Technology Assessment

# Getting to the core of the bio-economy:

## A perspective on the sustainable promise of biomass

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Rathenau Instituut

The Rathenau Instituut focuses on the influence of science and technology on our daily lives and maps its dynamics; through independent research and debate.

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# Getting to the core of the bio-economy: A perspective on the sustainable promise of biomass

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# Foreword

Plant-based material is increasingly replacing fossil-based raw material such as petroleum, not only for energy purposes, but also as an ingredient in materials and medicines. This trend may mark the start of a major shift: the transition to a *bio-based economy* or *bio-economy*.

Hopes are high for the bio-economy. Like the Dutch government, the US, Chinese and Brazilian governments, the OECD, and the European Commission all expect great things from a bio-economy. The use of biomass may finally bring the long battle between economic interests and sustainability to an end. Such use may make it possible to reduce total $CO_2$ emissions.

The transition to a bio-economy will be far-reaching. It will involve much more than replacing fossil-based raw materials and introducing new technologies; society will need to change in a way that clashes with the status quo in some cases. The global economic system will change. New dependencies may arise. Countries with an abundance of farmland may gain a firmer power base compared with oil-producing nations.

Because the transition to a sustainable bio-economy is an international affair, we aim to use this study to engage in dialogue with others around the world. That is why we have had the report translated. Whether we are referring to policy, technology, or the social dimension, this analysis of the development of the bio-economy in the Netherlands can contribute to political and public debate about the bio-economy in other countries.

This study looks at how government can effectively guide the transition to the bio-economy. That transition involves a number of urgent social issues that require close attention, for example the use of genetically modified organisms, the rise of new global and national economic systems, and the potential negative effects of the bio-economy such as deforestation.

Our advice is the following: do not try to plan out the bio-economy on the drawing board and do not assume that the problems associated with existing technologies will be solved merely by introducing new technologies. Remember that the problems caused by the first generation of biofuels only became clear after we began using them. Learn by doing which applications are sustainable, feasible and desirable – and which are not. Do not ignore unsuccessful technologies, but instead try to learn from their failure. In all cases, apply a transparent set of sustainability criteria that has broad international support. Such criteria are vital to gaining the trust of producers, consumers, and governments in a sustainable bio-economy. Help those who develop promising technologies gain access to the market, which is sometimes dominated by conservative forces. The bio-economy

has already demonstrated its Utopian appeal, but it is only in everyday practice that it can realise its true potential.

We provide our recommendations in detail in the concluding chapter of this report. We hope that they offer the EU guidance as it develops its own bio-economy strategy. The EU is expected to announce its new strategy in late 2011, with discussion in the Council of Ministers following in early 2012. We hope that the Council agrees with our proposal to 'learn by doing' within a transparent framework of sustainability criteria.

But our world is much bigger than Europe alone. By examining the situation in the Netherlands, this report will also give stakeholders on other continents some notion of European political attitudes towards the bio-economy, and, in doing so, shed light on the differing strategies and opinions of the actors on the world stage. Whereas one stakeholder sees sustainability criteria mainly as a barrier to economic development, the other considers them a necessary condition. And whereas one regards the first generation of biofuels largely as a problem, the other sees them mainly as an opportunity. We hope that this report will contribute to the much-needed global debate on the sustainable bio-economy.

***Mr. drs.*** **Jan Staman**
director Rathenau Instituut

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# Executive Summary

The bio-economy is a highly promising prospect for a more sustainable economy. Ideally, the bio-economy should be an efficient economic system that produces no waste and no longer relies entirely on fossil-based feedstock but runs mainly on biomass, i.e. plant-based raw materials such as trees, other vegetation and algae, and animal material such as offal and cooking fat. Our study shows that the bio-economy only really has a future if it is ecologically sustainable, socially just, and publicly supported.

The proposed transition to a sustainable bio-economy will not be smooth or trouble-free. Chapter 5, the historical review, makes clear that we are dealing with transition processes that will take several decades to unfold and that are highly unpredictable in nature. The future is, as it were, still obscure. We have identified four major challenges for policy on the road to a sustainable, socially just and publicly supported bio-economy. These four challenges are related to the value pyramid, sustainability criteria, innovation strategy and notions of naturalness. Here we summarise these challenges and our recommendations to tackle them.

## Ascend the value pyramid

The first challenge is to make the core of the bio-economic concept – optimal biomass valorisation – a policy imperative. Because the political debate has emphasised the potential negative effects of biofuels, we have lost sight of the possibility that we can make more efficient use of biomass, achieved by means of optimal valorisation. In other words, derive the most economically valuable components from the biomass first – for example, those that can go to produce food or chemicals – and use what remains for low-value applications such as energy. Optimal biomass valorisation appears to offer enormous economic and ecological opportunities and is also supported by a wide range of social actors. Dutch and European policy does however not firmly support the bio-economy concept at the moment but instead promotes less optimal applications such as biofuels from feedstock that can also be used for food.

If we view the situation from the perspective of the value pyramid, then the approach should be clear: using biomass for food must take precedence over using biomass to generate energy and chemicals. Biomass policy should focus on getting biomass to ‘ascend’ the value pyramid as much as possible. This should also be the aim of cross-ministerial (and international) policy coordination. Additionally bio-economy policy should look more closely on how to make farming practices more sustainable, for example by making the agricultural system less dependent on fossil fuels (low carbon agriculture) and by encouraging less wasteful forms of consumption. Both targets should become an integral part of the value pyramid.

### We need sustainability criteria

The second major challenge is to monitor the sustainability of the bio-economy. The large-scale use of biomass does not in itself guarantee sustainability, let alone a socially just world economy. What is needed is an internationally harmonised system for monitoring the negative effects of biomass use that can count on international support. Although it is not easy to operationalize sustainability, tangible criteria are needed. These criteria should be based on a broad definition of sustainability, one that takes local development, human rights, social justice and similar issues into account.

We claim that operationalizing the sustainability of biomass use should be organized as an ongoing learning process in which policy-makers involve as many civil society organisations as possible at international level and consider the sustainability of agriculture and of patterns of consumption as well.
The Netherlands should continue to lead the way when it comes to biomass sustainability criteria. Its work should involve operationalizing the criteria, boosting international support for them, investigating the most suitable approach to monitoring, and reflecting on the usefulness, necessity and side-effects of the criteria. We should assume that in the long run, sustainability criteria will apply for all the various uses of biomass. The growing public demand for value chain transparency and the quest to arrive at a sustainable bio-economy indicate that this will happen in the future.

### Combine 'learning by doing' with 'proceeding with caution'

The third overriding question in public debate is whether the best route to a sustainable bio-economy is one of 'learning by doing' or 'proceeding with caution'. According to the first view – the view supported by trade and industry – the economy cannot be changed overnight. We need the existing economic resources and structures in order to develop new technologies. Even if some applications in themselves are not sustainable, such as first generations biofuels, they will help us to arrive at a sustainable bio-economy by 'greening' the existing economy without creating economic instability. A gradual transition of this kind may open our eyes to the possibilities that bio-based feedstock offers. It will, for example, allow us to develop a number of chemical biomass applications based on knowledge derived from production of the first generation of biofuels. This view, that new technologies and economic practices will become more sustainable step by step is based on optimism.

According to the second view – supported primarily by environmental organisations – the first generation of biofuels are in fact a barrier on the road to a truly sustainable economy. To begin with, the first generation of biofuels is not making the economy 'greener' at all, because their carbon footprint is often larger than that of fossil fuels. There is a further risk that this unsustainable type of bio-economy will be so successful that it becomes very difficult to change. This view alerts us to the possibility of a socially unacceptable lock-in effect, i.e.

encouraging unsustainable practices under the guise of sustainability. Both viewpoints have much to teach us, and appear to be complementary rather than mutually exclusive.

The first generation of biofuels gives us the opportunity to prepare ourselves to use other biofeedstock while making use of the existing social and economic infrastructure. This will allow us to acquire a better understanding of the properties of biomass, to encourage experimentation with sustainable agriculture, and to comprehend the complex social debate and how to deal with various issues. We can draw lessons from the problems encountered with the first generation of biofuels and show how they can be solved. The first generation of biofuels can in this way blaze a trail for more efficient solutions.

We should however not blindly assume that the first generation of biomass applications is unsustainable and that the second and third generations will be sustainable. We should judge every technology on its merits according to objective sustainability criteria. Every application will have to be evaluated on its merits. It will also help to support the intelligent social and economic incorporation of biomass applications into the existing social and economic system, thereby encouraging the rise of a sustainable bio-economy, for instance by designing a favourable tax-system for more sustainable applications of biomass.

### Be clear about genetic engineering and sustainability

The fourth and final challenge concerns how we deal with natural resources and nature. The bio-economy joins natural, bio-based raw materials to mechanised, optimised processes in order to create an efficient production system. Plants are no longer used merely as food, animal feed or clothing; they also serve to produce chemicals and generate energy. This means shifting the dividing line between 'natural' and 'synthetic' as society understands these categories today. That shift merits attention, because these categories may play a crucial role in the relevant public debate with genetic engineering as the prime example.
The bio-economy concept is associated with two contradictory images: will it lead to a society that lives in harmony with nature, or one that is in fact out to completely subdue nature? The bio-economy can be regarded either as green and harmonious or as mechanistic, soulless, and industrial. The latter interpretation, in which the bio-economy is about controlling nature, has raised suspicions among many civil society organisations. Genetic engineering plays a key role in that discussion.

It must be absolutely clear that GM crops can satisfy sustainability criteria, for example by demonstrating that they contribute to more efficient biomass use. But even if GM crops do satisfy sustainability criteria in the instrumental sense, public acceptance of them is far from assured.

Government must explain its underlying view of the bio-economy in the most

explicit terms possible, for example by making clear that the industrial development and processing of bio-based organic feedstock as well as genetic engineering are in the service of sustainability, and that sustainability often takes shape in large, mechanised complexes instead of in idyllic, self-sufficient agricultural settings. If it fails to do so, the public may start to suspect that it is being sold the image of a harmonious green future when the reality will be much less idyllic, namely involving genetic engineering and industrialized large scale agriculture. It will furthermore be necessary to make a sharp distinction between genetic modification in industrial biotechnology (white biotech) and plant biotechnology (green biotech). Green biotechnology applications based on genetic modification are likely to continue provoking public resistance, more so than other advanced plant improvement techniques. There is little disagreement about genetically modified micro-organisms and enzymes used to produce medicines and biochemicals, biomaterials and biofuels (white biotechnology). White and green biotechnology will grow more closely entwined as the bio-economy continues to develop. Considering the controversial nature of this issue, government would be wise to continue making a sharp distinction between the two domains of genetic modification in its policymaking. When it comes to GM plants in particular, sustainability criteria and public acceptance are critical success factors in the continuing development of a bio-economy.


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# 1 The bio-economy: fertile soil for policy targets

Lotte Asveld, Rinie van Est and Dirk Stemerding

Is our economic system on the verge of a transformation? According to various visionary scientists and policymakers, it most certainly is. They have forecast the rise of an economy based on biological materials, i.e. the 'bio-based economy' or simply 'bio-economy'. At the moment, we live in a petroleum-based economy. The question is how long it can continue. Some experts believe that world oil production has in fact already peaked (Hirsch, 2007). Our use of fossil fuels is also worrying: it leads to emissions of $CO_2$, a gas that is changing our climate. The spectacular rise of emerging economies such as China and India has also increased the demand for fossil and other raw materials enormously. As a result, all around the world – including in the Netherlands – the quest has begun for new sources of energy and materials. "What Germany did for solar energy and Denmark for wind energy, the Netherlands must do for bio-based technology," according to the former Dutch Minister of Agriculture, Nature and Food Quality, Gerda Verburg (Ebbers, 2010: 16).

The underlying premise of the bio-economy is that biomass will constitute the key feedstock and photosynthesis will be the most important production mechanism. Biomass consists of plants, wood, and algae, but also of offal. These ingredients are fed into the process of biorefinery, where enzymes or bacteria help convert them into sugars, fibre, proteins and synthetic gas, the components of products such as biofuels, bioplastics and medicines. They can be also be treated by thermal processes that use heat to generate energy. The hope is that the bio-economy will solve many of the problems that currently beset our economy, and that it will create new economic opportunities at the same time. The Dutch government is not the only one thinking in these terms. The governments of the USA, the European Union and Brazil also believe that biomass offers many opportunities.

A transition of this kind will be quite far-reaching. Right now, the bio-economy is an ideal. We have only just begun to turn it into reality. It is a huge undertaking to reorganise a petroleum-based economy and turn it into a bio-economy. That will require new production lines and new alliances that may be resisted by the powers that be. As with any far-reaching change, the question is whether the original goals – sustainability, innovation, more independence – can in fact be achieved, and at what price. The present study explores what issues society faces in a possible transition to a bio-economy.

In this introductory chapter, we begin by reviewing how various scientists and policymakers, both in the Netherlands and elsewhere, describe the bio-economy ideal. These descriptions reveal their hopes, but also indicate what changes will be required to turn their dream into reality. We started off referring to the 'bio-based economy' – the term commonly used in Dutch – but we will refer to the 'bio-economy' in the rest of this publication. This is the term used most often in international circles, and it basically refers to the same idea. At the end of this chapter, we describe how the rest of the report is organised.

## 1.1 Views on the bio-economy

Numerous documents have been published in the Netherlands and elsewhere describing – and thereby promoting – the ideal of an economy that runs on biological materials. We have clearly entered a phase in which we are developing a greater and more explicit understanding of what the bio-economy is. This section looks at how policymakers, scientists and businesses are shaping the concept of the bio-economy. We begin by describing why the bio-economy is being put forward as an ideal, and the problems that it might be able to solve for society. We then describe the technologies required to make the transition to a bio-economy possible. Finally, we explore what the various documents say about controlling the negative effects that may arise during such an enormous change in our economic structure.

Our description of the bio-economy concept is based on seven prestigious documents published by key Dutch and international organisations. The Dutch documents are: *Overheidsvisie op de bio-based economy in de energietransitie* [Government's Strategic Agenda for the Bio-Economy], by the then Ministry of Agriculture, Nature and Food Quality (LNV 2007), and an advisory report by the Social and Economic Council (SER) in 2011. The other documents are: E*n route to the knowledge-based bio-economy* (The Cologne Paper), by the European Commission under the German Presidency (2007) and *The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges*, also published by the European Commission under the Belgian Presidency (2010); the policy paper *Biomass Multi-Year Program Plan* by the US Department of Energy (DOE, 2010); and The Bioeconomy to 2030 by the OECD (OECD, 2009). The two publications by the European Commission (2007 and 2010) do not necessarily reflect the opinions of the Commission but in fact express the views of various international groups of scientists who have inspired the EU's policy. Finally, we have also made use of the personal views of scientist Robert H. Carlson (2010) as documented in his book *Biology is Technology: The Promise, Peril, and New Business of Engineering Life*.

### 1.1.1 Arguments in favour of the bio-economy

The first question that must be posed when considering a particular view of the bio-economy is: why? Why are so many different parties pushing to use biomass as a feedstock? What problems can the bio-economy solve? All the documents

reviewed for this report basically put forward the same five arguments in favour of encouraging the transition to a bio-economy: sustainability, climate change, energy security, self-sufficiency, and economic opportunities. Some of the authors – the OECD, the authors of the Cologne Paper, and Carlson – also include health considerations. Because healthcare has its own dynamic that the Rathenau Instituut has discussed in other publications,[1] we will disregard that aspect in this report.

**Sustainability**

Sustainability is one of the key shared objectives in each of the aforementioned documents. As the OECD expresses it: "The emerging bioeconomy is likely to be global and guided by principles of sustainable development and environmental sustainability" (OECD, 2009: 22). The European Commission's publications also note the possibility of a sustainable society based on plant material:

> "The growing demand for a sustainable supply of food, raw materials and fuels is the major driving force behind the KBBE (Knowledge Based Bio-Economy, *red.*). A giant leap in agricultural production and yields - at least by a factor 2-3 - will be needed within the next two decades. This must be achieved in an ecologically sustainable way, e.g. by avoiding large losses." (Europese Commissie, 2010: 6)

> "The expected rapid development in plant biosciences will greatly facilitate the transition to a renewable, resource-oriented economy in the areas of energy, chemicals and materials - especially when combined with microbial biotechnology." (Europese Commissie, 2010: 11)

The Dutch government has also made sustainability a key objective, focusing in particular on the three familiar aspects of people, planet and profit. 'People' involves retaining the current level of (rising) prosperity; 'planet' refers mainly to combatting climate change; and 'profit' means the economic opportunities available to Dutch businesses (LNV, 2007: 15).

**Climate change**

Climate change is considered the biggest threat to a sustainable society: "On a global scale, climate change is regarded as one of the most challenging issues to be addressed right now" (European Commission, 2007: 4). The Social and Economic Council, a Dutch consultative body made up of a wide spectrum of civil society organisations, was asked by the Dutch government to advise it on the bio-economy. It said in the relevant advisory report that:

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1 For example *Medische technologie: ook geschikt voor thuisgebruik* (2009) and *Nader gebruik nader onderzocht. Zeggenschap over lichaamsmateriaal* (2009).

> "Climate considerations should, after all, be regarded as among the most important reasons behind the bio-economy, and the use of biomass should lead, at the very least, to improvements in relation to climate change."
> (SER, 2011: 82)

**Energy security**

Another frequently cited objective is energy security. The US government is most explicit about this: the aim is to keep cars on the road even when oil reserves shrink.

> "Biomass is the single renewable resource that has the potential to supplant our use of liquid transportation fuels now and help create a more stable energy future. Using our indigenous biomass resources, we can potentially fuel our cars and provide new economic opportunities across the nation."
> (DOE, 2010: i)

The use of biofuels will allow us to maintain the existing infrastructure for motorised vehicles. Biofuels are therefore more appealing than switching to cars run on hydrogen or electricity, as both of these would require us to make many more adjustments.

**Self-sufficiency**

Although biofuels offer us a way of making the transition to a sustainable world while retaining existing systems, they may even lead to new economic structures. For example, production of biofuels can be decentralised if waste becomes a major source of raw materials.

> "Conversion of municipal waste to liquid biofuels would provide a valuable and important commodity in areas of dense human population, exactly where it is needed most. Thus microbial production of biofuels could very well be the first recognizable implementation of distributed biological manufacturing. Someday soon, there is a very real possibility of fueling up your car with biofuels produced within your own neighborhood."
> (Carlson, 2010: 170)

Local fuel production would offer the ultimate form of autonomy from other countries. We would not only be able to continue driving our cars, but also produce our own fuel. At long last, we would rid ourselves of the galling bonds with politically problematical regimes in oil-producing nations, and do so with clean-energy solutions! This is an inviting prospect not only for the developed world, but also for developing nations, as the SER reports:

> "Local bio-energy production can reduce dependence on fossil fuel imports. Many of the poorest countries on earth are net importers of oil. What they spend on oil cannot be spent in other crucial areas. Some developing

> countries spend six times as much on oil imports as on healthcare. A heavy dependence on oil imports is also a serious drain on household income and business operating costs." (SER, 2011: 91)

**Economic opportunities**
Energy security and domestic economic opportunities are often mentioned in the same breath. The shift to local production can certainly serve to stimulate the domestic economy. That is in any case a key element in the US's position on the bio-economy, given the enormous amount of farmland available there.

Although the Dutch authorities are extremely international in outlook, they also recognise the opportunities of the bio-economy for the domestic economy. The Netherlands does not have much disposable farmland and will have to depend largely on biomass imports in order to achieve a bio-economy. However, it does have other facilities – indeed, some unique ones – required by a bio-economy. The Dutch government therefore believes that the Netherlands can play a significant role as a node in the international bio-economy.

> "Both the authorities and the business sector believe that the transition to a bio-economy can create exciting opportunities for Dutch businesses and the regions in which they are located. These opportunities are the result of the existing structure of the Dutch economy, which already features precisely those parties that will play a key role in this transition: agriculture and the agro-industry, which will provide the feedstock and are already utilising various biorefinery techniques; the chemicals industry for processing intermediate and end products; transport and logistics, which will take care of distribution; and energy producers, which will deliver the power that drives all the rest. No other country in the European Union has a concentration of such activities like ours." (LNV, 2007: 15)

The international nature of the Dutch bio-economy means that it will also impact other countries. According to the Dutch government, biomass production will offer developing countries in particular many economic opportunities. The OECD (OECD, 2010: 193) also sees a key role for developing countries that will be delivering a growing share of energy and materials to the global market.

### 1.1.2 Instruments
What means will be used to create the bio-economy? Below we describe five main instruments that the various parties identified above consider crucial. These are: biorefinery, efficient chain management, developing new resources, genetic modification, and an open and innovative market.

**Biorefinery**
In a bio-economy, all forms of biomass basically undergo a process of refinement. Bio-refinery is comparable to conventional refinery, in which petroleum is

converted into a wide range of different products, for example fuels (diesel, kerosene), and the feedstock for chemicals and plastics. In bio-refinery processes, however, the raw material is biomass, not petroleum. There are many different types of biomass to choose from. Some, like food products, are already important factors in the economy. Others, like waste, already exist but have so far had little economic value. Still others only exist on paper, for example products made of synthetic bacteria. The methods used to produce and process such feedstock also vary widely, from common processes such as incineration and gasification to more technologically advanced processes such as industrial biotechnology and synthetic biology.

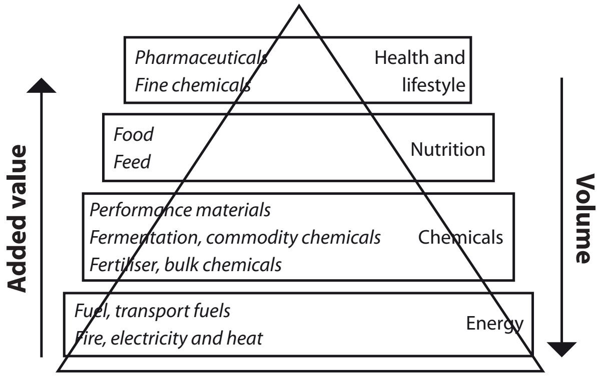
> "Biorefineries of the future will be able to extract novel, value-added compounds, like fine chemicals, and convert the remaining biomass into energy or building blocks for chemical synthesis, leaving only small amounts of waste whose inorganic components could be recycled for use as fertilizer. Process technologies required for a zero-waste biorefinery will be available by 2020, at least at the level of semi-commercial demonstration plants." (European Commission, 2007: 6)

The Dutch authorities view 'cascading' as essential to the biorefinery concept. Cascading involves first obtaining the most valuable products from biomass and only then the lower-value products; what is then left is used to generate energy. In line with the views expressed in the Cologne Paper, then, the point is to derive the highest value from all the various parts of a plant. Every part of the plant can be used: the process produces zero waste.

The US government, on the other hand, is not as keen as the Dutch government to obtain the highest-value products from biomass first. The US biomass programme was born out of the country's need to have access to renewable sources of transport fuels, and that aim is often cited as the most important. Nevertheless, the US government also believes that biorefinery can only be profitable if a variety of different products can be produced simultaneously.

> "Most bio-derived products are now produced in facilities dedicated to a single primary product, e.g. ethanol, biodiesel, plastics, paper, power (corn wet mills are an exception). …Ultimately the industry is expected to move toward large integrated biorefineries cost-effectively producing biofuels, high-value bioproducts and potentially cogenerating heat and/or power for onsite use." (DOE, 2010: 1-6)

**Figure 1.1:** 'Value pyramid'




Source: LNV, 2007:19

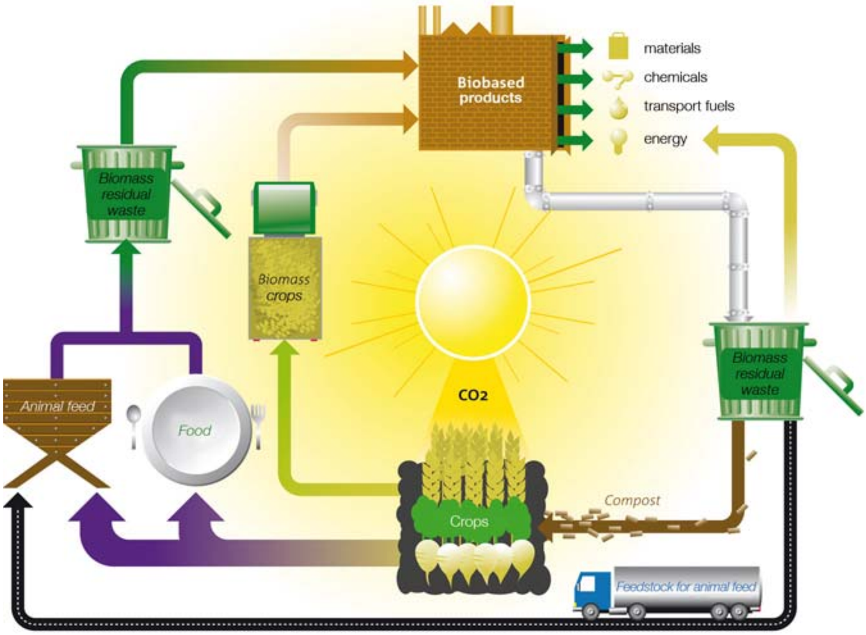
**Efficient chain management**

Efficiency is the key to the bio-economy, according to the Dutch government. That means using waste as a potential source of functional material. It is not an option to expand the amount of land devoted to agriculture in the Netherlands, but the Dutch agro-industry does produce many by-products that can be used more efficiently than they are now. That is precisely where the Dutch are seeking to increase the potential of biomass:

> "….we can go a long way towards meeting the growing demand for biomass by making the food chain more efficient. In particular, this involves using less energy, utilising by-products and waste, and using different raw materials to do what we do now." (LNV, 2007)

This view is illustrated on the next page.

**Figure 1.2**




Source: LNV, 2007

The sun is the main source of energy, and some clever logistical planning prevents even a cell of biomass from being lost. The chain hence becomes a closed loop. This means that materials that are not currently part of the economic system, or only marginally so, will offer new opportunities for economic growth.

## Developing new resources

The idea is that biorefinery can turn all kinds of material into functional intermediate or end products. That includes material that we now still regard as waste.

If waste is in fact utilised efficiently, it will solve an important problem that has so far stood in the way of the bio-economy. Biofuels are the most important bio-economic application, alongside biomass incineration as a source of heat. In many cases, biofuels are still produced from food crops such as maize, sugarcane and palm oil – the 'first generation' biofuels – but this has led to quite a few problems. Specifically, the first generation of biofuels competes with food, whereas the demand for food is only set to increase in the future. Most stakeholders regard the use of food crops for biofuel as temporary, and have high hopes for future applications that will primarily use non-edible biomass as a feedstock. The Chinese government, for example, will no longer issue licences for the production of biofuels from food crops (Zhong, 2010).

Lignocellulose, which is found mainly in the woody parts of plants, may be a suitable substitute. The technology needed to convert lignocellulose into fuel appears to be within reach.

> "It is anticipated that by 2020 or earlier the conversion of ligno-cellulosic biomass (straw, wood, etc.) by enzymatic hydrolysis will have become standard technology and will open up access to large feedstock supplies, thus avoiding direct competition with food production."
> (European Commission, 2007: 8)

The US government is also banking on lignocellulose, in part because the technology is already quite advanced and in part because there is already a market for ethanol, which can be made from lignocellulose (DOE, 2010: 1-5).

In addition to using existing forms of biomass, such as food and by-products, governments and scientists are also searching for new biomass sources. Carlson (2010: 165-6) has identified elephant grass (*Miscanthus*) and switchgrass (*Panicum virgatum*) as alternative energy crops. Another relatively well-known example is jatropha (*Jatropha curcas*), a plant with oil-bearing seeds; the oil can be used in engines without further processing. Because the plant grows easily on poor soil, it does not compete with food.

**Genetic modification**
Governments have high hopes for genetic modification (GM) in their quest to find the best forms of biomass. To begin with, biomass can be genetically modified to meet specific needs.

> "By 2030 energy crops that store more energy (in terms of GJ/ha) and can be used in their entirety will have become available from advanced breeding technologies, including genetic engineering. Varieties of energy crop plants adapted to different local conditions should achieve an additional increase of biomass. Plants considered as weeds in some regions could be cultivated and improved to deliver annual biomass yields above 30 odt/ha [odt: oven-dried tonne, Ed.]. The increased efficiency of nutrient uptake should reduce the use of fertilisers which partly have to be imported from outside Europe and are generally expensive and energy-consuming to produce and transport." (European Commission, 2007: 7)

Genetic modification also opens new doors when it comes to converting biomass into functional products, not to mention the opportunities created by synthetic biology.

> "The fermentation of sugar to produce ethanol and butanol will be short-term solutions. The strategy of improving the biofuels production pathways in existing organisms will rapidly be supplanted by new organisms, modified

> via metabolic engineering and synthetic biology, that directly convert feedstocks into transportation fuels similar to gasoline. The application of these technologies is already well past academic exploration and into commercialization." (Carlson, 2010: 168)

The bio-economy therefore appears to be headed for a rosy future. Although the initial steps are based on existing types of biomass, many are eagerly awaiting the succeeding generations, such as genetically modified varieties of algae. Another example is biosolar cells, which improve the process of plant and cell photosynthesis to produce liquid energy carriers. In short, we expect to see a change from using edible crops to using crops that have been genetically modified specifically to meet the demands of the bio-economy.

**Open innovative market**

According to all the documents reviewed for this report, for the bio-economy to succeed there must be a competitive commercial market in which innovation is given free rein. Both the Dutch and the US governments believe that they have a role to play in this market as 'launching customers', i.e. using their procurement policy to stimulate the market for bio-based products. In addition, there are also funding schemes that support new technologies. Both Carlson and the authors of the Cologne Paper advocate keeping regulatory measures to a minimum and harmonising them internationally as much as possible.

The authors of the Cologne Paper are also in favour of making the European investment climate as attractive as possible, for example by maintaining a low tax rate for biotechnology firms. Both Carlson and the OECD want knowledge to be readily accessible, with patents not impeding information-sharing.

### 1.1.3 Managing the negative effects

Like many technological advances, the bio-economy is likely to have negative effects as well. It can, for example, have undesirable social consequences for some stakeholders. Various authors have addressed this subject and suggested instruments for keeping the effects within reason.

**Food and biodiversity**

This chapter has already touched on the competition between food and fuel. Biomass that is used to produce energy or material can no longer be eaten. It can also have a negative impact on biodiversity: it requires land that cannot then be used for other purposes.

> "The impact on food security is one of the core social factors to be conside-red in the development of the use of renewable resources for biofuels and material use in biorefineries." (European Commission, 2010: 6)

The bio-economy may not turn out to be entirely positive for developing countries in this respect. Indeed, the status of the developing world in the bio-economy is a source of worry for the Dutch government, which has, after all, decided on an international course of action in which developing countries play the role of producer. "It is naturally important to guard against any negative effects on local circumstances, for example local food production and the affordability of energy carriers" (LNV, 2007: 15). Such concern about negative effects in other countries is not one shared by the US government, which focuses mainly on domestic production.

**International regulation**
A number of options are suggested for dealing with these potential negative effects. The Dutch government is a strong advocate of biomass certification, a view that is shared by the authors of the Cologne Paper. A certification system can ensure that biomass is in fact sustainable. It would let businesses know what criteria they must meet to practise corporate social responsibility. One proviso is that the system must be set up to operate internationally.

> "A properly functioning international market for sustainable biomass is of huge importance for the EU in general and for the Netherlands in particular. We will therefore be seeking to collaborate internationally in the most appropriate forums (including the EU, FAO, UNCTAD, OECD, ISO and UNEP) in order to ensure that the sustainability criteria that are ultimately developed have broad support among stakeholders." (LNV, 2007: 22)

The European Commission's 2010 report also calls for international monitoring of sustainability.

> "Addressing sustainability issues through all segments of the value chain of bio-based products (from biomass production to end-use) in a fair, evidence based regulatory framework, is a major challenge for biofuels and other bio-based products. In doing so, the sector has to demonstrate that it possesses sustainability credentials in order to gain a strong 'license to operate' from governments and consumers, especially if supporting policies have to be developed. Unfortunately the lack of widely-accepted schemes to assess and confirm sustainability is a significant barrier to consumer and government confidence." (European Commission, 2010: 9)

In their quest to develop international regulatory and incentive frameworks for the bio-economy, the Dutch government and the European Commission have the approval of the OECD, although it does not explicitly support the use of sustainability criteria. Instead, the OECD focuses mainly on biotechnology, with genetic modification playing a major role. It sees many opportunities in this

area, but cites as a proviso that safety must be monitored internationally, in particular because developing countries are likely to play a huge role in producing biomass. Such countries often do not have the necessary facilities to monitor safety and sustainability.

> "International agreements to promote collaborative research, regulatory systems, and market incentives for the use of biotechnology will likely be essential to addressing many global problems. …Regulations should not be unduly burdensome, but they must also protect the public interest in safety and/or efficacy." (OECD, 2009: 289)

The authors of the Cologne Paper are particularly worried about the fragmented nature of European legislation.

> "EU legislation needs to be fully and correctly transposed into national law. In addition, the implementation of EU legislation is not always harmonised across the member states, which leads to inconsistencies, such as diverging national requirements and guidelines. … Regulatory improvements should aim at simplified, transparent, science-based procedures, while at the same time maintaining a high level of safety." (European Commission, 2007: 16)

The US government has nothing to say about international regulations, but it does argue in favour of more research into the potential negative effects on the environment and food supply, leading to a systematic evaluation of those effects.

> "A systematic evaluation of the impact of expanded biofuels production and use on the environment and food supply for humans and animals is lacking. Analytical tools to facilitate consistent evaluation of energy benefit and greenhouse gas emissions of all potential biofuels feedstocks and production processes are needed." (DOE, 2010: 1-14)

This approach embraces 'consistent analysis' in order to understand negative effects, but does not interpret it as a need for actual legislation. Indeed, the American author Carlson has major doubts about attempts to regulate bio-technology.

> "Those arguing for attempting to improve safety and security through regulation and restriction must demonstrate successful examples of such policies within market economies. Front-end regulation will hinder the development of a thriving industry driven and supported by entrepreneurs and thereby engender a world that is less safe. (Carlson, 2010: 239)

Although a number of stakeholders think that regulation can only be successful in an international context, opinions worldwide differ considerably as to the

usefulness of regulation. Even in the Netherlands, there are those who question the usefulness of instruments such as sustainability criteria, as we will see below.

**Public acceptance**

In addition to its potential negative impact on humans, animals and the environment, the bio-economy will also have a social dimension that various stakeholders believe should be considered. For example, the OECD and the authors of the Cologne Paper call for dialogue with society and industry in order to facilitate the transition to a bio-economy.

> "Governments should create an active and sustained dialogue with society and industry on the socio-economic and ethical implications, benefits and requirements of biotechnologies." (OECD, 2009: 292)

> "…the following remedies still seem very relevant: intensify the dialogue with the public, address the problems, stick to the facts. The key persons are scientists, farmers, NGO experts, and opinion leaders who are essential to building trust. It should be accepted that in Europe there will always be two schools of thought about biotech: a more progressive one vs. a very cautious one. Too aggressive campaigns aimed at changing public opinion can be counterproductive." (European Commission, 2007: 13)

Oddly enough, the Dutch government does not appear to have any intention to engage in dialogue with the public, although the Dutch have in fact often resisted government policy on biotechnology. The American government is also silent on the topic of social dialogue. In its view, public acceptance of the bio-economy will come from the quality, value and safety of the products (DOE, 2010: 1-14). The Dutch government does not even refer to 'public acceptance' in its documents. That may be because it sees the success of the bio-economy as depending largely on acceptance by industrial users, rather than end users.

**Existing structures**

Technological advances and dissemination can be impeded by a lack of public acceptance. On the other hand, society can also be disrupted by new technologies.

> "Biotechnological research is generating innovations that will disrupt current business models and economic structures. …Although a difficult challenge, policy makers will need to implement flexible policies that can adapt to and support socially and economically beneficial disruptive and radical biotechnologies." (OECD, 2009: 290)

If a society that runs largely on petroleum switches to bio-based fuels and materials, it is likely to undergo many changes in the process. The OECD is the only stakeholder that mentions this explicitly as a point of concern. Most of the

others see the necessary social changes mainly as obstacles on the road to an effective market. That is true of the US government:

> "Energy production from biomass on a large scale will require careful evaluation of U.S. agricultural resources and logistics, as these will likely require a series of major system changes that will take time to implement." (DOE, 2010: 1-13)

The US government is worried about not having the right infrastructures or assurances for potential investors. The Dutch government is also somewhat worried about industry's willingness to explore new avenues.

> "Industry has invested heavily in production and knowledge, much of which has yet to be written off, and it is loath to destroy capital by investing in new knowledge and technology." (LNV, 2007: 21)

In its advisory report, the Social and Economic Council describes various instruments for stimulating the bio-economy, for example taking negative effects on the environment into account in the price of products and repealing prohibitive rules (such as existing legislation on waste) that make it impossible to recycle residual waste streams (SER, 2011).

## 1.2 Guide to this publication

The documents referred to above show that there are high hopes for the bio-economy. At the same time, the transition will require a great deal of political support, technical and economic conversion, and social and organisational change. Nor are the stakeholders that regard this economic change desirable entirely blind to potential negative consequences.

The present report explores the significance for society of an economy based on biological materials in the following way.

Chapter 2 describes the role that the concept of the bio-economy plays in the Dutch policy context. As the documents produced by the former Ministry of Agriculture, Nature and Food Quality and the Platform for Bio-based Raw Materials show, the bio-economy concept is a recent one. We look at how it has been adopted by politicians and policymakers in The Hague and show its interaction with older political discussions and policies, for example those concerning the use of biofuels.

Chapter 3 looks at the public debate under way in the Netherlands concerning the broad area embraced by the bio-economy concept.

Chapter 4 looks at matters from a technological perspective. Where does the technology stand and what challenges lie ahead?

The bio-economy is not simply the future. The Dutch economy was based on biological resources In the nineteenth century as well. Compared with today, however, people lived in impoverished circumstances to which we have no wish to return. Chapter 5 therefore explores the past: how did the Netherlands move from widespread indigence based on biological raw materials to our present economy based on fossil fuels? Reviewing the past can give us a better idea of what our society will be required to do if we wish to move towards a new bio-economy.

Chapter 6 gives an overview of the lessons learned from the previous chapters. We conclude this study with a closing chapter in which we identify a number of concerns that merit the attention of policymakers.

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2

# 2 Bio-economy policy: inspiring but not leading

Doenja Koppejan and Rinie van Est

## 2.1 Introduction

The bio-economy as a policy concept is an attempt to integrate various already existing policies into an all-encompassing sustainable economy. Previously designed policies concern the use of biomass to generate energy and transport fuel. The bio-economy concept prescribes that these uses of biomass become subject to the cascading model. The integration of previously existing policies makes the transition to a bio-economy a huge challenge for policymakers in the Netherlands, also because such a transition touches on issues related to the climate, energy, trade, agriculture, food supply, knowledge generation, biodiversity, and transport (LNV, 2007: 5). This chapter describes how the Dutch authorities are meeting this challenge.

We begin by reviewing the background of the Netherlands' policy on biomass as a source of electricity and heat and biofuels. Policymakers have been interested in biomass for decades. In the 1980s, they attempted to find new markets for agricultural products under a policy of 'agrification', i.e. growing crops for industrial applications. Since the 1990s, they have turned their attention to using biomass to meet the Netherlands' energy requirement. This policy encourages the use of biomass to generate electricity and heat and to produce biofuel.

Section 2.3 looks specifically at the bio-economy policy, which first appeared on the Dutch policy agenda in 2007. That policy specifically targets the use of biomass to generate energy (co-firing and blending) but also for chemical and other purposes. Section 2.4 considers the interaction between the above-mentioned three lines of policy and the extent to which the new policy domain of 'bio-economy' succeeds in linking these separate lines into a single, coherent story. We close with a number of conclusions concerning the task that government faces today.

## 2.2 Policy on using biomass for electricity and heat

The Dutch government has encouraged the use of biomass to generate electricity and heat in recent years. One important reason for its support was to reduce emissions from coal-fired power plants. Biomass also fits in well with government's broader aim of moving the country towards a more sustainable, dependable, and affordable energy supply. This section reviews a number of milestones in the Dutch government's policy (see Table 2.1).

