Chapter 3
Biomass Resources and Sustainability Issues for a Flexible Bioenergy Provision

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Abstract Biomass available for the flexible provision of bioenergy is a major factor in discussing the potential contribution flexible bioenergy systems could make to the overall energy system. Even though the quality of the biomass used has an impact on the potential availability of biomass, it might not be the most decisive factor. More important is the origin of the biomass since the production of biomass has a complex impact on land and land use and can also provoke change in land use. Many studies have been carried out to estimate future biomass potentials. Their results differ greatly, due to different methods, definitions and assumptions regarding the scope of the studies. Sustainable provision of biomass is a precondition for smart bioenergy supply. With liquid biofuels as a starting point, a number of certification schemes have been developed over recent years and recognised by the European Commission. The future development of these schemes and possible expansion to the whole agricultural or forestry sector will also influence the future biomass potentials of energy crops. This underlines the uncertainty surrounding the future potential of energy crops. In regards to smart bioenergy provision, one possible option is to make (existing) larger production units using energy crops more flexible by widening their product portfolio. To satisfy the specific technical demands of flexible provision greater quantities of feedstock will be required.

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3.1 Introduction

The resources available for the flexible provision of bioenergy are a major factor in discussing the potential contribution flexible bioenergy systems could make to the overall energy system. In general, bioenergy production is based on a wide variety of technologies and feedstock:

– For thermochemical conversion a dry, carbon rich source is needed. This includes woody biomass and lignocellulosic material, taken from forestry or wood processing industry, straw and husks from agricultural production and different residues from gardening, land scape management etc.
– For biochemical conversion biomass with high water and sugar and/or starch content (depending on the fermentation process) is favourable. Typical feedstock for biochemical conversion include residues from livestock production and food processing industry, organic waste and different energy crops, including sugar cane, sugar beet, maize and grain crops.
– For physico-chemical conversion a source with high oil content, such as palm, rape seed, sunflower seed etc. Additionally, there are small quantities of used cooking oil available today. Algae feedstock is also discussed as a long term source solution.

Even though the quality of the biomass used has an impact on the potential availability of biomass, it might not be the most decisive factor. More important is its origin as the production of biomass has a complex impact on land, land use and can provoke change in land use.

The discussion surrounding biomass potentials for this specific sector of bioenergy production is therefore closely linked to the wider discussion on biomass potentials for bioenergy. In regards to this matter, important aspects to consider include the potential environmental impact of biomass production and the measures needed to avoid or minimise this impact. There are different expectations of the realistic future use of biomass, as a product of domestic production or import, in different countries [30]. Therefore, the assessment of biomass potentials has to take the global perspective into account. The objective of this chapter is therefore twofold: The first section will summarise the ranges of biomass available for the production of bioenergy and will describe the main drivers influencing the scenarios used for assessing biomass potentials. The second section of this chapter will touch upon the important topic of potential environmental impact both on a local and global scale. In the first part of this chapter, a number of potential local environmental aspects from the production of biomass in agricultural systems will be discussed. The environmental impact of biomass production on a global level is addressed within a number of sustainability certification schemes for biomass and bioenergy production. The second part of this chapter includes a discussion on recent development in this area as well as a brief summary of existing schemes and the environmental criteria included in their standards.

3.2 Biomass Potentials and Drivers

Biomass potentials for bioenergy production have been the subject of numerous studies considering a variety of geographical areas and resolutions, biomass assortments, assumptions and time frames. Available results therefore differ greatly, with some reports concluding that biomass has no potential while others conclude that biomass has huge potential and could satisfy the world energy demand multiple times offering a long term solution. Since each of the studies available considers different scoping questions and thus different framework conditions, the results of existing potential assessments are difficult to compare. Amongst other parameters, the individual definition of biomass potential is an important point for consideration and has a decisive effect on the outcome of the assessment of biomass potential. Different definitions of biomass potentials exist. Kaltschmitt et al. 2009 [18] distinguishes between:

