantium's headquarters in Amsterdam. 'The pilot plant operates 24/7, so it has to be equipped with everything that is needed for chemical processes: electricity, steam and gases, and the facilities to transport resources and products, remove waste and purify waste water. The entire infrastructure has been set up on this site, including the necessary regulatory provisions. It's ideal. And it enables us to proceed according to a strict schedule,' says Ed de Jong.

Finding the niche

Avantium started as a spin-off of Royal Dutch Shell 12 years ago. The technology service company initially focused on high-throughput experimentation. This technology is used to perform many experiments in parallel, which makes it possible to develop new processes or catalysts in a short time. 'Initially we only did service work and contract research for our clients,' says De Jong. 'At a certain point, venture capitalists took over, and they were more interested in implementing a steady growth model, which is not what a service organization offers. In around 2005 our shareholders decided that we had to establish our own development programme.'

After extensive screening, one of the possibilities that emerged was the conversion of sugars into furan intermediates, a primary building block in chemical processes. 'We were able to take full advantage of our in-house technology and expertise, as an alternative to the classical enzymatic fermentation to ethanol. At that time little was being done with the chemical catalytic conversion of sugars as building blocks for fuels and chemicals. It was a niche market,' says De Jong.

YXY – green from within

The next step was to figure out the chemistry. 'It literally boils down to dewatering sugar,' says De Jong. 'For many applications sugar contains too much oxygen. You can remove oxygen by removing carbon dioxide. That is what happens when you make ethanol. Another way is to remove water, and that is what we do when we make furan dicarboxylic acid from glucose.'

The furanic building block carries the mysterious brand name YXY (pronounced *iksy*). 'We called it YXY because as a concept this name is still empty. The disadvantage is that people don't associate anything with it yet. On the other hand, that means we can market and position it from scratch. The actual idea behind the name is that it might become a household notion like "Intel inside" for end users when they use a bottle or buy clothing that contains YXY. We are, after all, a business-to-business company.'

Better than PET

Initially Avantium intended to use the YXY building blocks to make fuels, but that idea lost steam over time for a number of reasons. One is that of all conceivable applications, fuel has the largest market in terms of volume, but fetches a low price and makes a slim profit. So it is difficult to launch a totally new product in this market. 'Besides, the main building block of YXY, FDCA, is a molecule with high potential,' explains De Jong. 'The properties of FDCA-based polyesters are superior to their fossil-based counterpart polyethylene terephthalate (PET). The oxygen barrier of polyethylene furandicarboxylate (PEF) is six times better than PET, while the carbon dioxide barrier is two times better, as is the water barrier.'

Figure 7.2
The PEF bottle

PEF's better barrier properties make it possible to explore packaging alternatives, such as completely replacing the aluminium can. 'That gives a company like Coca-Cola the possibility to use one packaging material for their entire portfolio and become independent of fossil fuels,' De Jong says.

First of a kind

The first commercial plant to produce 50.000 tonnes a year must be up and running by 2016. Several industrial plants are in the pipeline for the ensuing years. Arranging the necessary funding is a high priority. 'It is important to minimize the risks as much as possible in these first-of-a-kind plants. The biggest risk is building a factory that does not use its designed capacity,' says De Jong. That is why Avantium has been building partnerships with end users and producers, such as Coca-Cola, Danone and Solvay. By creating demand for the products, they act as launching customers and help the technology to develop. "These partners want to secure their demand via off-take agreements from this first plant. We expect a large part of the plant's output to be covered by pre-orders before we build it. That diminishes the overall risk significantly. Coca-Cola is the world's biggest buyer of PET and the company has ambitious growth plans. The amounts of PET being consumed today makes you realize how small the capacity of the first plant is.'

The location of the commercial plant has not been decided yet. The availability of feedstock resources is one of the factors that will determine the location. 'To minimize the risks we will initially use commercially available first-generation feedstock. On basis of dry matter we need about 100.000 tonnes of carbohydrates. But it isn't possible yet to find carbohydrates in such quantities and at a competitive price from second-generation feedstock.'

Sustainable and recyclable

The recent cradle-to-grave study by Utrecht University's Copernicus Institute , which compares PEF to its petrochemical counterpart PET, the fifth-largest bulk plastics worldwide, shows how durable PEF is. Substituting PEF for PET can reduce non-renewable energy use by approximately 40% to 50% and greenhouse gas emissions by approximately 45% to 55%. Greenhouse gas emissions could be further reduced by switching to lignocellulosic feedstocks, such as straw, and the material cycle can be completed by recycling it.

There are several ways to recycle PEF. It can be recycled mechanically or it can be reused. 'In the past, bottles became fleece jackets,' says De Jong. 'But the recycling industry is developing, and today the number of bottles being recycled into bottles is growing substantially.' The other method is to hydrolyze straight into the YXY building blocks.

That is more expensive because it requires a lot of energy, but at the same time it ensures good quality. The building blocks have the same specification as the virgin material. Both methods are possible. 'The long-term expectation is that PEF will be separated from PET and converted into 100% bio-based recycled materials. All further recycling work is done with our partners and the industry.'

New applications, new partners

Avantium has established partnerships with other brands to enhance YXY's market appeal. For example, Avantium is working with Teijin Aramid, Solvay and Rhodia to develop new bio-based polyamides. 'The T in PET stands for terephthalic acid, which is a benzene ring with two carboxylic acid groups. That molecule is used for many applications, including in polyamides. It's found in nylons, in aramids such as Teijin's Twaron fibre, and in resins and plasticizers too,' De Jong explains. 'Basically, whenever terephthalic acid is used, it can be replaced by our furan dicarboxylic acid. We focus particularly on applications in which YXY's properties would have both a technical advantage and a green benefit.'

Plastics are the primary focus for the time being, but Avantium is still looking into the possibility of using YXY to produce fuels. Engine tests with furan-based mono- and diethers, which have good fuel blending properties and a relatively high energy density, are being conducted with vehicle manufacturer DAF Trucks. 'Second-generation biomass sources contain lignocellulose, which can be converted into C6 (glucose) and C5 (xylose) sugars. Furans can be made from both of these sugars, but the C5 sugars produce a molecule with "one arm". That doesn't matter for biofuel, but these molecules are unsuitable for application in polymers, where we need a building block with "two arms". Biofuel is still on our long-term agenda. But first the production of second-generation biomass has to mature.'

7.4. Sowing the seeds of the third industrial revolution
Willem Sederel, Green Chemistry Campus

Willem Sederel studied polymer chemistry and also did his PhD at the University of Twente, the Netherlands. From 1981 onwards, he worked for General Electric Plastics both in the Netherlands and in the United States. When GE Plastics became SABIC Innovative Plastics in 2007 he became technology & innovation leader. He is also the initiator of the Green Chemistry Campus.

According to Willem Sederel, technology and innovation leader at SABIC Innovative Plastics, 'while there is a growing need for bio-based feedstock, the agricultural and food sectors are looking for a market for their residues. At Green Chemistry Campus we try to establish a link between the agrofood and chemical sectors.' Sederel spends about half of his working hours on that endeavour. 'The transformation into a bio-based economy won't happen overnight', he says, 'but now is the time to sow the seeds of the inevitable third industrial revolution.'

Willem Sederel walks us to a futuristic building on the SABIC site in Bergen op Zoom in the Dutch province of North Brabant. There is a great deal of open space inside the building. There are conference tables and seats for meetings and offices separated by glass walls for a small but rapidly increasing number of companies that are turning innovative ideas into products or processes. These companies can use SABIC's office and laboratory facilities for their work. And they can turn to SABIC or other large companies in the region for co-siting if their innovation turns out to be successful.

Sustainable goals

One of the main driving forces behind the third industrial revolution is that both the chemical industry and its customers have set themselves goals for sustainable development. 'For many CEOs,' Sederel says, 'it is clear that we cannot continue to exploit the Earth's limited resources and pollute our environment. This growing awareness is reflected in key performance indicators, not only in terms of profit, but also in terms of people and the planet. As a supplier of innovative plastics it is our aim to help our customers to achieve these sustainability goals as well.'

Developments in the packaging industry serve as an example of how companies are switching to sustainable practices. The gyre of garbage in the Pacific Ocean, and in other oceans, is causing sustainable development to become an increasingly important priority.

'Though we do not supply packaging materials to businesses, we have noticed a strong push for both bio-plastics and biodegradable plastics. The development of PEF, a bio-based alternative for the PET bottle, is one example' (see the interview with Ed de Jong from Avantium Technologies).

This drive towards more sustainable development is also evident in the automotive industry, one of SABIC's key customers. In the 1980s and 1990s part of the steel used in cars was replaced by lighter materials, such as aluminium and plastics. Most plastics were used in bumpers or in car interiors.

'Right now, plastics, sometimes reinforced with natural fibres, are being used to make large parts of car bodies. The chassis and body of the Mercedes SLS E-cell has even been replaced by a monocoque made of carbon-reinforced plastic. Weight reduction is now priority number one, two and three, and that is where plastic – preferably bio-plastic – enters the equation.'

The other driving force behind the third industrial revolution is economic. Oil and gas are becoming more and more expensive as a feedstock for the chemical industry. 'I am the first to admit that the transition towards a bio-based economy will take years, even decades. Higher demand from emerging economies and their burgeoning middle classes, and lower output from oil and gas fields means the price of fossil feedstocks can only go up. Of course, the price will fluctuate over the years – shale gas, for instance, will certainly have an impact on feedstock prices – but eventually fossil feedstocks will be more expensive than bio-based feedstocks.'

Well defined

The question is, what kind of biomass will eventually replace oil and gas? 'An important criterion that will determine what kind of biomass emerges as the winner,' says Sederel, 'is how effectively it can be refined into well-defined feedstock. If this process takes more than three or four steps, then the yield will be too low to be economically viable. A great deal of research is now being done to develop refinery processes that can be performed simultaneously ("one-pot" processes), either by biocatalysts (a series of enzymes) or in a fermentation process using micro-organisms.'

Another criterion is that the bio-based economy stay away from foods such as starch, sugar and edible oils. 'There are situations where there is an excess of food ingredients,' says Sederel, 'such as beet sugar in Western Europe. We should also keep in mind that a new market of non-food applications helps to keep the cost of food down, because it encourages farmers to grow more of this crop. Or it could stop them from taking land out of production.'

Second generation

There is no doubt that second-generation biomass such as crop residue, trees and grasses such as *Miscanthus sinensis* (elephant grass) will be used in the future. 'Algae are also an interesting possibility', says Sederel, 'but then we are talking about the period after 2020.'

The common trait of second-generation sources of biomass is that they mostly consist of lignocelluloses. Indigestible to humans, they therefore do not compete as a food source. Another reason to explore second-generation biomass is that it is an abundant resource.

'The annual world production of sugar is a little less than 200 million tonnes. Ten times more starch is produced, 2 billion tonnes. And the amount of lignocelluloses available is ten times larger than that, 20 billion tonnes per year. A small part of it is used for energy production, but most of it is just being burned or left to rot in fields.'

New technologies are being developed to break down lignocellulose into its different components: cellulose, hemi-cellulose and lignin. The amount of cellulose and hemi-cellulose in these different feedstocks varies between 65% and 75%. Traditionally they are used as pulp, but they can also be hydrolysed into sugars and further converted into ethanol. It is a proven technology that is applied in full-scale plants for 'advanced biofuels'. Like fuels, it can also be used as feedstock for the chemical industry.

Lignin

Lignin is another story. In 2^{nd} generation feedstock the percentage of lignin varies from 25% to 35%. Lignin has a great potential as a feedstock, but there is still a lack of effective methods to convert the material into more valuable substances. Most of it is still burned for energy.

Lignin can be partly depolymerized into a heterogeneous blend of aromatic compounds, making it a natural library of multi-functional compounds. Many of the aromatic compounds can be used to produce pharmaceuticals and food additives, but they can also be used to form caprolactam, the building block for nylon.

'Thanks to highly productive agricultural and horticultural systems in the Netherlands we have concentrated supply of lignocellulose and hence lignin. Instead of breaking down lignocellulose's aromatic compounds into ethane or other simple molecules, we should try and use it for the production of chemical specialties. As our technological strengths lie in biocatalysis, fermentation and process technology, it makes sense that in the Netherlands, and specifically in our chemical industry, we specialize in building a bio-based economy.'

According to Sederel the focus on converting biomass into chemical specialties should lead the Dutch effort to build a bio-based economy to go further than just develop and export the technology. Indeed, the technology should be manufactured in the Netherlands as well. Sederel does not think it will be easy, however. 'The government encourages innovation and technology development through its policy to support nine "top sectors". There are hardly any policy instruments, however, financial or other, to encourage the scaling up of processes. As a result, semi-commercial and full-scale plants are mostly built elsewhere.'

Interface for innovation

It is important that all stakeholders, including large-scale manufacturers, are involved in the development of the bio-based economy. 'This transformation transcends the boundaries between sectors,' says Sederel, 'which is good, because the interface between disciplines is a perfect breeding ground for innovation.'

