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Final Report

Global and Regional Spatial Distribution of Biomass Potentials – Status quo and options for specification –

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LIST OF ABBREVIATIONS

(A)ATSR	(Advanced) Along Track Scanning Radiometer
AEP	Agricultural structure development plan
AFP	Agricultural specialised planning
AGr	Agricultural grassland
AL	Arable land
APA	Action Plan for Agriculture
B	Bioenergy scenario
B&E	Bioenergy with increased environmental and nature protection restrictions - scenario
BA	Burnt Area
BAU	Business as usual - scenario
BAU&E+F	Business as usual with increased environmental and nature protection restrictions and change in food patterns - spatial scenario
BDC	Biomass development concept
BauGB	German Town and Country Planning Code
BEF	Biomass expansion factor
BEPS	Boreal Ecosystem Productivity Simulator
BETHY/DLR	Biosphere Energy Transfer Hydrology Model modified and expanded by DLR
BHKW	Combined heat and Power Plant
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BtL	Biomass to Liquid
CCI	Climate Change Initiative
CF	Continuous Field
CIS	Commonwealth of Independent States
CO_2	Carbon dioxide
cp.	compare
CYCLOPES	Carbon cycle and Change in Land Observational Products from an Ensemble of Satellites, name of an EU-FP5 project
DFD	German Remote Sensing Data Centre
DLR	German Aerospace Centre
DCS	Dual cropping system
DM	Dry matter
e. V.	Registered association
e.g.	for example
ECMWF	European Center for Medium-Range Weather Forecast
ECV	Essential Climate Variable
EEG	German Renewable Energy Sources Act
EFP	Specialised energy planning
EJ	Exajoule
ESA	European Space Agency
etc.	et cetera
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
Fig.	Figure
GBA2000	Global Burnt Area 2000, initiative of the European Commission
GIS	Geo information system
GL	Permanent grassland
GLC2000	Global Landcover Characteristics 2000
GlobCarbon	Name of an ESA project
GLOBSCAR	GLObal Burn SCAR, name of an ESA project
GMES	Global Monitoring for Environment and Security
GOME	Global Ozone Monitoring Experiment
GPP	Good Professional Practice

GPP	Gross Primary Productivity (Gesamte-Primär-Produktion)
GUS	Commonwealth of Independent States (CIS)
ha	hectare
HA	Harmonic analysis
IEKP	Integrated Climate and Energy Programme
IKONOS	Name of a commercial Earth observation satellite from GeoEye
ILE	Directive "Integrated Rural Development“
INSPIRE	Infrastructure for Spatial Information in the European Community
IPCC	Interngovernmental Panel on Climate Change
KTBL	Association for Technology and Structures in Agriculture
L3JRC	Global VGT burnt area product 2000 - 2007
LAI	Leaf Area Index
LANDSAT	Name of an American satellite series of NASA
LCCS	Land Cover Classification System
LCLU	Land Cover and Land Use
LEADER	Liaison entre actions de développement de l´économie rurale (Links between actions for the development of the rural economy)
LRP	Landscape framework plan
LU	Livestock units
m	Metre
m^2	Square metre
m^3	Cubic metre
MARS	Meteorological Archival and Retrieval System
MERIS	Medium Resolution Imaging Spectrometer
MJ	Megajoule
MKRO	Conference of Ministers for Spatial Planning
mm	Millimetre
MMK	Meso-scale agricultural site mapping
MOD44B	Name of the MODIS-CF product
MODIS	Moderate Resolution Imaging Spectroradiometer
MODIS-CF	MODIS - Continuous Field
MW	Megawatt
n. d.	Without year specification
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NDVI	Normalized Difference Vegetation Index
NFI	Second Federal Forest Inventory
nFKWe	Available soil moisture of the effective root zone
NKGCF	National Comittee for Global Change Research
NPP	Net Primary Productivity
NUTS	Nomenclature des unités territoriales statistiques (Nomenclature of Territorial Units for Statistics)
nZP	Average annual growth in plantations
nZW	Average annual net growth in productive forest
P.	Page
SCR	Short-rotation coppice
SEA	Strategic environment audit
PCB	Polychlorinated biphenyles
PF	Plantation acreage
PJ	Petajoule
POSTEL	Pole d’Observation des Surfaces continentales par TELedetection (Observation of Continental Surfaces by Teledetection)
RELU	Rural Economy Landuse Programme
RMSE	Root Mean Squared Error
ROG	Regional Planning Act

RP	Regional plan
RPO	Global sustainable raw wood potential
RV	Raw wood consumption
SIR-C	Spaceborne Imaging Radar operating in the C-band
SNG	Synthetic Natural Gas
SPOT	Satellite Pour l'Observation de la Terre, name of a French satellite
SRU	German Council of Environmental Advisors
SRC	Short rotation coppice
SUPG	Act on the Introduction of Strategic Environmental Assessment and Implementation of Directive 2001/42/EC
t	ton, measuring unit
Tab.	Table
TP	Sub-project
tsd.	thousand
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
uRPO	Unused raw wood potential
USA	United States of America
USD	US dollar
UVPG	Environmental Impacts Assessment Act
VEF	Volume expansion function
VEGETATION	Name of a French sensors onboard of SPOT 4 and SPOT 5
VRG	Priority area
WBGU	German Advisory Council on Global Change
WCS	Whole crop silage
WGS84	World Geodetic System 1984
WHG	Federal Water Act
WRH	Forest wood residues

0 EXECUTIVE SUMMARY

The German Government's Integrated Energy and Climate Programme (IEKP) and the National Biomass Action Plan set ambitious targets for the further development of bioenergy until 2020. The share of energy from biomass is supposed to reach 8 % and 9.7 % of the total power consumption and of the total heat usage, respectively. The share of biofuels on the total consumption of fuels for transportation should rise up to 12 % (energetic) by 2020.

This project aims to assess the possibilities of achieving the IEKP targets for bioenergy in a regional and global context. On a regional as well as global level, the potentials of different biomasses were determined in different development scenarios until 2020. Furthermore, the extent to which remote sensing could contribute in improving the spatial specification of biomass resources and whether it could be used as a monitoring system for the early detection of land use changes was investigated. On the regional level, the spatial implications of energetic biomass use was analysed with regard to environmental impacts and land use conflicts. Depending on their significance of spatial impacts, instruments of spatial planning were assessed in order to steer the supply of bioenergy.

The contents of the work packages, the methodology, the results, the conclusions and recommendations are presented in the following sections:

Using **material flow analyses based on statistical data,** Germany was estimated to have a technical fuel potential of 1.5 to 1.8 EJ/yr from both agricultural, forestry and residual biomass sources in the year 2020. Therefore, the resources necessary to meet the IEKP targets are, in principle are available. Under the assumptions made in this project, all three scenarios (Business as usual, Bioenergy and Bioenergy with increased restrictions due to environment and nature protection) can even exceed the objectives for power and heat using domestic biomass (in 2020 around 16 - 20 % share of biomass on the total power usage and around 22 - 26 % on the total heat consumption). However, the scenarios predicted biofuels to meet only two thirds of the 12 % target objective for transport fuels. This is caused by the scenario assumptions concerning the cultivation mix of energy crops. The cultivation of biomass resources for the production of biofuels (mainly rapeseed, cereals and sugar beet) takes place on approx. 1.7 million ha of agricultural land (this equals to approximately half of the area potentially available for the cultivation of energy crops). If these potentials are widely used, it would require a doubling of the current existing bioenergy production facilities. Additionally, innovative technologies like Synthetic Natural Gas (SNG) and Biomass to Liquid (BtL) could contribute to the provision of bioenergy.

On a regional level, the implementation of the IEKP targets using domestic biomass could result in conflicts, if the demands of the biomass provisions are opposed to other social, economic and ecological objectives. In the context of the case study "Western Saxony", the analysis of **spatial interdependencies** points out that the supply of bioenergy leads on the one hand to positive as well as negative environmental impacts and on the other hand to land use conflicts but also positive spatial synergies. The intensity of the spatial interdependencies is determined by the local natural conditions of the specific region as well as by the technical requirements of the bioenergy provision. The definition of favourable, restricting and excluding areas for specific energy crops and cropping systems as well as favourable areas for bioenergy plants proved to be a suitable instrument to steer the provision of bioenergy according to the aims of regional development.

Specific technical contributions of spatial planning could provide information for the fields of nature, landscape conservation, land use and technical infrastructure. These could be merged into a 'Biomass Development Concept' that in turn could be part of a 'Regional Energy Concept'.

The strengths of such a 'Biomass Development Concept' are not so much in its steering effects, which are considered to be low due to its non-binding, informal character, but moreover the region-specific preparation and availability of data. This concept represents a flexible and manageable basis for the assessment, decision measures and projects relevant to regional planning which in turn could make possible a comprehensive weighing of spatial interests.

Although the regional-plan (RP) of Western Saxony includes no specific textual or graphic information on the spatial demands of bioenergy production, it identifies a significant number of points which need to be tackled. The current aims and principles of the regional spatial plans include not only aspects that are connected to bioenergy plants, but also aspects that influence agricultural use in the planning region of Western Saxony. In practice, however, the formal RP encounters two problems. On the one hand, the RP is too static for reacting adequately to 'new' developments (technologies, cropping systems, market development etc.). On the other hand, it can only have limited content to make it easier to read and handle.

Due to the fact that the IEKP target for biofuels can probably not be achieved entirely by domestic resources from Germany, the **import of biomass and/or bioenergy carriers** will become increasingly important in the future. According to this development, the future global biomass potentials have to be seen in the following context:

- The global residual potential was analysed with the help of a resource-based analysis using statistical data, especially the product-to-residue ratios and the per capita production. The results add up to a global potential of organic co-products, residues and waste of about 30 EJ/yr. Straw and forest residues are the largest fractions (approx. 13 and 10 EJ/yr). Due to the worldwide increase in population and associated consumption, the residual potential will probably increase further by 2020. However the import of residues or residue-derived bioenergy carriers will be of low importance due to low energy density and less favourable substrate characteristics. From an economic and ecological point of view, the decentralised utilisation makes more sense.
- The global technical potential of agricultural biomass is calculated with the help of the GAPP simulation model (Global Agro Production Potential) which uses statistical agro-economic modelling. Different scenarios up to the year 2020 show that the global area and bioenergy potentials depend mainly on the global food demand and on increases of productivity of arable land. In the last two decades, the agricultural commodity markets were characterised by a structural surplus production. In the future, this trend could be reversed in the direction of market deficits. In all scenarios, the continents and parts of continents are developing into different directions: Europe, North and South America show significant and constant surplus area potentials available for the cultivation of energy crops, whereas Asia and Africa have an increasing demand on food imports. Assuming that a global balance of trade will be achieved, the surplus areas would arithmetically-speaking be used to produce food for the deficit countries. At the same time, the possible global scarcity of resources could cause food price effects which in turn could cause an increase of productivity. The quantification of these effects is difficult. In the scenario 'Bioenergy' (B), which assumes a strong increase in productivity, 200 million ha arable land would be available in 2020 for the

production of energy crops corresponding to an import potential of liquid or gaseous biofuels of about 6.5 EJ/yr. In addition to the current annual biofuel production, 187 million tons of bioethanol, 31 million tons of biodiesel and 6.6 billion m^3 of biomethane could be provided (three times the production in 2008). Key production countries could include; Russia, Brazil, U.S.A. or Indonesia. The implementation of further environmental or nature protection standards (e. g. no direct land use change through ploughing up of grassland or deforestation of primary forests (Scenario B&E), use of 2 % of the arable land for nature protection purpose) would possibly reduce the potentials significantly.

- A further potential increase in biomass production could be through the cultivation of energy crops on degraded lands. A very broad range of the global expansion of degraded lands can be found (from 6 to 35 million km^2). Furthermore, the quality of degraded soils, the expected yields and the uses of these areas vary significantly. Therefore, a general assessment of the potential on degraded land is not possible. Synergies between the revaluation of land and bioenergy production, even if produced for international markets, can be very likely.

- The potentials of forestry biomass were calculated by using statistics, extrapolating time series of the global development of forests as well as evaluating regional data and country-specific information. The analysis shows a global decline of forest areas, whereas the plantation areas continuously increase until 2020. Depending on the scenario, the worldwide raw wood potential for 2020 is estimated between 3.2 and 4.2 billion $t_{dm.}$ The raw wood production and its use have been calculated by connecting time series of production and consumption rates with the country-specific development of the gross domestic product and the population number. The comparison with the global consumption of raw wood shows that even after the subtraction of material use of raw wood consumption in 2020, the resources are not yet exhausted and that a surplus would be available for energy production. Nevertheless, in some African, Asian as well as European countries the raw wood consumption would exceed the sustainable and available raw wood potential. These countries would have to increase the import of wood or use more raw wood from indigenous forests than could be provided in a sustainable way to cover the deficit in 2020. In the short term this could lead to a decline of wood reserves, in the medium or long term it could result in a degradation of forests. Despite the large amounts of raw wood calculated for Russia, North America or Brazil, it should be kept in mind that the mobilisation of the potential is a big challenge from an economic and ecological point of view. Depending on the scenario, the global technical potential from forestry biomass in 2020 lies between 36 to 57 EJ/yr. In principle, these potentials are a promising feedstock for future biofuels like BtL or SNG. Nevertheless, these technologies will need time for final development and implementation in the market. Therefore, the import potential for second generation biofuels is expected to be low in 2020.

The overall global biomass potential on the level of the technical fuel potential are summarised in the following table. For 2020 is significant potential between 68 and 116 PJ was estimated.

	BAU	B	B&E
Energy crops	0.3 EJ	16.1 EJ	0.5 EJ
+ 50% yield increase	*0.45 EJ*	*24.1 EJ*	*0.75 EJ*
Forestry	44 EJ	57.1 EJ	36 EJ
Residues	29.9 EJ	29.9 EJ	29.9 EJ
Residues (theoretical)	*35 EJ*	*35 EJ*	*35 EJ*
Sum	74-79 EJ	103-116 EJ	66-74 EJ

Within the context of a global reduction of agricultural areas, the need to use these existing areas in a sustainable and efficient way becomes increasingly important. Currently, sustainability standards and certification systems for biofuels are under development. Furthermore, established approaches for certification in forestry and sustainability standards are translated into the field of energy crop cultivation and possibly further expanded on food, fodder and material production. Therefore, the expansion of the global biomass market needs to be accompanied by monitoring systems to identify land use changes as early as possible. Such a screening of areas at 1 km spatial resolution could be realised with the help of **remote sensing data** and their processing in the vegetation model BETHY/DLR (Biosphere Energy Transfer Hydrology Model). In this project, linear relations between remote sensing data and statistical information have been shown (up to 94 % for forest areas and up to 74 % for agricultural areas). The development of such an instrument should be possible within the upcoming three to five years. Currently, corresponding development activities are initiated by the Climate Change Initiative of the European Space Agency. Furthermore, remote sensing could improve the data basis for the assessment of agricultural and forest biomass resources especially in areas with incomplete in situ data availability (e. g. forest data of Africa and Asia) and could help to identify regional 'hot spots' of biomass resources.