- Theoretical potential describes the theoretically usable physical energy supply (e.g. all energy stored by phyto- and zoomass) of a given region in a certain time span. It is solely defined by the limits of physical use and thus represents the upper limit of biomass' theoretically feasible contribution to energy supply. Due to inseparable technical, ecological, structural and administrative barriers usually only a minimal realisation of its theoretical potential is possible.
- Technical potential is a function of the abilities of the technology which is currently available. Additionally, technical potential takes into account structural, environmental (e.g. nature conservation areas) and other non-technical restrictions. Technical potential therefore describes renewable energy's possible contribution to the satisfaction of energy demands for technical purposes, depending on time and location. As technical potential is primarily dependant on technical constraints it is less subject to fluctuations than the economic potential. The results summarized in this chapter represent technical potentials.
- Economic potential describes the proportion of the technical potential that is economically exploitable according to the given basic conditions. Since there are different ways to assess the economic efficiency of an option, there is always a multitude of economic potentials. Furthermore, continuously changing basic conditions (e.g. oil price changes, changing CO_2-tax models, energy and eco-taxes) influence economic potential.

The following figure summarizes the results from 19 different studies on the potential of biomass for bioenergy including energy crops, organic residues and waste. The majority of these publications focus on long-term energy potential of biomass (2050 and even 2100). Few publications specifically address the short and mid-term potential (2020 and 2030).

The figure shows that energy crop potentials are the most uncertain. Residue potentials are much less variable and range between 20 and 50 PJ/a [34]. Particularly from a long term perspective, the ranges for energy crop potentials are extremely wide (ranging between 0 EJ/year and values of 1,272 EJ/year for very optimistic assumptions). In comparison, the global primary energy supply in 2012 was approximately 500 EJ [14].

The definition of biomass in regards to the category forest residues is not consistent between the studies analysed. While some authors limit the use of this term only to residues obtained from thinning and logging, industrial production processes, and waste, others also include the annual forest increment. Due to the existing disagreements regarding the definition of forest derived residues, this resource shows the most significant changes across studies of a residue fraction. Its potential ranges from zero to 150 EJ/year in 2050. It should also be noted that the biomass potential discussed in recent publications tends to range between 50 and 200 EJ (cf. [3, 29]). The potential of biogenic wastes and residues is an important fraction for a sustainable supply of bioenergy through biomass. According to [34] this potential amounts to approx. 50 EJ/a. Given the intense debate questioning whether a large scale use of biomass to produce bioenergy is sustainable, these ranges seem to indicate greater potential for future bioenergy strategies and scenarios.

Besides methodical differences between the different studies, two additional points regarding the summarized results for the biomass residue potentials and the energy crop potentials have to be considered. Firstly, the studies analysed in Fig. 3.1 include different material flows (i.e. forest and agricultural residues, industrial residues, waste streams considering the demand of renewable materials for certain production processes, nutrition cycles, etc.) under the term biomass residues.

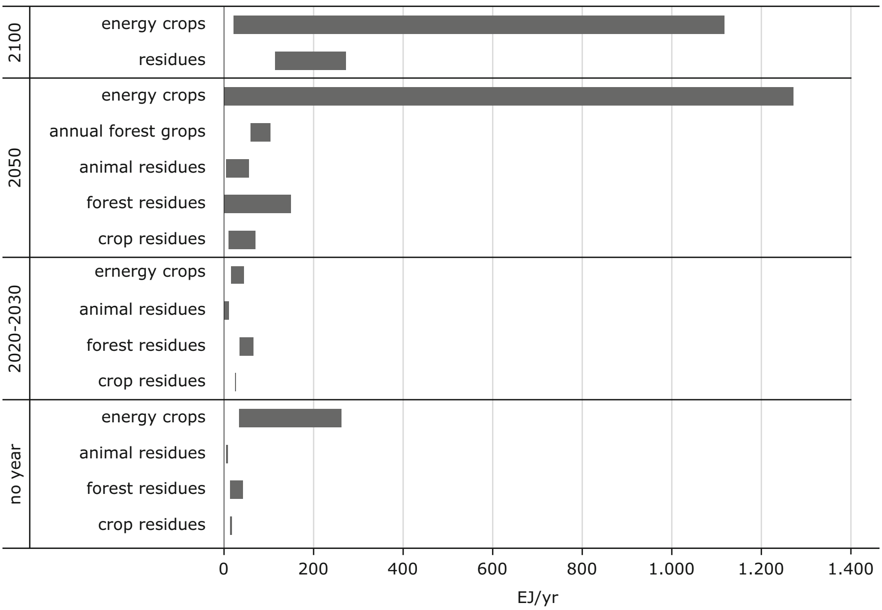

Fig. 3.1 Ranges of biomass potential of different resource fractions and years; from [31], data from [1, 2, 4, 7, 9, 11–13, 15, 17, 20, 21, 26–28, 35–37]

