15 Bioeconomy and Ethics

Bart Gremmen

Abstract

Although many empirical studies have been done to elaborate the meaning of sustainability, the core of its meaning is normative. When the concept of bioeconomy emerged, the overarching concept of sustainability was used to place bioeconomy in a normative, long-term development. For example, in Germany bioeconomy is defined as a new model for industry and the economy. It involves using renewable biological resources sustainably to produce food, energy, and industrial goods. It also exploits the untapped potential stored within millions of tons of biological waste and residual materials. This definition focuses on renewable resources and biological waste. Other definitions focus on the use of biotechnology in the production of (bio-based) goods, services, or energy from biological material (or biomass) as the primary resource base. In this paper we will present an overview of the ethical issues of bioeconomy in Europe. On the one hand, we will compare the bioenergy situation in Germany and the Netherlands. We will show that the Netherlands is now switching from a bio-based economy to a circular economy. This process has been accelerated by a recent number of serious problems with the use of wood as biomass. On the other hand, we will focus on the latest developments in biotechnology and show that, next to already known ethical problems about genetic modification, CRISPR-Cas9 leads to a number of new specific ethical problems.

Keywords

Sustainability · Circular economy · CRISPR-Cas9

B. Gremmen (✉)
Department of Social Sciences, Philosophy: Ethics in Life Sciences, Wageningen University, Wageningen, The Netherlands
e-mail: bart.gremmen@wur.nl

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1 Introduction

More than 25 years ago the concept of sustainability became a topic on academic agendas. It survived fierce discussions about its definition[1] and slowly became fashionable in the political and societal arenas of Europe. Although many empirical studies have been done to elaborate the meaning of sustainability, the core of its meaning is normative. When the concept of bioeconomy emerged, the overarching concept of sustainability was used to place bioeconomy in a normative, long-term development. For example, in Germany bioeconomy is defined as a new model for industry and the economy.[2] It involves using renewable biological resources sustainably to produce food, energy, and industrial goods. It also exploits the untapped potential stored within millions of tons of biological waste and residual materials.[3] This definition focuses on renewable resources and biological waste. Other definitions focus on the use of biotechnology in the production of (bio-based) goods, services, or energy from biological material (or biomass) as the primary resource base.[4] In this paper we will present an overview of the ethical issues of bioeconomy in Europe. On the one hand, we will compare the bioenergy situation in Germany and the Netherlands. We will show that the Netherlands is now switching from a bio-based economy to a circular economy. This process has been accelerated by a recent number of serious problems with the use of wood as biomass. On the other hand, we will focus on the latest developments in biotechnology and show that, next to already known ethical problems about genetic modification, CRISPR-Cas9 leads to a number of new specific ethical problems.

What do we mean by ethics? Ethics may be studied from several disciplinary backgrounds: law, theology, psychology, philosophy, and social science. In this paper we will study ethics from a philosophical background[5] and define it as the critical, systematic reflection on implicit and explicit moral assumptions about what we do. Traditionally, the focus is on the individual: what should/must I do? In contrast we will focus on policy making, government, and society. Our strategic vision on applied ethics is that many of the societal and scientific challenges in relation to agriculture, food, and the environment involve value conflicts, and that scientific understandings and technological solutions are often contested. In a pluralistic society, philosophy can offer proactive and constructive ways to deal with such value conflicts. Our mission as applied ethicists is to strengthen reflection on, and deliberation about, these problems and about scientific and societal responses, and thus to contribute to responsible policies and practices. The aim is to clarify the nature of values such as integrity, intrinsic value, and sustainability and explore possibilities for responsible innovation in plant and animal production systems.

[1] Cf. Gremmen and Jacobs (1997).

[2] Cf. German Advisory Council on Global Change (2009).

[3] Cf. Federal Ministry of Education of Research (2011).

[4] Cf. Energy Transition – The Global Energiewende (2019).

[5] Cf. Petersen and Ryberg (2007).

Our pragmatic approach starts from case material and concrete actual developments, and aims at interdisciplinarity, dialog, and collaboration.[6] In this empirical way of doing ethics, philosophical and ethical concepts are used as flexible tools that can be adapted to specific contexts. Whereas academic debates often revolve around the question of whether these sciences are benign or a threat,[7] we discuss life sciences from within.[8] This means that *the societal impact* of our work is strengthened by our bottom-up approach.