Regarding the role of bioenergy, the results of the project demonstrate that the German Government's IEKP targets for bioenergy can be achieved and that significant reductions of greenhouse gas emissions can be expected by 2020. However, the energetic use of biomass can cause global and regional effects, such as; insecurities concerning the future availability of area potentials under the premise of securing global food supply, the need for efficient utilisation systems and the debate on limitation of resources and associated problems of distribution. Therefore, more flexible systems, which have up to now been restricted in the IEKP approaches and instruments, are required to achieve a sustainable provision of regional bioenergy. This requirement is also a challenge for spatial planning.

Due to the fact, that the impacts of bioenergy use occur on the global as well as national and regional scale, there are the following **options to act** for all three levels.

The IEKP targets for bioenergy and the **target system for the use of bioenergy** respectively **have to be developed further**. Particularly, taking into consideration the scarcity of the resources, future conflicts (for example climate protection vs. energy security) have to be discussed and weighed for society as a whole. On the national scale a roundtable on bioenergy could be the initial point for such a socio-political discussion about the IEKP targets. The IEKP approach with its defined objectives for certain segments (as biofuels) as well as specific volume demands of the EU biofuel objectives leads to a fixed quota for biofuels derived from food crops, which may intensify possible reactions due to food shortage. Therefore, it is important to develop steering approaches that support the stabilisation of food supply. Such **mechanisms for the achievement of the IEKP targets have to be adapted** and initiated on the European level. The further development has to consider more flexible instruments.

The energetic use of organic residues is associated with comparatively low environmental impacts. However, it is difficult to exploit the potential, due to a lack of data about the spatial and due to the decentralised nature and less favourable substrate characteristics of organic residues. Therefore, the **conditions for a comprehensive accessibility of the residual potential** have to be established. These could also include the provision of systematic and spatial information as well as target-oriented funding instruments.

On the regional scale, **regionally based energy concepts could make an important contribution to ensuring energy provision**. For the conception of bioenergy plants, both producers of the feedstock as well as the energy supplier and/or energy user should be involved. This shall ensure a continuous production based on long term agreements (even if agricultural prices are fluctuating) and simultaneously reduce speculative bandwagon effects. For the conception and implementation of regional energy concepts sufficient resources and information have to be provided.

The energetic use of biomass based on energy crop cultivation increases the pressure on agricultural areas in addition to food and fodder production. The looming shortage of resources requires a **target-oriented use of resources regarding land use as well as conversion efficiency** of bioenergy and the mitigation of greenhouse gases.

The **steering effects need to be strengthened by regional planning** in order to implement the site-specific demands of the provision of bioenergy. An essential measure is the amendment of the formal regional planning by informal instruments. Parts of the regional energy concepts can even in the short term represent an appropriate basis for assessment and decision-making to steer the energetic use of biomass in accordance with regional spatial and socioeconomic principles. Participative planning processes might legitimise politically and socially the action of the regional planning authorities. Moreover, relevant information generated from informal processes should be integrated into the formal regional spatial plan, using a comprehensive weighing of current spatial aims and principles. The institutionalisation of separate sectoral planning for energy and agriculture might contribute to provide the data that is relevant for the implementation of the planning processes described above.

In the global context **all possibilities of a sustainable agricultural production and forestry** should be supported in order to use all sustainable agricultural and forestry biomass potentials worldwide. Important aspects are: the intensification and systematisation of the agricultural research to achieve huge yield increases, the prevention of deforestation, the forestation of degraded lands, and the transfer of technology and consequent management of water. Other important aspects include: determining areas for the establishment of effective agricultural management systems, the systematic analysis and reduction of agricultural greenhouse gases, the assurance of land rights and the participation of the local habitants. Focusing on the energetic use of agricultural and forestry biomass to reduce greenhouse gas emissions should also be an important consideration.

Approaches for the support of a sustainable land use should also be developed bilaterally in **international cooperation**. Chances for international cooperation exist especially in the fields of standardisation of biomass, bioenergy carriers, transport and logistics. International projects should be supported if synergies can be found within the development of infrastructure and energy supply in rural regions of industrialising and developing countries. A promising subject for research is the use of degraded lands (transfer of technology and knowledge). The exploitation of these resources requires careful acting and a consideration with respect to individual cases. Therefore, a wide variety of model projects should be planned and implemented until 2020 to benefit from the synergies between revaluation of land and biomass production. Furthermore, cooperation with Eastern Europe is an interesting option since large agricultural areas are expected to be used in the future in this region for the cultivation of energy crops as the appropriate infrastructure already exists (e.g. gas grid for the biomethane supply).

At all scales, international, national and regional, increasing capacities for the provision of bioenergy are due in the near future. Therefore, a **monitoring system using remote sensing** should be established in order to identify “hot spots” of land use changes and biomass production. On a regional scale, a lot of indicators can support the description of the state of change and the future potential of biomass use. Furthermore, it can help to gain target-oriented parameters to assess the regional strategy and options to act out of the multitude of available regional information.

1 BACKGROUND

The energetic use of biomass increasingly gains importance in the sectors of electricity, heat and fuel supply, on both a national and global context. This is initiated by specific legislation (e.g. Renewable Energy Sources Act /12/, Market Stimulation Programme for Renewable Energies /14/, Renewable Energies Heat Act /15/, EC Directive 2009/28/EG /30/) and the establishment of political subsidy tools, but also due to massive increases in the price of fossil energy sources at the beginning of the millennium. The Federal Government's Integrated Energy and Climate Programme (IEKP) and the National Biomass Action Plan set ambitions targets for further development of bioenergy until 2020. The share of energy supply from biomass is supposed to reach 8 % of the total power consumption and 9.7% of the total heat usage. The share of biofuels on the total use of fuels for transportation should rise up to 12 % (energetic) in 2020.

Besides the contribution for climate protection, the production of biomass can significantly contribute to securing energy supply and thus promote sustainable development in particular in the rural areas. However, this positive contribution is not given in every case. Conflicts arise if the requirements of bioenergy provision cannot be brought in line with other social, economic and ecological targets. In particular, the provision of bioenergy is not only in competition with food and fodder production with respect to space and utilisation, but also with other material uses of biomass. Demands created through the requirement to provide energy from biomass for the region need to be co-ordinated with other demands of the region. These pertain for example to the usage of space as well as the demand for infrastructure and resources for different processing and technology chains. Furthermore, requirements result from the construction and operation of bioenergy plants, including the operational and distribution logistics. Such heterogeneous spatial demands of the region at the same time may be linked to considerable ecological, as well as socio-economic effects. Accordingly, this requires targeted spatial coordination to minimise these negative effects and also to promote synergies involved with the energetic utilisation of biomass. To achieve optimal biomass use from a spatial point of view, existing spatial planning instruments should be adjusted to these new challenges and new instruments should be established, if required.

Basically, a large number of different resources are available for energetic biomass utilisation (among them energy crop, forest wood, straw, cereals, liquid manure). They come from agricultural and forestry production and/or the industries downstream of both sectors and also from the waste industry. For the development of a long-term sustainable biomass strategy (such as e.g. the targets of the Federal Government's IEKP (Integrated Energy and Climate Programme) until 2020) it is crucial to consider not only the current biomass resources, but also all medium to long-term biomass resources.

(1) Currently, national and partly global markets are developing to satisfy the significantly growing demand for biomass and/or bioenergy sources at a reasonable price. These are of importance particularly in the range of energy crop and/or the bioenergy sources produced from it (notably biofuels).

(2) In parallel with this, the spatial availability and utilisation is decisive on a regional level with increasing demand for biomass. This spatial availability and utilisation of biomass is determined by a multitude of influencing factors, e.g. from agriculture, energy management and waste industry, which are influenced by the currently available production and utilisation technologies. Adjusted strategies and instruments can only be developed if we succeed to depict and classify (e.g. to sup-

port targets of climate protection and energy policy, such as IEKP 2020, but also under aspects of spatial planning, infrastructure and land utilisation) the expected resources and the expected biomass utilisation with regard to regional dispersion.

(3) The entire bioenergy discussion currently turns out to be very dynamic and partially controversial (e.g. the dispute on empty plate - full petrol tank). An appropriate situation analysis and/or comprehensive exchange of experience by the experts from the fields of biomass utilisation, spatial planning, remote sensing and politics can contribute to the evaluation of the abilities to act and support the development of adjusted instruments.

2 OBJECTIVES

Against this background, the project is handled in three sub-projects. While in sub-project 1 the focus is on the regional biomass potentials in Germany, sub-project 2 analyses the global biomass potentials (see Fig. 1). To reach the targets of the project an international conference on "Biomass in Future Landscapes – Sustainable Use of Biomass and Spatial Development" took place from 31st March to 1st April 2009. Around 400 international delegates attended, including decision makers from the political arena, experts from both the environmental and agricultural sector, as well as from the regional planning sector. Questions regarding the sustainable use of biomass despite the rising demand, increasing spatial and eco-logical impacts as well as the resulting needs for action were dis-cussed. The results of the conference are published as a conference volume.

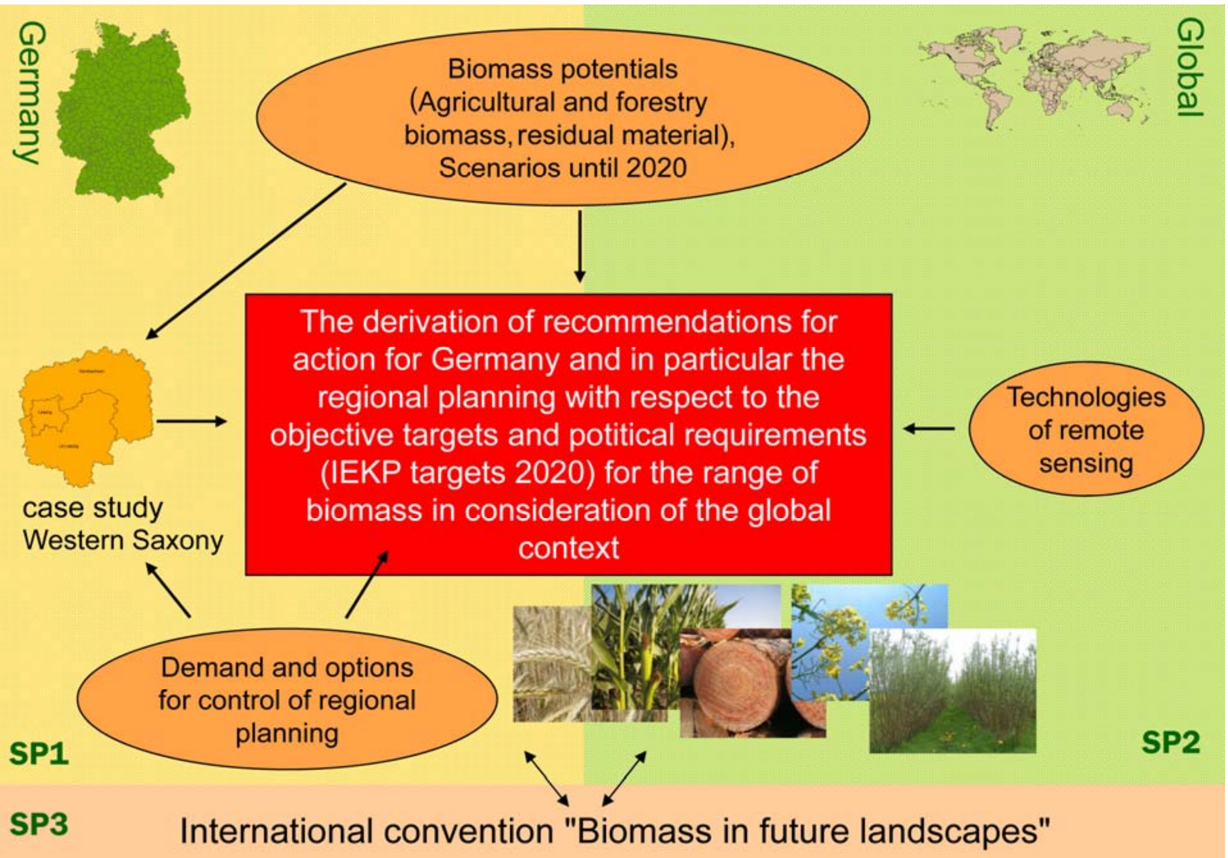

Fig. 1: Illustration of the sub-projects (SP) and their linkage (source: DBFZ)

The technical fuel potentials of biomass and remaining materials from agriculture and forestry are evaluated both on a regional and global scale (see section. 5.1 and 6.1 to 6.4) in different development scenarios until 2020. Furthermore, the spatial implications of energetic biomass utilisation are analysed in sub-project 1. Possible impacts on the environment and possible land use conflicts are analysed in order to identify spatial planning requirements and options for spatial management (see section 5.2).

Based on the results in sub-project 2, potential suppliers (countries, groups of countries) can be evaluated, from where sustainably produced (certified, if applicable) biomass can be obtained and/or imported to achieve Germany's targets with regard to climate and energy policy. The methodology pursued here basically gives preference to the use of agricultural biomass for securing the global demand for food towards other utilisation. Therefore, the evaluations of global potential consider the particular country-specific home requirements of food (see section 6). The work package "Remote Sensing" additionally examines which options remote sensing can offer for better spatial specification of biomass resources (see section 6.5).

In a final step, the results from all sub-projects are subsumed to assess the possibilities for an implementation of the Federal Government's IEKP targets for 2020 in a regional and global context (see sections 7 and 8).

The final report is made up of this main part and six topical appendices:

- Appendix I: Material Flow-Based Potential Calculations for Germany
- Appendix II: Regionally Compatible Provision of Biomass Energy
- Appendix III: Global Agricultural Biomass Potentials
- Appendix IV: Global Forestry Biomass Potentials
- Appendix V: Global Residual Material Potentials
- Appendix VI: Remote Sensing of Biomass Resources

The appendices are available as individual documents. While this Final Report focuses on the fundamental results and the conclusions and recommendations for action derived from it, the appendices explain in detail the methodologies used as well as the results and conclusions.

Along with the main report and the appendices, the following products are prepared in the scope of this project and attached to the Final Report as CD:

- GIS database on the aspects of a) regional and b) global biomass potentials
- Overview of the technology chains
- ACCESS database on opportunities for action for spatial planning
- Results of the written nationwide opinion survey of the persons responsible for spatial planning

3 DEFINITIONS

The foundation for the energetic utilisation of biomass is its basic availability. This is expressed by the biomass potential, which is defined differently, depending on the point of view. At first, the level is used to differentiate where the determination of the potential takes place: area potential, raw material potential, fuel potential or bioenergy potential (see Fig. 2).