Secondly, the future demand of arable land for food production, one of the main parameters determining the potential of energy crops is considered differently by the studies considered in Fig. 3.1. On the one hand, an increasing population together with a change in food consumption patterns and an increasing urbanization lead to an additional demand for arable land for food production. On the other hand, increasing yields might reduce the specific area demand for the food production significantly. Besides the utilisation of biomass from residues, the production of energy crops in agricultural production systems is of high significance. The land availability for energy crop production depends on the overall amount of available agricultural land and the demand of land for food and fodder production. There are various drivers which influence the present and future food and feedstock demand. Their magnitude depends on the climate zone, the soil quality and specific local conditions. However, the main factors are universally valid in a global context. In the following table, an overview of the main influential factors is given (Table 3.1).

Out of these factors, the most important ones are the growth in (global) population, the future per-capita consumption – both driven by worldwide economic growth – and developments in the yield for food, fodder and biomass production. Climate change and its impact on agriculture production will also be an important factor which is however difficult to quantify. In order to estimate biomass potential these factors need to be considered altogether. The assessment of the future potential of biomass involves a great deal of uncertainty and therefore raises a complex question.

An important aspect in the general debate about the sustainability of biomass production for bioenergy (including flexible bioenergy provision) is the potential environmental impacts associated with its production. Besides global environmental

Table 3.1 Overview of major variables and drivers for biomass potentials

Variable	Explanation
Development of crop yields	High yields reduce the size of the agricultural area required for food and fodder cultivation, thus land and therefore energy crop potentials increase
Population growth	Determines the demand for foodstuffs and thus the area available for biomass cultivation
Development of livestock numbers	Influences the size of the area required for fodder cultivation
Impervious surfaces	Reduce the total available area of arable land
Per capita consumption	Extent of food consumption per capita influences the size of the area required for food and fodder cultivation
Foreign trade balance	Determines the level of self-sufficiency and thus the size of the available area
Conservation of land development	Determines the availability of land through changes in cultivation management
Climate change	May result in decreasing yields due to changing climatic conditions, amongst other things

aspects, such as greenhouse gas (GHG) emissions resulting from the intensification of agricultural processes or the effects of changes in land use, a number of local environmental aspects should be considered. The next subchapter will therefore focus on the discussion of a number of local environmental aspects of biomass production.

3.3 Environmental Aspects of Biomass Production and Certification

General Aspects

The concept of environmental sustainability is broadly defined per se. It includes, in simple terms, the preservation of nature and the environment for future generations. This objective affects a variety of aspects such as the conservation of biodiversity, climate protection, landscape maintenance, the protection of natural areas and the careful use of natural resources as well as the consideration of numerous additional environmental aspects. Furthermore, the close relationship and interdependency between all these environmental aspects makes the discussion about sustainable production of flexible bioenergy provision even more complex. Despite this complex concept of sustainability and the interdependencies described above, the political and social discourse is mainly focused on aspects such as climate protection or biodiversity. Major principles of sustainable biomass cultivation are important elements in various regulations on European and national level (e.g. in Germany). Since the production of energy crops to produce flexible bioenergy is part of general agricultural production systems in Europe, the respective regulatory framework for the agricultural sector and therefore many of the regulatory documents mentioned are relevant for the production of energy crops. The cross-compliance rules at European Union (EU) level for example include a number of requirements for good agricultural practice in biomass production. On a national level, additional measures (e.g. the Federal Immission Control Act[1]) supplement the European regulations by adding additional requirements (e.g. on thresholds for local emissions and environmental impacts). Compliance with the existing legal requirements enforcing sustainable cultivation of biomass is therefore a prerequisite for the establishment and running of energy plants to produce flexible bioenergy (e.g. in biogas systems).