2 From Bioeconomy to Bio-Based Economy

From the mid-2000s policy makers and governments paid more and more attention to the term “Bioeconomy.” They believed that the bioeconomy could help to solve the fossil fuel problem,[9] because the use of biomass can ease the transition from fossil fuels to a sustainable alternative.[10] The bioeconomy is also seen as food and non-food applications of biotechnology, especially GMOs.[11] The bioeconomy became popular with its adoption by the *European Union* (EU) and the *Organization for Economic Co-operation and Development* (OECD) as a policy agenda and framework to promote the use of biotechnology to develop new products, markets, and uses of biomass. Since then, both the EU[12] and the OECD[13] have created dedicated bioeconomy strategies, as have an increasing number of countries around the world. According to the European Commission Europe must make the transition to a post-petroleum economy.[14] In their view a greater use of renewable resources is no longer just an option, it is a necessity. As a consequence the EU has adopted a strategy “Innovating for sustainable growth: A bioeconomy for Europe”.[15] In this strategy the European Commission defines the bioeconomy as “the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge.”[16] Also the importance of the bioeconomy is highlighted by calculating its economic worth. The Commission estimates that the EU’s

[6] Cf. Gremmen (2002).

[7] Cf. Singer (1975) and Sandoe and Christiansen (2008).

[8] Cf. Gremmen (2007).

[9] Cf. Golembiewski et al. (2015).

[10] Cf. U.S. Energy Information Administration (2016).

[11] Cf. Heijman and Schepman (2018).

[12] Cf. European Commission (2012).

[13] Cf. Organisation for Economic Cooperation and Development (2009).

[14] Cf. European Commission (2012).

[15] Cf. ibid.

[16] Ibid, 9.

bioeconomy sectors are worth 2 trillion Euros in annual turnover and account for more than 22 million jobs and approximately 9% of the workforce.[17] The Commission is convinced that to solve the problems connected with the scarcity of non-renewable resources, global warming, and environmental pollution, the development of the bioeconomy is crucial.[18] In 2012 the USA also announced a National Bioeconomy Blueprint to encourage biological manufacturing methods.[19]

The term "bioeconomy" is a normative term because finite resources *must* be used in the most effective, efficient, and sustainable manner possible.[20] From the above we can also see a close relationship between problems that were earlier disconnected: non-renewable resources, climate change, and environmental pollution. Bioeconomy has become a normative umbrella concept with the economy at its core. It is studied from different disciplines. The result is a multifaceted concept with different definitions,[21] which makes it difficult to compare the bioeconomy on an international scale.[22] There are different views on the bioeconomy which we will use the three conceptual distinctions of.[23] Firstly, the *biotechnology view* of the bioeconomy emphasizes the importance of research into biotechnology and the commercialization of biotechnology. This view underlines understanding mechanisms and processes at the genetic, molecular, and genomic levels, and applying this understanding to creating or improving industrial processes, developing new products and services, and producing new energy. Secondly, the *bio-resource view* of the bioeconomy focuses on the role of research and development related to raw resources in the primary sector as well as establishing new value chains. Lastly, the *bio-ecology view* focuses on the importance of ecological processes that optimize the use of energy and nutrients and promote biodiversity. The first two views are largely focused on research and development in global systems. Because the bio-ecological view emphasizes the potential in regional systems, we will refer to it as the circular-economy view.

The EU strives for different goals in the transition from a fossil fuel-based to a bioeconomy.[24] It is expected that the bioeconomy will reduce its dependency on fossil fuels and achieve more sustainability as well as contribute to climate and environmental protection.[25] In bio-refineries plants are broken up into their component parts as completely as possible and converted into all kinds of materials. In this way the term "bioeconomy" is conflated with the term "bio-based economy," which

[17] Cf. ibid., 11.

[18] Cf. European Commission (2012).

[19] Cf. The White House (2012).

[20] Cf. Wield (2013).

[21] Cf. Heijman and Schepman (2018).

[22] Cf. Staffas et al. (2013).

[23] Cf. Bugge et al. (2016).

[24] Cf. European Association for Bioindustries (2011).