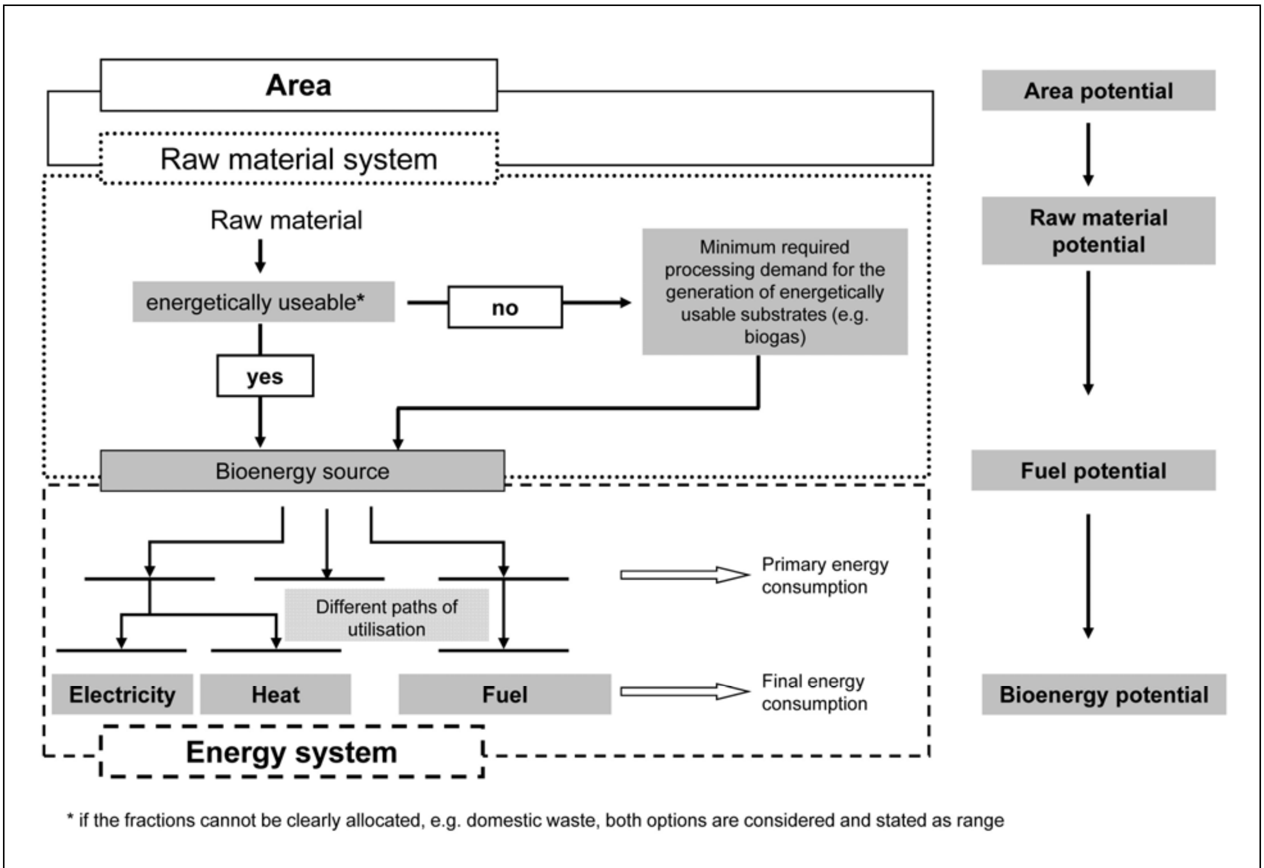

Fig. 2: Illustration of the different levels of the utilisation path and the appropriate potential terms (source: DBFZ)

The determination of potentials requires the definition of system limits and ancillary conditions. The majority of the previous examinations therefore uses potentiality terms which are substantiated by adjectives such as "theoretical", "technical" or "economical". The "theoretical" potential e.g. describes the energy supply theoretically physically usable in a given region within a specified period of time (e.g. energy saved in the entire crop mass). It is solely determined by the given limits of physical utilisation and thus marks the upper limit of the contribution for energy provision which can be theoretically realised. Since due to certain restrictions, the theoretical potential can often be tapped to a very small portion only, it is of no practical relevance for the assessment of the actual availability of the biomass.

This project therefore mainly deals with technical potentials. While the term of the theoretical potential is handled rather consistently in literature, the criteria taken as a basis for the evaluation of the technical potential vary in the individual studies. Technical, structural and environmental restrictions as well as legal requirements will partly be considered in this process. The technically potential amount of different biomass fractions therefore has no precisely defined value, but depends on numerous ancillary conditions and assumptions. Taking appropriate plausible assumptions, plausible statements can be made on the realistic approach of specific political targets by means of the technical potential.

The procedure in this project is outlined below. The technical potential describes the part of the theoretical potential which can be used in consideration of the given technical restrictions. In addition to this, the given structural, ecological, administrative and social limitations as well as legal requirements will be considered, since they ultimately are to be regarded as "insurmountable", similar to the technically determined limitations (e.g. technical: efficiency in conversion, ecological: objectives of nature conservation, administrative: cross-compliance regulations, social: priority of use for the food sector).

The different limiting factors will have deviating effects on the different biomass fractions and systems under consideration. In a global context for example, energy crops will only be cultivated on surplus and/or non-food areas due to the priority of food production, while in the scenarios for the exemplified region, all agricultural areas are available for energetic biomass utilisation. The "insuperableness" of the limitations is based on the particular problem, the region to be examined and the scenarios used, if applicable. In addition, only quantifiable factors are incorporated.

The technical potential in turn can be divided into the technical raw material potential, the technical fuel potential and the technical bioenergy potential.

The technical raw material potential identifies the amounts of biomass available for energetic utilisation on a specific area. The biomass can be directly available as a primary energy source such as wood, or as a raw material, which at first needs to be converted to a secondary energy source, such as corn to biogas. Besides, some raw materials such as e.g. liquid manure cannot be directly energetically utilised, but require certain prior processing (see Fig. 2).

The technical fuel potential identifies the energy content, normally the lower calorific value, of the available bioenergy sources. It therefore represents the total energy content of the biomass to be used for energy. The technical bioenergy potential in turn reflects the final energy content, which is achieved after utilisation in the individual utilisation paths (conversion to electricity, heat and fuels). Due to the strong dependency of the bioenergy potentials upon the utilisation paths, this project focuses on the consideration of the least processed level of energy sources, which already can be used for energy (evaluation of the technical fuel potential).

Term 'planning region': Planning regions are partial areas of the Federal States, defined by functional criteria. Such administrative delimitations are determined by federal state planning and therefore are not subject to criteria identical in all Federal States. They partially correspond to administrative boundaries such as administrative districts or regions, or are composed of such districts or regions, as e.g. in the Free State of Saxony /107/.

4 SCENARIO APPROACH

The project work is based on the preparation of scenarios for future energetic utilisation of biomass. Since different spatial levels are to be examined in the project, scale-specific approaches are pursued (see Fig. 3). While a quantitative procedure is selected for the global and Germany-wide scenario approach, mainly qualitative approaches in the form of verbal-argumentative procedures are used for the development of the scenarios for spatial distribution of biomass production in the exemplified region of Western Saxony, next to quantitative evaluation of the agricultural potential. These are suitable for complex problems such as those of the present analysis, which are subject to distinct processes of discussion and negotiation.

After initial examination of the spatial and instrumental conditions, the Western Saxony planning region proved to be a particularly suitable choice as a case study, not least due to the updated regional development plan. The plan includes concept for nature conservation and landscape management, the strategic environmental audit (SEA) and the Flora Fauna Habitat (FFH) Impact Assessment. An advanced environmental information system and a broad database of the regional planning office were also favourable. This enabled easy access to geo-referenced environmental data, and to basic spatial information, analysis of spatial potentials and disposals. Regional planning agencies were highly interested, not least, since Free State of Saxony's has requested its planning regions to develop energy concepts.

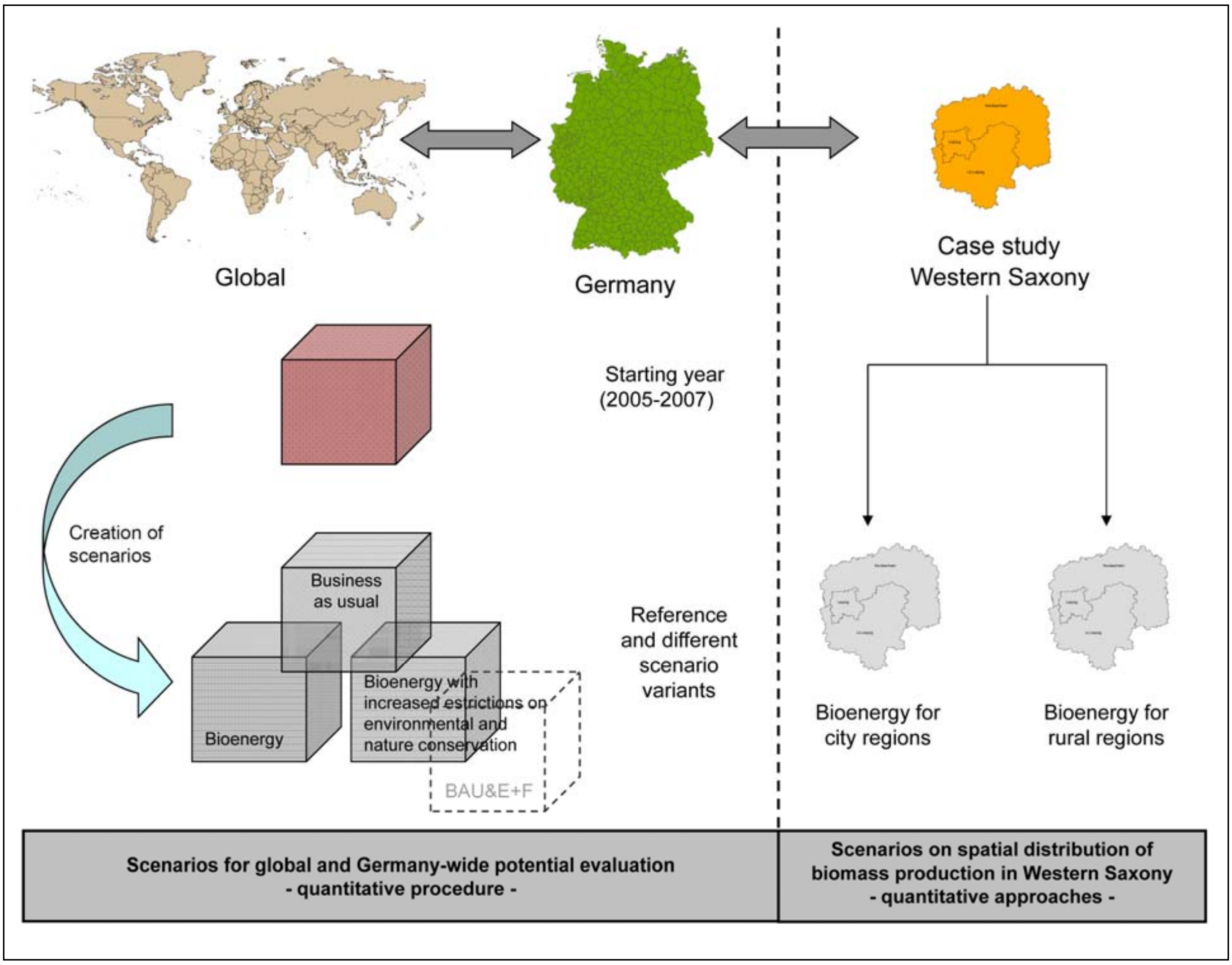

Fig. 3: Illustration of the different scenario approaches for the global and Germany-wide considerations as well as for the case study of Western Saxony (source: DBFZ)

4.1 Scenarios for the evaluation of potentials

The future development of biomass potentials depends on many influencing factors. The energetic potentials on a national and in particular on a global level are determined by development in agriculture, energy management and waste control as well as by technical progress. A scenario-oriented approach therefore seems indispensable for qualified assessment of future potentials.

Different scenarios are used to expand a corridor, which reflects the development with a high degree of probability. It should be noted in this process that scenarios do not represent reliable forecasts, but depend on the special framework conditions and selected parameters, depicting model environments by means of *if - then* statements. They are based on assumptions made, and therefore only are possibilities of how development could proceed until e.g. 2020. The reference development carries forward the trend in the short and medium term, while measures assumed in scenario variants can change this development.

4.1.1 Scenario drivers

The basic influencing factors for the spatial and fuel potentials are mentioned below and their fundamental and scenario characteristics are briefly explained. The importance of the scenario drivers may vary depending on the level of consideration (regional or global).

Demographic development: The demographic development is one of the basic scenario drivers, since it determines the demand for food and thus the available area for the cultivation of energy crop. Furthermore, the demand for food and consumer goods and therefore the quantity of waste are also based on the future demographic development. On a global level, data from the United Nations provided the statistics for the database. The regional considerations in Germany take the population forecast of the regional statistics agencies into account.

Per-capita consumption: Next to the demographic development, the consumption of food per-capita also is an important driver of agricultural development and thus of the spatial potentials in the global scenario approach.

Trend of crop yield: The trend of crop yield is an important influencing factor for the calculation of the biomass potentials. On the one hand, it determines the development of the spatial potentials: with high crop yield in intense agriculture, the demand for land is less than with a smaller crop yield (e.g. with a high share of organic farming). On the other hand, the yields of energy crops and thus the biomass potentials, are also based on the development of this factor.

Changes in the mix of crop growing: The provision of biomass can be covered by a range of different plants. For the global considerations, the mix of crop growing is selected on a regional basis. The three or four key plants/crop types are determined per country or group of countries and then, depending on the scenario, reasonable modifications are developed for the regional cultivation structures.

Land degradation: Land degradation is understood as a decline of the functions and the productivity of an ecological system over a specific period of time. Land exposed to degradation processes such as salinisation, erosion etc. is subject either to limited agricultural use or is completely eliminated from agricultural production. The development of the degraded land is included in the global scenarios and considered in the development of the crop yield and/or the development of the fallow land.

Development of nature conservation areas: The development of nature conservation areas depends on the political framework conditions and determines the availability of agricultural crop land for the production of biomass and/or possible reduction in crop yield on land of different categories of protection.