One of the main drivers for the promotion of bioenergy systems in recent years has been the strong interest to reduce anthropogenic GHG-emissions. This aspect and potential benefit of bioenergy production in particular has been subject to intense debate in the recent past. In particular, the potential GHG emissions from

[1] Siebzehnte Verordnung zur Durchführung des Bundes-IMmissionsschutzgesetzes (Verordnung über die Verbrennung und Mitverbrennung von Abfällen – 17. BImSchV) vom 29.Januar 2009 (BGBl. I S.129)

the effects of change in land use (e.g. from the conversion of natural lands into cropland) as well as an inefficient use of biomass resources can reduce or even negate the potential GHG savings from the use of bioenergy (e.g., [8, 25]). This discussion illustrates the importance and need for the implementation of additional legal requirements for the biomass sector and bioenergy production. In regards to liquid biofuels, the Renewable Energy Directive has introduced a number of additional sustainability criteria [5]. The introduction of precise GHG-mitigation thresholds for biofuel systems are, among other criteria (e.g. requirements regarding good agricultural practice and the definition of no-go-areas) one key element of this directive. Expanding these criteria to all areas of bioenergy and biomass production (including the material use of biomass) in the years to come appears to be important and necessary in order to further increase the sustainability of biomass production.

3.3.1 Potential Environmental Issues Surrounding the Production of Energy Crops for the Provision of Flexible Bioenergy

The cultivation of energy crops for the production of flexible bioenergy follows the existing legal framework for agricultural production at European and national levels. Requirements and rules for good agricultural practice at national level (e.g. the Plant Protection Act (PflSchG),[2] the Federal Soil Protection Act (BBodSchG) and the Fertilisation Act (DüV) on a national level in Germany) are also relevant for the cultivation of energy crops (e.g. for biogas production) must also be adhered to for the cultivation of other crops (e.g. feed and fodder). From a legal perspective, the binding nature of these rules basically ensures the avoidance of severe negative effects on the soil from biomass cultivation for bioenergy production. This is also true for high potential emissions from the conversion of natural land into areas for agricultural production (land use change, LUC). In countries outside of the European Union this important aspect can be tackled with the help of sustainability certification schemes for biomass and bioenergy.

However, in addition to the general legal framework on the definition of good agricultural practice in the context of the existing cross-compliance, crop rotation systems, which include a wide variety of crops, show additional environmental benefits. Systems which include different shallow and deep rooting plants or plants providing carbon benefits etc. in particular can help to reduce potential risks from weeds, fungal diseases and other pests and to increase the overall nutrient and water availability in the soil compared to the monocultures. The use of elements such as plant protection agents might therefore be reduced. Furthermore, the cultivation of energy crops as part of a diverse crop rotation system can help to increase

[2] Gesetz zum Schutz der Kulturpflanzen (Pflanzenschutzgesetz in der Fassung vom 02. Dezember 2014).

soil cover and thus reduce soil erosion and the risk of nitrogen loss during the winter period [32, 33]. The potential effects of energy crop production on some of the environmental aspects discussed are explained in the next few paragraphs.

Soil Erosion

Improper or unsustainable cultivation of agricultural land can trigger and aggravate soil erosion through wind or water. The consequence of this development is the erosion of the fertile upper soil classes, a resulting degradation of the soil and possible soil devastation. These effects can influence the productivity of the soil and, due to the discharge of nutrients, also contribute to other undesired effects such as the eutrophication of water bodies. In addition to various other factors, the canopy in particular has a significant influence on the effects of possible soil erosion. For this reason, the integration of crop production for flexible bioenergy provision into diverse crop rotation systems and the avoidance of monocultures are of high importance.

Humus Balance

The term humus encompasses the whole of the soil organic matter, the designated organic residues and their degradation products. The maintenance or slight increase of the humus content on agricultural land due to a positive influence on the carbon and nitrogen turnover is one of the basic requirements and safeguards to ensure mid and long term soil quality [22].

Due to the permanent activity of soil organisms, the soil humus content is subject to a constant process of reduction, conversion and construction. This process is influenced by various additional parameters such as the type of vegetation, climatic factors or land use. The Humus content as well as its composition significantly influences the soil characteristics. The humus content in arable soils is therefore characterized, for example by intensive mixing with minerals and is approximately between 1.8 % and 2.5 %. The oversupply of soils with organic matter is just as detrimental as a lack of supply. This oversupply can result in uncontrolled mineralization and increased nutrient loss. For this reason, the overall humus balance of a cropping system is of significant importance. The supply of organic material (e.g. fermentation residues, green manure, straw, manure, slurry) can compensate possible humus deficits. It should be noted, that this basic principle of good agricultural practice should be applied and considered regardless of the final use of the produced agricultural goods (e.g. bioenergy production, food, fodder, industrial use). In contrast to other production systems, one advantage of the production of energy crops for biogas (e.g. for flexible energy provision) is the option of using the digestate (as co-product of the biogas process) to return a significant proportion of nutrients and carbon to the agricultural land [24].

