Biomass potentials and competition for biomass utilisation

Short study in the context of the

scientific supervision, support and guidance of the BMVBS in the sectors Transport and Mobility with a specific focus on fuels and propulsion technologies, as well as energy and climate

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Abbreviation	Explanation
Art.	Article
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle (German Federal Office of Economics and Export Control)
BAU	Scenario 'business as usual'
BImSchG	Bundes-Immissionsschutzgesetz (German Federal Immission Control Act)
BImSchV	Bundes-Immissionsschutzverordnung (German Federal Immission Protection Ordinance)
BioKraftFÄndG	Gesetz zur Änderung der Förderung von Biokraftstoffen (Act on the Amendment of the Promotion of Biofuels)
Biokraft-NachV	Biokraftstoff-Nachhaltigkeitsverordnung (German Biofuels Sustainability Ordinance)
BiokraftQuG	Biokraftstoff-Quoten-Gesetz (German Biofuel Quota Act)
BiomasseV	Biomasseverordnung (German Biomass Ordinance)
BioSt-NachV	Biomassestrom-Nachhaltigkeitsverordnung (German Biomass Electricity Sustainability Ordinance)
BLE	Bundesanstalt für Landwirtschaft und Ernährung (German Federal Office for Agriculture and Food)
BMVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung (German Federal Ministry for Transport, Building and Urban Development)
BtL	Biomass-to-Liquid fuel
CAP	Common Agricultural Policy
CDS	Condensed Distillers Solubles
CHP	Combined heat and power (Cogeneration)
CO_2-Eq.	Carbon dioxide equivalent
DBFZ	Deutsches Biomasseforschungszentrum gGmbH (German Biomass Research Centre)
DDGS	Dried Distillers Grains with Solubles
DME	Dimethylether

Abbreviation	Explanation
DW	Dry Weight
EAG EE	Europarechtsanpassungsgesetz Erneuerbare Energien (European Law Adaptation Act for Renewable Energies)
EC	European Commission
EEG	Erneuerbare-Energien-Gesetz (German Renewable Energies Act)
EEWärmeG	Erneuerbare-Energien-Wärmegesetz (German Renewable Energies Heat Act)
EG	European Community
EnStG	Energiesteuergesetz (German Energy Tax Act)
Eq.	Equivalent
EU	European Union
EU-RED	EU Directive 2009/28/EC (Renewables Directive)
FAO	Food and Agriculture Organization of the United Nations
FQD	Fuel Quality Directive
FT	Fischer-Tropsch diesel
GHG	Greenhouse gas
HEFA	Hydrotreated Esterified Fatty Acids
HVO	Hydrotreated Vegetable Oil
KWKG	Kraft-Wärme-Kopplungsgesetz (German Combined Heat and Power Act)
MFS	German Mobility and Fuels Strategy
NREAP	National Renewable Energy Action Plan
RE	Renewable Energies
t abs-dry	Ton absolute dry weight
t air-dry	Ton air dried

1 Summary

The present short study assessed the potentials of arable land and grassland for the cultivation of biomass for energy or material purposes at the German federal state level to the year 2030 using a statistical approach. The model was based on the total of agricultural land available in Germany. In the process, existing demands for other established purposes (e.g. food and feed production, areas for landscape and nature conservation etc.) were successively deducted. A scenario-based approach allowed the investigation of the consequences of a stronger focus on selected ecological aims and goals (including the expanded use of organic agriculture practices) for available land potentials. The total area available for the production of food, feed and renewable resources is expected to decrease by 2030. However, current projections on demography and potential improvement of agricultural yields and production efficiency indicate a slight increase of agricultural land available for bioenergy production by the year 2030.

Based on the model calculations, potentials of 2.7 to 3.3 and 3.0 to 3.9 million ha arable land could be identified in 2020 and 2030, respectively. The percentage of agricultural land utilised for the cultivation of renewable feedstocks will thus be between 27 and 34 % of total arable land available. A comparison among the federal states shows that by far the largest land potentials are located in Lower Saxony and Bavaria. Considerable potentials are further found in Mecklenburg-Vorpommern, Saxony-Anhalt, Brandenburg und Baden-Württemberg.

In addition to the utilisation of renewable feedstocks, the production of bioenergy derived from residues or waste materials holds considerable promise. The national technical potentials of residues and waste materials including forestry biomass for bioenergy production are estimated to be on the order of 1,000 PJ/a in 2020.

The land and biomass potentials presented are not exclusively available for the production of biofuels. Biofuel production technologies are currently competing for area and biogenic feedstocks at several levels. Competition may be further exacerbated through the variety of funding policies including subsidy schemes and incentives, as well as the differing targets for the development of the individual bioenergy sectors. For the purpose of discussion and development of a quantitative target for biofuels in the national transport system, a number of factors should be considered. These include the availability of land and biomass potentials for energy generation purposes, the influence of incentives and subsidies (e.g. feed-in tariff in the German Renewable Energy Act versus biofuel quota for biofuels in transport), as well as the development targets of the individual bioenergy sectors. Future harmonisation and concerted advancement of these incentives and development targets are recommended.

2 Introduction and aims of the study

In the past, a number of different policies in combination with high oil prices resulted in a dynamic development of the production of bioenergy for the electricity, heat and mobility sectors. Overall, demand for a diversity of biomass fractions increased significantly. Thus, existing biomass markets were stimulated and new biomass markets were established both at regional and international level. Intense public debate on aspects of sustainability surrounds the recent rise of bioenergy development. In addition to the consequences of bioenergy development for the countryside (e.g. an increase in the cultivation of maize crops), this debate is strongly focused on aspects of the arising competition between the cultivation of foodstuffs for human and animal consumption and energy crops. In this context, potential ecological and social consequences of biomass imports (e.g. deforestation of virgin rainforest areas for the purpose of palm oil or soybean cultivation) feature prominently in the debate. The present study explores the potential contributions of biofuels to the general Mobility and Fuels Strategy (MFS). For this purpose, it models the areas of arable land and grassland in Germany available for bioenergy production in theory to the year 2030. These land potentials are designated by federal state and may be applied during the continuing scientific supervision of the MFS (e.g. in the fuel matrix). In addition to the calculation of land potentials for utilisation for energy purposes, the study provides an overview of the current status of potentials derived from residues and waste materials as well as forestry biomass potentials in Germany. An outlook on international biomass potentials from both agriculture and forestry complements the study (Chapter 4).

Biofuels are competing for land and biogenic feedstocks at several levels. The first part of the study illustrates available land potentials. Thus, the biofuel potential may be inferred. However, for this purpose, consideration of both the social acceptance of energy crop cultivation and the interactions and competition for biomass utilisation between the various bioenergy sectors is of vital importance.

The present short study therefore aims to inform and support the debate on the allocation of the available land potentials for the production of electricity, heat and biofuels within the scope of the MFS (e.g. in context with the short study RE in transport). For this purpose, the present study provides an exemplary overview of both the policy framework of incentives and subsidies for bioenergy production and the cost structure of exemplary biofuels technologies.

3 Essential conclusions from the short study for the MFS

- Calculations reveal a current land potential for the production of renewable resources of approximately 2.2 million ha of arable land in Germany. The future land potential for the production of renewable resources ranges between 2.7 and 3.3 million ha of arable area in 2020 and between 3.0 and 3.9 million ha in 2030. The present calculations were carried out under the assumption that the status quo of import and export levels for food and feed in Germany will remain constant. Changes in the level of self-sufficiency or increased exports for the purpose of safeguarding global nutrition would impact the reported potential.
- The calculated land potentials are available for a number of uses. Among these are the production of biomass for the purpose of electricity, heat or biofuel generation, material use of renewable resources as well as the pursuit of sustainability aims and goals (e.g. extension of nature conservation areas). In this context, the allocation of available potentials is strongly influenced by a variety of funding policies including subsidy schemes and incentives, as well as the expansion targets of the individual sectors. The effects of contrasting policies on the development of the bioenergy sectors including the biofuels sector should be subject to further investigation during the scientific supervision and guidance of the MFS (e.g. in the context of the short study RE in transport).
- Technologies for the production of biofuels are competing for area and biogenic feedstocks at several levels. Both differing policies for subsidy schemes and divergent expansion targets for the development of the individual bioenergy sectors may further exacerbate the competition. Therefore, discussion and development of a quantitative target for biofuels in the national transport system should consider a number of factors. These include the availability of land and biomass potentials for energy generation purposes, the influence of policies for incentives and subsidies (e.g. feed-in tariff in the German Renewable Energy Act versus biofuel quota for biofuels in transport), as well as the development targets of the respective bioenergy sectors. Future harmonisation and concerted advancement of these incentives and development targets are strongly recommended.
- For the purpose of assessing the potential contribution of biofuels, both the social acceptance of the expansion of the overall bioenergy sector and the interactions between the various bioenergy sectors have to be taken into account.

- The environmental impacts of the utilisation of residues and waste materials are much lower than those associated with the cultivation of biomass. However, these materials frequently accumulate in a decentralised manner, thus resulting in additional logistic challenges compared to the production of biofuels derived from energy crops.
- Future competitiveness of biofuels is largely dependent on the underlying cost structures. Production costs of current biofuel options are clearly dominated by the influence of the cost of feedstocks. Thus, there are few opportunities for cost reduction. For future biofuel options, however, biomass conversions costs are the determining factor. In the case that the evident cost reduction potential is realised, the competitiveness of these options will significantly benefit.

4 Land potentials for the production of bioenergy in Germany

Energy derived from biomass plays a key role in the development of future energy systems due to its versatility. Feedstocks suitable for the production of bioenergy include agricultural and forestry substrates as well as residues and byproducts such as straw and livestock manure. Energy crops for the production of bioenergy may be cultivated on agricultural land, including both arable land and grassland. Areas of arable land and grassland potentially available for the future production of heat, electricity and fuels are in short supply due to competition for utilisation. In this context, a number of parameters and variables have to be considered.

The present short study calculated the arable land and grassland potentials in Germany at the federal state level to the year 2030 in order to estimate the area that may potentially be available for the production of bioenergy carriers in the future. The following presentation of results first introduces the general approach, or rather the methodology employed for the estimation of the potentials. Development of scenarios allows the analysis of the influence of various parameters on the size of the available areas. Furthermore, these scenarios illustrate the range of magnitudes the potentials may cover. The results may serve as a base for future work and discussion within the scope of the MFS. In addition, the results may be integrated with current work on the biofuels matrix and the short study ‘Renewable energies in Transport’.

The calculation of the following potentials for arable land and grassland included a number of assumptions for the definition of certain variables. These assumptions in turn affect the results of the calculation of the potentials to a varying degree. A selection of the variables is presented in Table 1.

Table 1: Land potentials: Overview of major variables (scenario drivers)

Variable	Explanation
Development of crop yields*	High yields reduce the size of the agricultural area required for food and fodder cultivation, thus increasing land potentials
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 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

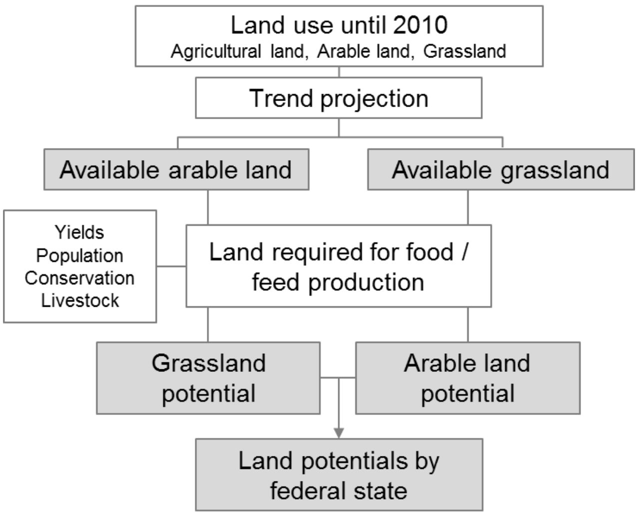
* Asterisk in Table 1 denotes factors included in the study. The following chapter 4.1 illustrates the methods for the modelling of these factors.

4.1 Methodology and procedures

All calculations of land potentials for arable land and grassland were based on the data available at federal state level as published by the German Federal Statistical Office (STATISTISCHES BUNDESAMT, 2013). For the calculation of land potentials within the scope of the present short study, an Excel-based tool was developed. The tool allows constant updating of the input data as well as changes to variable parameters that require adjustment. The overall approach is illustrated in a simplified overview in Figure 1.

The initial calculation step included an assessment of the total area of arable land and grassland available for the production of food, feed and bioenergy. Published statistics report the arable land and grassland currently under cultivation as well as the total agricultural area per federal state. The annual change in land use in the period between 2003 – 2010 was extrapolated to the year 2030 under consideration of the current legal framework. In this context, it should be pointed out that 'the percentage of permanent pasture of the agricultural area in question may not be significantly reduced in reference to the year 2003' (BUNDESMINISTERIUM DER JUSTIZ (idF. v. 2004)).). In the case that the mandatory limit (max. 5 % of the area in 2003) for the conversion of permanent grassland in a federal state is reached, the model automatically caps the conversion. The area total of grassland is then maintained constant at the minimum permitted. Any additional area required due to the conversion cap is balanced by existing arable area.