[25] Cf. McCormick and Kouto (2013).

refers to the *bio-resource view* of bioeconomy.[26] For example, since 2005 the Netherlands has sought to promote the creation of a bio-based economy by starting pilot power plants, a centralized organization, and supporting research (Food & Bio-based Research) being conducted. The bio-based economy is focused on biomass (crops, crop refuge as well as seaweed and algae). Bio-refining biomass results in products ranging from highest added value and lowest volume of biomass to lowest added value and highest volume of biomass: fine chemicals/medicines, food, chemicals/bioplastics, transport fuels, electricity, and heat. The main advantage of biomass is that it can produce all three types of energy carriers: electricity, heat, and fuel (liquids, solids, and gas). Another advantage is that it is easily storable, compared to energy sources such as sun or wind. However, there are two main drawbacks from an ethical point of view. The first is that, compared to energy form sun and wind, energy from biomass is not sustainable by definition. The energy of sun and wind is independent of our use. Although biomass is overall a renewable source of energy, it is also a finite source of energy: the plants that are used must definitely be replaced or regrown. It takes many years to regrow them (e.g., most tree species). The second main drawback is that the global use of biomass for fuel by rich countries may conflict with the food needs of poor countries. Other drawbacks of crops grown for fuel are: possible resource depletion and reduction of biodiversity.

Although the term "bioeconomy" may have a broad meaning,[27] the resource view is prominent in the EU. Within this view many countries focus on the use of biomass for bioenergy. In the next section we will compare two countries, Germany and the Netherlands, in their recent attempts to build a sustainable bioenergy system.

3 Bioenergy in Germany and the Netherlands

Forestry and agriculture are generally the two sources of bioenergy. Germany is, within the EU, the greatest producer of wood, and wood is by far the greatest source of bioenergy in the country.[28] It is estimated that roughly 40% of German timber production is used as a source of energy, with the rest being used as material.[29] Germany is also the leading biogas market—beginning in 2015, almost two-thirds of Europe's biogas plants were installed in Germany. In the part on biomass, we find that energy crops used in 2017 nearly 2.4 million hectares of its arable land, representing around 14% of the agricultural land in Germany. There is still room for expansion because the upper limit for bioenergy is four million hectares by 2020.[30]

[26] Cf. ibid.

[27] Cf. ibid.

[28] Cf. Energy Transition – The Global Energiewende (2019).

[29] Cf. ibid.

[30] Cf. ibid.

In contrast, the Netherlands is, within the EU, a very small producer of wood. In the past the sources of biomass for bioenergy were varied: manure, VFG (vegetable, fruit and garden waste), and roadside cuttings. In recent years, three-quarters of the wood that is burned in biomass power stations originated in the Netherlands. Most of it is pruning waste or residual wood. This flake wood is mainly from the northern provinces of the Netherlands and is left over from maintenance of forests. After fragmentation the biomass power plants buy this wood from Staatsbosbeheer and gardeners and generate steam and electricity by incineration. For example, the electricity of the medium scale power plant "Brouwer Biocentrale BV" at Balkbrug goes to the energy grid, good for 1100 households. The steam goes to neighbor Friesland Campina, which saves 5.5 million cubic meters of natural gas.[31] That wood would otherwise remain in the forest, rot, and thus emit CO_2. The Dutch government regards biomass as an important and sustainable energy source that will be needed in the coming years to achieve the climate goals and to close the gas tap in Groningen. It is expected by the government that biomass will generate more renewable energy in 2020 than solar energy or offshore wind energy. There are currently 372 power plants in the Netherlands that use wood as fuel. Of these 372,219 are operational and 153 are planned.[32]

In Germany the use of biomass for energy is not without criticism. Environmental impacts of energy crops are high on the agenda of environmental organizations. For example, the adverse effects of energy crops on the quality of groundwater and soil erosion have been debated. Also the plowing of valuable grassland to increase cultivation of corn for use in energy production has been criticized. Germany's Renewable Energy Act[33] has been developed to counteract these effects. It limits the amount of corn and grain eligible for special compensation. In addition, a set of incentives encourages the increased use of less environmentally polluting substrates.