Pesticides and Fertilizers

As described previously, the production of biomass for the provision of flexible bioenergy has to follow the very same existing governmental legal framework conditions as the production of other biomass for feed, fodder or other purposes. This includes requirements and thresholds for the use of pesticides or fertilizers. In some respects, systems for the production of feedstock for the supply of flexible bioenergy (e.g. silage maize) can be slightly modified in order to increase the methane yield of the energy crops. Some examples include the use of slightly higher seed densities, earlier harvest times at lower degrees of lignification and an ideal dry matter content as well as reduced chop lengths (to improve the enzymatic degradation of the biomass during fermentation) [10].

A decisive factor for the biomass and thus biogas yield is fertilizer management. Compared to conventional cropping systems (e.g. the production of wheat for food production) slight adjustments to the total amount of fertilizer used as well as to the time the fertilizer is applied are possible. This provides both environmental and economic benefits [32]. Furthermore, fertilizer management and application is one of the most crucial aspects affecting overall GHG emissions from the biomass production process [19]. GHG emissions from the use of nitrogen fertilizers for biomass production are influenced by two factors. The first is upstream emissions from the production of synthetic fertilizers. It should be noted that upstream emissions differ significantly depending on the chosen nitrogen fertilizer. Selecting a particular nitrogen fertilizer is therefore a promising method of decreasing emissions from the biomass production process [19]. The second important factor involves nitrous oxide emissions from the application of nitrogen fertilizer in agricultural systems. These emissions, often referred to as direct emissions or field emissions, are influenced by a variety of factors, namely climatic and regional aspects as well as spatial aspects such as the technique used for fertilizer application (e.g. especially for organic fertilizer). Their quantification therefore requires exact knowledge of the specific parameters of the site in question. However, a number of simplified approaches for the estimation of nitrous oxide emissions can be found in literature. The Intergovernmental Panel on Climate Change for example provides the methodology for a simplified calculation approach assuming approximately 1 % of the introduced nitrogen to be converted into nitrous oxide [16] Sustainable production of feedstock for the provision of flexible bioenergy therefore requires optimization of fertilizer management, not only of the economic but also environmental aspects.

Biodiversity

The literature available today does not allow for generalized statements on the impact of energy crop production on biodiversity. This impact is site specific and depends on the general characteristics of the cropping system. It can be stated, however, that the cultivation of energy crops provides both opportunities and risks for biodiversity. Positive effects are possible if the production of energy crops leads to improvements in the management system of the area compared to its initial state. As with the aforementioned environmental impacts, these potential positive effects are primarily influenced by the agricultural management system in place and only secondly by the specific type of crops cultivated. Consequently, a high diversity of crops and intelligent management of the crop rotation system with mixed culture species (including a reduction in the use of fertilizers and pesticides) can possibly contribute to increased biodiversity at the site [32]. This might lead to the conclusion that the use of crop rotation systems should not only be optimized in regards to yield increases, but also to achieve the greatest possible contribution to the enrichment of cultural landscapes in terms of different cultural groups of species and cultivation periods [32]. In addition, the use of wastes, residues or landscaping materials (e.g. in the biogas process) in particular can contribute to the protection of valuable habitats and the conservation of biodiversity. The cultivation of energy crops on agricultural land can comprise significant risks to biodiversity. In particular, the intensification of agricultural production systems and the cultivation of monocultures (e.g. due to the resulting increased use of pesticides) can lead to a serious decline of habitats and a significant loss of species. The increasing global demand for biomass for bioenergy and for industrial purposes results in additional pressure on natural areas. In this context, the cultivation of non-native and invasive species presents an additional risk for the conservation of biodiversity. Agricultural areas are the habitat of a variety of organisms. The cultivation of substrates for flexible bioenergy production provides, under consideration of the various guidelines and the existing legal framework for environmental sustainable production, a number of options and opportunities to increase biodiversity. However, the consideration of good agricultural practice and the cultivation in regionally appropriate and meaningful crop rotation systems is always a prerequisite for the cultivation of substrates.