Figure 1: Approach for the assessment of land potentials for bioenergy purposes



First priority in the production of biomass for energy purposes is assigned to the safeguarding of food and feed supply. Utilisation of land for the cultivation of energy crops is permitted strictly on the condition that future demands for food and feed are fully met. **The total area required for the production of food and feed** depends on a number of variables. Among those are the development trajectories of yields and the resident population, the political framework or changes to the per capita consumption rate etc. (Table 1).

Therefore, a subsequent calculation step analysed and quantified the influence of the trajectories of crop yields, population growth, nature conservation areas and livestock numbers in correlation with the area required for food and feed production (Figure 1). A number of additional factors, such as changes to the material flows between regions or changes in cultivation, were excluded from the present study. The calculation of the parameters included in the model follows below.

To estimate the areas required for food and feed production, an assessment of the development trajectory of **crop yields** is of vital importance. An increased yield may be achieved through progress in crop breeding or optimised use of operating resources. Due to the fact that the physiological growth limitations of individual crops limit crop yield development, the present study does not assume a linear relationship of crop yield trajectory over time. Future annual yield increase projections are based on the relevant literature (Fritsche et al., 2004; Simon, 2007; Bringezu et al., 2008; Schönleber, 2009; Bringezu et al., 2009). These data allowed the inference of crop-specific yield increases. Information on the distribution of crops[1] in each federal state allowed an estimate of the yield trajectory to the year 2030 in the following calculation step. Thus, significant expected yield increases for crops such as rapeseed feature more strongly in the federal states of Mecklenburg-Vorpommern or Saxony-Anhalt due to extensive local cultivation. Employing this method, the average annual yield increase rate is calculated to the year 2030 for each federal state. For grassland, no yield increase is expected.

Due to the fact that the projection of future yields is subject to considerable uncertainty, the influence of the parameter was further estimated with a sensitivity analysis (see Appendix, Figure 19).

For nature conservation purposes, both the Habitats Directive and the Water Framework Directive are of relevance. In this context, the calculation tool accepts input of the size of the areas and application of a factor to quantify yield decreases related to restricted cultivation. The area requirements for nature conservation purposes vary considerable between federal states. In some cases, data on these areas may only be obtained from the individual state agencies. Therefore, area requirements for selected landscape and nature conservation goals are factored in the 'base scenario with added environmental restrictions' (see Chapter 4.2) only.

1 Wheat, rye, barley, oats, triticale, rapeseed, maize, potatoes, sugar beet.

Furthermore, existing regulations are currently subject to discussion within the scope of the Common Agricultural Policy (CAP) reform. Thus, the future development of these areas is difficult to predict at present.

Population growth at the federal state level as one of the variables affecting the potential was estimated by the German Federal Statistical Office to the year 2030. The overall population decline is likely to result in a decreased demand for land for food and feed production.

The estimate of the **agricultural land potential** was based on agricultural areas under cultivation of foodstuffs for human or animal consumption in 2010. The size of these areas is expected to fluctuate in correlation with annual changes in the population of each federal state. In this context, a general maintenance of the status quo of food and feed imports and exports is assumed. Furthermore, the level of self-sufficiency is assumed to remain constant. At the same time, the average yield increase is expected to result in a decrease of the area total required for food and feed production. Additional land may be required, however, as a consequence of yield decreases resulting from conservation measures. The agricultural land potential is defined as the difference of the calculated total agricultural area and the total area required for food and feed production.

The development trend of **livestock numbers**, including the correlated demand for forage, represents a major factor influencing the area of grassland and pasture required for the production of forage crops. Demand for forage crops is calculated in two steps. Initially, the projected future numbers of relevant grazing stock including cattle, sheep and horses are calculated by extrapolation[2] for each federal state.

In a subsequent step, a typical feed ration is assigned to each species according to KTBL, 2009 and KTBL, 2012. In addition, the respective yields of grasses from pasture and grassland, hay and silage are calculated under consideration of dry weight loss. The combination of the numbers of livestock, the respective feed requirements and the average crop yields allows the calculation of the area required for annual feed production for each federal state. Thus, the **grassland potential** is defined as the difference of the total area of grassland and pasture and the total area required for the production of forage crops.

[2] Extrapolation was carried out following a linear or an exponential trend depending on the coefficient of determination.

4.2 Scenarios for the calculation of potentials

Due to the influence of multiple factors, the projection of future potentials is generally fraught with uncertainties. In consequence, it is recommended to report orders of magnitude or ranges into which resulting potentials may fall. In this context, it is possible to modify variables in a number of ways, thus generating a multitude of scenarios. The present study developed two scenarios, which are presented detailing the underlying assumption in the following.

A projection based on the status quo is carried out in the **base scenario**. In this scenario, grassland is continuously converted to arable land up to the area limit stipulated by current legislation. The area is then capped at the limit and no further conversion takes place. All variables under consideration are expected to follow current trends.

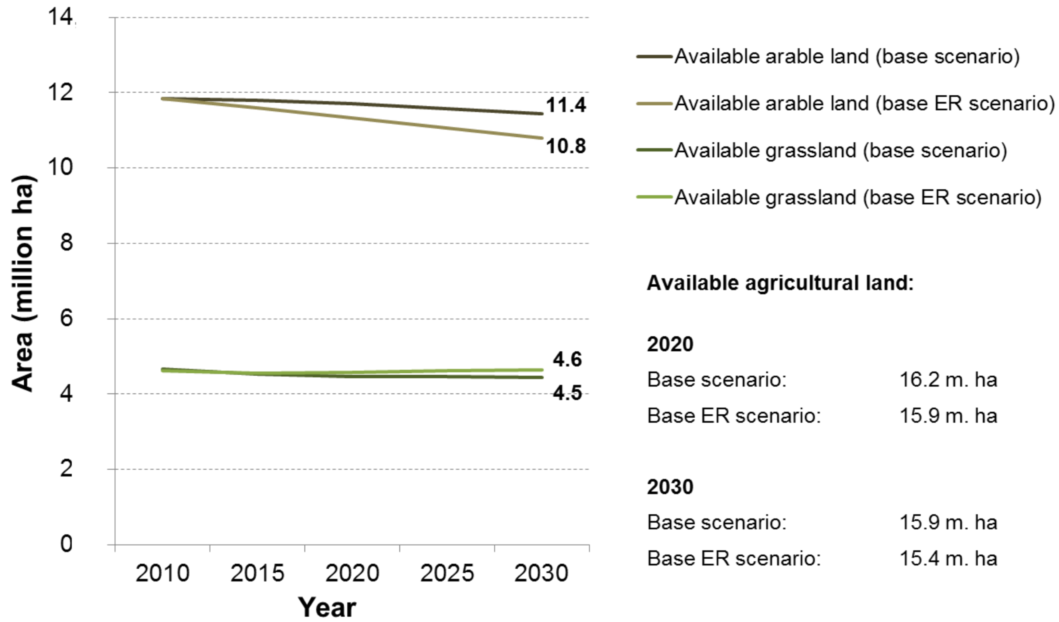
By contrast, the base scenario with added environmental restrictions (base ER scenario) is strongly focused on environmental concerns and nature conservation efforts. Contrary to current legislation, the conversion of grassland ceases with the year 2013. Due to the more rigorous conversion cap, agricultural areas are required to balance a larger area demand compared to the base scenario. Moreover, aims and goals of the 'National Strategy on Biological Diversity' adopted by the German cabinet in 2007 were given special consideration (BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ UND REAKTORSICHERHEIT (BMU), 2011). According to the strategy, by the year 2020 'nature may develop without interference or disturbance in an area of 2 % of the total area of Germany (e.g. in mining restoration sites, […], in mires and in alpine regions) to create areas of wilderness'. The strategy assumes that the target may be achieved in full by abandoning the agricultural management and farming of mire habitats. The implementation requires discontinuation of utilisation of 480,000 ha mire terrain utilised as grassland and 240,000 ha utilised as agricultural land. In addition, the base ER scenario realises the goal of the Strategy to apply organic farming practices to 20 % of the total agricultural land by 2020. In 2010, the percentage of agricultural land farmed organically was 5.6 % with an increase of 2.6 % since 1999 (BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND VERBRAUCHERSCHUTZ (BMELV), 2012). Organic farming practices result in decreased yields in these areas[3]. Furthermore, organic livestock farming is increasing annually, and feeding is adapted accordingly.

[3] Yield decrease through organic farming of agricultural area was estimated 37 %. Yield decrease through organic farming of grassland was estimated 20 %.

4.3 Results

Figure 2 illustrates the projections of the total agricultural land divided into arable land and grassland for both scenarios. The projected areas are available for food and feed production as well as the production of renewable resources (for material and energy purposes). Over time, the total area available as arable land or grassland will continue to decline. The decrease is due to expanding development of human settlements and transport infrastructure, amongst other factors. In 2020, an area of 16.2 million ha is projected to be available in the base scenario, whereas the base ER scenario results in an area total of 15.9 million ha. The available arable land is projected to be shrinking in both scenarios. However, grassland areas remain constant in the base ER scenario due to conversion cap.

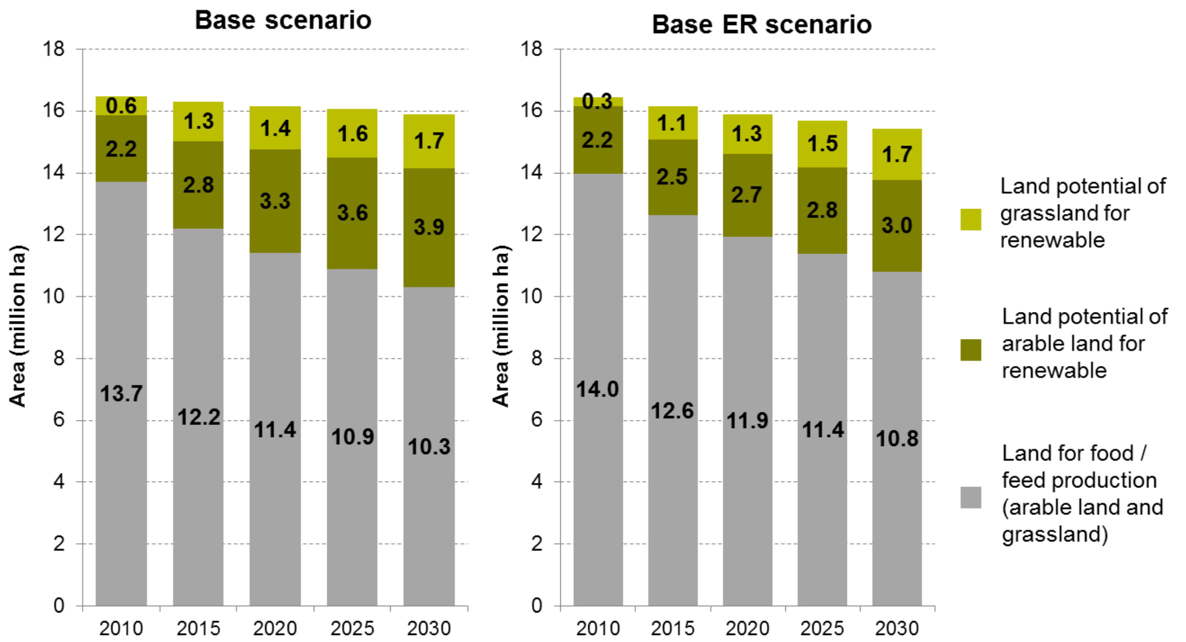
Figure 2: **Projection of the area available as arable land and grassland (Calculation by DBFZ)**



Declines in population growth and livestock numbers in combination with yield increases steadily reduce the area required for food and feed production (Figure 3). In consequence, this reduction leads to an increase in the land potentials of arable land and grassland despite that overall decline of agricultural areas. Thus, the percentage of renewable resources in cultivation on arable land could range between 24 and 29 % in 2020, and between 27 and 34 % in 2030, depending on the scenario. Currently, approximately 21 % of the arable area is utilised for the cultivation of energy and industrial crops (Fachagentur Nachwachsende Rohstoffe e. V. (FNR), 2012). The difference between the scenarios arises due to the stronger focus on environmental concerns and nature conservation in the base ER scenario.

The differences between the scenarios are less pronounced in regard to grassland potentials. Despite the more stringent grassland conversion cap and the emphasis on organic agriculture and livestock farming in the base ER scenario, both potentials are projected to be approximately 1.7 million ha in 2030. This represents 36 or 39 % of the total grassland area, depending on the scenario.

Figure 3: Projection of the land potentials within the agricultural areas – comparison of scenarios (Calculation by DBFZ)



For an integrated presentation of results, land potentials of both scenarios for the year 2020 are reported in comparison with current statistics on the cultivation of renewable resources (Figure 4, Figure 5) (Fachagentur Nachwachsende Rohstoffe e. V. (FNR), 2012). The figures further illustrate the distribution of current energy crop cultivation across the individual bioenergy sectors.