For innovations to mature into established products and processes you have to overcome the stakeholders' linguistic, cultural and motivational differences. 'That is why the green chemistry campus is so important,' says Sederel. 'It is not only a nursery for innovative start-up companies, but also a platform to actively engage all stakeholders in developing a bio-based economy.'

7.5. Waste is culturally defined
Jalal Laham, Teeuwissen

Jalal Laham was born in Lebanon and studied electrical engineering at the University of Dusseldorf in Germany. In 1982 he joined Teeuwissen, then a trader in meat by-products for the pharmaceutical industry, and turned it into a multinational group with approximately 100 companies and joint ventures and over 4,000 staff worldwide.

'It doesn't really matter what you call it, waste or residue. Nature does not produce waste. It is waste because WE call it waste. At Teeuwissen we like to turn it around: instead of developing ways to process this so-called waste, we see it as a raw material for premier products.'

Jalal Laham is the president of Teeuwissen Group. With approximately 100 companies and joint ventures on all continents, it is one of the world's largest specialists in meat by-products and casings. 'Keeping in mind that the world population is set to increase by another two billion people and that we all want to live decent lives,' says Laham, 'upgrading the by-products of meat processing is not only a business but also a moral obligation.'

The Teeuwissen Group started 33 years ago, trading pancreases for the production of insulin. 'In a slaughterhouse all of the by-products were collected in-house by small, independent companies and sold to traders like us,' explains Laham. 'We limited ourselves to collecting and controlling the quality of the pancreases and selling them to pharmaceutical companies. They were used as a raw material, mainly for the production of insulin, but also for other drugs and food supplements. In those days the pancreases were the only source of insulin, making it the most expensive part of the animal, sometimes more than five times the price of tenderloin.'

Re-inventing ourselves

The good times did not last. About 20 years ago the major producers introduced 'human insulin', which was produced synthetically by genetically modified bacteria. 'Although we saw it coming, it still was quite a blow to our business,' says Laham. 'We decided to change course and re-invent ourselves to become a producer of intermediates, not only for pharmaceuticals but also for human consumption, pet food, proteins and casings, made from residues and by-products from the meat industry.'

Instead of only collecting pancreases, Teeuwissen started looking at all by-products, including intestines, stomachs and bladders, 'red offal' such as hearts, lungs and livers, and other remaining parts such as bones, ears and heads. A large part of the material that is collected is still suitable for human consumption, but people do not want to eat it. Culture plays an important role in what parts of the animal people will or will not eat.

'It was a long shot', Laham says. 'We started our own in-house companies (gut rooms) in slaughterhouses all over Europe. We either started a new company or took over an existing one. We have our own machines on the slaughtering line to separate the gut contents, the heart, lungs and other organs. The meat processors were happy with us, because instead of having to deal with 13 or 14 different trucks a day, each of which collected about 100 kg of by-product, they were now dealing with a single truck that collected all their by-products.'

Total package

'At the same time we adapted our strategy. Instead of focusing on just the animal pancreas, we decided to focus on all animals, all countries and all by-products: the total package. Of course, we also had to find and develop the markets for these products. That turned out to be quite a job, because we wanted it to be as easy as possible for our customers. To be able to deliver the products (often more than one) in one truckload at the right time with the correct paperwork demands a logistic operation that is quite complicated.'

The operations got even more complicated because meat is not just a product – like pencils or tyres – but often also plays a part in the local culture. 'You can cut an organ for human consumption, a liver for instance, in 30 different ways,' Laham says. 'Each culture demands that its meat be cut in a way they are used to. Apart from these cultural differences you have to take into account the legal and veterinary requirements that differ from country to country. It is like a lottery ticket: the combinations are endless but to succeed you have to have the right six numbers.'

'If you want to succeed in this business', says Laham, 'you have to go for the highest price you can get for the meat by-products. That means offering your product at the right time and with the quality that your customers desire. We are talking about 800 to 900 different products in 140 countries. Our existence depends on our ability to deliver the complete package at the right time at the right price.'

From hunter to builder

The other reason for the Teeuwissen Group's turnaround was Laham's premonition that the days of making a great deal of money by trading meat by-products had come to an end. 'We were hunters, not builders,' he says. 'A pancreas was more valuable than a diamond, because we could sell it for four or five times the price we paid for it. That couldn't last because the world has got smaller thanks to the telephone, fax, e-mail and the internet. Eventually your suppliers and buyers will get to know each other and then you are out. So we decided to not just sell meat by-products but to move upstream and produce them.'

The switch from hunter to builder was also prompted by the growing awareness that though there is a rapidly rising global population and growing prosperity, the world's resources are finite. 'We cannot afford to throw away anything anymore,' says Laham. 'It is our assignment to add value to waste. Teeuwissen Group is in the fortunate position to be able to see the whole picture. A great deal of waste is not used because people are too narrow-minded. They limit themselves to one technology or one market and hence miss the other opportunities. We are constantly looking for new ways to do other things with residual materials from meat processing.'

'To be able to do that and earn money without resorting to government subsidies, you have to be able to anticipate developments and effectively control your operation', according to Laham. 'A pig, for instance, weighs about 100 kg when it is slaughtered. Half of it is meat, of which bacon is the most valuable part. The other 50 kg consists of organs, bones, hide and hoofs, etc. Part of it – the organs for example – is still fit for human consumption and used in meats, sausages and hamburgers. Part of it can be used in pet food and part of it is not fit for human or animal consumption, but can be used for technical applications, such as glue or grease or as a raw material for drugs. About 8 kg has no use at all.'

The 50 kg of meat represents 90% of the economic value of the pig. The other 50 kg only represents 10% of the value. 'First of all,' says Laham, 'we have succeeded over the years in reducing the 8 kg of waste to 2 kg. Second, we narrowed the ratio in terms of economic value between the meat and other parts of the pig by increasing the value of the non-meat part. Thanks to our efforts, the ration is now 60 to 40.'

New markets

Chicken is even more of a success story, but that is mainly because Teeuwissen Group developed new markets for chicken legs with Tyson Foods. 'In Anglo-Saxon culture,' Laham says 'people only eat the white meat of the chicken (the fillet) and its wings. In other parts of the world, like China or Africa, people prefer the red meat of the chicken, i.e. the chicken feet and chicken legs, respectively.'

'About 10 years ago the breast meat represented 90% of the economic value of a chicken, whereas the wings and feet only 10%. By developing the African market the ratio has changed to 65% for the white meat and 35% for the red meat. By building an infrastructure of cold storage and transport there is now a regular supply of chicken meat for reasonable prices in most African countries.'

It sometimes vexes Laham to see how much 'waste' is needlessly lost. Rice bran, for instance, is a rich source of protein, but instead of using it as feed it is left to rot or burnt. 'By processing it,' Laham says 'we could easily replace a large part of the soy that is imported for feed in Europe. Another example is the papaya fruit. In Africa the meat is eaten and the seeds are thrown away. In Portugal it is just the other way around; the Portuguese eat the seeds and throw the meat away. A lot of waste is culturally defined.'

8 Resource efficiency in the metal and consumer electronics industries

Electronic devices and domestic appliances generally contain two types of material: plastics and metals. Most plastics are extremely durable and persist well beyond the economic lifetimes of products, yet cables, cars and consumer electronics and the large volumes of plastics they contain are dumped or incinerated as waste, even though they could be recycled. The metals – including iron, copper and aluminium – may be present in the form of alloys, immobilized in structures, dissolved in liquids or in powder form, making it difficult and expensive to recover them in the quantities and levels of quality needed for their eventual reuse.

This chapter presents examples of companies that are attempting to improve their resource efficiency by recycling metals and plastics. In its ongoing efforts to improve production processes, Tata Steel has succeeded in producing more steel from the same amounts of iron ore and coal each and every year. Even the floors of the plant are swept to collect iron and coal dust, which is fed into the sintering furnace. As part of its EcoVision programme, Philips has set itself ambitious goals, including doubling the amount of recycled materials in its products and the global collection and recycling of its products by 2015. Its showcase product is the Senseo Viva Café Eco, a coffee machine made largely of recycled plastics. Only the components that come into contact with coffee and water are still made of virgin materials, in line with European regulations.

For waste processing companies such as SITA Northern Europe Waste Services there is as yet no positive business model for recycling many waste streams. Except for wood, metal and paper, recycling actually costs money. Nevertheless, SITA is determined to work in partnership with its customers to close several material loops in order to gain value from waste. The final example, again from Philips, shows the potential of new business models for achieving its ambitious targets in terms of energy savings and resource efficiency. For two breakthrough innovations – Pay per Lux and Luz Verde – the key is to provide added value for customers and other stakeholders by offering a service instead of merely products.

8.1. Improving raw material efficiency in the steel industry
Hans van den Berg, Tata Steel

Hans van den Berg studied physics and obtained his PhD (on cryogenics) at Leiden University. He joined the R&D department of Hoogovens, now Tata Steel, in IJmuiden, in 1991. He was head of maintenance and plant manager, before becoming director of manufacturing. He is responsible for the conversion of raw materials into steel and all the processes in between.

Making more efficient use of raw materials is possible, even in a mature industry like steelmaking. 'When I started working in the sector more than 20 years ago, I didn't think we could become more efficient', says Hans van den Berg, director of manufacturing at Tata Steel in IJmuiden. 'But each year we manage to squeeze more steel from the same amounts of iron ore and coal than the year before. It will be very difficult to develop a new steelmaking process that beats this one.'

Nevertheless, that is just what Tata Steel is aiming to do. Tata is a member of the Ultra-Low CO_2 Steelmaking (ULCOS) programme, a consortium of 48 companies, research institutes and universities that aims to reduce the industry's CO_2 emissions by at least 50%, with the support of the Netherlands government and the European Union. In spring 2011 the company launched a pilot blast furnace to test a new steelmaking process known as HIsarna. If successful, the process could drastically reduce the plant's CO_2 emissions within two decades.

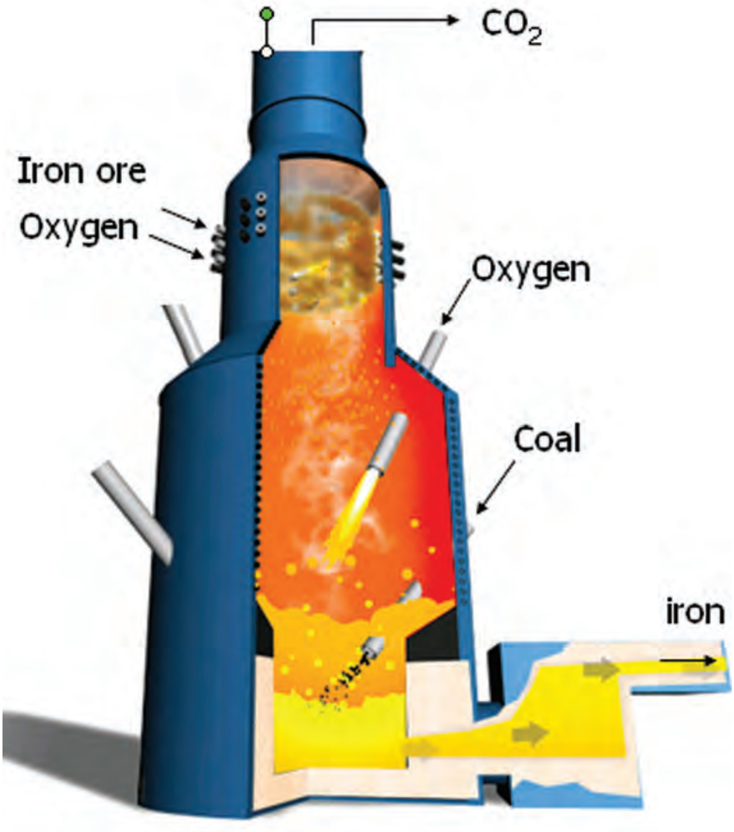
The HIsarna process

In the traditional steelmaking process, iron ore and coal are heated in a blast furnace at a temperature of 1500°C to produce pig iron. First, however, the iron ore has to be pelletized in a process known as sintering, while the coal has to be turned into coke by driving off the volatile constituents in an airless furnace at a temperature of 2000°C. Both of these are energy-intensive processes.

The HIsarna process is based on the cyclone converter furnace, a technology developed in 1986 at what was then known as Hoogovens in IJmuiden. Later it was combined with high-intensity smelting, HIsmelt, a process developed by Rio Tinto, in which crushed iron ore is injected into the furnace with oxygen and mixed with coal powder. The big advantage of the new process is that iron ore no longer has to be pelletized, and coal powder is used instead of coke, saving energy and CO_2 emissions. 'It is a real breakthrough technology', says van den Berg. 'In 2011 we showed that the theory works in practice by making liquid iron at the pilot plant, and in autumn 2012 we started a second test campaign. But we are only in the early stages of testing and developing the technology. If it proves successful, it may take 20 years before we reach the stage of industrial implementation, and existing steelmaking processes can be gradually phased out.'