3.3.2 Sustainability Certification

The previously mentioned environmental aspects of biomass production for the provision of flexible bioenergy have been described under the precondition of an existing and functioning governmental framework which addresses the sensitive aspects of agricultural production systems. Unfortunately, such a framework is not in existence in all parts of the world. Considering the fact that biomass feedstocks are increasingly becoming globally traded commodities this could lead to additional problems as far as the sustainable production of (especially) imported biomass is concerned. In this context, the use of liquid biofuels for transport purposes in particular has been discussed intensively within the recent years. As a result of this ongoing debate, the European Commission introduced the Renewable Energy Directive including a set of mandatory sustainability criteria as part of an EU sustainability scheme for biofuels and bioliquids [5]. Currently, these criteria only apply to a small share of the potential feedstocks for the provision of flexible bioenergy (biomass for liquid biofuel production). However, it seems possible and meaningful to expand these sustainability criteria also to other sectors of biomass and bioenergy production (including flexible bioenergy provision) in the future. For this reason, the current status of the available systems for the sustainability certification of biomass production, including a brief overview of the criteria included in their standards, will be discussed in the following paragraphs.

Most of the available schemes for the certification of a sustainable biomass production follow the set of sustainable criteria included in the Renewable Energy Directive. These criteria can be structured into three main elements. (I) The Directive excludes several land categories, with recognised high biodiversity value, from being used for biomass production. These are: (a) primary forests and other wooded land, (b) areas designated for nature protection or for the protection of rare, threatened or endangered ecosystems or species; (c) highly biodiverse grassland, either natural or non-natural. Biomass should not be produced from material from peatland and land with high carbon stock such as:(a) wetlands, (b) continuously forested areas, (c) land covered by trees higher than 5 m and a canopy cover between 10 % and 30 %. (II) For the biomass feedstock produced in the EU, the cross-compliance rules of the Common Agricultural Policy apply, in accordance with the requirements for good agricultural and environmental conditions. The EU cross compliance regulations refer to preservation of soil and water quality, of biological diversity, careful use of fertilisers and pesticides and air pollution. (III) Third major aspect of the sustainability criteria included in the Renewable Energy Directive is the introduction of mandatory GHG-mitigation thresholds for biofuel technologies compared to a fossil reference value (35 % relative to fossil fuels, to increase to 50 % in 2017 and 60 % in 2018 for new biofuel plants). Furthermore, in 2010 the Commission has published a report to provide EU Member States with recommendations for developing national schemes for solid and gaseous biomass used in electricity, heating and cooling [6].

Based on these criteria a number of certification schemes have been developed over recent years and recognised by the European Commission. Several of these schemes for the agricultural sector address a core set of concerns relating to sustainable farming practices, agrochemical handling and use, safety and health and food traceability, with the sustainability criteria addressing mainly environmental aspects. In addition, a number of new initiatives faced rapid development to establish sustainability certification schemes for biofuels feedstock production in tropical countries, such as palm oil, sugarcane and soybean. The existing certification schemes cover a wide area of objectives from specific sectors (agriculture, forestry, etc.) to specific purposes (fair-trade, environmentally sound cultivation, organic agriculture, etc.). While certification schemes for the agricultural sector (such as IFOAM,[3] GlobalGAP,[4] SAN[5] and FAIR TRADE) have been developed primarily developed to

[3] IFOAM: International Federation of Organic Agriculture Movements.

[4] GlobalGAP: Global Good Agricultural Praxis.

[5] SAN: Sustainable Agriculture Network.

ensure health and safety of given products or develop organic agriculture, forestry standards (such as FSC[6] and PEFC[7]) were set to ensure sustainable management of forests. The following table provides a general overview of different existing certification schemes related to biofuel and bioenergy certification. Depending on their main focus, the detail of the environmental, economic and social sustainability aspects included in the standard of the schemes differs strongly across the different schemes. The Table 3.2 summarises the complexity and the completeness of the environmental criteria included in the main certification schemes for biofuels and bioenergy. It furthermore shows great differences between the schemes with regards the completeness of their standards. Since major aspects for environmental sustainability such as the protection of natural areas are of high relevance for the use of all biomass (not only biomass for bioenergy) the existing certification schemes and initiatives should be developed further with regards to the considered indicators and the markets addressed (food, feed, fibre, fuel etc.).