Figure 4: Comparison of the land potentials in the base scenario and the current land use for the cultivation of renewable resources (Calculation by DBFZ, FNR 2012)

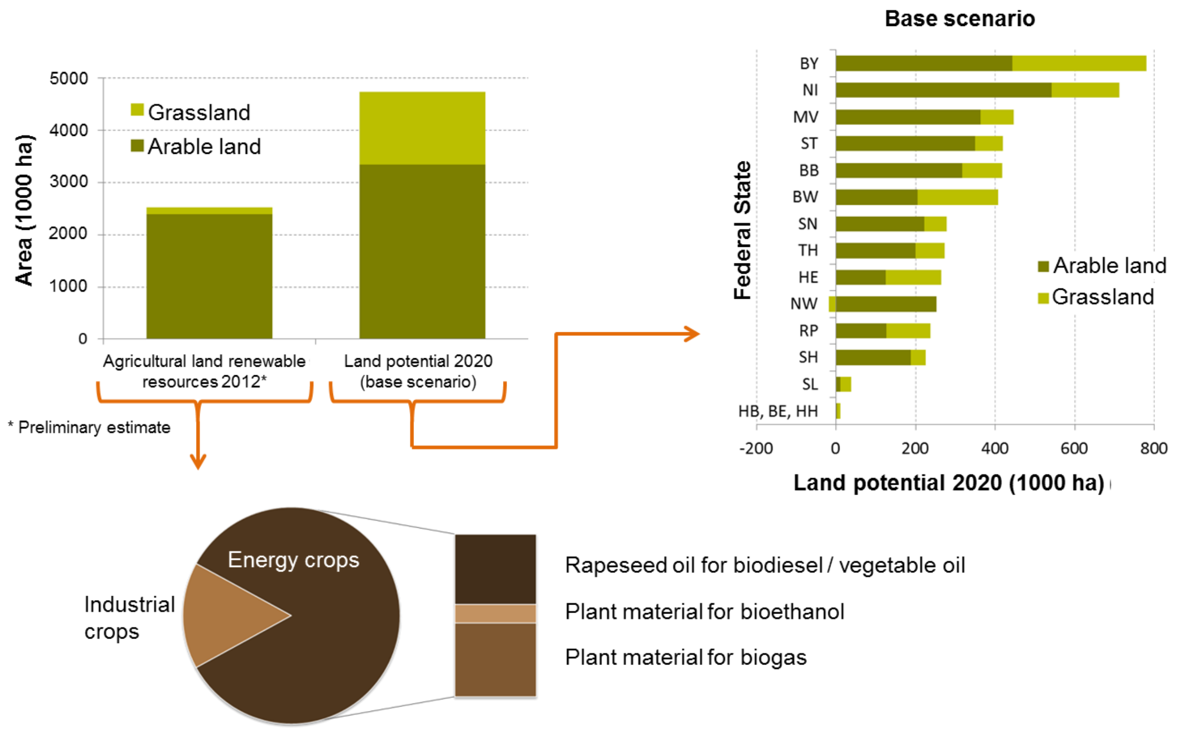


Figure 5 illustrates the results of the base scenario with added environmental restrictions (base ER scenario) for the year 2020 in comparison with current land use for the cultivation of renewable resources (energy and industrial crops).

Figure 5: **Comparison of the land potentials in the base ER scenario and the current land use for the cultivation of renewable resources (Calculation by DBFZ, FNR 2012)**

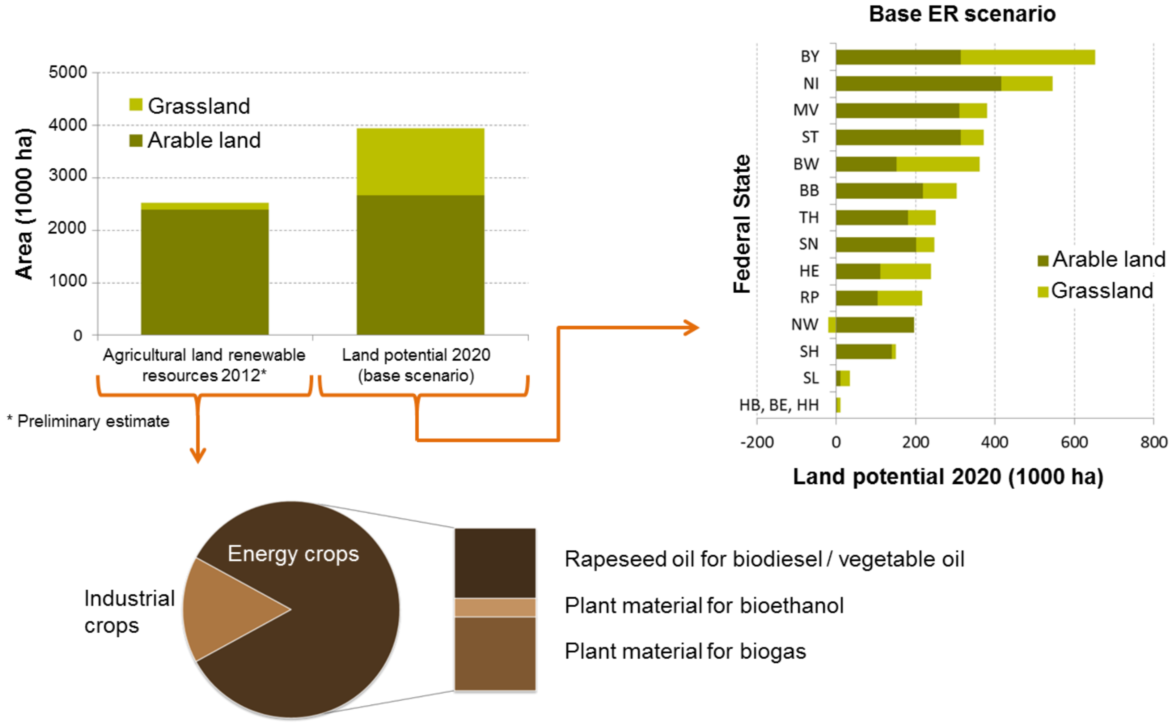
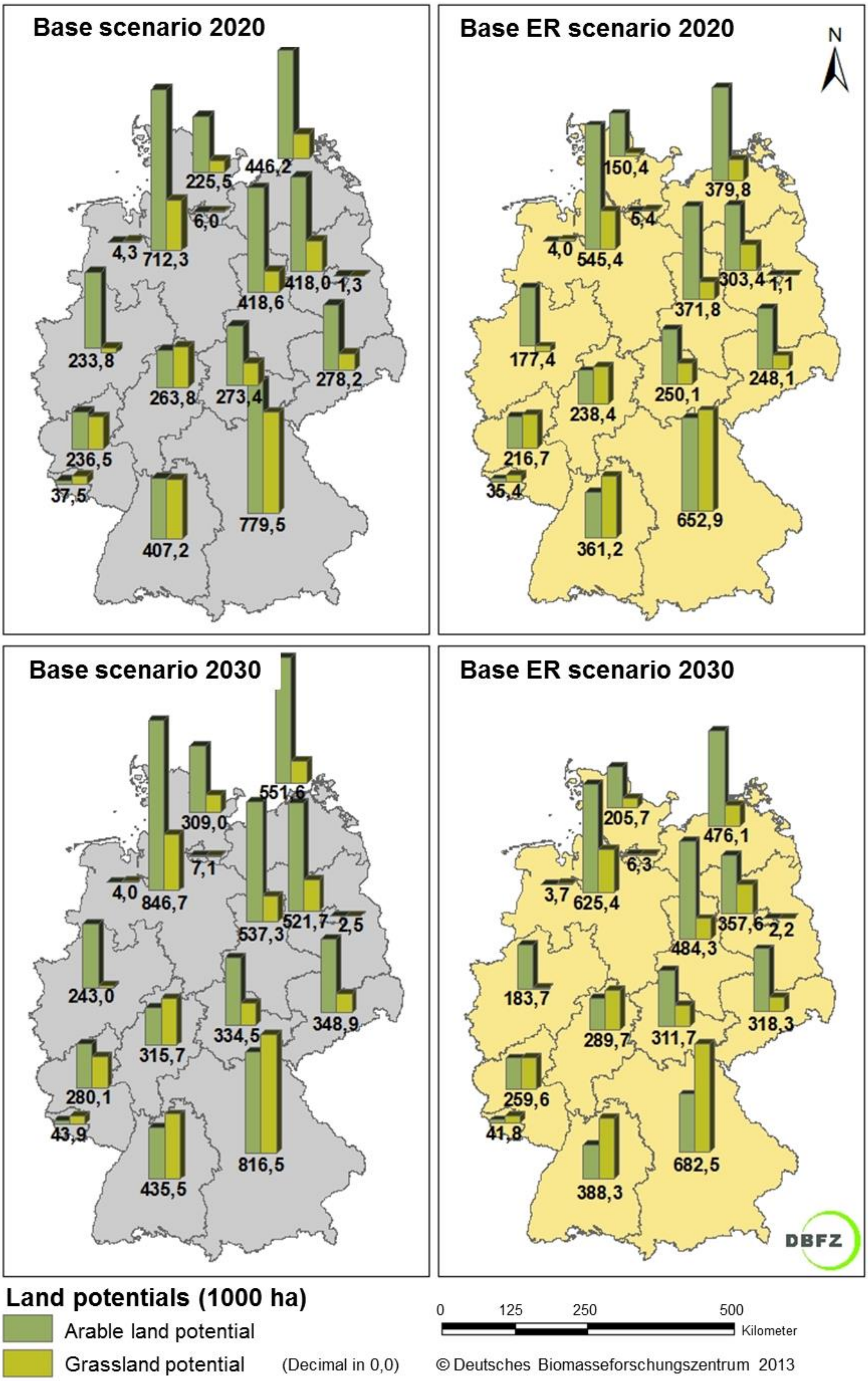


Figure 6 illustrates the distribution of potentials of arable land and grassland for both scenarios in 2020 and 2030. In all federal states except Bremen, land potentials are on the increase within that period. The greatest land potentials by far were identified in Lower Saxony and Bavaria. Potentials of similar significance were detected in Mecklenburg-Vorpommern, Saxony-Anhalt, Brandenburg und Baden-Württemberg. The lowest potentials were found in the city-states Berlin, Bremen and Hamburg due to a low overall proportion of agricultural area. A general trend identified considerable grassland potentials in the south of Germany in particular. These significantly exceed arable land potentials, most notably in the base ER scenario. A detailed description of all arable land and grassland potentials in both scenarios may be found in the Appendix in Table 4 and Table 5.

Figure 6: Distribution of land potentials in Germany in 2020 and 2030 (Calculation by DBFZ)



Excursus: Land potentials in Germany in the literature – a meta-analysis

The future areas available for the cultivation of biomass for material and energy purposes have been estimated in a number of studies. A comparison of these studies reveals a wide range of results. For instance, the calculated land potentials in the year 2020 vary between 0 ha and 7.6 million ha (). In 2030, the potentials range from 0 ha to 6.1 million ha (Figure 8). The majority of the studies employ similar methodology. The considerable differences in outcome are primarily related to the parameters factored into the models. The extent of available brownfield land, the assumptions for the realisation of conservation goals (including organic farming) and future yield expectations are among the factors that most frequently differ between studies. In this context, the various parameters are modified inconsistently depending on the scenario, which could result in high maximum values. Furthermore, a number of studies investigate the potentials of arable land only, whereas others consider the total agricultural land including grassland.

Figure 7: Land use potentials in Germany 2020 – meta-analysis of available literature

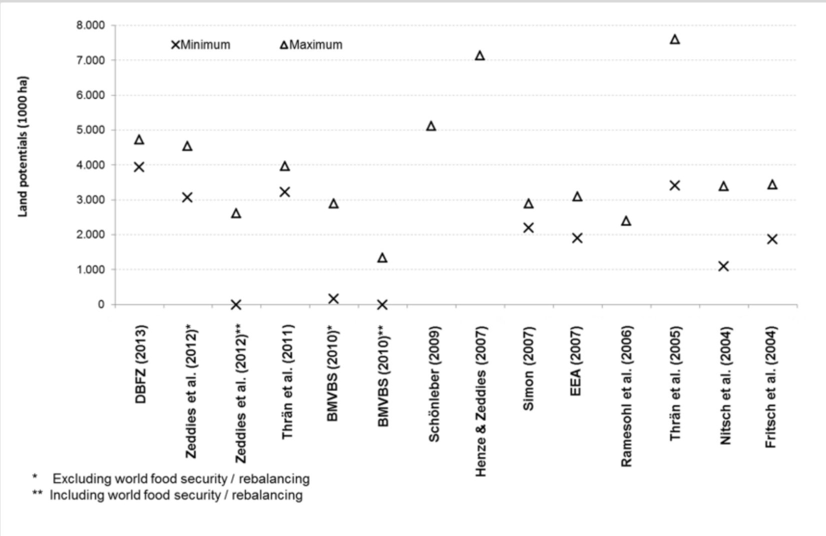
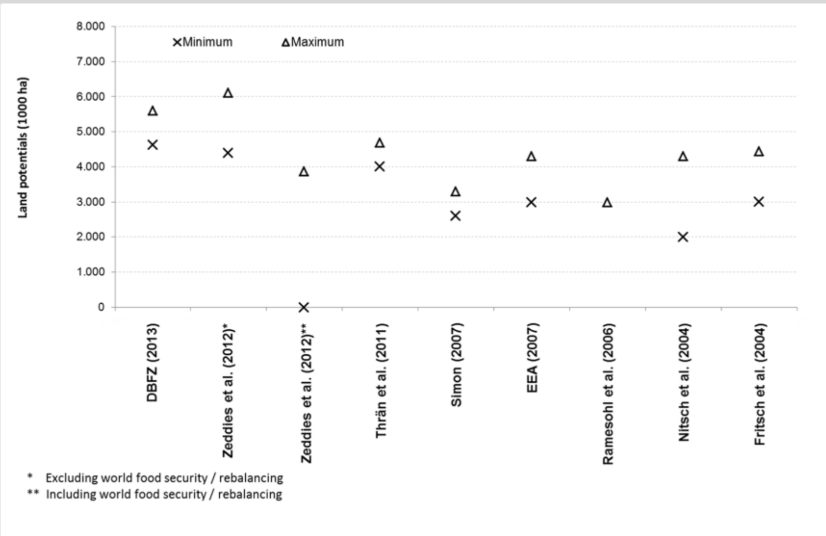