**Table 2.1** Milestones in the Dutch government's policy on using biomass for electricity and heat

| Year | Policy |
|---|---|
| 1995 | *Third White Paper on Energy*: 5% of all energy from renewable sources by 2010 and 10% by 2020 |
| 1997 | Netherlands signs the Kyoto Protocol |
| 1999 | *White Paper on Climate Change Policy Implementation* gives co-firing extra support |
| 2000 | *White Paper on Renewable Energy*: 4.4% of all renewable sources of energy to be based on biomass and waste by 2020 |
| 2001 | Ministry of Economic Affairs, *White Paper on Long-Term Energy Supply* |
| 2002 | Introduction of 'MEP' grants (intended to encourage environmentally responsible generation of electricity)<br>Instalment of Energy Transition Platforms |
| 2006 | MEP grants discontinued |
| 2007 | White paper, *Clean and Efficient: New Energy for the Climate*: 20% of all energy from renewable sources by 2010<br>'SDE' incentive scheme promoting renewable energy succeeds MEP scheme<br>Bio-based Raw Materials Platform: *Energy Transition Green Paper* (target: replace 30% of all fossil raw materials by bio-based raw materials by 2030) |
| Late 2008 | Agreement on the EU's Renewable Energy Directive (RED): 20% of all energy from renewable sources by 2020 |
| 2010 | RED enters into effect |

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**Co-firing cleans up coal-fired power plants**
Very little electricity was generated from biomass in the early nineties, but all that changed in mid-decade, when biomass co-firing in coal-fired power plants became increasingly popular in the wake of specific policy targets for generating more energy from renewable sources.

The target defined in the *Third White Paper on Energy* (1995) was for the Netherlands to obtain 5% of its energy supply from renewable sources by 2010, and 10% by 2020. In 2000, the government defined a further target, i.e. that by 2020, 4.4% of all renewable energy had to be derived from biomass and waste (ECN, 2000: 2). This target led directly to the start of various biomass projects, specifically ones involving biomass co-firing in coal-fired power plants (De Jong et al., 2005: 151). Such initiatives were also supported by the Ministry of Housing, Spatial Planning and Environment as part of its climate change policy, a specific aim of which was to reduce $CO_2$ emissions from coal-fired power plants. That led in 1999 to extra funding for research into the large-scale use of co-firing technology (ECN, 2000: 2).

**Funding**
Funding was an important way of stimulating the use of biomass as a source of energy. From 2002, it was provided through the MEP scheme [*Milieukwaliteit Elektriciteitsproductie*], a funding programme designed to help government achieve its renewable energy targets. The grant amounts were reduced several

times, however, because the scheme proved almost too popular. As soon as it became clear that the intermediate targets would be achieved, the scheme was discontinued (*Energieverslag Nederland*, 2010). In effect, it was the victim of its own success. The government's funding regime came in for severe criticism from environmental organisations and the business sector (see Box 2.1.). The amount of biomass used to generate energy more than doubled between 1990 and 2002, but changes in funding led to a decline in biomass co-firing in 2003. There was a further sharp rise in 2004, however (BTG, 2005: 10). The MEP scheme was cancelled for good in 2006.

*Box 2.1 Criticism of government funding policy*

*The Dutch government's funding programme has been the object of much criticism. Funding was said to be too short-term in nature and to lack continuity, the latter because the targets politicians set for renewable energy had not been given a statutory basis (FD, 2009a). For example, one of the major power companies, E.ON, announced that it would not be investing in renewable energy in the Netherlands because "there are too many changes in policy and in funding" (Volkskrant, 2010a). Environmental organisation Natuur en Milieu reproaches policymakers for ignoring long-term targets, for example encouraging innovation or helping to make applications cost-effective. "Co-firing can continue almost endlessly, and government can keep on providing funding. But as soon as it stops the funding, then co-firing stops as well, and we won't be one step further" (interview with Natuur en Milieu representative, 2009). According to Wolter Elbersen (Wagening University and Research Centre), short-term funding of co-firing also meant that businesses were not inclined to invest in even more sustainable biomass applications: "There was a short-term subsidy but no-one knew whether that subsidy would still be around the following year. In that case, the cheapest option is to burn the palm oil in the power plant. You order a boatload of palm oil and it's there the next week. If the subsidy is no longer available, you just cancel the boat" (Resource, 2009: 15). In addition, the co-firing grants were regarded as a 'waste of money' because the power plants had already been forced to cut $CO_2$ emissions under the emissions trading system (interview with Natuur en Milieu representative, 2009). According to the environmental organisation, the money would have been better spent on other forms of renewable energy.*

**Climate change targets**

The use of biomass has become more entrenched in recent years owing to ever-stricter climate change targets. The MEP scheme was followed up in 2007 by the SDE scheme [*Stimulering Duurzame Energieproductie*], which aimed to offer incentives for sustainable energy production. It is regarded as a key policy

instrument for achieving the 20% renewable energy target by 2020. This target matches the target set in the EU's Renewable Energy Directive (RED), which was adopted in June 2009 and entered into effect in late 2010.

Doubts concerning the feasibility of the climate change targets have made the policy on climate change an even more important factor in the drive towards biomass. A series of reports published in 2009 subjected the targets to critical examination,[1] augmenting the need for a rapid solution. One such solution is thought to lie in biomass. In late 2009, the then Ministry of Housing, Spatial Planning and Environment (VROM) announced that it would investigate additional policy options if it became clear that the targets could not be met. However, in late 2010, the then Minister of Economic Affairs, Agriculture and Innovation, Maxime Verhagen, announced that the funding for biomass co-firing would once again be discontinued. Although the Minister regards co-firing as an attractive source of alternative energy, he also finds it too expensive. He is developing other policies to encourage co-firing (Verhagen, 2010). In response, the business sector called on the minister to make co-firing mandatory (*Volkskrant*, 2010b)

**Bio-based raw materials in the energy transition**

Besides pursuing its climate change targets, the Dutch government is also encouraging renewable energy so as to improve the Netherlands' food security, reduce its dependence on oil-producing nations, and for cost reasons. A genuine transition is required to achieve these aims. The former Ministry of Economic Affairs took the first steps towards drawing up a new 'contract' between government and the market, arising from the search for a new form of policy that would be based on interactivity (De Jong et al., 2005: 213). A new project, 'Energy Transition' [*EnergieTransitie*], was set up to tackle this challenge. Several ministries now work together in this project with representatives of business and industry, science, and the civil society. The project initially focused on three themes: gas, industrial efficiency, and biomass (*EnergieTransitie*, 2010). In 2004, the 'transition channels' set up for this purpose were further divided into seven categories. Each of these has its own platform, meant to create innovative opportunities and identify problems in policy and regulations. Four of these platforms – those concerned with sustainable mobility, new gas, sustainable electricity supply, and bio-based raw materials – are considering the potential of

1 For example: (1) *Verkenning Schoon en Zuinig* (ECN in cooperation with PBL, April 2009). Conclusion: the energy efficiency target would not be met. Agreements with energy-intensive sectors needed to be more specific and ambitious. The share of sustainable energy in 2020 would not exceed 20%, but even that would require a huge effort. Expressed in monetary terms: an investment of more than EUR 18 billion. (2) *Milieubalans* 2009 (PBL, September 2009). Pessimistic about the effects of the recession on the development of innovative environmental technology. (3) *Duurzame elektriciteitsmarkt?* (CE Delft, October 2009). Conclusion: overcapacity of fossil fuel-fired power plants frustrates the development of sustainable energy.

biomass. The Bio-based Raw Materials Platform [*Platform Groene Grondstoffen*] is looking specifically at the role of biomass in the energy and chemicals industries. According to its 2007 *Energy Transition Green Paper* [*Groenboek EnergieTransitie*], it will be possible to replace 30% of fossil fuels by bio-based raw materials in 2030.

## 2.3 Biofuels policy

The biomass policy described above, which focuses on using biomass to generate electricity and heat, is the product of Dutch policymakers. The policy on biofuels, on the other hand, is much more the product of the business sector and international policymaking. Initially, the Dutch government made little headway in this area. The 2003 EU Biofuels Directive, however, put pressure on the Netherlands, particularly because the Dutch business sector recognised biofuels as a significant growth market in which other countries were clearly already generating profits. The public quickly expressed its concerns, however, and the Dutch government took these criticisms seriously. Although the former Ministry of Housing, Spatial Planning and Environment had long been in charge of this particular policy dossier, other ministries gradually became involved in the subject. For example, the Ministry of Transport, Public Works and Water Management (which merged with Housing, Spatial Planning and Environment in late 2010 to form the new Ministry of Infrastructure and Environment) is charged with the task of achieving the targets in the transport sector. The Ministry of Agriculture, Nature and Food Quality and the Ministry of Economic Affairs (which have also merged to form the new Ministry of Economic Affairs, Agriculture and Innovation) have sought to play a role in this area as well, as has the Ministry of Development Cooperation (now part of the Ministry of Foreign Affairs). The policymaking process shows that biofuels is a difficult administrative and political issue. This section reviews a number of milestones in that process (see Table 2.2).

**First incentives, poor result**

The farm surpluses of the 1990s led to a debate in the Netherlands about the functionality of the agro-sector. A search began for new markets in line with a policy of 'agrification' (Bos, 2008). Despite urging from the EU, agrification did not lead to an increase in biofuels, although they were mentioned increasingly as a long-term option once the next generation became available (MNP, 2006: 31). As mentioned earlier, the biomass targets set in the *Third White Paper* on Energy led primarily to co-firing in coal-fired power plants. During the 1990s, the EU offered a growing number of incentives to use more renewable sources of energy, including setting targets for biofuels. These targets did little to encourage the production of biofuels either in the Netherlands or elsewhere, however (MNP, 2006: 37).

**Table 2.2** Milestones in biofuels policy

| Year | Policy |
|---|---|
| 1995 | *Third White Paper on Energy*: 5% of all energy from renewable sources by 2010 and 10% by 2020 |
| 1997 | Netherlands signs the Kyoto Protocol |
| 2000 | European Commission begins developing the Biofuels Directive |
| 2001 | The Netherlands' Fourth National Environmental Policy Plan ('NMP4') underlines biofuels as key sustainable option |
| 2003 | Biofuels Directive adopted (2003/30/EC): 5.75% of energy content of fossil fuels to consist of biofuels by 2010 |
| 2005 | European Commission reprimands the Netherlands for tardiness in implementing the Biofuels Directive |
| 2006 | The Cramer Committee (Sustainable Production of Biomass Project Group) is installed to draw up sustainability criteria |
| 2007 | White paper, *Clean and Efficient: New Energy for the Climate*: 20% of all energy from renewable sources by 2010<br>Cramer Committee's final report<br>Biofuels Decree: petrol and diesel suppliers compelled to blend biofuels into fossil fuels at a minimum of 2% energy content |
| 2008 | Dutch biofuels obligation reduced from 5.75% to 4% by 2010 |
| Eind 2008 | Agreement on the EU's Renewable Energy Directive (RED): 10% of all transport fuels in 2020 to be from renewable sources (replaces 2003 Biofuels Directive)<br>European Fuel Quality Directive (FQD) |
| 2010 | RED enters into effect |

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**International developments**

Shortly after 2000, international interest in biofuels increased significantly. The driver this time was not agrification, but an undesirable dependence on fossil feedstocks and the Kyoto Protocol (signed in 1997) (Wardenaar, 2008: 36). The German and French governments were particularly keen to support biofuel development, and the farm lobby in the Netherlands was also eager to jump on the bandwagon (MNP, 2006: 38). The EU was also working on its Biofuels Directive in the same period (2003/30/EC), which set crystal-clear targets: by 2005, 2% of the energy content of fossil fuels was to consist of biofuels, rising to 5.75% by 2010. The scenario even called for a target of 20% by 2020 – confirmation of the huge economic potential of the biofuels market.

Initially, the Dutch government did not make much progress in complying with the directive. The business sector, which was afraid of missing the boat, continued to put pressure on policymakers, however. A strategic policy agenda published by the Ministry of Economic Affairs (EZ, 2003) listed ambitious long-term targets for biofuels in traffic and transport, comparable to those for electricity generation: by 2040, 30% of all energy supply should come from biomass. However, the grand long-term plans were undermined by paltry short-term efforts, putting the targets laid down in the Biofuels Directive out of reach. In 2005, the European Commission duly warned the Netherlands (and 19 other Member States) that it was late in implementing the directive

(*Energieverslag Nederland*, 2010; NRC, 2005). It urged the Netherlands to make every effort to meet the 2% target as soon as possible. Both Parliament and industry felt that the Dutch government's biofuels policy was 'unsatisfactory' and 'not ambitious enough' (*Energieverslag Nederland*, 2010; *Volkskrant*, 2005).

**Sustainability criteria**

Reports of negative effects tempered biofuel ambitions. What role did biofuels play in agriculture elsewhere in the world? Were biofuels in fact energy efficient? Were they sustainable? Did they compete with food production? The complex nature of the debate became clearer during this period. In 2006, the Netherlands Environmental Assessment Agency [*Milieu- en Natuurplanbureau*] said that "Dutch policymakers are navigating through a complex minefield in which several factors play a role: the need to meet the short-term Kyoto targets, the desire to follow European trends and agree to plans developed by businesses, the need to take potential negative effects into account, and the results of cost-effectiveness analyses. Their long-term policy has therefore lacked clarity and consistency" (MNP, 2006: 9). The government's concern about negative effects led it in 2006 to install a new project group on the sustainable production of biomass, known as the Cramer Committee, which was charged with establishing sustainability criteria (see Box 2). This took place within the context of the Energy Transition project. In the meantime, the international market continued moving ahead. A number of large companies, for example Virgin, attracted media attention for their biofuel plans (NRC, 2006).

A number of events converged in 2007. The coalition agreement of the fourth Balkenende Government placed considerable emphasis on sustainability; the 'Clean and Efficient' climate change programme was drawn up; and the Cramer Committee presented its concluding report. The work programme *Clean and Efficient: New Energy for the Climate* banked on reducing greenhouse gas emissions by 30% in 2020 (reference year: 1990). *Clean and Efficient* cites biomass as an important renewable energy source, specifically for transport purposes (VROM, 2007). Like solar, wind and water power, biomass was a sustainable alternative to fossil feedstocks. The Biofuels Decree [*Besluit Biobrandstoffen*] of 2007 made it mandatory for petrol and diesel suppliers in the Dutch market to provide 2% of their product in the form of biofuel ('blending'). In that same year, the Cramer Committee presented its report on the sustainable production of biomass to the Ministers of the Environment and Development Cooperation. The report concluded that under certain conditions (the sustainability criteria, see Box 2.2), biomass would offer numerous advantages. Still, negative reporting on biofuels has gained the upper hand since then (Sengers, 2009).

In 2008, the Dutch Government decided to adjust the target values set out in the Biofuels Directive. By 2010, the Netherlands would be obliged to have 4% of its fuel for road transport purposes consist of biofuels, and not 5.75%. Doubt

concerning the energy efficiency and sustainability of biofuels was the main reason for this adjustment (VROM, 2008). It is indeed not yet possible to accurately trace biofuel origins and production circumstances, and there is no generally reliable certification system. In late 2008, the European Union adopted the Climate and Energy Package, which included the Renewable Energy Directive (RED), and the Fuel Quality Directive (FQD). The RED, which entered into effect in December 2010, replaces the Biofuels Directive of 2003 and obliges every Member State to derive 10% of its transport fuels from renewable sources, e.g. biomass, hydrogen and renewable electricity, by 2020. While the sustainability criteria set out in this directive are not as strict as the Cramer criteria, they are a direct result of Dutch efforts in this area.

*Box 2.2 Sustainability criteria in a nutshell*

*Two concerns led to the decision to develop sustainability criteria for biomass. On the one hand, there were doubts as to whether biomass actually reduced* $CO_2$ *emissions. On the other, using farmland to cultivate biofuels could put the global food supply at risk. Headed by chairwoman Jacqueline Cramer (who had not yet been appointed a minister at that point), the committee – which consisted of various stakeholder representatives – studied the sustainability of biomass. In 2007, the committee presented a set of general sustainability criteria. They are divided into six categories: (1) greenhouse gas balance, (2) competition with food, local energy supply, medicines and building materials, (3) biodiversity, (4) prosperity, (5) wellbeing and (6) environment. In 2009, the Dutch Standardisation Institute (NEN) introduced a voluntary certification standard based on the 'Cramer criteria'; the standard, known as the NTA 8080, allows suppliers to demonstrate that the biomass they are using has been sustainably produced. Dutch policymakers used the same criteria as input for the EU-level discussion of the new RED. The old directive, which dated from 2003, did not set any strict criteria. The new directive does, although even these are more lenient than the criteria recommended by the Cramer Committee. The most important criterion in the new directive is that biofuels must offer at least 35% carbon emission savings compared to fossil fuels, rising to 50% in 2017 and 60% in 2018. In addition to biofuels, renewable electricity and hydrogen are also considered renewable fuels. Work on developing worldwide sustainability criteria for biofuels has continued since then. In july 2011 the European Commission approved seven sustainability certification schemes, some of which came from industry itself while others were drafted by a wide range of stakeholders (EurActiv, 2011).*

*In addition, both the European (CEN) and international (ISO) standardisation organisations are working on this issue. At the moment, the criteria only apply to biofuels (liquid biomass). The Dutch Committee on Biomass*

*Sustainability Issues [Commissie Duurzaamheidsvraagstukken Biomassa, CDB], which succeeded the Cramer Committee, advised extending the RED sustainability criteria to cover solid biomass for energy purposes (electricity, heat or biogas).*
*The European Commission decided that this would not be desirable, however. The European Commission also felt that initially, the criteria should not take indirect displacement effects into account, as this was better dealt with at international level (EurActiv, 2010). However, the Commission did launch a consultation round in the autumn of 2010 to investigate whether including indirect displacement effects would be desirable after all. At the moment the European Commission has furthermore mandated the CEN to develop sustainability criteria for bio-based products. The lead in this initiative is given to the Dutch Normalisation Institute (NEN, 2011). In the following chapter, we look in more detail at a number of issues associated with sustainability criteria and certification.*

## 2.4 Bio-economy: an integrative policy concept

There was a flurry of activity concerning the use of biomass in and around 2005. The Ministry of Agriculture, Nature Management and Fisheries (since 2010 part of the Ministry of Economic Affairs, Agriculture and Innovation) wanted to play a key role in biomass policy and decided to present an overall strategic agenda on this topic: the 'bio-based economy'. Interestingly enough, there was a precedent for the wish to make greater use of bio-based feedstocks: the Ministry's agrification policy of the 1980s and 1990s. This section reviews a number of milestones in the evolution of the Dutch bio-economy policy (see Table 2.3).

**Table 2.3** Milestones in the bio-economy policy

| Year | Policy |
|---|---|
| 1980s and 1990s | Ministry of Agriculture's 'agrification' policy |
| 1997 | Kyoto Protocol |
| 2005 | Energy transition: Bio-based Raw Materials Platform<br>Memorandum to Parliament announcing strategic agenda for the bio-economy |
| 2007 | White paper, *Clean and Efficient: New Energy for the Climate*: 20% of all energy from renewable sources by 2010<br>Bio-based Raw Materials Platform: Energy Transition Green Paper<br>Government's Strategic Agenda for the Bio-based Economy within the Framework of the Energy Transition<br>EU Lead Market Initiative (LMI) promoting biomaterials |
| 2009 | Launch of cross-Ministry Bio-economy ('BBE') Programme |

Rathenau Instituut

**Agrification, farm crises and climate change policy as overtures**

The farm surpluses of the 1980s were one of the main reasons for policymakers to seek other uses for agricultural products. Farm subsidies had left the EU with surpluses that it attempted to sell in new markets. In the 1990s, the focus shifted increasingly to the environmental benefits of bio-based feedstocks (Bos, 2008: 12). This drew ministries other than Agriculture to become active in this area, resulting, for example, in the energy policy described above. The agrification policy leaned heavily towards achieving agricultural policy targets at this point. At the start of the new century, however, it became clear that very few products made of bio-based feedstocks had actually been commercialised. Government came to consider the agrification policy a failure (Bos, 2008: 14). Industry was less negative about it, however, and expected the policy to lead to sound applications in the foreseeable future.

Although the Dutch and international agrification policy did not produce a huge rise in the number of new products, it did provide the basis for other advances in what is now referred to as the bio-economy. The quest for new ways to use bio-based feedstocks received a fresh impetus at the start of the present century. After various crises had hit the farming sector, for example BSE ('mad cow disease'), dioxin pollution and swine fever, certain by-products were banned from animal feed, stimulating the development of non-food applications for these by-products. At the same time, the international climate change agreements encouraged the broader use of bio-based feedstocks. One good example was the Dutch government's policy on biofuels, leading to more innovative uses for bio-based feedstocks in sectors other than agriculture (Bos, 2008: 15). Other important reasons to consider the broader concept of the bio-economy were: (1) geopolitical considerations, especially in the US, which wanted to use biomass to reduce its dependence on other countries; (2) the rise of industrial biotechnology, in which bio-based feedstocks are used to produce chemicals; (3) the EU's aim of encouraging innovative technologies; and (4) the increase in oil prices since 2004 (Bos, 2008: 15-17).

**2007: Breakthrough of the bio-economy policy concept**

In October 2007, the Dutch Ministry of Agriculture, acting on behalf of the Ministry of Housing, Spatial Planning and Environment, Development Cooperation, Economic Affairs, and Transport, Public Works and Water Management, presented a document setting out the Dutch government's strategic agenda for the bio-economy within the context of the energy transition [*Overheidsvisie op de Bio-based Economy in het Kader van de Energietransitie*, LNV, 2007]. In order to take action on that strategic agenda, the government set up a new programme in 2009 headed by the Ministry of Agriculture, i.e. the Cross-ministerial Bio-economy Programme ('IPBBE'). The programme will undertake a number of pilot and demonstration projects in the coming years, for example domestic biomass refinery, large-scale refinery of imported biomass close to seaports, refinery of residual waste and rubbish, aquatic biomass, and

'white' (industrial) biotechnology (LNV, 2009c: 5). The purpose of the pilot projects is to identify factors that can accelerate or impede the intended system innovation, in the expectation that the market will be the key driving force behind the bio-economy (interview with Bol, 2009).The market for biomaterials is also being encouraged at European level in the EU Lead Market Initiative[2] (LMI); this involves investigating incentive measures, for example offering tax breaks on bio-based products. In April 2011, the IPBBE published a knowledge and innovation agenda for the bio-economy in which it presents a technological and economic roadmap for the transition to a profitable and sustainable bio-economy and analyses the knowledge required to achieve it. In addition to developing the necessary expertise in logistics, chemicals and refinery, the agenda also advocates setting up a programme to study the social aspects of the bio-economy (WTC, 2011).

**Government's strategic agenda on the bio-economy**

The core of the Dutch government's 2007 strategic agenda is 'optimal biomass valorisation'. Prioritising high-value products such as biomaterials and using residual waste to produce transport fuels, electricity and heat mean that all the biomass is put to good use. 'Co-production' is an important concept in this respect, with biorefinery as the key technology. Biorefinery makes it possible to first isolate the most valuable components. The by-products can then be used for low-value applications. This approach is referred to as 'cascading'.

The strategic agenda lists three reasons for government needing to play an active role in implementing biomass use (LNV, 2007). The first is that such involvement will help promote general sustainable growth. Government must ensure that biomass production does indeed satisfy the sustainability criteria. The point is to clarify what 'sustainable biomass' means and whether certification offers a good solution. Government can also play a role in developing the necessary technologies. Such aspects as biorefinery, biogas and high-value biomass applications and sustainable production should be encouraged because, without such encouragement, they cannot make the major contribution to the Dutch economy that they are capable of making. Government must also anticipate the questions that will be raised by the large-scale application of the biomass concept.

The strategic agenda lists both opportunities and risks in the transition to a bio-economy. "The government's strategic agenda is therefore based on a parallel strategy: on the one hand, clear support for the development of the bio-economy; on the other, study, consultation and monitoring in order to track the sustainable use of biomass and adjust the approach taken when necessary"

2 European policy for six key sectors, focusing on removing barriers to the commercialisation of new products and services. The Commission works with Member States and industry on the relevant action. Two of the sectors are associated with bio-based products and renewable energy. The policy instruments consist of rules and legislation, public procurement, standardisation, and aid.

(LNV, 2007: 16). The policy agenda that follows on from this strategy has the following priorities: (1) more efficient use of biomass, with biorefinery as the key technology; (2) development of a market; (3) making the production of biomass sustainable worldwide; and (4) encouraging production of biogas and renewable electricity. One of government's main policy instruments for encouraging innovation and the application of biomass is funding, for example the Energy Transition and the Energy Innovation Agenda programmes. The bio-based raw materials programme (which should not be confused with the Bio-based Raw Materials Platform), part of the same Innovation Agenda, can be regarded as the semi-practical implementation of the policy agenda described in government's strategic agenda.

## 2.5 Bio-economy policy not leading

This section explores the extent to which the new bio-economy policy concept has been an integrative and influential impact. We first consider which ministries are responsible for which policy targets. We then discuss the influence of international agreements, specifically at European level. Finally, we look at the troubled conceptual relationship between the government's biofuels policy and the core of its bio-economy policy, i.e. 'optimal biomass valorisation'.

### Ministries' wide-ranging responsibilities

The aim of the bio-economy policy programme is to link various strategic policy agendas and instruments related to the use of biomass into a coherent whole in order to improve cross-ministerial governance (VROM and LNV, 2009).
The programme therefore touches on many policy issues associated with the climate, energy, trade, agriculture, food supply, knowledge, biodiversity, and logistics. "The bio-economy is really quite a big deal that way" (interview with Shell representative, 2009). Without the involvement of the Ministries of Economic Affairs, Agriculture and Innovation, Infrastructure and Environment, and Foreign Affairs, the bio-economy policy cannot succeed, because each of these ministries represents a specific area within that policy. Nevertheless, each minister or state secretary contributes to the policy from his or her own perspective (see Box 2.3). The bio-economy policy programme is therefore being pursued by different ministries for different purposes.[3] The Ministry of Economic Affairs, Agriculture and Innovation has assigned it an overarching role, however, and it therefore influences policymaking throughout this ministry. Economic Affairs, Agriculture and Innovation has positioned itself firmly as the lead ministry, but other ministries continue to intervene in specific policy aspects.

At the moment, the bio-economy concept is not the dominant policy. The focus differs from one ministry to the next, and with it the importance attached to the bio-economy policy concept.

3 Ook in de EU, die de kaders vaststelt waarbinnen het Nederlandse beleid zich kan bewegen, is het thema bio-economie versplinterd: het is verdeeld over liefst 7 DG's van de Europese Commissie (interview Bol, 2009). Het komt er ongecoördineerd aan bod onder noemers als 'biobrandstoffen', 'milieu', 'landbouw' en 'bedrijfsleven'.

*Box 2.3 Ministries' responsibility for biomass policy*

*Many different ministries are involved in biomass policy, each one based on its own policy responsibilities (although that is less so since October 2010, when various ministries were merged). In July 2009, the then Minister of Housing, Spatial Planning and Environment and Minister of Agriculture, Nature and Food Quality replied to questions from Parliament (dating from late 2008) concerning the ministries involved in biomass policy and their responsibilities. Taking the recent mergers into account, the following picture emerges. The Ministry of Economic Affairs, Agriculture and Innovation is responsible for (1) energy policy, including bio-energy for electricity and heat, and industrial policy, except for the foodstuffs sector (these were formerly the tasks of Economic Affairs) and (2) coordinating the bio-economy and agricultural feedstocks, forest and wood, the foodstuffs industry, i.e. biomass production/supply (these were formerly the tasks of Agriculture, Nature and Food Quality). The Ministry of Infrastructure and Environment is responsible for (1) biofuels policy, and plays a coordinating role with respect to biomass sustainability criteria (formerly the tasks of Housing, Spatial Planning and Environment); and (2) achieving the biofuels blending targets in the transport sector (formerly the tasks of Transport, Public Works and Water Management). The Ministry of Foreign Affairs (DG International Cooperation) is responsible for the Action Plan for Global Biomass [*Plan van Aanpak Biomassa Mondiaal*] (encouraging biomass production and refinery in developing countries and a harmonised development policy concerning biomass and biofuels).*

**Mandatory international frameworks**

The Dutch biomass policy is heavily influenced by international discussions and agreements. In their March 2008 response to the tense debate about biofuels, Minister Jacqueline Cramer of Housing, Spatial Planning and Environment and Minister Bert Koenders of Development Cooperation said that proposals to terminate the Netherlands' involvement in biofuels were unrealistic. The Netherlands had an obligation to implement the relevant European Directive. It had to remain active in biofuels for that reason alone: "Instead of sitting on the side lines and complaining that we ought to withdraw from biofuels, we think it would be better to ensure that they are produced as sustainably as possible. … Because whether we like it or not, biofuel production is set to continue at a brisk pace worldwide, influenced mainly by the major economies" (*Volkskrant*, 2008). That does not mean that the Netherlands has been relegated to the side lines, however.

To begin with, it is itself developing plans to transpose the relevant European directives into national law. Although the methods used to demonstrate

sustainability must be the same throughout the EU, the Member States nevertheless have some choice in the matter (interview with PGG, 2009). Secondly, the Netherlands' self-appointed position in the vanguard offers it all kinds of opportunities to influence the international policy agenda. As we saw earlier, it plays a key role in developing criteria for the sustainable application of biofuels. The European Union has, however, referred a number of guarantees that the Netherlands would like to see incorporated into EU policy to larger international forums. For example, the EU does not wish to monitor indirect land-use change because the European Commission believes this will only work if the entire international community cooperates (EurActiv, 2010). Brazil and other developing countries have also made clear that they would not consider any regulations legitimate unless the relevant methodology was accepted internationally (EurActiv, 2009a). That would undermine the influence of the Netherlands on the sustainability criteria. If certification is decided on internationally, the Netherlands will not be able to refuse an import of certified biomass that it did not consider sufficiently sustainable, as that would constitute an unfair trade barrier.

**The bio-economy policy conflicts with the biofuels policy**

The complex interaction between the three lines of policy described above leaves the mandate of the integrated bio-economy concept highly uncertain and weak compared with the established biomass policy.[4] The key aim of the bio-economy policy – to make the most efficient use possible of bio-based feedstocks – is at loggerheads with the biofuels policy. According to the latter, biomass is meant to be used as a biofuel. Using biomass as a source of energy is a low-value application, however, i.e. at the bottom of the value pyramid (see Figure 1.1). Biofuels are part of the bio-economy, in other words – but a low-priority part. The bio-economy concept, on the other hand, requires using biomass for high-value applications first, for example in the chemicals sector. As the programme manager for the cross-ministerial Bio-economy programme has said: "Biomass should really only be used to a limited extent as a fuel… We should be focusing much more on electric cars. Energy conversion is much smarter than going the biofuel route" (interview with Bol, LNV, 2009). After all, it takes a lot of energy to produce biofuels. It would be more efficient to use the raw materials in ways that have a much greater added value. "Huge quantities are the name of the game in the fuel world. The European fuel market alone comes to about 300 million tonnes. So the mandatory 10% blending means 30 million tonnes, or 120 million tonnes of dry biomass. And that's only the 10% being blended in the transport sector" (same interview). However, the Dutch government's strategic policy agenda takes little notice of this discrepancy between its biofuels policy and its bio-economy policy.

4 The use of biomass by-products to generate electricity and heat seems to clash less with the bio-economy concept, in any event if the by-products are those resulting from the high-value forms of biomass utilisation.

## 2.6 Conclusion

This chapter described three lines of policy related to biomass and how they are connected: the policy concerning electricity and heating, transport fuel, and the bio-economy. The strategic policy agenda for the bio-economy advocates taking an all-encompassing look at the efficient use of biomass in many different areas, ranging from energy and transport to chemicals. The key aim of this approach is to optimise biomass valorisation. A 'value pyramid' is employed as a guiding factor. According to this pyramid, biomass is most valuable when it is used in the interests of health and lifestyle. Food comes in second, and chemicals third. The lowest priority is using biomass as a source of energy. The bio-economy policy encompasses the other two policy areas in this way, and positions them on the least interesting level of the value pyramid. In doing so, it creates a whole new set of policy-related, technical and organisational challenges related to the future sustainable use of biomass.

The influence of this approach, i.e. of optimal biomass valorisation, on Dutch biomass policy is still very minor, however. That is in part because the responsibility of biomass policy is divided between so many different ministries and because there are also mandatory international agreements in this area. For example, the Netherlands has committed itself to the EU policy on blending biofuels. The notion of optimising biomass valorisation is also overshadowed in political and public debate by the discussions concerning biofuels. It would be conducive to the political debate to pay more attention to the heart of the bio-economy concept: optimised biomass valorisation and efficient biomass value chain management. That would also have implications for the discussion of biofuel sustainability criteria. The value pyramid within the bio-economy concept shows that the use of biomass must first be weighed up against the most efficient possible use of biomass.

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# 3

# 3 The public debate: an accumulation of controversies

Doenja Koppejan and Lotte Asveld

The bio-economy offers an appealing prospect, i.e. the promise of a sustainable economy. At the same time, it is also the breeding ground for a profound public debate in which opinions sometimes clash. This chapter describes that debate.

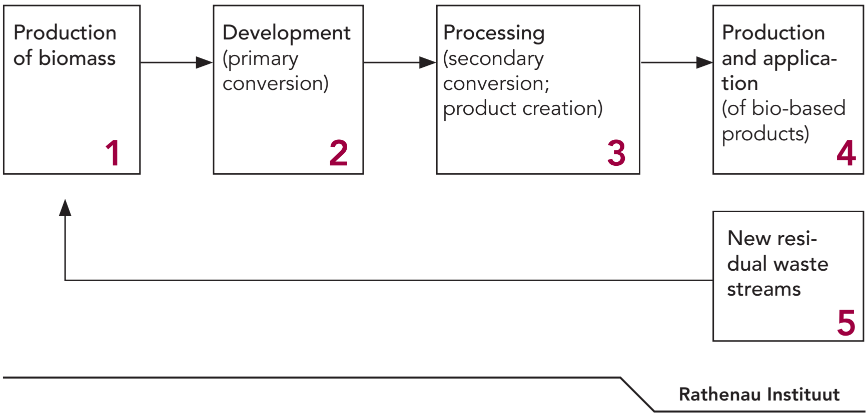
Most of the parties participating in this public debate embrace the idea of the bio-economy. They also support efficient chain management and optimal biomass valorisation. All the parties further believe that the bio-economy can lead to economic and ecological benefits. What they do not agree on is whether a sustainable bio-economy will in fact become reality, and, if so, in what way that will happen.

One major difference of opinion can be traced to the disagreement between those who support 'gradual transition' and those who say "do it right or don't do it at all". Some parties believe that existing applications – for example first-generation biofuels – are a stepping stone to more sustainable ones. Others have less confidence in a gradual transition; they believe that applications should be completely sustainable before we begin using them. It is notable that the difference of opinion does not simply follow the pattern of 'environmental movement' versus 'industry': viewpoints also differ within both groups. As we will see below, that difference of opinion can be traced in part to opposing views concerning the 'naturalness' of the bio-economy. We will also compare the social issues associated with the bio-economy concept to the questions arising from the biofuels debate, similar to our approach in Chapter 2.
The bio-economy concept appears to have broad support, whereas – at best – biofuels are endorsed as groundwork for more sustainable applications. In this chapter, our description of the biomass value chain (illustrated below) touches on the key issues of the debate: from biomass production to primary and secondary conversion to production and application and, finally, to new residual waste. It should be noted that the public debate mainly concerns biomass production, and scarcely considers the way in which biomass is ultimately used.

## 3.1 Biomass (biomass production)

With respect to biomass production, opinions differ on three important points: its availability, its sustainability, and the role of genetically modified organisms (GMOs). As a small country, the Netherlands has only a limited amount of farmland available. That means that if it does make the transition to a bio-economy, it will have to import much of the biomass it needs, raising questions

Figure 3.1




about the supply of biomass available worldwide, how much can be produced sustainably, and how that supply can be increased. One method of increasing biomass supply continues to spark off considerable debate: the genetic modification (GM) of crops.

### 3.1.1 Supply of sustainable biomass available

Is there enough biomass available to meet the demands of the bio-economy? Estimates concerning the amount of available biomass differ. Various methods to increase the supply have been suggested: using domestic residual waste, biotechnological solutions (for example GM), and cultivating crops on marginal land. But are these solutions socially acceptable ones, and will they really produce enough extra biomass to feed the bio-economy? This section looks more closely at the related viewpoints.

**Biofuels debate**

Stakeholders disagree as to whether there is enough sustainable biomass worldwide to satisfy some (or all) of our energy needs. Many consider sustainability a key requirement. Assuming that biomass will indeed be obliged to meet certain sustainability criteria, environmental and development organisations in particular take a dark view of its availability, citing various complications. The demand for food crops is enormous and will only continue to grow in the years ahead. The OECD (2007) estimates that the Earth's population will increase to approximately 9 billion by 2050. This implies an even greater demand for food, while current demand already exceeds supply by a large margin in many regions (although other regions appear to have surpluses). The demand for biomass for non-food applications will ratchet up the demand for bio-based raw materials. Proponents point out that marginal land can be used for non-food biomass production, but others dispute this. Although biomass cultivation on marginal land certainly has potential, sceptics – including environmental and develop-

ment organisations – say that the cost of improving productivity in such regions would be excessive. These regions often suffer severe water shortages and are regarded as marginal for a good reason. The crop yields on such land will consequently be marginal (De Nie, 2007: 23). In addition, there are also questions about potential indirect effects. Where will we get the extra water needed to cultivate crops on marginal land? What was the land used for previously? Where do these former activities now take place? Box 3.1 looks more closely at the relationship between biofuels and food supply in the light of sustainability criteria.

Another important issue is the discrepancy between 'theoretical' availability and 'actual' availability. There may be enough biomass available on paper, according to certain calculations, but many environmental organisations claim that things often turn out very differently in real life. The extra demand for biomass must be fit into the existing economy of agricultural and forestry products. Producing accurate estimates is therefore a very complex affair, according to Natuur en Milieu, because no solution operates in a vacuum (interview with Natuur en Milieu representative, 2010). The political situation in the source countries, the land rights of farmers, and other factors go to determine the actual amount of sustainable biomass that is exported, but none of these things can be accurately expressed in terms of 'availability'. According to Natuur en Milieu, it is far too easy to assume that 'the whole world is our back garden', that it can be laid out as we want, and that we can 'rake together' the harvest (interview with Natuur en Milieu representative, 2009). The Bio-based Raw Materials Platform [*Platform Groene Grondstoffen*, PGG] also sees a potential discrepancy between theoretical and actual availability. It has consequently launched a study into the large-scale import of biomass from Mozambique, the aim being to consider, in cooperation with that country's stakeholders and government, what is required, how it can be achieved, and on what scale (interview with PGG representative, 2009). According to the General Energy Council [*Algemene Energieraad*], the high cost of raw materials hampers large-scale investment in R&D and, subsequently, in production capacity. As a result, theory may not be borne out in actual practice (AER, 2008).[1]

1 According to calculations commissioned by Greenpeace in 2005, a large sustainable biomass power plant (1000 MW, enough to power 2 million households) would be technically and financially feasible. Greenpeace believes that the supply of clean biomass will increase as the demand rises. It regards biomass as 'clean' when it comes from specially cultivated plants (such as elephant grass), agricultural waste, and offcuts of wood from sustainably managed forests or the wood industry. It rejects any biomass that would cause ecological damage in some other manner. Genetically engineered crops or waste products from intensive animal husbandry do not fit in to this category, according to Greenpeace. Source: Greenpeace, '*Schone biomassa*', at: http://www.greenpeace.nl/campaigns/klimaatverandering/de-oplossing/schone-energie/schone-biomassa, consulted most recently on 10-3-2010.