Today, Germany uses biomass mainly of domestic origin. The challenge will be to increase biomass usage for energy without drastically increasing imports. According to the German Federal Ministry of Education and Research the expansion of biomass production for energy use must not conflict with food security, the right to food, and the protection of the environment and nature.[34] The ministry is in favor of strong sustainability criteria for biofuels and other liquid bioenergy carriers. However, we believe that enforcing these strict criteria will be a major challenge, not only in Germany, but also to prevent globally the use of biomass for energy to become the cause of increasing food prices.

Compared to Germany, the Netherlands is relatively small and most of the agricultural land is used for food crops. More than 25% of the required biomass is imported, mainly wood from the USA and wood pallets from Estland. Opponents of the use of biomass claim that forests would be cut down to meet the demand from

[31] Cf. Vries (2019).

[32] Cf. ibid.

[33] Cf. Federal Ministry of Education of Research (2011).

[34] Cf. ibid.

coal and biomass plants. According to experts this is not true.[35] They claim that all wood that comes from the USA and ends up in our biomass plants is waste wood. However, critics[36] claim that in the south of the USA, Enviva, which supplies pellets to the Netherlands, mainly uses hardwood. In short, wood from forests located in the heart of a global hotspot for biodiversity. The state of North Carolina, one of the most important pellet production centers, recently announced that burning wood for biomass is not part of the state's clean energy plan and that large-scale use of forests in North Carolina on foreign markets at national and international levels must be challenged.[37] Both in the Dutch Energy Agreement from 2013 and in the provisional Climate Agreement, there is a strong commitment to biomass. However, the Dutch government wants to know for all types of biomass how sustainable they are. Researchers are preparing an overview of the available biomass in the Netherlands, the current import and all existing applications.[38]

While the German government aims to develop the complete range of products with a focus on innovation, the Dutch government focuses on the production of electricity and heat in biomass power plants. Old coal-fired power stations are converted (in whole or in part) thanks to subsidies of many hundreds of millions of euros into biomass power stations, such as those from Uniper on the Maasvlakte and from RWE in the Eemshaven and Geertruidenberg.[39] Because biomass is more expensive than coal, there are billions of euros in subsidies available for it. Yet, there is a lot of discussion about it. Opponents are afraid that it is not just about residual products, but that more trees are disappearing than are being planted instead. In addition, the discussion is about how much biomass is available worldwide and in the Netherlands. According to Vattenfall, one of the main biomass users, every effort will be made to minimize the emission of particulate matter when building new power plants.[40] The use of filters cleans the flue gases, so that the amount of particulate matter that is already present in the air hardly increases, according to the company.[41] In addition, Vattenfall is only concerned about extracting wood from sustainably managed forests.[42] That means that they will only get their biomass from forests where more wood grows than what is extracted from it. According to the company, it is only about residual wood, from trees that are already cut down to make planks.[43]

In 2019 it became clear that relatively small biomass power plants were a danger to the health of people and the environment. The *European Academies Science*

[35] Cf. Vries (2019).

[36] Cf. Luiga and Swart (2019).

[37] Cf. ibid.

[38] Cf. Vries (2019).

[39] Cf. Mersbergen (2019).

[40] Cf. ibid.

[41] Cf. ibid.

[42] Cf. ibid.

[43] Cf. ibid.

Advisory Council (EASAC) recently stated that the method—burning wood to generate energy—is bad for the climate rather than CO_2-neutral, as the government and industry argue. In addition, a report by DNV GL consultancy, commissioned by the *Ministry of Infrastructure and Water Management*, revealed that biomass plants emit more harmful substances than plants on natural gas and even coal. The majority in the Dutch parliament want to significantly reduce the use of biomass. A motion by the political party D66 to set requirements for the emissions of smaller biomass plants is supported by the coalition partners.[44] These biomass power plants emit much more nitrogen and particulate matter than coal plants. However, they do not have to meet strict air quality requirements. The coalition parties also want no more subsidies to be given for new biomass plants. To date, more than 14 billion euros have been promised by the government. Johan Remkes' nitrogen committee recently advised the cabinet to stop subsidies for co-firing biomass.[45]

Due to these problems the government is now slowly shifting its focus from a bio-based economy to circular economy.[46] By 2050 a circular economy in the Netherlands has an interim target of reduction in the use of primary raw materials by 50% by 2030. A nation-wide Circular Economy Programme has been set up.[47] Its core concept is "Closing the loop": all raw materials and residual flows must be kept within the loop for as long as possible while keeping their quality as high as possible. Cascading and multifaceted value creation are key ambitions. For biomass and food, the key principle is to maintain soil balance, with a key focus on maintaining and boosting soil health: a key factor in sustainable production.