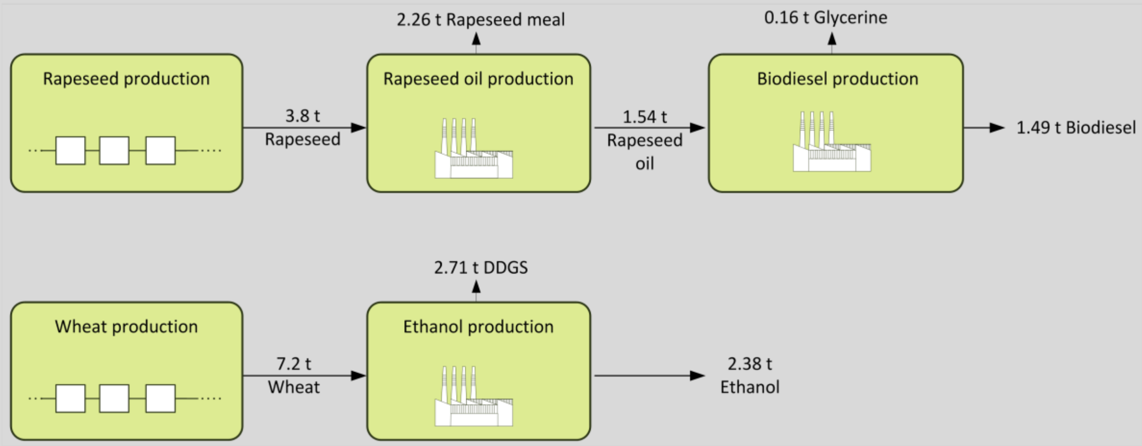
Figure 8: Land use potentials in Germany 2030 – meta-analysis of available literature



Excursus: The links between land potential and biofuel potential

Land potentials may be perceived as an abstract concept for the consideration of energy or transport matters. Figure 9 exemplifies the relationships between land potentials and biofuel potentials for the biofuel potential per ha of two biofuel production pathways, i.e. biodiesel (from rapeseed) and ethanol (from wheat). The fuel yields may differ significantly due to differences in specific yield of the various energy crops and variable conversion efficiencies depending on the fuel technology. For these reasons, considerable differences between the various biofuels and their respective fuel yields per ha exist.

Figure 9: Biofuel potential of biodiesel derived from rape seed and bioethanol derived from wheat per ha (calculation by DBFZ)



Excursus: Valuable byproducts of the fuel production pathway

The process chains of the biodiesel and bioethanol production pathways produce byproducts that may be utilised for agricultural purposes, thus replacing imported feed. Distillers grains from ethanol production and rapeseed meal / cake substitute other feed such as barley or imported soy meal, thus reducing competition for utilisation and greenhouse gas emissions.

Ethanol production from cereals produces protein-rich distillers grains as a byproduct during fermentation. Fresh distillers grains are utilised as feed. Due to a short shelf live and considerable transport costs (high water content > 90 %, high temperature upon delivery > 50°C and high enzymatic solubility of cell wall components and yeast residues), the utilisation of fresh distillers grains is limited (local consumption). Distillers grains may be processed into DDGS (dried distillers grains with solubles), resulting in a valuable and commercially attractive feed.

In addition to glycerine, the **production of biodiesel** from rapeseed produces rapeseed meal as a by-product. According to the oilseed processing industry, 7.7 million t of rapeseed were processed into 3.2 million t of rapeseed oil in Germany in 2011, thus generating 4.4 million t of rapeseed meal (OVID-Verband, 2012).

4.4 Overview of national and global technical fuel potentials

To complement the information of national land potentials presented above, the following section provides a brief overview of the current status of technical fuel potentials derived from forestry biomass and residues in Germany. The data are based on calculations carried out within the scope of a BMVBS project on the spatial distribution of regional and global biomass potentials. The results presented here originate from the 'business as usual' scenario (BAU 2020). This scenario models current trends regarding land use change and the development of the agricultural sector and population growth to the year 2030.

A conversion of the land potentials presented in section 4 into energy crop potentials or biofuel potentials is not attempted in the context of this study. The relevant scenarios for the development of crop rotation, or rather the fuel sector, are the subject of a subsequent short study. Thus, national fuel potentials presented here do not include biomass cultivation potentials from agriculture (which in turn include grassland).

Due to the fact that feedstocks for the production of biofuels are now traded in an international market, there is merit in further reporting the current status of international biomass potentials in this context.

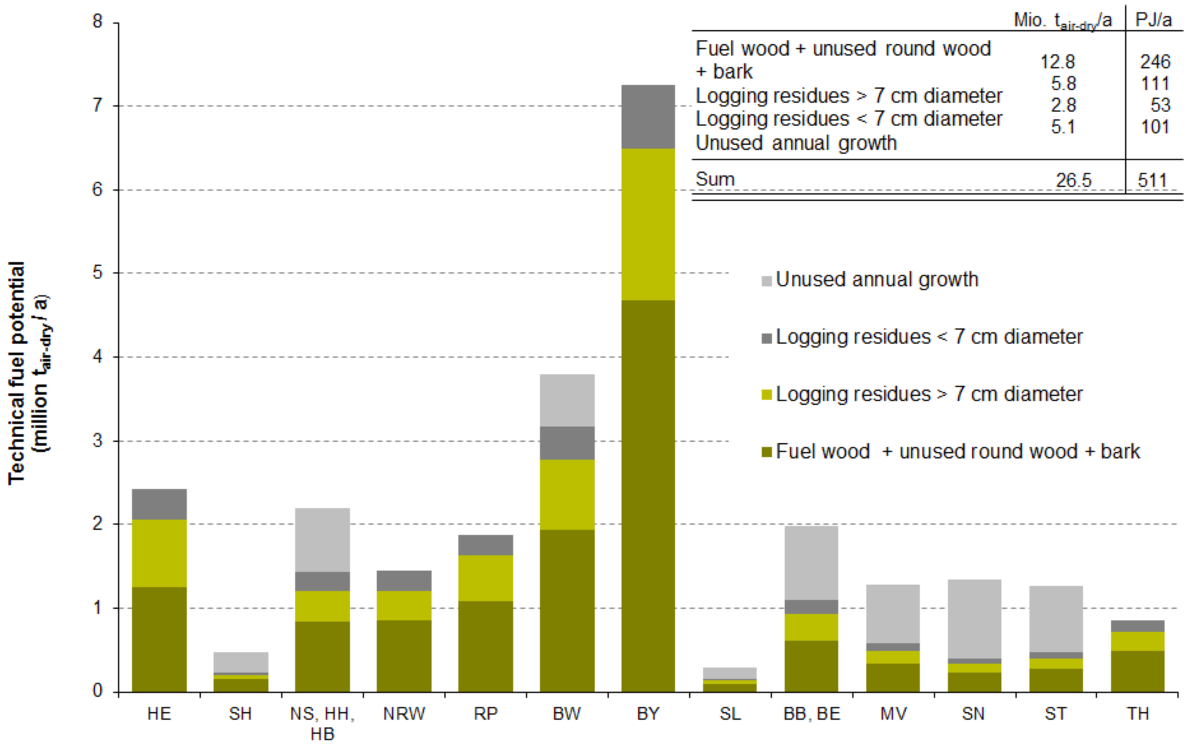
Calculations of the listed technical fuel potentials reflect existing technical, structural and ecological restrictions or statutory regulations. The technical potential thus illustrates the potential contribution to the utilisation of renewable energies dependent on time and location from a primarily technical angle. The technical potential in general is subject to minor temporal variation. The conversion of mass-specific data to energy units (fuel potentials) is carried out factoring the substrate-specific caloric values, specific gas yields and average caloric values for biogas.

4.4.1 National fuel potentials

4.4.1.1 **Forestry biomass**

The total technical fuel potential for Germany amounts to 511 PJ/a (mean 2002-2008). The calculation of the technical fuel potential of forest timber includes logging residues, wood already utilised for energy purposes and unutilised logs and bark. Figure 10 illustrates the fuel potentials of forestry biomass at the federal state level.

Figure 10: Technical fuel potentials for forestry biomass at the federal state level, Ø 2002-2008 (*Globale und regionale räumliche Verteilung von Biomassepotenzialen - Status Quo und Möglichkeit der Präzisierung*, 2010)



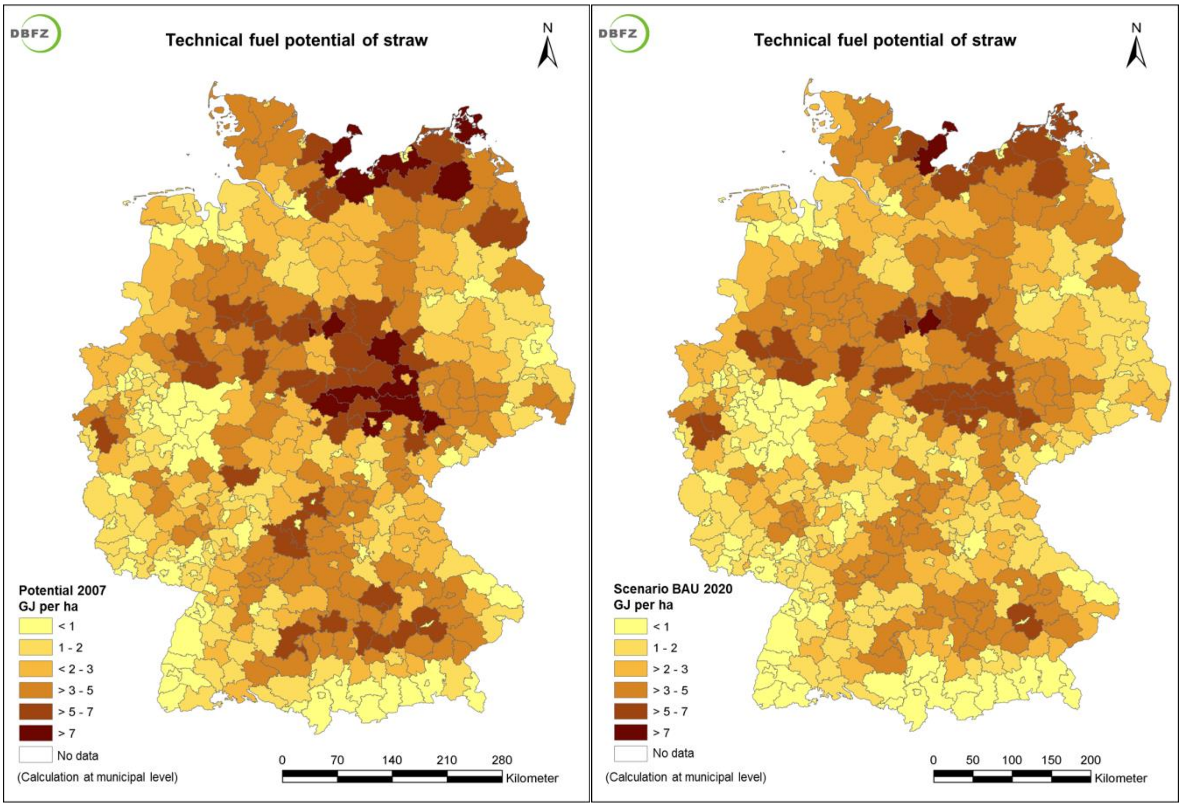
	Mio. $t_{air-dry}$/a	PJ/a
Fuel wood + unused round wood + bark	12.8	246
Logging residues > 7 cm diameter	5.8	111
Logging residues < 7 cm diameter	2.8	53
Unused annual growth	5.1	101
Sum	26.5	511

With a technical fuel potential of 246 PJ/a, the combination of forestry wood utilised for energy purposes, unutilised logs and bark represents the major proportion of the forestry potential. Logging residues are associated with a potential of 164 PJ/a (> 7 cm diameter 111 PJ/a, < 7 cm diameter 53 PJ/a). In addition, the annual growth currently not harvested offers considerable potential at 101 PJ/a. The most extensive fuel potentials in forest timber are located in Bavaria (ca. 140 PJ/a), Baden-Württemberg (ca. 70 PJ/a) and Hesse (ca. 45 PJ/a).

4.4.1.2 **Straw**

The technical fuel potential of cereal and rapeseed straw in Germany in 2007 amounted to 110 PJ. Thus, considering the area utilised for cereal and rapeseed cultivation, the estimate for the BAU scenario in 2020 reveals a potential of 184 PJ/a. The quantities of straw available are correlated with both the area utilised for cereal and winter rapeseed cultivation and the grain-straw ratio. After consideration of all competing utilisation pathways (e.g. utilisation as bedding for livestock, as a substrate for the mushroom cultivation), it was assumed that 20 % of the straw could be harvested without disturbance of humus formation and soil functions. Regions with a high technical fuel potential are thus located in areas with a high proportion of cereal or winter rapeseed cultivation. Figure 11 illustrates that these areas are predominantly located in Mecklenburg-Vorpommern and central Germany.