*Box 3.1 Competition between biofuels and food*

*One key consideration when drawing up sustainability criteria is the competition between biofuels and food. The question is whether biofuels are elbowing out food crops and, if so, whether certification can prevent this. The debate between Michiel Keyzer (VU University Amsterdam) and Gerda Verburg (former Minister of Agriculture, Nature and Food Quality) in the leading Dutch newspaper NRC Handelsblad illustrated the two main points of view in the debate. Keyzer stated that if governments were to continue their current biofuels policy, there would be another food crisis in two years' time, similar to the crisis of 2008 (NRC, 2009a). The Minister responded in a letter to the editor: "It was wrongly suggested that the demand for biofuels is one of the main culprits. … The real reason, however, lies in the many years during which the international community neglected agriculture as the source of food security and development. …Agriculture is now an important part of the solution" (NRC, 2009b). These two opposing views are typical of the debate: is the bio-economy part of the problem, or part of the solution? In theory, the bio-economy can offer developing countries new prospects. Higher prices for crops will create jobs and may lead to investment in rural economies and infrastructure, both of which are urgently needed in the developing world (LNV, 2008: 17). Biofuels can lead to diversification in agricultural production and help developing countries generate their own energy and diversify their exports. Food production can also be part of the bio-economy, if the edible portion is first removed from the biomass and the remainder is then refined and processed further (Faaij, 2008). Nevertheless, many organisations have sounded the alarm (Natuur en Milieu, 2008; Rice, 2010). They often cite an OECD report (OECD, 2008), which argued that the price increases arising from the 10% blending target set for 2020 were structural rather than incidental. They also claim that although local producers may benefit from price increases, "there is a real danger that the risks…will be borne by the most vulnerable group in developing countries, i.e. the people whose daily budgets are spent largely on food" (Natuur en Milieu, 2008a). If this is indeed a major problem, to what extent can certification offer a solution? Monitoring is much more difficult in less well-organised societies, and corruption prevents the right people from benefitting from developments (Trouw, 2009). One recent problem is that of land grabbing, with huge tracts of land in developing countries being leased (or at risk of being leased) to richer countries to produce food and biofuels for the latter's domestic markets (NRC, 2009c). Such agreements are made possible in part because there are often no clear-cut rules of law concerning land ownership in developing countries. Certification would obviously not solve this problem directly.*

**Bio-economy: new solutions and issues**
The bio-economy concept offers various solutions to the problem of availability because it promotes more efficient use of biomass and utilisation of domestic residual waste in high-value applications. At the same time, the bio-economy also raises new questions. Examples are the extra demand that it creates, genetic modification as a means of increasing crop yields, and the potential disadvantages of using entire plants.

*Optimisation*
The bio-economy concept hopes to increase the supply of sustainable biomass by means of optimisation. Co-production followed by optimal utilisation can guarantee a sufficient supply of biomass. In addition, much can be gained by making more efficient use of biomass, i.e. through efficient chain management and by avoiding waste. A cow, for example, eats five times more energy than a person gets out of consuming dairy products. If we can refine grass so that we give cows only what they need nutritionally and feed the remaining protein to pigs, then we would be able to reduce our soybean imports (Resource, 2009: 17). The quantity of biomass available depends largely on the way in which we organise its use. The challenges are not only technological in nature; they are also largely a question of allocation.

*Using residual waste*
The bio-economy can help solve the biomass availability issue by assigning the Netherlands (and Europe) a key role in biomass production. This is certainly the case for high-value applications, for example in the chemicals industry. Efficient chain management and the utilisation of residual waste streams have the most potential as a domestic 'source' of biomass. Many people also regard this as a highly sustainable and efficient option. Nevertheless, it will not be easy to bring about. Using residual waste, more efficient chain management, co-production: all are still under development and have yet to become competitive in terms of price. Imports might be considerably cheaper. How can we ensure that a more sustainable generation of biomass can compete with first-generation biomass imports, which are often much less sustainable? How can 'more sustainable' compete with 'inexpensively sustainable'? Can we give precedence to small-scale local operations?

Some commentators have also pointed out the potential negative impact of using an entire residual waste stream. Biomass incineration processes can result in nutrients becoming contaminated with heavy metals and other undesirable substances. That would make it difficult to achieve efficient chain management. 'Dual purpose' agriculture – with one portion of the crop yield destined for food and the other for energy or chemicals production – could disrupt the carbon and nitrogen balance of the soil. When stalks and roots are left behind on the land after harvesting, the nutrients have a chance to return to the soil, leading to more fertile farmland. If we harvest the entire plant, however, this will not

happen, and the soil may become impoverished and degraded (Natuur en Milieu, 2007).

Critics say, for example, that much of the vegetable matter referred to as 'waste' in publications does in fact have a function in today's economy. In a report dating from 2001, Delft research and consulting firm CE pointed out that the demand for offcuts of wood to generate energy competes with other forms of use and recycling (Bergsma, 2001). Straw still plays an important role in farming, not just as bedding in animal-friendly shelters, but also as straw manure, which serves to maintain the organic content and structure of the soil and the soil biota. Straw manure is a particularly effective means of increasing agricultural output on sandy and heavy clay soils (Animal Sciences Group, 2005). A rising demand for straw for energy purposes can once again lead to competition and displacement effects.

Greenpeace (2010) has also questioned the use of biomass produced by the factory farming system (manure, for example). In their view, such use helps prop up a non-sustainable practice because the factory farming system bears much of the responsibility for greenhouse gas emissions in the Netherlands.

*Extra demand for biomass*
The bio-economy may deal more efficiently with the biomass that is available, but because a growing number of sectors are laying claim to these raw materials, competition with other land use may nevertheless increase steadily – meaning competition with food production or with biodiversity. It is also unclear what the extra demand (i.e. above and beyond the current demand) will mean for the supply of sustainable biomass. What if every country wants to make the transition to a bio-economy? What if almost every sector – and not just electricity and fuels – decides to switch to bio-based production?

### 3.1.2 Guaranteeing sustainability

Climate change is one of the important drivers of biomass use. The $CO_2$ gains made possible by biofuels have been called into question, however (PBL, 2010; Karimi, 2008; NRC, 2008c, IEEP, 2010). Another frequently cited problem is the displacement of food production. As described above, there are also worries about biodiversity, the effects on the soil, and the use of water. How can we guarantee the sustainability of biomass imports? The relevant discussion centres on the aim of creating a sustainable and open system of world trade, with certification and sustainability criteria as the means to this end. Existing sustainability criteria only apply for liquid biomass, but there are growing calls to extend them to solid biomass as well. The effectiveness of such measures has been disputed, however. There is disagreement concerning the strictness of the criteria, whether or not indirect effects should be taken into account, the scope of the criteria, and the potential barriers that they create for developing countries. These issues have mainly played a role in the debate concerning biofuels that

arose within the context of the EU directive that makes biofuels blending mandatory. Here too, however, the bio-economy concept introduces various new factors into the debate: extending the sustainability criteria to cover solid biomass; the problems in determining sustainability in co-production systems; and the growing need for sustainability and transparency in the worldwide trade in bio-based feedstocks.

**Certification of biofuels and the related criteria**

Many consider certification as the obvious channel for guaranteeing biomass sustainability. How strict the criteria should be and what precisely they ought to cover are controversial topics, however. Stakeholders are divided into roughly three camps. The first consists of the opponents. The EU's Directorate-General for Energy and Transport is said to have resisted additional criteria, for example (EurActiv, 2010b). The second camp consists of the proponents who want to speed things up, but also require guarantees. This group includes government authorities in the environmental sector and industry. Finally, there are the proponents who are in no hurry, and for whom the criteria can hardly be strict enough. Some environmental organisations, for example Friends of the Earth Netherlands [*Milieudefensie*] and Natuur en Milieu, have adopted this point of view (Milieudefensie, 2009).[2] The various camps upbraid one another: one is accused of focusing too much on limiting administrative red tape and therefore of keeping far-reaching criteria at bay; the other is reproached for wanting to achieve an unfeasible level of sustainability. We have already briefly described the background to the Dutch and European sustainability criteria in the previous section (see Box 3.1). Below, we look at the key points of debate concerning sustainability guarantees.

*Enforcement*

One controversial issue is enforcement. How do we monitor everything? To what extent can we rely on the information that source countries provide? And how much should monitoring be allowed to cost? One huge problem is whether or not government is capable of controlling biomass use. As long as biofuels are unable to compete with fossil fuels, government can make its incentive measures subject to certain requirements. Only those that comply with the requirements are awarded funding and can count their use of biofuels towards emission reduction targets. But if the price of biomass drops below that of petroleum – as it is expected to do in the foreseeable future – then government will not be in a

2 Natuur en Milieu has its own perspective on biofuels (Natuur en Milieu, 2008b). "'Bio-energy offers an uncertain remedy for the problem of climate change." Natuur en Milieu has therefore drawn up a set of criteria for the use of biomass that are stricter than the Cramer criteria. It wishes to set up a certification system that reviews biofuels on factors such as origins, production chain and social aspects and requires high net $CO_2$ gains across the entire chain (80% long-term).

position to make many demands. What will the sustainability criteria be worth then? That is why Dorette Corbey, who chairs the Dutch Committee on Biomass Sustainability Issues [*Commissie Duurzaamheidsvraagstukken Biomassa*] or Corbey Committee, believes that enforcement is one of the crucial questions in the sustainability criteria debate (interview with Corbey, 2009).

*Direct and indirect land use*

Much of the debate about biofuels focuses on contextual issues, for example the displacement of forests rich in biodiversity, competition with food production, and the actual contribution of biofuels to $CO_2$ reduction. Boxes 3.1 and 3.2 briefly describe the food and $CO_2$ controversies and what they mean for sustainability criteria.

Many believe that these criteria can only be guaranteed if indirect changes in land use are taken into account (known by the acronym ILUC or 'indirect land use change'). The Cramer criteria, for example, focus on the plantations. Satisfying the sustainability criteria therefore says nothing about the effects that come about via the world market, i.e. about sustainability at macro-level.

According to those who advocate taking ILUC into account, integrating biofuel production into the worldwide agricultural economy will influence this entire economy. A rise in demand will ultimately affect market prices, and in turn the amount of available farmland. Prem Brindraban of Wageningen University and Research Centre puts it this way: "Whichever way you look at it, every hectare of land used to grow biofuel crops leads to another hectare being brought into cultivation for food. It may be two hectares or it may be a half, but you still need to take account of these indirect effects when considering whether biofuels are possible from an ecological point of view" (*Resource*, 2009: 15). It's not that simple, says his colleague Ken Giller: "Why are rainforests cleared? The primary reason is for the wood. …Then the land is taken over by someone else for another purpose. The oil palms, the plants, get the blame. But it's not the plants clearing the rainforests, it's people." (*Resource*, 2009: 15).

Natuur en Milieu believes that awarding certificates at micro-level will only work if there is a moratorium on increasing the acreage: the 'unsustainable' palm oil will otherwise make its way into all sorts of food products and cosmetics, with little public pressure to enforce sustainability (interview with Natuur en Milieu representative, 2009). In other words, making one sector (biofuels) sustainable may make another sector (such as cosmetics) less sustainable, so that, taken across the board, the use of biofuels still leads to negative effects. Various environmental and development organisations believe that the process of ensuring sustainability and certification should first be undertaken within the existing, and ever-expanding, food market. "It would be undesirable for there to be an additional demand for these crops for the benefit of the European energy supply" (Natuur en Milieu, 2008a). Monitoring at macro-level would clarify

whether it is sensible to encourage all forms of biomass or to promote some and even attach penalties to the use of others.

Others question that idea. Development organisation Both Ends does not regard certification as a guarantee: "Even the most ideal certification system cannot adequately address indirect and macro-effects" (Both Ends, 2008: 5). Still others do not consider an ILUC factor as strictly necessary. It is very difficult in the real world to identify a genuine cause-and-effect relationship (interview with Van Seventer, WUR, 2009): is biomass really the cause of changes in land use? An ILUC factor can make matters unnecessarily complex (interview with Ministry of Agriculture representative, 2009).

The European Commission has announced that any ILUC factor must be taken into account at international level, preferably in the next UN convention on climate change (EurActiv, 2010a). In the meantime, the Commission is conducting consultation rounds with stakeholders to investigate the arguments for and against including an ILUC factor in the EU's sustainability criteria. The Dutch government is in favour of such inclusion (Response by the Netherlands, 2010). Indeed, funding schemes for sustainable biomass (and biomass imports) are being set up in the Netherlands that take the Cramer Criteria as their starting point (interview with PGG representative, 2009). Environmental organisations worry that this will cause organisations and governments to lose sight of the macro-level. After all, certification could give rise to the impression that all the relevant aspects have already been taken into account, even though certification will actually only cover micro-level concerns. The Social and Economic Council (SER, 2011) also supports the idea of including an ILUC factor in the sustainability criteria in its recent advisory report on biomass.

**Certification in the bio-economy**

The broader context of the bio-economy adds an extra complication to what is already a complex discussion of certification and sustainability criteria. More efficient use of biomass may mitigate displacement effects, but such effects cannot be ruled out entirely, especially if the demand for biomass continues to grow. Sustainability is an equally important point of concern in the more advanced, high-value application of biomass to produce chemicals and materials. Expectations play a major role in this: new technologies can lead to big improvements by increasing chain management efficiency and by making use of raw materials that are less polluting, for example waste, biomass by-products, woody crops and algae. However, the question then is to what extent developing countries can make use of these technologies and at what point they will become available in any practical sense.

*Co-production and criteria*

Even if the bio-economy were to function in all its glory, and even if biomass chain management was entirely efficient, co-production would still give rise to

*Box 3.2 Greenhouse gas balance*

*One underlying reason for developing sustainability criteria has to do with the greenhouse gas balance of biomass. Specifically, biomass use is seen as a means of reducing $CO_2$ emissions; planting the necessary plantations, however, involves taking over land in nature areas. According to Greenpeace, deforestation is itself responsible for a fifth of all $CO_2$ emissions worldwide (Greenpeace, 2010). It is therefore possible that establishing a new plantation will generate more $CO_2$ than is saved by using biofuels from the same plantation (Karimi, 2008; NRC, 2008c). Natuur en Milieu believes that biomass cultivation in the Netherlands or elsewhere in Europe should also take the greenhouse gas balance into account: cultivation involves using fossil fuels and nitrogen-based artificial fertilisers, which cause $CO_2$ and $N_2O$ emissions (Natuur en Milieu, 2010). Researchers at VU University Amsterdam and Wageningen University and Research Centre have shown that the natural absorption of $CO_2$ by European forests and grasslands is cancelled out entirely by greenhouse gas emissions in agriculture, for example methane. The researchers warn that the intensification of agriculture, specifically in Eastern Europe, will cause even more disruption to the greenhouse gas balance (AD, 2009). In addition, incineration of biomass produces 'black carbon', which is suspected of having a huge impact on climate change (EurActiv, 2010b).*

*Does this mean that the greenhouse gas balance in the bio-economy will be little better than in the fossil economy? The bio-economy is not just about the quantity of biomass, but about how to utilise it as efficiently as possible, for example with advanced technology. The World Wildlife Fund has estimated that industrial biotechnology has the potential "to prevent emissions of between 1 billion and 2.5 billion tonnes of $CO_2$ equivalent per year by 2030" (EurActiv, 2010c). The European Directive stipulates that biofuels must cut down on $CO_2$ emissions by at least 35% compared with fossil fuels, rising to 60% in 2018. (Natuur en Milieu would like this to rise to 80%, and see ILUC taken into account.) Increasing the level of co-production is an important factor in this regard, as it can improve efficiency and help generate a more positive greenhouse gas balance. It is also important not to generalise. Some applications simply have a better greenhouse gas balance than others: the low energy yield of liquid biomass for transport purposes means that its $CO_2$ balance is less favourable than solid biomass derived from woody crops used in a power plant. In addition, there are differences between biomass sources: palm oil gets relatively high marks, whereas rapeseed does not (WWF, 2006).*

certification problems. There is already considerable discussion of how to measure sustainability across the entire value chain. This will become even more difficult if the biomass is 'multifunctional', a common occurrence in the biomass chain and taking the form of co-products such as electricity or cosmetics. The aim in the bio-economy is to use as much of the biomass as possible for different purposes. How can we effectively attribute the environmental impact of the entire system to the various co-products? It is also very difficult to incorporate productivity improvements and co-production into an ILUC factor. If land is first used to grow food crops and then to grow both food and non-food crops, does that count as 'indirect land use change' (ILUC)? There are some who therefore object to using this concept in a bio-economy (interviews with Van Seventer and Bol, 2009). In October 2010, the Bio-based Raw Materials Platform and the Corbey Committee (CDB) argued that ILUC should be taken into account after all.[3] Their reasoning was that ILUC is fairly simple to calculate. If land was first used to grow food crops and then switched to biofuel crops, they believe it is entirely plausible that new land has been developed for food crop cultivation. Only when efficiency gains are demonstrably the result of productivity increases or co-production can a lower ILUC factor be justified. The authors regard ILUC as a means to improve agricultural efficiency (CDB & PGG, 2010).

The second problem related to certification is that co-production undermines existing criteria for biofuels (interview with Corbey, 2009). The Corbey Committee therefore advocates establishing criteria in the EU Directive for *solid* biomass as well. Co-production blurs the distinction between biomass for transport fuels and biomass for electricity in a bio-economy, as the same crop can serve two different purposes. Applying the same criteria creates a level playing field for the various applications (CDB, 2009). A number of Member States have spoken out against this, however, and the European Commission has decided that, for the time being, it would not extend the criteria to cover solid biomass. Most of the resistance came from the Scandinavian countries, which – with their huge tracts of forest – are major suppliers of solid biomass. They are wary of placing an even greater administrative burden on a sector that is already being forced to meet all sorts of sustainability criteria. The Corbey Committee believes that the extra red tape will be minimal once all the existing systems, for example that of the Forest Stewardship Council (FSC), have been recognised and declared applicable in this context (interview with Corbey, 2009).

3 The Biomass Sustainability Issues Committee (CDB) – also known as the Corbey Committee – has succeeded the Cramer Committee. Its task is to determine how the Netherlands should implement the Renewable Energy Directive (RED).

*Sustainable open world trade*
If the Netherlands wishes to import biomass on a larger scale, the success of the bio-economy will come to depend on the sustainability and transparency of the global trade in biomass. It then becomes very important to create a level playing field. According to the Bio-based Raw Materials Platform (PGG), it is vital for industry to have easy access to feedstock and semi-manufactures (PGG, 2009a). At the moment, there are major differences between feedstocks: the market for such crops as maize and grain is free, but the EU maintains high import tariffs for bio-ethanol. There is also no uniform legislation for genetically modified organisms (GMOs): some crops have been licensed in the US, but not (as yet) in the EU.

Development organisations point out the importance of small local businesses in world trade: how do we ensure that developing countries can in fact benefit from the world trade in sustainable biomass? Transparency is a necessary condition, but it is one that is difficult to achieve in many countries, in particular in the developing world. Corruption is often rampant in such places, and businesses – often foreign ones – eager to make a profit exert a considerable influence there. When and how can small farmers in developing countries participate in defining the criteria that they themselves are meant to satisfy? Oxfam asked investors to treat small farmers honestly and transparently and to give them enough choice when selecting products to guarantee food security and food safety for themselves and their families (Oxfam International, 2008: 3). The world trade in biomass should also be sustainable and open. If it is set up inefficiently, then the global transport of large quantities of biomass could result in a negative greenhouse gas balance. The logistics must therefore be organised in such a way that they create opportunities for ports, for local populations, and for the climate.

### 3.1.3 The role of GMOs
Another discussion fuelled by the bio-economy concerns the role of genetic modification. Crops that are genetically modified have higher yields and they are therefore more readily available for the bio-economy. Opinions concerning GMOs have long been sharply divided, however. We see a similar discussion in the biofuels debate, but the perceived risks are smaller. Feelings therefore do not yet run as high as when genetically modified biomass is intended for direct consumption. The issue could become much trickier in any future bio-economy, however, when genetic modification is expected to play a much greater role (as Chapter 4 will show) and the distinction between GMO applications in the food and non-food sectors becomes more blurred. That will undoubtedly fan the flames of the GMO debate in the bio-economy.

Proponents of genetic modification believe that it represents huge advantages for any future bio-economy. If certain crops can produce more energy through genetic modification, cultivation will require less land and food production need

not be put at risk. And if genetic modification leads to crops that require less water, marginal land can be used to cultivate them. Opponents of genetic modification argue that we must not use the world as an experimental laboratory (Greenpeace, 2010). The risk of GM crops infiltrating non-GM populations cannot be ruled out. In addition, plants that are suitable for second-generation biofuels may be more vulnerable to extreme weather conditions and potentially less pest and disease-resistant (joint nature and development organisations, year of publication unknown). Development organisations also emphasise the social and economic consequences of genetic engineering. The patents on this technology are often owned by large multinationals, which do not consider that many farmers customarily trade and store seed. Patenting makes farmers dependent on a company that will only sell them the seed for a lot of money, often plunging them into debt (interview with Oxfam Novib representative, 2009). Because the discussion of GMOs in the Netherlands and the EU has long been a difficult one, the GMO licensing policy is much stricter here than outside Europe. That is true not only for food crops, but also for non-food applications. The Bio-based Raw Materials Platform expects that stricter licensing will have a negative impact on the Dutch and European bio-based industry in the medium and longer term (PGG, 2009a).

What is notable about the GMO and biofuels debates is that they deal with similar issues. One important question in both is that of sustainability. According to its opponents, genetic modification does not fit in with the idea of a sustainable society – which is precisely what the bio-economy is supposed to help achieve. They suggest that sustainability criteria should therefore also be applied to GMOs. Experts, however, regularly comment that it is impossible to generalise either about the sustainability of GM crops or the sustainability of biomass in the bio-economy. All this goes to complicate the debate concerning the bio-economy. In the end, food and non-food production must take place side by side in the bio-economy (co-production), whether or not genetic modification is applied. In its *Biotechnology Trend Analysis* (January 2010), the Netherlands Commission on Genetic Modification (COGEM) therefore advised the then Environment Minister, Jacqueline Cramer, that "it is necessary for all the parties to have a sufficient understanding of the possibilities and impossibilities, consequences, and objections [with respect to genetic modification in the development of a bio-economy], so that informed choices can be made" (COGEM et al., 2010: 35).

## 3.2 Biorefinery

Once produced, biomass must be prepared for use in various applications. As described in Chapter 4, the biorefinery concept is central to this process. Biorefinery creates opportunities to use biomass as efficiently as possible, with the aim of developing the maximum number of applications by means of co-production. This involves using advanced forms of conversion that require new generations of technology. It is no surprise, then, that 'techno-trust' plays a major role in discussions of the bio-economy. This section begins by reviewing the debate concerning the

latest generation of biofuel technologies and the trust (or lack of trust) with which they have been greeted by the relevant parties. We then consider *where* the process of biorefinery – as a key technology in the bio-economy – should take place. That is an important question because those who actually develop and refine biomass (thereby making it a valuable commodity) are the ones who will derive the greatest economic benefits from it.

### 3.2.1 'Techno-trust': confidence in the latest generations of technology

The parties engaged in the biofuels debate often pin their hopes on the latest generations of technology, which allow us to use biomass in new ways. Opinions nevertheless differ on this point. There is confusion about what the 'latest generations' are and disagreement concerning how long it will take before these second and third-generation technologies are available for practical purposes. Stakeholders also disagree about the contribution that the latest technologies will make to sustainability.

**Speed of innovation**

Chapter 4 will show that many bio-economy innovations focus on second or third-generation biofuels. But what precisely do we mean by 'first', 'second' and 'third' generation? Do we mean the types of biomass that can be processed? Do we mean the percentage of $CO_2$ emissions that can be reduced by the technology? Or do we mean how 'advanced' the technology is? It is often unclear in this discussion whether parties are referring to 'second-generation feedstock', for example woody crops and algae, or to 'second-generation conversion technologies'. Algae are often labelled 'third generation', so that the term seems to refer to the raw material. In reality, however, even 'second-generation' technology can already process a wide variety of different biomass feedstock.

Opinions also differ considerably as to when new generations of technology will become available. Optimists say that the breakthrough is just around the corner. The question, of course, is which version they are referring to: 'generation 2, version 1.0' – the less sustainable version – or 'generation 2, version 2.0' – the much more sustainable version. André Faaij (Copernicus Institute) expects to see many more efficient methods become available shortly, whereby biofuels will be able achieve an energy yield of 60% (NRC, 2007). Others, however, do not expect to see the second generation of biofuels hit the market before 2018 (Wardenaar, 2008: 45). That is because such biofuels will require a major investment, which has so far been limited. After reviewing the National Renewable Energy Action Plans (NREAPs) that EU Member States are required to submit to the European Commission to show how close they are to achieving their sustainability targets in 2020, Greenpeace concluded that most countries will continue using mainly first-generation biofuels during this period (Greenpeace 2010).

Harriëtte Bos (Wageningen University and Research Centre) believes that significant progress is being made: enzymatic processes, for example, have been optimised considerably in recent years. That does not mean that they will be ready for use tomorrow, however. "It's nature, after all, and nature is unpredictable" (interview with Bos, 2009). The resulting technologies must also be economically profitable. What works in the laboratory may be too expensive when applied on an industrial scale. One example is the use of algae as raw material. The managing director of Europe's largest algae producer, Ingrepro, has said unequivocally that the commercial market is underestimating the technological challenges involved in large-scale production (*De Financiële Telegraaf*, 2009). Algae are micro-organisms, and when applied on an industrial scale, micro-organisms do not always simply do what one wishes (EurActiv, 2009c). There is a long list of other technologies that are not yet ripe for industrial application.

**Will new technology improve sustainability?**
Even if we can rely on new generations of technology becoming available in the short term, much of the 'faith' in the bio-economy nevertheless depends on whether this technology will in fact help solve the most pressing sustainability problems. Opinions once again differ considerably on this subject.

Optimists suggest that the new technologies will make it easier to meet sustainability criteria. That does not erase the problem cited above, however: these technologies will be forced to compete with less expensive processes, for example those that make use of first-generation technologies. More sustainable technology must therefore be profitable if it is to have a long-term economic effect and compete with alternatives that are economically interesting without requiring government support. At the moment, the palm-oil and sugarcane sectors are powerful because they control popular feedstocks. They naturally wish to retain their market share (interview with Oxfam Novib representative, 2009). Malaysia has already resisted the imposition of stricter sustainability criteria for liquid biomass in the World Trade Organization (MPOC, 2010). Many environmental and development organisations believe that mankind will have to do its utmost to solve the looming food crisis (interview with Natuur en Milieu representative, 2009; interview with Oxfam Novib representative, 2009). They are also sceptical about attempts to maintain our present pattern of consumption based on new, more 'sustainable' forms of biomass. "How many algae will you need to fuel a round-trip flight to Japan?" (interview with Natuur en Milieu representative, 2009). According to the ETC Group, a Canadian watchdog, biofuels based on algae and lignocellulose will not actually cut down on $CO_2$ that much. The ETC Group does not believe that there is much scope for sustainable biomass applications, including chemicals and materials (ETC Group, 2010).

The World Wildlife Fund (WWF) is more hopeful than Friends of the Earth

Netherlands or Natuur en Milieu that biotechnology will help tackle the problems associated with climate change. In its view, the knowledge produced by first-generation technologies provides a basis for developing biorefinery techniques and for replacing oil-based materials with biomaterials. According to the WWF, large-scale crises such as climate change require a bold approach. "Advancing the industrial biotechnology sector into a rapid establishment of a biorefinery infrastructure, able to compete with the petrochemical complex, is a great example of such a bold (…) approach" (WWF, 2009: 3).

The chairman of the Bio-based Raw Materials Platform (PGG) has also expressed his confidence in the role of new technology. In his view, enough knowledge of biomass technology and applications has now been amassed. "The job of the Bio-based Raw Materials Platform now is to investigate the market and find ways to stimulate it" (*Energietransitie*, 2010). The former Ministry of Economic Affairs expects the technology to be the least problematic factor; success will depend more on operational cooperation. Once companies are working together, the technology will soon emerge (interview with Economic Affairs representative, 2009). Opinions differ greatly concerning the contribution of technology to a sustainable bio-economy, in other words, and the confusion about what constitutes 'better technologies' does not help clarify what is already a wide-ranging discussion. A transparent, broadly supported description of the various 'generations' could help the various stakeholders reach consensus: *that* version of *this* particular technology utilising *that* raw material is sufficiently sustainable and profitable to adopt.

### 3.2.2 Biorefinery: where?

Biorefinery is a vital link in the biomass processing chain. It adds value by preparing biomass for various different applications. Economically speaking, biorefinery is an essential activity in a mature bio-economy and every country will want a piece of the biorefinery action. After all, biomass enters the process as fairly inexpensive feedstock and comes out as a much more valuable commodity, at least when the process is sufficiently developed to be profitable. Gerda Verburg and Bert Koenders therefore assume that the bio-economy will only be advantageous for developing countries if they move beyond treating biomass as mere feedstock destined for export and also transform it into a valuable commodity at local level (LNV, 2008: 17). The question is therefore: will biomass imports be refined in the country of origin, or will they be refined after they reach the Netherlands? The latter would give the ports of Rotterdam, Eemshaven/Delfzijl and Ghent/Terneuzen a huge economic boost and generate employment there. Although it is to the country of origin's advantage for the Netherlands to import refined biomass, doing so may also limit the economic significance of the Dutch bio-economy.

There is a similar problem when it comes to biomass produced in the Netherlands. Biorefinery is well suited to small-scale, local application, unlike in

the petrochemicals industry, where the need for very high temperatures makes production profitable only on an industrial scale. Some believe that a distributed structure is preferable in bio-based production. Huge tracts of land are needed to cultivate the necessary raw material, and it would therefore be better to refine that material locally, close to where it has been grown. Local processing of biomass and residual waste can generate new forms of employment and new markets. If the Netherlands and Europe import huge quantities of biomass, ports will be particularly popular places for biorefineries. If we really do intend making a wholesale conversion to bio-based feedstock, then the most profitable option is to integrate the relevant processing techniques into the existing structures and sales channels of the chemicals industry. That means developing biorefinery locations close to chemicals sites and the main logistical nodes. This idea is, however, inconsistent with the smaller, local approach that the EU in particular has envisaged for biorefineries, which would work with regional residual waste streams.

We can let the market sort this problem out, of course, but the question is whether that will automatically offer the best chance of capitalising on the promise of the bio-economy. Can local and distributed biomass processing mean more for the rural economy and sustainability than centralised processing in economic hotspots? And if so, how do we compare the broader economic advantages? How will we deal with this collectively? In answering these questions, we might consider the possibility of local government playing a role as the custodian of local interests. The various options – local and distributed versus large-scale and concentrated – have implications not only for the economic success of the bio-economy but also for the landscape, local employment, and the surrounding infrastructure. In 2009, the then Ministry of Agriculture, Nature Management and Food Quality asked the Social and Economic Council to analyse the spatial and logistical issues involved in developing a bio-economy (LNV, 2009a). The draft advisory report was published in late 2010 (SER, 2010)

## 3.3 Application

As a link in the biomass value chain, ‘application’ means not only the final form that biomass takes as a non-food commodity, but also the consumption of that commodity. This can be as a biofuel, a biomaterial, a biochemical, etc. The issues involved in this particular phase of the biomass processing chain concern the interests that arise when we encourage the demand for particular applications and the relationship between bio-based applications and consumer behaviour.

**Biofuels application**

When we stimulate the demand for biomass, new markets emerge. The biofuels debate also concerns how we will make the transition from first to second-generation biofuels if first-generation bio-ethanol proves to be very profitable (interviews with Oxfam Novib and Shell representatives). Government can act as a catalyst in this regard by stimulating the demand for biomass-based applications.

Once the market is able to operate under its own steam, it becomes difficult to move on to even better and more sustainable applications. Another, lesser, factor in the biofuels debate is the role of the consumer. Consumers have very little influence over how biofuels are used because that use is often hidden from view, leaving them with little choice in the matter. Biofuels are blended into fossil fuels without users being aware of it. This is clearly not a consumer-driven market (interview with PGG representative, 2009). Consumer choice plays a more important role when it comes to bio-based gas and renewable electricity. A third point is the extent to which biofuels go to maintain an unsustainable system. Biofuels lend a 'pretence of sustainability', but according to the World Wildlife Fund, they in fact go to support a $CO_2$-intensive transport system and increase social, institutional and cultural dependence on that system (WWF, 2009: 3).

**Bio-economy application**

The points cited above, which have influenced the debate about biofuels, return in the thinking about the bio-economy. Indeed, the role of the consumer and the 'pretence of sustainability' may play an even bigger role in the bio-economy than they do with respect to biofuels. We will look more closely at both these points.

Despite the economic significance of the 'demand' side, the debate about the bio-economy does not give enough consideration (as yet, at least) to the role of the consumer, even though it has been amply shown that consumers can yield considerable power. If consumers do not trust bioplastics, it will be difficult to make them a commercial success. Consumers may also feel the need to flex their muscles in such cases. In addition to trusting a product, another important factor in consumer choice is for consumers to see and understand what 'bio-based' actually means. How much biomass should a product contain before it can carry the bio-based label? The prefix 'bio' has become fashionable and is frequently used incorrectly. For example, a biodegradable 'bioplastic' is not necessarily made of biomass (NEN Website, 2010) – one reason why the European standardisation organisation for plastics is working on a report that will define the vocabulary for bioplastics. What this will mean for information provision is uncertain: will the definitions lead to a 'bio-based' product logo? What implications will that have for new bio-based applications?

There is reason to think that the success of the bio-economy in creating efficient biomass value chains may depend on consumer behaviour. After all, product recycling starts in every household's rubbish bin and in how they separate their waste. It is important, then, for consumers to know whether something is recyclable or bio-degradable. Consumers generally associate the world 'bioplastics' with 'natural' and 'biodegradable'. If that term leads them to assume that an object is biodegradable when it is not, they will dispose of it incorrectly. In addition, consumers are often unaware that bioplastics are not always as wonderful as they seem. Many bioplastics can only be composted in specific

industrial settings; they do not simply break down in a landfill site. In addition, the genetically modified origins of such crops as maize, sugarcane or starch potatoes – which form the basis of PLA (polylactic acid) – make it more difficult to compost the product (Lindo, 2009). "Not only does it place a band-aid on the consumption and waste production problems, but it also encourages further use of bio-plastic because, 'don't worry, it's compostable'" (Lindo, 2009). The positive emotional association that many consumers have with the prefix 'bio' is not always correct, in other words. According to Bos (Wageningen University and Research Centre), product functionality should also be a key factor in the decision to give a bio-based product precedence. Plastic can be made stronger by applying many thin layers, whereas paper requires more material to achieve the same degree of strength. "And you can reuse a plastic bag five times. The paper bag rips after two uses. But if the paper bag is less harmful to the environment, then it would be my choice" (interview with Bos, WUR).

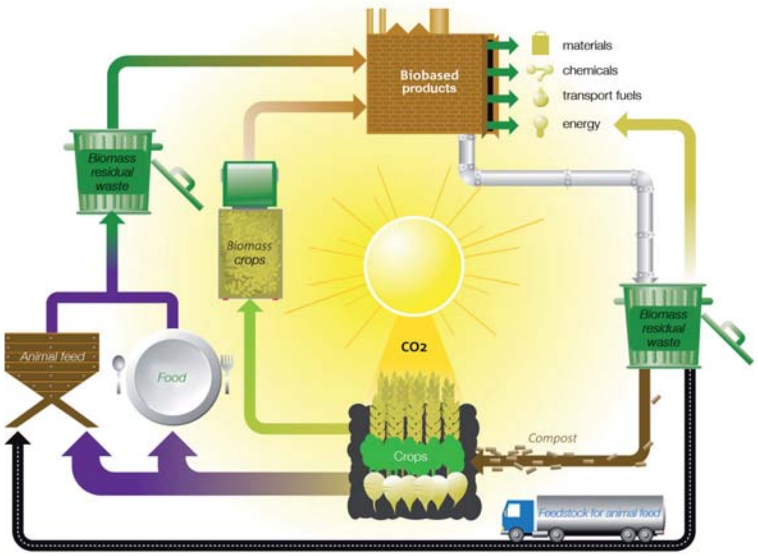
Can environmentally aware consumers make their influence felt in the bio-economy? A mature economic system benefits from a healthy balance between supply and demand. The foregoing considerations make clear that the bio-economy can also create the illusion of sustainability, although in reality it may simply be a green veneer applied to what is essentially a wasteful and unsustainable system. Specifically, the bio-economy offers no incentive to limit our voracious appetite for consumption. Indeed, it implies that we can keep driving our cars, packaging our products and throwing away the packaging because, after all, 'it's green'!

It is possible that using biomass will make the impact of our consumer behaviour clearer, causing consumers to deal more carefully with feedstock as a result.
It will not be easy to change our consumer society, however. Consumption will continue to play an important role in how we deal with dwindling resources and in our battle against climate change. This elementary issue is frequently left out of the discussion of the bio-economy.

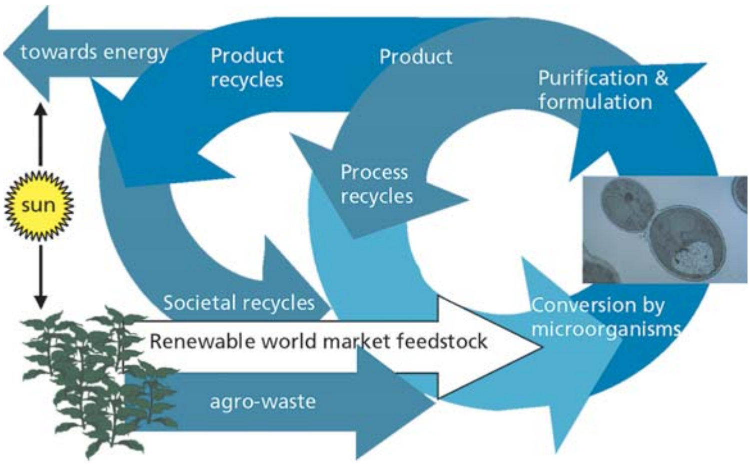
## 3.4 New residual waste: efficient chain management

Efficient chain management is a key concept in the bio-economy. It is also a good example of the factors that the bio-economy concept adds to the linear use of biomass, for example as a biofuel or in a co-firing process. Efficient chain management must be achieved, for example, by using existing agricultural by-products. Ideally, the harvest should be separated into a number of components, each of which is processed and commercialised separately. One of the main challenges of the bio-economy is to turn such linear chains into closed loops. Figure 3.2 shows how government and the B-Basic research consortium imagine these closed-loop systems. The closed-loop perspective raises major logistical and organisational questions, but it also identifies various points at which different parties can collaborate, as the final part of this section will demonstrate.

**Figure 3.2** How government and the B-Basic research consortium envisage closed-loop systems in the bio-economy (top, developed by the Wageningen University and Research Centre, source: LNV, 2007, and bottom, source: B-Basic).




Source: LNV, 2007




Source: B-basic

**Logistical and organisational challenges**
Closed-loop systems require close collaboration between parties, a tight logistical organisation, and a profitable way of using (or reusing) residual waste. The transition to a bio-economy therefore demands considerable organisational skill: huge volumes of biomass must be transported and the residual waste reprocessed in order to achieve a closed-loop system. That involves adapting, and to some extent reengineering, the logistical system. Pipelines, for example, must be altered to make them suitable for bio-ethylene. Ports must be prepared to quickly and efficiently ship or even process huge quantities of incoming raw biomass and residual waste. Biorefineries must take delivery of biomass and waste from local farmers. And if at all possible, even the lorries required to transport the biomass should run on biofuel or electricity generated in a biomass power plant, to prevent excessive $CO_2$ emissions from tipping the greenhouse gas balance in the wrong direction. The physical organisation is only one aspect, however; what is also vital is to get parties working together that have no traditional relationships with one another. The status of farming vis-à-vis other sectors will change, for example: the chemicals industry will have to start regarding farmers as feedstock suppliers and work closely with them in order to match the right products to the right applications. That will require close collaboration between two highly divergent cultures. It will also require the two sectors to give their people the latitude to innovate and make new connections.

**Statutory barriers**
Government has chosen to play a facilitative role in order to tackle the challenges described above. Both the Bio-based Raw Materials Platform and government would like to use businesses cases to gain the necessary practical experience with these issues, so that they can identify key problems and opportunities (interview with PGG representative, 2009; LNV, 2009).
Government policy is not supportive on some points, however; in fact, when it comes to closed-loop systems, it even stands in the way of innovation. For example, the EU will have to reconsider its definition of 'waste' if it intends helping the bio-economy reach maturity. The current rules pertaining to waste are so strict that recycling is simply not profitable, says the Netherlands' Biotech Industry Association (Niaba) (*Trouw*, 2008). At the moment, for example, mown grass that is not suitable as animal fodder is composted. Composting generates less money than it costs, which is why suppliers began to search for new, more profitable markets. They now supply grass to the paper and chemicals industry, which in their turn had been seeking more sustainable feedstock. The current waste legislation makes it difficult to sell grass, however (*FD*, 2009c). The use of industrial sugar as a bio-based feedstock is also uninteresting because it costs much more in Europe than elsewhere. This type of prohibitive legislation could cause bio-based activities to move abroad (*Trouw*, 2008).