Climate change: The potentials from agriculture and forestry are changing under the influence of climate change. In case this has already caused effects on the potentials, they are included in the assessment of future potentials, because the latter are based on trend assessments of the crop yield from time series since 1989. It is therefore considered, that Australia for example mainly shows a declining growth of crop yield due to the climate, and no increasing crop yield at all can be expected in the future. However, we do not act on the assumption of an increase in climatic yield depression deviating from the trend, because due to the climate change, positive reduction of yield is expected in the highly productive, regions with normally high precipitation, which partly will compensate for the yield effects of the negatively affected areas. In addition, significant effects from disproportionate climatic effects which will reduce the crop yield, can only be expected from the middle of the century. For the rest, the effects of adjustment strategies to climate changes by plant breeding (water stress) and cultivation management (water-saving soil cultivation, crop rotation and others) cannot be reliably assessed.

4.1.2 Scenario description

The discussion of the basic scenario drivers results in three scenarios as a basis for the calculations of the different technical fuel potentials. In the scenario "Business as usual" (BAU) the short and medium-term trends are extrapolated. The "Bioenergy" scenario and "Bioenergy with increased environmental protection and nature conservation restrictions" scenario is developed in order to let the development described in the "BAU" scenario vary in different directions, by changing the scenario drivers. As a brief excursus, the calculation of the global agricultural biomass additionally considers a pure land use scenario "Business as usual with increased restrictions on environmental and nature conservation restrictions and change in food patterns".

Business as usual (BAU): The "Business as usual" scenario represents the extrapolation of the short and medium-term trends and developments. The year 2007 is selected as a basis year for the global considerations 2005 (2002 - 2005) and for the regional calculations of the potential. For the "BAU" scenario, the extrapolation of the trends is essential with regard to agricultural development, changes in land use and the demographic development.

Bioenergy (B): In the "Bioenergy" scenario, the assumptions are changed so that energetic utilisation of biomass is strongly forced. For example, stronger increase of the crop yield will be achieved by higher propensity to invest. The mix of crop growing is changed in such way that the most fertile crops are cultivated disproportionately to maximise the yield of biomass, and thus bioenergy (e.g. SRC (short rotation coppice), silage maize, see Table 1).

Bioenergy with increased restrictions on environmental protection and nature conservation (B&E): The scenario "Bioenergy with increased restrictions on environmental protection and nature conservation" depicts a model environment, in which the importance of environmental protection and sustainability is emphasized. Therefore, further restrictions are assumed for better consideration of restrictions on environmental protection and nature conservation as compared to the "Bioenergy" scenario.

Land use scenario - Business as usual with increased restrictions on environmental and nature conservation and change in food patterns (BAU&E+F): Due to the strong effects of agricultural land use on a global scale, the considerations on the global agricultural biomass potentials are extended by aspects of nutrition. Both environmental issues and changes in food patterns are emphasized. It is assumed that e.g. the energy consumption is gradually reduced by up to 30

% in all population groups with excess nutrition of calories and proteins, however not below the level of supply which is required for healthy nutrition. All population groups still undernourished however will further realise an increase in the per-capita food consumption according to the previous trends.

Table 1 presents the assumptions for the three global scenarios and the land use scenario. The same changes of population, per-capita consumption and re-designation of agricultural land into settlement areas and circulation areas are assumed in all four scenarios.

Table 1: Presentation of the assumptions in the individual scenarios for the global considerations (source: Universität Hohenheim, vTI, DBFZ)

Scenario	Manifestation of drivers
Business as usual (BAU)	- Change in land utilisation such as forest clearance and ploughing up of grassland, - Increase in crop yield by technical progress, e.g. for short rotation coppice wood production (SRC) and forestry plantations 10 % in 15 years, - Share of cultivation continues to exist (as found at the basis, main focus on food production), - Growth of organic farming is linear proportional to the growth in the last 18 years.
Bioenergy (B)	- Change in land utilisation such as forest clearance and ploughing up of grassland, - Change of the cultivation mix towards crops with maximum yield (so-called energy crop rotation) → 1/3 ligneous substrates (SRC in moderate climates, plantations in the tropics), in each case the crops with maximum yield of the established crops of the countries or groups of countries up to site-specific crop rotation limits - Significant increase of the soft commodity prices and as a result, great incentive to achieve yield increase by 50 % for all farming crops compared to the "BAU" scenario.
Bioenergy with increased restrictions on environment protection and nature conservation (B&E)	- Assumptions for cultivation mix and yield increase as in "B" - Strict prohibition of primary forest clearance and ploughing up of grassland, - 10 % of the forests in the boreal and moderate areas taken out of utilisation and turned into a preserve for species conservation and biotope protection, - 50 % of the area in tropical primary forests protected and no longer utilised, - Extension of the areas under nature conservation by provisioning of another 2 % of the farmland for purposes of redesignation.
Pure land use scenario: Business as usual with increased restrictions on environment protection and nature conservation and change in food pattern (BAU&E+F)	- Calorie consumption of persons with excess nutrition reduced by up to 30 %, - Change in demand for products from organic farming → Disproportionate extension of organic farming (doubling in 10 years) - Low yield increase compared to the "BAU" scenario: reduced by 5 % until 2010, by 10 % until 2015, by 15 % until 2020 and by 45 % until 2050.

4.2 Scenarios for spatial distribution of biomass production in Western Saxony

In contrast to the procedure of scenario development as explained above, with biomass potentials being calculated on a global level as well as Germany-wide, and the quantitative results being mapped, quantitative approaches are amended by qualitative approaches in the example of the Western Saxony planning region. The interweaving of these approaches results from the individual phases of scenario development on a regional level:

- Preparatory phase: During the preparation of the scenario development, the different potentials a region has for the provision of bioenergy were determined and depicted in a map, for each of the technology paths under consideration. Included are statements on favourable agricultural areas and on the region's infrastructural qualification (cp. section 5.2.3). The procedure is basically of a qualitative nature.
- Execution: The scenarios were developed during a two-day, project-internal workshop. The spatial distribution of the technology paths in Western Saxony to be considered was discussed and outlined by means of the potential maps.
- Reflection phase: After the scenarios had been developed for the planning region, the assumptions for the spatial distribution of biomass production were weighted and categorised on the one hand, and criteria for the identification of favourable and unfavourable areas were derived on the other hand. Furthermore, the relevance of the scenario technique was pointed out in its use for the support of informal approaches in regional planning to be able to exert influence on the spatial development of the biomass production. This phase is primarily characterised by verbal-argumentative procedures.

The following extreme scenarios were developed for Western Saxony (cp. section 5.2.3):

- Scenario I: Bioenergy for city regions – The focus of bioenergy supply is on the Leipzig regional metropolis, as shown in the RP, on the basic centres of the Leipzig city region as well as on the medium centres in the entire planning area.
- Scenario II: Bioenergy for rural areas – The focus of bioenergy supply is on the municipal nuclei of supply and population and the basic centres outside the Leipzig city area.

The mapping scenario is selected as the scenario method, which is used to display the considered development paths in summary on highly generalised synthesis maps /82/. The method is suitable to visualise desired and also undesired developments and thus to process expert knowledge for non-specialised local actors. When developing mapping scenarios, regional actors can be integrated into the planning process at an early stage, which at the same time will sensitise them for possible spatial developments.

5 REGIONAL BIOMASS POTENTIALS

The utilisation of biomass in Germany continued to be expanded in the past years mainly in the field of heat and fuel utilisation. This trend will continue in the future. In addition, as already explained in section 1, the EU and the Federal Government will issue targets for the reduction of the CO_2 emissions until 2020 and for the contribution of renewable energies to the energy supply in the range of electricity, heat and fuel for transportation.

Against this background, the technical fuel potentials are evaluated in sub-project 1 on the one hand for different fractions in Germany with regard to spatial differentiation (see section 5.1) and on the other hand, potential spatial effects of the biomass fractions are considered for the Western Saxony planning region and the evolved demands for governing are identified (see section 5.2).

Taking the evaluations of the technical fuel potentials as a basis it should be assessed, what degree of contribution to energy supply of biomass can be expected in the year 2020. Furthermore, the results are to be used to make statements on how much the energetic biomass utilisation can contribute to achieve the IEKP targets in Germany.

The examinations in the case study should demonstrate which factors influence the production of biomass and their effects in the region. Also possible conflicts of utilisation in the region shall be monitored and potential demands for governing shall be derived from it. This process considers opportunities for action by the instruments of regional planning currently available as well as conceivable further developments.

5.1 Material flow-based potential calculations

(DBFZ)

The biomass potentials in Germany are analysed in sub-project 1 on a regional basis and technical fuel potentials are evaluated for the years 2007 and 2020. Agricultural biomass, i.e. energy crop, forestry biomass and residual material is under consideration. The residual material includes agricultural residual material such as liquid manure and straw, but also bio waste and green waste as well as wood processing industry residues and scrap lumber. To determine the potentials from energy crop, three scenarios are developed for 2020 on the basis of the national land evaluations from subproject 2 (see section 4.1).

An overview of the methodological approaches and the results of the project work are provided below.

5.1.1 Agricultural biomass

In the scope of this study, exclusively energy crops and grassland are included in the agricultural biomass. Energy crops belong to the renewable primary products and are cultivated for energetic utilization, i.e. they supply biomass for the generation of electricity and heat as well as for the production of fuels. Since the calculations are based on the land scenarios from sub-project 2 (see section 6.1), the grassland is also considered here accordingly.

In the scope of the examinations, the technical fuel potential of energy crops is evaluated on a district level for the year 2007 as well as in three scenarios for the year 2020 in Germany.

Methodology

The biomass potential from energy crops is determined by means of a material flow analysis based on statistical data. Statistics of the State Offices of Statistics on a district level are used as original data. This, for example, includes data on land use such as areas used for the cultivation of individual crops on farmland and their yield. Furthermore, data on current utilisation of agricultural biomass for energetic purposes is included in the considerations. In addition, for the evaluation of the crop yield we act on the assumption that part of the farmland is located in protected areas of different categories, e.g. biosphere reserve or water protection area. Due to restrictions in cultivation, such as less use of fertiliser or pesticides, reduced yield is assumed for such areas.

The non-food areas from the results of the global area calculations are used for the calculation of the three scenarios for the year 2020. We use the national areas without balance of trade (see section 6.1). These are areas not needed for the production of food and thus are available for the cultivation of energy crops. The non-food farmland according to the global trade balance to ensure global food supply is considered in section 6.1. However, the allocation of such areas is changed in comparison to the global scenarios (see Table 2). Next to a different allocation of areas, the share of nature conservation areas on the farmland is also varied in the scenarios.

Table 2: Crop distribution on the non-food areas (source: DBFZ)

	As of 2007 [%]	BAU [%]	B [%]	B&E [%]
Silage maize	15.0	25.8	30	20
SRC	-	10.0	33	40
Winter rapeseed	67.0	35.0	15	11
Cereals	17.9	29.0	12	20
Sugar beet	0.1	0.2	10	7
Sunflower	-	-	-	2

The technical fuel potential is finally computed from the resulting crop yield of the individual crop types, using the lower heating value. Due to the high water content, the specific biogas yield is evaluated for silage maize, whole-plant cereals silage and sugar beet and the technical fuel potential is determined with the calorific value of the biogas.

The potential of the grassland areas in Germany is evaluated on the basis of the national area calculations from sub-project 2 of the project. The grassland areas for non-food usage which will be released until 2020 in comparison to the reference year are determined here, and by means of the yield per hectare, are taken as a basis for the evaluation of the amount of grassland growth which can be harvested on such areas.

Results

Fig. 4 shows the results for Germany. This results in a technical fuel potential of energy crops of approx. 176 PJ/yr for the year 2007. In the scenario "Business as usual", approx. 501 PJ/yr can be provided from energy crops in 2020 and approx. 860 PJ/yr in the "Bioenergy" scenario. The result of the scenario "Bioenergy with increased restrictions on environment and nature conservation" lies in between, with approx. 580 PJ/yr. In Fig. 4, the technical fuel potentials of grassland growth are added to these results. The calculations add up to an amount of approx. 6 million t_{DM} of grassland growth, corresponding to a technical fuel potential of approx. 100 PJ/yr in the year 2020.

The regional distribution and development is shown in Fig. 5. This makes it clear that the technical fuel potential is significantly lower in 2007 than in the scenarios for the year 2020. The regions with the largest potentials are mainly located in the areas with a high share of agricultural land such as in large parts of Northern Germany, e.g. in the north-west of Lower Saxony and in the northern part of Mecklenburg-West Pomerania. But also the regions of central Germany in Thuringia and Saxony and/or Saxony-Anhalt are characterised by large potentials of energy crops. However, some districts of Southern Germany, e.g. the area around Munich, also sporadically show a high share of farmland and thus, increased cultivation of energy crops.

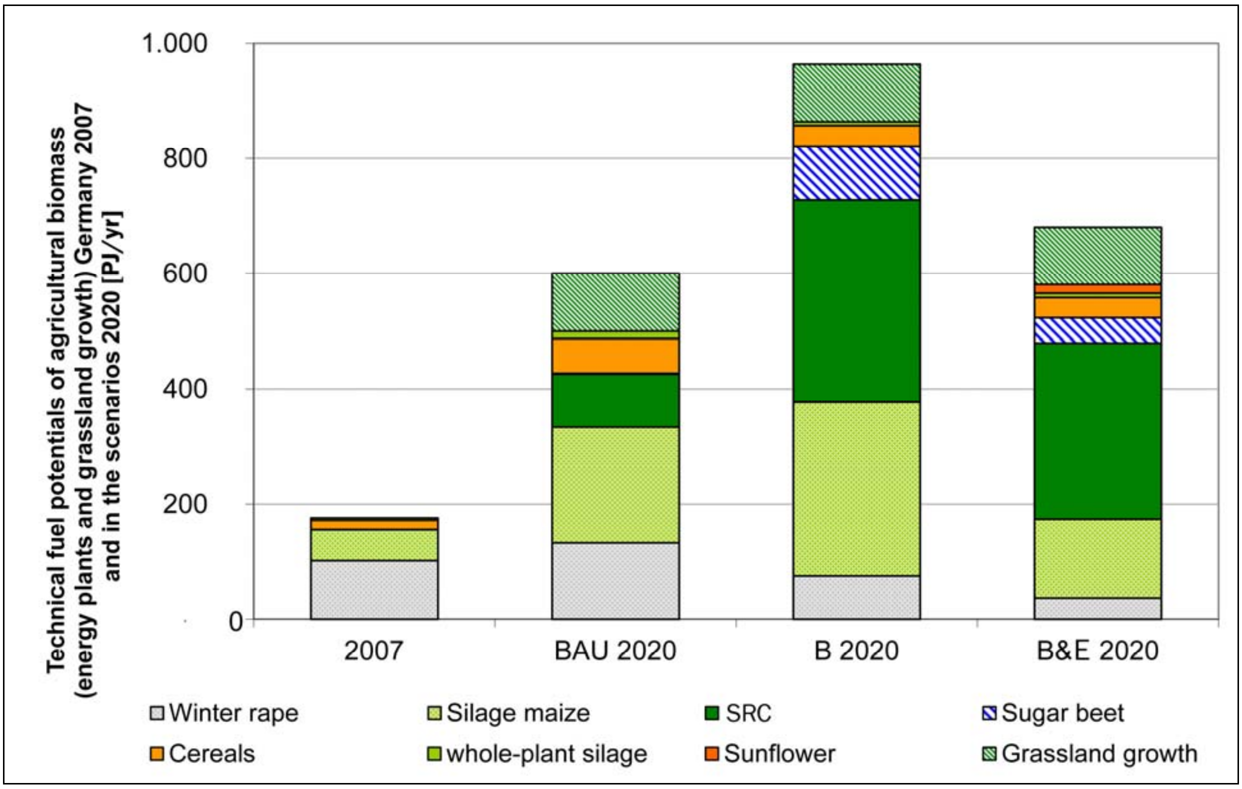

Fig. 4: Technical fuel potentials of agricultural biomass (energy crops and grass growth) Germany 2007 and in the scenarios 2020 (source: DBFZ)