Figure 11: Technical fuel potential of straw for 2007 and the scenario BAU 2020 (Source: DBFZ 2010)



4.4.1.3 **Liquid manure**

The calculations result in a volume of liquid manure or bedding of 139 million t available for the utilisation for energy purposes. This in turn amounts to a total biogas yield of 4 billion m^3/a, corresponding to a technical fuel potential of approx. 90 PJ/a. The majority is derived from cattle manure at approx. 55 PJ/a, whereas pig manure and bedding and chicken litter are represented in the potential with approx. 30 PJ/a and 3 PJ/a, respectively. In the distribution across Germany, the highest potentials are located in the northeast of Lower Saxony and in the southeast of Bavaria.

4.4.1.4 **Biodegradable waste and green waste**

The annual quantities of biodegradable and green waste generated in Germany in 2007 totalled at approx. 8 million t. Discounting of contaminants, loss during collection and water content results in a technical fuel potential of approx. 23 PJ. The regional distribution of the potential is distinctly correlated with population density.

4.4.1.5 **Waste wood and industrial waste wood**

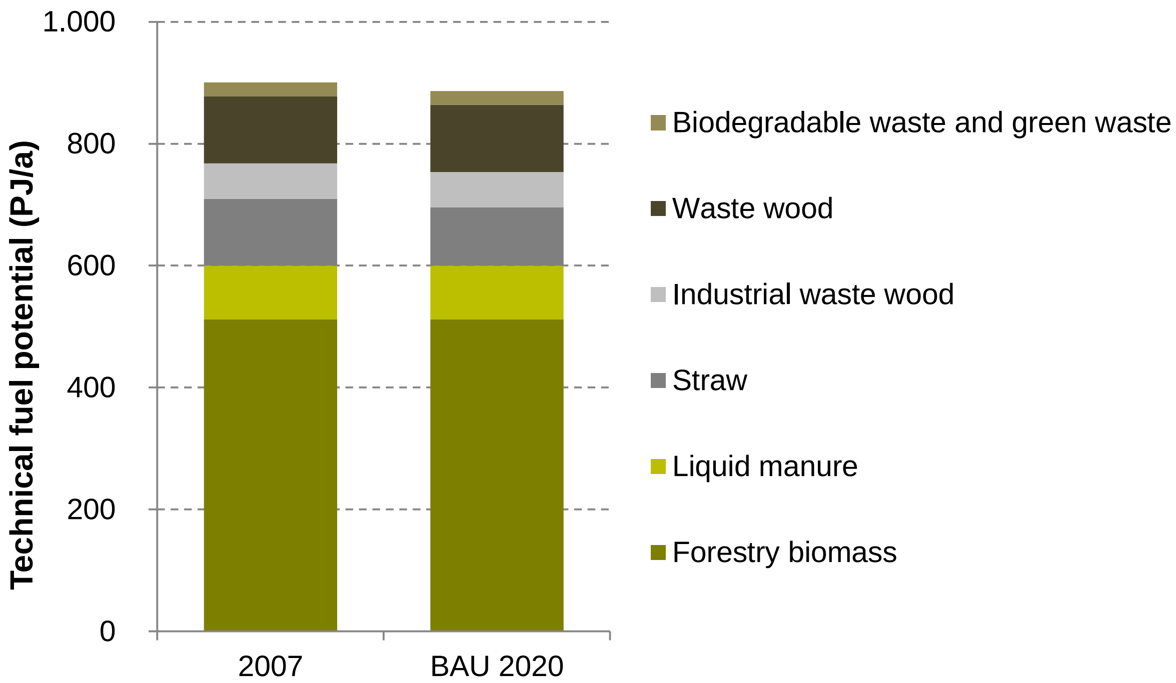
The annual total of waste wood in Germany amounts to approx. 9 million t of pure wood fractions and approx. 1.5 million t wood from mixed waste fractions (status 2006). A waste wood total of 7 million t air-dry could be utilised for energy purposes, which represents a technical fuel potential of 110 PF. The greatest quantities are generated in North Rhine-Westphalia and Lower Saxony.

A major part of industrial waste wood (approx. 12 million m^3) is already processed for subsequent material use within the respective industries. Thus, it is no longer available for utilisation for energy purposes. The technical fuel potential available for energy generation in Germany therefore amounts to about half at 58 PJ/a. The majority of these potentials is located in Bavaria and Baden-Württemberg at 23.4 and 19.8 PJ/a, respectively.

4.4.1.6 **Summary of national fuel potentials (excluding agricultural biomass)**

The total technical fuel potential (excluding agricultural biomass and grassland) slightly declines from approx. 900 PF in 2007 to 885 PF in the projection for the scenario BAU 2020. The forestry potential contributes a major part of the total at 512 PJ.

Figure 12: Sum of all technical fuel potentials in Germany in 2007 and for the BAU 2020 scenario (excluding energy crops; Source: BMVBS 2010)



4.4.2 Global fuel potentials

In the following, a brief overview of global fuel potentials derived from agriculture, forestry and waste materials complements the information presented above (*Globale und regionale räumliche Verteilung von Biomassepotenzialen - Status Quo und Möglichkeit der Präzisierung*, 2010).

The reference year for actual data is 2007, whereas the projection for 2020 is based on the scenario 'business as usual' (BAU 2020). The calculations of agricultural fuel potentials are based on national land potentials without rebalancing of trade[4]. The BAU 2020 scenario illustrates the projection of short and medium term trends and development trajectories based on the principal assumptions. The land potentials available for non-food purposes are derived from agricultural (surplus) production that was traded globally with the support of subsidy schemes in the past. Furthermore, brownfield land (arable land only) abandoned out of political obligations (e.g. within the EU-27), or not in use during the reference period due to social or economic constraints (e.g. in Russia), is included in the calculations. Major factors of the projection in the BAU scenario are population growth, per capita consumption, land use change or rededication, and changes in yield. A detailed description of the assumptions of the scenario may be found in section 4 of Appendix III of the BMVBS project (*Globale und regionale räumliche Verteilung von Biomassepotenzialen - Status Quo und Möglichkeit der Präzisierung*, 2010).

4.4.2.1 **Agricultural fuel potentials**

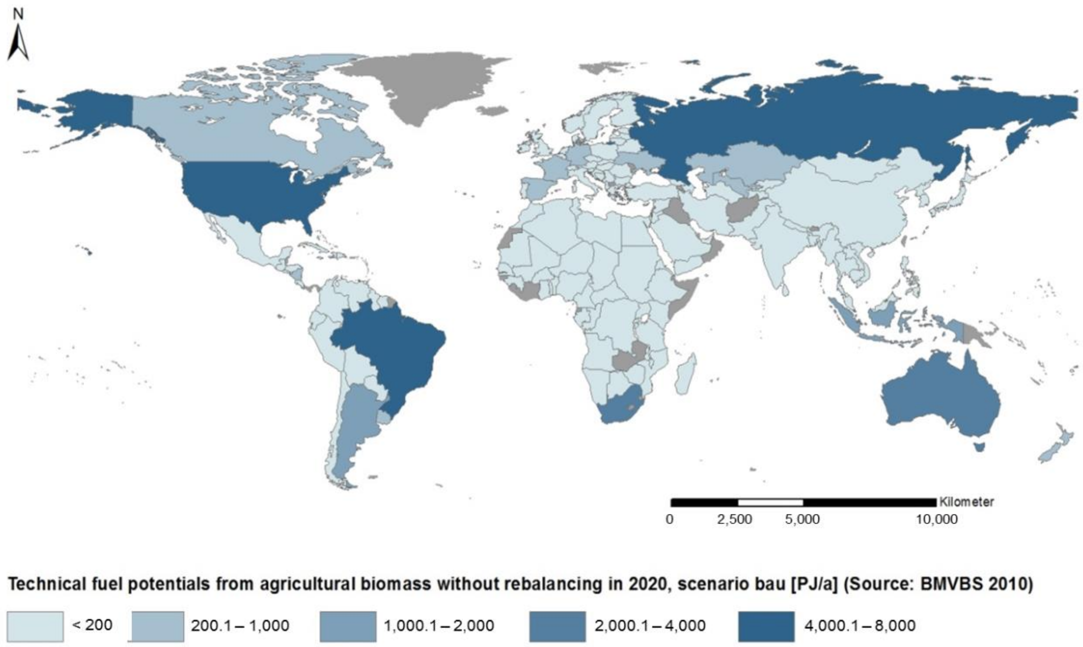
The availability of agricultural biomass for the supply of bioenergy depends on the future availability of areas not in use for food production (so-called non-food land). Such areas are thus available for the production of biomass. The estimate of global agricultural biomass potentials factors the utilisation of regional agricultural production to date under consideration of regional landscape features and economic and politic constraints. The major factors in this context, i.e. population growth, consumer behaviour and the productivity of agricultural production, are liable to change over time.

Figure 13 illustrates agricultural fuel potentials which in the present scenario total at approx. 32 EJ/a. Major potentials are located especially in South America (10.2 EJ/a), Europe (7.3 EJ/a) and North America (5.1 EJ/a). The European frontrunner in this context is Russia with a fuel potential of approx. 4.1 EJ/a.

[4] In contrast to the scenario 'global rebalancing', the countries in question do not utilise their surplus land for the production of foodstuffs for export to countries in deficit.

The biomass potentials presented in this section are based on a scenario approach, comparable to the results of the national land potentials in the preceding chapters. The scenario approach is influenced by a considerable number of factors and assumptions (see Table 1). Global land and resource potentials for non-food purposes are strongly dependent on the food demand on the one hand, and on increasing yields in a finite agricultural area space on the other. Future development rather consistently reveals a uniform trend in multiple scenarios. Land potentials in Europe, North and South America are expected to be stable and consistently able to utilise surplus land for the production of bioenergy crops. In many countries in Africa and Asia, however, the land available for food production is insufficient to meet the national demands. In consequence, these countries struggle with a growing need to import foodstuffs. Simultaneously, almost 80 % of the agricultural area is utilised for animal production (STEINFIELD et al., 2006). These mere facts are evidence for the considerable uncertainty associated with global energy crop potentials.

Figure 13: Technical fuel potentials from agricultural biomass without rebalancing in 2020, scenario BAU [PJ/a] (Source: BMVBS 2010)



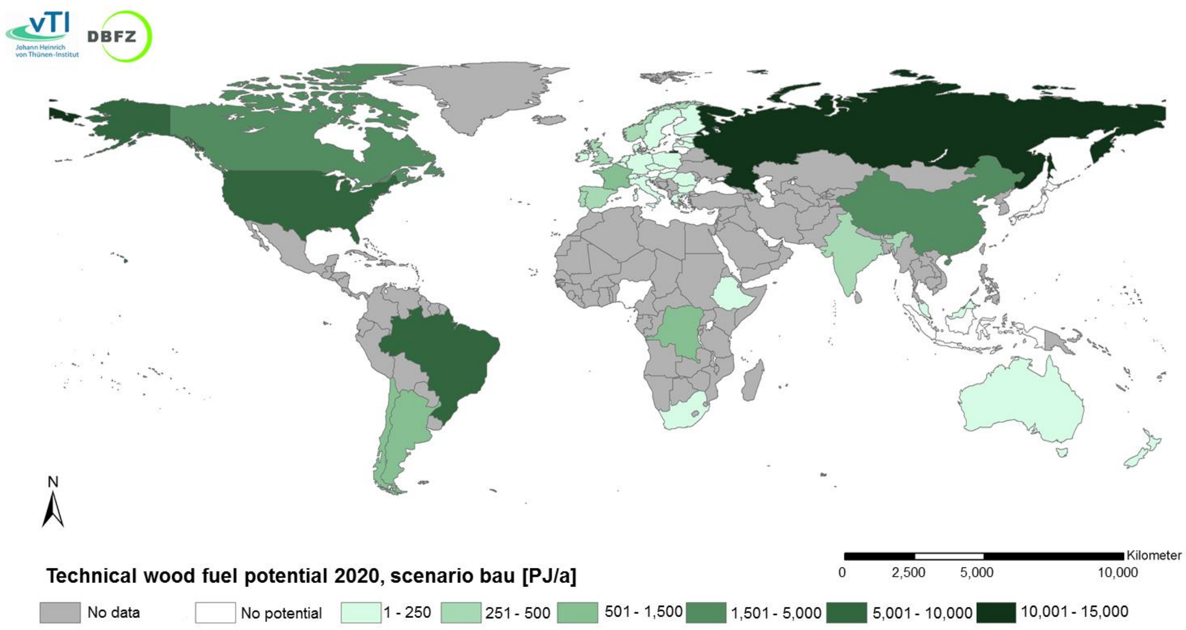
In an international context, this is particularly relevant in relation to the potential utilisation of degraded land for the production of energy crops. The land potentials for these areas based on published data range between 6 and 35 million km^2 (*Globale und regionale räumliche Verteilung von Biomassepotenzialen - Status Quo und Möglichkeit der Präzisierung*, 2010). The possible development and utilisation of these potentials for the cultivation of energy crops, and the associated costs and eventual yields, are again subject to uncertainty.