4 Bioeconomy as Genetic Modification

After the first half of the twentieth century, molecular biology developed ways to alter DNA in controlled ways. Genetic modification (GM) allowed the cutting and then splicing together of DNA-molecules.[48] Two methods were developed: the particle gun method and the agrobacteria method. These methods were used first in mono-cellular organisms, and subsequently applied to multi-cellular organisms. A "transgenic" mouse (a mouse containing DNA from another species) was the first GM-mammal, made in the mid-1970s. In 2015 the first GM-product to be approved for consumption in America has been the GM-salmon.[49]

Although the application of some methods and technologies is different, the basic genetics is more or less the same in plants and animals. Mutation breeding (increased mutation frequency through chemicals or radiation), for example, is not possible in

[44] Cf. Luiga and Swart (2019).

[45] Cf. ibid.

[46] Cf. Ministerie van Infrastructuur en Waterstaat (2019).

[47] Cf. ibid.

[48] Cf. Gremmen (2017).

[49] Cf. ibid.

animals, for both ethical and economic reasons, but is a common and legal method for plants. Genetic modification and marker assisted selection (MAS) have been used in plant breeding for many years. Recently genomic selection (GS), a method used in animal breeding, has become an increasingly promising method for plant breeding as well.

There are three different legal regimes of GM applications in the European Union.[50] The industrial application of GM is the first regime. Industry transfers molds, viruses, and bacteria into GMOs. This so-called contained use is allowed because it is done in sealed containers. Agriculture is the second regime. Unless there are serious arguments against it the application of GM to plants is allowed. However, the application of GM to animals is not allowed, unless there are serious arguments to do it anyway. The application of GM to humans is the third regime. This is the most severe legal regime: the genetic modification of humans is not allowed.

Although it is legal to develop and cultivate GM plants, the long and expansive regulatory road in the last decades has led to one crop in one country: corn in Spain.[51] Compared to the thousands of hectares soy, corn, rapeseed, and cotton in South- and North America, GM plants are almost non-existent in Europe. Lower price, higher quality, higher environmental value, and higher nutritional value are the potential benefits of GMOs. Higher food security, better food safety, more affordable food, higher societal health, more sustainability, and biodiversity are potential societal values of GMOs. An important problem is that these benefits and values may clash. For example, a higher food security or better price could result in a lower health or a lower food safety. It is all about setting the right priorities.

In 2010 the results of the Eurobarometer showed that people in the EU do not see benefits of GM-food.[52] Some people think that GM is probably unsafe or even harmful.[53] People in the EU have strong reservations about safety and do not see the benefits of horizontal gene transfer. They have some reservations about safety and the potential impact on the environment but accept the potential benefits of vertical gene transfer.[54] Other people have strong reservations about ethical issues, such as the use of human embryos, but consider that the science of regenerative medicine should be allowed to develop. Although strict laws are needed to alleviate concerns about ethical issues, they approve of stem cell research, transgenic animal research, and human gene therapy.[55]

The ethical arguments about GMOs are very varied in society.[56] On the critical side, some people have objections to a particular technology as such. For example in

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[50] Cf. ibid.

[51] Cf. ibid.

[52] Cf. Gaskell et al. (2011).

[53] Cf. ibid.

[54] Cf. ibid.

[55] Cf. ibid.