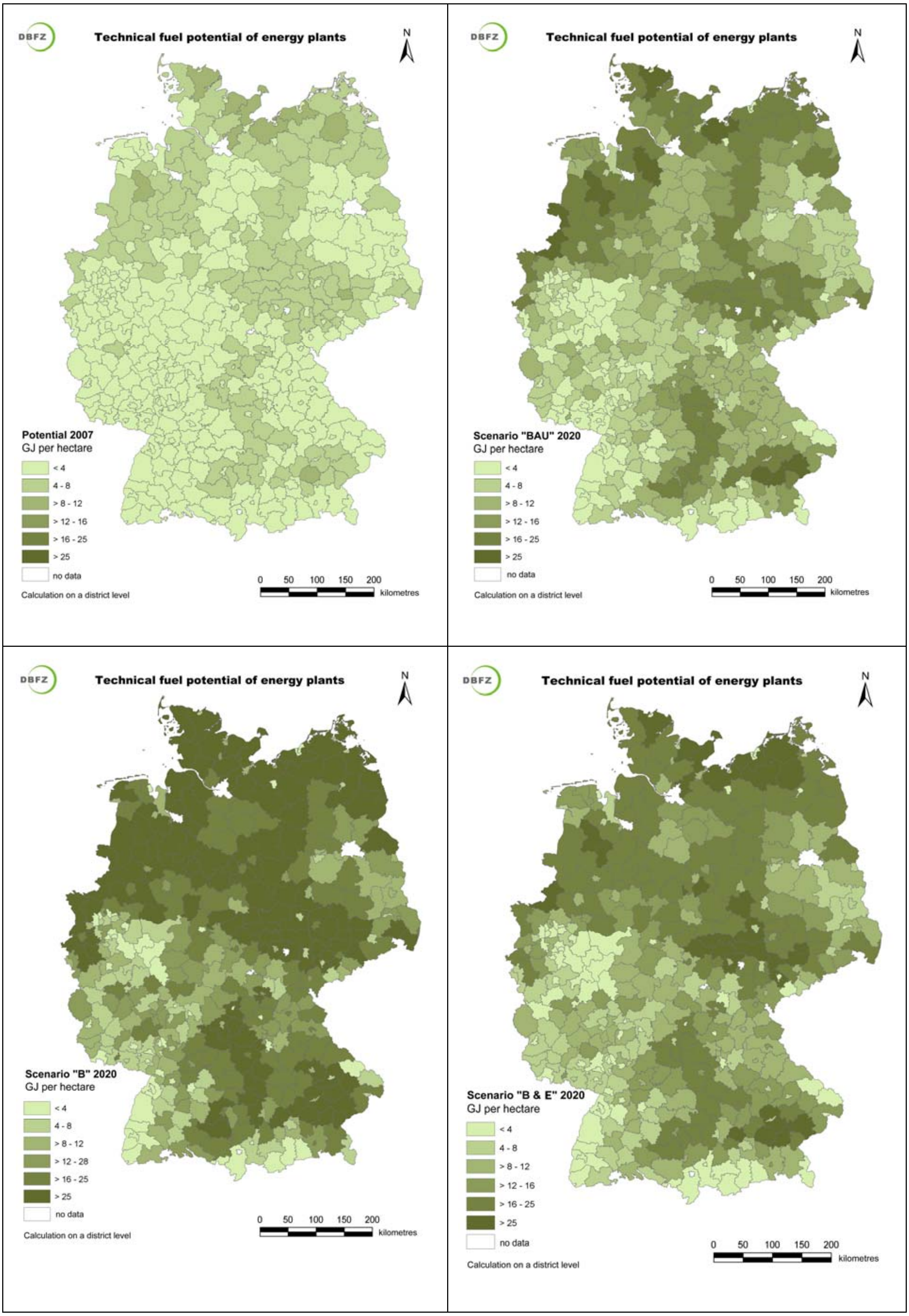

Fig. 5: Technical fuel potentials of energy plants 2007 and in the scenarios 2020 (source: DBFZ)

5.1.2 Forestry biomass

The biomass from forestry in Germany is determined on a state-wide level in the scope of the project. The residual forest wood as well as the stem wood and bark which have already been used energetically are included for the calculation of the timber technical fuel potential.

Methodology

The statistical data of the Federal Forest Inventory 2 as well as own projections were used for the evaluation of the forestry potentials and a model forest was created, which represents the average distribution of deciduous, coniferous and mixed forest as well as the age structure of the trees of the individual federal states. Furthermore, data on nature conservation areas on forested land is included and abandonment of use in these protected areas is specified. Other basic data include statistics on current wood harvest, deductions for securing sustainable forestry and assumptions for securing the share of dead wood in the forest. This results in the technical fuel potential of forest wood on a state-wide level.

Results

The calculations on the forest potential in Germany add up to a technical fuel potential of approx. 511 PJ/yr. This is made up of the currently still unused increase of forest wood and forest residues, which in turn can be divided into merchantable residual forest wood and residual forest copse wood (see Fig. 6). Furthermore, the potential also includes the amount of forest wood, which is already energetically utilised and which includes stem wood and bark.

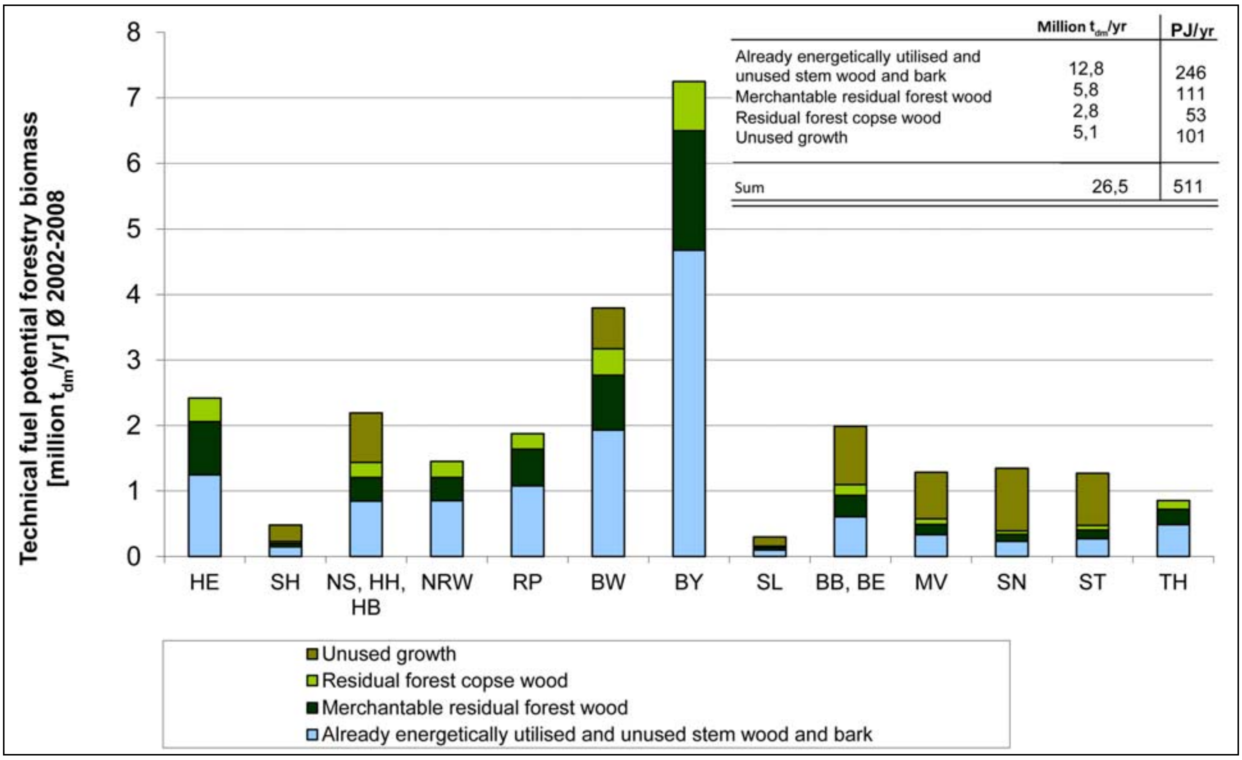

Fig. 6: Technical fuel potential of forestry biomass in the German federal states, Ø 2002 - 2008 (source: DBFZ)

The forest wood, which is already energetically utilised and also stem wood and bark not yet used, take the largest share of approx. 246 PJ/yr in the forestry potential. The forest residues have a potential of 164 PJ/yr, with a share of merchantable wood in the forest residues being 111 PJ/yr and the share of copse wood of 53 PJ/yr. Furthermore, the increase of forest wood, which is currently still not in use, still offers a large potential for utilisation with 101 PJ/yr. The largest technical fuel potentials of forest wood are in Bavaria (approx. 7 million t_{dm}/yr and 140 PJ/yr resp.) [t_{dm}/yr =absolute dry matter p.a.], Baden-Württemberg (approx. 4 million t_{dm}/yr and 70 PJ/yr resp.) and Hessen (approx. 2.5 million t_{dm}/yr and 45 PJ/yr resp.).

5.1.3 Residual materials

The residual materials which can be used for energetic utilisation are to be considered in this section. These include the agricultural residual materials such as straw and liquid manure, but also residues from the wood-processing industry. Furthermore, the potentials of biological waste and green waste as well as from used wood are included in the considerations.

Straw

The technical potential of straw is determined for the year 2007 and the scenarios for 2020 on a district level. The cereal straw and the straw from the cultivation of winter rape are included in the considerations.

Statistics on the acreage of cereals and winter rapeseed under cultivation as well as the particular yield per hectare in the individual districts are used as basic data for the determination of the technical fuel potential of straw. Lastly, the yield of grain and/or rapeseed is multiplied by the grain-straw ratio for the calculation of the entire straw volume.

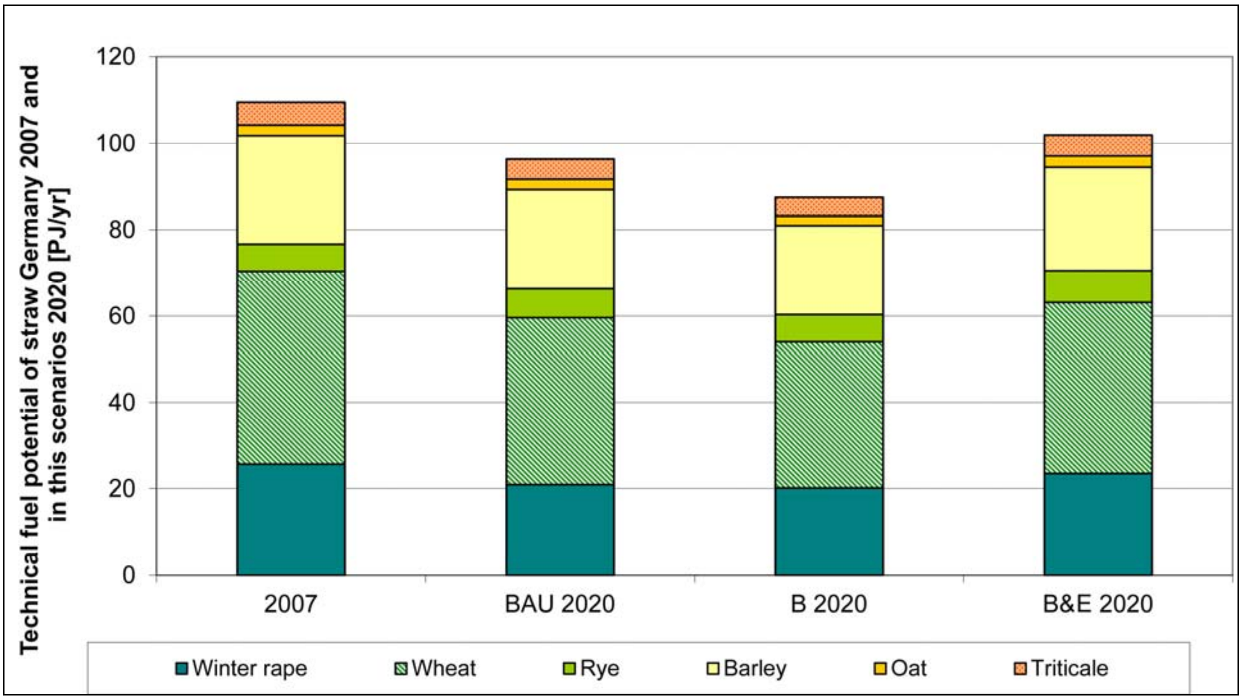

Fig. 7: Technical fuel potential of straw Germany 2007 and in the scenarios 2020 (source: DBFZ)

The calculations in the scope of this study result in a volume of straw of 32 million t_{dm} in 2007. Due to smaller acreage under cereals and rape cultivation, the amount of straw for the scenario "Business as usual" with approx. 28 million t_{dm} and for the "Bioenergy" scenario with 25 million t_{dm} is somewhat smaller. The calculations from the "Bioenergy scenario with increased restrictions on environmental and nature conservation restrictions" result in a straw volume of 29 million t_{dm}. It is assumed that 20 % of these amounts are available for energetic utilization. The remaining share of material is already utilised, e.g. as litter in animal husbandry, or remains on the field for the preservation of the humus balance. The resulting technical fuel potential is shown in Fig. 7. The potential is largest in the year 2007, while the "Bioenergy" scenario for 2020 shows the smallest straw potential. The regional distribution of the potential corresponds to the grain growing areas. Large potentials are seen in Lower Saxony, in the north of Mecklenburg-West Pomerania and in Central Germany.