4.4.2.2 **Forestry biomass**

Forest and plantation wood

Due to the fact that a multitude of unforeseeable events may influence the potentials of raw timber and wood fuel, there is no reliable way to accurately predict exact quantities for the year 2020. However, a number of different scenarios may indicate tendencies that could develop by 2020 according to the assumptions of the model (forest and plantation area total, annual net growth, raw timber production and consumption). Figure 14 illustrates the global fuel potential of forestry biomass in the scenario BAU 2020 (excluding logging residues). The analysis includes the projected development in 46 countries. Their combined raw timber production and consumption covers approx. 80 % of the global total.

Figure 14: Global technical fuel potential of forestry biomass in 2020 in the scenario BAU (Source: BMVBS 2010)



The scenario BAU results in a total technical wood fuel potential of approx. 34 EJ/a for the 46 countries in 2020. Thus, an estimated total wood fuel demand of 22 EJ/a required in 2020 could be covered in full.

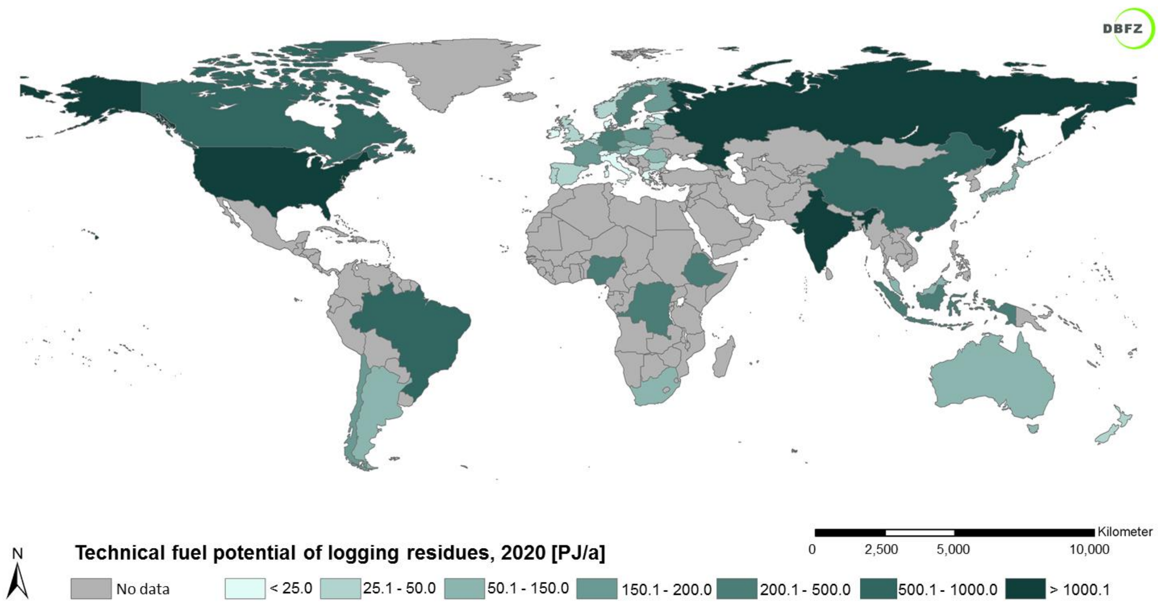
Up to 13 EJ/a would be additionally available for the utilisation for energy purposes as only about 63 % of the theoretically available wood fuel potential would be exploited.

The largest potentials would be available in Russia, the United States and Brazil (Figure 14). In the EU-27 countries, France, Portugal, Spain and the United Kingdom would hold the most significant wood fuel potentials.

Logging residues

Logging residues are defined as harvest residues arising from logging activities. Thus, quantities are correlated with the utilisation of raw timber.
The technical fuel potential of logging residues was calculated in the BMVBS project for the year 2020 under consideration of technical and ecological restrictions, e.g. mobilisation capacity and soil conservation. The calculation accounted for solid wood, brushwood and harvest residues.
The estimate for the 46 countries is based on the projected raw timber production in 2020 and amounts to a global technical fuel potential of approx. 9.380 PJ/a (Figure 15).

Figure 15: Global technical fuel potential of logging residues in 2020, (Source: BMVBS 2010)



4.4.2.3 Waste materials

The generation of waste materials in general is correlated with the development of the corresponding industrial sector (except for municipal waste). However, waste potentials in a number of different scenarios are rather consistent (FRITSCHE et al., 2004). Moreover, projections on global industrial development are associated with considerable uncertainty as a rule. For these reasons, no scenario-based data are presented here. An attempt to capture the current status proves difficult due to the fact that data world-wide are incomplete, fragmentary and heterogenic. Global, transnational quantitative statistics on waste generation are unavailable. Therefore, the arising totals have to be inferred from product-waste ratios from FAO data on production volumes, e.g. livestock farming data or specific waste generation rate per capita.

The following table summarises technical fuel potentials that may be interpreted as a coarse approximation of the current situation. Particularly high waste potentials are located in China, the United States, India and Brazil. Due to the positive trend in global population growth it is expected that technical fuel potentials derived from waste materials will be increasing until 2020.

Table 2: Results for current global technical fuel potential allocated by waste material fraction (* Fuel potential result in theory; (Source: DBFZ 2010))

Waste material fraction		Countries included	Technical fuel potential [PJ/a]
Straw		All	13.317
Municipal waste – biowaste		All	1.164
Municipal waste – waste wood		All	1.660
Livestock manure		All	2.369
Industrial scrap wood		64 countries	698
Production-specific organic waste	Bagasse	All	3.647*
	Palm oil	All	1.049*
	Coconut	All	409*

The highest fuel potentials based on waste materials were identified in China (3.62 EJ/a), India (2.75 EJ/a), the United States (2.72 EJ7a) und Brazil (2.39 EJ/a) (Table 3). The relatively small country Indonesia follows next with 1.15 EJ/a due to generation of high quantities of coconut and palm oil residues during oil production.

Table 3 summarises the ranking of the fuel potentials of the feedstocks in the countries included in the analysis.

Table 3: Ranking of potentials for the respective feedstock classes (Agriculture: energy crops incl. grassland; no rebalancing, Forestry: wood fuel incl. logging residuals, Waste materials: straw, animal manure, biodegradable waste, waste wood, industrial waste wood, bagasse, palm oil residues, coconut residues), (Source: DBFZ 2010)

Fuel potentials in EJ/a								
Agriculture			Forestry			Waste materials		
BAU 2020			BAU 2020			2003-2007		
Rank		EJ/a	Rank		EJ/a	Rank		EJ/a
1	Australia	7.97	1	Russia	12.5	1	China	3.6
2	Argentina	4.63	2	USA	8.3	2	India	2.8
3	New Zealand	4.12	3	Brazil	5.9	3	USA	2.7
4	South Africa	2.55	4	China	3.6	4	Brazil	2.4
5	Uruguay	2.30	5	Canada	2.1	5	Indonesia	1.2
6	Russia	1.64	6	India	1.5	6	Russia	0.5
7	Uzbekistan	1.19	7	D. R. Congo	1.4	7	Argentina	0.5
8	Ukraine	0.91	8	France	1.1	8	Mexico	0.5
9	Germany	0.80	9	Chile	0.8	9	Thailand	0.5
10	Paraguay	0.70	10	Argentina	0.7	10	Malaysia	0.5

5 Competition for biomass utilisation

The results presented in Chapter 4 identify technical land potentials for the production of bioenergy. In the process, allowances were made to factor the biomass demand for the supply of foodstuffs for human and animal consumption. However, in order to infer the contribution of biofuels to the Mobility and Fuels Strategy, existing demand for biomass from other energy sectors may be relevant.

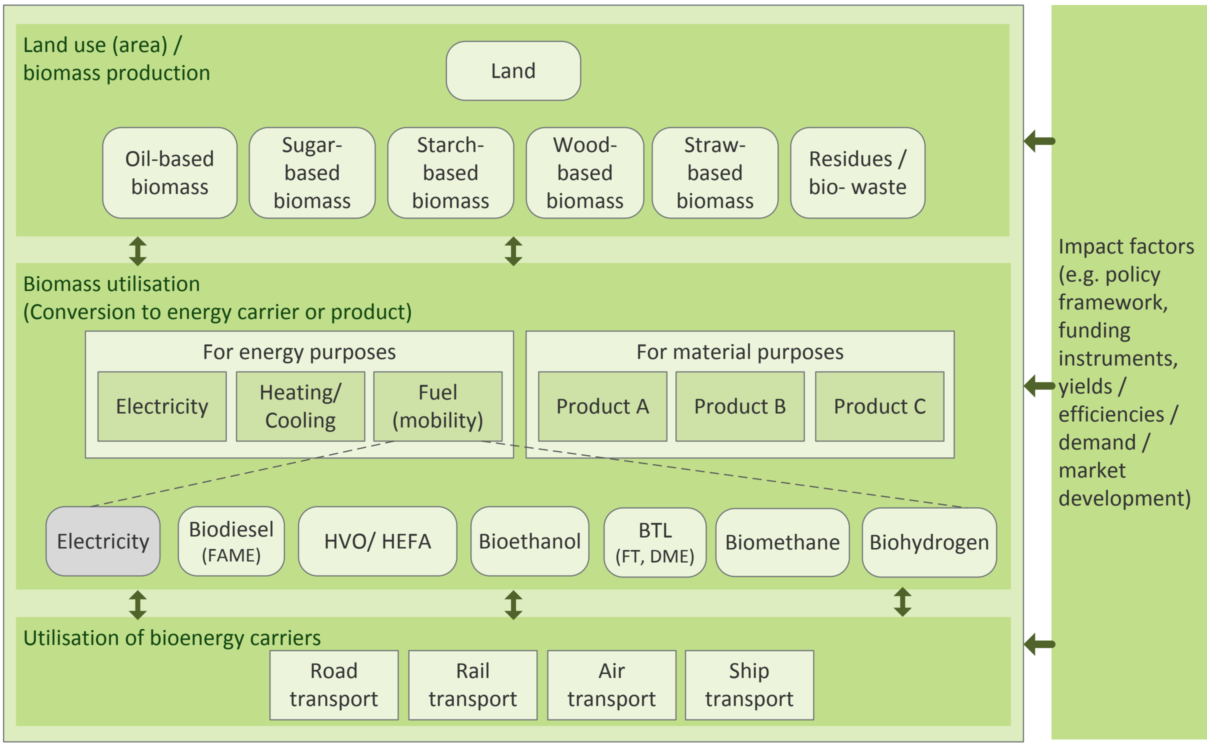
In the past, a number of instruments and policies in combination with high oil prices gave rise to dynamic development of the supply of bioenergy in the electricity, heat and mobility sectors. Overall, demand for a diversity of biomass fractions increased significantly. Thus, existing biomass markets were stimulated and new biomass markets were established both at regional and international level.

At present, competition between biomass utilisation for energy purposes and food and feed production, or material utilisation of wood, have been subject to intense public debate. Positive global population growth is associated with increasing levels of meat consumption and rising energy demand. Thus, the demand for bioenergy resources is expected to increase considerably. In the process, competition for biomass from material uses and security of food supply looms large. Furthermore, the threat of negative impacts on nature conservation and environmental safety is growing. It is of vital importance to consider these aspects in the assessment of future bioenergy and biofuel potentials. However, the consequences of competition for utilisation of biomass may not be altogether negative (Thrän et al. 2011). In many cases, competition will act as an incentive to promote increasingly efficient use of available resources. For the development of the bioenergy sector, it is vital to recognise competition at an early stage and respond with adequate measures. Future efforts should include the harmonisation of incentives and subsidies within the policy framework of the individual bioenergy sectors (e.g. the German EEG, KWKG or the German Biofuels Sustainability Ordinance) and their respective expansion targets.

In principal, competition for land and biomass ensues on a number of levels. These may range from the supply of biomass from a given area to the contribution of bioenergy to the energy system. In the context of competition for utilisation of biomass for energy purposes, there may be conflicting options for the cultivation of renewable feedstocks on the available arable land (e.g. maize for biogas production versus cereal for ethanol production). At the level of biomass utilisation, the production pathways of electricity, heat and biofuels may compete for land and resources used as feedstocks.

Finally, the utilisation of energy produced from biomass represents another level of competition. Figure 16 provides an overview of the different levels of competition for land use, produced biomass and bioenergy carriers.

Figure 16: Schematic diagram of competition for utilisation (Figure by DBFZ)



The following chapter provides a brief overview of the policy framework of major incentives and subsidies for bioenergy and biofuels to support an informed discussion on the potential contribution of biofuels to future mobility and fuel concepts. Examples of the cost structures associated with individual biofuel production pathways are included. As described above, the individual bioenergy sectors are to some extent competing for land and feedstocks. Therefore, differences in the individual bioenergy sector subsidies and expansion targets may influence competitiveness of biofuels in the competition for renewable resources available.

5.1 European funding policy and national implementation

The utilisation and supply of renewable energies within the European Union (EU) has been actively promoted for more than a decade. For instance, the European Electricity Directive (2001/77/EG) and the European Biofuels Directive (2003/30/EG) have specified precise expansion targets for the corresponding sectors for the year 2010 (Proportion of the total consumption: 12.5 % of total electricity and 5.75 % for total fuels). In 2009, the 'EU Directive on the promotion of the use of energy from renewable sources' (EU-RED; 2009/28/EC) entered into force as part of the European climate and energy package, thus replacing the previous EU directives on 01.01.2012. In the EU-RED, the expansion targets of the individual sectors electricity, heat and fuels are expressed in a common legal framework for the first time. In compliance with the directive, Germany is required to supply a minimum of 18 % of the gross final energy consumption from renewable energies. In contrast, the mobility sector is subject to a uniform mandatory proportion of 10 %[5] for all EU member states.