**Quiet agreement?**
The aim of chain management efficiency may give rise to various issues, but it is

also the element of the bio-economy that receives the most backing. Although civil society organisations criticise it, they also recognise opportunities in the basic concept. Natuur en Milieu, for example, praises the smart use of as many local residual waste streams as possible (Natuur en Milieu, 2008a). That largely matches its own ideas, as described in its publication *Heldergroene Biomassa* [Bright green biomass] (Natuur en Milieu, 2008b). Many environmental organisations believe it is important not to increase the demand for feedstock, but rather to make more efficient use of the feedstock that we already have. The key challenges in this context are efficient chain management and the use of residual waste.

Development organisations recognise opportunities in the attention now being given to productivity increases. In their view, investment in agriculture in developing countries has long been inadequate. It would be wonderful if biomass production were to lead to an increase in the level of investment in a way that helped those suffering from hunger. “We have to grasp those opportunities, but the question is: how ambitious are we? Who will benefit? And what will have to be sacrificed to make it happen?” (interview with Oxfam Novib representative, 2009). So it appears that there is some support for chain management efficiency as the basis of the bio-economy, but not for the import of huge quantities of biomass.

## 3.5 Innovation strategy

The controversies concerning the various steps in the biomass production and processing chain demonstrate that the development of a bio-economy involves a complex process of change fraught with uncertainties. There are many different opinions as to how we should be dealing with this process of change. Should we simply tackle the challenge and learn by doing, or should we ensure that have the right – i.e. sustainable – methods before we increase the demand for biomass? In 2008, the General Energy Council [*Algemene Energieraad*] advised government not to wait too long: “The Netherlands must push to tighten up the EU’s sustainability criteria during the negotiation process. The Council believes that we must start somewhere, and that we will learn by doing” (AER, 2008). The Bio-based Raw Materials Platform also wants to work on reaching solutions, and not always proceed with caution. The Platform hopes that by setting up projects, it can learn first-hand where difficulties may arise and how to guide progress in a sustainable direction (interview with PGG representative, 2009). As the director of Solarix, a firm that is already working to develop such innovations, commented: “We are too much inclined to base our actions on threats instead of opportunities. That’s not going to get us anywhere” (interview with Hoitsma, 2009).

Many environmental and development organisations disagree, however. They fear that it will be impossible to undo the negative consequences. “To be honest, we think that the sequence is backwards: policy is always formulated

and implemented *first*, and only *then* is consideration given to whether things can be done sustainably as well" (interview with Oxfam Novib representative, 2009). As long as the macro-effects are not properly monitored, said these organisations in a collective letter to the Dutch Parliament, it is crucial that we proceed with caution, "for example by cancelling the 4% blending obligation in 2010" (Natuur en Milieu, 2008c). And if we do go ahead with sustainability criteria and certification, let us do so within the existing, steadily expanding food market before increasing biomass demand by introducing other applications. Another criticism is that policy tends not to question technological advances, extra investment or other assumptions. "We say: turn it the right way round. *First* look at what can be done sustainably, and *then* adjust your policy to the outcome" (interview with Oxfam Novib representative, 2009).

Does 'learning by doing' in fact involve more 'error' than 'trial', or does 'proceeding with caution' actually mean 'sitting around doing nothing'?

Some reproach government for encouraging biomass applications without making strict demands on production, import and use in order to guarantee sustainability. Others say that we must do something *now* to start making the sustainable society a reality, and that every silver lining has its cloud. We must not go round finding fault with everything, but instead look at the benefits that a bio-economy can have compared with our current fossil-based economy. One hundred per cent sustainability is a Utopian ideal, but can we at least try to improve the unsustainable situation that we are now in?

On top of that, we often do not look closely enough at total emissions in our fossil-based economy, so that the comparison with the bio-economy is unfair. Many people in the Netherlands are not aware of the damage that oil-drilling operations wreak on the drilling sites (interview with Bos, 2009). In other words, we must be careful about only raising objections to the new system when we are not even fully aware of the disadvantages of the old system.

With so many differing opinions concerning the best innovation strategy, scarcely anyone seems to be considering the points on which the parties do agree. The core of the concept – optimising biomass use – is hardly ever mentioned precisely because there is overall agreement on this point.

## 3.6 Naturalness

Notions about 'naturalness' play a key role in the debate about the bio-economy because they are related to the various opposing positions taken up in the debate. The role of naturalness was already a factor in the controversy surrounding genetic engineering. Some of the parties engaged in that debate expressed concern about the possibility of creating cross-species. The dividing lines between species were seen as natural barriers that, if crossed, would create unforeseen risks. Proponents of genetic engineering placed less emphasis on

such assumed natural barriers and the associated risks. They pointed out that mankind had been tinkering with 'natural' phenomena since prehistoric times, and that 'naturalness' remained an entirely ambiguous concept.

Notions of naturalness clearly inform the views of those taking part in the debate, then, even though – initially at least – such notions generally smoulder beneath the surface. This section attempts to clarify the concept of naturalness by describing three radical views that offer us a good idea of the arena in which the debate is taking place: a romantic view of nature, a utilitarian view of nature, and a controlling view of nature. Alongside these radical views, there are also more moderate and mixed positions. By explaining the radical positions, we hope to clarify various factors that can also be detected in other views.

**Bio-economy: living in harmony with nature**

The following quotation provides a good example of the romantic view of nature and the bio-economy. It is taken from a speech given by Cees Veerman, former Minister of Agriculture, Nature and Food Quality, at a conference on 'Sustainability, rural development and rural tourism' in 2005.

> "Ever since man began to grow food, herd cattle, build simple dwellings, his economy has been based on renewable natural resources. It has been like that for untold ages; let me remind you that the petroleum-based economy is a mere 140 years old and unlikely to survive into the next century. So let's not talk about the emergence of bio-based economy; let's call it a triumphant come-back."

As we will see in another chapter, the period before the transition to a petroleum-based economy was far from rosy. It is by no means clear, then, whether everyone considers the come-back of the bio-based economy as 'triumphant'. The romantic view promotes the idea of a new and harmonious relationship with nature. New technologies will make it possible to find a new, natural balance. By assigning an economic value to biomass, we will have a good reason to protect eco-systems, which will, after all, become valuable sources of raw materials. That also, however, involves making far-reaching changes to our global social and economic system. The bio-economy must be organised locally and be capable of dealing with a huge variety of different types of biomass. It will succeed if small-scale farms and local markets are given precedence over the large multinationals and monocultures that supply the world market today. If genetic engineering can satisfy these requirements, it too can become part of a successful bio-economy. These views are among those expressed by a number of environmental and nature conservation organisations, development organisations, and in some international policy.

**Bio-economy: making efficient use of nature**

We can also consider the development of new feedstock as a means towards

making our consumer society 'greener'. Fossil materials will give way to renewable, plant-based feedstock in a way that does not pollute the food chain or the natural environment. We do not need to dismantle the entire economic system; we simply have to deal more efficiently with our natural resources. If we truly wish to escape the limitations of the fossil economy and the threat of climate change, we must not shy away from grand gestures. Our current global economic system already has the necessary infrastructure, and efficiency is an important prerequisite. Essentially, we can achieve that greater efficiency through nature. There are many valuable plant-based substances that could be useful to industry. Where necessary, genetic modification can improve natural efficiency. The bio-economy and, in its wake, genetic modification can also make crop cultivation on marginal land possible. Farmers can increase both their markets and their productivity in this way, giving them an opportunity to benefit from the current economic system. This is the view propounded by the producers of bio-based products, for example the chemicals industry, biofuels producers and organi-sations such as the Bio-based Raw Materials Platform. It is a view also shared by the World Wildlife Fund (at least to some extent).

**Bio-economy: controlling nature**

In this view, nature offers us the ultimate feedstock for a sustainable society, and mankind need not sacrifice any comfort, convenience or opportunities to achieve economic progress. In fact, biological material will make it possible to improve society in many different respects. Whereas the previous view advocates replacing existing raw materials by plant-based ones, in this concept the focus is on using plant-based feedstock to create new alternatives. Most important is that plant-based feedstocks provide the basis for new, human-engineered designs, for example by means of genetic modification or synthetic biology. This is the view put forward by a number of leading scientists, among them Robert Carlson (2010), Craig Venter and Lee M. Silver (2006), and by such innovative biotech firms as Amyris. The idea of controlling nature through technology has always met with considerable public resistance. Critical environmental organisations such as the ETC Group (2010) see the search for new feedstocks as the ultimate mechanisation of nature. They fear that every bit of natural material will be broken down into functional components and guzzled up by the Western consumer society, placing them out of reach for developing countries and removing them from the cycles of nature. Opponents of genetic modification concur with this view to some extent. Such critics feel a sense of unease when we 'tinker with plants'; to them, it seems as if we are making nature entirely subordinate to our needs and no longer recognise the inherent value of the natural world. A similar criticism has been voiced by a number of environmental and nature conservation organisations, including Greenpeace. There are also fears concerning the safety of genetically modified organisms and our ability to monitor and control such organisms. Genetic modification has also met with resistance because it reaffirms the power of big business, which now has the option of patenting living material. This underlines the above-mentioned

fear that living material will become mere feedstock for the life sciences industry, with such vulnerable groups as small farmers coming off second-best.

## 3.7 Conclusion

Most of the controversy surrounding the bio-economy concerns biomass production, as we have seen in this chapter. To some extent, the controversy has arisen because the parties have differing views of 'naturalness'. There is broad agreement concerning the idea of chain management efficiency and biomass valorisation, although opinions once again differ when considering how chain management efficiency should be achieved. Below, we review the most important discussion points.

**Biomass production**

The first part of the value chain is the most fiercely debated. The large-scale import of biomass has led to discussions concerning its availability and how to guarantee sustainability. Some critics believe that we should not increase the demand for biomass because mankind is already facing shortages of food and water and a decline in biodiversity. Others are confident that new technologies and greater efficiency will ensure a sufficient supply of biomass.

One of the most controversial points is how to guarantee biomass sustainability. How do we enforce sustainability criteria when biomass becomes cheaper than oil? And how do we cope with the macro-effects? The situation becomes even trickier if the sustainability criteria only apply for some of the biomass (i.e. liquid biomass used as a biofuel). Preferential treatment of this kind could undermine support for the existing criteria. In the case of co-production, a further and much more difficult question is whether and when an application can be called 'sustainable'. If we use residual waste from the factory farming system, for example, does that make factory farming 'more sustainable'? Because the bio-economy increases world trade in biomass, the need for transparency and sustainability on the world market will be greater than ever.

One issue that may become even more controversial under the influence of the bio-economy concerns genetically modified crops (GMOs). The controversy is already smouldering beneath the surface in the biofuels debate, but the question may well become even trickier if co-production makes it harder to define the purpose that a particular quantity of biomass will serve. If part of a plant is destined for consumption and part for the chemicals industry, then consumers are likely to find it important that none of the plant is genetically modified.

**Biorefinery**

The discussion concerning the following steps in the chain – development and processing, or rather refinery – focuses on whether our confidence in new generations of technology is justified. New technologies such as biorefinery and

artificial photosynthesis are the backbone of the bio-economy. Can these new technologies actually solve the problems we face with respect to effectiveness and efficiency and the negative indirect effects of biomass use? Opinions differ on this score: on one side are the optimists, and on the other are those who point out that there are still many obstacles on the road from dream to reality. The rise of new technologies also raises questions about openness: how can poor countries participate in the bio-economy if the right to use the technologies is restricted, for example owing to patents? A related question is where the process of biorefinery should take place: where will the value be added to the biomass, and who will profit?

**Application**

The environmental movement has asked questions about the sustainability of the bio-economy as a new system with respect to product consumption. It is an economy based on biological materials, and not one that will necessarily lead to a change in human behaviour. Indeed, it seems as if it will even increase our dependence on unsustainable practices, such as motorised transport. Thanks to biofuels, society will not have to undergo any vital change: we simply make the existing practice 'green' and hope that it becomes more sustainable as a result. The role that consumers play in all this is, furthermore, unclear. It is difficult for them to be critical buyers because they will simply be unable to determine whether a product is bio-based and, if it is, what that means for its sustainability. The chemicals industry can indeed save energy by using biomass, but doing so gives our pattern of consumption a semblance of 'greenness' that is not always deserved. It may even lead to more consumption, "because it's green, isn't it?". On the other hand, it seems that new solutions often have to meet stricter requirements than existing systems, and – compared with the present petroleum-based economy – a bio-economy may turn out to offer a quicker and more realistic path to sustainability than we can expect to achieve in the foreseeable future with behavioural change.

**New residual waste streams: efficient chain management**

Efficient chain management is a vital element of the bio-economy and appears to be supported by the majority of stakeholders. This particular link in the chain is consequently the least disputed. The chain management perspective has, however, raised questions about logistical challenges and statutory roadblocks. Choosing a particular closed-loop system may also give rise to vested interests that prevent an even more efficient system from developing.

**Innovation**

The question now is how the shared aim of chain management efficiency can be achieved. There are two opposing views concerning this issue. The advocates of *learning by doing* believe that sustainability is still a vague concept, but that it will gradually become clear how to use biomass in the most sustainable way possible. Their opponents are those who advocate *caution*. They think biomass

is a good alternative only when it is incontrovertibly sustainable. If that fails to happen, then there is a risk of a lock-in, with unsustainable applications capturing a huge share of the market and defining the infrastructure, leaving little scope for sustainable alternatives.

**Naturalness**

The debate concerning the bio-economy has its roots partly in differing views of nature and naturalness. There are three main viewpoints. The idea that the 'bio-economy means living in harmony with nature' is mainly supported by environmental and nature conservation organisations, and in some cases by government and scientists. The idea that the 'bio-economy means dealing efficiently with nature' is supported mainly by industry and the scientific community. Finally, the idea that the 'bio-economy means controlling nature' is supported by pioneering scientists and innovative industry. These notions influence such questions as whether genetic modification can make a valuable contribution to the bio-economy. They also play a role in the question of whether technology can lead to a sustainable bio-economy. The first group of stakeholders – those who view a sustainable bio-economy as being at one with nature – believe that major changes are required in our current economic system. Society needs much more than new technology alone; it must learn to deal with raw materials in an entirely different way.

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4

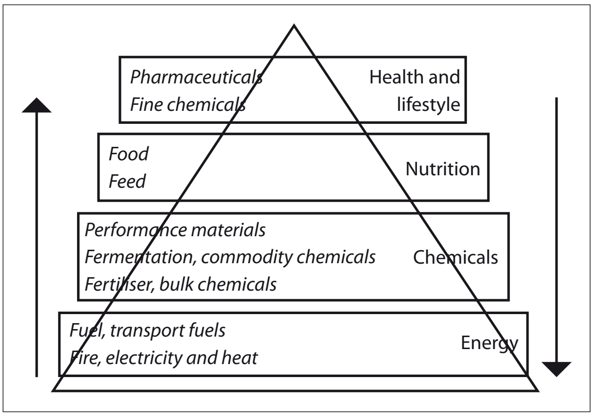
# 4 Innovation: en route to a bio-economy?

Huib de Vriend and Dirk Stemerding

The idea behind the bio-economy is that biomass can meet even more of the demand for biobased products than it now does. Innovation is the key, but a bio-economy involves more than technological advances alone. It also means a process of 'transition' that is geared to optimising coordination between the various biomass production and conversion chains. In this chapter we will look more closely at how innovation can contribute to the development of a bio-economy.

As explained in previous chapters, one of the key concepts in the bio-economy is that of biorefinery. The idea is that breaking biomass down into its constituent parts is much more efficient and of greater economic value than using it in raw form, without breaking it down. This idea returns in the 'value pyramid'. The value pyramid shows how we can optimise our use of biomass by closely coordinating the various biorefinery processes.
In the future, for example, the potato starch industry will focus on producing high-value proteins and on using miscellaneous by-products to generate biogas. Conventional potato processing plants concentrate on producing starch, and the by-products are either left behind on the land (plant leaves) or are used in animal feed (potato pulp).

**Figure 4.1:** 'Value pyramid'




Source: LNV, 2007:19

This chapter consists of three sections. The first discusses the techniques and fields of technological innovation that play a role in the biorefinery concept. The second section focuses on biomass processing and the related technological innovations in the various segments of the value pyramid. The final section considers the way in which the various activities that make up the bio-economy need to be coordinated with one another. It makes clear that in order to arrive at a bio-economy, society must undergo a transition whose success depends not only on technology (new or existing), but also on political, economic, and ecological issues that have not yet been resolved.

This chapter is based on an extensive study of the literature. In addition, the authors asked a number of stakeholders to share their views on the opportunities and threats associated with bio-based applications in the economy.

## 4.1 Biorefinery

The biorefinery concept has gone beyond the drawing board stage. Numerous research institutions and enterprises are already working hard to generate the necessary knowledge, technology and logistical solutions needed to make the large-scale, sustainable production and processing of biomass possible. The necessary coordination between links in the production and distribution chains is already taking shape in various partnerships between enterprises that specialise in the production of sugars (for example Tate & Lyle, Cosan in Brazil) and petrochemical companies (DuPont and Shell; see DuPont, 2007). In a few cases, coordination takes place within an enterprise; examples include companies that specialise in the production and processing of grains (Cargill and ADM) and businesses that use bio-based products (car makers Toyota and Mitsubishi).

This section discusses the techniques and technological innovations that play a key role in the development of biorefinery. We distinguish between mechanical separation techniques, thermochemical conversion techniques, and biochemical conversion techniques. The techniques that offer the most potential for biomass refinery are the biochemical conversion techniques. Advances in biotechnology, genomics research, and synthetic biology play a vital role in this regard. These advances not only involve conversion of biomass into a variety of products, but also alignment of plant and algae traits to the requirements of optimal productivity, processing and utilisation.

### 4.1.1 Mechanical separation and thermochemical conversion techniques

Bio-based products can be derived from entire organisms (e.g. plants or algae), from by-products (e.g. part of a plant or manure), or from a solution containing micro-organisms in a bioreactor. We have numerous separation and refinery techniques at our disposal that take the form of physical, mechanical, thermal, or chemical processes. The first step usually involves separating solids and liquids and extracting a product; the following steps are concentration, purification, and refining (Vogel and Tadaro, 1997).

### Mechanical separation

The mechanical separation of different categories of biomass takes place during crop harvesting and processing, when the useful parts of the plant – the leaves, roots, tubers, fruit, seeds, and fibre – are separated from the rest. Non-useful parts are often left behind on the land to be ploughed under later. Increasingly, however, such by-products are harvested separately so that they can be turned into more high-value products. This includes seeds and fruit left behind after juicing, the peels and skins of fruits and tubers, residual sugar beet pulp following sugar extraction, and sawdust and other wood waste.

One way of separating the solid and liquid components of biomass is with a centrifuge separator, for example as used to dewater manure. Filtration devices such as sieves and membranes can separate particles of differing sizes, such as when cleaning landfill gas to bring it up to natural gas standard. Mechanical separation techniques ultimately ensure that biomass is separated into fractions of the right composition, purity and size. The separation process can be used to recover various recyclable elements such as glass, metals and combustible components such as *plastics* and *biodegradable waste* from residual waste streams. Mechanical separation also makes it possible to optimise any further refinery and use. One example is Grassa, a consortium in the Dutch agro-sector that intends using grass to produce protein for the animal feed sector by relatively simple means. Their product can replace protein-rich feed such as soybean pellets. Grassa has a test plant (in the town of Oenkerk in the Dutch Province of Friesland) where grass is pulverised until the juice can be squeezed from it, leaving only the fibre behind. The grass protein is in the juice. Heating the juice turns the protein into a solid, which can then be filtered out. The residual fibre can be used as a new, renewable material for the paper and cardboard industry. The ultimate aim is to set up a mobile grass refinery plant.[1] Similar approaches have been developed by other institutes, companies and industrial consortia such as the Research Institute of Bioactive Polymer Systems e.V. (BIOPOS)[2] and BIOWERT, a producer of insulation materials and cellulose-based construction materials[3], both in Germany, and the Green Biorefinery Austria (Van Ree, 2007)

### Thermochemical conversion

The most common form of thermochemical conversion is combustion. Biomass is used directly in power plants as a co-firing agent, usually after it has been prepared (compaction, dehydration) so as to optimise the combustion result. New combustion technologies developed in recent decades provide for the clean and efficient conversion of biomass to energy. Examples are fully-automatic pellet boilers, co-firing systems, and CHP systems that can run on many different types of biomass.

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1 www.grassanederland.nl

2 www.htc-labs.org/en/home/

3 www.biowert.de/biowert/

Another type of thermochemical conversion is gasification. Biomass is depolymerised at a temperature in excess of 200° C. One of the end products is furfural, an oily, colourless to light-yellow liquid that is heavier than water. Furfural is used primarily to produce other chemical and pharmaceutical substances, but it is also used in perfumes, as an impregnating agent, as a fuel additive, and as a solvent in the petrochemicals industry. The oxygen-poor combustion of biomass followed by steam reforming, catalysis, and purification can also produce syngas (synthetic gas), a mixture of carbon monoxide and hydrogen. Syngas can be used to produce synthetic hydrocarbons. This is known as the Fischer-Tropsch process and was widely used in Germany before and after the Second World War to make synthetic fuels for motorised vehicles. It is now attracting interest because of the potential to produce diesel from biomass in this way (Boerrigter and Van der Drift, 2004). There are a number of technical problems to solve first, especially when it comes to producing a fuel suitable for today's engines and finding a good way to process the tar that is left as a by-product.

Torrefaction and pyrolysis are thermochemical conversion methods in which biomass is converted at high temperatures in the absence of oxygen. The best known example of torrefaction is the charcoal production process. It can also be used to convert agricultural by-products into biocoal,[4] which can be used in co-firing processes in coal power plants. Pyrolysis can convert biomass into oil. In 2005, the Innovation Network, the State Forest Service, the Biomass Technology Group (BTG) in Enschede, and a number of other parties launched the Grasol project. Its purpose was to use grass grown in nature conservation areas to produce pyrolysis oil, which can be used in co-firing processes in power plants and in the greenhouse horticulture sector; it can also be blended with transport fuels or turned into other high-value components. The project ended in late 2007. Work on the technology has continued, but it will be a number of years before the large-scale production of pyrolysis oil becomes possible (Innovatienetwerk, 2008; Dossier Biomassa, 2010). The Biomass Technology Group also participates in the EU-funded EMPYRO project, which started in December 2009 and will run until November 2013. The main aim of the project is to build and demonstrate a 25 MWth polygeneration pyrolysis plant to produce electricity, process steam and fuel oil from woody biomass. The produced fuel oil can be used on-site, sold to a regional customer or exported. EMPYRO brings together a number of Dutch, German and Danish companies specialised in industrial chemicals, recycling, sustainable biomass energy systems, machine design and fluid mechanics (EMPYRO, 2010).

### 4.1.2 Biochemical conversion

**Fermentation processes: from grass silo to high-tech enzymes**

Biochemical conversion has long been a customary method of fermenting biomass and takes a variety of different forms. Fermentation processes can be

4 www.dutchtorrefactionassociation.eu

applied directly to raw biomass or to the fractions obtained after mechanical separation. Examples of traditional fermentation processes including brewing beer, retting flax to produce linen, ensiling maize and grass for animal feed, and fermenting manure and other waste. There is considerable research being carried out into biomass fermentation; most of these studies focus on improving the fermentation process so that it adds value to the chain.

In fermentation processes, enzymes made by micro-organisms function as biocatalysts. Companies such as Novozymes, DSM, and Genencor-DuPont also produce pure forms of enzymes commercially for a variety of different production processes. Enzymes trigger specific biochemical conversions and generally function under less extreme conditions, so that the related processes do not require much energy. Enzymes are also biodegradable, making them an environmentally friendly alternative to aggressive substances and pollutants in many cases. There are already quite a number of commercially-produced enzymes for industrial applications, for example laundry detergents, cleaning products and cosmetics, in the paper, textile, fodder, and leather industries, and for the production of biofuels. Enzymes are an alternative to acids in the starch industry; in the textile industry they replace alkaline and other substances; they can be used as an alternative to sulphides in leather tanning; and paper mills can use them instead of chlorine to bleach paper. Sewage treatment plants also work with enzymes.

**An outstanding example of measurement and control technology**
Anyone touring the plants operated by DSM in Delft or Genencor in Ghent will see a number of huge steel vessels there fitted with pipes, valves, and a lot of measuring instruments. Such components are typical of high-tech bioreactors, where biochemical conversion processes take place on an industrial scale.
A bioreactor is a vessel containing micro-organisms of a specific strain that make a product under optimised circumstances. The micro-organisms feed on a substrate that generally consists of sugars. The circumstances within the bioreactor are monitored closely. Factors such as the oxygen level, acidity, temperature, cell density, and concentrations of substrate and product are measured constantly and adjusted when necessary (Ahmann and Dorgan, 2007). The mixture must be agitated, aerated, and cooled; nutrients must be added; and the products and waste products must be removed. All this requires precise measurement and control technology.

A number of different bioreactor types have been developed in the past forty years, ranging from vessels with agitators to bubble columns. It takes a great deal of know-how to apply new, laboratory-tested fermentation processes on an industrial scale. Computer modelling is essential to controlling all the processes. Computer-generated models incorporate knowledge about the way microbial metabolism develops in the reactor. In order to analyse large metabolic networks, it has become common to use isotope-labelled substrates to track the

processes taking place in the cell. Real-time sensing of liquid flows and of intermediate and end products in the reactor makes it possible to validate reactor models on an industrial scale, constantly monitor the biochemical conversion processes, and make adjustments (automatically) if necessary. In the past, this work was done by electrochemical sensors and spectroscopic techniques. A more recent method uses green fluorescent protein (GFP) expression induced by the presence of certain molecules. This makes it possible to track the presence and concentration of a product, for example (Ahmann and Dorgan, 2007).

### 4.1.3. Biotechnology as a new key technology

Biotechnology also offers a growing number of ways to re-engineer the metabolic pathways of organisms/micro-organisms. New techniques are rapidly becoming available that enable the analysis of huge quantities of genetic material. The possibility of genetic modification has become so advanced that the techniques used to develop the first transgenic micro-organisms and crops can almost be called 'conventional'. Biotechnology has become a key technology for the development of a bio-economy. That development encompasses both 'white' (i.e. industrial) biotechnology and 'green' (i.e. agricultural) biotechnology. In white biotechnology, innovation helps improve how we use micro-organisms to convert biomass into useful components and for the production of fuels. In green biotechnology, it helps us optimise both the crops and algae that can serve as new sources of biomass. Below, we look more specifically at a few trends in biotechnology that make a special contribution to innovation in both these areas.

**Analysis and identification: from microarrays to DNA markers**

Using computers to rapidly 'read' DNA has made it possible to analyse huge quantities of genetic material in a very short span of time. Microarrays ('DNA chips') play an almost indispensable role in this area. Thanks to the large-scale analysis of genetic material, we are coming to learn more about DNA markers, i.e. DNA sequences that always occur in combination with a certain trait. For example, we have already found many different DNA markers for numerous crops indicating such traits as disease resistance, salt tolerance, baking quality (wheat), and a high concentration of lycopene (tomatoes). These genetic markers make it possible to determine to a high level of accuracy whether a particular trait is present in a conventional hybrid product. The test involves taking a DNA sample; it is therefore no longer necessary to cultivate the next generation and select plants on the basis of physical or chemical traits. That is an enormous advantage for plant breeders, and it also allows them to select plants on the basis of traits that are difficult to detect using the traditional methods (EU-SOL, 2010; Lammerts van Bueren et al., 2010; Vogel, 2009).

**Exploring biological diversity: x-omics research**

Large-scale analysis of genetic material also makes it possible to explore the

biological diversity of our planet in new ways. In addition to approximately 400,000 plant species, the earth also has a virtually endless number of different strains of micro-organisms and algae, only a tiny fraction of which has been identified (Whitman et al., 1998). They are expected to have many traits that will turn out to be useful in the bio-economy. It is partly for that reason that scientists around the world are attempting to map the earth's biodiversity. One example is Craig Venter's Sorcerer II expedition. Venter and his crew are sailing the oceans of the world on a luxury yacht, stopping every 200 nautical miles to take a sample of water (Shreeve, 2004). Thanks to modern equipment, it is possible to rapidly determine the order of the nucleotide bases in a sample's DNA (DNA sequencing). Because there are huge numbers of samples to analyse and the samples are taken from many different environments and therefore represent huge quantities of DNA, this type of research is sometimes referred to as 'metagenomics'. Thanks to ever-faster DNA sequencing techniques, meta-genomics research has really taken off (Marco, 2010; Madrigal, 2008). The latest generation of sequencing systems can read more than 1 billion bases in two hours time – in other words, more sequences than in an E. coli bacterium (4.6 million base pairs) or in brewer's yeast (Saccharomyces cerevisiae, 12.1 million base pairs). New software, nanotechnology and other techniques are expected to increase the speed even more (Bourzac, 2009; Karow, 2010; Ion Torrent, 2011). Comparable research is being conducted using samples taken from different types of soil and from numerous other biotopes, with there being particular interest in locations that typically have extreme oxygen levels, pH values, temperatures, and so on (Schloss, 2009).

Linking all this DNA data to cell traits and cell function has given rise to a whole array of technologies, sometimes known as 'x-omics'. Roughly four scientific disciplines are combined in x-omics (CBD, 2009): genomics, which studies the genome (DNA) of organisms; transcriptomics, which studies gene activity (RNA expression); proteomics, which studies the structure of gene products (proteins); and metabolomics, which studies the role of small organic molecules in cell metabolism. Together, these disciplines show us how molecular processes in living cells are interrelated and how cells function under a variety of conditions.

**Modification of genetic traits: from recombinant DNA to synthetic biology**
Our growing understanding of the genome and its functions also allows us to alter the genetic traits of organisms in specific ways. Recombinant DNA techniques, in which one or more genes are added to a cell's DNA, are now considered 'conventional'. A more radical form of genetic modification is DNA shuffling, i.e. slicing genes randomly into segments and allowing them to recombine (Coco et al., 2001; Joern, 2003). This gives rise to a large number of mutants that can then be screened for specific traits. The process can be repeated if necessary. The approach is also referred to as 'directed evolution' (Trafton, 2010). DuPont Pioneer has already used this process successfully to improve the biocatalytic activity of industrial enzymes and to develop herbicide-tolerant maize (Hibbert

and Dalby, 2005; Rubin-Pitel and Huimin, 2006; Castle et al., 2004).

Going a step further is the use of automated systems for combinatorial DNA technologies, for example multiplex automated genome engineering (MAGE) and accelerated evolution. MAGE involves grafting pieces of synthetic DNA (see below) into the genomes of dividing cells, so that cell uses the new DNA when copying itself. Each subsequent cell division gives rise to more and more chromosomal mutations. This technique allowed researchers to produce a billion mutations of the E. coli bacterium in a single day. It then took them only a few days to isolate strains of E. coli that produced five times more lycopene than usual (Wang et al., 2009). Lycopene is a bright red antioxidant that occurs naturally in tomatoes and other red fruit and is added to butter, margarine, soups, sauces, and pastry as an ingredient and nutritional supplement. There is evidence that lycopene may have health benefits.

We can also alter specific traits of organisms by influencing gene expression. Gene expression is the process by which the genetic code stored in DNA is transcribed to produce RNA and then proteins. This process can be controlled in a variety of different ways. The efficiency of gene expression can be increased with the aid of specific promoters, i.e. relatively short sequences of DNA. RNA interference can be used to shut down genes as well; this involves introducing RNA strands to induce suppression of specific genes (Ahmann and Dorgan, 2007). These techniques are commonly used to modify plants (Schaart and Visser, 2009) and micro-organisms.[5]

When combined, the techniques referred to here offer growing opportunities for metabolic pathway engineering, i.e. for adjusting the metabolic pathways in both micro-organisms and plants (Yang et al., 1998; DellaPenna, 2001; Novozymes, 2010). Computer-simulated metabolic pathways (*in silico* models) make it possible to predict the effect of specific genetic modifications on cell behaviour. Based on these predictions, it becomes possible to introduce ever-more specific genetic modifications into micro-organisms for the production of enzymes, and into plants leading to high-value biochemical components such as pharmaceutical proteins (Hasunuma, 2009). Enzyme activity can also be adjusted in specific ways by means of rational design. It is not only the biochemical composition that determines enzyme activity, but also their tertiary structure, i.e. the way in which enzymes fold into their three-dimensional form. Techniques that reveal this structure and computer programs designed to produce simulation models have shown us much more about how enzyme folding influences their effectiveness. That has made it possible to engineer specific DNA mutations that improve enzyme effectiveness.

5 www.eurekalert.org/features/doe/2004-11/ddoe-sdg111104.php

Several years ago, it became possible to produce 'customised' synthetic DNA for genetic modification and rational design. There are dozens of small enterprises worldwide that can provide synthetic DNA sequences in every order imaginable. It is basically possible to create or recreate any genome we want with synthetic DNA, although it is very difficult to do so flawlessly. In 2010, researchers at the J. Craig Venter Institute in the USA created a completely artificial genome capable of growing and reproducing inside a host cell (J. Craig Venter Institute, 2010). Our increasing ability not only to 'read' DNA, but also to 'write' it has given birth to synthetic biology, a new scientific discipline (Van Est et al., 2007; GR, 2008). Research in this area focuses on engineering/reengineering biological systems using standardised DNA modules whose functions are already known. The engineering method used can essentially be applied at all biological levels, from individual molecules to entire cells, tissues and organisms. Synthetic biology is still in its infancy and is primarily in the experimental phase, but it may eventually become a hugely significant factor in bio-economy innovation.

## 4.2 The use of biomass in the value pyramid

How can innovation contribute to the optimal use of biomass? This section takes the value pyramid as a basis for further investigation. We discuss the possibility of using biomass in various value segments to produce 1) pharmaceuticals and fine chemicals, 2) bulk chemicals and biomaterials, and 3) energy. Discussions about innovation frequently focus on the 'latest generation' of technology. That is also true in discussions concerning the bio-economy, for example 'second-generation' biofuels. This chapter makes a distinction between short-term and long-term advances. With respect to the short term (up to five years), we look at the use of conventional biomass sources and the associated technical advances. With respect to the longer term (5 to 20 years), we look at new technological possibilities that we can expect to see. We focus in particular on the promise of 'white' and 'green' biotechnology for the more efficient utilisation of biomass based on genetically modified micro-organisms and plants. Finally, we consider a number of advances that may lead to more radical – but very distant and highly uncertain – innovation. These are based on technological concepts that make direct use of solar energy. Although they involve biological processes, biomass does not play a role in them.

### 4.2.1 Pharmaceuticals and fine chemicals

The top of the value pyramid is occupied by the high-value biomass products, i.e. pharmaceuticals and fine chemicals. Fine chemicals include vitamins, specific fatty acids, and hydraulic fluids. Pharmaceuticals include antibiotics, vaccines, and immunotherapeutic proteins. Alongside conventional sources, genetically modified micro-organisms play an increasingly important role. Researchers have also been experimenting for some time now with the production of pharmaceutical proteins in genetically modified plants.

**Conventional sources**

There are numerous conventional sources of biomass that can produce fine chemicals and pharmaceuticals. Examples include *Calendula officinalis* (marigold), the oil of which can be used as a paint thinner, and *Ricinus communis* (castor bean), the source of castor oil, a known laxative and also used as a hydraulic fluid. Algae are also a source of special oils. The chlorella alga is known for its high productivity levels. At thirty to forty tonnes of dry substance per hectare, its yield exceeds that of any other agricultural crop. Chlorella is also a rich source of proteins, vitamins, and trace elements; approximately forty per cent of the alga is oil. It has become very popular among advocates of alternative nutrition due to the assumed health benefits of omega-3 fatty acids. It is also used as an ingredient in cosmetics and in fish and animal feed (Van Kasteren, 2007). A well-known conventional microbial source of pharmaceuticals is *Penicillium chrysogenum*, used to produce penicillin. Codeine, morphine and other similar pharmaceuticals are derived from *Papaver somniferum* (the opium poppy); the anti-malarial drug artemisinin is derived from *Artemisia annua* (sweet wormwood); and the anti-cancer chemotherapy drug vincristine is extracted from *Catharanthus roseus* (Madagascar periwinkle). Until the 1980s, insulin was derived from the pancreas of pigs and cattle.

**Genetically modified micro-organisms**

Human insulin produced with the help of genetically modified micro-organisms – human insulin DNA is inserted into E. coli bacteria – has been commercially available since 1982. The end result is not precisely the same as natural human insulin, but ongoing improvements in technology mean that it is becoming more similar all the time. Genetic modification has also been used for many years to produce penicillin from the *Aspergillus* mould. DSM used genetic modification to develop an economical, 'green route' for the production of the amino acid 7-ADCA, an important intermediate for antibiotics (DSM, 2001). BASF produces vitamin B2 – vital to both humans and animals and a familiar yellow colouring agent in food – using the genetically modified *Bacillus subtilis* bacterium (GMO Compass, 2010).

**Genetically modified plants**

'Pharma crops' are a separate category; these are genetically modified crops used to produce pharmaceutical drugs (COGEM, 2004). Shortly after 2000, several hundreds of field tests were conducted in the United States involving maize, rice, alfalfa and tobacco that had been genetically modified to produce vaccines and therapeutic proteins. Dozens of similar field tests have also been carried out in France. Until 2004 companies and research instututes in the United States and Canada applied for more than 250 trials for maize, rice, safflower, rapeseed, tobacco and barley that produce pharmaceutical substances or industrial enzymes (Bauer, 2006). Another technique involves the plant production of veterinary vaccines[6] (Mayer, 2003). The hope is that such crops

6 www.bio.org/healthcare/pmp/factsheet2.asp

can serve as raw material for the pharmaceutical industry or can be marketed as 'edible vaccines'. Because the unrestrained dispersal of pharma crops may carry environment and health risks, civil society organisations in the United States and Europe have fiercely resisted their cultivation. The future of these crops is uncertain.

### 4.2.2 Biochemicals and biomaterials

Many different types of biomass are already being used as a base material for biochemicals and biomaterials. The most important applications are bioplastics, fibre products, and various base materials for synthetics, adhesives, resins, laundry detergents and medicines. The base materials of these products consist of fibres, sugars, starch, oils, fats, and proteins, all derived from plant origins. Sugarcane and sugar beet are the most important sources of monosaccharides and disaccharides ('free sugars'). Starch is derived primarily from maize, wheat, potato, and cassava. Rapeseed, soybean, and oil palm are common sources of vegetable oil. Researchers are also investigating the possibility of using genetically modified micro-organisms and plants to produce the raw material for biochemicals and biomaterials.

**Conventional sources**

Bioplastics can be derived from starch and may take the form of biodegradable starch plastic, used in end products ranging from flower pots to packaging foil (Bolck, 2006; Shen et al., 2009).Because they are compatible with the human body, they can also be used in implants. Among the more popular raw materials for producing bioplastics are polyhydroxyalkanoates or PHAs, derived from vegetable oils. They have one significant disadvantage compared with conventional plastics, however: the production process is energy-intensive (Van Ast et al., 2004). One PHA producer is Telles, a joint venture between the international grain processor ADM and renewable chemical company Metabolix. They built the world's largest commercial-scale PHA plant in the US, which is designed to produce 50,000 tonnes/year of the corn-based plastic. The plant is expected to be running at full capacity by mid-2013. Other large producers of PHA are PHB Industrial in Brazil, Mitsubishi Gas Chemical in Japan and Bio-on in Italy (de Guzman, 2011). In March 2008, DSM contributed to a EUR 200 million investment in the Chinese company Tianjin Green Bio-Science, which is now constructing China's largest PHA plant (DSM, 2008). Bioplastics based on polylactate acids (PLAs) obtained from fermentation are also used in many end products. One of the big PLA producers is NatureWorks, a subsidiary of Cargill, the largest grain processor in the world. Other key PLA manufacturers are Toyota and Mitsui (Zuidhoff, 2007) and PURAC Biomaterials, a subsidiary of CSM, the Netherlands. DSM recently marketed a high-value plastic composite for the car industry that is produced largely from renewable sources, including castor oil (DSM 2010a; Green Car Congress, 2010a).

Biofibres are used in insulation. Wool, hemp, wood fibre or flax wool makes a good replacement for the conventional mineral glass wool and stone wool. The Dutch company Isovlas makes various end products based on flax, for example subfloors, roofing and geotextiles for the road construction sector (Vellema, 2003). It also uses various residual products in its building materials, for example wood from prunings in sheeting materials and coconut fibre in coconut matting (Van den Dobbelteen and Alberts, 2001). Biofibres are also increasingly being used in composites. For example, Tech-Wood produces wood composites that offer a sustainable alternative to hardwood. Because they are lightweight, they are popular in the car industry. The lighter the car, the more efficiently it runs.