Liquid manure

Relevant quantities of liquid manure result from livestock farming, primarily from cattle and pigs, and are used exclusively in biogas plants for energetic utilisation. Litter, i.e. straw, saw dust and similar is also suitable for energetic utilisation. The potentials of droppings from cattle and pigs for Germany are determined on a district level and for liquid and solid poultry manure, on the level of federal states. The following section provides an overview of the methodology and the results of the potential evaluation for liquid manure and litter. The farm animal species cows, pigs and chickens are considered for the evaluation of the biogas potential for energetic utilisation. All resulting droppings from animal husbandry, which are shown as potential, can actually be energetically utilised. There will be no competition with regard to possible use as fertiliser, since the digestate can also be spread on the field and the nutrients are even more available for the plants.

The calculations result in a quantity of liquid manure and/or litter of 139 million t available for energetic utilisation. This results in a total biogas yield of 4 billion m^3/yr, corresponding to a technical fuel potential of approx. 90 PJ/yr. The largest share hereof is cattle droppings with approx. 55 PJ/yr, while liquid manure and litter from pigs still has a share of approx. 30 PJ/yr. Liquid chicken manure has a share of 3 PJ/yr of the potential. The largest potentials in Germany-wide distribution are found in the north-eastern part of Lower Saxony and south-eastern Bavaria.

Bio waste and green waste

According to the Biological Waste Ordinance, biowaste is waste of animal or plant origin. Biogenic residual matter is a very heterogeneous mixture, which on the one hand comes from private households as well as business and comes around as kitchen and canteen waste and/or waste from the food industry. On the other hand, green waste is also included in this category. In the scope of this study, the potential of biowaste and green waste is evaluated for the years 2007 and 2020 on a district level. The quantity is distinguished between biowaste and green waste, with garden waste also being included.

The annual quantity of biowaste and green waste in Germany is approx. 7.6 million t in 2007. If extraneous materials, loss in collection and water content are subtracted, this amounts to a technical raw material potential of 2.9 million t_{dm}. Part of the green waste is thermally utilised and biogas is produced from the remaining material. Thus, a technical fuel potential of approx. 23 PJ results for the year 2007. Due to a slight decline in population until 2020, the potential of biowaste and green waste will also decrease. A total of 7.5 million t of biogenic material will still accumulate in 2020, corresponding to a technical fuel potential of 22.5 PJ. The regional distribution of the potential is clearly linked to the populous regions. Large potentials are shown for example in Berlin and Ruhr area.

Used wood and residues from wood-processing industry

The fuel potentials of scrap wood and industrial waste wood are evaluated on a federal state level. The volume of scrap wood is identified via the analysis of waste statistics and the particular waste fractions. The pure wood fractions as well as the quantities of waste fractions are included, where wood only appears as mixed fraction. The wood-processing industries and their share of residual material will be considered in the raw material input. The material utilisation of the corresponding residual materials, such as saw dust in the cellulose and paper industry, is also taken into consideration. In total, approx. 9 million t solely of wood fractions and approx. 1.5 million t of wood from mixed fractions accumulate in Germany (as of 2006). A total of 7 million $t_{(air\ dried)}$ is available for energetic utilisation. Thus, a technical fuel potential of 110 PJ results for scrap wood. The largest quantities are available in the federal states of North Rhine-Westphalia and Lower Saxony. Industrial waste wood however amounts to approx. 18 million m³/yr, which corresponds to the theoretical potential. A large part of this volume (approx. 12 million m³) already is materially processed in the industries and therefore is no longer available for energetic utilisation. The technical fuel potential therefore corresponds to 58 PJ/yr in Germany. The federal states of Bavaria and Baden-Württemberg have the greatest share with 23.4 and 19.8 PJ/yr respectively (see Fig. 8). Negative results in the potential evaluations, e.g. in Saxony Anhalt, result from intense utilisation of the material, which even exceeds the volume of wood residues.

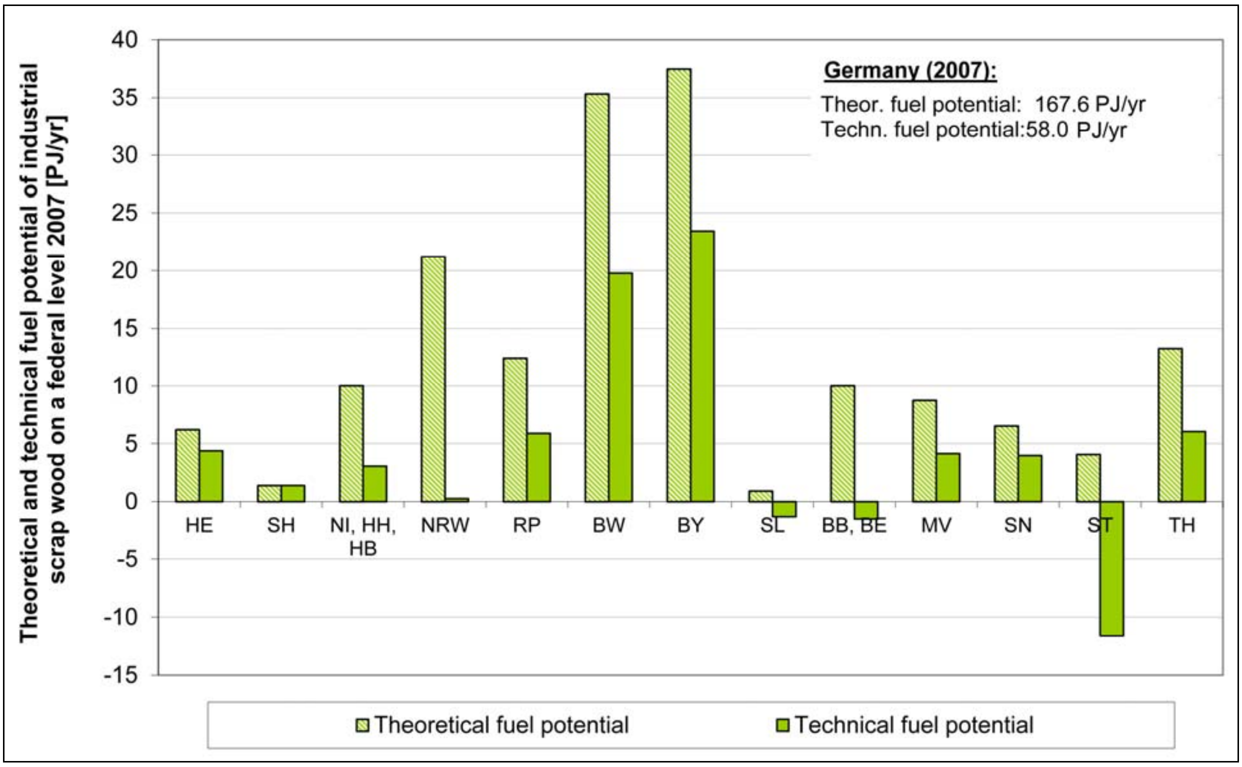

Fig. 8: Distribution of theoretical and technical fuel potential of industrial wood residues in the federal states for 2007 (source: DBFZ)

5.1.4 Technical fuel potentials for Germany and IEKP targets

When adding the total technical fuel potentials of the individual biomass fractions, this results in a significant potential increase of from 2007 to 2020. Approx. 1,000 PJ is totally achieved already in the year 2007 (see Fig. 9). The "Bioenergy" scenario with approx. 1,800 PJ/yr shows the largest biomass potential, whereas the technical fuel potential of the energy crops has the greatest share. Also the increase of the total potential mainly results from the increase of the energy crop potential. The forestry potential with 511 PJ also contributes a large share to the total potential.

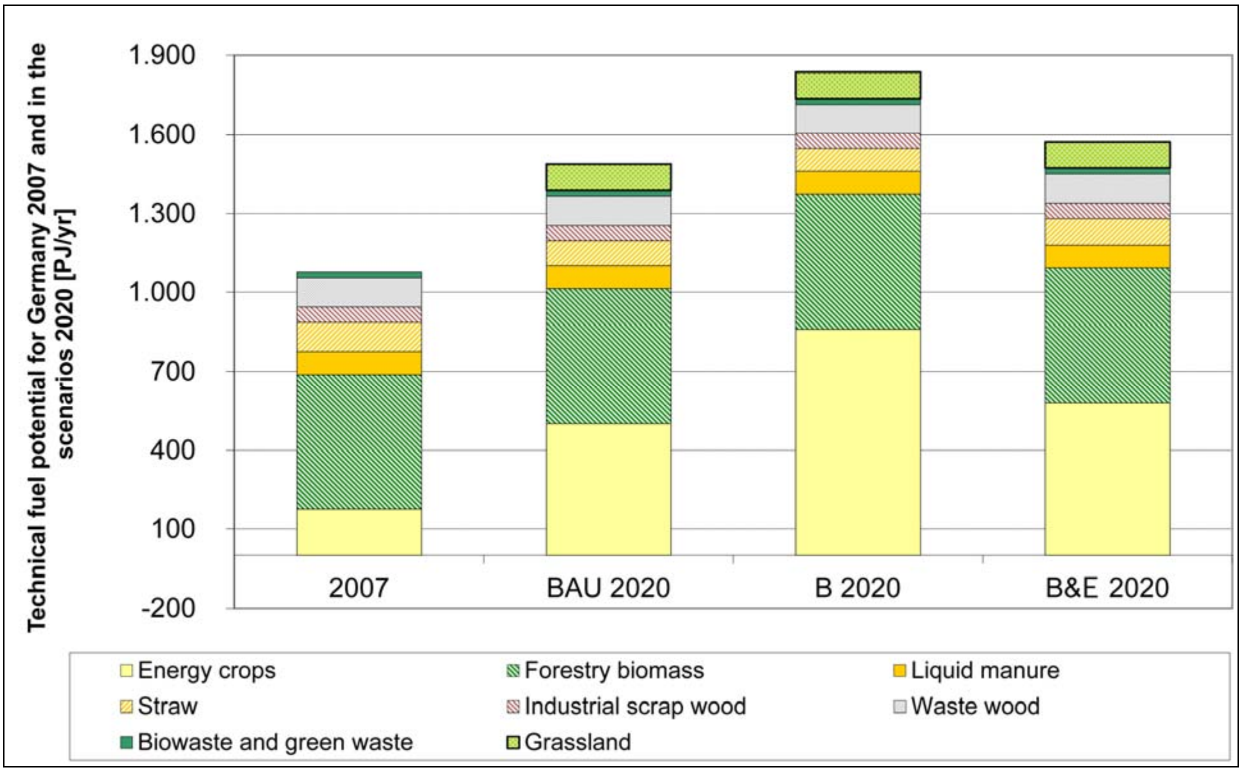

Fig. 9: Sum of technical fuel potentials for Germany 2007 and in the scenarios 2020 (source: DBFZ)

In the scope of sustainable climate politics, the Federal Government's Integrated Energy and Climate Programme aims at an intense development of renewable energies and the increase of energy efficiency, but also at safeguarding the security of energy supplies. In this process, the development of energetic utilisation of biomass is part of the measures for realisation of such targets. In Germany, the targets in the scope of biomass are incorporated in the framework of the National Biomass Action Plan /11/ and in the Master Study of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) /13/. Also the targets for the development of the energetic biomass utilisation are exactly specified here. Below, the results of the scenarios will now be compared with the targets.

According to the master study 2008 of the BMU, there will be a total demand for final energy of 8,132 PJ in the year 2020, which is composed of about half of the heat consumption requirements, almost 30 % from the demand for fuels for transportation and approx. 20 % of electricity consumption (see Table 3).

The targets for the share of energy provision form biomass are (see Table 3):

- 8 % share of electricity from biomass in the overall electricity consumption,
- 9.7 % share of heat from biomass in the overall heat supply, and
- 12 % (energetic) biofuels /13/.

Table 3: Final energy demand 2020 and share of energy from biomass (source: DBFZ according to /13/)

	Final energy demand 2020 [PJ/yr]	Target share of biomass [PJ/yr]
Final energy electricity 2020	1,791	143.3
Final energy heat 2020	4,033	391.2
Final energy fuel 2020	2,308	277.0

The energy sources are allocated to their respective utilisation paths to evaluate the energy quantities, which can be provided from biomass based on the results of the scenarios. Biogas, for example, is transformed to electricity and heat in a combined heat and power plant (CHP). Considering the specific average degree of efficiency, approx. 41 PJ of electricity and 42 PJ of heat can be produced from 100 PJ of biogas.

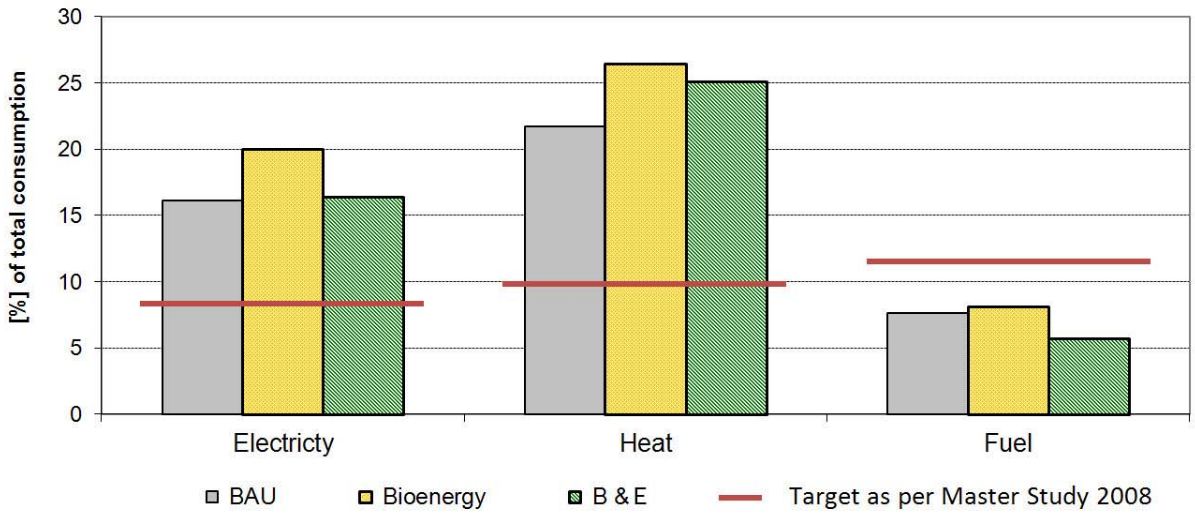

Fig. 10: Possible share of the total final energy consumption in the 2020 scenarios (source: DBFZ)

Fig. 10 presents the shares of the final energies evaluated in the scenarios in the total consumption in Germany. In all scenarios, the yield from heat is significantly higher than the yield from electricity and fuel, whereas in the "Bioenergy" scenario the largest contribution can be provided each time. Thus, the electricity demand in the scenarios "Business as usual" and "Bioenergy with increased restrictions on environmental protection and nature conservation" can be provided from biomass up to approx. 16 %. Even up to 20 % are achieved in the "Bioenergy" scenario, so that the target of 8 % electricity from biomass is clearly achieved in all three scenarios. The share of heat which could be provided from biomass is even higher compared to electricity. Therefore, in scenario "BAU" 21 %, in scenario "B" 26 % and in scenario "B&E" up to 25 % of the heat demand from biomass could be provided. Thus, also the heat target of 9.7 % from biomass is also met in all scenarios. Another situation is shown for the fuel target of 12 % from biofuels. The required energy cannot be provided by the amount of biofuels calculated in the scenarios. Approx. 7 % is achieved in the "BAU" scenario and in scenario "B", 8 % of the fuel demand can still be provided from biomass. Only 5.4 % is achieved in scenario "B&E".