Furthermore, the EU-RED established sustainability criteria for the production and utilisation of biofuels. Major factors include i) greenhouse gas (GHG) emissions of biofuels, ii) exclusion of certain areas for the cultivation of biomass for biofuel production as well as iii) the stipulation of guidelines for good farming practice in the production of biomass.

In addition to the EU-RED, the Fuel Quality Directive (FQD) acts as a major driver of the establishment of biofuels among the EU member states. The mandatory percentage of fuels from renewable energies in the gross final energy consumption specified in the EU-RED is complemented in the FQD with a separate stipulation for a GHG reduction target of no less than 6 % by 2020 (in reference to 2010; defined intermediate goals -2 % by 2014 and -4 % by 2017).

The specific implementation of the EU directives in the member states is carried out with national funding schemes and additional national implementation measures. The National Renewable Energy Action Plan (NREAP) introduced in the EU-RED was passed by the German Federal Government in 2012. In addition to existing measures and expansion targets, it defines a number of instruments and adaptations in support of the development of renewable energies.

[5] A proposal for an amendment of the EU-RED and the FQD was submitted by the European Commission in October 2012. It includes a limit of biofuels from agricultural biomass of max. 5 % and aims for multiple credits for biofuels derived from certain residues and waste materials against the 10 % goal.

5.2 Support framework biofuels

Due to the number of individual laws and regulations on the development of renewable energies applicable to the three major sectors electricity, heat and fuels, the funding situation within the respective conversion pathways differs considerably. Existing funding instruments in Germany may be classified into five individual groups. These are feed-in compensations, investment incentives, tax benefits, quota systems including green certificates and public tender and procurement systems. Several combination schemes exist, in particular with regard to tax benefits. Recently, biofuels are subsidised almost exclusively with quota systems.

In contrast to direct financial support in the electricity and heat sectors (i.e. compensation for the utilisation of certain substrates, technologies and market strategies regulated by the EEG), support instruments in the fuels sector (i.e. quota systems, tax benefits, investment incentives) influence pricing and production costs indirectly.

Overlap and potential competition within and between the three sectors ensues in particular when the same feedstocks are utilised. Figure 17 provides a brief introduction to the most relevant funding instruments in the fuels sector. Due to the dynamic nature of the funding situation, please note that the reference year for the data presented in Figure 17 is 2012.

Figure 17: Implementation of the EU-RED 2009/28/EC in national law and schematic diagram of the resulting compensation structure (focused on biofuels)

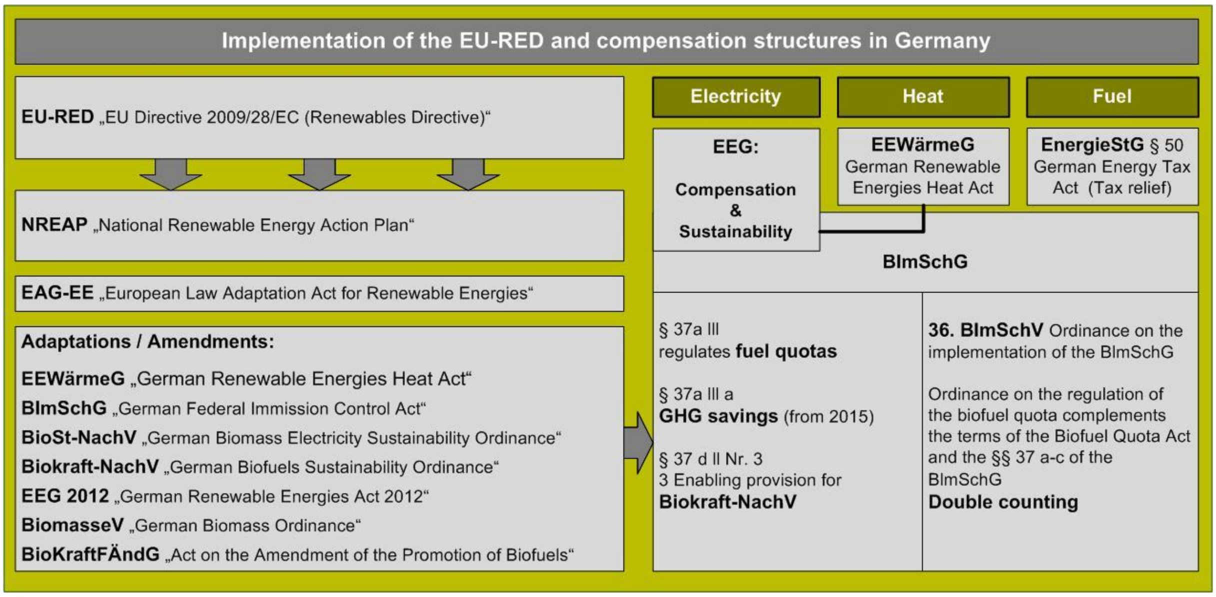


Figure 17 illustrates that biofuels do not receive immediate funding, yet they are indirectly subsidised in the form of tax benefits, quota commitments and GHG savings schemes. Future development of the biofuel sector may be influenced by the proposed readjustment from an energy-based biofuel quota to a GHG-based quota (scheduled for 2015). This readjustment sends an important signal regarding the efficient utilisation of land and biogenic feedstocks. However, it also reduces predictability and planning security for producers of biofuels.

5.3 Examples of cost allocation of biofuel options

Assessment of the current and future competitiveness of biofuels should consider both market trends in the conventional fuel sector and the cost structures of current and future biofuel options.

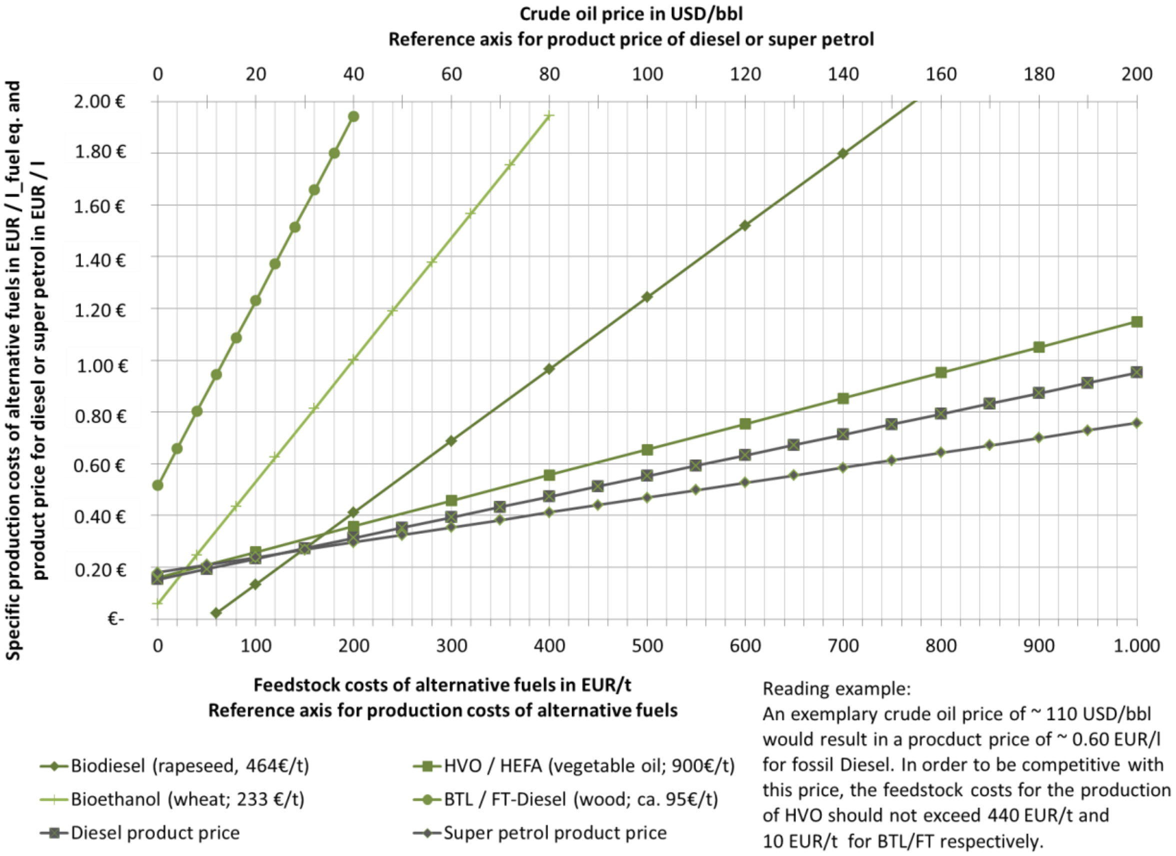
The current generation of biofuels is defined as the types of biofuels that are readily available in substantial quantities on the current market. Relevant examples include bioethanol derived from plant material rich in sugar and starch, and biodiesel. Fuels derived from pure vegetable oil are no longer of importance due to the recent fiscal policies. However, the recent debate on agricultural diesel may prove the agricultural sector the exception to that trend. Production technologies for biofuels of the current generation are mature and well established. In general, specific parts of plants (also used cooking oil and animal fat in the case of biodiesel) are utilised for the production. In many cases, byproducts are generated in substantial quantities during the production process of current generation biofuels. These may in turn be utilised as animal feed, feedstocks for the chemical industry, as fertilisers or for further energy production purposes.

Future generation biofuels are defined as biofuels that are generated with production technologies in the exploratory stage. Therefore, no significant quantities are available as yet.

Production costs of biofuels are dependent on a number of parameters, such as cost of feedstock, operational costs of the conversion units or the potential revenue from byproducts. These parameters (feedstock prices in particular) are subject to considerable fluctuation. For this reason, figures of examples of specific biofuel production cost are not presented here. However, Figure 18 illustrates the variables of a number of parameters influencing the production costs of four examples of biofuel options. It allows the calculation of the production cost of bioethanol derived from cereal, biodiesel derived from rapeseed, (HVO / HEFA (Hydrotreated vegetable oil or Hydrotreated Esterified Fatty Acids) derived from rapeseed and BtL (Biomass-to-Liquid fuel, in this case Fischer-Tropsch diesel / FT) derived from short-rotation coppice in the context of a number of feedstock price assumptions.

Furthermore, the figure allows the calculation of the marginal costs for the production of biofuels or biogenic feedstocks that renders the resulting biofuel competitive with fossil fuels.

Figure 18: Influence of different parameters on the production costs of various exemplary biofuel options (Calculation by DBFZ, 2012)



The figure clearly illustrates the influence of feedstock prices on the production costs in the biofuel options investigated. The current price for rapeseed of approx. 470 EUR/t thus results in production costs of approx. 1.16 EUR/l fuel equivalent. The production costs of Ethanol at 1.19 EUR/l fuel equivalent considering a current price for wheat of 240 EUR/t.

The strong influence of the costs of feedstocks on the production costs is demonstrated in the figure for both the fuel options currently available and for the future option BtL. A major difference between current (e.g. biodiesel from rapeseed) and future (e.g. BtL) biofuel options is evident in the significant influence of other cost parameters on the production costs as well as the expected cost reduction potentials.

The production of biodiesel and bioethanol is based on established technologies. Future reduction of costs during the conversion of biomass to biofuel is possible only to a very limited extent. The feedstocks applied (e.g. vegetable oil and cereal) are commodities traded on the international market, and prices are expected to rise rather than fall. In contrast, many of the options considered as biofuels of the future (e.g. BtL) may be produced from residues and waste materials. In the context of feedstock prices, this may act in the favour of future biofuels compared to current biofuel options based on agricultural biomass. In addition to the reduction of feedstock costs, competitiveness of future biofuel options in comparison with current alternative fuels may be promoted by activation of cost reductions potentials during the conversion of biomass to fuel. However, the challenge lies in overcoming the specific investment expenditure currently associated with future biofuel options. Due to the sophisticated technical requirements and considerable complexity of processing plants, investment is generally much higher compared to established biofuel options. Moreover, rising overall demand for residues and waste materials is expected to result in price increases for these feedstocks as well.