[56] Cf. Gregorowius et al. (2012).

the case of genetic modification, this argument amounts to the claim that it is *unnatural* and therefore morally problematic. Also arguments about threatening the integrity and/or the intrinsic value of plants can be found. In another argument it is claimed that GM technology amounts to a form of *hubris* concerning man's relationship to nature (are we allowed to "play God"?).[57]

Many critics might be opposed to the different applications of GM technology and not so much opposed to GM technology as such.[58] From a consequentialist ethics perspective this means that even people who do not have an objection in principle to the technology still can be critical to its use in agriculture in general, and in food production in particular.[59] With respect to the distribution of economic benefits from its use current applications of agricultural biotechnology have also been criticized from the viewpoint of *justice*.[60] Criticism has also focused on the autonomy of consumers in deciding whether to put the products on the table and the *autonom*y of farmers in deciding whether to use the technology (e.g., are patents allowed?).[61] The *risks and uncertainties* with this new technology are emphasized by some of the critics and they argue either that there are risks to human health or the environment (e.g., sustainability and biodiversity), or that there might be such risks, and that for this reason some version of *the precautionary principle* should be applied.[62] Are these ethical issues of GM also present in more recent genetic engineering techniques like CRISPR-Cas9?

5 Genome Editing: CRISPR-Cas9

In plant breeding several new genetic engineering techniques, also referred to as genome editing, have been developed in short time. "Genome editing" can be defined as "the practice of making targeted interventions at the molecular level of DNA or RNA function, deliberately to alter the structural or functional characteristics of biological entities."[63] Because of their ability to cut and alter the DNA of any species at almost any genomic site with ease and precision, these genome editing techniques are faster, more accurate, cheaper, and more widely applicable than older techniques.[64] They have been developed to determine the site of mutation or insertion of the genes and to overcome the problem of randomness that results from mutation breeding.

[57] Cf. Comstock (2010).

[58] Cf. ibid.

[59] Cf. Jasanoff et al. (2015).

[60] Cf. ibid.

[61] Cf. Comstock (2010).

[62] Cf. ibid.

[63] Nuffield Council on Bioethics (2016, 4).

[64] Cf. Jasanoff et al. (2015).

In plant breeding CRISPR-Cas9,[65] one of the most popular genome editing techniques, has come into use in a short time. In 2012 the development of this system enabled precisely targeted alterations to DNA sequences in living cells. CRISPR-Cas9[66] is based on the "virus library" of bacteria (a natural way of bacteria to defend against phage infection) and uses RNA to locate the exact spot in a genome. It is possible to insert a new piece of DNA (in case of a cis- or transgene plant), but it also cuts the unwanted piece of DNA (i.e., point mutations).[67]

Applications of plant gene editing techniques are varied, many, and rapidly evolving, including applications that promise benefits in drought- and salt tolerance, and disease resistance. A new tomato variety that grows like a bush is one of the first cultivars. To realize the promised significant benefits of the gene editing technology, the technology needs to be firmly and fully embedded in society. For example, the "Tomelo," a variety of tomato plant geneticists from Tübingen have developed that is resistant to powdery mildew. The powdery mildew-resistant tomato has a deletion in the SlMlo1 gene. CRISPR-Cas9 enabled them to achieve this in less than 10 months, a relatively short period of time.[68] They also demonstrated that the new tomato variety is indistinguishable from naturally occurring deletion mutants and contains no foreign DNA (no natural species barrier was crossed).[69]

Although there are all kinds of material on the internet about the ethical discussion of GM, there are almost no journal papers about ethics and CRISPR-Cas9. How to refer to the new technology is an important issue: gene editing or genetic manipulation CRISPR-Cas9 or genetic modification? The use of an adequate name in the societal debate is very important.[70] The public will link the name of a new technology to an element in the name if they lack knowledge of that new technology. For example, *gen*omics has been linked to *gen*etic modification.[71] Also the aims and functions of the new technology are already described in different ways: tinkering with the genome; manipulation of DNA; repairing the genome; tools to create mutations; text processing of DNA. An inappropriate wording proves to be very hard to correct.[72]

How can we use CRISPR-Cas9 in genomes of humans, animals, and plants? First, the technology can be used to *repair* the genome (i.e., inheritable diseases), but in some cases a natural alternative to repair a genome is also possible. *Prevention* is a second use (i.e., inheritable diseases) and *improving* the genome (existing traits or new traits) is a third. Improvement by adding new traits offers endless possibilities.

[65] Cf. Zhang et al. (2014).

[66] Cf. Ibid.

[67] Cf. Jasanoff et al. (2015).

[68] Cf. ibid.

[69] Cf. ibid.

[70] Cf. Boersma and Gremmen (2018).