Table 4 shows the number of bioenergy plants which would be required for the transformation of the biomass produced in the scenarios. In the scenario "Business as usual (BAU)" for example, 13,000 biogas plants (500 kW) would be required for the production of the biogas.

Table 4: Number of biogas plants required for the generation of the energy in the scenarios 2020 (source: DBFZ)

Plant type	BAU	B	B&E
Biogas plants (500 kW)	13,000	15,970	10,850
Forest wood CHPs	4,750	6,000	6,140
Biodiesel plants	690	448	192
Bioethanol plants (1st generation)	188	388	275
Bio-SNG plants	10	10	10
Bioethanol plants (2nd generation – lignocellulose-based)	1	1	1
BtL plants (biomass to liquid)	3	3	3

The biomass potentials were also evaluated for the Western Saxony planning region, which plays an important part in the regional planning analyses and the achievement of the IEKP targets was examined at least for electricity and heat. The region around Leipzig shows that the targets for electricity and heat can also be achieved here.

5.2 Spatially compatible provision of bioenergy – Options for governing on regional planning level

(ZALF)

The production of biomass for energetic utilisation can promote sustainable development, in particular in rural areas. Not least, it can significantly contribute to climate protection and energy security and can help to secure energy provision. However, the effects of biomass production for bioenergy provision may not always be positive. Conflicts could result if the requirements to provide bioenergy cannot be brought into line with other social or economic targets. Special conflict potentials exist not only between biomass cultivation and food and fodder production, but also with other land users. In particular, environmental impacts can be linked to the intensification of bioenergy provision. Such negative effects to the environment can result from both intensive farming methods with monocultures and an increasing number of biomass plants and the areas used for it. Systematic spatial coordination can contribute to using available biomass potentials, to minimising negative effects, but also to supporting positive developments and synergies involved with energetic utilisation of biomass.

5.2.1 Methodical approach

In practice, current and future options for action and management of regional planning need to be identified, which can be used to spatially manage further developments of bioenergy provision.

Next to the original instrument of regional planning, the regional development plan, further institutional rules and standards at all other planning levels, including other sectoral planning topics, need to be examined in order to ensure sustainable regional development. This project approaches the complexity of this topic and thus the broad thematic discussion with (case) specific examinations. They are based on:

- nine selected **technology chains**, of which two are already established and seven are in the development and/or pilot phase,
- the analyses focusing on the **cultivation of biomass** as well as on the **plants for biomass processing**,
- the selection of the analyses exemplified by the **case study of the Western Saxony planning region**.

Factors beyond regional areas of influence and effects will be excluded. This pertains to national and in particular international economic conditions, first of all market and price developments as well as policies of subvention (see Section. 2.1. appendix II).

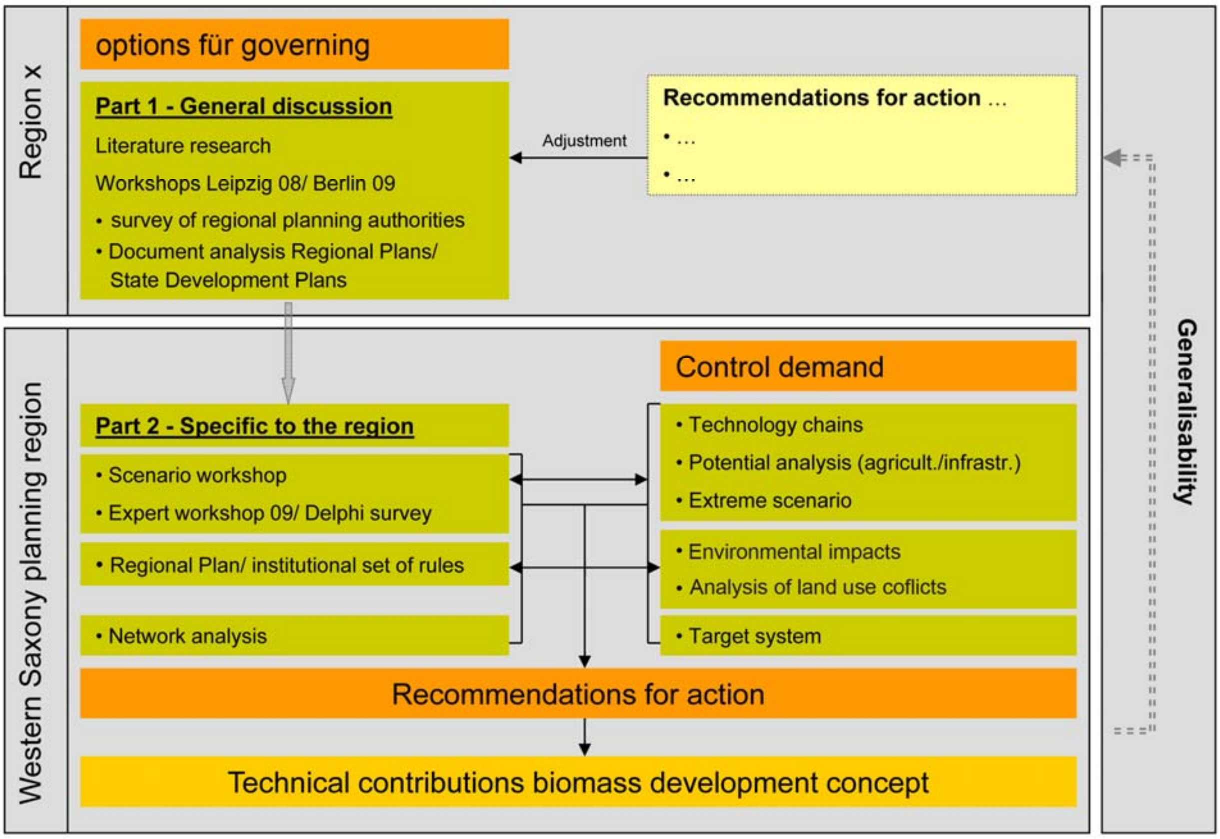

Fig. 11: Steps of examination for the evaluation of options for governing (source: ZALF)

According to the methodical procedure illustrated in Fig. 11, the examination is composed of the analysis of the **options for governing** on the one hand and of the **demands for governing** on the other hand. While the analysis of the demands for governing is exclusively related to the Western Saxony planning region, the analysis of the practical opportunities for action in the Western Saxony planning region (Part 2) is preceded by an analysis of the general theoretical and social discussion on the options for action of regional planning (Part 1). This first part deals with literature research and evaluation, expert polls in the scope of workshops with national and international experts, and nationwide survey of all regional planning authorities as well as a document analysis of the online released state development plans and regional plans (see CD in the appendix). Initially an internal workshop with experts from the ZALF and DBFZ was organised in October 2008. This was followed by a specialist workshop with national and international experts in November 2008, an international conference in April 2009, as well as a workshop with regional experts in August 2009. This workshop included a Delphi survey.

The findings gained in Part 1 serve as an evaluation framework for the region-specific analysis of the options for governing in Part 2. This in turn basically builds up on the findings from the analysis of the **demands for spatial coordination** for the Western Saxony planning region. The management demand, i.e. the requirement for action which could result from increased bioenergy provision in the planning region, is identified in four steps. At first, the particular **agricultural as well as infrastructural potentials** are evaluated and mapped for the Western Saxony planning region according to the requirements of the technology chains forming the basis of the project. In a participatory process, a regionally precise **extreme scenario** is developed for the planning region on an expert basis and by analysing the agricultural and infrastructural potentials; with the objective to utilise as much of the potentials as possible for bioenergy provision in the planning region (see section 2.1 appendix II). Taking the results from the extreme scenario as a basis, the third step identifies the possible **environmental effects and land use conflicts** which then will be analysed for the planning region, irrespective of the setting of the area of the scenario for the planning region. While the area-wide ecological risk analysis of environmental impacts is oriented on the Strategic Environment Audit of the RP (see section 2.2 appendix II), the examination of land use conflicts is based on a verbal-argumentative analysis of the targets and principles as well as other requirements of the Regional Plan for Western Saxony (see section 2.3 and 2.4 appendix II). The assumptions derived from the scenario process for the spatial development of bioenergy provision finally forms a building block for the preparation of a **target system** for the Western Saxony planning region, which is established in Step 4 (see section 2.5 appendix II). The results of the analysis on the demands for governing are coordinated with regional experts from the special fields of climate protection and climate change, landscape planning, construction, renewable primary products, agriculture, silviculture and forestry as well as general policies and state and regional planning of the Free State of Saxony (regional expert workshop in Leipzig August 2009).

Along with the validation of the results on the demands for governing, the regional workshop, as a relevant step in Part 2, serves for the discussion of political instruments and approaches for the spatial coordination of bioenergy provision in the Western Saxony planning region. The findings on the options gathered in Part 1 are formulated as hypotheses as a basis for the discussion. In addition to the results of the discussion, the expert opinions are collected in the scope of a Delphi survey. The aim of the two-stage survey procedure at the beginning and end of the workshop is to focus more strongly the possibly wide-spread range of expert assessments both on the governing demands and on the options for governing. Furthermore, an **analysis of existing networks** in the Western Saxony planning region is performed in Part 2, actively dealing with the subject of energetic utilisation of biomass. The objective of this network analysis is to answer the question to what extent regional planning is currently integrated into such local and/or inter-municipal activities and whether it is able to influence the spatial expansion of bioenergy provision by cooperation. In the third step of the region-specific analysis on the options of governing the **RP** is finally examined to the effect of to what extent it can be used to exert influence on the environmental impacts and land use conflicts identified for the Western Saxony planning region. If there is no direct or indirect steering effects by the formal RP, the analysis states which institutional set of rules and regulations is applicable to minimise environmental impacts and land use conflicts or to promote synergies.

Finally, recommendations for action are derived from the comparison of governing options and demands for governing specifically for the planning region. Furthermore, the available instruments of regional planning will be amended by **technical contributions for a biomass development concept (BDC)**, which in turn is planned as a possible building block for a regional energy concept, and further developed. The technical contributions for a BDC mainly include information from the results of the agricultural and infrastructural potential analysis as well as from the analysis of environmental impacts and land use conflicts (see section 3.3 appendix II).

Furthermore, the transferability of the recommendations for action prepared for the Western Saxony planning region on the one hand, and of the methodical proceeding for the development of technical contributions on the other hand will be discussed. In particular, the relevance of the target system derived from the scenario process and of regional networks is discussed and finally, **generalised recommendations** are formulated to be applicable beyond the Western Saxony planning region.

5.2.2 Demands for governing the bioenergy provision as exemplified by the Western Saxony planning region

Scenarios

The use of the scenario method has two significant meanings in the present analysis. On the one hand, by the development of extreme scenarios we try to collect a range of environmental impacts and land use conflicts. That ought to be as wide as possible in order to enable us to examine a broad variety of demands and the according opportunities for action. It thus forms an initial intermediate methodical step for the analysis of the requirements for spatial coordination. On the other hand, a participative approach is tried with the process of scenario development to enter the subject of bioenergy provision, which is a new subject from the aspect of regional planning, and to assumptions and objectives for regionally sustainable bioenergy provision can thus be developed jointly with regional stakeholders.

Environmental impacts

The intensive agricultural production (e.g. /5/) and thus also the intensive biomass production often have a negative impact on the different landscape factors. Nevertheless, biomass production for the provision of energy can also have favourable impacts on the landscape functions /92//97//125/.

In the scope of the analysis of environmental impacts of bioenergy provision, the expected adverse effects with spatial relevance to the environmental factors (§ 2 EIA (Environmental Impact Assessment Act) /120/) and/or to the relevant landscape functions /126/ are therefore evaluated. Reference are the developments depicted in the scenarios. With respect to their significance environmental impacts are evaluated area-wide in an ecological risk analysis on the basis of the SEA of the Western Saxony RP. Focus of investigation in particular is on the intensive cultivation of energy crops adhering to **good professional practice (gPP)** as well as the use of residual forest wood. Furthermore, the impacts of the construction and operation of bioenergy plants environmental impacts are evaluated. The principles, objectives and requirements of regional and landscape planning formulated in the planning region serve as a standard for evaluation (see section 2.2 appendix II).

The individual adverse impacts to the landscape functions by the cultivation of biomass are evaluated for selected crops and cultivation systems. The selection of these crops and cultivation system is based on the raw material demand of each technology as described in the characteristics for the technology chains.

By aggregation of all environmental impacts, areas of different environmental impacts can be illustrated in the Western Saxony planning region for the cultivation of different field crops and for different types of cultivation. Those areas should be divided into such with considerable negative environmental impacts, with no effects or with considerable positive effects (Table 5). In certain areas, no effects are to be expected if specific requirements for utilisation or limitations (e.g. conservative soil cultivation, extensification of biomass utilisation) are met (see section 2.2 appendix II). These are above the minimum standard of **good professional practice (gPP).**

Table 5: Overview of the areas subject to different environmental impacts in the Western Saxony planning region (source: ZALF, coordinated in the regional expert workshop /75/)

Type and intensity of environmental impacts	Area criterion (→ relating to crop type/ utilisation/ cultivation system)
Considerably negative environmental impacts	Grassland of high habitat value (→ AL/ SRC), grassland of high recreational/landscape value (→ AL/ SRC), alluvial meadows of the habitat system (→ AL), rare culturally significant soils (→ SRC), natural soils of historic importance (→ AL/ SRC), grassland with high retention capacity (→ AL), highly endangered forests (→ LR)
No considerably negative environmental impacts when requirements are met	Intensely used grassland (→ AL), agricultural areas of the habitat system (→ AGr/ PG), landscape of the habitat system to be kept open (→ SRC), post-mining reclaimed land of the habitat system (→ all kinds of utilisation), erosion-prone areas (→ erosion developing crops) rare/culturally significant soils (→ AL), natural soil of historic importance (→AGr/ PG), areas with a high rate of new formation of groundwater (→ DCS/ SRC), areas with regionally important formation of cold air as well as their air flow paths (→ SRC), forests on soil with poor nutrient supply (→ LR)
No considerably negative or positive environmental impacts	Areas with low sensitivity towards adverse effects and high soil fertility (→ AL), areas with low sensitivity towards adverse effects and high water holding capacity (→ DCS/ SRC), forests with good nutrient supply (→ LR)
Considerably positive environmental impacts	Very strongly contaminated areas or strong anthropogenic influenced areas with very small habitat value (→ GL), erosion-prone areas (→ AGr/ PG/ SRC), areas of low retention capacity (→ AGr/ PGL/ SRC), areas of little recreational/ landscape value (→AGr/ PG)

References: AL = agricultural land, SRC = short rotation coppice, LR = utilisation of logging remains, AGr = agricultural grasslands, PG = permanent grassland, DCS = dual cropping system

Land use conflicts due to biomass production

The production of biomass requires very large areas. The energy density of biomass is considerably less than with other energy sources, which increases the spatial effects. An extension of biomass production can therefore increase competition for the limited resource of land. However, also synergy effects between biomass production and other types of area utilisation can be expected besides land use conflicts.