In the meantime, the traditional processes of making pig iron and steel will probably become more efficient than they are today. 'This is an ongoing effort', says van den Berg,

Figure 8.1 The HIsarna blast furnace



'that is driven by our responsibility towards society and towards future generations and by the need to reduce the cost of making steel.'

Over the last decade there have been tremendous changes in the economics of steel-making. The prices of the two main raw materials, iron ore and coking coal, used to be fairly stable, but since the rapid development of emerging economies such as China and India and their huge demand for steel, the markets for ore and coal have become very volatile. Since 2000 the cost of these raw materials as a proportion of the price of steel has risen from 20-30% to more than 60%. And because of the economic crisis in Europe, the demand for steel has fallen, squeezing European steelmakers' margins. 'We don't need an incentive like the EU's CO2 Emissions Trading Scheme to make our processes more efficient', van den Berg insists. 'The market provides more than enough. Having to pay for CO2 emissions is actually counterproductive, because there is less money to invest in process improvements, while our competitors in other parts of the world do not have to carry the burden of these costs. This could hurt the European steel industry, even though it is leading in environmental performance.'

Closing the loop

'To increase the company's competitive edge and create a process that closes the circle, we need to make the most of our raw materials', says van den Berg. As an example, each blast furnace generates as much as 250 kg of slag per tonne of pig iron. The company now grinds this blast furnace slag to a powder and sells it to a neighbouring company, ENCI (Eerste Nederlandse Cement Industrie), where it is used in cement production. That means that ENCI can use less clinker – a mixture of limestone and clay – that is an essential ingredient of Portland cement. 'It is even better than clinker', says van den Berg, 'because we can control its chemical and mechanical properties by fine-tuning the process parameters. Also, using blast furnace slag in cement making generates a lot less CO_2 than Portland clinker.'

As well as the large volumes of slag, the IJmuiden plant produces smaller streams of material that are returned to the sintering furnace and then to the blast furnace. The plant also recycles its own waste. From his window overlooking the site, van den Berg points to a street sweeper vacuuming up iron ore and coal dust that is also fed into the sintering furnace.

Another by-product of the steelmaking process is the sludge from the water treatment plant. Van den Berg points to the 'converter' where the pig iron is converted into steel by blowing 100% oxygen over it. Most of the carbon in the pig iron is turned into carbon monoxide, a gas that is eventually used to produce electricity, but first has to be washed to remove the coal and ore dust. Once these particles have settled, the sediment is left to dry and is then also fed into the sintering furnace. 'Actually', says van den Berg, 'our sintering furnace is a huge recycling device that consumes a lot of our by-products, mostly iron and calcium, which can be put to good use, thus minimizing the amount of waste. More than 99% of our by-products are reused, the highest percentage recorded by any steelworks.'

Apart from mopping up the streams of waste, small and large, that still contain either iron ore or coal ('closing the loop', as van den Berg calls it), the process itself is also being scrutinized to make optimal use of the available raw materials. While the blast furnace is loaded with alternate layers of iron ore pellets and coke, the efficiency of the process is improved by blowing a hot wind containing 34% oxygen into the furnace along with coal dust. The coke works as a reduction agent and the ore melts, releasing a stream of pig iron.

'Contrary to popular belief, it is not the iron ore but the coke that is the limiting factor', says van den Berg. 'Apart from occasional shortages, there is enough iron ore, even in the long run. Also, we can easily use scrap iron to make steel. Steel can be endlessly recycled without losing its quality, making it an ideal recyclable material. What is becoming scarce, and hence expensive, is the special type of coal that can be used to make coke.'

Tweaking processes

Tata Steel is addressing the scarcity of coke in two ways. 'First, instead of using 100% coking coal, which is expensive, we now use a mixture of coal types', says Van den Berg. 'We have the technology and testing equipment to assess the behaviour of different coal types in the coke-making process. Our ability to use many kinds of coal from all over the world gives the company a competitive advantage, and minimizes the use of a scarce resource.'

The second way to reduce the amount of coke lies in the blast furnace itself. Alternating the layers of coke and ore pellets is needed to prevent the iron melting into one large heap of impenetrable stone. Obviously the coke also plays a role in keeping the furnace at a high temperature, but that role is taken over for a large part by the coal dust that is blown into the furnace with the oxygen. 'By increasing the amount of coal dust', Van den Berg explains, 'we can reduce the amount of coke. We can't continue to do that indefinitely, of course, because the intricate construction of ore and coke will collapse, but we have not reached the limit yet.'

Downstream opportunities

By constantly tweaking these processes, Tata Steel is trying to make the most of its inputs of raw materials. On the output side, the company is working with its customers to improve the quality and the sustainability of its products, says Van den Berg. 'The automotive industry, for instance, wishes to move towards lighter vehicles as a way to reduce vehicle fuel consumption. We have responded by developing lighter, high-strength steels that are now also being used in other sectors such as construction. By doing so we are limiting the amount of resources needed to make many steel products, and hopefully also contributing to a more sustainable society.'

Another innovation is Magizinc, an innovative metallic coating consisting of a mixture of zinc and magnesium. It offers improved corrosion protection with a 50% reduction in the use of zinc, one of the critical materials.

'There are many opportunities to optimize the use of raw materials both in our own processes and further downstream', van den Berg believes. 'Tata's IJmuiden plant produces 7 million tonnes of steel per year. If we can improve our efficiency by as little as 0.1%, that will save a lot of raw materials.'

8.2. Making recycled materials mainstream
Eelco Smit, Philips

Eelco Smit studied industrial design at Delft University of Technology. He is senior sustainability manager Philips consumer lifestyle division, where he is responsible for ensuring that the company complies with recycling regulations, and for coordinating activities related to the use of recycled plastics.

A circular economy is only possible if we reuse recycled materials in high-value applications and make them mainstream, according to Eelco Smit, senior manager sustainability within Philips consumer lifestyle division. 'To do that we have to work together with the suppliers of both recycled and virgin materials, and with our competitors.'

One of the three goals that Philips wants to achieve by 2015 is to double the amount of recycled material in its products, as well as to double the global collection and recycling of its products. A showcase product is the Senseo Viva Café Eco, an environment-friendly coffee machine designed and produced by Philips. The machine is not only more energy efficient, but 50% of its plastic components, 45% of the metal parts, and 90% of the packaging are made from recycled materials. It also weighs 10% less than competing coffee machines.

'There is a solid business reason for doing this', says Smit. 'We expect that in the near future many of the raw materials we use will become scarcer and prices will rise. So recyling these materials will help to reduce our costs. Actually it does already, because the energy contents of recycled plastics and metals are lower than those of virgin materials. The cost difference is not large in the case of plastics, but considering the amounts we use, a price difference of just a few percent is all that is needed to get things moving.'

Philips' ambitions for recycling do not mean that the company wants to become a materials supplier. 'What we want to do with our pilot projects, like the new Senseo, is to increase the stream of recycled materials and thereby set a course that we hope others will follow. We don't want to do it all ourselves. It would be ideal if the large suppliers of virgin materials were to join forces with small suppliers of recycled materials and start to supply both recycled and virgin materials to our specifications.'

High-value applications

All of the outer parts of the new Senseo are made from recycled plastic. The top is recycled polycarbonate derived from used CDs and DVDs, while the drip tray is recycled polypropylene, harvested from old Philips electrical appliances collected under the EU's Waste Electrical and Electronic Equipment (WEEE) directive. The base is made from acrylonitrile/butadiene/styrene (ABS) polymers that also originate from WEEE waste. The casing, the most visible part, is made from packaging such as yoghurt containers. The parts that come into contact with the coffee and water are still made from virgin material, however, because under European regulations recycled materials cannot be food grade.

'It was the first time these recycled materials had been used for high-value applications', says Smit. 'We discovered that very little was known about the mechanical properties of the plastics, such as tensile strength and impact resistance, so we had to do a lot of testing to get to know the materials. Another problem was contamination. The suppliers, mostly waste service providers, do not test the materials they recycle, because for most low-value applications it doesn't matter too much. For us it did, so together with our suppliers we developed methods and systems to prevent the inclusion of contaminated materials. That was quite a step forward for all of us.'

Risk analysis

Another problem was the use of additives in the plastics for electrical appliances that are now frowned upon, such as brominated flame retardants and plasticizers. 'Flame retardants are not a big problem because they can be separated based on their specific gravity, and it is possible to reduce the plasticizer content by mixing large volumes of plastics', says Smit. 'The real problem is that it is not possible to know what other additives they contain, and we cannot test for them all. That's why we have developed a method for assessing the risk and analysing all batches of recycled materials we use.'

The next challenge was the colour of the recycled materials used in the Senseo Viva Café Eco. The great Henry Ford might have been able to get away with the statement that customers could buy a Model T in any colour as long it was black, but today's consumers wouldn't accept that. According to Smit, 'The visible parts are made from white or colourless waste plastic, which we can make the desired colour. The non-visible parts are black. We also want to make some visible parts that are black from recycled plastic, but as yet the black we can achieve is not black enough.' To prove his point Smit shows an experimental black drip tray made from recycled plastic. It seems to be no different from an original one, at least to the untrained eye, but it is still below Philips' quality standards, and at this moment no change of specifications is acceptable.

Mainstreaming waste

To make recycling economically worthwhile it is important that recycled materials become 'mainstream'. 'We are now slowly replacing "virgin" parts with parts made from recycled material, not only in the Senseo Eco, but also in all Senseo coffee machines and other products', Smit says. The bottom end of a range of vacuum cleaners, steam irons and DVD recorders contains recycled materials, for instance. 'Our goal is to use 4000 tonnes of recycled plastics in our consumer products by 2015. That may not seem very much compared with the overall volume of material we use each year, but in absolute terms it is quite a lot.'

Philips cannot pull this off by itself, however, and so is now working with waste service companies that can supply the recycled materials. 'Together we are on a learning curve that works fine for now', Smit says. 'Eventually it is inevitable that the large suppliers of virgin materials will join us, and that will greatly improve the reliability of our supplies. We will then be able to use recycled material when it is available and virgin material as a backup.'

To make recycled materials mainstream, other producers of electrical and electronic appliances – Philips' competitors – need to be convinced to use them as well. 'The costs of collecting and separating waste materials are just too high at the moment', says Smit. 'That's why we are talking with our competitors and with the large recycling companies to join us in this process and thus create more volume.'

Smit believes it is still too early for legislation requiring manufacturers to use certain percentages of recycled materials, as has been suggested. 'A law would apply to all products. I can only speak for Philips, but we are not ready for that, partly because we would have to redesign all our products, which would involve a huge effort, and partly because adequate supplies of recycled materials of the right quality are not yet available. A better option would be for companies voluntarily to include larger volumes of recycled plastics in certain product ranges. That would lead to the same higher level of use of recycled plastics, and would allow industry to focus its efforts on products where it is possible to use them. This could also be done at the European level, if producers made a voluntary commitment, for instance, to increase their use of recycled materials to 50,000 tonnes by 2015.' Such commitments would give the waste industry the incentive they need to invest in better collection systems and new recycling technologies.

Designing for recyclability

To make recycling really worthwhile, manufacturers will have to redesign their products for recyclability. One issue that designers will need to address is how parts made from different materials are joined together. In the case of some types of glue, for example, it is often almost impossible to separate the parts during disassembly. 'Based on the experiences with the Senseo Eco', says Smit, 'we have drawn up a set of guidelines for our engineers and designers to help them design for recycling. We hope they will be adopted throughout the industry because, again, it is better if we all do this together than on our own.'

Within Philips the staff of various divisions will also have to work together to make recycling a success. For example, process engineers will have to work with designers to fine-tune the injection moulding process and adjust it to the recycled materials, preferably without adapting the mould itself, because that would add to the cost.

Another important group within Philips is the marketing managers who keep a sharp eye on product quality and performance. The engineers and designers are always enthusiastic about their improvements, but the marketing staff may be more critical. They may be happy when prices fall, but they also see the downsides of using recycled materials and they do not want to take risks with successful products. 'We engineers may not always be happy with the marketing people', says Smit, 'but it is good that someone is willing to hit the brakes and challenge us to ensure that using recycled materials will not affect the quality of the products. Because we are still talking business.'

8.3. Waste management and the circular economy
Freek van Eijk, SITA Northern Europe Waste Services

Freek van Eijk studied mining engineering and geosciences at Delft University of Technology. He began his career in 1988 as project manager and geotechnical and environmental specialist at Omegam. He then held various management positions at Arcadis, an international consultancy, and has been SITA's director of strategy & marketing since 2002.

Making the circular economy a reality requires, first and foremost, creating value from waste, says Freek van Eijk, director of strategy & marketing at SITA Northern Europe Waste Services, based in Arnhem. SITA specializes in the recovery of secondary resources such as metals, plastics and even energy from waste, and aims to become a European leader in the sector.