Sugars and oils serve as raw materials for polyurethane, used to produce resins and foams (Bos and Van Rees, 2004). Resins are also made of furfural, mentioned above (see the section on thermochemical conversion). The Belgian company TransFurans Chemicals produces furfural alcohol and derivative resins and also develops new applications, for example resins that will improve the durability, hardness and strength of wood in an environmentally friendly manner (SenterNovem, 2009). Vegetable oils can also be used as a base material for adhesive. Oregon State University has applied for a patent on a recipe to make tape adhesive from corn, rapeseed, or soybean oil. No volatile organic solvents are used in this process (Dijkgraaf, 2010). It is also possible to replace phthalates, used as plasticizers in soft plastics, by technically equivalent alternatives based on vegetable oils. Traditional phthalates are released into the atmosphere by the plastics into which they are mixed and may be environmentally harmful. Danisco produces an alternative plasticizer based on castor oil, glycerol, and acetic acid (Danisco, 2006). Wageningen University and Research Centre has worked with industrial partners to develop alternative plasticizers, but these are not yet commercially available. Sorbitol is a sugar substitute made of starch and widely used in food, cosmetics, pharmaceuticals, and technical products (Mollenveld, 2006).

Long-chain dicarbon acids and citric acid, for example based on starch or molasses, a by-product of sugar production., are used in numerous industrial processes involving fermentation. China has two plants that produce long-chain dicarbon acids for the production of musk aromatics, nylons, lubricants, and medication. China also produces citric acid – an important food additive – on a large scale. Citric acid is used to stabilise acidity in effervescent tablets and cleaning solutions. It also acts as a binding agent in biodegradable laundry soap and dishwasher detergents. Propanoic acid is used as a preservative in food and animal feed and also serves as an intermediary in the production of polymers. It is still chemically synthesised, but can also be made using micro-organisms (Li et al., 2010).

Waste products, including used wood, waste fats and glycerol, can also be used to produce biomaterials. The most common waste products (produced after

fermentation and combustion) are tar, ash and carbon dioxide. Along with sulphur, nitrogen oxides, and other combustion gases, they are the end waste products of the bio-economy.

**Genetically modified micro-organisms**
We now also have examples of biochemicals and biomaterials produced using genetically modified micro-organisms. DuPont in the US and Tate & Lyle in the UK (which produces sugar and maize derivatives) have together invested USD 100 million in a new 1,3-propanediol (PDO) production plant based on corn sugar. The monomer is made using genetically modified micro-organisms developed by DuPont in partnership with Genencor. PDO is the most important ingredient in the production of Sorona, an artificial fibre used in carpeting and other products. It is also used in some cosmetics and personal care products (Science Blog, 2003; Rao, 2006). Nylon is made of caprolactam, a synthesized cyclic organic compound that is produced by chemical processes. DSM is one of the biggest producers of caprolactam. The company is investigating the possibility of producing caprolactam by means of fermentation using genetically modified micro-organisms. So far, however, the process cannot compete with petrochemical caprolactam and has therefore not (yet) come on stream (DSM, 2007).

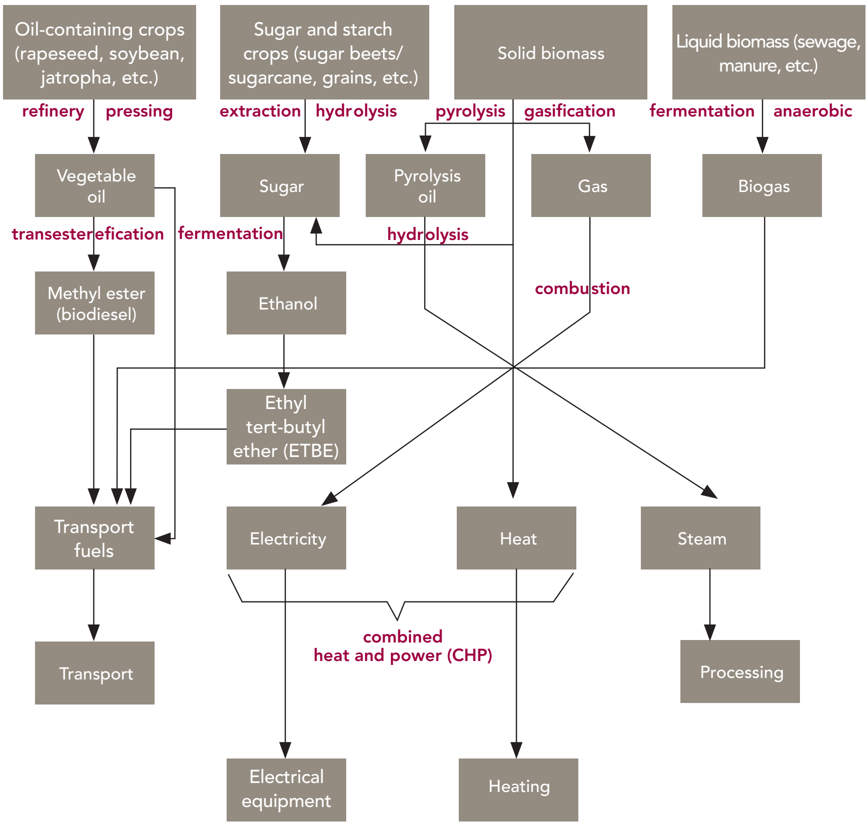
**Genetically modified plants**
In view of the EU's relatively strict licensing policy, it is unlikely that genetically modified crops will be cultivated within its borders for the production of biochemicals and biomaterials in the near future. One potential exception is the starch potato with modified starch content. In March 2010, the European Commission approved the licence for the Amflora, a genetically modified starch potato developed by BASF. This cleared the way to using the starch derived from this GM crop in industrial applications (BASF, 2010). Dutch company AVEBE has developed a similar potato, the Modena, which is awaiting licensing by the EU. AVEBE has also developed the Eliane, a non-GM potato with modified starch (AVEBE, 2010).

More progress has been made outside the EU with respect to genetically modified plants. As in the case of GM crops, short-term advances have all brought about improvements in agricultural traits, for example higher yields and resistance to diseases and pests. Monsanto has introduced genes in sugarcane that make plants resistant to the herbicide Roundup and to insects (Monsanto, 2010a). In the medium term, we can expect to see crops that use water and nutrients more efficiently (Monsanto, 2010b; Pioneer, 2010). Between 2015 and 2020, we will see the introduction of genetically modified plants for industrial purposes. For example, ProdiGene in the US has developed GM maize that produces the enzyme laccase. Laccase is found in many plants, fungi, and micro-organisms and plays a role in the formation of lignin. It is used to bleach textiles and paper pulp and in many other industrial applications. In future, the genetic modification of plants (or micro-organisms) will also make it possible to

produce cobweb proteins as a base material for ultra-light and very strong fibres; proteins such as elastin and collagen for plastic surgery and cosmetics; and PHAs for the production of bioplastics (Moschini, 2006).

**Genetically modified animals**
GM rabbits, goats, sheep, cows and pigs are developed to produce an increasing number of pharmaceutical products in their milk. In 2006, the first human therapeutic protein, Antithrombin III (ATryn, GTC Biotherapeutics), derived from the milk of GM goats was approved by the European Commission for the treatment of patients with hereditary antithrombin deficiency. Also being used to produce serum biopharmaceutical products, such as antibodies that can be used for the treatment of infections, cancer, organ transplant rejections, and autoimmune diseases such as rheumatoid arthritis (Van Eenennaam, 2008). GM can also be applied to animals to produce new biomaterials such as spider silk, a material that comines extreme strength (five times as strong as steel) with

**Figure 4.2** **Conversion of biomass for the generation of energy transesterefication**



softness. In 2011 Kraig Biocraft Laboratories partnered with Sigma Life Science to develop genetically modified silkworms for the production of spider silk, using Sigma's proprietary Zinc Finger Nuclease (ZFN) technology. The transfer of silk genes from the spider to the silkworm is expected to allow the mass production of silk with enhanced strength and elasticity with potential textiles and biomedical applications, such as sutures, tendon and ligament repair, bulletproof vests, and automobile airbags (Sigma-Aldrich, 2011).

### 4.2.3 Energy

As noted in previous chapters, biomass is currently being used mainly to generate energy. This takes many different forms: it is used in co-firing systems in power plants, to produce biogas by means of fermentation, and – above all – to produce biofuels (see also the diagram below). Bio-ethanol derived from sugar and starch is mass-produced worldwide. In addition, oil-containing crops are an important raw material for biodiesel. Great hopes have been pinned on the use of genetically modified micro-organisms, plants, and algae as sources for new, more sustainable fuels. Looking even further ahead, there may be a role for artificially engineered biological systems that can convert sunlight directly into electricity or hydrogen.

**Conventional sources of biomass**

Biomass has already been used in co-firing systems in conventional power plants for many years. There are various companies in the Netherlands that supply power plants with wood chippings.[7] Supply chains for wood pellets, coffee husks and other by-products have also emerged around the world. Locally, the Province of Utrecht is subsidising farmers who cultivate and use *Miscanthus*, a tall perennial grass, to provide for their own energy needs, under the terms of the Sustainability, Energy and Climate Incentive Scheme (DEKU) (Netwerk Platteland, 2010). *Miscanthus* is on the list of 'good biomass' (along with willow and cane) maintained by Dutch environmental organisations (Natuur en Milieu, 2008). Its use as a source of energy may also lead to technological innovations. Together with the Institute of Biological, Environmental and Rural Sciences (IBERS) in Wales, Wageningen University and Research Centre is investigating how to improve this crop genetically.[8] Switchgrass (*Panicum virgatum*) has been researched for biomass energy production In the U.S. since the mid-1980's. It is a native perennial grass that is tolerant to drought and flooding. The crop is easy to manage, and needs little fertilizer (Samson, 2005). In his 2006 State of the Union George W. Bush proposed using switchgrass for ethanol (Bush, 2006).

Converting livestock manure into a domestic renewable fuel source (biogas) that could be used to reduce greenhouse gas (methane and nitrous oxide) emissions.

7 see, for example, www.mensinkbosbouw.nl/biomassa.html and www.denoudenbv.nl/nl/page/biomassa.html

8 www.themabiobasedeconomy.wur.nl/NL/Projecten/BE01_Geneticimprovement/

Manure biofermentation is growing increasingly popular as a method for using biomass to generate energy. In theory, any type of manure or organic by-product can be used in biofermentation. In 2009, the Netherlands had almost two hundred manure biofermentation companies (Persbureau Noordoost, 2009).
The larger companies in this field tend to use animal manure, often mixed with other agricultural waste. Fermentation gives rise to a mixture of methane (55-65%) and carbon dioxide (35-40%). The low energy density of this mixture means that the storage capacity of the resulting biogas is always limited to a few hours' production, and that it is converted on site into heat and electricity by a CHP generator. Some of the heat is returned to the fermenter to maintain the right temperature; the rest can be used as space heating, for example. The electricity that this process generates can supply the farm and be passed on as 'green electricity' to the grid. The fermented manure can be used to fertilise the land or undergo further processing to produce specific fertilisers (SenterNovem, 2006). Researchers from the University of Texas at Austin calculated that the 95 million animal units in the U.S. could produce about 293,000 GWh of renewable energy per year, amounting to approximately 1% of the US total energy consumption. Converting the biogas into electricity using standard micro-turbines could produce 88 ± 20 billion kWh, or 2.4 ± 0.6% of annual electricity consumption in the US. Replacing coal and manure GHG emissions with the emissions from biogas would produce a net potential GHG emissions reduction of 3.9 ± 2.3% of the annual GHG emissions from electricity generation in the US (Cuéllar, 2008).

The production of liquid biofuels from biomass is attracting the most attention worldwide. As we saw in previous chapters, of all possible biofuels, bioethanol is most in the limelight at the moment. Today's 'first generation' of bioethanol is made of sugar (cane sugar) and maize. Maize is a controversial raw material, however, owing to the negative $CO_2$ balance. Sugarcane is a much more efficient source of energy and some critics therefore consider it a better raw material for biofuel (De Wit, 2008). Nevertheless, a considerable amount of money is being invested in both forms of energy production.

The biggest bioethanol plant in China is scheduled to come on stream in 2011. It is supposed to produce eleven million litres a year, using maize as a raw material. The plant is the result of an agreement between three parties, concluded in 2010: the Danish enzyme manufacturer Novozymes, the Chinese oil and chemicals giant Synopec, and the Cofco Group, China's biggest importer of oil and food and one of the largest food production companies in the country. In the same year, Shell and Cosan, the largest sugar and ethanol manufacturer in Brazil, decided to set up a joint venture for the production and distribution of bioethanol made of sugarcane. The joint venture will begin operating in 2011 with USD 12 billion in start-up capital (FD, 2010).

Butanol is also attracting attention as a potential biofuel. It has a higher energy density level than ethanol, comparable to petrol. It is therefore easier to blend than ethanol, and in larger quantities. Butanol is also less corrosive than ethanol, making it possible to use existing blending, storage, and transport facilities for transport fuels without too many adjustments being necessary. DuPont and BP formed a joint venture in 2006 specifically for the introduction of biobutanol (Ebert, 2008). There are also various small biotech companies in the United States dedicated to the development of biobutanol (Wesoff, 2010).

Pure plant oils (PPOs) made of rapeseed, soybeans, sunflower seeds, and oil palm fruits are a common raw material for biodiesel. Waste produced by abattoirs (animal fat), the food industry, and the hospitality sector (for example chip pan grease) can also be used in this way.[9] The large-scale production of biodiesel based on PPOs is a rather precarious undertaking at present, at least in the Netherlands. In late 2005, energy company Delta began to develop the first biodiesel plant in the Netherlands (Biovalue). The prospects were good at the time, because it had become a legal requirement in that year to blend biodiesel into regular diesel. Initially, the legal requirement was 2% biodiesel, but under the EU Directive that was to increase to 5.75% in 2010. In 2008 and 2009, however, massive imports from the US, Indonesia, Malaysia, and Argentina put serious pressure on the market. In addition, the Dutch government reduced the blending requirement to 4%. The decline in demand meant that Biovalue was forced to cease production for three months in 2009, and it ended the financial year with a loss. In June 2010, Delta decided to shut down the bio-diesel plant (DELTA, 2010). Germany's 4.8 million tonne annual capacity bio-diesel industry, Europe's largest, produced only 2.5 – 2.6 million tonnes in 2010 and 2009, down from 2.8 million tonnes in 2008 and 3.3 million tonnes in 2007 (VDB, 2011).

The production of plant biodiesel based on jatropha seed oil (*Jatropha curcas*) might have a better chance of succeeding .Because the plant flourishes in semi-arid climates and requires very few nutrients and very little care, it is attracting attention as a potential source of biodiesel in developing countries. It is poisonous and therefore non-edible. It has long been used as a source of lamp oil and as a traditional medicine in the tropics and sub-tropics. The Food and Agriculture Organization estimates that there are 900,000 hectares of jatropha plantation worldwide, mostly in Asia (Brittaine, 2010). That is expected to increase to approximately 13 million hectares by 2015. In August 2010, Life Technologies, a biotech firm, and SG Biofuels, a plant science company, announced that they had completed the sequencing of the *Jatropha curas* genome. That will make it possible to identify molecular markers and trait genes to accelerate development of elite cultivars with vastly superior yields and

9 see, for example, http://www.biodsl.nl/, http://www.biodieselkampen.com/ and http://www.solarix.eu/nl/ news/23

profitability (Life Technologies, 2010). Jatropha can make a particular contribution in the fight against poverty; local communities can plant the crop on marginal land or on dry soil as a barrier to contain cattle (Brittaine and NeBambi, 2010). So far, however, efforts have focused on large-scale cultivation in plantations. The Canadian firm of Bedford Biofuels has developed 160,000 hectares of jatropha for energy supply purposes in eastern Kenya and plans to purchase a further 200,000 hectares (Christian, 2010).

The Dutch firm BIOeCON has developed an approach to biodiesel production that may also have a future in the Netherlands. The company has developed a process based on biomass catalysis and thermal conversion that uses 'woody' plants as a raw material. The technology will be trialled abroad first. The company has announced a joint venture with PetroBras of Brazil to produce biodiesel from bagasse, a by-product of sugarcane (Green Car Congress, 2010b). Another approach – this time a mobile processing plant for producing biodiesel – was developed by researchers at Purdue University in the US. In this process, biomass and hydrogen are heated to 500o C in less than a second. The hydrogen would come from natural gas or syngas (Green Car Congress, 2010c).

**Genetically modified micro-organisms**

The hopes of many are pinned on 'second generation' bioethanol, derived from cellulose, the non-edible, woody parts of plants. To produce cellulose-ethanol, the cellulose must first be converted into sugars. This can only be done efficiently if advanced enzymes and fermentation techniques are used. Genetically modified micro-organisms play a key role in this process. The International Energy Agency (IEA) has surveyed the state of affairs worldwide in the development of cellulose-based biofuels. The IEA report reviews 66 different projects. Despite all the activity in this field, researchers do not expect the new transport biofuels to be widely available within five years. A major effort will be required to scale up new and proven technologies and to make them commercially available (Bacovsky et al., 2010). Nevertheless, businesses and governments are investing eagerly in cellulose-based bioethanol. BP is aiming to take pole position in the US in this area by taking over the existing activities of other companies (BP, 2010). In 2007, the US Department of Energy decided to invest USD 385 million within the space of four years in six biorefinery projects that are to produce 500 million litres of bioethanol. The purpose is to make bioethanol competitive with petrol by 2012 (DOE, 2007). The EU-funded BIOLYFE project is working with industry to explore how to optimise biorefinery processes, the target being the production of cellulose-based ethanol.[10]

**Genetically modified plants and algae**

At the same time, efforts are being made to improve plants as energy crops by means of genetic modification. Swiss company Syngenta has developed a

10 www.biolyfe.eu/

variety of genetically modified maize that contains the enzyme alpha-amylase, which remains active at high temperatures. It promotes improved conversion of corn starch during ethanol production. The crop has already been licensed in Australia, Canada, Japan, Mexico, the Philippines, Russia, Taiwan and the US (USDA, 2008; Syngenta, 2010; CERA GM Crop Database, 2010). In the spring of 2010, Bayer CropScience joined forces with Centro de Tecnologia Canavieira in Brazil to develop sugarcane varieties with higher sugar content, making the crop a more attractive raw material for bioethanol production. Bayer CropScience believes it will be able to apply for licensing in 2015 (Bayer CropScience, 2010).

Plant biotechnological research in the United States and China also focuses on fast-growing perennial crops, such as *Miscanthus* and various tree varieties (Verwer et al., 2010). These crops have a better energy balance than annuals such as sugarcane, sugar beets or maize (Zhu et al., 2008). Lignin is difficult to break down, however, and there is too much of it in natural wood to produce bioethanol efficiently. That is why researchers are trying to develop crops that produce less lignin. One example in Europe is a genetically modified poplar with a much lower lignin content developed by the Flanders Institute for Biotechnology [*Vlaams Instituut voor Biotechnologie*, VIB]. Greenhouse trials have shown that the wood of the transgenic poplar will produce up to 50% more bioethanol than standard poplars (VIB, 2010).

In the longer term, algae are considered a very promising  source of fuel. Algae are not easy to cultivate, however, and vital knowledge is still lacking. Cost, quality management, production, and harvesting are all problematical areas (Roeloffzen and Oudshoff, 2008).
The cost of algae-based biomass will have to be reduced tenfold before it can compete with current fuels. A group of international experts associated with the International Energy Agency do not expect the production of algae diesel to reach an appreciable scale before 2030, at the earliest (Darzins et al., 2010). Researchers at Wageningen University are more optimistic: they believe that recent advances in system biology, biorefinery techniques and genetic modification will make the large-scale production of biofuels from algae possible within ten to fifteen years (Wijffels, 2010).

In June 2011 Wageningen University and Research Center started AlgaePARC (Algae Production And Research Centre), a facilty that allows comparison of different outdoor photobioreactor designs for microalgae. The objective of AlgaePARC is to develop knowledge, technology and process strategies for sustainable production of microalgae as feedstock for fuel, chemicals, food and feed at industrial scale. From 2011, a five year research program has been started at AlgaePARC as a project within BioSolar Cells that is supported by eighteen companies in the food, oil, chemical and technology development sectors.

The BioSolar Cells initiative, a 42 million euros research programme led by a partnership of six Dutch universities, aims at direct production of fuels, for example in photosynthetic cyanobacteria or algae that produce butanol, and increasing the photosynthetic efficiency of plants (BioSolar Cells, 2011). In the meantime, US oil giant ExxonMobil is investing heavily in algae R&D. In mid-2009, the company announced plans to spend USD 600 million on developing algae-derived biofuels in cooperation with Synthetic Genomics, Craig Venter's firm. The partnership will give ExxonMobil access to the knowledge and technology that Venter's firm has acquired in genomics/metagenomics, genetic modification, and synthetic biology. The aim is to find useable algae and to improve them with a view to developing efficient cultivation systems (Howell, 2009; Synthetic Genomics, 2009). Another US firm, Solazyme, is developing techniques for producing biodiesel and biomaterials from algae. In 2010, Solazyme signed an agreement with Bunge, a large agribusiness and foodstuffs company with stakes in the sugarcane industry and in the production of plant oils (Solazyme, 2010).

**Radical innovation**

The promise of the bio-economy also lies in innovations that make use of biological systems in completely new ways. At the moment, these innovations are a long way from having any practical application. Examples include energy-generation processes based not on biomass as a raw material but on the ability of biological systems to convert sunlight directly into useable energy. It is theoretically possible to develop solar cells that mimic photosynthesis. In the US, researchers at the University of Arizona and the University of Tennessee are collaborating with counterparts at the Massachusetts Institute of Technology (MIT) to develop 'artificial leaves', i.e. flexible solar cells based on plant proteins. A layer of conductive material is applied to a thin layer of spinach plant proteins. The main question is how to actually tap into the energy that is generated. So far, experimental solar cells have a lower energy yield (12%) than conventional solar cells (20 to 30%) (Eng, 2004; Regalado, 2010).

In Europe, 2009 saw the start of the PlantPower project, an EU-funded research programme aimed at developing a plant microbial fuel cell (Plant-MFC). Living plants and living microbes form an electrochemical system that is capable of generating green electricity or biohydrogen from solar energy. The plants themselves do not need to be harvested (Strik et al., 2008). Also the Dutch BioSolar Cells programme aims to combine natural and technological components in 'artificial leaves' that highly efficiently produce hydrogen gas or syn-gas from solar energy (BioSolar Cells, 2011).

Some algae that occur in nature also have the ability to produce hydrogen. Researchers at the universities of Bielefeld and Queensland have genetically modified the single-cell green alga *Chlamydomonas reinhardtii* in such a way that it produces a large amount of hydrogen (Fuelcellworks, 2006). Various

projects are currently working to improve the efficiency of this process. One of these, funded by the US Department of Energy, has succeeded in improving the sunlight-to-hydrogen energy conversion efficiency of *Chlamydomonas reinhardtii* to 25% out of a theoretical maximum of 30% (Melis, 2008).

## 4.3 Coproduction and sustainability as significant challenges

We have seen that biomass is used in many different ways on the various tiers of the value pyramid, and that serious efforts are being made to develop innovative technologies and processes based on biomass. Many of the results achieved so far are one-offs and will have to be verified in future. Even if a process proves viable in the laboratory, whether it remains feasible when used on an industrial scale or in the open field often remains to be seen. In that respect, technological innovation remains a laborious, uncertain and time-consuming process. On top of this, the transition to a bio-economy will also require more than just technological innovation, as we indicated at the start of this chapter. The biggest challenges lie in two different areas. To begin with, it will take much more effort to fit the various activities and technological innovations into the biorefinery concept so that biomass can be used optimally in properly coordinated coproduction or cascading chains. Secondly, practical implementation will need to adhere to sustainability criteria, given that our society regards these criteria as vital to a bio-economy.

### 4.3.1 Coproduction: integration into existing chains and development of new chains

Coproduction takes on many different forms out in the field. Sawdust from the woodworking industry is used in sheeting material. Stockbreeders feed their animals beet pulp and potato peels provided by the sugar beet and potato processing industry. There are even examples of coproduction in innovation, for example the partnership between the Dutch company BIOeCON and the Brazilian firm of PetroBras, which have joined forces to produce biodiesel from sugarcane waste. PetroAlgae, a US company that focuses entirely on algae, believes that coproduction is a hugely important factor in setting up economically viable production systems in any future bio-economy. The company therefore concentrates on two areas: obtaining high-value proteins for food and animal feed and generating energy in various ways.[11] In an article on algae-based biofuels in *Science*, researchers at Wageningen University describe why coproduction is important. If we imagine that all European transport fuel was produced from algae oil, then an annual 300 million tonnes of protein would be available as an ingredient in food and animal feed. That is forty times the amount of protein provided by the 18 million tonnes of soy that Europe imports every year (Wijffels, 2010). In the Netherlands, researchers are exploring the possibility of extracting nutritional ingredients from algae within the framework of a two-year collaboration project between the Netherlands Organisation for Applied Scientific Research (TNO) and algae producer Ingrepro Renewables.

11 www.petroalgae.com/technology.php

The researchers are investigating whether algae proteins are a sustainable alternative to meat. They are also exploring potential uses for carbohydrates derived from algae (TNO, 2010).

Several EU-funded projects, such as the Biosynergy project, aim at the establishment of facilities for integrated co-production of bulk quantities of chemicals, fuels and energy from a range of biomass feedstocks in Europe[12].The European BIOCOUP project aims to develop a chain of process steps, which would allow biomass feedstock to be co-fed to a conventional oil refinery. Energy and oxygenated chemicals will be co-produced. The overall innovation derives from integration of bio-feedstock procurement with existing industries (energy, pulp and paper, food) and processing of upgraded biomass forms in existing mineral oil refineries. Shell and TOTAL are the major industrial partners in this EU-funded project .[13]

Another research project that combines the strengths of a wide range of actors is the BE-Basic consortium. BE-Basic is a collaboration between nine Dutch and two German universities, three research institutes, and ten industries, including large (DSM, AKZO) and small-medium enterprises. TU Delft is coordinating the new consortium that includes, among others, an R&D budget exceeding 120 million euros, of which 60 million euros is made available by the Dutch government. BE-Basic got started in January 2010. The consortium hopes to create clean biobased chemicals, materials and energy industries through the use of biotechnology, microbial processing and synthetic biology. It strives to develop a multi purpose Bioprocess Pilot Facility (BPF). The BPF accommodates pre-treatment and mid scale fermentation, large scale fermentation and downstream processing as well as future innovations in these areas. This pilot facility should facilitate the step from laboratory to industrial scale;

To ensure the success of this type of innovation in the future bio-economy, a growing number of links in the production and logistical chains must be closely coordinated. It would be pointless to obtain high-value protein from biomass if the relevant producer had no way of efficiently marketing other components and the by-products. In some cases, coproduction can be achieved by integrating innovative technologies into existing production systems and infrastructure such as those present in the organic chemicals/petrochemicals or sugar and starch industries. In many cases, however, coproduction will need to be coupled with new organisational and infrastructure arrangements. In these new arrangements, production and processing of biomass would take place at the same location, with the biomass being turned into raw material and products that are easy and inexpensive to transport to other sites for further processing or use. Radical new technologies such as artificial leaves and plant microbial fuel cells will make it possible, and even necessary, to organise the supply of energy in new, smaller-scale ways.

12 www.biosynergy.eu

13 www.biocoup.com/

### 4.3.2 Strategic choices and dilemmas

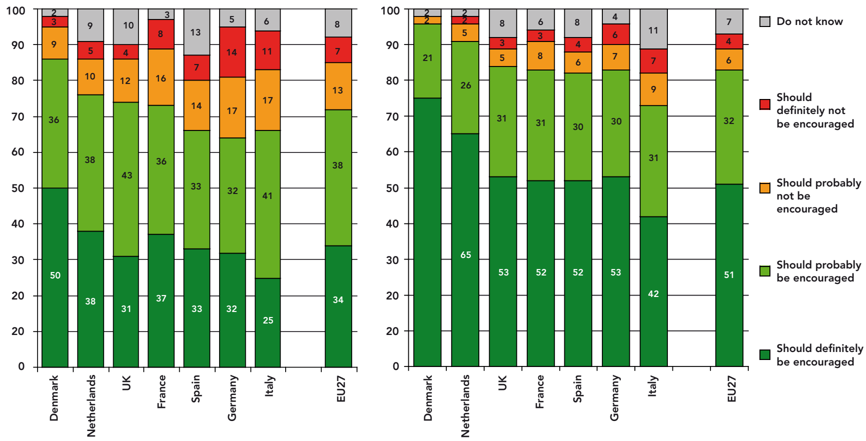
One important question in all this is what Europe, or a specific country such as the Netherlands, should focus on when investing in the bio-economy. Opinions differ in this regard. Some believe that the greatest opportunities lie in capitalising on 'bulk' at all levels of the value pyramid. They believe the Netherlands can play a key role in the worldwide exploitation of biomass by concentrating on agriculture, petrochemicals, and logistics. Others believe that the Netherlands, as an innovative 'knowledge economy', should give priority to high-value products at the top of the pyramid. Such differences of opinion not only imply a need to make strategic choices; they are also associated with specific dilemmas.

If the Netherlands invests in bulk processing of biomass, the deep seaports of Rotterdam, Vlissingen-Terneuzen, and Eemshaven are logical sites because they are easy for bulk carriers to access. After primary conversion, the product can be transported to its next destination by inland vessel, train, or pipeline. The decision to invest in bulk operations and work with the existing infrastructure means running the risk of a lock-in. The bio-economy would, in effect, be grafted onto the structure of the current fossil fuel economy, offering few incentives to explore alternative, potentially superior innovations (Foxon, 2002). Another approach is that taken by the Dutch Biorefinery Cluster, which emphasises new forms of collaboration and knowledge-sharing between various companies in the agro-food sector, paper industry, and other industrial sectors. By sharing knowledge, expertise, facilities, and resources, the affiliated companies aim to bring biomass to its full potential and create new, high-value products and sustainable, closed-loop production chains. It should be noted that the market for high-value products is generally limited and that the amount of biomass required to produce them is therefore also small. For example, a relatively small area of land would already be enough to meet the demand for pharmaceutical ingredients (Wisner, 2005). That means that only a very small share of the demand for the raw materials used in low-value energy applications can be covered by the by-products of the upper segments of the biomass value pyramid.

### 4.3.3 Sustainability criteria and genetic modification

The discussion concerning the Netherlands' strategic choices in the new bio-economy is framed by sustainability aims supported by all the relevant parties. But opinions also differ as to how those aims are to be achieved, as Chapter 3 made clear. Sustainability criteria should be viewed as an important benchmark when developing the coproduction network, with certification as an important tool. One problem, however, is that certification requires relatively well-organised supply and production chains, something that may in fact be detrimental from the perspective of coproduction and closed-loop chains. As a criterion, then, sustainability should not apply exclusively to specific chains and products (such as biofuel), but 'inclusively' to the entire network of production and conversion in the value pyramid.

**Figure 4.3 Support for biofuels, EU27 and various Member States**




Source: European Commission, 2010

Chapter 3 also showed that genetic modification is still a controversial issue. The question then is what role resistance to genetic modification will play in the discussions concerning the sustainability of the bio-economy. Recent public surveys show that a large majority of Europeans (72%) feel that biofuels should definitely/probably be encouraged. The biggest critical response was in Germany (21% against) and France (28% against). The countries that were most supportive of biofuels were Slovakia (88% for) and Denmark (86% for). Opinions in the Netherlands and the United Kingdom lay in between these two extremes. When the question specifically concerned sustainable biofuels, support increased across the board by 11%. The Netherlands (+15%) moved up to a position just below the most supportive Member States. Sustainability is also very important to Germans (+19%), but less so for Italians (only +7%) (European Commission, 2010).

Previous similar reports revealed that of the 25,000 people surveyed, more than two thirds would choose biofuel instead of conventional fuel, even if genetic modification had been applied, provided that the price remained the same (Gaskell et al., 2006). These results were confirmed by more a recent survey among Dutch citizens (Stol and Nelis, 2010). Public surveys concerning synthetic biology show that people feel very ambivalent about the ‘engineering’ that it is based on, but that most of them are sympathetic to potential biofuel applications (Pauwels, 2009; The Royal Academy of Engineering, 2009; Bhattachary et al., 2010).

Nevertheless, it is difficult to predict how citizens and consumers would respond if industrial and plant biotechnology became more closely intertwined within the

context of the bio-economy. In those circumstances, the boundary between the restricted use of genetically modified micro-organisms and the open field cultivation of genetically modified crops would become blurred. Environmental organisations are very likely to resist open field cultivation owing to the ecological risks.

## 4.4 Conclusion

This chapter took the biomass value pyramid as its reference. Based on that pyramid, we discussed how innovation might contribute to the potential of the bio-economy. The key concept in our discussion was that of biorefinery. This involves separating and processing biomass in different but mutually coordinated conversion chains in a way that optimises the process of value utilisation in a variety of products. We have seen that biomass is already being used in many different ways in the field. Technological innovation is creating new opportunities for biorefinery, in particular with respect to biochemical conversion, with biotechnology functioning as a key technology. Before the bio-economy can be achieved, however, we must answer two questions: how do we ensure that coproduction processes are properly organised and logistically sound, and how do we guarantee sustainability in those processes?

In the future bio-economy, the initial stages of biomass production and conversion will take place locally at a variety of different locations. The basic raw materials will produced at the same locations on a relatively small scale and relatively inexpensively; these products will be sufficiently non-perishable and valuable enough to be transported to different locations. Once they have arrived at their destination, they will undergo further, more centralised and more value-added forms of processing. We do not yet know what the networks of coproduction in various biomass value chains will look like on a national and international scale, or what the most important negotiable basic raw materials will be. What is in any event important for a sustainable bio-economy is to make more efficient use of available biomass and to work with closed-loop supply chains that make optimal use of by-products. But we have not yet heard the final word about sustainability, as Chapter 3 has shown. Chapter 2 also concluded that so far, policy has focused on using biomass for energy purposes; the integrative concept of the bio-based economy has not had much of an impact yet. If we consider the contribution of innovation as described in this chapter, we see the same picture. Worldwide, investment and technological innovation are focusing on the use of biomass as a source of energy, i.e. on applications in the lowest segment of the value pyramid. The integrated concept of the bio-economy or bio-based economy, however, requires prioritising investment in the upper segments. There is some interest in innovation in this area in the Netherlands, but opinions differ as to the strategic choices that must be made. Should the Netherlands embark on the bulk import of biomass, making it a global competitor at every level of the value pyramid, or should it concentrate on the knowledge-intensive innovation and production of high-value products in a future bio-economy? We will return to this question in the concluding chapter

of this report. However we answer that question, this chapter has once again demonstrated that both white biotechnology and green biotechnology will play a key role in the bio-economy. The success of the bio-economy therefore depends on generating public support for innovation in biotechnology, specifically with respect to the genetic modification of crops.

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# 5

# 5 From arcadia to utopia?

## The history of organic raw materials in the Netherlands, 1800-2010

Frank Veraart, with Giel van Hooff, Fred Lambert, Harry Lintsen and Hans Schippers

*'Consider the bounty that Nature has bestowed. Come, let us go and view these treasures together, And let us enjoy all the good things she has given us!* [1]

Willem Bilderdijk - 1803

### 5.1 Introduction

To the nineteenth century Romantics such as Willem Bilderdijk, Nature was a treasury that offered mankind unlimited opportunities. It illustrates the worshipful attitude towards the unsurpassed – sublime – riches of nature at the time. In a somewhat more modern form, the same lines can serve as a motto for the advocates of the bio-economy, which is based on renewable raw materials of biological origin.

The bio-economy offers us an attractive alternative: a society that uses biological materials as its primary raw material. That society is not just a matter of speculation, however; it in fact pre-existed, in the pre-industrial age. Analysing the past may help us think more clearly about the bio-economy and what we expect from it. In reviewing this history, we touch on a number of key issues that can inform our current discussion of the bio-economy.

In the past two hundred years, the Netherlands changed from a society based largely on biological materials to one that runs mainly on fossil fuels. Section 2 below investigates the nature of that original society. Was it Arcadia, a society that lived in harmony with nature? We explore the limits of the traditional bio-economy. In section 3, we discover how that society began to transform itself into an economy that, from 1850 onwards, gradually broke away from bio-based raw materials. We consider the speed at which this process unfolded and ask ourselves what factors defined that speed. Section 4 describes the

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1 Translation of *"Beschouw wat overvloed Natuur heeft uitgegoten. Kom, gaan we, en laat ons saam die schatten overzien, En geven we ons 't genot van 't geen ze ons aan koomt biên!"* by Willem Bilderdijk, *Het Buitenleven in vier gezangen*, Johannes Allart, Amsterdam 1803, pp. 86-87. The poem is a translation of Jacques Delille's *l'Homme des champs.*

overture to the current discussion of the bio-economy. It shows how constant pressure to push back the boundaries led to a modern industrial economy based on the widespread use of fossil raw materials such as coal, oil and gas. We study how industry grew up around these fossil fuels and how it branched into energy supply, chemicals and agriculture. Section 5 shows how this modernisation process penetrated the agricultural sector and created industrial agriculture. The final section describes the growing doubts about industrialisation and modernisation from the 1970s onwards. It shows how the concept of a bio-economy was revived as an alternative to the use of fossil fuels and fossil materials. The pressure has grown since the 1990s with the increasingly urgent warnings concerning climate change. Based on this historical review, we close by reflecting on the transition to a sustainable Netherlands and the role that the bio-economy can play in this process. What challenges await us in the twenty-first century if we indeed make the transition to a sustainable bio-economy?

## 5.2 Arcadia? The Netherlands until 1850

In the first half of the nineteenth century, the Netherlands was a society that still operated largely on the basis of renewable biological raw materials and other local resources. Mills, mechanical equipment and methods of conveyance ran on wind power and thanks to the physical efforts of both humans and animals. Heating came from burning peat and wood cleared from small woodland plots and embankments.

The Netherlands was a trading nation with an agricultural economy. In 1850, it had more than three million inhabitants. It was also a patchwork of different regions, however, and each one had its own specific culture, landscape and economy. Viewed from the vantage point of agriculture, commerce and industry, the Netherlands in the mid-nineteenth century could be divided into roughly two areas. The most important region in economic terms consisted of the lowlands in the west. This was the location of the biggest cities, centres of international trade, and of fertile farmland dissected by a dense network of canals. The highlands in the east had a different economic structure: these areas were mainly rural and economically self-sufficient. The farming communities there lived in small villages that lay between the vast peat moorland and sand drifts like green oases. Was this the epitome of the Arcadian bio-economy, in which people lived in harmony with their natural surroundings?

### Self-sufficient on sandy soil

The Dutch who lived on the sandy soil in the east and south were highly self-sufficient. The farms in these regions were generally small holdings. Their inhabitants grew rye (for bread), buckwheat (porridge and pancakes), potatoes, cabbage, carrots or beans, all for their own consumption. They had some access to pork, fat, milk, buttermilk, dairy butter, eggs, rapeseed oil, and orchard fruit. They also supplied themselves with fuel by chopping wood or cutting peat. They made their own textiles by spinning yarn from wool and flax (linen) and

weaving fabrics. Selling meat and dairy products gave them money to buy other provisions that the local market was unable to supply, for example salt, soap, vinegar, treacle, coffee, tea, beer, and tobacco, and the occasional furnishings, shoes, pottery, and tools. In general, the villages were just able to meet their own needs.[2] The romantic idea of a self-sufficient agricultural society living in harmony with its surroundings – i.e. the image suggested by the foregoing description – is far removed from reality, however. The balance between input, consumption, and output was very fragile. Self-sufficiency was a necessity, not a goal.[3] The vicissitudes of nature sorely tested people's ability to survive on the sandy soil. Average life expectancy was low, approximately 35 years. In the eighteenth century, life in the eastern part of the Province of North Brabant (the 'Meierij') was described as 'slave labour accompanied by poverty and misery'[4] Farmers tried every possible means to alleviate their poverty. In addition to labour-intensive farming, they ran cottage industries (textiles, leatherworking) during the slack periods of the year.