Literature

BMVBS, Bundesministerium für Verkehr, Bau und Stadtentwicklung (Hrsg.): *Globale und regionale räumliche Verteilung von Biomassepotenzialen - Status Quo und Möglichkeit der Präzisierung*, *BMVBS-Online-Publikation* (Endbericht Nr. 27(2010)), 2010. — ISSN 1869-9324

Bringezu, Stefan ; Schütz, Helmut ; Arnold, Karin ; Bienge, Katrin ; Borbonus, Sylvia ; Fischedick, Manfred ; von Geibler, Justus ; Kristof, Kora ; Ramesohl, Stephan ; u. a.: *Nutzungskonkurrenzen bei Biomasse. Auswirkungen der verstärkten Nutzung von Biomasse im Energiebereich auf die stoffliche Nutzung in der Biomasse verarbeitenden Industrie und deren Wettbewerbsfähigkeit durch staatlich induzierte Förderprogramme* (Nr. Endbericht) : Wuppertal Instituts für Klima, Umwelt, Energie GmbH (WI), Rheinisch-Westfälischen Institut für Wirtschaftsforschung (RWI Essen), 2008

Bringezu, Stefan ; Schütz, Helmut ; Schepelmann, Philipp ; Lange, Uta ; von Geibler, Justus ; Bienge, Katrin ; Kristof, Kora ; Arnold, Karin ; Merten, Frank ; u. a.: *Nachhaltige Flächennutzung und nachwachsende Rohstoffe Optionen einer nachhaltigen Flächennutzung und Ressourcenschutzstrategien unter besonderer Berücksichtigung der nachhaltigen Versorgung mit nachwachsenden Rohstoffen* (Nr. UBA-Texte Nr. 34/2009). Dessau-Roßlau : Wuppertal Institut für Klima, Umwelt, Energie (WI), Umweltbundesamt (UBA), 2009

Bundesministerium der Justiz: Gesetz zur Regelung der Einhaltung anderweitiger Verpflichtungen durch Landwirte im Rahmen gemeinschaftsrechtlicher Vorschriften über Direktzahlungen und sonstige Stützungsregelungen (Direktzahlungen-Verpflichtungengesetz - DirektZahlVerpflG), 2004

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV): *Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten der Bundesrepublik Deutschland 2012*. Bd. 56. Münster : Landwirtschaftsverlag GmbH, Münster-Hiltrup, 2012

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU): *Nationale Strategie zur biologischen Vielfalt*. 3. Aufl. Berlin, 2011

Fachagentur Nachwachsende Rohstoffe e. V. (FNR): *Anbau nachwachsender Rohstoffe 2012 auf 2,5 Millionen Hektar*. URL http://www.nachwachsenderohstoffe.de/presseservice/pressemitteilungen/aktuelle-mitteilungen/aktuelle-nachricht/archive/2012/august/article/anbau-nachwachsender-rohstoffe-2012-auf-25-millionen-hektar/

Fritsche, Uwe R. ; Dehoust, G ; Jenseit, W ; Hüneke, K ; Rausch, L ; Schüler, D ; Wiegemann, K ; Heinz, A: *Stoffstromanalyse zur nachhaltigen energetischen Nutzung von Biomasse* (Endbericht F&E-Vorhaben). Freiburg, Darmstadt, Berlin : Öko-Institut e.V., 2004

KTBL: *Faustzahlen für die Landwirtschaft*. 14. Aufl. Darmstadt : Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V., 2009

KTBL: *Betriebsplanung Landwirtschaft 2012/13. Daten für die Betriebsplanung in der Landwirtschaft.* 23. Aufl. Darmstadt : Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V., 2012 — ISBN 978-3-941583-64-1

OVID-Verband: *Ovid-Verband, Daten und Grafiken, Kennzahlen Deutschland. Stand*

12.09.2012. URL http://www.ovid-verband.de/unsere-branche/daten-und-grafiken/kennzahlen-deutschland/. - abgerufen am 2012-09-19

Schönleber, Nicole: *Entwicklung der Nahrungsmittelnachfrage und der Angebotspotenziale der Landwirtschaft in der Europäischen Union*. Stuttgart, Institut für Landwirtschaftliche Betriebslehre der Universität Hohenheim, 2009

Simon, Sonja: *Szenarien nachhaltiger Bioenergiepotenziale bis 2030. Modellierung für Deutschland, Polen, Tschechien und Ungarn*, Technische Universität München, 2007

Statistisches Bundesamt: *GENESIS-Online Datenbank*.

Steinfield, Henning ; Gerber, Pierre ; Wassenaar, Tom ; Castel, Vincent ; Rosales, Mauricio ; de Haan, Cees: *Livestock's long shadow. Environmental issues and options*. Rom : Food and Agriculture Organization of the United Nations (FAO), 2006

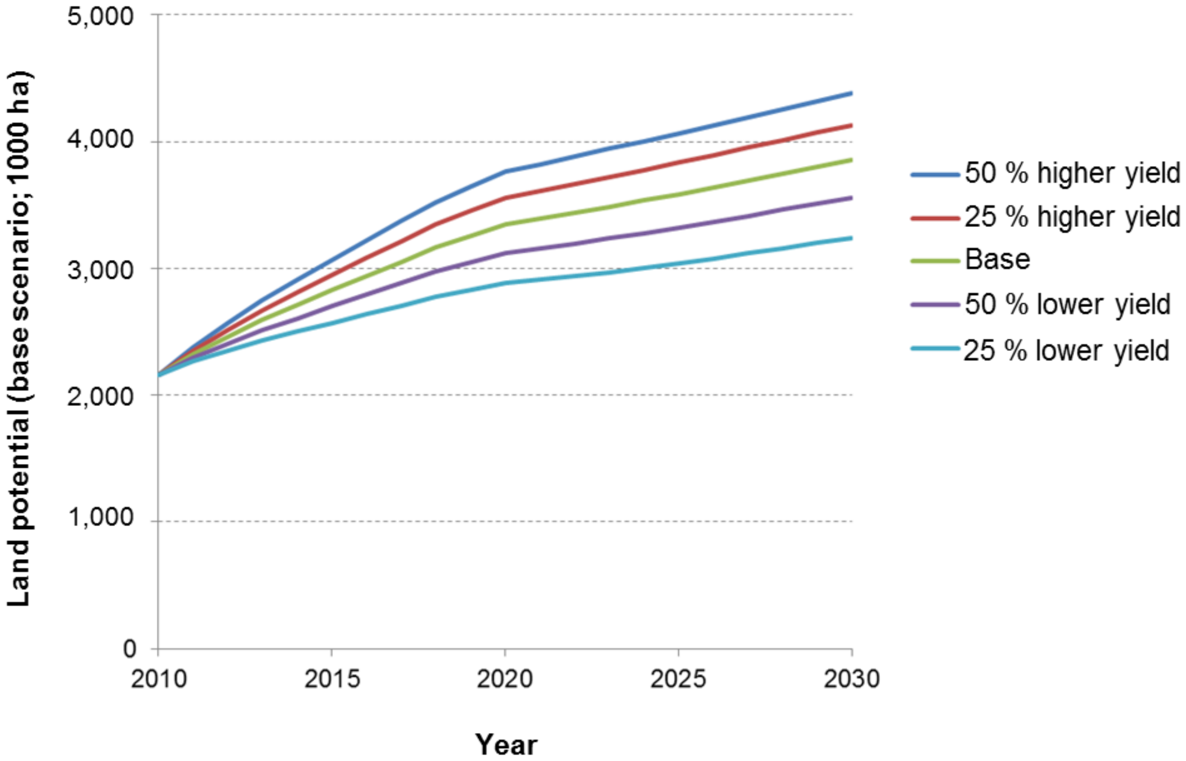
Appendix

Sensitivity of yields

Land potentials at the federal state level

Sensitivity of yields

Figure 19: Projection of the land potential based on a growth rate ± 25 % and 50 %



Land potentials at the federal state level

Table 4: Land potentials at the federal state level in the base scenario

	Land potentials in the base scenario (1.000 ha)														
	2010			2015			2020			2025			2030		
Federal state	Arable land	Grass land	Total	Arable land	Grass land	Total	Arable land	Grass land	Total	Arable land	Grass land	Total	Arable land	Grass land	Total
Baden-W.	150.9	139.3	290.2	182.0	195.8	377.9	205.5	201.7	407.2	197.9	223.0	420.9	193.2	242.3	435.5
Bavaria	373.5	163.7	537.2	421.2	307.0	728.2	442.4	337.1	779.5	403.1	391.3	794.5	376.6	439.9	816.5
Berlin	0.3	-0.1	0.2	0.6	0.2	0.7	0.9	0.4	1.3	1.2	0.6	1.8	1.5	0.9	2.5
Brandenburg	187.8	34.1	221.9	257.2	92.1	349.3	316.5	101.5	418.0	356.9	110.1	467.1	404.1	117.6	521.7
Bremen	0.3	3.6	3.9	0.0	4.4	4.4	-0.3	4.6	4.3	-0.7	4.8	4.1	-1.0	5.0	4.0
Hamburg	1.0	3.3	4.3	1.4	3.9	5.3	1.8	4.2	6.0	2.1	4.4	6.5	2.4	4.7	7.1
Hesse	86.8	73.1	159.9	107.8	120.6	228.4	125.1	138.7	263.8	133.3	156.6	289.8	141.9	173.7	315.7
Mecklenburg-V.	197.2	1.5	198.6	287.3	83.0	370.3	363.0	83.2	446.2	416.1	83.1	499.2	469.2	82.4	551.6
Lower Saxony	339.2	58.9	398.2	461.5	148.5	610.1	542.0	170.3	712.3	587.0	191.2	778.1	635.5	211.2	846.7
North Rhine-W.	191.5	-44.4	147.1	229.2	-19.2	210.0	252.4	-18.6	233.8	243.2	-5.2	238.0	235.7	7.4	243.0
Rhineland-P.	73.1	84.0	157.1	100.8	105.7	206.5	127.2	109.3	236.5	146.0	112.3	258.3	163.1	117.0	280.1
Saarland	6.8	19.1	25.9	9.3	23.9	33.2	11.3	26.2	37.5	12.5	28.3	40.8	13.5	30.4	43.9
Saxony	131.2	23.2	154.4	179.5	48.2	227.6	221.4	56.8	278.2	248.9	65.0	313.9	276.3	72.6	348.9
Saxony-Anhalt	182.3	19.1	201.4	273.5	57.9	331.4	348.9	69.7	418.6	399.3	81.2	480.5	445.1	92.2	537.3
Schleswig-H.	122.7	-21.2	101.5	155.1	23.1	178.2	188.1	37.4	225.5	213.2	50.7	263.9	245.8	63.2	309.0
Thuringia	111.6	58.3	169.8	160.2	67.7	227.9	199.8	73.6	273.4	226.2	79.0	305.2	250.6	83.9	334.5
Germany	**2,156.1**	**615.5**	**2,771.6**	**2,826.7**	**1,262.7**	**4,089.3**	**3,345.9**	**1,396.0**	**4,741.9**	**3,586.2**	**1,576.6**	**5,162.7**	**3,853.6**	**1,744.4**	**5,598.0**

Table 5: **Land potentials at the federal state level in the base ER scenario**

	Land potentials in the base ER scenario (1.000 ha)														
	2010			**2015**			**2020**			**2025**			**2030**		
Federal state	**Arable land**	**Grass land**	**Total**	**Arable land**	**Grass land**	**Total**	**Arable land**	**Grass land**	**Total**	**Arable land**	**Grass land**	**Total**	**Arable land**	**Grass land**	**Total**
Baden-W.	150.9	114.7	265.6	156.5	186.9	343.4	152.3	209.0	361.2	144.5	229.7	374.2	139.7	248.6	388.3
Bavaria	373.5	101.0	474.5	353.9	280.9	634.7	314.3	338.6	652.9	269.5	396.3	665.8	237.9	444.5	682.5
Berlin	0.3	-0.2	0.3	0.5	0.1	0.6	0.7	0.3	1.1	1.0	0.6	1.6	1.3	0.9	2.2
Brandenburg	187.8	9.1	196.9	204.4	72.3	276.8	217.9	85.5	303.4	224.8	107.6	332.4	238.6	119.0	357.6
Bremen	0.3	3.4	3.7	-0.1	4.2	4.1	-0.4	4.4	4.6	-0.8	4.7	4.8	-1.1	4.9	3.7
Hamburg	1.0	3.1	4.1	1.2	3.7	4.9	1.4	4.0	5.4	1.6	4.3	5.9	1.8	4.6	6.3
Hesse	86.8	59.8	146.6	100.7	108.7	209.4	111.9	126.4	238.4	119.9	144.3	264.2	128.4	161.3	289.7
Mecklenburg-V.	197.2	-24.0	173.1	259.6	65.5	325.1	310.0	69.8	379.8	350.4	81.9	432.3	390.9	85.2	476.1
Lower Saxony	339.2	6.7	345.9	388.2	110.6	498.8	415.6	129.8	545.4	429.5	161.3	590.7	446.3	179.2	625.4
North Rhine-W.	191.5	-70.8	120.8	200.0	-31.6	168.5	197.1	-19.8	177.4	188.1	-7.9	180.2	180.7	3.0	183.7
Rhineland-P.	73.1	74.5	147.6	90.6	101.6	192.1	104.6	112.1	216.7	116.2	122.1	238.3	128.8	130.8	259.6
Saarland	6.8	17.9	24.6	8.7	22.8	31.5	10.4	25.0	35.4	11.5	27.2	38.7	12.6	29.3	41.8
Saxony	131.2	12.4	143.6	169.0	37.7	206.7	202.4	45.8	248.1	229.9	53.7	283.6	257.4	60.9	318.3
Saxony-Anhalt	182.3	6.2	188.5	253.8	46.7	300.5	313.5	58.2	371.8	359.7	72.2	431.9	401.1	83.2	484.3
Schleswig-H.	122.7	-48.2	74.5	129.8	-3.3	126.5	140.7	9.7	150.4	151.2	26.0	177.2	168.4	37.3	205.8
Thuringia	111.6	50.6	162.1	150.2	61.5	211.7	180.8	69.3	250.1	205.3	76.9	282.2	227.9	83.8	311.7
Germany	**2,156.1**	**316.2**	**2,472.3**	**2.467.1**	**1,068.4**	**3,535.5**	**2,673.2**	**1,268.2**	**3,941.5**	**2,802.2**	**1,500.8**	**4,303.0**	**2,960.6**	**1,676.4**	**4,637.0**