In India it is estimated that about 70% of municipal waste ends up in uncontrolled open dumps. In Europe the situation is much better, with an average of about 40% of household waste being disposed of in landfills. Yet this average hides some enormous differences, from more than 80% in Greece to less than 1% in the Netherlands. 'Just 40 years ago the Dutch used to bury all their waste. Now we tend to pretend that waste does not exist, and refer to it as raw materials. But looking around the world, it is clear that few countries share that point of view', says van Eijk. 'The United States still dumps about half its waste, which is an enormous waste of resources and energy, and a significant source of greenhouse gas emissions if the sites are not professionally managed. That's bad news for the planet, of course, but it also offers tremendous opportunities.'

In 1919 the first motorized trucks of the Société Industrielle des Transports Automobiles (SITA) began collecting garbage in Paris. SITA is now the waste management branch of the SUEZ Environnement Group, which operates in more than 70 countries. The group is active throughout the waste chain – collection, sorting, recycling, composting, waste processing and landfill management.

Closing the loop

SITA has embraced the concept of the circular economy, in which waste management plays a vital role in 'closing the material loop'. The traditional waste manager is becoming a leading player in the secondary resource market. 'In a world facing increasing climate stress and resource scarcity we can no longer afford to waste waste', van Eijk believes. 'By giving waste a second life as secondary raw materials or as a source of energy, we can conserve primary resources and at the same time achieve tremendous and cost-effective reductions in greenhouse gas emissions that could amount to almost 20% of the EU's emissions reduction target by 2020.'

However, for many waste streams there are as yet no positive business models. With the exception of materials such as scrap metal and paper, recycling actually costs money. Closing the loop for plastic packaging, for example, is still not a viable option, as it costs more than € 600 per tonne to collect, sort and recycle.

In Europe, many recycling initiatives have emerged in response to EU directives regarding waste, climate and energy. The EU's Registration, Evaluation and Authorization of Chemicals (REACH) regulations, for example, have affected producers, products and the recycling business. Producers are obliged to collect and process their used products, such as batteries, cars and electronic equipment, at the end of their useful lives. The aim is to create recycling chains that will develop and become more professional and more efficient as primary resources become scarcer and more expensive.

SITA hopes to work with its customers to create value from waste. 'By helping them to comply with the regulations we also are enabling them to become more cost effective and less dependent on virgin raw materials', van Eijk says. 'But to be successful we have to work in partnership. We need access to the front of the market, since waste is generated at many levels. At the other extreme, if we are to operate on global commodity markets we must be able to produce raw materials according to clients' specifications and to guarantee security of supplies. That means we need sufficient volume in order to be able to calculate and control the risks of volatile global resource markets.'

SITA collaborates with various partners in operations ranging from regenerating chemical solvents and catalysts, to recycling flooring materials, to bottle-to-bottle recycling and transforming expanded polystyrene packaging foam into 'Geoblocks' for road building. In the area of metal recycling, the company is working with three major European companies in initiatives to promote the dismantling and recycling of cables, cars and aircraft.

ReCycables

In 2008 SITA teamed up with Nexans, an international cable producer, in ReCycables, a joint venture that recycles copper and aluminium cables at the end of their useful lives. At SITA Agora's Eco-park site in Noyelles-Godault in Northern France, 35,000 tonnes of cables are recycled each year. These include thick undersea cables and cables for electronic and telecommunications systems. The end products are small piles of copper powder and aluminium that are very valuable and so are well protected.

The copper powder is delivered from the recycling plant to the Nexans plant next door, where it is used in the production of new cables. Copper is becoming a very valuable metal as world supplies are projected to be exhausted by 2039. 'The main drivers for Nexan to start recycling have been the need to reduce risks such as supply disruptions, unstable copper-producing countries and the logistics of maritime transport', van Eijk explains. Recently ReCycables started working on the recycling of the plastic sheaths surrounding the cables. An important step, because they account for 50% of the weight of each cable.

The Re-Source initiative

All European car manufacturers are now obliged to take back used cars at the end of their life and recycle them. In line with a 2000 EU directive, at least 85% (by weight) of each vehicle must be recycled or reused, and the percentage will rise to 95% in 2015. To speed up the treatment of vehicles in France, in 2008 SITA and Renault created a 'world first' joint venture by acquiring INDRA, a vehicle recovery company that has a reverse assembly line, also located at SITA's Agora Eco-park, that can dismantle 50 cars per day. This Re-Source initiative has achieved 85% material recovery, compared with the national French average of 81%. Most of the components, such as cables, textiles and metal, are reused. 'According to Lansink's ladder – a hierarchy of preferred methods of dealing with waste – reuse is better than recycling', says van Eijk. 'And it is cheaper; used car parts retail at 50-70% less than new ones.'

With this joint venture Renault is able to comply with European recycling regulations and demonstrate its own 'green' credentials. The Re-Source initiative has become an R&D project, and the knowledge gained in dismantling vehicles is now helping Renault's engineers to design cars in such a way that all materials and assembly techniques are now selected to facilitate dismantling and recycling. That is the basis of eco-design: products designed for reassembly and reuse. 'That holds for metals and plastics, since

Figure 8.2 Recycling of copper cables

most products are made of both materials', says van Eijk. Renault aims to include 20% recycled plastics in all its new vehicles by 2015.

Tarmac Aerosave

SITA and its third partner, Airbus, have set up a joint venture called Tarmac Aerosave to dismantle aircraft and recycle the parts and materials, and to offer aircraft storage and maintenance. 'It started very small, with a site in France that could handle 25 aircraft per year. Now we have a second facility in Teruel, Spain, which is the world's largest aircraft dismantling site, with a capacity to store up to 250 aircraft', van Eijk says. 'Some components, such as engines, electronics and pumps, can be reused in other aircraft once they are checked and recertified by the suppliers. Metals can also be melted down for use as raw materials to make new airframes, automotive parts or even beer cans.'

To recover metals for recycling, Tarmac Aerosave has developed a separation process that depends on a precise knowledge of the components of each plane. The system can distinguish between different metals such as aluminium, titanium and copper, and even their grades, so that the materials can be melted down, recast and reused in the aircraft construction industry. 'Just as with cars, we are using the recycling process to learn about how to design a plane in such a way that it will be easy to dismantle and recycle'.

A materials roundabout

Recovering and recycling rare earths is complex because these elements are present in very small quantities in a variety of waste streams (<1%). They are of interest to a few specialist companies such as Rhodia and Umicor, but there are few businesses that have sufficient capacity to retrieve the small quantities of materials involved. But in France an innovation platform, PLAT'INN, is being set up to promote the recovery of rare earths and precious metals. It will bring together experts in the public and private sectors, including SITA, to find solutions. 'The platform has not started yet, but it shows where French priorities lie', says van Eijk, 'just as Germany set a course for the development of renewable energy sources to replace nuclear power.'

Van Eijk sees many opportunities for waste management in the Netherlands. 'With its knowledge of raw materials, experience in waste management and the logistical advantages of the Port of Rotterdam, the Netherlands could become the ideal European hub – a materials roundabout – for collecting high-grade waste and turning it into usable secondary raw materials. We could create a plastic valley, a metal valley or a biobased valley. I hope the Dutch will be the first to catch the sustainability wave.'

8.4. Sustainability as a driver of innovation
Robert Metzke, Philips

Robert Metzke studied physics at the Humboldt University of Berlin, where he developed an interest in complex adaptive systems and chaos theory. He worked for five years as an editor for Science magazine until he decided to broaden his scope by studying for an MBA. After five years at McKinsey & Company he joined Philips in 2008 as senior director of the EcoVision programme.

The world's population is expected to reach 9 billion by 2050. 'If all those people are to have a good life within the limits of Earth's carrying capacity, we will have to develop innovative solutions', says Robert Metzke, senior director of Philips EcoVision programme. 'Not just technical innovations, but also business innovations. Sustainability is about generating cash flows from the added value of products for society and for the environment.'

'It is not just about being green', says Metzke, pointing to a graph showing the Human Development Index of the UN Development Programme and the ecological footprints developed by the World Wide Fund for Nature. 'The footprint of three quarters of the world's population fits perfectly within the limits of Earth's carrying capacity. But most of them have only the bare minimum to live on – or even less. Sustainable development also means increasing the prosperity and wellbeing of all people. It is about maintaining a balance between our quality of life and ecological footprint.'

EcoVision

In 2012 Philips launched its fifth EcoVision programme. Like its predecessors, it focuses on doing more with less (energy and raw materials), but it also takes a more holistic approach. The programme has three targets, says Metzke. 'The first target is to bring care – including healthcare – to more than half a billion people by 2015. The efforts to achieve this target will be led by the healthcare division. But it won't stop there; our long-term vision for 2025 is to improve the health and wellbeing of three billion people worldwide.'

The second target is to improve the energy efficiency of all Philips products by 50%, and is led by the lighting division. 'We already had a goal of reducing our own CO_2 footprint by 25% by 2012, which has made us a world leader', says Metzke. 'But life cycle analyses of our products showed that most of the impacts of our products derive from their use. So we decided to raise our ambitions to increase the energy efficiency of the entire Philips product portfolio by 50% in less than five years.'

The third target, led by the consumer lifestyle division, is to contribute to closing the materials loop by doubling the global collection and recycling of Philips products, and the amounts of recycled materials used in Philips products by 2015 compared with 2009 (see section 8.2).

'Reaching these three targets means we have to take a different approach to the business', says Metzke. 'If we are to improve the lives of billions of people and at the same time reduce our impact on the environment and use fewer resources, we cannot continue to run the business on the basis of quarterly turnover and profit figures alone. We have to define new key performance indicators that show its impact on customers and on society as a whole. But in the meantime, we also have to develop new business models, because we still have to produce those quarterly figures.'

One of the consequences of the new philosophy is that it is not enough to come up with smart technological solutions and put a lot of effort into marketing them. 'For example, the light-emitting diode, or LED light bulb, is a very energy-efficient source of light. Per lux, a LED uses 70-80% less energy than an incandescent light bulb. One fifth of all the electricity produced worldwide is used for lighting. If we can reduce energy demand by 40% using LEDs, that will mean that 600 medium-sized power stations won't have to be built.'

Pay per Lux

Despite the huge advantages of LEDs and compact fluorescent lamps (CFLs), both for the energy economy and the environment, their market penetration is still rather slow. 'So to speed up the transition we are developing new business models', says Metzke. 'One of these is Pay per Lux, which we introduced in 2011 together with the Amsterdam-based architect Thomas Rau. Another is Luz Verde, a project in Mexico City where Philips gave away 20 million CFLs.'

The cooperation with Thomas Rau started when Metzke met him at a conference. 'Rau told me he wanted his office to be completely cradle to cradle. I challenged him by asking what he intended to do about lighting. He didn't have a solution so I went to his office with one of our lighting designers. The starting point was not so much energy efficiency, but to use lighting to create an atmosphere in which people would feel good. We already had some experience with that based on SchoolVision, our lighting system for classrooms.'

Energy use was the next challenge. The lighting system selected for the office was based mainly on LEDs with some fluorescent lamps and tubes. 'We decided that we would pay the electricity bill – green electricity, of course – for the lighting', Metzke explains. 'That would be an incentive for us to install the latest, most energy-efficient lighting system that would meet their requirements. So Rau pays only for the light he uses, nothing else; hence Pay per Lux.'

The main feature of the new business model is that the customer doesn't have to pay for the lamps or the installation of the lighting system. Philips will remain the owner of the system for up to 20 years – the expected lifetime of an LED – and maybe beyond. 'The materials used in the LEDs and CFLs have a value because they contain scarce materials', says Metzke. 'Each lamp can be seen as a reserve of raw materials that will remain valuable for us. It is impossible to know what the value of these materials will be in 20 years' time, but we suspect it will rise. The lighting systems can be refurbished and used again, maybe in a classroom or meeting room.'

Luz Verde

Pay per Lux is based on the idea of offering lighting as a service instead of selling light bulbs. It is an example of a business model based on creating added value for customers and for society as a whole. Another example is Luz Verde, a project in which Philips distributed 20 million CFLs for free in Mexico City as a way to reduce energy consumption and the country's carbon footprint. 'We were able to finance the investment with CO_2 credits', Metzke explains. 'Under the clean Development Mechanism of the Kyoto Protocol we were able to turn the amount of CO_2 saved into CO_2 emission rights that have a certain value. It sounds magical, but the CO_2 emission rights created a cash flow that was sufficient to pay for the 20 million CFLs.'

Both Pay per Lux and Luz Verde show that it is possible to develop innovative business models that support sustainable development. 'The underlying principle is that the innovation creates added value for customers and for other stakeholders. The idea is to try to identify who benefits from this added value. It may be society as a whole, as in the case of Luz Verde, because CO_2 emissions have been reduced. Or it may be a customer like Thomas Rau, who gains by paying for light rather than for light bulbs. As long as you can create a cash flow to pay for an investment in sustainable development you can make it scalable. These kinds of projects may need more effort, but they also give more satisfaction. We know we are working on something that is future-proof.'

9 Resource efficiency in fashion and furnishings

Fashion and furnishing fabrics bring colour to our lives. Because tastes differ and styles change over time, the textile industry produces a wide range of different products with very short economic lifetimes. Resource efficiency is an issue here. Not only because even the highest-quality products are disposed of as waste within a limited time, but also because their production is energy and resource intensive. In addition, most textile companies use fresh water in their production processes to ensure the quality of the final products. This results in considerable volumes of waste water.