3.4 Conclusion

The resource basis for bioenergy consists of biomass residues, by-products and waste from different sectors and from energy crop production. The global potential of residues, by-products and waste is in a scale of 5–10 GJ per capita and year, including a wide range of qualities needing additional effort to convert them into bioenergy. Due to the strong influence of a number of parameters (e.g. development of crop yields, population growth, per capita consumption, foreign trade balance etc.) available studies on the global biomass potential of energy crops reach different conclusions.

As a result of the recent discussion about the sustainability of bioenergy, different initiatives and schemes for sustainability certification have been developed and implemented for a number of bioenergy pathways (cf. Table 3.2). The existing schemes differ significantly in regards to the variables they consider and thus in the complexity of their indicators and standards. Since major issues for environmental sustainability, such as the protection of natural areas, are highly relevant to the use of all biomass (not only biomass for bioenergy) in terms of developing a more coherent sustainability framework, the existing certification schemes and initiatives should be developed further by addressing the indicators and markets considered. Furthermore, these certification schemes and initiatives should be made an integral part of international agreements. The future development of these schemes and the possible expansion of their application across the whole agricultural or forestry sector will, additionally, influence the future biomass potentials of energy crops and highlight the actual uncertainties of these future potentials.

[6] FSC: Forest Stewardship Council.

[7] PEFC: Programme for the Endorsement of Forest Certification Schemes.

Table 3.2 Environmental aspects considered by different certification schemes (+ aspect included, – aspect not included) (According to [23])

	EU-RED	GBEP	RSB	ISCC	NTA 8080	RTFO	RSPO	FSC	PEFC	GLOBAL GAP
Environmental impact assessment	–	+	+	+			+	+		+
Good farming practice	+		+		+	+	+	+		+
Site history				+				+		+
Sustainable use of resources	–									
Carbon conservation										
Preservation of above/below ground carbon	+			+	+	+	+			
Land use change	+	+	+	+	+		+	+		
GHG emissions	+	+	+	+	+		+			
Biodiversity conservation										
Biodiversity	+	+	+	+	+	+		+	+	+
Natural habitats, ecosystems	+	+	+		+	+		+	+	+
High conversation value areas	+		+	+		+	+	+		+
Negative, endangered and invasive species	+	+	+			+	+	+	+	
GMO	–		+				+	+		+
Soil conversation										
Soil management, soil protection	+	+	+	+	+	+	+	+	+	+
Residues, wastes, by-products	+		+				+	–		
Use of agrochemicals	+		+	+		+	+		+	
Waste management	+		+	+	+	+	+	+		+
Sustainable water use										
Water rights			+	+						
Water quality	+	+	+		+	+	+			+
Water mangement, conversation			+	+	+	+	+			
Efficient water use		+	+							
Air quality										
Air pollution	+	+	+	+	+	+				
No burning for land clearing/ waste disposal		+			+	+	+			
No burning residues, waste, by-products			+			+				+

In regards to the provision of flexible bioenergy two conclusions can be drawn:

– In regards to the provision of flexible bioenergy, a stronger focus on specific conversion pathways also leads to a higher demand for specific feedstock or additional feedstock preparation. However, this might not change the discussion on sustainable biomass potentials dramatically.
– The biggest challenges relate to biomass potentials from energy crops, which are highly uncertain. With regard to smart bioenergy provision, one possible option could be to increase the flexibility of (existing) larger production units based on energy crops by widening their product portfolio.

Finally, it can be stated that the biggest potential for additional bioenergy provision can be provided by accelerating the transition from traditional to modern bioenergy use. Since almost two-thirds of the current global use of biomass for bioenergy is converted in inefficient processes, such a transformation would also provide a wide range of benefits with regards to social (e.g. health issues as a result of particle emissions), economic (adding value due to a more efficient use of a scarce resource) and environmental (increasing the efficiency of future bioenergy systems might be one important method of reducing the pressure on natural areas) issues.

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