[71] Cf. ibid.

[72] Cf. Boersma et al. (2019).

The fourth way to use this technology is to *design* new genomes. This could lead, in the case of humans, to the return of earlier ethical debates about eugenics.

What are, in general, the ethical issues of CRISPR-Cas9? Since it is also possible to insert (a) gene(s) through gene editing, first of all the ethical issues of genetic modification apply. Are there any other ethical issues specific of CRISPR-Cas9? We will analyze the main technological characteristics of CRISPR-Cas9 to answer this question:

1. Compared to genetic modification it is said to be very accurate.[73] However, side effects, like off-target mutations and unexpected results, have also been reported after certain gene editing applications. How safe is CRISPR-Cas9?
2. It is said to be cheap compared to genetic modification.[74] This makes abuse by experts and companies more worthwhile.
3. It is said to be relatively fast.[75] This means that it will be difficult to exercise societal control. Because of the speed and number of innovations regulation could be slow and sometimes even implemented too late.
4. It is not by definition a transgene technique.[76] In the media a denial of its transgenic possibilities is used to make it more likeable.
5. It is said to be relatively easy.[77] This makes abuse by amateurs/terrorists more conceivable.
6. A point mutation deletion caused by CRISPR-Cas9[78] is impossible to detect. As a consequence the difference between GM and non-GM becomes undetectable, thereby blocking one of the cornerstones in the regulation of genetic modification. Therefore, it will be difficult to exercise societal regulation. It also means that it is difficult to label products developed by this technology. New transparent and responsible chains have to be developed to ensure the consumer's right on information.
7. May gene drives be used as the ultimate weapon against diseases like Malaria and the Zika-Virus? By causing mutations of chromosomes after only a few generations, gene drives are able to install new traits in every individual of a species.[79] An example is a species of mosquitos unable to carry the malaria parasite. One of the problems is that mutations can't be reversed. The long-term consequences are also unclear. For example, when we wipe out Malaria, an even more dangerous parasite could take its place. A solution may be to build in control via "safety nets": genetically decoupling of the steering parts of a gene drive. This may be understood as a kind of molecular "un-do"-button via a second

[73] Cf. Nuffield Council on Bioethics (2016).
[74] Cf. ibid.
[75] Cf. ibid.
[76] Cf. ibid.
[77] Cf. ibid.
[78] Cf. ibid.
[79] Cf. ibid.

gene drive. Specific ethical questions of gene drives are: is it a threat to biodiversity? Is it acceptable to disrupt nature? Is it acceptable to use techniques we do not yet understand and control fully? Compared to genetic modification, CRISPR-Cas9 brings about a number of extra ethical issues. Because there are relatively low costs involved and that it is relatively easy to develop innovations from an ethical point of view the possible abuse by all kinds of stakeholders is particularly worrying.

On July 25th 2018 the *Court of Justice of the European Union* (CJEU) decided that all products made by the toolbox of New Plant Breeding Technologies (NPBTs) are GMO's. NPBTs are technologies to increase and accelerate the development of new traits in plant breeding, and gene editing, especially CRISPR-Cas9, is its main technology. The content of the NPBTs toolbox has been described by two research institutes of the European Commission.[80] It contains intragenesis (technologies using transformation with genetic material restricted to the species' own gene-pool), cisgenesis, emerging techniques to induce controlled mutagenesis or insertion (ODM, Zinc Finger Nuclease technologies 1–3) and other applications such as or reverse breeding or grafting on GM-rootstocks.

There has been a long debate in European Union about the regulation and legal categorization of NPBTs. Discussions at the policy level have evolved around the question whether products from NPBTs are or should be subject to special regulation.[81] As most NPBTs could not be separated from conventional breeding techniques, some people believe that they should also not be subject to special regulation.[82] Others, highlighting the requirements of the precautionary principle, call for regulation following the regulations for GMOs.[83] Most NPBTs are subject to regular GM regulation in the EU according the CJEU judgment[84] on the mutagenesis exemption in Directive 2001/18/EC[85] (hereafter Directive). This ruling has created a regulatory system for NPBTs which is unique in the world. If organisms obtained from NPBTs are put in the same basket as GMOs, this may carry a serious risk: transferring analogous ethical problems that GMOs encountered in the past, to organisms obtained from NPBTs, while they may not address similar risks.[86]

[80] Cf. JRC and IPTS (2011).