Closing material loops, integrated chain management, cradle to cradle production and the circular economy are just some of the many concepts that have emerged over the last two decades, and many industries are working hard to apply them in practice. Ambitious projects have led to impressive results, but all those involved acknowledge that the key to success is cooperation between all links in the production chain.

This chapter presents four examples of companies that have succeeded in closing the material loop. Three of them have been inspired by the cradle to cradle[1] approach developed by Michael Braungart and William McDonough. These companies have demonstrated that it is possible to use recycled secondary materials to make better than standard products. They have shown that it is possible to design short-cycle products that can be 'reincarnated' at the end of their economic lifetime. Their experiences make it clear that it is possible to identify new business opportunities by looking at the product chain as a closed system.

For the fourth company described in this chapter, the key is water – or, rather, the substitution of water by supercritical carbon dioxide as a solvent for dyeing fabrics. This revolutionary method of dyeing fabric eliminates the need for vast amounts of fresh water and chemical dispersants, while radically reducing the use of energy and emissions of waste water.

1 Cradle to Cradle® is a registered trademark of MBDC, LLC. Cradle to Cradle Certified[CM] is a certification mark licensed by the Cradle to Cradle Products Innovation Institute™. See http://mbdc.com/images/MBDC%20C2C%20Certified.pdf

9.1. Adding volume to the circular economy
Frans Beckers, Van Gansewinkel

Frans Beckers studied logistics at the Rotterdam University of Applied Sciences and the Dutch Association for Purchasing Management (NEVI) in the Netherlands, and advanced management at the Vlerick Business School in Belgium. Before joining Van Gansewinkel in 1998, he worked for DSM Resins and the Atrium Hospital Group. In 2009 he attended the Cradle to Cradle Champion training at the Environmental Protection Encouragement Agency (EPEA) in Hamburg, Germany, established by Michael Braungart.

The growing scarcity of many raw materials means that we must start to recycle the waste we produce. 'But that will only be economically feasible if we are able to create sufficient volume', says Frans Beckers, director of materials, concepts and infrastructure at Van Gansewinkel, a group of companies that collect process waste to produce new raw materials and energy. 'Large volumes are needed to make the systems for collecting and recycling waste more efficient, and to ensure that companies like ours can supply customers with quality raw materials in the quantities they need.'

When Leo van Gansewinkel created the company in 1964, his philosophy was that the waste streams of today are the raw materials of tomorrow. 'If you look at the growing prosperity', says Beckers, 'especially in the newly industrializing countries, and the diminishing reserves of almost all raw materials, it is inevitable that we will have to reuse waste on a much larger scale than we are doing now.'

'If you think about it, it is quite absurd, says Beckers. 'You buy a pair of jeans for € 100, and that is their value, for you at least. You wear the jeans for a while and during that period they keep their value. Then one day you decide to throw them out and suddenly their value drops from € 100 to zero. Of course that's not true, the jeans still have some value, but the question is how to recover it.'

The answer, Beckers believes, is to increase resource effectiveness, which is quite different from resource efficiency. 'Resource efficiency means that we try to use natural resources more economically, thus extending their availability. But that's old economics. Resource effectiveness means that production and consumption cycles are organized in such a way that it is always possible to recover the materials used with no loss of value. That's cradle to cradle thinking.'

Cycles

Of course some materials lose their useful characteristics when they are recycled. In cradle to cradle terms one can say that 'upcycling' is not always possible, but in such cases 'cascading' – reusing materials several times in products of diminishing quality – can help to get the most value out of them. 'Look at that pair of jeans again', says Beckers. 'Maybe you can sell them to a second-hand store. There is a lively trade in second-hand clothing both within Europe and between Europe and Africa. Or you can reuse the fibres, spin them into yarn and make new fabrics. Or you can use them as cotton waste, which can be burned as a fuel to produce electricity and heat.'

Other materials can be reused in the biological cycle. Paper, for instance, can be recycled six or seven times, but each time the fibres become shorter, until eventually they are too short to produce quality paper. 'When that happens', says Beckers, 'the paper fibres cease to have a function in the technological cycle, but could be used to improve the soil, for example. But that means that you have to prevent soil contamination by using inks and dyes that are non-toxic and biodegradable. Cradle to cradle means you have think about both technological and biological cycles.'

A solid business case

In this period of transition to resource effectiveness, the problem is to develop a solid business case for reusing materials. In the case of recycled plastics, says Beckers, 'the secondary plastics need to be as pure as possible so that they can be used in the same or maybe even higher-value applications. You have to prevent the mixing of different kinds of plastic. At the same time, this means that the costs of collecting and separating plastics are high and the return streams are small. In some cases, the costs are so high that the plastics are not collected separately at all, and are burnt as waste. Or they may be mixed with other streams, but this reduces the quality and value of the return stream even further, and the plastics can only be used for low-value applications such as traffic poles.'

There are several ways to overcome this paradox, says Beckers. 'One is to use systems that are already in place. A good example is the distribution of spare parts for automobiles. There is a system in place to provide garages with spare parts, often on a daily basis. That system could also be used to collect the parts that have been replaced. The next step is to design those parts in such a way that they can be easily disassembled. That is now happening more often, making it easy to reuse the parts for high-value applications.'

Another example of a system in which Van Gansewinkel is involved, is the reuse of fibres from police or army uniforms. 'From a systems point of view, uniforms – like spare parts – represent a closed system,' says Beckers. 'Often the uniforms are washed and mended by a service provider, which means there is a collection and distribution system in place. That system could also be used to collect old uniforms and recycle them, for instance by pulping them and selling the fibres to spinning mills. These fibres can then be used to make new clothes or for other applications.'

There are other ways to resolve the trade-off between quantity and quality. One is to accept the loss you make on collecting waste materials and hope that it will be possible to recoup it later. Many consumers are willing to pay a premium for 'green' products, 'but only to a certain extent', says Beckers. 'At some point you have to fall back on the next option, which is to cooperate with competitors in setting up a collection system. Another option would be to use the secondary materials to make better than standard products. An example is the carpet Desso is making from recycled materials, which captures dust and is anti-allergenic. People are willing to pay a premium for the new feature, and not just because it is greener.'

Evolution

Beckers sees two main lines of development over the next 10 or 20 years. One of these can be described as a closing the material loop. Devices are collected, taken apart, the components are reused and the materials recycled by the same company or group of companies that produced them. Instead of asking customers to pay a premium because the product is 'green', the original manufacturer may impose a surcharge to cover the costs of collection, disassembly and reuse. A recent example is Auping, a bed producer, which imposes a surcharge of less than 5% of the purchase price of its mattresses. The challenge is to extend the closed loop and create sufficient volume to make recycling economically viable. It may also be possible to upcycle the material by adding a new feature, as Desso has done, that increases the value of the new, recycled product.

The second line of development will involve the production of commodities from secondary materials that can compete with virgin materials. 'Nylon carpets and fabrics, for instance, can be recycled to produce fibres that can be reused for the same application', says Beckers. 'They can also be depolymerized into caprolactam, a monomer from which nylon is made, which is virtually indistinguishable from the "virgin" caprolactam produced from fossil fuels. But the competition between secondary and virgin materials would then be subject to price volatility of the virgin material on global markets. As a student, I worked at a plant where nylon from carpets was depolymerized into caprolactam. But when the price of virgin caprolactam plummeted, recycling was no longer viable and the plant was shut down.

As well as the price volatility of virgin materials, several other aspects have to be taken into consideration when secondary materials are offered as a commodity. One of them is volume. 'Most chemicals are produced on a large scale, sometimes about 1.5 million tonnes per year', Beckers explains. Will secondary materials be available in such volumes, not for one year but for a decade or more? And will they be of the right quality? Customers have to be comfortable with products made from secondary raw materials. But sufficient volume is also needed both to create large enough streams of secondary materials and to justify the investment needed to collect and process them. That will be a huge challenge for service providers like Van Gansewinkel.

9.2. Designed for reincarnation
Rien Otto, Dutch aWEARness

Rien Otto first worked as an engine lathe operator and then in the social services sector. As director of the foundation Local Heroes, he worked with young people in developing countries to improve their prospects for the future. Inspired by the notion of sustainability, in 2005 he launched the fashion company DutchSpirit. Now, with Dutch aWEARness, he hopes to make the circular economy work in the fashion industry.

In the new circular economy, products will be regarded as resource banks. But first, product chains will have to be closed and all companies involved – from manufacturers to recyclers – will have to work together as partners, share responsibility for the products and materials, and agree on how the circle should operate. ‘Only then will it be possible to turn sustainability into a real business model’, says Rien Otto, sustainable entrepreneur in the world of fashion.

At the end of a row of historic buildings in the centre of Den Bosch, the new building of the European Design Centre comes into view. It houses the offices of Rien Otto’s company, Dutch aWEARness, from where he is promoting sustainable entrepreneurship in the world of fashion.

Otto has long been inspired by the concept of sustainability. In 2005 he launched his first company, DutchSpirit, and the world’s first ‘eco-effective’ clothing brand. ‘We started with organic cotton, which was becoming trendy at that time. Now I know it was even worse than bad. We then switched to the label ‘climate-neutral’ long before the term was widely used. At the Live Earth concert during the UN climate conference in Copenhagen in 2009, we presented a fashion show featuring only climate-neutral clothes.’

Closing the chain

For Otto, climate-neutral was the stepping stone to cradle to cradle, the concept of waste-free industry developed by chemical engineer Michael Braungart, in which all products and materials are kept within their technological cycles. ‘I had long conversations with Braungart on how to put this concept into practice’, says Otto, ‘and I came into contact with the Austrian textile manufacturer Reinhard Backhausen, who made furniture fabrics.’

Together with Braungart he visited Backhausen and over dinner the three men became creative. Otto believes that for real creativity, three things need to come together. First, you need some form of belief or conviction – in this case the cradle to cradle concept. Second, you need art, or a creative person in any of the visual arts. Last, but by no means least, you need science – in this case, the expertise of Backhausen. ‘As a result of that meeting something magical happened. We developed a new environment-friendly fashion fabric, Returnity, made of 100% recyclable polyester, that was the first tangible example of cradle to cradle production. But the real challenge had only just begun. We knew that the material was recyclable up to the right level, but we didn’t have the tools to do it ourselves. The market was not ready, and we had neither sufficient volume nor the necessary knowledge.’

They figured that the only way to solve the problem was to close the chain themselves. And that led to the concept of the circular economy as a follow-up to the linear economy. ‘We all know that the linear economy has caused many of today’s problems, including the shortages of raw materials and the ways people interact, refuse to take responsibility, and look only at their own bottom line. We are not going to solve any of these problems under the same system that created them. The time has come to embrace the circular economy’, Otto insists. ‘If you look at the circular economy the picture is entirely different. People work in partnership, share their knowledge and are more transparent. They divide the profit they make with each other and earn no more profit than necessary.'

Profit sharing

Otto has closed the cycle for his fabric Returnity. 'That means we make garments and have our partners for recycling in place. We have agreements on the quality of the products and the profit we want to make. All costs throughout the chain must be covered by the price of the product at the start of a new product cycle. All of the partners involved can come to transparent financial arrangements, and earn the same net profit.'

The financial arrangements can be a matter of debate, as Otto discussed with economist Herman Wijffels, professor of sustainability and social change at Utrecht University. 'If we are to move towards a circular economy, as Brussels has depicted, that can only be done if the partners in the chain are allowed to come to financial arrangements regarding the sharing of costs and profit. Brussels is still chained to the old linear economic system and its rules. In the circular economy there is no place for resource abuse, it's all about use.'

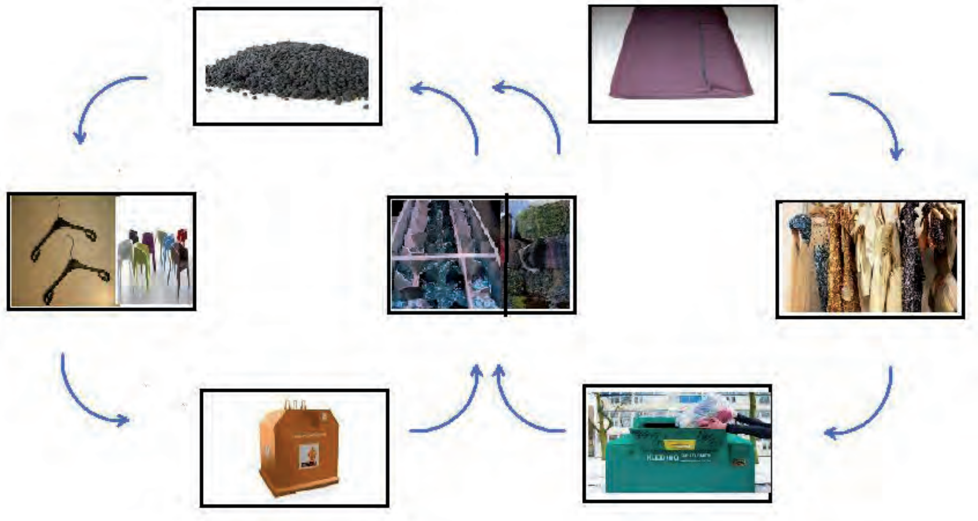
By shifting from consumption to use, every product becomes its own 'resource bank'. The concept works for Otto's fabric Returnity as follows. Since consumers become users, they do not own the garments they buy, but pay to use them and return them to the manufacturer at the end of their useful lives. To make sure that users return the garments, the company asks for a deposit. The used garments are collected in the municipality of Almere by a network of partners who take care of logistics and arrange the recycling process. The garments are processed and converted into new raw materials of the original quality by GreenGran, a Belgian company, without mixing it with virgin raw material. Trevira, a German polyester fibre manufacturer, then makes new yarn from the recycled material, which is in turn woven into new fabric by Backhausen in Austria. The fabric can be used by fashion houses to make new garments, and the cycle is closed.