**A thirst for raw materials: manure, the second God**

The misery of the countryside could be alleviated only by increasing agricultural output. The lack of nutrients in the soil was one of the biggest obstacles, however. Manuring was an absolute necessity for farmers working on sandy soil. The farmers in Brabant even referred to manure as their 'second God'.[5] Only by adding more manure to the soil could they increase their output. In order to achieve the same yields as their counterparts on riverine and sea clay soil, however, farmers working the sandy soil needed more than two hundred cartloads of manure per hectare per year, but the amount of manure produced by their own limited livestock was often much less than that. To supplement this, farmers cut sod and mowed heather, rushes and other rough shrubs on an almost daily basis to use as organic litter for their farm animals.[6] This practice had various negative side-effects, however. The homogenous composition of the manure made the soil acidic and gradually led to the disappearance of economically advantageous grain crops such as barley and oats, replaced largely by rye. In the eighteenth century, the growing demand for manure led to an increase in the amount of sod being cut. In the Province of Drenthe, intensive manure production led to a shift from cattle to sheep farming. Eventually, the

2 Gabriël van den Brink, *De grote overgang, een lokaal onderzoek naar de modernisering van het bestaan. Woensel 1670-1920*, SUN, Nijmegen, 1996, p. 131 en 136

3 Jan Bieleman, *Boeren in Nederland, geschiedenis van de landbouw 1500-2000*, Uitgeverij Boom, Amsterdam 2008. p. 234)

4 Translation of *"een slaeffelijken arbeyt, geaccompaneert met armoe en miserie"* in *Syncere Remonstratie en nederigh vertoog,* drawn up by the representatives of Brabant in 1716 to describe the differences between farming in Holland and Brabant. Quoted in Gabriël van den Brink, *De grote overgang*, 1996, p. 113

5 W.J.D. van Iterson, *Schets van de landhuishouding der Meierij, herinneringen*, 's-Hertogenbosch, 1868, cited in Bieleman, *Boeren in Nederland*, 2008, 266

6 Gabriël van den Brink, *De grote overgang*, 1996, p. 112.

plateau of Drenthe had the largest concentration of sheep in the country.[7]

Agricultural output in these rural communities was based on collective land management. The stewardship of woodland and peat moorland was in the hands of various bodies so called commons that first developed in the Middle Ages. They decided how many head of cattle could be kept and how much peat and wood could be removed. They tried to maintain a certain ecological balance. As economic pressure from beyond the sandy regions gradually increased, however, commons were unable to prevent the slow, steady overuse and depletion of the environment. Intensive sheep-farming turned the Dutch highlands into a barren, empty landscape. The relentless removal of sod meant that the vegetation had little chance to recover. In some areas that led to sand drifts and desertification, causing ongoing problems for local populations.[8]

There was little that recalled a self-sufficient Arcadia in the sandy regions of the Netherlands, in other words. Instead, they can be described as ecological and social disaster areas. The climate and the limited availability of manure drove down the standard of living. The people who lived between the barren peat moors and the sandy plateau tried every possible means to eke out a living and to maintain the fragile balance between output and basic necessities.

**The Dutch lowlands: grass and cash crops**

The situation in the western and northern regions of the Netherlands differed in many respects from the miserable conditions in the sandy regions. The west and north had flourishing cities surrounded by green pastureland filled with livestock, orchards nestled between large rivers, and fertile arable farmland that produced potatoes and cash crops such as flax, hemp, madder, and tobacco. There was plenty of water in the lowlands: countless river arms, ponds, navigable channels, and canals that ensured excellent communication links between compact, densely populated cities (see Table 5.1). The cities themselves were beehives of international economic activity, with transhipment and shipbuilding being the most notable occupations in and around the ports, supported by various industries dedicated to refining imports and local products.

Here too, however, we must adjust our idyllic initial impressions. The endless pastures were in fact the result of an earlier ecological crisis that first arose in the late Middle Ages. Until then, the population of the western regions of the Netherlands had been confined to the dunes and riverbanks. Between the tenth and fourteenth centuries, however, the counts of Holland and the bishops of Utrecht granted concessions to develop the peat bogs. During this 'great improvement' [*grote ontginning*], as it was called, the swamp forest was uprooted

7 Bieleman, *Boeren in Nederland* 2008, p 244-246

8 J.L van Zanden en S.W. Verstegen *Groene geschiedenis van Nederland*, Het Spectrum, Zeist, 1993, p. 23-25; Auke van der Woud, *Het lege land, de ruimtelijke orde van Nederland*, 1798-1948, Meulenhof, Amsterdam, 1987, p. 213-216

and the peat – which lay half a metre to four metres above sea level – was drained via ditches constructed to channel the water into canals and natural streams. Once drained, the former fen served as farmland, primarily for the cultivation of grain. Drainage caused the peat to oxidise, however, and this biological degradation process led to irreversible subsidence.

Farming accelerated the process of soil compaction, and so began Holland's historic battle against the water. Dams, discharge sluices, and dikes were meant to keep the compacted soil dry. From the thirteenth century onwards, it became increasingly difficult to grow grain. The sodden soil was suitable only for extensive animal husbandry in the pastures and for 'fishing and birding'. Much of the rural population migrated to the cities, where they were welcomed as cheap labour. The city and the countryside became intimately entwined. The cities became transhipment centres for specialist agricultural products such as cheese and butter, industrial products, and imported grain and wood. This led to a market economy based on trade that was well ahead of its time.[9]
Locally grown crops such as hemp and flax (linseed) were useful in this traditional bio-economy. The mills pressed oil from the seed. The residue, the linseed cake, was used as fodder and became a second important commercial product.

**Table 5.1** Number of inhabitants and population density in the five largest Dutch cities, 1850[10]

| City | Inhabitants | Inhabitants per square km |
|---|---|---|
| Amsterdam | 224,000 | 13,500 |
| Rotterdam | 90,000 | 11,900 |
| 's-Gravenhage | 72,000 | |
| Utrecht | 49,000 | |
| Leiden | 37,000 | 21,400 |

Source: Netherlands Interdisciplinary Demographic Institute (NIDI)

The plant fibres were important raw materials for the domestic linen and yarn industry and for the many hundreds of rope yards that turned them into cables and ropes.[11]

9 P.C.M. Hoppenbrouwers, 'Van Waterland tot stedenland' in Thimo de Nijs en Eelco Beukers, *Geschiedenis van Holland, deel 1 tot 1572*, Verloren, Hilversum, 2002, p. 103-148; J.L van Zanden en S.W. Verstegen *Groene geschiedenis van Nederland*, Het Spectrum, Zeist, 1993, p. 19-23

10 Peter Ekamper, Rob van der Werf en Nicole van der Graag, *Bevolkingsatlas van Nederland, demografische ontwikkeling van Nederland 1850 tot heden*, Nederlands Interdisciplinair Demografisch Instituut, Elmar, Rijswijk, 2003

11 D.A. Zoethout, *De Plant in Nijverheid en Hande*l, 1914 (p. 46-47); B.R. Feis, H. Hoogendoorn en P.M. Stoppelenburg, *Holland in touw, hennepteelt en touwfabricage in het Groene Hart, Groene Hart* Producties, Woerden, 2002

Trade was the most important economic activity in the region, which benefited from the safe trade routes 'behind the dunes' between the Hanseatic cities and Flanders. The rise of industry led to a bigger demand for fuel to heat buildings and drive production processes. Initially, this demand was met by removing peat from the fens. This 'peatification' changed vast swathes of land into ponds; the land was eroded from within. The impact on the landscape was enormous: gigantic lakes developed in the environs of Gouda and Haarlem that defined the landscape of Holland for many centuries.[12]

The Netherlands depended almost entirely on imports for its main building material, wood. Wood was used to build homes and merchant and navy ships. The Zaan district (Province of North Holland) was home to an early modern industrial complex that turned wood from Norway and the Baltic into building material. Lumber yards in Dordrecht and environs processed the wood transported from Germany in gigantic timber fleets.[13]

Imports and the arrival of exotic goods led to an increase in trade during the seventeenth century (the Dutch 'Golden Age'). Technical innovation improved the output of the Dutch Republic.[14] Windmills were used to pump inland lakes dry. City-dwellers invested in the drainage operations, and farmers then used the land for capital-intensive dairy farming. Commerce and industry flourished thanks to the position of the Netherlands, and Amsterdam in particular, as a logistical node. Specialist firms turned imports and raw materials into end products, most of which were destined for export.

The economic success of the Dutch Golden Age left its ecological mark on the immediate environment, however. Around 1640, virtually all of the Netherlands and the adjoining areas of Germany had been deforested to meet the relentless demand for wood for shipbuilding and housing. The 'Dutch timber fleet' on the Rhine led to deforestation in the German areas of Baden-Württemberg. The Dutch Republic's enormous thirst for timber meant that oakwood became scarce on the Rhineland plateau in the Odenwald Forest, the Palatinate, and in the areas surrounding Hanover.[15] In Germany, the wholesale destruction of Europe's forests led to the first publications on sustainable forestry.[16] In the centuries thereafter, the ideas and expectations concerning the depletion of natural resources would often clash with economic interests.

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12 Jan de Vries en Ad van der Woude, Nederland 1500-1815, de eerste ronde van economische groei, Balans, Amsterdam, 1995, p. 58

13 J. Buis, *Historia Forestis: Nederlandse bosgeschiedenis*, Proefschrift Landbouwhogeschool Wageningen, 1985, p 487-518

14 Thomas. J.Misa, *Leonardo to the Internet, technology & culture from renaissance to the present*, John Hopkins University Press, 2004, p. 33-58

15 Henk van Zon, *Geschiedenis en duurzame ontwikkeling, duurzame ontwikkeling in historisch perspectief; enkele verkenningen*, Vakreview duurzame ontwikkeling deel 5, Universitair Centrum Milieuwetenschappen, Katholieke Universiteit Nijmegen, 2002, p. 61-63

16 Henk van Zon, *Geschiedenis en duurzame ontwikkeling*, Nijmegen, 2002, 19-22

The Netherlands could only meet its material needs by increasing the volume of international trade. The population of the lowlands had extended their traditional bio-economy to beyond the Dutch borders. The location of the cities, on the crossroads of many different trade routes, played a crucial role in this. Even before the industrial revolution, the economy of the Dutch lowlands was tied up with foreign suppliers of wood and grain, building materials, and fuel. The Dutch acquired these commodities in exchange for industrial products and speciality crops. Pumping kept the lowlands dry. This too proved to be a fragile system, in which only the windmills and commerce enabled the inhabitants to keep their heads above water, both physically and economically.

At the start of the nineteenth century, the rise of new economic relationships in Europe and the growing salinization of the soil owing to increasing soil compaction presented the Netherlands with new difficulties. Only radical changes in technology and organisational structures would allow it to tackle the problems that had arisen in both its lowland and highland regions.

## 5.3 Transition to an industrial society

By the beginning of the nineteenth century, the Netherlands was a mere shadow of the economic miracle that it had been its Golden Age. Mercantilist practices had gained the upper hand in the international marketplace, and in terms of technology, the Netherlands had been overtaken by the enlightened economies of France and, in particular, Great Britain, where the industrial revolution had begun. Britain's economic success was due to its worldwide colonial empire and the rise of modern industry based on mining, steel, and textiles. Coal – the 'underground forest' – provided the necessary energy. The steam engine became the icon of the industrial revolution.[17]

After Napoleon's defeat at Waterloo in 1815, the new Dutch kingdom briefly cherished the hope that it would soon be entering this new age. The unification of the Austrian Netherlands in the south and the Dutch Republic in the north married the industrial areas of Wallonia (in what is now Belgium) to the trading centres in Holland. Plans were developed for closer integration, but they were nipped in the bud by the Belgian Revolution of 1830.

The technological and economic advances of Great Britain and Belgium were an enticing spectacle for Dutch society in the mid-nineteenth century. The obvious question is why the Dutch did not immediately make the transition. The introduction of new technology and the switch to a new, industrial society required a different mentality and the removal of old limitations. That in turn demanded radical changes in social, cultural and economic structures. This transition process will be illustrated below by two examples, the manuring and improvement of sandy soil and the innovations in madder processing, madder being a

17 Rolf Peter Sieferle, *Der unterirdische Wald, Energiekrise und industrielle Revolution*, C.H. Beck München 1982.

source of natural dyestuffs and one of the nineteenth century cash crops of the Dutch lowlands.

**Transition in sandy regions: manuring and improvement**

How did the inhabitants of the sandy regions escape from the impoverished circumstances surrounding them? Initial attempts to improve the soil were made as far back as around 1800, but almost a century would pass before soil improvement in the south and east of the country altered the landscape into fertile arable farmland and pastureland. Why did this take so long, and what were the most important factors in the transition? The most obvious answer is that artificial fertiliser had yet to be invented, but that explanation is too simple. We will see that other obstacles had to be removed first.

The radical change required in these areas could only take place after a number of interrelated limitations had been overcome. To begin with, these concerned the uncertainties about property ownership and the related scope for investment. It will be clear that small, impoverished farmers were unable to run any major financial risks. They did not have the resources to innovate and experiment. They also did not possess the knowledge of farming needed to make radical improvement of the soil and an increase in output possible.

**Property ownership and investment**

The first obstacle to improving the sandy soil was the legal status of the land. Some of the farming communities managed the land (or in any event part of it) communally, and had developed their own governance and farming practices. As we saw earlier, collectively owned peat moorland was an important source of material for increasing the production of manure, but it was virtually impossible to achieve economic growth or prevent the steady depletion of the soil.

The traditional practices and social structures offered farmers virtually no incentive to extend their productive holdings, and they also prevented economic and social progress in these regions. In 1806, King Louis Napoleon launched the first plans to develop these *petits déserts* ('little deserts'). It took more than forty years before the necessary regulations had been drafted and put into place, however. The delay was due to resistance by local administrators and the many political changes that washed over the country in the early nineteenth century. Uncertainty about property ownership made it difficult to purchase land. Only gradually did it become possible for the Land Registry, which had been established (or rather, re-established) in 1832, to sort out the many conflicting claims. The notation in the land registry, the taxes, and all the other bureaucratic fuss involved in purchasing property meant that it was more advantageous to purchase huge tracts of land than small ones. The regulations thus favoured the 'landed gentry' and large landowners with more financial clout.[18]

18 Auke van der Woud, *Het lege land*, p. 213-226; Eric Berkers, Geodesie, de aarde verbeeld, berekend en getekend, Walburg pers, Zutphen, 2004

**Knowledge and opportunity**
The second obstacle to a rapid transition in the sandy regions was the restricted knowledge of soil improvement practices and limited opportunity to practise them. The lack of affordable manure was the biggest restriction in this respect. Some prosperous investors solved the problem by planting forests to fertilize grounds naturally. After twenty or thirty years, the forest would be logged and a fertile layer of compost remained. This natural fertilization required a long-term investment and well-filled pockets (see the box 'Reforestation in the Netherlands').[19]

Alongside such long-term investment, the first small-scale improvement programmes began. These involved experiments with different types of manure. It was the various Agricultural Societies [Maatschappijen van Landbouw] that took the initiative; these organisations were founded in the first half of the nineteenth century by the local elite, for example local administrators, lawyers, and large landowners. Following the example of the British and French Agricultural Societies, the founders focused on applying enlightened scientific methods in agriculture.

The agricultural societies played an important role in agricultural innovation by experimenting with new technologies, including the many tests they carried out with new manuring practices.

Various experiments in the Netherlands and elsewhere showed that fertilizing could turn poor sandy soil into fertile arable farmland. Faeces and waste brought in from the cities made suitable manure. The fen communities in Groningen (the far north) and the horticulture sector in North and South Holland made considerable use of such fertilisers. The main obstacles to their wide-spread use were the quantities required to improve the sandy soil and the transport costs involved. This changed with the arrival of guano, i.e. dried bird manure that the British brought to Europe from Peru. British experiments demonstrated that guano, which was first introduced in 1841, was an effective fertiliser. The first guano was exported to the Netherlands in 1843, and experiments soon showed its effectiveness. Reports revealed that 1 tonne of guano equalled 30 tonnes of horse, cattle or pig manure. This enormous efficiency made it cheaper to import guano than to use the standard fertilisers, despite the greater distance that the guano had to travel.[20] Experiments with and subsequent use of this artificial fertiliser consequently increased rapidly. Guano was harvested by Chinese labourers, who worked for little pay and under wretched circumstances. The Chilean and Peruvian coastlines and islands were soon destroyed by the harvesting operations.[21]

19 Auke van der Woud, *Het lege land*, p. 197 en 236; W. Boerhave Beekman, *Hout in alle tijden, deel V*, toegepast hout van thans, Kluwer, Deventer, 1951, in inleiding (z.p.); J.L van Zanden en S.W. Verstegen *Groene geschiedenis van Nederland*, Het Spectrum, Zeist, 1993, p. 65

20 J.L. van Zanden, 'Mest en Ploeg' in H.W. Lintsen (red.) *Techniek in Nederland, de wording van een moderne samenleving*, 1800-1890, deel 1, Walburg Pers, Zutphen, 1992, pp. 53-69

21 Clive Ponting, *A New Green History of the World, The environment and the collapse of great civilizations*, Penguin Books, London, 2007, p. 193

*Reforestation of the Netherlands*

*We do not have figures that indicate the scale of natural fertilization for the Netherlands as a whole, but a study of land use in Woensel (Province of North Brabant) shows how natural fertilization led to an increase in forest rather than to other land use, especially peat moorland.*

**Table 5.2** Land use in Woensel (North Brabant) in percentages

| | farmland | grassland | forest | other | Total |
|---|---|---|---|---|---|
| 1794 | 21 | 14 | 2 | 63 | 100 |
| 1832 | 30 | 13 | 4 | 53 | 100 |
| 1852 | 31 | 14 | 9 | 46 | 100 |
| 1880 | 32 | 14 | 15 | 39 | 100 |
| 1895 | 31 | 16 | 21 | 32 | 100 |

Source: Van den Brink, De grote overgang, p. 115

*In 1833, the Netherlands had about 170,000 ha of forest (approx. 5% of its land area); by 1900 this had increased to 250,000 or 7.6% of the land area. It was the first time that there had been an increase in the amount of forest in the Netherlands since the sixteenth century. By the end of the nineteenth century, forests served increasingly for timber production: industrialisation had raised the demand for pine, with the trunks serving as struts in the coalmines. The amount of forest remained virtually static in the twentieth century, but the Netherlands – along with Great Britain and Ireland – remained one of the least forested countries in Europe and unable to meet its own demand for wood.*

The best guano stocks were depleted in only a few decades and so the search for substitutes began. Dried bird manure from other regions of the world proved to be less effective, and domestic mixtures seldom met with success. Chemists sought to explain why guano was such an efficient fertiliser. Gradually, it became clear that its high phosphate and nitrate content made it so effective. Research into plant nutrition and fertilisation was one of the priorities of the State Agricultural School in Wageningen, founded in 1876 (which later became the the Wageningen University). Its founding marked the start of agricultural science in the Netherlands.[22]

The amount of guano used in the Netherlands was fairly small. At the height of the guano craze, in around 1870, about 7000 tonnes were used, somewhat less than three kilograms per hectare. The real significance of guano lies not in the

22 J.L. van Zanden, 'Mest en Ploeg' in H.W. Lintsen (red.) *Techniek in Nederland, de wording van een moderne samenleving*, 1800-1890, deel 1, Walburg Pers, Zutphen, 1992, pp. 53-69

amount used, but in the role that it played in demolishing old socio-technical structures. The use of guano undermined the local cycle of nutrients based on manure and waste from urban and rural areas. It also initiated a scientific approach to the problem, supported by the agricultural societies.

Improved transport, for example steamships, led to a farming crisis between 1880 and 1895, with imports of grain and other agricultural products driving down prices, including in the Dutch hinterland.[23] At the same time, livestock numbers increased and the fertilisation problem grew less acute after 1880.[24] Government urged farmers to cooperate more closely in order to head off the crisis. The Cooperation Act of 1876 made it possible for small farmers to buy and sell collectively, thereby gaining an advantage. The first such arrangement was a cooperative society for the purchase of fertilisers (the *Welbegrepen Eigenbelang* society in the Province of Zeeland). It was soon followed by others. The *Nederlands Landbouw-Comité* [Dutch Agricultural Committee], founded in in 1891, improved cooperation between the agricultural societies and research institutes. This led after 1890 to a flood of new artificial fertilisers, such as superphosphates. Other artificial fertilisers, products of the coal mines and petroleum refineries, would follow in the twentieth century.

It took another fifty years before artificial fertiliser overtook stable manure in importance, however.[25] The transition had begun, but like other changes, it proceeded at a modest pace, contingent on the rate of social and economic change.

**Transitions in the commercial economy of the Dutch lowlands**

It took almost a century before improvement initiatives in the sandy regions of the Netherlands grew to any notable proportions. Old structures had to be revised in order to make investment and innovation possible. The lack of financial resources was less relevant in the Dutch lowlands, but it nevertheless

23 J. Bieleman, J. en H.K. Roessingh, 'Wie zaait zal oogsten? De ontwikkeling van het rogge-beschot op de noordelijke zandgronden op lange termijn', in H. Diederiks, J.-Th. Lindblad & B. de Vries (Eds), Het platteland in een veranderende wereld. Hilversum, 1994, pp. 1994, p. 176-178

24 Merijn Knibbe, 'Landbouwproductie en -productiviteit, 1807-1997' in Ronald van der Bie en Pit Dehing (red.), *Nationaal goed, feiten en cijfers over onze samenleving (ca.) 1800-1999*, Centraal Bureau voor de Statistiek, Voorburg, 1999, 37-55

25 Ernst Homburg en Henk van Zon, 'Grootschalig produceren: superfosfaat en zwavelzuur, 1890-1940' in J.W.Schot et. al. (red.) *Techniek in Nederland in de twintigste eeuw, deel II: Delfstoffen, Energie en Chemie*, Walburg Pers, Zutphen, 2000, p 278-297; Jan Bieleman, *Boeren in Nederland,* p 285-287; Hans Veldman, Eric van Royen en Frank Veraart, *Een machtige schakel in de land- en tuinbouw, de geschiedenis van Cebeco-Handelsraad*, 1899-1999, Stichting Historie der Techniek, Eindhoven, 1999, p. 16-22, Merijn Knibbe, 'Landbouwproductie en -productiviteit, 1807-1997' in Ronald van der Bie en Pit Dehing (red.), *Nationaal goed, feiten en cijfers over onze samenleving (ca.) 1800-1999*, Centraal Bureau voor de Statistiek, Voorburg, 1999, p. 55

took several decades before the transformation process got under way there as well. Why was progress so slow? How were pre-industrial firms transformed into a modern industry?

A good example of how industrialisation involved more than just introducing new equipment or other technical inventions can be found in the innovations in madder processing. When dried and pulverised, the roots of the madder plant produce a red dye for textiles and leather. Madder was cultivated on the sea clay of the south-western part of the Netherlands.

Until the 1820s, the Netherlands dominated the market in this dye. Thereafter, it encountered stiff competition in the British market from French madder growers. The French succeeded in expanding their market share after 1830 by using a chemical process to concentrate the dyestuffs obtained from the plant into a new product. The French called this concentrated pigment *garancine* or garancin. Dutch producers scarcely took notice, however. It was only after 1845 that plans were implemented to industrialise the Dutch madder industry. Once again, we must ask ourselves: what kept the Dutch producers from innovating?

Our explanation must begin by noting the differences between the Dutch and French production methods. The Dutch producers worked on a small scale. Farmers would band together to run the meestoof, the long outbuilding where madder roots were dried and pulverised. Every farmer stored his harvest of madder in his own section of the outbuilding. Each one sold his own harvest individually to the wholesaler, who in turn sold it on to dye makers and printers. The French, on the other hand, used an industrialised production system that turned large quantities of roots into a homogenous product. The manufacturers sold the madder directly to the textile industry, and the farmers merely supplied the roots.

From the 1830s onwards, Dutch entrepreneurs attempted to start up madder factories, but their efforts often ended in failure. The reasons must be sought, first of all, in the prohibitive legislative framework. There were countless city, provincial and rural regulations that set out rules to protect the good reputation of the madder. For example, to prevent falsification, it was forbidden to mix different grades of madder together. The quality of the madder was determined by its taste. After 1845, new testing methods, for example with wax or by chemical analysis, made a more objective assessment of the dye's quality possible.[26] The prohibition on mixing different grades of madder was rescinded, but the course of industrial production did not always run smoothly. Farmers and traders resisted the establishment of madder factories; the farmers feared losing their autonomy, and the traders their business. The growing demand for a homogenous product put more pressure on Dutch madder producers, however.

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**26** Harry Lintsen, *Made in Holland*, 2005, p. 298

As a result, an intermediate form emerged in which the farmers supplied madder to garancin factories set up by traders. Twenty garancin factories were founded between 1847 and 1865, and these represented the beginnings of a large-scale chemicals industry in the Netherlands. Although profitable, however, the Dutch garancin industry was short-lived. From 1870 onwards, German producers of synthetic alizarin – another dyestuff derived from the madder root – began to compete for market share. Within just a few years, they had conquered the market for red textile dyestuffs. Very little changed for the buyers, who easily made the switch to alizarin. But Dutch manufacturers lacked the chemical expertise and skill to make the transition. Dutch garancin production slowly faded away and was reduced to a number of tiny niche suppliers that met the demand for special colour nuances.[27]

**A long series of transitions**

The transition to a modern society was a lengthy one with many obstacles to overcome. The two examples of radical change in the Dutch lowlands and highlands make this clear. Nor were the introduction of artificial fertiliser and the industrialisation of the madder industry exceptions. In other areas of Dutch industrialisation as well, the pace of transformation to a modern society was determined by the speed of social and economic change.

It was almost eighty years, for example, before the steam engine made its breakthrough in the Netherlands. Until recently, historians considered this one of the outstanding examples of Dutch industrial backwardness in the nineteenth century. Here too, however, local circumstances played a role. The Netherlands lacked the industrial sectors – such as mining, iron-forging, and large-scale textiles – that had developed steam engines elsewhere. Instead, the steam engine in the Netherlands was first used to drain the polders. It was only when steam engines became smaller and more energy-efficient that they came into more general use, and from 1880 onwards they were ubiquitous in the Netherlands as well (see Table 5.3).[28] The transition from stable manure to artificial fertiliser took fifty years. Other changes in agriculture also took a very long time. Research shows that farmers continued to use horses for another forty or more years after the introduction of the lorry in 1925. The widespread use of pesticides took more than fifty years.[29]

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27 J.W.Schot en E.Homburg, 'Meekrap en garancine' in H.W.Lintsen et. al. (red.) *Techniek in Nederland, de wording van een moderne samenleving 1800-1890*, deel IV, Walburg Pers, Zutphen,

28 Harry Lintsen, Made in Holland, p. 133-141, H.W. Lintsen, 'Een land met stoom', in H.W.Lintsen et. al. (red.) *Techniek in Nederland, de wording van een moderne samenleving 1800-1890*, deel VI, Walburg Pers, Zutphen, 1995, p. 191-216

29 Merijn Knibbe, 'Landbouwproductie en -productiviteit, 1807-1997' in Ronald van der Bie en Pit Dehing (red.), *Nationaal goed, feiten en cijfers over onze samenleving (ca.) 1800-1999*, Centraal Bureau voor de Statistiek, Voorburg, 1999, p. 55

**Table 5.3** Number of power generators in industry, categorised by type and number[30]

| | Around 1850 | Around 1860 | Around 1880 | Around 1890 |
|---|---|---|---|---|
| **Horse mills** | 1930 | 1710 | 910 | 570 |
| **Windmills*** | 3050 | 3400 | 3120 | 1790 |
| **Watermills** | 470 | 500 | 250 | 160 |
| **Steam engines** | 290 | 820 | 2740 | 3930 |
| **Gas engines** | | | 10 | 500 |

* not including polder-draining mills

Natural resources from the Dutch Indies (now Indonesia) also played a key role in the Dutch industrial revolution. The Dutch exploited colonial raw materials and in many cases transported them to the Netherlands for processing and refinement. In 1830, this practice was given an added boost by the introduction of a 'forced farming' system in the colony. This led to enormous sugar, palm oil, and rubber plantations, as well as the cultivation of other crops useful to a modern economy. At the same time, the industrial revolution was advancing in the Netherlands, with technologies based on wood, wind and plant matter being supplanted by a technical regime based on coal, iron, salt, sulphur and lime.

The changes were initiated by the new technical advances, but they were implemented in the course of a process that required society and the social, scientific, and economic structures to change. New structures meant developing new customs, rules, and power relationships. Traditional working methods dis-appeared and old economic and power relationships were eroded. The transition led to friction in many locations and therefore moved very slowly.

## 5.4 The fossil economy

The limitations of the traditional bio-economy represented a major problems for Dutch society. Progress in the Netherlands was hampered by local circumstances and trade with other countries. In the Dutch highlands, these circumstances had led to self-sufficiency, out of sheer necessity. In the Dutch lowlands, specialised products were traded to meet the demand for grain, wood, and other basic necessities. The use of fossil raw materials broke down the boundaries of the bio-based raw materials cycle, leading in the late nineteenth and twentieth

30 Figures are rounded to the nearest ten. Gegevens H.W.Lintsen et. al. (red.) *Techniek in Nederland, de wording van een moderne samenleving 1800-1890*, deel VI, Walburg Pers, Zutphen, 1995, tabel 7.1 p. 192

centuries to a succession of scientific and technical advances. The fossil revolution and its implications became clear in two particular applications: as a source of energy and in the development of new materials.

**Fossils as a substitute for bio-based resources of energy**
In the Netherlands, the industrial revolution – which began in the second half of the nineteenth century – led to many different changes in the supply of energy. Bio-based sources of energy gave way to machinery powered by coal-fired steam engines. At first, steam engines replaced human and animal power and water power (see Table 5.3). Towards the end of the nineteenth century, they also replaced the traditional windmills, which had thus far powered the Dutch industrial revolution. This switch increased industrial capacity considerably (see Table 5.4).

**Table 5.4** Sources of energy in industry and construction, 1815-1913 (in kW per 1000 inhabitants)[31]

| | 1815 | 1830 | 1846 | 1873 | 1895 | 1913 |
|---|---|---|---|---|---|---|
| **Wind and water** | 21,6 | 17,5 | 16,0 | 14,9 | 10,5 | 5,4 |
| **Steam** | 0,1 | 0,7 | 3,1 | 35,9 | 89,8 | 128,7 |
| **Electricity** | | | | | 0,6 | 80,4 |
| **Coal gas** | | | | | 0,4 | 7,7 |
| **Oil/Petrol** | | | | | | 8,9 |

Source: Albers 1998

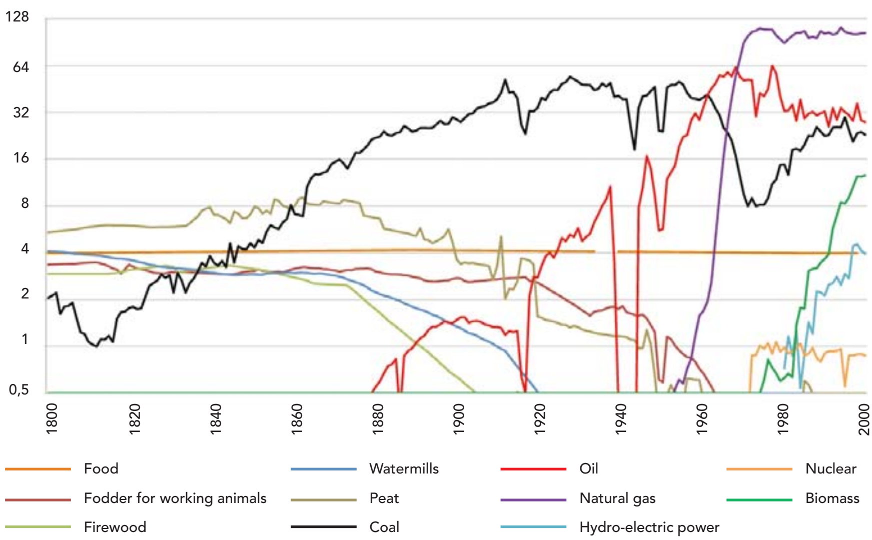
The transition reached beyond industry. Figures on overall energy consumption in nineteenth and twentieth-century Netherlands clearly show how peat, wood, and human/animal power were replaced by fossil energy sources (see Figure A). The diagram shows the gradual rise of the fossil economy, with the breakthrough of coal midway through the nineteenth century, the rise of petroleum products starting in the 1920s, and the breakthrough of gas in the 1960s. The figures concerning coal consumption obscure two technical transitions of indirect uses of coal, one to electricity and the other to coal gas. Both had an equally large impact in helping establish new patterns in industry and in households. Both were primarily fuelled by coal, which was converted into electrical current and gas in power stations and gasworks. Besides the rise of new energy sources, the diagram also shows the gradual decline of peat and other bio-based energy sources and the resurgence of biomass in the final decades of the twentieth century. The fact that modernisation led to a rapid increase in total energy consumption can be seen in Figure B. The figures provide evidence of complex processes: industrialisation, the rise of the consumer society, and a growing level

31 Converted from HP to kW. Source: R.M. Albers, *Machinery Investment and Economic Growth: the Dynamics of Dutch Development, 1800-1913*, Groningen 1998, Appendix Table A-6.3, cited in Jan Luiten van Zanden en Arthur van Driel, *Nederland 1780-1914, staat, instituties en economische ontwikkeling*, Uitgeverij Balans, 2000, p. 387

of mobility. The Dutch demand for energy increased very rapidly after the Second World War. Between 1948 and 2000, total per capita energy consumption quadrupled. The increase in energy supply and consumption was the driver behind today's welfare state and the population distribution over many towns and smaller cities. This chapter can scarcely do justice to the scale of these processes; we will be able to discuss only a very small part.

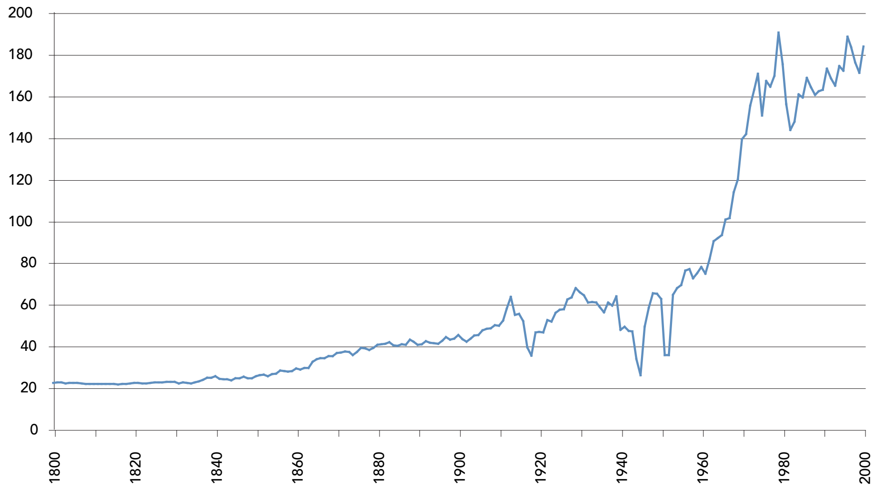
It is notable that in terms of energy sources, the transition appears to be virtually unrelated to local sourcing. The growth of the Dutch coalmining industry – kicked off by the opening of the Oranje-Nassau Mine and the State Mine at the start of the twentieth century – took place only after the transition to coal had already been completed. The transition was in fact based on imports. That was also true of the later transition to petroleum. Only the transition to gas was driven by the Netherlands' own gas reserves.

**Figure A** Energy consumption in the Netherlands in GJ/inhabitant (logarithmic)[32]




32 From Ben Gales, compiled from figures provided by Statistics Netherlands, the International Energy Agency, and the author's own reconstruction. Published in G.B.A. Gales, "Delfstoffen" in J.W. Schot et al. (red.) *Techniek in Nederland in de twintigste eeuw, deel II: Delfstoffen, Energie en Chemie*, Walburg Pers, Zutphen, 2000, diagram 2.1, p. 22

**Figure B** Energy consumption in the Netherlands in GJ/inhabitant




**The development of the Dutch chemical-industrial complex**
Exploitation of the Netherlands' natural (fossil) reserves did have a significant impact on the Dutch chemicals industry, however. In 1900, that industry was made up of small and medium-sized companies.[33] The expansion of the country's coalmining industry and the exploration and production of colonial petroleum radically changed the focus of the industry in the twentieth century.

Around the turn of the century, Germany's chemicals industry was in the lead. It was based largely on coal, with coal tar – a by-product of gas and coke production – being the most important raw material. Distillation and other processes produced aromatics, the base material for end products such as medicines, colouring agents, and explosives. A similar cluster developed in the Netherlands in connection with the exploration and production of colonial petroleum by the *Bataafsche Petroleum Maatschappij* (now Shell Petroleum N.V.), a subsidiary of Royal Shell. The high aromatics content found in oil from Borneo led to the founding of the Shell laboratory in 1907. Shell applied the knowledge gained in coal tar chemistry to its own crude oil and intermediate products. In Rotterdam, the company built a refinery for oil imported from Balik Papan (Borneo). It also built a nitration plant near Düsseldorf, which produced colouring agents from refined petrol. The location was decided by the German market for colouring

33 Ernst Homburg, 'Chemische techniek en chemische industrie', in J.W.Schot et. al. (red.) *Techniek in Nederland in de twintigste eeuw*, deel II: *Delfstoffen, Energie en Chemie*, Walburg Pers, Zutphen, 2000, p. 270-277

agents.[34] The First World War drove concentration in the Dutch chemicals industry forward. The production of explosives resulted in a partnership of various chemicals companies. This led, at a later stage, to the production of alizarin, the synthetic dyestuff that had virtually wiped out the madder industry.[35] As the chemicals industry expanded, collaboration between companies in various supply and production chains became increasingly important.

**Chemicals get scientific**

The chemicals industry grew along with the need to synthesise and refine different substances. A network of interdependent supply chains and intermediate products developed. The necessary fundamental knowledge was supplied by university and corporate chemistry laboratories.

At the end of the nineteenth century, the systemisation of organic and inorganic chemistry was almost complete. Scientific knowledge had now reached the point at which a transformation to a modern society became possible. In the twentieth century, the challenge would lie in preparing and studying new chemical compounds and identifying their properties.[36] University – and increasingly, corporate – chemistry labs eagerly rose to meet this challenge. In 1885, the Yeast and Alcohol Plant [*Gist- en Spiritusfabriek*] in Delft set up the first commercial chemistry laboratory in the Netherlands. The *Bataafsche Petroleum Maatschappij* followed suit in 1906. Other commercial laboratories were set up around the time of the First World War. The war gave rise to a new research agenda. With international trade virtually at a standstill, raw materials became scarce in the Netherlands as well, resulting in a quest for alternatives. Because international competition from abroad had declined, there were also plenty of opportunities for new products and processes. The First World War provided the basis for Dutch industrial research, which increased sharply between the two wars and after the Second World War (see Table 5.5).[37]

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34 Ernst Homburg, 'Van carbo- naar petrochemie, 1910-1940 ', in J.W.Schot et. al. (red.) *Techniek in Nederland in de twintigste eeuw*, deel II: Delfstoffen, *Energie en Chemie*, Walburg Pers, Zutphen, 2000, p. 332-357; Ernst Homburg, 'Explosives from oil: the transformation of Royal Dutch/Shell during World War I from oil to Petrochemical Company' in Brenda J. Buchanan, Gunpowder, Explosives and the State, a technical history, Ashgate, Aldershot, 2006, p 385-408

35 Ernst Homburg, 'De Eerste Wereldoorlog, samenwerking en concentratie binnen de Nederlandse chemische industrie', in J.W.Schot et. al. (red.) *Techniek in Nederland in de twintigste eeuw*, deel II: *Delfstoffen, Energie en Chemie*, Walburg Pers, Zutphen, 2000, p. 316-331

36 H.A.M. Snelders, *De geschiedenis van de scheikunde in Nederland 2, de ontwikkeling van chemie en chemische technologie in de eerste helft van de twintigste eeuw*, Delft University Press, 1997, p. 1- 13

37 Ernst Homburg, Ari Rip en James Small, 'Chemici, hun kennis en de industrie' in J.W.Schot et. al. (red.) *Techniek in Nederland in de twintigste eeuw*, deel II: *Delfstoffen, Energie en Chemie*, Walburg Pers, Zutphen, 2000, p. 296-315

**Table 5.5** Number of employees in the six largest industrial laboratories[38]

| | 1940 | 1950 | 1955 | 1960 | 1970 |
|---|---|---|---|---|---|
| Kon. Shell Laboratorium Amsterdam (KSLA) | 1350 | 1640 | 1800 | 2173 | 2000 |
| Philips Natuurkundig Laboratorium - Eindhoven | 516 | 900 | 1250 | 1600 | 2200 |
| Algemene Kunstzijde Unie* - Arnhem | 150 | 530 | 925 | 1075 | 1500 |
| Centraal Laboratorium Staatsmijnen /DSM | 80 | 420 | 630 | 780 | 1200 |
| Unilever Research - Zwijndrecht, Vlaardingen en Duiven | 30 | 50 | 175 | 500 | 1350 |
| Gist & Spiritusfabriek /Gist-Brocades - Delft | 90 | 165 | 290 | 430 | 555 |

* including test plant

## Replacing nature: synthetics

Scientific research cleared the path for the development of entirely new substances. At first, these were based on natural products and processes, but as the science advanced, the examples and applications from nature gradually faded into the background and a generation of entirely new synthetic products emerged.