[81] Cf. Sprink et al. (2016).

[82] Cf. New Techniques Working Group (2008).

[83] Cf. Then and Bauer-Panskus (2017).

[84] Cf. CJEU (2018): Case C-528/16.

[85] European Parliament and Council of the European Union (2001).

[86] Cf. Poortvliet et al. (2019).

6 Conclusion

In this paper we presented an overview of the ethical issues of bioeconomy in Europe. With regard to the *bio-resource view* of bioeconomy we compared the German and the Dutch bioeconomy policies. While the German government aims to develop the complete range of products with a focus on innovation, the Dutch government focuses on the production of electricity and heat in biomass power plants using mainly wood. German biomass is mainly of domestic origin and the challenge will be to increase biomass usage for energy without drastically increasing imports. Most of the Dutch biomass is wood, and the expectation is that imports will drastically increase. The Netherlands is not only too small to meet its wood needs, but also almost all agricultural land is used for food crops.[87] From the recent debates about the environmental and health impacts of the wood fueled biomass power plants we can conclude that the recent attempts to build a sustainable bioenergy system more or less failed. The debates triggered a shift in government policy from a bio-based economy to a circular economy. But is this government policy realistic? In the current situation the Dutch regional economy only provides 25% of its inputs. In case of a truly circular economy we can predict a severe reduction of agricultural production.

With regard to the biotechnology view of the bioeconomy we have first given an overview of the ethical issues of genetic modification. Many critics might be opposed to the different applications of GM technology but not to GM technology as such. Current applications of agricultural biotechnology have also been criticized from the viewpoint of the autonomy of farmers and from the viewpoint of justice. Many people[88] emphasize the *risks and uncertainties* with this new technology about human health or the environment (e.g., biodiversity and sustainability) and think that GM is probably unsafe or even harmful. Our conclusion is that the ethical arguments about GMOs in society are still very varied. This means that genetic modification will remain a controversial topic.

We also reviewed the ethical issues of the latest development in biotechnology: CRISPR-Cas9. We asked the following questions: are there any ethical issues specific to CRISPR-Cas9? How can we use CRISPR-Cas9 in genomes of humans, animals, and plants? We answered these questions by analyzing the most important technological characteristics of CRISPR-Cas9 and described seven specific ethical issues of it.

If organisms obtained from NPBTs are put in the same basket as GMOs, this may carry a serious risk: transferring analogous ethical problems that GMOs encountered in the past, to organisms obtained from CRISPR-Cas9, while they may not address similar risks. At the stage of legal interpretation (such as with the CJEU) possible consequences like those can hardly be considered. Insights from ethics on the effect of a legal definition should be taken into account in the debate on whether and how to

[87] Cf. Gremmen et al. (2019).

[88] Cf. Gaskell et al. (2011).

change this definition. To accommodate the New Plant Breeding Technologies, and CRISPR-Cas9 in particular, the existing ethical frameworks on biotechnology[89] have to be broadened. This will help stakeholders, scientists, and policymakers to understand, monitor, and evaluate, the integration of the technical, social, and ethical aspects of the modern GM-toolbox also in view of a further development of bioeconomical applications.

Putting organisms obtained from CRISPR-Cas9 in the same basket as GMOs may carry a serious risk—transferring analogous ethical problems that GMOs encountered in the past, to organisms obtained from CRISPR-Cas9, while they may not address similar risks. Possible consequences like those can hardly be considered at the stage of legal interpretation (such as with the CJEU). Rather, as discussion now unfolds whether and how to change the legal definition, insights from ethics on the effect of such a definition should be taken into account. In our view, the existing ethical frameworks on biotechnology[90] have to be broadened to accommodate the New Plant Breeding Technologies and CRISPR-Cas9 in particular. This will help scientists, stakeholders, and policymakers to understand, evaluate, and monitor the integration of the technical, social, and ethical aspects of the modern GM-toolbox also in view of a further development of bioeconomical applications.

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[89] Cf. Holland and Johnson (1998); Rollin (2006).

[90] Cf. Rollin (2006); Holland and Johnson (1998).

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