Business model

Throughout the process, partners and manufacturers are responsible for the products and for the valuable raw materials they contain. 'The big advantage is that we are no longer dependent on speculators who manipulate the prices of raw materials', says Otto. 'Compared with five or six years ago, the difference is that sustainability is connected to and supported by a sound business model, for every partner in the product cycle at the same time. This can only work if the chain is closed. Sustainability becomes attractive if there is a sound business model. You may have to explain it first, but then people start moving.'

Backhausen's first customer was DutchSpirit, who used the fabric for corporate clothing and tailor-made suits sold under its own label. But not for long. 'Fashion designer Tommy Hilfiger has now joined us', Otto says with pride. 'He can order his fabrics directly from Backhausen and does not need Dutch aWEARness as an intermediary.' That has meant that the role of the company has changed. Otto has become the manager of the product chain so it can keep on turning. 'We are the axis on which the wheel of the cir-

Figure 9.1 Closing the product chain



cular economy of fashion runs, which is pretty unique. We are now rolling out the concept in the UK, Germany and Belgium.'

Connecting cycles

Recycling polyester suits is now well under control, although blended wool suits presented a problem, since the materials cannot be separated. 'Normally woollen clothing is burned, and they call it green energy,' Otto says. 'That was not enough for me, and I thought for a long time about how to resolve it.' On a trip to Tunisia, he saw pellets of wood being glued and pressed together with steam. 'That's the principle of a filler and a binder. I thought that if I use a batch of woollen textiles as a filler and add a biobased polymer, I would obtain a solid composite that could be extruded and used to make clothes hangers, tables or garden chairs, over and over again.' With that idea in mind, Otto visited various companies and within less than four years had closed the composite fibre cycle.

'Even for a material that we cannot recycle to the same level of quality as the original raw material, there may still be a sustainable solution in another material cycle', says Otto. 'That's the hard part, since we can only sell our products as cradle to cradle if the cycle really is closed. So first we do a showcase version, since people have to see a tangible product before they will agree to join in.'

To develop new recyclable materials, Otto always starts at the end and then develops the process backwards to create a circular economy. 'At every step in development, we bring together around the table many areas of expertise – weavers, fashion designers, engineers, scientists, and so on – to design for reincarnation,' he explains. Adopting the circular economy involves more than chain and product responsibility. 'We have to learn to work together, talk together and take responsibility together: for each other, for the raw materials and for nature. That is the long-term solution.'

9.3. Sustainability with substance
Rudi Daelmans, Desso

Rudi Daelmans trained as a chemical engineer and started his career at Esco, which merged with Desso in 1981. He worked in innovation & research and later became I&R manager and a member of Desso's plant management team. He has been director of sustainability at Desso since 2007.

When carpet manufacturer Desso became independent again after a management buyout, one of the cornerstones of its new strategy was sustainability. 'But with substance', says Rudi Daelmans, director of sustainability. 'Not just the routine things like saving energy and water, but a kind of sustainability that would distinguish us from our competitors. We needed a vision and a range of products that would appeal to our customers.'

Desso is a European carpet and sports systems manufacturer, which focuses on superior floor design and cradle to cradle high-quality carpet tiles and broadloom carpets at its factories in Belgium and the Netherlands. The company began by producing woven carpets for residential and commercial premises in 1930. In 1981 Desso merged with Esco, a producer of needle felt carpets and later carpet tiles. In the 1990s the company was taken over, but following a management buyout in 2007 it became independent again.

'At the time of the takeover we were a healthy company producing high-quality but rather old-fashioned products', Daelmans recalls. 'To distinguish ourselves from our competitors, we adopted a new strategy based on three innovations: stunning design, added functionalities and cradle to cradle production. At that time I was responsible for environmental affairs, which meant I was busy ensuring we complied with the law and with the ISO 14001 standard.'

Sons of bitumen

When Daelmans was appointed director of sustainability, he first set out to explore what that could mean for Desso. 'I discovered that people talked a lot about sustainable development and corporate social responsibility, but if anything it always involved doing more with less: resource efficiency. I didn't think we could distinguish ourselves by doing the same as everyone else. But then I heard a talk by Michael Braungart, one of the founders of the cradle to cradle philosophy of resource effectiveness. I started to read up on the subject, and on the day I planned to introduce the concept to our management team, Stef Kranendijk, our CEO, came to me and said that he wanted to make all our products cradle to cradle. He too had heard Braungart speak and had decided that was the way forward for Desso.'

Braungart was invited to give a presentation to the board and the management team. After learning more about the composition of their carpet tiles, which have a bitumen backing, his response was 'son of a bitumen'. Bitumen can never be fully cradle to cradle, because as a by-product of oil refining, its composition cannot be defined precisely at the molecular level. But Braungart added that there was no need to be perfect from day one, so we heaved a sigh of relief. In 2010 we introduced Desso EcoBase,[2] which is based on polyolefin, as an alternative to our bitumen backing, and can be 100% safely recycled in our own production process.' Carpet tiles with Desso EcoBase backing have achieved cradle to cradle 'Silver' certification,[3] which means that up to 97% of the constituent materials have been positively identified, and have been assessed as either 'green' (optimal) or 'yellow' (tolerable) according to the cradle to cradle criteria.

Hearts and minds

The next step was to instil the cradle to cradle approach into the hearts and minds of the people working for Desso. 'That took a while', Daelmans recalls, 'because at that time we had just had a reorganization and the staff didn't want any more change; they just wanted to do their jobs as they had always done. So we organized workshops for all departments and they played a crucial role in making the staff enthusiastic. We did a lot of talking, until gradually people understood that we were serious and, more important, that cradle to cradle was fun. The consistent support of senior management in integrating the cradle to cradle philosophy into our business strategy was crucial.'

We chose Pallas, a successful carpet tile, as the first product to undergo the cradle to cradle certification procedure. 'It was not easy', says Daelmans. 'First we had to identify all the components used in the product, and their CAS numbers (CAS, the Chemical Abstracts Service, issues a unique number for every chemical described in the scientific literature). Not all suppliers are able to provide that information, either because it is classified or they simply don't know. On top of that, we were not talking about 20 ingredients, as we first thought, but close to 200. In the end it took nine months to get all the information we needed to obtain our first certification.'

Supply side

All of Desso's suppliers then had to be convinced to have their products certified as cradle to cradle by the Environmental Protection Encouragement Agency (EPEA) in Hamburg. Together with Desso's chief operating officer, Daelmans visited many suppliers, some of them more than once. 'Some were eager to help us in our journey to certification, others were not too keen, while yet others simply didn't want to come along for the ride. We told them that Desso would have to start looking for alternative suppliers, but we didn't close the door right away.'

For a product to obtain cradle to cradle certification, it must meet five criteria:[4]

- material health – it uses only cradle to cradle approved materials that are safe and healthy for humans and the environment;
- material reutilization – it contains materials that are recycled or renewable, and are designed to be recycled in future life cycles;

2 EcoBase®, TakeBack™, Refinity®, Econyl®, AirMaster® and RollerDocs™ are trademarks of Desso BV.
3 There are four levels of cradle to cradle certification: Basic, Silver, Gold and Platinum.
4 See http://mbdc.com/

- renewable energy use – it must be made using solar, wind, geothermal or other renewable sources of energy;
- water stewardship – any waste water has to have a positive effect on the biosphere, so that water leaving the factory should be as clean as or cleaner than when it came in; and
- social responsibility – it must contribute to the health and wellbeing of co-workers and society.

Metabolism

The term 'cycle' does not really describe what is meant by cradle to cradle. 'Actually it is more a metabolic system than a cycle', says Daelmans. 'The ideal situation resembles an ecosystem in which the products and by-products of one company are the raw materials for other companies. But such cross-industry cooperation is still the exception. As long as there is little or no cooperation, the metabolism remains a cycle.'

For Desso, closing the seemingly straightforward carpet-to-carpet cycle turned out to be rather complicated. First, there was the logistics problem. Selling carpet tiles via wholesale and retail outlets is one thing, but getting them back is quite another, especially as the tiles may be in use for 10 years or more. To resolve this problem, Desso offers clients a 'Take Back' service to ensure that products are recycled in accordance with cradle to cradle principles. The company will take back Desso products at the end of their useful life, and will safely reuse them in new carpet products, or in other recycling initiatives.

Yarns

The first step in the recycling process involves mechanically separating the yarns and other carpet fibres from the bitumen backing, creating two material streams. Desso has developed an innovative separation technique called Refinity, which in 2011 was used to process 800 tonnes of used carpet. The bitumen backing (which is currently used in most carpet tiles in Europe) is reused in road building and roofing materials, while non-recyclable fractions are used as an energy source in the cement industry. The carpet fibres (of the required purity) are further processed and transported to a manufacturer for the production of new yarn. In the process, some virgin material may be needed to compensate for losses and process inefficiency.

For example, waste polyamide 6 yarn from the Refinity plant is sent to Aquafil, one of Desso's suppliers, where it is used to produce Econyl, a yarn made from 100% regenerated nylon. This recycled yarn is then returned to Desso to produce AirMaster, a carpet that clears the air. Because of the way the yarns are tufted this carpet captures fine dust particles that can be easily removed by vacuuming. AirMaster is eight times more effective in capturing fine dust particles than hard floors,[5] and can improve indoor air

5 Based on tests with Desso AirMaster® versus standard PVC hard floor performed by GUI, a testing institute in Germany.

quality, which can have a positive effect on human health. 'Desso encourages its staff to think outside the box and design products that will make a positive contribution to people's lives and the environment. They have come up with some wonderful new ideas. It shows that the cradle to cradle philosophy can also promote innovation.'

RollerDocs

Although Desso's staff were enthusiastic about the reuse of carpet tiles, the installers have not been too keen to collect them, wrap them up and return them to Desso. Compared with the alternative of burning them in a waste incinerator, it involves a lot of work. 'To encourage them to return the tiles to us we had to find a solution for their internal logistics', says Daelmans. 'For that we developed RollerDocs, a cart that can carry 130 m^2 of carpet tiles and is easy to handle, even in small spaces. Companies that supply and fit new carpet tiles can now easily pick up the used tiles, load them onto the RollerDocs and return them to us.'

While the installers have welcomed the RollerDocs, a new obstacle hindering the reuse of carpet tiles emerged – the old economy. 'Many countries, including the Netherlands, anticipated that the volume of waste would continue to grow, and so built many waste incinerators. So many, it now seems, that the incinerators have lowered their fees substantially in order to attract as much waste as possible. Such unforeseen problems can be a real threat to any recycling initiative, including ours.'

9.4. Dyeing textiles without water
Reinier Mommaal, DyeCoo Textile Systems

Reinier Mommaal trained as a commercial engineer at The Hague Polytechnic. Before he joined DyeCoo in 2007, he worked in several sectors, mostly telecoms, developing metalworking machines, and even for a while for Disneyland, where he was able to combine his commercial and technical skills.

Every year worldwide some 3500 billion litres of water, about the size of a small lake, are used to dye textiles As an alternative, DyeCoo Textile Systems is developing a new dyeing machine that uses supercritical carbon dioxide as a solvent, saving not only water but also the dispersants needed to dissolve the pigments. It also uses a lot less energy than conventional dyeing machines, and the process is twice as fast. The company began the commercial rollout of the technology in 2012 with the production of textiles for sports gear.

'We wanted to test our first full-scale prototype in a commercial environment', says Reinier Mommaal, CEO of DyeCoo Textile Systems, based in Weesp. 'We needed not only to test the machine, but also a launch customer with a lot of experience in the textile industry, and who is trusted by his clients. Because he has to convince them that dyeing with supercritical CO_2 is not only ecologically sound, but also guarantees a colour quality that is as good as or even better than water dyeing.'

DyeCoo found its launch customer in Thailand. The Tong Siang Company, part of the Yeh Group, was prepared not only to test the DyeCoo machine in their factory, but also to invest in the development of the first full-scale prototype. In December 2010 the equipment was shipped to Thailand and was put to the test in a real production environment in early 2011.