British and American chemists used cellulose to develop celluloid, the first commercially successful synthetic substance. It was presented as a substitute for ivory.[39] Bio-based materials such as cellulose and casein constituted the basis for the production of 'artificial silk' (rayon) and synthetic horn, first produced in the Netherlands in the 1910s.[40] Belgian chemist Leo Baekeland patented the first entirely synthetic material, Bakelite, in 1909. He presented it as a substitute for shellac, a natural resin secreted by the *Kerria lacca* insect (lac bug). In the 1920s, it became a popular component in electrical appliances and in 1923 Philips in Eindhoven opened a Bakelite factory.
On the eve of the Second World War, German, British and American chemists developed and found uses for synthetic materials, which became extremely

38 Ernst Homburg en Lodewijk Palm (red.), *De geschiedenis van de scheikunde in Nederland 3, de ontwikkeling van de chemie van 1945 tot het begin van de jaren tachtig*, Delft University Press, 2004, p. 6, tabel 1.1 37

39 M. Boot et al, *De eerste plastic eeuw*, Haags Gemeentemuseum, 1981, 10 en T.Friedling, voorgeschiedenis van de kunststoffen in H.M. Brüggemann (red.) *Kunststoffen 1986 Terugblik en Toekomst*, 12

40 E. Bijker et al, *The Social Construction of Technological Systems*, 7e editie, 1999, 177; P.M.A.V Hooghoff, *70 Jaar Plastics, van persplastiek tot spuitgietwerk*, Van Nifeterik in Putte van 1929 tot 1999, Putte, 1999, 11. ; Frank van der Most, et. al 'Nieuwe synthetische producten: plastics en wasmiddelen na de Tweede Wereldoorlog in J.W.Schot et. al. (red.) *Techniek in Nederland in de twintigste eeuw,* deel II: *Delfstoffen, Energie en Chemie*, Walburg Pers, Zutphen, 2000, p. 296-315

popular during the war. They replaced metals important to the war effort and were also used in the rapidly developing field of aeronautical engineering.

In the post-War period, it was Germany that provided the knowledge required by the Dutch synthetics industry. As part of German war reparations, patents awarded to German chemicals companies became available. In March 1946, the Dutch Ministry of Economic Affairs ordered a study on the potential for developing synthetics in the Netherlands. A number of producers, including Dutch State Mines (now DSM), made use of this opportunity. Dutch State Mines used German know-how to turn itself into one of the key producers of caprolactam, the main ingredient in the production of nylon by the General Rayon Union [*Algemene Kunstzijde Unie*, AKU]. Production of polythene, synthetic rubber, and various other synthetic materials followed in the 1950s, giving State Mines/DSM a good basis for expanding its production of synthetic materials.[41] Shell started production of PVC in 1946. Its synthetics arm expanded in the 1950s when it acquired various American and British firms, making Shell a producer of synthetic rubber, polystyrene, polyethylene and resin.[42]

Bulk production after the Second World War led to lower prices and increased the popularity of synthetic materials. Plastics were the epitome of modern Dutch society in the 1950s and 1960s, as predicted by the women's magazine Libelle in 1946:

> *"...in a few years you will be dressed entirely in synthetic fabrics, because your shopping bag and shoes will also be made of plastic."*[43]

After the Second World War, synthetic materials increasingly replaced natural ones. The trend became very clear in clothing and household utensils. Synthetics were also inexpensive and made physical prosperity affordable for everyone. Nylon stockings were probably the most powerful symbol of this transformation. Natural materials were considered antiquated and unfashionable – who wanted to go about wearing woollen socks or a cotton bathing suit? The future lay in synthetics, it seemed. Synthetic building materials were still considered 'sustainable' in the 1960s because of their indestructible nature. As the list of synthetic products and applications – in particular inexpensive ones – grew, however, it was precisely the durability of synthetics that turned people against them. When they came into widespread use in packaging and cheap products, the 'disposable culture' began to emerge. The result was environmental pollution by objects that refused to disintegrate. 'Plastic' became synonymous with cheap and unnatural. Synthetics became a waste problem. Along with air and water

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41 F. Veraart en T. van Helvoort, 'Grondstoffen voor Kunststoffen, 1945-1970, in H.Lintsen et al, *Research tussen Vetkool en Zoetstof*, Stichting Historie der Techniek, Eindhoven, 2000, p. 32-43

42 Stephen Howarth en Joost Jonker, *Stuwmotor van de koolwaterstofrevolutie*, 1939-1973, *Geschiedenis van Koninklijke Shell*, deel 2, Boom Amsterdam, 2007, p. 346-353

43 C. Erkens 'Plastic het wonderproduct' in *Weekblad Libelle*, 1946, nr. 9 (juni), p. 16-17.

pollution, they took on symbolic meaning in the 1970s and 1980s among critics of industrialisation.[44]

## 5.5 Industrial agriculture

The fossil economy became manifest not only in sources of energy and new materials; agriculture, often associated with the natural world, was also industrialised. Agriculture followed changes in the pattern of consumption throughout society. Like the rest of the population, farmers also switched to fossil fuels to satisfy their heating and transport needs.

After the crisis in agriculture in the nineteenth century, the state began to play a more influential role in farming. The Farming Crisis Act [*Landbouwcrisiswet*] of the 1930s increased its influence. Sizeable funding programmes kept farmers and the food supply afloat. After the Second World War, the Minister of Agriculture and later the European Community's Commissioner of Agriculture, Sicco Mansholt, led the crusade to formulate a new policy. Its aim was to guarantee the supply of food in the Netherlands and Europe. Known as 'regional economic policy', it made output and economies of scale a priority. This policy was built on mechanisation, major land consolidation programmes, and price-fixing within the European Community (the forerunner to the European Union).[45]

Close collaboration between science and agricultural societies made industrialisation possible. That collaboration was reinforced by the setting up and expansion of various research and teaching institutes, including the Agricultural School in Wageningen. After the Second World War, agricultural research, information provision, and education became institutionalised. Researchers, educators, and farmers collaborated successfully throughout various agricultural policy forms, for example on such matters as mechanisation and other innovations intended to increase output. The new partnership also brought about the introduction of new production methods, for example based on steam engines and, later, tens of thousands of tractors.[46]
Another result of the successful partnership between research, information provision, and education was the increase in the use of artificial fertiliser (see Figure C). Until the 1920s, most Dutch farmers still used imported manure. This was later replaced by ammonium sulphate, a by-product of coke production. It

44 E.M.L. Bervoets en F.C.A.Veraart, 'Bezinning, ordening en afstemming, 1940-1970' in J.W.Schot et. al. (red.) T*echniek in Nederland in de twintigste eeuw*, deel VI: *Stad, Bouw, Industriële productie*, Walburg Pers, Zutphen, 2003, 214-239.; Jesse Goossens, Plastic Soep, Lemniscaat, Rotterdam, 2009 43

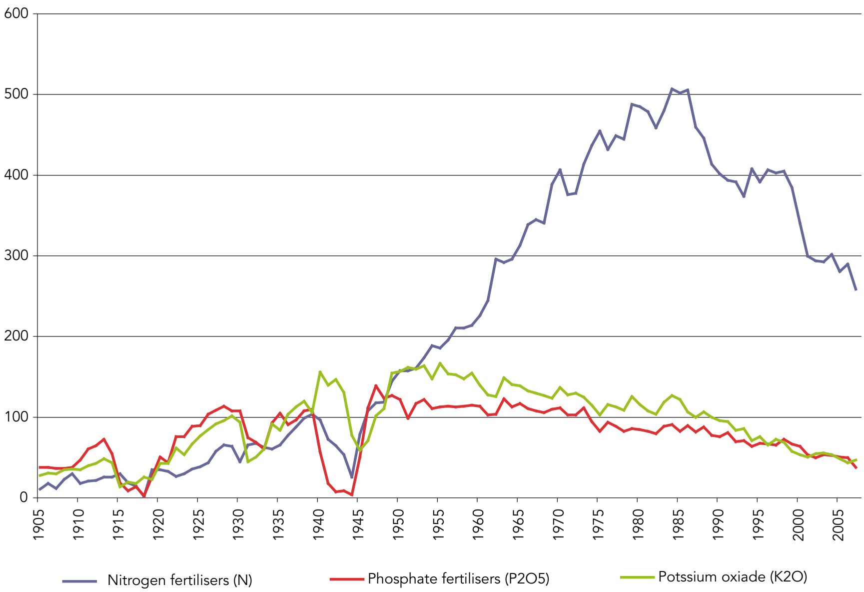
45 Jan Bieleman, *Boeren in Nederland*, p. 461- ; John Grin, 'Modernization Process in Dutch Agriculture, 1886 to the present', in John Grin, Jan Rotmans and Johan Schot, *Transitions to Sustainable Development*, Routledge, Oxon, 2010, p 249-264

46 J. Bieleman (red.), 'Landbouw' in J.W.Schot et. al. (red.) T*echniek in Nederland in de twintigste eeuw*, deel III: *Landbouw en Voeding*, Walburg Pers, Zutphen, 2000 p. 72-81; Jan Bieleman, Boeren in Nederland, p. 464

became popular when bans on German imports were lifted and after the coke works in Limburg (State Mines, 1919) and IJmuiden (Hoogovens, 1923) came on stream (see Table 5.6).

Nitrogen fertilisers became even more popular when local production expanded and prices plummeted owing to overproduction in the European market.[47] The use of artificial fertilisers spread rapidly. Between the wars, Dutch farmers began to use more artificial fertiliser per hectare than farmers in Germany and Belgium (see Table 5.7).

**Figure C** Use of artificial fertiliser in the Netherlands, 1905-2007, in kilotons




Source: : CBS/LEI

47 Ernst Homburg, 'Van carbo- naar petrochemie, 1910-1940 ', in J.W.Schot et. al. (red.) *Techniek in Nederland in de twintigste eeuw*, deel II: *Delfstoffen, Energie en Chemie*, Walburg Pers, Zutphen, 2000, p. 332-357 46

**Table 5.6** Share of nitrogen fertilisers used on Dutch farms, 1923/1924 – 1928/1929, in percentages[48]

| | 1922/1923 | 1924/1925 | 1926/1927 | 1928/1929 |
|---|---|---|---|---|
| **Sodium nitrate** | 83,3 | 57,6 | 32,6 | 32,1 |
| **Ammonium sulphate** | 14,7 | 39,9 | 57,5 | 41,7 |
| **Potassium nitrate** | 1,6 | 1,4 | 5,9 | 17,3 |
| **Cyanamid** | 0,4 | 1,1 | 1,0 | 3,1 |
| **Other** | - | - | 3,0 | 5,8 |

Source: Homburg 2004

**Table 5.7** Consumption of nitrogen fertilisers in some European countries (in kg per ha)[49]

| | 1913 | 1925 | 1926 | 1927 | 1928 |
|---|---|---|---|---|---|
| **Netherlands** | 7,1 | 16,5 | 20,5 | 21,6 | 26,3 |
| **Belgium** | 16,0 | 19,7 | 18,7 | 19,8 | 19,3 |
| **Germany** | 7,2 | 10,0 | 11,2 | 13,6 | 13,9 |
| **France** | 0,2 | 3,1 | 3,0 | 3,4 | 4,0 |
| **United Kingdom** | 2,3 | 2,0 | 1,8 | 2,1 | 4,0 |

Source: Homburg 2004

The period of the 1950s and 1960s were characterized by a great faith in technological developments. This was based on advances in nuclear energy and IT, as well as on the discovery of vast reserves of fossil fuels. In the Netherlands, this was the giant gas field around Slochteren. Air and water pollution in industrial and port areas revealed the dark side of industrialisation, however. The pollution led to the first environmental legislation on water (1968) and air pollution (1970) and to the establishment of a Ministry for Health and Environmental Protection in 1971. Increasingly, the Netherlands was being transformed into a modern society, evoking waves of nostalgia and also the rise of an active environmental movement.

48 Ernst Homburg, *Groeien door kunstmest*, DSM Agro 1929-2004,Uitgeverij Verloren, Hilversum, 2004, table 2.2, p. 43

49 Ernst Homburg, *Groeien door kunstmest, DSM Agro 1929-2004*, Uitgeverij Verloren, Hilversum, 2004, table 2.3, p. 44

**Table 5.8** Yields of various agricultural products in the Netherlands, in tonnes/ha [50]

| | Wheat | Rye | Potatoes | Barley | Sugar beets |
|---|---|---|---|---|---|
| **1852** | 1250 | 1100 | 6200 | 1800 | |
| **1881** | 1550 | 1200 | 8700 | 1930 | 24500 |
| **1898** | 1930 | 1480 | 12000 | 2280 | 31300 |
| **1910** | 2290 | 1830 | 12900 | 2550 | 36500 |
| **1938** | 3230 | 2370 | 21170 | 3230 | 36700 |
| **1970** | 4630 | 3260 | 35300 | 3640 | 47630 |
| **1996** | 8600 | 5430 | 43000 | 6300 | 56000 |

Sources: Knibbe, CBS/LEI

In the early 1980s, Dutch farmers used no less than 500 kilotons of artificial fertiliser a year, equal to approximately 250 kg per hectare.[51] The total annual energy output for the production of artificial fertiliser amounted to 17 petajoules (1 PJ = $10^{15}$ J). This is equal to the annual gas consumption of about 340,000 households, or the energy produced by the nuclear power plant in Borssele (the Netherlands' only nuclear power plant) in an 18-month period.[52] More than half of the fertiliser spread directly on Dutch farmland consisted of artificial fertiliser. This enormous input allowed the Netherlands to achieve the highest yields per hectare in the world (see Table 5.8). The success of the Dutch and European agricultural policy would have been impossible without the fossil raw materials on which the production of artificial fertiliser was based. Industrial farming became inextricably bound up with the fossil economy.

## 5.6 The controversy of industrialisation

The dark side of fossil-based industrialisation grew clearer at the start of the 1970s and beyond. Expectations concerning the potential of technology dating from the 1950s and 1960s – when energy consumption and prosperity seemed unlimited – became more controversial as time went on.

Nature conservationists had already begun lobbying politicians and drawing attention to the impact of industrialisation on the landscape at the start of the century. The Amsterdam-based environmental group Anti-Progil came up

50 Merijn Knibbe, 'Landbouwproductie en -productiviteit, 1807-1997' in Ronald de Bie en Pit Dehing (red.) *Nationaal goed, feiten en cijfers over onze samenleving (ca. 1800 - 1999)*, Centraal Bureau voor de Statistiek, Voorburg, 1999, p. 37-57

51 Ernst Homburg, *Groeien door kunstmest, DSM Agro 1929-2004*, Uitgeverij Verloren, Hilversum, 2004, p. 94

52 Eigen berekeningen op basis van gegevens Harry L. Brown, Bernard B. Hamel en Bruce A. Hedman, *Energy Analysis of 108 Industrial Processes* US Department of Energy, 1985 en A.J.D. Lambert, *Energy, Production and Process Integration*, (2e editie), Technische Universiteit Eindhoven, Eindhoven, 2008

with a new way of protesting. Following the example set by popular movements such as the Provos and the Kabouters, it campaigned against the founding of the Progil sulphur factor in 1968 by using the media to sway public opinion. This strategy, which involved headline-grabbing demonstrations and protests, was adopted as a standard by dozens of environmental action groups that sprang up across the Netherlands.[53]

The public debate about the environment of the early 1970s explains why the Dutch were so interested in the Club of Rome's 1972 report *The Limits to Growth*. The report presented various global scenarios for population growth, food supply, industrialisation, depletion of 'natural' - fossil - resources, and pollution. It proposed that industrialisation, if allowed to continue at the same pace, would initially lead to exponential growth but then result in the depletion of fossil resources and a dramatic decline in the world's population. The Club of Rome concluded that fundamental changes were needed to rein in the spiral of demographic and economic growth, and that a different distribution of wealth was also required.[54]

The Club of Rome's message was nothing new and immediately associated with the theories of the eighteenth-century demographer Thomas Malthus concerning the relationship between food production and population size. The threat of fossil resources being depleted had already been a heated subject of debate since the start of the industrial revolution. In 1866, the British Parliament even installed a Royal Commission on Coal, which reported in 1871 and 1905 on estimated coal reserves. Germany attempted similar estimates.[55] In the Netherlands, F.M. Jaeger reported in 1928 about the country's present and future 'natural' – fossil - resources [*'Over onze natuurlijke hulpbronnen in heden en in de toekomst'*].[56] Each such report sparked off a debate in which concerns were expressed about self-sufficiency, the depletion of fossil resources and reserves, and economic and social progress.

The report *The Limits to Growth* was unique, however, in that it took a global view. It also made a bigger impact because of the Arab oil boycott in 1973. The Dutch government introduced a petrol rationing (coupon) system and seven car-free Sundays. The Dutch were thus confronted with their growing

53 Jacqueline Cramer, *De groene golf, geschiedenis en toekomst van de Nederlandse milieubeweging*, Jan van Arkel, Utrecht, 1989.

54 Geert Verbong et.al., *Een Kwestie van Lange Adem, de geschiedenis van duurzame energie in Nederland*, Aeneas uitgeverij, Boxtel, 2001, p. 55

55 Henk van Zon, *Geschiedenis en duurzame ontwikkeling, duurzame ontwikkeling in historisch perspectief; enkele verkenningen*, Vakreview duurzame ontwikkeling deel 5, Universitair Centrum Milieuwetenschappen, Katholieke Universiteit Nijmegen, 2002, p. 33-51

56 F.M. Jaeger, 'Over onze natuurlijke hulpbronnen in heden en in de toekomst', Chemisch Weekblad XXV (1928), p. 482-491

dependence on oil. The oil crisis, the Club of Rome's report, and the extensive discussion that followed its publication put energy and the environment firmly on the political agenda. The energy issue initially focused on the generation of electricity and was dominated by the nuclear energy debate. It was not until the early 1980s that 'bio-energy' was taken seriously, however.[57]

**The controversy of industrial agriculture**

Starting in the 1970s, the use of fertilisers to improve farmland began to resemble a scene from Goethe's The Sorcerer's Apprentice. There were surpluses in various agricultural sectors: the milk lakes and butter mountains led to products being dumped on the world market. Surpluses of fertiliser created local problems such as acid rain and the rampant growth of algae in surface waters. Product and fertiliser surpluses were caused in part by the constant application of artificial fertilisers. The nitrogen that ended up in the Dutch soil came from foreign imports of fodder (which ended up in the animal manure) and from local crops grown with the help of artificial fertiliser (see Figure D). All these ingredients went to improve Dutch farmland continuously for almost a century.

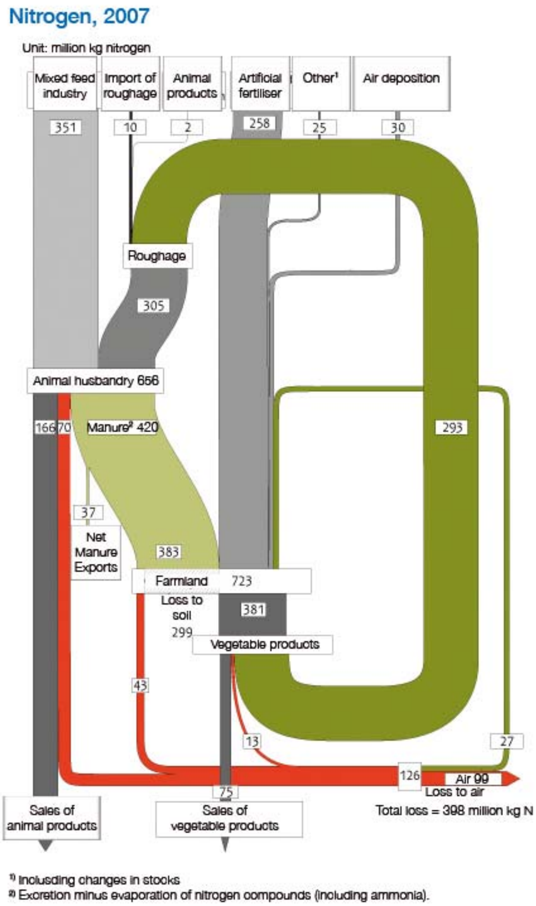
Society put considerable pressure on the Dutch government to change the country's agricultural policy. Policymakers introduced production quotas, fertiliser accounting ledgers, and new processing methods to combat ill-conceived policy. The structure of the agricultural sector also changed drastically. Privatisation and liberalisation, so popular in the 1990s, meant that research institutes and policy information units had become autonomous organisations. That signalled the end of the traditional partnership between agricultural research, information provision and education. One important turning point in the power structure came when the *Landbouwschap* – the industry board that had represented the entire agricultural sector since 1954 – was dispensed with in 2000 and its tasks redistributed among various commodity boards, each one representing the interests of a different commodity group. This created new opportunities and cleared the path for new participants in the field.[58]

When the EU introduced its Nitrates Directive (1991) to protect and enhance the aquatic environment, the use of nitrogen fertilisers declined. In 1990, the nitrogen surplus amounted to 209 kg per hectare; by 2007 this had fallen to 149 kg. Nevertheless, the Netherlands still had a cumulative surplus of 3500 kg of nitrogen and 435 kg of phosphor per hectare of farmland between 1991 and

57 Geert Verbong et.al., *Een Kwestie van Lange Adem, de geschiedenis van duurzame energie in Nederland*, Aeneas uitgeverij, Boxtel, 2001, p. 237-275

58 John Grin, 'Modernization Process in Dutch Agriculture, 1886 to the present', in John Grin, Jan Rotmans and Johan Schot, T*ransitions to Sustainable Development*, Routledge, Oxon, 2010, p 249-264; Hans Veldman, Eric van Royen en Frank Veraart, *Een machtige schakel in de land- en tuinbouw, de geschiedenis van Cebeco-Handelsraad*, 1899-1999, Stichting Historie der Techniek, Eindhoven, 1999

**Figure D** Flow chart for nitrogen in Dutch agriculture in 2007




Source: Statistics Netherlands/CBS

2005 – the highest in the world.[59] It turned out to be impossible to achieve the target of 50 mg of nitrogen per litre of surface water. In 2008, the Dutch Minister of Agriculture emphasised the urgency of changing manuring practices.[60] The various measures that have and are still being taken are steps on the road to sustainable manuring practices. Similar to previous eras, however, it is taking a long time to implement the new policy and to change organisational structures and behaviours, and these efforts are meeting with considerable resistance that can only be overcome gradually.

59 *Monitor Duurzaam Nederland 2009*, Centraal Bureau voor de Statistiek, Den Haag, 2009, p. 45

60 Ministerie van Landbouw, '4e Actieprogramma inzake de Nitraatrichtlijn' 17 juni 2008 - kamerstuk in *Dossier Mest en Milieu* via www.minlnv.nl (geraadpleegd 20 april 2010)

**The seeds of a modern bio-economy?**

Post-war industrial growth ended in the mid-1970s. The blame lay with monetary trends and rising wages, energy prices, and the costs bound up with environmental legislation. Textiles, mining, ship-building and other traditional industries fell on hard times, with many production sites being forced to shut their gates. Many of these sectors entered a period of reorientation and reorganisation. The economic crisis of the early 1980s led to scores of liquidations.[61] For example, the chemicals giant DSM gradually began to transform itself in the 1970s from a bulk manufacturer of chemicals to a niche producer of specialty products. Various take-overs allowed it to extend its operations into biochemistry and pharmaceuticals.[62] In the petrochemicals sector, a series of European directives enacted in 2003 promoted the production and consumption of biofuels. The transhipment of biodiesel in the Port of Rotterdam increased from 50 kt in 2005 to 1200 kt in 2007. In 2009, biofuels represented 3.1 per cent of petrol and 3.6 per cent of diesel consumption on the Dutch roads.[63]

Farm produce surpluses led in the early 1980s to a search for new markets, for example for specialist crops. 'Agrification' research focused on non-food crops, specifically knowledge-intensive, high added-value crops. The agrification trend came to an end as a policy in around 2000-2001. It was considered a failure since it resulted in very few useful applications and because it did not match up with trade and industry. The relevant knowledge network was revived in 2004, however, as policymakers began to focus on the bio-economy. Renewable energy and new products were the most important priorities.[64]

The debate on climate change caused the energy sector to view these experiments in a different light. Fermentation had already been proposed as a solution to the manure problem in the 1980s. The icon of these experiments, the large Promest manure processing plant in Helmond, ended in financial disaster in 1995. This led to a certain amount of antipathy towards manure processing technology in agricultural circles, but experiments were resumed in the late 1990s, now with a view to producing renewable sources of energy.[65]

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61 Jan Luiten van Zanden, *Een klein land in de 20e eeuw, Economische geschiedenis van Nederland 1914-1995*, Het Spectrum, Utrecht, 1997

62 H. Lintsen (red.) *Research tussen vetkool en zoetstof, zestig jaar DSM Research, 1940-2000*, Walburg Pers, Zutphen, 2000

63 Informatie SenterNovem, via www.senternovem.nl/gave/index.asp; Platform Groene Grondstoffen, *Biomassa, hot issue, Slimme keuzes in moeilijke tijden*, Sittard, z.j. (waarschijnlijk 2009); Gegevens biobrandstoffen in het wegverkeer via CBS Statline.

64 Harriëtte L.Bos, 'Beyond agrification: twenty five years of policy and innovation for non-food application of renewable resources in the Netherlands', in *Biofuels, Bioproducts & Biorefining*, 2008, p. 343-357

65 Rob Raven, *Strategic Niche Management for Biomass. A comparative study on the experimental introduction of bioenergy technologies in the Netherlands and Denmark*, proefschrift Technische Universiteit Eindhoven, 2005

The debate about climate change also put the mixing of biomass in combustion processes (waste-to-energy facilities and electrical power plants) on the agenda. The organisation representing the Dutch waste processing industry initially promoted the technology as a 'green source of energy'. It led to fierce debate between waste incineration companies, energy producers, and environmental groups. Among the most hotly contested issues were the emissions requirements imposed on waste incinerators and power plants. The parties also disagreed about whether this use of biomass could be considered sustainable. Once a number of compromises had been negotiated, however, incineration developed into one of the largest and fastest-growing forms of biomass use in the Dutch energy sector.[66]

The reorientation of the chemicals sector, the crisis in the agricultural sector and the climate debate all began in the 1980s. This convergence undermined established ideas and structures and created scope for new ideas and experiments in energy supply, agriculture and chemicals. The three sectors have sought for solutions to their own problems, and each one has had its own agenda. At times that has led to interesting combinations that may plant the seeds for the transition to a sustainable bio-economy.

**Ongoing need**

The need to change patterns of energy and materials consumption has continued unabated, as we can see from the many studies that have been carried out since the Club of Rome sounded the alarm bell in 1970. New data on fossil reserves may have given mankind somewhat more time to make the transition to renewable raw materials than was thought then. Forecasts concerning the consequences of climate change have made the transition to sustainability that much more urgent, however.

Research on Dutch patterns of consumption reveal that they are creating a growing and unrelenting demand for space. Projections concerning the short-term future agree.[67] Per capita $CO_2$ emissions are high in the Netherlands, as they are in other industrialised countries, and will only continue to increase in future, even though $CO_2$ emissions must be reduced by a factor of five in order to meet the 2°C maximum rise in temperature set as a target for 2040.[68] To turn the tide, the Netherlands Environmental Assessment Agency [*Planbureau voor de Leefomgeving*, PBL] has introduced an entire raft of measures (see Figure E). Computer modelling, which makes use of technical and economic indicators based on various assumptions, shows future contributions of various technical solutions. Unfortunately, these models are unable to take social components

66 Geert Verbong et. al., *Een Kwestie van Lange Adem, de geschiedenis van duurzame energie in Nederland*, Aeneas uitgeverij, Boxtel, 2001, p. 237-275

67 J.G. Elzenga, J.P.M. Ros en A.F.Bouwman, *Het ruimtebeslag van Nederlanders, 1995-2030*, Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven, 2000

68 *Monitor Duurzaam Nederland 2009*, Centraal Bureau voor de Statistiek, Den Haag, 2009, p. 123

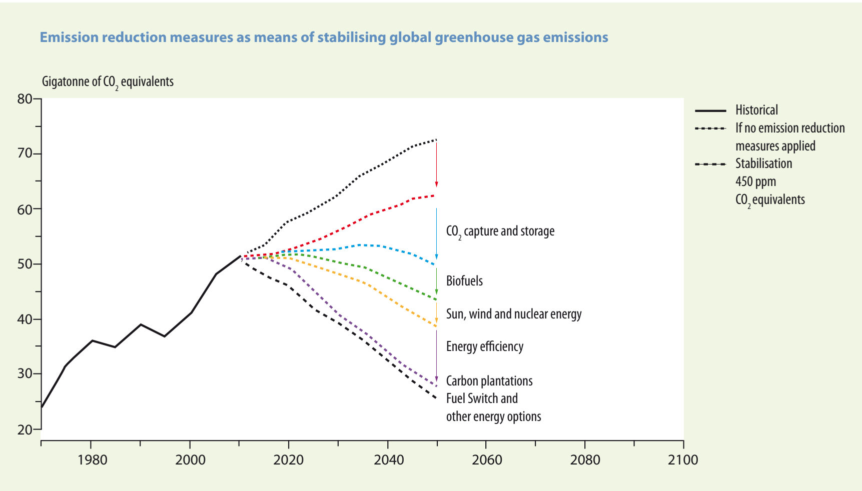
– political choices, changes in behaviour, and unanticipated events – fully into account. Our history lesson shows that these are precisely factors that have a huge influence on the choice of technology and the speed at which it is introduced.

## 5.7 Conclusion: from myth to challenge

Over the course of two hundred years, the Netherlands developed from a country based largely on biological raw materials, some of them imported from elsewhere, into a country with an open economy based mainly on fossil raw materials. This was an enormous change that should not be underestimated. The scale and impact of this transition is clear if we compare a number of important features typical of 1850 and 2010. Starting out as a poor country with few people and scattered population centres, the Netherlands became one of the most prosperous and heavily populated nations on earth. Between 1850 and 2010, its population grew by a factor of five and average life expectancy doubled (see Table 5.9).

Starting out as a largely self-sufficient country, it became a niche economy. This is clear when we look at the trends in various unrefined raw materials and

**Figure E** The 'optimal cost' emissions reduction developed by the Netherlands Environmental Assessment Agency (PBL). This calculates the technical and economic optimisations necessary to achieve a reduction in $CO_2$ emissions and to enable the Netherlands to contribute to meeting the 2°C maximum objective. [69]




Source: Netherlands Environmental Assessment Agency/PBL

69 A. Hanemaaijer (red.) *Nederland en een duurzame wereld. Armoede, klimaat en biodiversiteit. Tweede Duurzaamheidsverkenning*, Planbureau voor de Leefomgeving, Bilthoven, 2007

products between 1850 and 2005 (see Table 5.10). In 1850, the Dutch produced minerals and agricultural products mainly for their own consumption. By 2005, however, the picture had changed considerably, with producers concentrating on various specialty products. Natural gas, vegetables, and fruit are important export products, while petroleum, coal, ores, and grains are important imports. The volume of non-food biological products has declined dramatically, however, compared with minerals and agricultural products (with the exception of animal manure). Conditions in pre-modern society differed sharply from circumstances today in many respects. It was not the biological Arcadia that many perhaps imagine. The focus on biological materials was precisely what held the Netherlands back. Industrialisation and an increase in agricultural output based on fossil materials allowed the Netherlands to break through the pre-industrial production ceiling.

**Table 5.9** Key figures for the Netherlands, 1850 and 2010

| | 1850 | 2010 |
|---|---|---|
| Population | 3.1 million | 16.5 million |
| Average life expectancy[70] | 36 (m)- 38 (f) | 76 (m) - 81 (f) |
| | | |
| Land area [71] | 31640 km$^2$ | 33729 km$^2$ |
| Use of land area[72] | *(data from 1833)* | *(data from 2002)* |
| Farmland | 63,0 % | 67,8 % |
| Forest | 5,6 % | 10,6 % |
| 'Unspoilt nature' | 30,2 % | 3,7 % |
| Roads and railways | 0,4 % | 3,4 % |
| Built-up areas | 0,8 % | 11,6 % |

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Fossil fuels, new technology, and scientific insights were applied and institutionalised, although only after a slow, difficult process. This heralded the transformation to a modern industrial society in which fossil resources play a fundamental role in the supply of energy and materials. Depleting fossil resources, local pollution, and the threat of global climate change have pushed society to its limits, however, and created new challenges.

70 Peter Ekamper, Rob van der Werf en Nicole van der Graag, *Bevolkingsatlas van Nederland, demografische ontwikkeling van Nederland 1850 tot heden*, Nederlands Interdisciplinair Demografisch Instituut, Elmar, Rijswijk, 2003, 93-101.

71 Gegevens Centraal Bureau voor de Statistiek (www.statline.nl), Kerncijfers grondgebruik, Totale oppervlakte exclusief water

72 Gegevens 1833 omgerekend uit J.L van Zanden en S.W. Verstegen *Groene geschiedenis van Nederland*, Het Spectrum, Zeist, 1993, p. 65 (oorspronkelijke gegevens Verslag van den Landbouw 1875); Gegevens 2002 – CBS Statline – Regionale kerncijfers Nederland en Probos, *Kerngegegevens Bos en Hout in Nederland*, Stichting Probos, Wageningen, december 2009, p. 2

**Table 5.10** Use of various unrefined products in the Netherlands, 1850 and 2005

| | 1850 | | | | 2005 | | | |
|---|---|---|---|---|---|---|---|---|
| **Product** | **extraction/ production** | **net import** | **consump-tion** | **self-sufficiency** | **extraction/ production** | **net import** | **consump-tion** | **self-sufficiency** |
| | in kilotons | in kilotons | in kilotons | % | in kilotons | in kilotons | in kilotons | % |
| **Minerals** | | | | | | | | |
| Clay, sand and gravel[73] | 1.444 | 5 | 1.449 | 100% | 29.750 | 17.722 | 47.472 | 62% |
| Peat | 3.500 | 14 | 3.514 | 99% | 0 | 1.377 | 1.377 | 0% |
| Coal | 20 | 620 | 640 | 17% | 0 | 13.515 | 13.515 | 0% |
| Petroleum | | | | n/a | 1.402 | 51.513 | 53.005 | 3% |
| Natural gas | | | | n/a | 60.313 | -22.435 | 37.878 | 159% |
| **Farm products** | | | | | | | | |
| Grans (e.g. wheat) | 670 | 85 | 755 | 89% | 1.706 | 6.435 | 8.141 | 21% |
| Tubers (e.g. potatoes, sugar beets) | 8.660 | -10 | 856 | 101% | 13.910 | -2.332 | 11.578 | 120% |
| Vegetables (e.g. spinach, leek) | 70 | -10 | 60 | 112% | 1.516 | -1.026 | 490 | 309% |
| Vegetables classified as fruits (e.g. tomatoes) | | | | n/a | 1.500 | -1.203 | 297 | 506% |
| Orchard fruits (e.g. apples) | unknown | un-known | unknown | | 595 | -668 | 1.263 | 47% |
| **Non-food bio-based** | | | | | | | | |
| Wood | n.b. | 304 | >304 | > 0% | 1.000 | 5.000 | 6.000 | 17% |
| Animal/slurry manure | n.b. | -7 | n.b. | n/a | 70.100 | -250 | 69.850 | n/a[74] |
| Madder | 9 | 0 | 9 | 100% | 0 | 0 | 0 | n/a |
| Linseed | 10 | 18 | 28 | 40% | 4 | 16 | 20 | 20% |
| Rapeseed | 60 | 8 | 68 | 90% | 8 | 52 | 60 | 10% |
| Flax | 7 | 0 | 0 | >100% | 27 | -10 | 15 | 235% |

Refined and composite products are not included. They are difficult to estimate owing to their composite nature.

Source: Statistics Netherlands Import & Export statistics and own research

## A new challenge

Today, as the twenty first century enters its second decade, the Netherlands is on the eve of a new transition: the transition to sustainable energy and raw materials use. Biological raw materials may once again have a role to play. Our review of the past two hundred years of Dutch economic history has revealed numerous changes in society, in the use of energy and materials, in patterns of consumption, and in the role that science and technology have played. This review focused mainly on sociotechnical change, an element that is scarcely noted in technical and economic studies.

73 Excluding filler sand

74 Arbitrary definition of manure surplus

Our historical review reveals many parallels with current discussions and forecasts, and allows us to view them in a different light. It makes clear that the transition to sustainability must be seen as one in a series of transitions in the way we use materials and energy. Scarce raw materials, depletion of resources, and dependency on foreign suppliers are recurring themes in our history. It seems that transition takes a long time in the Netherlands. Forecasts concerning climate change, however, have added the key element of sustainability, which is unparalleled in our history. The transition to a sustainable society will be the main challenge facing the Netherlands in the twenty-first century. How we make this transition and by what means are vital questions, but unfortunately even a study of history cannot provide the answers. The previous sections and chapters clarified the complexity and scale of the transition to a bio-economy, and identified the questions and choices that will play a role during this process.

**Searching for new limits?**

In the transition to a modern economy, technical innovations made it possible to break through the limits set by pre-modern society. In the mid-nineteenth century, the Dutch economy, then based on natural materials, the wind, and animal and human effort, had reached its output ceiling. The country achieved its zenith of growth in the seventeenth century, but as its position as a trading nation declined, the Golden Age lost its lustre. Life for most Dutch people became one of unrelenting labour as they tried to keep their heads above water, sometimes quite literally.

New technologies based on fossil materials and new scientific knowledge were the only things capable of turning the economic malaise around. Steam engines made it possible to drain the polders permanently. Chemical analysis and synthesis allowed us to determine the composition of products objectively, so that quality control could take on entirely new forms. In the second phase, breakthroughs in our knowledge of chemicals led to new materials, based largely on the 'natural reserves' of fossil materials. After the Second World War, these processes were optimised, leading to an extensive chemicals industry with a physical infrastructure of terminals, transport modes, and pipelines that linked extraction sites and chemicals firms. The synthetic materials produced as a result increasingly replaced natural ones.

New transport options, new knowledge, and artificial fertiliser made it possible to increase agricultural output by a considerable margin. The population grew and life expectancy, prosperity, and wellbeing improved. The increase in material prosperity and industrialisation led to a growth economy, the driving force behind the capitalist economy model.
That economic model fell into disrepute in the 1970s as the dark side of industrialisation became clear. Pollution, social and global exploitation, ecologi-

cal depletion, and climate change have led us to view industrialisation based on fossil materials in a different light. Modern society has reached its limits. The fossil economy appeared to be in decline.

And now there are new prospects ahead: solar energy, wind power, the bio-economy, hydrogen, a combination of all these, or even nuclear fusion. All are promising technical options, but can we simply plug them in and start them up? Other factors that define how society functions appear to have been left out of the equation. It seems that the concept of sustainability will need to dispense entirely with limited cycles of finite reserves. But the search for solutions that provide an endless supply of energy and materials is a Utopian one that smacks of naiveté when viewed through the pragmatic prism of politics and policymaking.

Indeed, we should not be searching only for unlimited sources of energy. Instead, our concept of the bio-economy should focus on the smart, sustainable use of biomaterials within the natural limits of ecological cycles. However, this raises new questions concerning a number of present-day bio-economy initiatives.

**New questions about the new bio-economy**

Most present-day bio-economy initiatives appear to be motivated by interests in the agriculture sector – a sector that is still completely dependent on the fossil economy, however. Most of the ideas promoting a bio-economy focus on new uses for plant material, i.e. the output of the agriculture sector. The high level of agricultural output in the Netherlands, however, can be put down to the input of fossil raw materials. There appears to be a blind spot in the current thinking when it comes to how such high yields are achieved. The question is whether bio-economy initiatives are not simply a 'greenwash' by the industrial agriculture sector. On the other hand, it would not be easy to separate agriculture entirely from the fossil economy.