After the prototype machine, which handled 2500 batches of 100 kilogram rolls of textiles, a new machine with three pressure drums was designed and built. This new machine was used to dye a series of sport T-shirts for Adidas, which were marketed in time for the London Olympics in August 2012 under the slogan 'DryDye – Every drop counts' (i.e. Adidas saves water). At the London Olympics the other major sports label, Nike, supplied the Kenyan marathon runners with polyester singlets that were also dyed using supercritical CO_2 as a solvent.

'Sports clothing brands are keen to reduce the environmental footprint of their products, and to innovate', says Mommaal, 'so it was a very good market to launch our new technology. We knew we had a good product when Nike decided in 2012 to enter into a strategic partnership with us. They believe our technology has the potential to revolutionize textile manufacturing. You can imagine that a partnership with a world leader is very helpful for a young company like ours.'

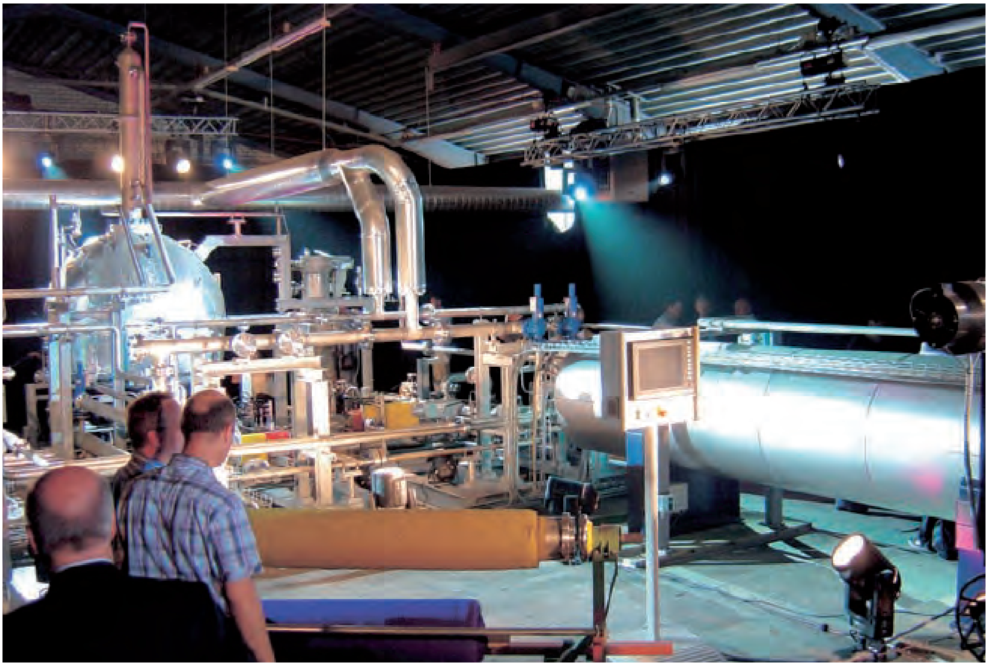
Decaf

DyeCoo as a company began in 2008, but the development of the technology started much earlier. In the early 1980s a German research institute developed a method to dye yarns using supercritical CO_2 as a solvent. The idea was based on the fact that at a certain combination of pressure and temperature CO_2 becomes a supercritical liquid, meaning it has the characteristics of both a gas and a liquid. Supercritical liquids are used, among other things, to extract caffeine from coffee, making decaf, and in the production of pharmaceuticals.

The traditional method of dyeing uses up to 200 litres of water per kilogram of fabric. To dissolve the pigments in water one kilogram of dispersant is added for every kilogram of pigment. 'Then the Germans showed that the pigments that are used for dyeing textiles can be dissolved in supercritical CO_2 without a dispersant and can then be impregnated into the yarn', Mommaal explains. 'I say "into", because at a certain temperature the polymer of the yarn starts to bulge, allowing the dye molecules to enter the polymer and stick to it. For polyester this temperature is around 120°C. For CO_2 to become supercritical at that temperature the pressure has to be 250 bar.'

Another advantage of supercritical CO_2 is that the solvent and the pigment are easily separated. As the solvent is supercritical it needs only a small drop in pressure to turn the CO_2 back into a gas, leaving the remaining pigment – about a glassful – to be mopped up. The only thing that the supplier of the dyes has to deliver is the pigment, that is, without the dispersant and other additives that are normally used.

Figure 9.2 The DyeCoo machine for waterless dyeing



Real life test

The idea was picked up again about a decade ago by researchers at Delft University of Technology and by Feyecon, DyeCoo's parent company, and Stork Prints, a company based in Boxmeer that produces textile printing machines. They developed a new technical approach by placing all the equipment – not only the dye and the rolls of fabric, but also the pigment reservoir and pump – into the pressurized drum. 'A simple idea, but it was very effective', says Mommaal. 'If you don't have to pump the pigments against a pressure of 250 bar, that can save a lot of energy.'

A small pilot plant, built at TU Delft, showed that waterless dyeing of fabrics was technically and economically feasible. As well as the Yeh Group, other investors included Feyecon and a venture capital firm, while the Dutch government provided a guarantee for part of the loans.

The full-scale prototype was tested for a year in the Netherlands, and in December 2010 it was shipped to Thailand for a 'real life' test in one of the Tong Siang Company's factories. In the meantime, the Dutch team designed and built a larger machine that could take three 150 kg rolls of fabric at a time, which has since also been shipped to Thailand.

Challenges

In the coming years DyeCoo faces two main challenges, Mommaal admits. 'One of these is technical – how to apply the technology of waterless dyeing to fabrics other than polyester, such as nylon and cotton. We are now working with pigment producers and researchers at several universities to develop a comprehensive technology for waterless dyeing that is attractive for the textile industry. At the moment our machine is still a lot more expensive than the traditional water-based dyeing machines. Although the return on investment is the same – because the exploitation costs are so much lower – the high investment cost may be a problem for small companies.'

The other challenge is to develop a sensible approach to roll out the technology. 'We have proved that waterless dyeing works on a commercial scale', says Mommaal, 'but that is only part of the story. To turn it into a successful technology we need time to resolve a number of teething troubles. We also have to build up an organization for service and maintenance. That is why we decided to focus on one country to market the machines.'

Although DyeCoo's experience with the Yeh Group in Thailand had been good, the company eventually chose Taiwan, which has many textile companies that produce for the high-end sports and outdoor clothing. 'Those are markets where producers can charge a premium for environment-friendly textiles', Mommaal explains. 'With the help of the Dutch Trade and Investment Office in Taipei we have found five or six companies that would be willing to use our machine and are large enough to survive if it unexpectedly breaks down.'

Once the business in Taiwan is running smoothly, DyeCoo hopes to make the leap and approach other large textile producers in the Far East. China has by far the largest number of textile dyeing companies, so Mommaal hopes to sell the waterless dyeing machines there. 'Many of these companies are located in the north of the country', he says, 'where there is a growing shortage of water, so I expect that our waterless machines will be well received.'

10 The challenges ahead

Mankind has long enjoyed the abundant food, arable land, water, energy, metals and minerals provided by planet Earth. We have come a long way from the primitive biobased economy in which mankind depended on the crops, prey, water, timber and tools that Earth's ecosystems handed to us. We learned to mine metals and minerals, developed new means and processes to apply them and gradually worked our way into the present minerals-based economy. The industrial revolution enabled a large jump in terms of quality of life, but it also marked a steep rise in the exploitation of metals, minerals and fossil fuels. Also, it became clear during the 20th century that our need for food, feed and fuel has profound effects on forests, land use, fish stocks and biodiversity.

The main challenge in managing natural resources for our future is to enable prosperity for everyone without crossing planetary boundaries. The world's population, which is expected to grow from 7 billion in 2012 to 9 billion by 2050, will experience the limits to growth if we continue to consume and produce at the same rate as we do today. And, as we witness in the rising number of conflicts over food, water, land and minerals, resource scarcity is not a problem in some vague future, but something we have to deal with right now. However, many questions remain to be answered. What do we really know about (constraints on) the use of natural resources and the related risks of over-exploiting scarce and vulnerable supplies? What new opportunities may arise for business and how can we identify and make use of them? And what can governments and international bodies such as the United Nations do to create the necessary economic and societal conditions for realising greater prosperity for more people with less resource extraction?

This last chapter will not present the final answers to these and related questions. It will, however, present some food for thought and action, based on the knowledge and experiences summarized in the previous chapters.

10.1. Understanding the challenges

Although general knowledge about resource challenges is essential to raise awareness among companies, governments and society, more detailed and specific data and expertise are required to assess vulnerabilities and develop robust strategies that will ensure sufficient, timely and affordable access to resources for the future. These data deal with both long- and short term supply and demand issues and cover both micro-economic and process data on the one hand, and macro-economic indicators on the other.

Among the data required for the development of long-term strategies are data on mining, trade and the uses of raw materials, which are often not easy to obtain and even harder to interpret. Macro-economic analyses of resource consumption in various industrial sectors and countries reveal knowledge of interdependencies between nations and industries. Although not widely known, various instruments have been developed to monitor and assess how resource efficient the world, global regions or even countries as a whole are. The pioneering work of institutes such as the Wuppertal Institute in Germany, the Institute of Social Ecology in the United States, the Institute of Environmental Sciences at Leiden University in the Netherlands, and the Sustainable Europe Research Institute in Austria has been consolidated in the form of OECD publications and Eurostat manuals.

Although such macro-economic data are essential for long-term strategies, making short-term improvements and addressing vulnerabilities require detailed knowledge at the company or micro-level. Both the processes within a company as well as the processes within their (often complex) supply chains need to be assessed and known in detail in order to initiate cost-effective strategies. Some well-known instruments that would support strategies at the company level include Life Cycle Analysis (LCA) and analyses of Cost of Ownership. They can demonstrate both the extent to which cost prices are vulnerable to changes in the availability and price of consumables, and where substantial and robust process and product improvements can be expected.

Box 10.1. Quantitative information

There is an urgent need for standardized, quantitative information regarding the environmental costs of resources, processes and products. The EU's EXIOPOL project was a key contributor to expanding and synthesizing a database on the costs of environmental burdens within the EU, measured in monetary terms. The EXIOPOL project had three main objectives:

- to synthesize and develop comprehensive estimates of the external costs for Europe of a broad set of economic activities;
- to set up a detailed environmentally extended (EE) Input-Output (I-O) framework, with links to other socio-economic models, in which as many of these estimates as possible are included. Such an EE I-O table for the EU-25 does not exist, but could be used to estimate the environmental impacts and the external costs of various economic activities, final consumption activities and resource consumption for EU countries; and
- to apply the results of the external cost estimates and EE I-O analysis for the analysis of policy questions of importance, as well as to evaluate the impacts of past research on external costs on policy making in the EU.

The EXIOPOL project analysed and assessed the damage due to emissions of air and water pollutants. The project therefore updated and detailed the external costs by type of pollutant, industry sector and country, as well as for a range of themes, including health, agriculture, biodiversity, forestry and waste. This knowledge base was extended in EXIOMOD and EXIOBASE, but further effort is still needed to support the development of efficient and effective resource management strategies. For now, EXIOBASE defines economic, material and energy flows (including physical waste flows) in 43 countries, up to 180 industrial sectors and some 5000 traded products. It includes quantitative data on the extraction of 80 resources, land use and water, and the emissions of up to 40 pollutants. The database is available at www.exiobase.eu (version 1.0, for a not-for-profit fee).

While it may seem self-evident that a sound knowledge of one's own business is essential, the current situation with respect to resources represents a new set of combined and dynamic complexities, or 'linkages of sustainability' (a term coined by Ester van der Voet and Tom Graedel, the editors of the book of the same name). In the current situation of resource constraints, expected and unexpected nonlinear dependencies call for system dynamic approaches, not coincidentally the methodology introduced by Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, and William W. Behrens in their famous book, *Limits to Growth,* published in 1972.

10.2. Business opportunities

What new opportunities may arise for business in the sustainable use of natural resources and how can we identify and make use of them? In recent years many inspiring business visions have been developed by leading companies (such as those represented in the Dutch Sustainable Growth Council) and by international bodies such as the World Business Council for Sustainable Development. In addition, thought leaders have developed valuable conceptual approaches for guiding action, such as the cradle to cradle approach by William McDonough and Michael Braungart, and most recently Ellen MacArthur's circular economy. Such inspiration and conceptual guidance is essential. However, the proof of the pudding is in the eating. It is in their implementation that these visions and approaches will reveal their real impact. This implies pioneering efforts, hard work and intensive learning processes for all involved: producers, consumers and governments.

The previous chapters discussed and illustrated some results of this pioneering work. Some 21 business cases presented a wide range of strategies by which companies may contribute to a more sustainable use of natural resources. These strategies vary from the optimization of existing manufacturing processes, to initiatives directed at closing material loops and intensified use of products, to radical changes in the design and use of products and resource substitution.