Separation, re-tooling, and revising skills and traditions: these are all huge steps and they cannot be taken all at once. Once again, radical change seems to be necessary, but such change is not always compatible with the interests of the petrochemicals and agricultural sector, or parts thereof. It is painful to act against one's own interests. A transition of this kind will represent a major challenge for future generations. The consequences may be far-reaching, with many different challenges to be faced in terms of technology, economic structures, and global coordination

**The long road**

The foregoing history shows how the Netherlands changed from a pre-modern to a modern society in the course of two hundred years. Starting out as a country that adopted the technologies of its neighbours, it has now dedicated itself to knowledge valorisation and intends to meet the challenges of the twenty-first century as proactively as it can. The introduction of new knowledge

and technology has played a huge role in its transformation. The process involved much more than simply 'plugging in' new technologies, however; indeed, that kind of simplistic strategy often led unavoidably to failure. Technical innovation raised questions about established practices, organisational structures, rules and regulations, finances, and the balance of power. The process of change was slow and painful. Not only was new technology introduced, but society was also changed in the process.

Our history has shown us that the economic and living conditions in the Netherlands today do not at all resemble those of our grandparents in the mid-nineteenth century. Radical change took approximately one hundred and fifty years. How can we explain this slow pace? Were our forebears simply conservative, and are we more prepared than they were to give up our customs and habits, and how we have organised society? There are no signs that change will be any more rapid today than it was back then, especially considering the increased international complexity of the social and economic order and the way interests and materials have become technologically and economically intertwined. As in previous transitional periods, it will be an unimaginably difficult and complex process to arrive at a new, sustainable society, and it will take a very long time.

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6

# 6 A bio-economy with a future: lessons learned

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Our study has discussed conceptual approaches to the bio-economy in a variety of different ways. We have looked at strategic agendas, Dutch policy, social issues, innovation, and historical background. The present chapter compares and contrasts the various lessons learned by exploring a number of key themes. The points identified in this way serve as an overture to the recommendations given in the final chapter, where we summarise the lessons learned.

Chapter 1 described how scientists and government policymakers today see the future of an economy that will run mainly on biomass and will consequently be less – even much less – dependent on fossil fuels. Chapter 2 looked specifically at biomass policy as pursued in the Netherlands. In particular, we described the difficult relationship between the bio-economy concept and current Dutch policy on biofuels. Chapter 3 then looked at a series of public controversies. Key questions include whether we can increase our use of biomass in a sustainable manner; whether, in addition to replacing fossil feedstock by biomass, we should not be scaling down our use of raw materials; and whether there will even be enough biomass to go around. Chapter 4 took a technical view of the bio-economy, describing what is already possible and what innovations lie ahead. We saw that one of the main driving forces is the idea that technology advances in 'generations'. In other words, technological advances will make a sustainable bio-economy possible, starting with today's first-generation biomass products and proceeding to second and third-generation technologies. Finally, Chapter 5 looked at the current thinking about the future bio-economy from an historical perspective. The rise of the fossil-fuel based economy delivered the Netherlands from the clutches of the impoverished bio-economy of the nineteenth century. Now, however, our economy – which runs on easily obtainable and inexpensive fossil fuels – is reaching the limits of its potential.

We are attempting to design a sustainable bio-economy based on the limitations of the present economy, but we have come up against a number of barriers. Four serious challenges lie ahead. The first is to make the core of the bio-economic concept – optimal biomass valorisation – a policy imperative. The second major challenge is to create a sustainable bio-economy. The large-scale use of biomass does not in itself guarantee sustainability, let alone a socially just world economy. The third overriding question in public debate is whether the best route to a sustainable bio-economy is one of 'learning by doing' or 'proceeding with caution'. The fourth and final challenge concerns how we deal

with natural resources and nature. Genetic engineering plays a key role in that discussion.

## 6.1 A more influential role for bio-economy policy

Our study shows that the ideological basis of strategic policy on the bio-economy enjoys broad support. The aim of the bio-economy policy is to use biomass to generate the greatest added value, in accordance with a 'value pyramid', which offers us a guideline. According to that pyramid, biomass is most interesting in economic and ecological terms when it is used to produce medicines and health products. A major percentage of the remaining biomass should subsequently be used as a source of food and animal feed, chemicals and materials. What is then left can be used as a source of energy. Closed-loop systems play an important role in this hierarchy. Politicians, scientists, businesses, and environmental organisations are keen to support this core bio-economy principle. Although the bio-economy policy offers what is potentially an all-encompassing approach to the use of biomass, its influence and integrative effect have so far been minimal. We argue that optimal biomass valorisation should play a bigger role in political and public debate, both in the Netherlands and in the international arena. One crucial proviso is that the relevant policy must be better coordinated between ministries in the Netherlands and between international organisations.

### 6.1.1 Shift the focus to optimising biomass valorisation

One reason for the limited influence of the bio-economy policy – a policy domain still in its infancy – is the fact that it clashes with two somewhat older bio-energy policies, each with its own, distinct objectives. Since 2002, the Dutch government has made specific funding available to support the use of biomass to generate electricity and heat. Since 2003, the Netherlands has been obliged to implement its policy on biofuels in accordance with EU directives. The purpose of that policy – partial substitution of fossil fuels by biofuels – is at odds with one of the aims of the bio-economy policy, which is to make the most efficient use possible of biomass. The latter policy has sparked off a debate about the relationship between biofuels and food supply: will the growing use of biofuels drive up food prices? If we view the situation from the perspective of the value pyramid, then the approach should be clear: using biomass for food must take precedence over using biomass to generate energy and chemicals. Because the political debate has emphasised the potential negative effects of biofuels, we have lost sight of the possibility that we can make more efficient use of biomass. Since the late 1970s, Dutch policy on waste has been based on the 'Lansink Ladder', a hierarchy for waste treatment that puts waste prevention on the top rung, followed by recycling, incineration, and landfill on the bottom rung. The value pyramid should play a similar role for biomass. This would give both the debate and policy concerning effective and efficient biomass utilisation greater scope and more structure.

*Lesson 1: Optimal valorisation*
*Make the core of bio-economy policy – optimal biomass valorisation – the focus of political and public debate about the future of the bio-economy.*

### 6.1.2 Optimal valorisation requires policy coordination

Biomass can be used in many different ways, for example as food, animal feed, to produce chemicals, and to generate energy. Responsibility for biomass utilisation is divided between a number of different Dutch ministries. Until October 2010, when various ministries were merged, the Ministry of Economic Affairs (EZ) and the Ministry of Housing, Spatial Planning and the Environment (VROM) were responsible for bio-energy policy, and the Ministry of Transport, Public Works and Water Management (V&W) was responsible for implementing the EU's Biofuels Directive. The Ministry of Agriculture, Nature Management and Food Quality (LNV) oversaw the use of biomass in food and animal feed and also headed the cross-ministerial bio-economy policy. Officially speaking, however, that policy did not and does not have a higher status than any of the other lines of policy. In order to optimise biomass valorisation, cross-ministerial policy coordination is crucial. It is obvious, then, that the bio-economy policy should eventually exert a stronger influence. The mergers that gave rise to the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) and the Ministry of Infrastructure and Environment (I&M) offer new opportunities in that regard. The bio-economy policy has been accorded a key role within the Ministry of EL&I, but the Ministry of I&M remains influential. A similar complaint concerning fragmented policy can often be heard within the EU, where fourteen different Directorates-General provide input for the Union's new sustainable bio-economy strategy. That strategy is expected to be announced in the autumn of 2011.

*Lesson 2: Ascend the value pyramid*
*Biomass policy should focus on getting biomass to 'ascend' the value pyramid as much as possible. This should also be the aim of cross-ministerial (and international) policy coordination.*

## 6.2 Working towards a sustainable bio-economy

Biomass can potentially replace petroleum as feedstock for all sorts of products. Sustainability is the great promise held out by the bio-economy in that regard. However difficult it may be, then, we must find ways of operationalizing sustainability.

Chapter 5 showed us that in the nineteenth century, the developing Dutch economy depended heavily on imports of raw materials from other parts of the world. Imports allowed the Netherlands to push beyond the 'natural' limitations of the traditional bio-economy, and ultimately to lay the groundwork for our

current prosperity and population density. In around 1850, local conditions on the land meant that many farmers could scarcely hold their heads above water. It was imports of raw materials that allowed the Dutch agricultural sector to expand and succeed. Guano (dried bird manure) was the first resource to break through local limitations, at the cost of rich eco-systems in Peru, its country of origin. It was the first step along the road to the large-scale use of artificial fertiliser, a vital element in the transition to industrialised, mechanised farming based on fossil feedstock.

The use of biomass can be regarded as the next stage in the development of new raw materials that will help overcome the limitations of our present economic system. Fossil-based feedstock, which drives our economy today, is not inexhaustible. Petroleum reserves are finite and the incineration of fossil-based raw materials is changing the Earth's climate. The bio-economy may be able to overcome these limitations and lead us to a sustainable society. To realise that potential will require us to take a broader view of sustainability. Only then will it be possible to monitor and reward the sustainability of biomass production and processing, and in doing so to push beyond the limits of the existing system. At the moment, policymakers are busy drawing up sustainability criteria for biofuel production. Applying these criteria more widely to a range of different biomass applications would seem to be an obvious development.

### 6.2.1 Sustainability requires more than new technologies alone

For now, biomass production is itself coming up against many ecological and social barriers, for example a shortage of fertile land and, in connection with that shortage, mass deforestation and the worldwide trade in farmland ('land grabbing'). A counterweight is provided by the numerous technological innovations that may make it possible to extend the current limits of biomass production and use in the future. Chapter 4 described new technologies that make it possible to use biomass such as algae and the non-edible parts of plants in new ways as a feedstock and source of energy. These technologies will allow us to dramatically increase the productivity of marginal land and the surface of the ocean. Innovators are therefore focusing on more radical technological solutions, for example biosolar cells, which immediately convert the energy generated by photosynthesis into liquid energy carriers without requiring the intermediate step of biomass. These new technologies embody the bio-economy ideal of making intelligent and efficient use of the potential of biomass. Right now, however, such technologies play a role of little significance. The danger of pinning our hopes on a 'technological fix' is that it clouds the political debate: it almost automatically gives the use of biomass the sheen of sustainability without actually proving that such use is, in fact, sustainable. These new tech-nologies offer an appealing (but so far speculative) prospect so powerful that they sometimes appear to legitimise even the negative social and environmental effects of existing applications. After all, our current problems seem temporary with such a rosy future ahead of us. Rather than temporary, however, the current

debate concerning the widespread use of biofuels exemplifies what awaits us as we move towards developing a bio-economy, namely that the effects of new technologies will only really become clear when we are using them on an industrial scale. If we wish to guide technological progress in a sustainable direction, we must always bear our main objective in mind: to arrive at a sustainable bio-economy.

Achieving this aim will involve much more than using advanced technology to help us replace fossil feedstock by biomass. The mere fact that a raw material is renewable does not mean that its use is also sustainable. The first barrier lies in the unsustainable underpinnings of our present agricultural system. That system depends heavily on fossil feedstock, for example in artificial fertiliser production. In addition, biomass production has run up against other physical barriers, for example the depletion of farmland and the limited availability of fertile soil and water. Secondly, the aim of sustainability involves not only the production of raw materials (supply side), but also their consumption (demand side). In its current form, the value pyramid focuses in particular on the supply side and pays little attention to the demand side and the potential to reduce the consumption use of raw materials. One difficult point, for example, is the fact that we use grain as animal feed for meat production. That is highly inefficient from the bio-economy point of view. It is therefore important that bio-economy policy should not only consider replacing fossil-based raw materials by biofuels, but that it should also advocate cutting down on our use of raw materials, for example by encouraging the public to consume less meat. Thirdly, sustainability is not only about reducing $CO_2$ emissions in the interests of climate change. It should be interpreted more broadly as a concept that also embraces such matters as local development, human rights, and social justice.

*Lesson 3: Make agriculture and consumption sustainable*
*Bio-economy policy should look more closely on how to make farming practices more sustainable, for example by making the agricultural system less dependent on fossil fuels (low carbon agriculture) and by encouraging less wasteful forms of consumption. Both targets should become an integral part of the value pyramid.*

*Lesson 4: Pursue sustainability in a broader sense*
*The success of the bio-economy will depend on a broader definition of sustainability, one that takes local development, human rights, social justice and similar issues into account.*

### 6.2.2. Learning to operationalize sustainability

Aside from a broad definition it is also important to make sustainability something tangible, that can be measured. Awareness of the negative aspects of

biomass use is already firmly entrenched in the public debate and in policy, in part owing to the biofuels controversy. Cultivation of biofuel crops can lead to deforestation and the loss of biodiversity. Biofuels have also sparked off considerable debate: Does biofuel crop culti-vation compete with food crops? Do biofuels in fact reduce $CO_2$ emissions, compared with fossil fuels? There is also the danger of the West and Asia grabbing farmland in Africa. Large companies are increasingly attempting to acquire land ownership rights there. Small farmers often do not have land ownership rights in many of these countries, or if they do, there is no legal system to protect them. As a result, small farmers or others with limited access to the legal system may become the victims of a battle for land that threatens to erupt within the context of the bio-economy. It would be untenable for Europeans to import supposedly 'green' products that have unsustainable and negative effects elsewhere in the world. But it is nevertheless difficult to determine what types of biomass and what applications are and are not sustainable. Sustainability is difficult to define, both in political and in scientific terms.
To begin with, there is frequently disagreement or confusion about what sustainability actually means. On top of that, not every aspect of sustainability is quantifiable. It is difficult, for example, to determine the social and indirect impact of biomass production.

Sustainability criteria for biofuel production have been on the Dutch and international political agenda in recent years. The Cramer Committee in the Netherlands put this topic on the EU policy agenda. At the moment, the Dutch Corbey Committee is developing these criteria in greater detail. One difficult problem is the risk of indirect land use change (ILUC). ILUC occurs, for example, when a large company buys up land from local farmers in order to cultivate biomass crops. The change in land use does not lead directly to deforestation, but local farmers often go on to clear forest so that they can use the land for farming. Biofuel production thus leads not to direct but to indirect deforestation. Various parties are now arguing that the EU's sustainability criteria should take indirect land use change into account in the form of an ILUC factor. The Netherlands' Social and Economic Council (2010) recommends including an ILUC factor in sustainability criteria. The EU will decide in mid-2011 whether to do so.

Defining and certification of sustainability are controversial topics worldwide. Countries such as Brazil and Malaysia regard the EU's sustainability criteria for biofuels as covert trade policy, i.e. a way of blocking their access to the European markets. What is needed is an internationally harmonised system for monitoring the negative effects of biomass use that can count on international support. Since the Netherlands wishes to play a key role in the global bio-economy, it should obviously continue to lead the discussion concerning the development and implementation of sustainability criteria. Consideration must also be given to the potential 'perverse effects' of such a system. For example,

sustainability criteria may make it difficult for small farmers to sell their products. If the criteria involve too much bureaucratic red tape, only large organisations will be able to satisfy them. Such criteria must therefore not be used as a mechanism for excluding small and less cash-rich producers. Such farmers should be supported in that case, for example by providing training workshops or by giving them extra assistance in filling in the necessary paperwork. For example the Netherlands Standardisation Institute (NEN), which organises voluntary biomass certification programmes, is less stringent with small farmers and gives them the option of obtaining certification in groups, so that they can share the cost.

***Lesson 5: Make sustainability something tangible***
*Although it is not easy to operationalize sustainability, tangible criteria are needed to monitor biomass sustainability on an international scale.*

***Lesson 6: Ensure that the Netherlands continues to lead the way with respect to sustainability criteria***
*The Netherlands should continue to lead the way when it comes to biomass sustainability criteria. Its work should involve operationalizing the criteria, boosting international support for them, investigating the most suitable approach to monitoring, and reflecting on the usefulness, necessity and side-effects of the criteria.*

### 6.2.3 Biomass certification as social trend

The public's demand that sustainability criteria should be developed for the production of biofuels from biomass is not an isolated incident. Recent decades have shown that consumers are becoming much more receptive to information about the impact of their consumption on the environment in other countries. That has led to various types of certification programmes for specific products and value chains. One well-known example in the Netherlands is the 'Max Havelaar' fair trade seal of approval. Another is the UTZ certification programme, set up in the late 1990s by Guatemalan coffee farmers and international food retailer Ahold, which guarantees that coffee, cocoa and tea bearing this seal have been produced on plantations that maintain satisfactory working conditions (for example no child labour) and with respect for the environment. The Dutch government has also set up the Dutch Sustainable Trade Initiative, which monitors the sustainability of various categories of feedstock and provides certification. The EU sustainability criteria for biofuel production, are in line with a broader social trend. It is important to consider the longer-term implications of that trend. The bio-economy concept can help in this respect, because it promotes the sustainable use of biomass.

The quest to use biomass sustainably makes it illogical to certify one particular type of biomass use (in this case, as a biofuel) but not other types (chemicals, food, clothing, medicines). In the first place, biofuels constitute only a small portion of the total amount of biomass worldwide; most of this is destined for food and animal feed. In 2007, for example, only 1.5% of the palm oil available worldwide was used for energy (Regieorgaan EnergieTransitie, 2008). In addition, it seems unjustifiable to prohibit rainforest logging to produce biomass for biofuels but to allow it for the production of bioplastics. Nevertheless, that is precisely the situation today: biofuels producers are required to meet all sorts of rules, whereas bioplastics producers are not. We can expect that eventually, sustainability criteria will also be imposed on other uses of biomass. If the existing criteria, i.e. those that apply for biofuels, are a success, they may serve as a model for these other uses. The requirement that all biomass, even all food crops, should be produced in accordance with sustainability requirements is likely to put enormous pressure on the production capacity of the available land, because it will restrict both the use of artificial fertilisers and pesticides and the possibility of expanding the acreage under cultivation. Clarifying the ecological and social limits of our Earth's biomass capacity could therefore have huge implications for patterns of consumption and, consequently, for the Western lifestyle.

*Lesson 7: In the long run, make all biomass subject to sustainability criteria*
*Assume that in the long run, sustainability criteria will apply for all the various uses of biomass. The growing public demand for value chain transparency and the quest to arrive at a sustainable bio-economy indicate that this will happen in the future.*

## 6.3 Give the bio-economy a chance by 'learning by doing'

It will be a very difficult and complex matter to convert our current fossil-based social and economic system into a bio-economy based on biomass as sustainable feedstock. Current public debate centres on the question of whether our existing social and economic infrastructure offers us a springboard to a sustainable bio-economy, or an obstacle. This section explores how we can work towards achieving a sustainable bio-economy by incorporating biomass applications intelligently into the existing system – a process that will involve trial and error and boldness on our part.

### 6.3.1 Learning by doing, proceeding with caution

Chapter 3 describes two different views: *learning by doing* versus *proceeding with caution*. According to the first view – the view supported by trade and industry – the economy cannot be changed overnight. We need the existing economic resources and structures in order to develop new technologies. For example, the knowledge we have gained in oil refinery and fuel distribution can be used to develop and transport biofuels. The same applies for the chemical

sector. The existing economic structures thus represent the first step along the road to another, more sustainable bio-economy. Start, for example, with a biological feedstock that we already know a lot about, for example sugars derived from food crops, and use it to make the existing structures sustainable. A gradual transition of this kind may open our eyes to the possibilities that bio-based feedstock offers. It will, for example, allow us to develop a number of chemical biomass applications based on knowledge derived from production of the first generation of biofuels.

According to the other viewpoint – supported primarily by environmental organisations – the first generation of biofuels are in fact a barrier on the road to a truly sustainable economy. To begin with, the first generation of biofuels is not making the economy 'greener' at all, because their carbon footprint is often larger than that of fossil fuels. That is because we must factor in deforestation in the development of new plantations and farmland. There is a further risk that this unsustainable type of bio-economy will be so successful that it becomes very difficult to change. The fear is that, once they have captured their share of the market, producers of this first generation of biofuels will defend it with all their might, including in the political arena. Malaysia, a major palm-oil producer, is already fighting off the strict climate change criteria that have been set for bio- fuels. Finally, it should be noted that the first-generation technology used to produce biofuels today is often entirely unrelated to second or third-generation technologies. For example, the technology used to produce biodiesel from palm oil is entirely different from the technology used to produce biodiesel from wood chips.

Both viewpoints have much to teach us, and appear to be complementary rather than mutually exclusive. The second alerts us to the possibility of a socially unacceptable lock-in effect, i.e. encouraging unsustainable practices under the guise of sustainability. The first urges us to seek out opportunities as we go along, and emphasises the role of serendipity. Chapter 5, the historical review, showed us that happenstance not only plays a role in technical innovation, but also in social, economic and cultural change. For example, guano prepared the way for the introduction of petroleum-based artificial fertiliser. An innovation can 'break the ice' for later and better applications, in other words. It is useful to think of the current, imperfect generation of biofuels in the same way. They have in fact put biomass on the map and, for example, provided the chemicals industry with a considerable supply of new feedstock. At the same time, the growing market share of the first generation of biofuels may divert us into new, unsustainable practices.

The foregoing illustrates that, in one way, the first generation is indeed blazing the trail for the following generations of technology, but that in another way it is not. The current generation of biofuels has, however, clearly broken the ice in political and social terms. It has unleashed a policy debate about sustainability criteria and sparked off a more fundamental discussion of the relationship

between the bio-economy and sustainability. Section 6.2 explored the more cautious route to a sustainable bio-economy. In this section, we focus on opportunities and argue in favour of learning by doing.

*Lesson 8: Regard the first generation as the trailblazer*
*Use the first generation of biofuels to blaze a trail for more efficient solutions. That first generation gives us the opportunity to prepare ourselves to use other biofeedstock while making use of the existing social and economic infrastructure. This will allow us to acquire a better understanding of the properties of biomass, to encourage experimentation with sustainable agriculture, and to comprehend the complex social debate and how to deal with various issues.*

### 6.3.2 Intelligent incorporation of biomass applications

The bio-economy ideal cannot be achieved without making changes to the social and economic infrastructure. The techniques and production systems where we can expect to make the most progress in terms of sustainability and efficiency must be incorporated into that infrastructure. The historical review presented in Chapter 5 demonstrated the importance of the socio-technical and economic context for innovation. That context often constitutes a barrier. If the social context is not ready for a new technology, that technology will not make any headway or only do so very slowly. For example, the transition to a fossil-based economy took place only after property ownership had been properly arranged and scientific know-how was made comprehensible for farmers. But the context can also provide opportunities for innovation – sometimes of a pioneering calibre. Integrating the economy and sustainability into a bio-economy will require the intelligent incorporation of biomass applications into the social and economic system. One example would be to adjust biomass production such that it takes up only the absolute minimum amount of land. The jatropha plant for instance, which has oil-bearing seeds, can be used to enclose existing farmland, and need not take up extra land. Residual waste streams that would otherwise simply be incinerated can also be used in a way that does not impinge on existing production land.

Nevertheless, even intelligent use of this kind requires structural changes in other areas. The type of biomass production described above requires a more distributed collection infrastructure and, as a result, a different logistical set-up than that for food crops. The efficient use of waste streams also demands new forms of collaboration and logistical organisation, often between sectors that have very little to do with one another at the moment, such as agriculture and chemicals. Innovation is necessary in a wide variety of different areas. Petrochemical and agricultural production lines must be reorganised in order to make better use of residual waste. Investment in infrastructure is needed in biomass production areas, especially in developing countries. The law on waste

processing will have to be amended accordingly as well. Financial support, for example in the form of tax advantages, would be a good option at this stage, specifically to encourage intelligent, integrated forms of biomass processing such as biorefinery for multiple purposes and second and third-generation applications. Another option would be to lower the tax on labour and raise the tax on feedstock, encouraging industry to deal more efficiently with raw materials. In other words, it is important to create scope and support for far-reaching innovation and to make it attractive to invest in more efficient biomass applications. If it ever becomes possible to run automobiles on household waste or human faeces (as is already the case for some city buses), then even more radical changes in infrastructure will undoubtedly be required. We can imagine there being a biogas installation in every neighbourhood, with large companies no longer supplying feedstock but instead offering maintenance and service.

*Lesson 9: Intelligent incorporation*
*Support the intelligent social and economic incorporation of biomass applications into the existing social and economic system, thereby encouraging the rise of a sustainable bio-economy.*

## 6.4 Between biology and technology

The bio-economy joins natural, bio-based raw materials to mechanised, optimised processes in order to create an efficient production system. Plants are no longer used merely as food, animal feed or clothing; they also serve to produce chemicals and generate energy. This means shifting the dividing line between 'natural' and 'synthetic' as society understands these categories today. That shift merits attention, because these categories may play a crucial role in the relevant public debate.

Chapter 4 showed us that both 'white' biotechnology and 'green' biotechnology play a key role in a bio-economy. It is important to ensure that the role of biotechnology becomes visible and to raise it for discussion. The debate about genetic engineering is part of a broader fundamental discussion concerning the relationship between mankind, technology and nature. That discussion plays a significant role in public acceptance of the bio-economy. That is why it is important to clarify the various notions of 'naturalness' that are intertwined with the differing perceptions of the bio-economy and to give such notions a prominent place in the discussion.

### 6.4.1 The role of biotechnology

When biomass is used to produce medicines and biochemicals, biomaterials and biofuels, genetically modified micro-organisms and enzymes produced by means of genetic modification play an important role. Innovation in industrial biotechnology is therefore crucially important to the continuing development of the bio-economy. There is little disagreement about this branch of technology: if

it can help make the chemicals sector more sustainable and lead to closed-loop systems based on biochemical conversion, then it can very likely continue to count on the public's support. As the public survey discussed in Chapter 4 made clear, there is public support for biofuels (biomass used for energy purposes), even if genetic modification is involved (European Commission, 2010). Public opinion surveys indicate that the public also supports synthetic biology for energy-related applications.

The picture is rather different if we look at the role of genetic modification in green biotechnology. There is fierce resistance worldwide to genetically modified farm crops, as we saw in Chapter 4. And although researchers continue to explore the genetic modification of plants and algae with a view to making them more suitable for biofuel and biorefinery applications, the European licensing policy still represents a significant barrier to GM crop cultivation in Europe. Green biotechnology applications based on genetic modification are likely to continue provoking public resistance, more so than other advanced plant improvement techniques. That applies equally to applications that introduce 'synthesised' micro-organisms into the environment. Chapter 3 showed that civil society organisations often consider such forms of biotechnology irrecon-cilable with sustainability – one of the key aims of the future bio-economy – because of their potential ecological and social consequences. Organisations such as the international ETC Group and Friends of the Earth have warned against the use of genetically modified plants and algae in reports concerning the bio-economy.

White and green biotechnology will grow more closely entwined as the bio-economy continues to develop. Considering the controversial nature of this issue, government would be wise to continue making a sharp distinction between the two domains of genetic modification in its policymaking. That means, first of all, that government must make crystal clear under what conditions green biotechnology and genetic modification will be permitted to play a role in the future bio-economy. Those conditions must be made visible in sustainability criteria and the associated legislation. Government would also be advised to communicate openly about this issue with the various relevant civil society organisations, and to consult closely with those organisations.

*Lesson 10: Green versus white biotechnology*
*Continue making a sharp distinction between genetic modification in industrial biotechnology (white biotech) and plant biotechnology (green biotech). When it comes to GM plants in particular, sustainability criteria and public acceptance are critical success factors in the continuing development of a bio-economy.*

### 6.4.2 Bio-economy and notions of naturalness

The bio-economy evokes a variety of different associations with nature and agriculture. Chapter 3 described three radical positions that frame the debate: a romantic, a utilitarian and a controlling view of nature. These views differ from one another on various points, for example the degree of confidence placed in industry, in scientific progress, and in mankind's ability to control nature. Notions of naturalness play a particularly important role in these various positions. Each of these three cultural perspectives allows us to examine the bio-economy concept in a different light.

It is not clear in the current public debate which of the three views is regarded as the ideal. That means that the bio-economy concept is associated with two contradictory images: will it lead to a society that lives in harmony with nature, or one that is in fact out to completely subdue nature? The bio-economy can be regarded either as green and harmonious or as mechanistic, soulless, and industrial. The latter interpretation, in which the bio-economy is about controlling nature, has raised suspicions among many civil society organisations. In particular, Canada's ETC Group – a fierce opponent of genetically modified crops – has based its campaign against the bio-economy on this scenario. Such suspicions are likely to increase if GM plants come to play an important role in the bio-economy. To clarify its course of action, government must explain its underlying view of the bio-economy in the most explicit terms possible, for example by making clear that the industrial development and processing of bio-based organic feedstock are in the service of sustainability, and that sustainability often takes shape in large, mechanised complexes instead of in idyllic, self-sufficient agricultural settings. If it fails to do so, the public may start to suspect that it is being sold the image of a harmonious green future when the reality will be much less idyllic. The risk is that a 'green rhetoric' will develop that lends all bio-economic activity a 'green halo', even if it is not really sustainable in the broadest sense of the word. Rhetoric of this kind will be resisted by civil society organisations – a replay of the scenario that unfolded in the debate about biofuels.

> *Lesson 11: Notions of naturalness*
> *Government must explain and clarify its views on the relationship between the bio-economy and naturalness. This will encourage a political and public debate concerning the various notions of naturalness.*

## 6.5 The twofold challenge of innovation

As we saw in Chapter 4, opinions differ as to the economic and innovative role that the Netherlands should play in the development of a bio-economy. Should the Netherlands transform itself into a global force at all levels of the value

pyramid? Or should it instead concentrate on knowledge-intensive innovation and the production of high-value products in the bio-economy? This discussion refers to two different development scenarios (Hoefnagels et al., 2009). The first is international in orientation, with biomass being imported in bulk from different corners of the world. The second is national and European in orientation, with the focus being on domestic and European biomass production. The scenario study shows that for the bio-economy to have a real shot at success, the Netherlands must in fact develop in both directions. The two scenarios have differing implications for the challenges that we have identified, however. A policy promoting the Netherlands as a global force requires us to pay particular attention to sustainability; the main message then is to 'proceed with caution'. A policy focusing on knowledge-intensive innovation can and must embrace 'learning by doing' in the course of developing intelligent biomass applications and embarking on the associated transitions.

> *Lesson 12: Be bold at home and proceed with caution at international level*
> *Seek out opportunities for the Netherlands in a bio-economy whose orientation is both domestic and international in nature. The first requires boldness, and the second caution.*

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# 7 Getting to the core of the bio-economy: policy recommendations

Lotte Asveld, Rinie van Est and Dirk Stemerding

The passionate political debate concerning the use of biofuels has shown that the proposed transition to a sustainable economy based on biomaterials will not be entirely smooth or trouble-free. Chapter 5, the historical review, made clear that we are dealing with transition processes that will take several decades to unfold and that are highly unpredictable in nature. The future is, as it were, still obscure.

It is in that awareness that we identified a number of crucial challenges in the previous chapter. These issues are so significant that they bear repeating here. There are four major barriers on the road to a sustainable bio-economy. The first is to make the core of the bio-economic concept – optimal biomass valorisation – a policy imperative. The second major challenge is to create a sustainable bio-economy. The large-scale use of biomass does not in itself guarantee sustainability, let alone a socially just world economy. The third overriding question in public debate is whether the best route to a sustainable bio-economy is one of 'learning by doing' or 'proceeding with caution'. The fourth and final challenge concerns how we deal with natural resources and nature. Genetic engineering plays a key role in that discussion.

In view of the opportunities that lie ahead and the four barriers that we have identified, this chapter makes four recommendations for creating a bio-economy that does indeed have a future. Our recommendations are based on the points identified in the previous chapter. They summarise the lessons learned, which were also described in the previous chapter.

**Make the bio-economy policy leading**

Biomass policy in the Netherlands is fragmented at the moment (Lesson 2). One line of policy focuses on stimulating the use of biofuels. The other targets biomass co-firing in power plants. These two, somewhat older, policies have laid the groundwork for new forms of biomass utilisation and in doing so have given the bio-economy a necessary boost. The bio-economy policy advocates optimal biomass valorisation. The bio-economy is a valuable, integrative policy concept because it aims to use biomass for multiple purposes simultaneously. Ecological and economic considerations determine the specific biomass application that takes precedence. If the bio-economy is to succeed, then the older policies

must be incorporated into the newer bio-economy policy and the dynamic of optimal valorisation (Lesson 1).

*Recommendation 1*
*Make the bio-economy the leading policy concept and clarify which ministers and ministries are responsible for it.*

**Operationalize ecological and social sustainability**
The promise of the bio-economy is closely related to its assumed sustainability. Sustainability is a unique selling point when it comes to promoting the bio-economy among consumers and producers. It means that the bio-economy, if it is to be viable, will have to fulfil that promise of sustainability. Sustainability should be interpreted broadly in this context; it represents an ideal that also embraces such matters as social justice (Lesson 4).

Efforts to guarantee the sustainability of the bio-economy include the drawing up of sustainability criteria. But such guarantees have proved difficult to achieve, for two important reasons. To begin with, the entanglement with unsustainable agricultural practices and patterns of consumption makes the transition to a sustainable bio-economy difficult (Lesson 3). Secondly, opinions differ as to what sustainability actually means and when the bio-economy can be said to have succeeded as a sustainable project. Nevertheless, it is important to be able to guarantee biomass sustainability; if we cannot, the market for bio-based products will never get off the ground. What is required is an ongoing learning process (Lessons 5, 6 and 7).

It will not be enough for government and industry (or parts of industry) to take up the message of sustainability. Without the backing and involvement of nature conservation and environmental organisations, the public's confidence in the sustainability of the bio-economy may be easily eroded. At the same time, sustainability must be operationalized in the international arena, because the bio-economy is an undeniably global affair. The sustainability of the bio-economy must be guaranteed in such a way that all the various parties can support it.

*Recommendation 2*
*Make operationalizing the sustainability of biomass use an ongoing learning process. Involve as many civil society organisations as possible at international level and consider the sustainability of agriculture and of patterns of consumption as well.*

**Judge technology according to sustainability criteria**
The tendency to think in terms of first, second and third-generation technologies plays a significant but often obfuscating role in the discussion of the bio-economy

and innovation. There is much debate about whether the current 'first generation' of biofuels is sustainable. Other points of concern are actual $CO_2$ reduction across the entire value chain and competition with food. Many people expect, almost as a matter of course, that the second and third-generation technologies will be more sustainable because they will be based mainly on the non-edible parts of plants or on algae. There are three underlying assumptions in this way of thinking that we wish to call into question, however.

First of all, it is too early to say that the first generation of biofuels is not sustainable. We would offer practical advice in that respect: 'Quantify before you qualify'. Judge every specific first-generation application according to objective sustainability criteria. Secondly, there is nothing that says that second or third-generation applications will in fact be more sustainable. The negative side-effects of the first generation of biofuels only became clear after they were being used, and the same will undoubtedly be true for subsequent generations. Every application will have to be evaluated on its merits. Broadly supported sustainability criteria offer a good yardstick in that respect. Thirdly, the first generation is not necessarily a stepping stone to the second and third generations. Many fear that the economic interests and structures that are now being set up in connection with the first generation will prevent new technologies from being introduced.

At the moment, however, all we can say is that the first generation of applications has served to open our eyes to the potential of biomass and to the many social and ecological issues associated with it. Learning by 'trial and error' in this way may in fact bring the prospect of a viable, sustainable bio-economy closer to reality, provided that government and other parties draw lessons from the first generation of applications, specifically with respect to sustainability (Lessons 8 and 9). If they do not, then the promise of 'learning by doing' will do nothing more than draw a 'green' smokescreen around the first generation of biofuels, giving the final blow to the bio-economy.

*Recommendation 3*

*Do not blindly assume that the first generation of biomass applications is unsustainable and that the second and third generations will be sustainable. Judge every technology on its merits according to objective sustainability criteria. Draw lessons from the problems encountered with the first generation of biofuels and show how they can be solved.*

**Dealing with GM crops**

Genetic modification is a key technology in the quest for an efficient bio-economy, but it can also be something of an Achilles heel if it is not treated with the necessary care and caution (Lesson 10). It must be absolutely clear that GM crops can satisfy sustainability criteria, for example by demonstrating that they

contribute to more efficient biomass use. But even if GM crops do satisfy sustainability criteria in the instrumental sense, public acceptance of them is far from assured. Public resistance to genetic engineering is also related to notions of naturalness (Lesson 11). In the bio-economy, sustainability is mainly a question of using technology and quantifiable criteria to deal efficiently with feedstock. As argued above, the technocratic approach is valuable in that it satisfies the need to describe sustainability in as objective a manner as possible. At the same time, this approach may conflict with other perceptions of 'green' or 'sustainable', in which a harmonious relationship with nature is held up as the ideal. In the harmonious approach, nature need not be made more efficient or improved in any way; the idea is to respect nature for its intrinsic features.

It must be clear in the development of the bio-economy which notion of sustainability is being taken as a basis. Identifying the core notion will prevent the opponents of genetic engineering from feeling that false promises are being made concerning the use of such technology, and will provide a better basis for trusting the good intentions of the proponents of genetic engineering.

*Recommendation 4*

*It is not enough for government to show how genetic engineering can contribute to sustainability. Government should also clarify its own views on naturalness and sustainability.*

# About the authors

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***Dr.* Frank Veraart** is a scholar in the History of Science and teaches Transition Studies at Eindhoven University of Technology's School of Innovation Sciences. He has published articles on trends in ICT and contributed in a variety of ways to the project, 'The History of Technology in the Netherlands in the 20th Century.' Since 2009 he has been involved in the project 'The History of Sustainability in the Netherlands' as part of the 'Studies in Sustainable Transition' series.

**Huib de Vriend** provides advice through his agency LIS (Life Sciences, Innovation & Society) Consult about socially responsible innovation in biotechnology. He studied Land Development in Wageningen and, for the past twenty-five years, has been active in the societal debate on genetic engineering. His publications and activities have helped put genetic engineering and consumer advocacy on the agenda. Huib has studied legislation, innovation, sustainability, safety, freedom of choice and public perception. He has also published on the social significance of new developments in genetic engineering and genomics.

# Interviewees

**Roel Bol,** Ministry of Agriculture, Nature and Food Quality, Cross-ministerial Bio-based Economy Programme

**Harriëtte Bos,** Wageningen University & Research Centre

**Ewald Breunesse,** Shell

**Geert van Grootveld,** Ministry of Economic Affairs, Energy Transition

**Marieke Harteveld,** Bio-based Raw Materials Platform, SenterNovem

**Jan Hein Hoitsma,** Solarix

**Madelon Meijer,** Oxfam Novib

**Patricia Osseweijer,** Kluyver Centre

**Erik van Seventer,** Wageningen University & Research Centre

**Willem Wiskerke,** Natuur en Milieu Foundation

# Advisory Committee

***Drs.* Wim van Velzen**: former Chairman of the Board of the Rathenau Instituut and member of the Innovation and Knowledge Expert Committee (Committee chairman).

**Erik van Seventer MSc**: DLO-BU Manager of the Agrotechnology & Food Sciences Group, Bio-based Products, Wageningen University.

***Prof. Dr. Ir.* Patricia Osseweijer**: Professor of Science Communication, Kluyver Centre, Delft University of Technology.

***Drs.* Willem Wiskerke**: Biomass Coordinator, Natuur en Milieu Foundation.

***Drs.* Roel Bol**: Programme Director, Bio-based Economy, Ministry of Agriculture, Nature and Food Quality.

***Drs.* Leen van den Oever**: Director of the Netherlands Institute of Bioscience (NIBI).

**Who was Rathenau?**

The Rathenau Instituut is named after Professor G.W. Rathenau (1911-1989), who was successively professor of experimental physics at the University of Amsterdam, director of the Philips Physics Laboratory in Eindhoven, and a member of the Scientific Advisory Council on Government Policy.
He achieved national fame as chairman of the commission formed in 1978 to investigate the societal implications of micro-electronics. One of the commission's recommendations was that there should be ongoing and systematic monitoring of the societal significance of all technological advances.
Rathenau's activities led to the foundation of the Netherlands Organization for Technology Assessment (NOTA) in 1986. On 2 June 1994, this organization was renamed 'the Rathenau Instituut'.

From biofuels to biopolystyrene and from bioplastics to biomedicines: the bio-economy has much to offer. Fossil-based raw materials such as petroleum are polluting the Earth, and reserves are finite. Plant-based materials such as grain, wood and algae appear to be good replacements. At first glance, the bio-economy looks very promising.

But what can we really expect from the bio-economy? Can it give us a sustainable society? What role can the Netherlands play in the global bio-economy? How does Dutch policy compare to trends and developments around the world? Will the bio-economy offer both richer nations and developing countries opportunities?

This report shows that the bio-economy will not live up to its promise just like that. Technological advances such as genetic modification represent only one of the factors involved. The existing global economic system will also have to change. If nature is to provide a growing share of our raw materials, public acceptance is required as well. This report offers a number of recommendations for 'learning by doing' as we make the transition to a bio-economy.

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