The resource strategies summarized in Table 10.1 have in common that their implementation results in an economically sound business case that substantially improves resource efficiency. They prove that the combination of innovation and entrepreneurship may lead to promising results, both commercially as well as in terms of resource efficiency. It should be noted that the best practices range from incremental innovations that can be implemented within the current societal, economic and technological models and know-how, to more radical innovations that challenge existing patterns of consumption and production. Companies such as DyeCoo and Avantium have shown that business opportunities do exist – at least in niche markets – for more radical innovations in product design and resource use.

Table 10.1 The scope of best practices in resource efficiency presented in this book

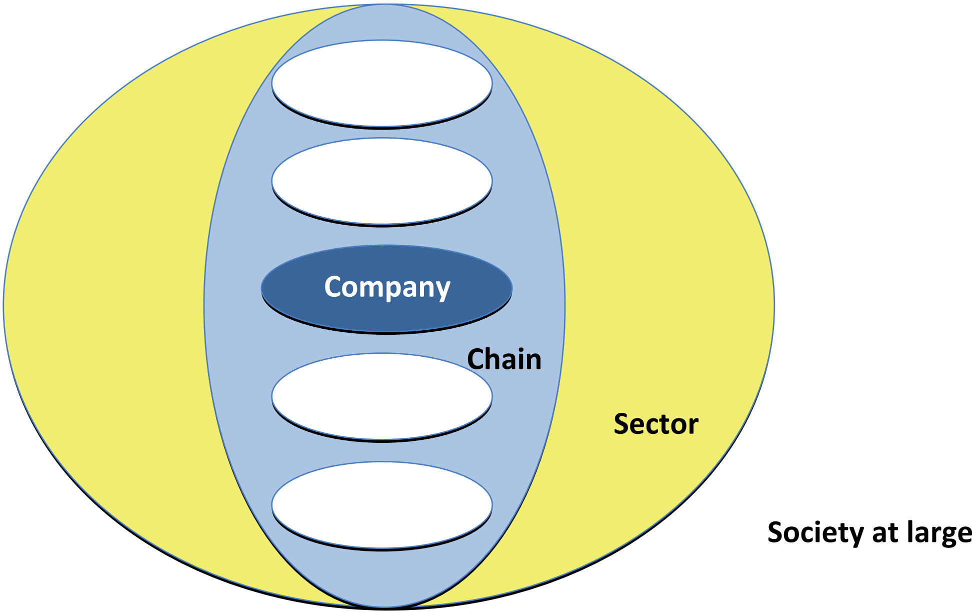
Step in the production-consumption chain	Manufacturing		Products and services		Use of products and services
Strategies	Process optimization	Materials recycling	Redesign	Substitution	Intensifying use and reuse
Best practices	Heineken (6.1) Smurfit Kappa (7.1) Tata Steel (8.1)	Delta Development (5.4) Green Deal (6.3) Philips (8.2) SITA (8.3) Van Gansewinkel (9.1) Dutch aWEARness (9.2) Desso (9.3)	Daas Baksteen (5.1) FrieslandCampina (6.2) Philips (8.4) DyeCoo (9.4)	ASCEM (5.2) Suiker Unie (7.2) Avantium (7.3) GCC (7.4)	ACR (5.3) Venik (6.4) Teeuwissen (7.5)

In general, is seems that it is easier to implement incremental innovations than it is to introduce and scale up more demanding, radical innovations. The cases illustrate, however, that the implementation of incremental innovations is no easy task either. The experiences of companies like Tata Steel and HEINEKEN demonstrate that process optimization requires substantial and continuous efforts. It demands a solid understanding of the company's technological processes and of the characteristics of the resources used. It also requires a tailor-made innovation programme and a thorough process of upgrading and educating staff, and of joint implementation with suppliers in the product chain.

Another look at Table 10.1 shows that for each category of resources, more than one strategy can be developed and applied. From the descriptions it becomes clear that in most cases a combination of resource strategies provides a more comprehensive solution. Process optimization may go hand in hand with materials recycling and intensified use of the product. Redesigning the product and radical process innovation may be necessary for resource substitution. So, practical experience shows that the resource strategies may influence and enhance each other.

Most of the resource strategies mentioned address more than one system level: materials, products, processes, the product chain, the product service system, the economic system, cultural values, etc. Each strategy that has an effective impact at one system level may result in additional costs and benefits at another system level or somewhere along the product chain. Consequently, the costs and benefits of the resource strategies are difficult to assess and in most cases are unevenly distributed across many stakeholders. Sound business cases demand transparency in costs and benefits along the chain. With many actors and interests at stake, the challenge is to build coalitions between these actors that enable a fair distribution of costs and benefits along the value chain so that actions may be taken from which all may benefit.

Figure 10.1 Levels of cooperation and co-creation: within the company or the value chain, within and between industrial sectors, with societal stakeholders



Multinational companies such as Unilever, Ahold, Mars and IKEA have learned that the implementation of sustainable resource management implies co-creation across international borders. It is only by building coalitions of businesses, civil society organizations and governments that the various interests of the stakeholders involved can be aligned. An illustrative and inspiring example is provided by the so-called roundtables initiated by companies, such as the global Roundtable on Sustainable Palm Oil, of which Unilever was one of the founders back in 2004. Roundtables bring together representatives of all links in the international chain of trade, including local businesses, unions, environmental organizations and local authorities. Together they conceive new and sustainable solutions that safeguard ecosystems and ensure reasonable incomes for local workers and their families. These experiences provide inspiring examples for other emerging business chains in shaping innovative coalitions for developing and implementing resource management strategies.

10.3. Creating the necessary conditions

We face the challenge of restructuring our industrialized economies from the present one based on an abundance of natural resources to a future economy that provides continuously improving goods and services for an increasing number of people, at prices they can afford, without unsustainable impacts and in ways that create jobs and true value (World Business Council for Sustainable Development, 2012). This truly represents a societal transition in which technological innovation goes hand in hand with the development of new business models, the building of new public-private partnerships, and new and supportive governance structures.

This last section presents an outlook on how governments and international bodies could enhance the necessary economic and societal conditions for 'absolute decoupling', resulting in more prosperity for more people using fewer primary resources and generating fewer impacts.

Pricing resources

The most common indicator of economic development, the Gross Domestic Product (GDP), has a systemic flaw. From the very beginning, GDP was never intended as a measure of progress or well-being. Its co-creator Simon Kuznets himself warned that 'the welfare of a nation can … scarcely be inferred from a measurement of national income as defined above.' And yet many policy makers, the public and the media have treated it precisely as such.

One key concern is that GDP only monetizes activities that have a defined and respected ownership. In this accounting convention, common goods such as ecosystems, biodiversity and species do not have a price, nor do environmental impacts. In the past, when human populations were small and resources were abundant, this was not a major problem. In our present society, however, this accounting convention eliminates important warning signals. A rising GDP might well mask a downturn in societal well-being and environmental quality. It might also weaken the incentives for resource efficiency.

Absolute decoupling would benefit if the societal and environmental impacts of resource extraction were to be monetized and incorporated in the market price of primary resources. True value pricing of natural resources, and of the unsustainable impacts of pollution and emissions, would influence consumer behaviour and drive companies to incorporate these externalities into their business strategies. It would discourage the overconsumption of resources and production beyond sufficient demand. Commitment to true value pricing would create an important stepping stone towards closing material loops and creating a circular economy. If we want a service-based economy to happen, an economy that favours repair and maintenance, that encourages the reuse of products and components, and that enhances the concept of shared ownership and product service systems, then it is vital that the development of these new services receives significant support. One option would be to reduce the rate of value-added tax on 'circular' services. Many of these changes would have to be coordinated on a European level, although regional (read: national) approaches should not be overlooked. Certainly, such changes present significant challenges for governments and international bodies, but perhaps in the end they are inevitable conditions for achieving green growth.

Radical innovations

In this book we have focused on best practices in industry. Some of these best practices represent innovations that have optimized current practices and can be implemented within the current societal, economic and technological models and know-how. Other best practices represent radical innovations that have involved redesigning the production process, substituting the resources used for more abundant resources, redesigning the product or radically intensifying its use, or even substituting products for services. The examples represent technological innovations such as waterless dyeing and bioplastics, and business innovations such as Pay per Lux and, last but not least, cross-sectoral innovations such as the Green Deal on phosphates. All of these examples of radical innovations present business opportunities in niche markets, but scaling them up will demand new and different economic, political and societal structures.

Substantial improvements in production and consumption patterns are needed if the needs of a global population of 9 billion are to be met without compromising the needs of future generations. Although many visions and strategies have been suggested, essentially we still do not know how to face this challenge. Nevertheless, it is good to note that in these various strategies three common elements can be discerned:

- Intense collaboration between knowledge institutes and industry in developing new technologies that will prevent the creation of waste and emissions or encourage the use of existing waste as a feedstock. One example of the latter is the use of carbon dioxide as a feedstock for the chemical industry.
- Intense collaboration between companies, both within product value chains and across sectors, in the codesigning of new and extremely resource-efficient products and services.
- Intense collaboration between companies and governments to identify and remove all possible barriers to enhancing resource efficiency in legislation, international agreements, market policies, waste management practices, and so on.

A new role for government

In its recent report, *Changing Pace,* the World Business Council for Sustainable Development (2012) presents a sharp analysis of limitations of the current role of government in sustainable development:

> Since the 80s, the notion spread that less government intervention is better for business and economic growth. Yet the resulting deregulated world, with its weak financial and multilateral governance, has a mixed record of progress. It also accumulates economic distress, social tensions and increased environmental risks. It deals badly

> with the magnitude, depth and urgency of our systemic challenges. Letting the "invisible hand" of the market sort out winners and losers in a vacuum of externalities, with a blind eye to the growing social inequality and the overuse of discounted natural resources, quashes the business case for the main beneficiaries to give up their power and initiate the changes. It only breeds the pursuit of business-as-usual, and resistance to change, except in the case of a close and direct crisis. In the current financial context, greener technologies and sustainable, inclusive business solutions are at a disadvantage when tested for short term returns. Their business case will not happen at scale and speed unless governments introduce measures to lower their barriers of entry and raise the costs, or remove the license to operate stranded assets and harmful practices.

The WBCSD makes it perfectly clear that *less* government regulation is no guarantee for success. Government is the only institution with the mandate to safeguard our future by taking measures that go beyond short-term interests. And government is the only stakeholder that is able to change the rules of the game through regulation. In Europe, for example, the introduction of the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)[1] regulation has had a significant influence on the use and development of chemical substances in Europe. REACH also influences supply chains with production (far) outside the European Union. Another example is the progress made in encouraging recycling in the Netherlands and the European Union. Although there is still room for improvement, there is no doubt that incentives to extend producer and retail responsibility have had a marked effect on the effectiveness of collecting end-of-life waste. Since Europe still represents the most wealthy consumer society worldwide, its potential to change production patterns should not be underestimated, even though many consumer products are now produced elsewhere. To enhance a breakthrough towards a circular economy, the European Union should discard legislation that imposes limitations on cross-sectoral or cross-national reuse and recycling. Additional regulations with respect to standardization of components and design rules that enable second life use would also be helpful.

There is a clear need for government intervention directed towards changing the rules of the game through a coherent set of policy instruments (either financial or regulatory). However, there is ample experience showing that *more* government regulation in itself does not provide any guarantee that absolute decoupling will indeed take place. Governments should continue to regulate where markets and businesses tend to neglect the public interest in the short or the long term. But governments should also develop new types of intervention to elicit and facilitate the societal transition towards a circular economy in the long term. One of the best practices, the Green Deal on phosphates, presented an inspiring example of a new type of government intervention. As

1 REACH is the European Community Regulation on chemicals and their safe use (EC 1907/2006), which came into effect on 1 June 2007.

the government representative in this Green Deal had no financial stake in any of the projects, he could play the role of mediator and broker between the parties involved in real or potential conflicts and bring it to a level that makes it easier to negotiate. Not from the outside, but as a committed partner, albeit with a focus on the public interest. Government as a broker, connecting companies, regulatory bodies, societal stakeholders and knowledge institutions in joint implementation of best practices and in groundbreaking innovation programmes. This new type of government intervention, inspired by a long-term vision of society and economy, is needed to ensure the availability of resources for our future.

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Resources for our Future

The publication *Resources for our Future* provides a very accessible account of the international resource question as well as an inspiring overview of industrial best practices. The authors clarify the main ecological constraints related to the use of a wide range of resources, such as water, industrial and construction minerals, and biotic resources. They present an analysis of the international trends that are shaping a geopolitical world order in which high resource prices and supply disruptions are becoming a threat to economic security.

Substantial steps towards green growth need to be taken soon if we are to ensure the availability of resources for our future, and to enable prosperity for all without crossing planetary boundaries. The book describes 21 inspiring best practices in resource efficiency in the chemical industry, the food sector, the building sector, the metal and high-tech industries, and the fashion and furnishing industries. These business cases demonstrate that innovation and entrepreneurship can result in substantial improvements in resource efficiency and that there are new business opportunities to be discovered in the resource question as well.

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