Land and use conflicts caused by biomass cultivation are examined on the basis of the scenarios prepared for the Western Saxony planning region in the scope of the project. The examination is based on the regional plan (RP) for the Western Saxony planning region. Potential land use conflicts are analysed and evaluated by means of the targets (priority areas) and principles (reserved areas). Other sources such as e.g. the environmental report of the Western Saxony RP, laws or specialist literature were additionally used.

Table 6: Overview of land use conflicts for biomass cultivation in Western Saxony (source: ZALF, coordinated in the Regional Expert Workshop /75/)

Spatial category	Land specification (→ related to utilisation/ cultivation system)
Excluding conflicts	Water protection areas zone I (→ agriculture) Priority areas for preventive flood protection/ priority areas for nature and landscape with flood protection function (→ maize, cereals, AGr, DCS)
No conflicts when restrictions* are met	Priority areas for nature and landscape (→agriculture) Reserve areas for nature and landscape (→agriculture) Water protection areas zone I (→ LR) Water protection areas zones II-III (→agriculture) Priority areas for water resources (→agriculture) Heath areas (→ SRC) Priority areas for forest protection (→ LR)
No conflicts	Water protection areas zones II-III (→ LR) Reserve areas for preventive flood protection (→agriculture, LR)
Synergies	Nature park (→ AGr and grassland) Areas for the conservation and improvement of water retention (→ SRC) Priority areas for preventive flood protection (→ SRC, grassland) post-mining reclaimed land south of Leipzig/ in the Oschatz uplands (→ large-scale SRC) Delitz and Brehna plain, Naunhof countryside (→ large-scale SRC) any type of landscape, in particular areas of small recreational/landscape value (→ small-scale strip cultivation of SRC using alleys or hedges)

* Restrictions can be spatial limitations or measures above gpp level. Refer to section 2.3 of the appendix for the restrictions required in certain areas to avoid competition.

Furthermore, it is analysed whether mutually exclusive competition or competition preventable by restrictions exist between the cultivation of the considered raw materials and individual land use, or whether synergies can be expected (see Table 6). The results are based upon our evaluations, coordinated with regional stakeholders within a workshop.

The analysis of protected areas in the Western Saxony planning region demonstrates that landscape conservation areas and nature conservation areas cannot be consistently evaluated due to their different conservation aims with regard to biomass cultivation. A qualification needs to be assessed in the individual case. Grassland is often encouraged in landscape conservation areas and extensive cultivation is aspired. The utilisation of forest residues is no competition towards the aim of conservation, at least in the analysed landscape conservation areas. Ploughing of grassland in landscape conservation areas is mostly prohibited and an extensive cultivation is aspired. The cultivation in the designated process protection areas is not allowed and spreading of liquid manure often is prohibited.

Land use conflicts due to bioenergy plants

The plant-related effects of bioenergy plants are examined on the basis of the RP along the lines of the analysis of land use conflicts resulting from the cultivation of biomass (see section 2.4 appendix II). Primarily excluded areas can be shown as a result of this examination. Due to missing empirical values (with regard to demand for land, construction height, emissions etc.) for the seven technologies under development, no plant-specific evaluation can be performed. The evaluation is therefore uniform for all plants. Separate statements can only be made at some points for biogas plants (e.g. water pollution control).

Table 7: Overview of land use conflicts regarding bioenergy plants in Western Saxony (source: ZALF)

Spatial category	Area description
Excluded areas	Priority areas (reserve areas) for nature and landscape Nature conservation areas Water protection areas zones I-II Priority areas for water resources Priority areas for preventive flood protection Areas for conservation and improvement of water retention Priority areas (reserve areas) for forest protection Priority areas (reserve areas) for forest enhancement Priority areas for agriculture and forestry Priority areas for recreation/ forest enhancement Priority areas (reserve areas) for raw material surface mining Priority areas (reserve areas) for brown coal mining Green strips and smaller adjacent green areas

The largest areas of conflict result in the range of nature conservation, water protection and provision for recreation / landscape pattern.

Soil sealing for the construction of bioenergy plants will inevitably lead to conflicts with nature conservation. The construction of plants is therefore excluded in the examined nature conservation areas of the Western Saxony planning region. For landscape protection areas, it is to be examined in an interrelation with the responsible authority whether the plant is in contradiction to the conservation aim and if yes, if the premises can be excluded from the protected area. No demand for governing is considered for the protected areas, because the existing regulations are adequate.

The rural areas have great importance for tourism and recreation in the Western Saxony planning region. Bioenergy plants may cause negative impacts on this recreation function if they disturb the appearance of the landscape. A landscape can appear technically oversized due to the size of some bioenergy plants and may affect the character of the area. The analysis of the 'Guidelines for Nature and Landscape' in the case study shows that bioenergy plants can create serious and non-compensable impairment of the nature of a landscape in the following areas: Characteristic mountain ridges, hilltops and hillsides, widely overlooked areas as well as non-separated landscape areas. In those areas with limited view, such as the north-eastern part of Western Saxony or in existing industrial and commercial areas however, no serious negative visual impacts are to be expected. As a destination for a visit, bioenergy plants may even have positive effects for tourism. This is formulated as possibly synergy in the maintenance and development concept of the nature park 'Dübener Heide' /81/.

Special requirements apply for some bioenergy plants for the aspect of water protection. According to §19g of the Federal Water Act (WHG) /127/ and the ordinance of the Saxony State Ministry of Environment and Agriculture on systems for handling substances hazardous to water, biogas plants must be treated as 'systems dealing with substances hazardous to water'. Biogas plants should therefore keep a minimum distance of 50 m from surface waters. The construction of biogas plants in water protection areas as well as in the priority areas for water resources should therefore be avoided.

Target system for sustainable bioenergy provision in the Western Saxony planning region

The findings from the analysis of environmental impacts and land use conflicts form a fundamental basis for the arrangement of a regional target system. In a higher-level target system, the responsible body of regional planning should define the specific tasks incumbent on them for further development of biogas provision. As to develop a system of spatial planning aims for the Western Saxony planning region (see section 2.5, appendix II for comprehensive details), guidelines for sustainable bioenergy provision that already exist (in particular from the biomass action plan) are initially compared with such from sustainable spatial development (here primarily from the Regional Planning Report 2005). Hence, the overall objectives are defined. The particular subordinate targets are mainly based on the assumptions for the spatial distribution of bioenergy provision as formulated in the scope of the scenario workshop. They are supplemented by findings from the analysis of environmental impacts and land use conflicts (see Fig. 12). As a basic principle, the target system is not to be considered as a static conception. It rather forms a conceptual framework for action for the regional planning authorities, who should then take their decisions within those limits.

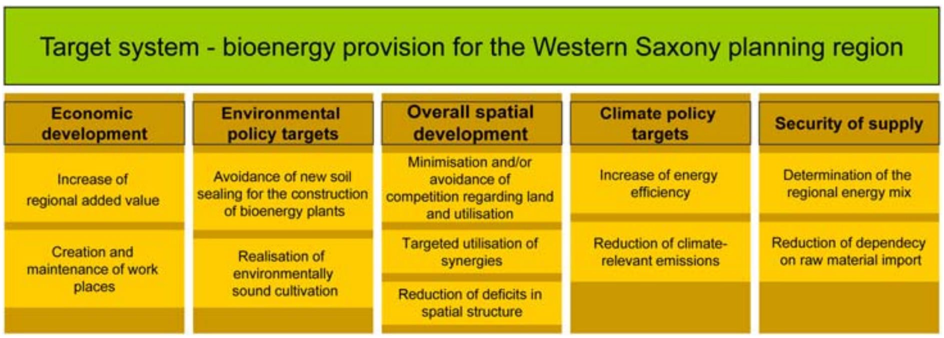

Fig. 12:Target system for dealing with bioenergy provision (source: ZALF)

Conclusion

In the overall consideration of all environmental impacts and land use conflicts, excluded areas, restricted areas and favourable areas can be shown for cultivation of different crops and the different cultivation systems in the Western Saxony planning region. In excluded areas, significant negative environmental impacts and/or exclusive land use conflicts are to be expected. Compatible cultivation of the particular type of crop is not possible from aspects of nature and landscape as well as from the point of view of regional planning and should therefore be excluded in such areas. In contrast, no environmental impacts and land use conflicts or even significant positive environmental impacts and/or synergies with other land use will result in favourable areas. The cultivation of the particular type of crop or the particular cultivation system should therefore be promoted in such areas. Cultivation of arable crops under good professional practice can lead to considerably negative environmental impacts or land use conflicts in restricted areas. However, they can be reduced or even avoided by certain requirements or restrictions of use (e.g. conserving soil cultivation, extensification of utilisation, spatial limitation).

The assessment of the environmental impacts and land use conflicts of biomass production shows that no significant difference to conventional agriculture can be expected. The deriving demand for governing therefore does not exclusively refer to biomass production. Dual-cultivation systems and wood production by short rotation coppices are exceptions, with both positive and negative environmental impacts and competitions as well as positive environmental impacts and synergies.

From economic point of view, along with these alternative cultivation systems other crops can also be used for the provision of energy in the future, in particular as a biogas substrate (e.g. Sudan grass, Silphium perfoliatum, sunchoke /34/, wild plant mixtures /71/). However, these are to be assessed differently. Often they are likely to be more favourably with regard to their impacts and could therefore contribute to the provision of so-called "non-commodity outputs" by agriculture /20//34//97/51//64/. The consideration of such crop types and wild plants as well as their promotion should be an item of future spatial planning.

The analysis of the environmental impacts and land use conflicts shows that the energy and climate policy objectives of the Free State of Saxony in the Western Saxony planning region and thus also the IEKP targets for electricity can be achieved in both scenarios. The IEKP target for the utilization of heat from biomass can however only be achieved in scenario I. The achievement of the targets therefore depends upon the selection of the technologies. The particular spatial demand for energetic biomass production in the scenarios as well as for food and fodder production can be satisfied (see chapter 2 appendix II).

5.2.3 Governing the spatial distribution of bioenergy provision - Options and constraints of regional planning

The task of coordinating different requirements to the area is the central role for regional planning to minimise conflicts resulting from bioenergy provision and to promote synergy effects. This section describes how regional planning can comply with this demand. The basis for the analysis are results from the conferences, workshops and literature research performed in the scope of the project, a document analysis of the nationwide online available regional and state development plans as well as a practical analysis of the regional plan (RP) of the Western Saxony planning region. In addition, the results of 40 evaluated questionnaires of a nationwide survey of the 114 responsible bodies of regional planning are considered. The survey is based on a standardised written procedure and has a rate of return and recourse, resp. of 35 % (cp. evaluation on the attached CD).

Competences of regional planning to govern biomass production

The nationwide survey shows that 82 % of the participants see basic demand for action to coordinate biomass production by space-related planning. The majority consider regional planning (60 %) to be responsible, followed by various sectorial planning (53 %) and finally municipal land use planning (40 %). Multiple answers were possible. At the same time it should be noted that 40 % of the respondents do not consider regional planning to be responsible. This is substantiated by the lacking competence of regional planning to be able to influence agricultural land use. In order to face these ambivalent opinions and to clear the grey area in regional planning, it is recommended to force the discussion on spatial planning in the range of energetic utilisation of biomass on the level of comprehensive regional planning as well as state planning. The spheres of competence should be clearly defined and jurisdictional boundaries for acting should be described. In Germany, the Advisory Board for Spatial Planning as well as the Conference of Ministers for Spatial Planning should take a central part in the discussion.

Governing bioenergy provision - by the regional plan – Status quo

A document analysis of the nationwide online available RP was performed in the scope of the project. Altogether, 84 RP were considered, two of them still being in the draft phase. A complete investigation in the Federal State of Lower Saxony could not be performed in the scope of the project. However, the comprehensive Regional Planning Programmes of the Hanover region as well as of the Larger Braunschweig Administration Union were audited. In addition, the Regional Planning Programmes of nine districts in Lower Saxony were examined as random sampling, whereas the selection was mainly orientated on the accessibility of the plans via the 'Metropolplaner' platform. Thus, 29 RP were not considered. This results in 111 legally binding RP in Germany. From the 82 legally binding RP considered 9 plans were not available online so that a total number of regional plans relevant for the analysis was 73; this is 67 % of the regional plans currently approved in Germany. In 30 of the plans under consideration (approx. 41 %), no reference to dealing with bioenergy provision could be identified. The majority of the statements (n = 35; approx. 43 %) are general intentions for action ('Biomass/ biogas is to be utilised. Its utilisation should be further developed.'). Only 7 regional plans (approx. 9 %) include differentiated statements and/or refer to the provision of bioenergy with regard to the region. The implementation of the renewable primary products bonus (NawaRo bonus) in the year 2004 cannot be considered a key factor for the discussion of the subject. It rather is characterised by the political discussion in the individual federal states. The responsible bodies of regional planning in Schleswig-Holstein, but also in Mecklenburg-Western Pomerania, Saxony, and Thuringia are actively dealing with this subject. In North Rhine-Westphalia however, the subject is of no relevance in the RP. In the regional plan of the Regional Planning Association Donau-Wald for example, the subject of "Energy supply" was cancelled by updating the RP.

The document analysis of the nationwide available online RP available on line demonstrates that previously, no spatially differentiated statements as text or drawings are made for the cultivation of biomass and for plants for energetic provisioning. In the survey, 18 % of the responsible bodies of regional planning indicate that their RP include statements on the cultivation areas, which are either formulated as targets or as principles. The document analysis however reveals that these are sparsely differentiated and only present intentions for action. Even if no separate specifications are made with text or drawings, the **RP** definitely exhibits a steering effect with regard to the bioenergy provision, as shown by the analysis of the Western Saxony RP (see section 3.3 and in particular Table 25 and 26 appendix II):

- For **45 %** of the identified aspects with demand for governing, which result from the **cultivation of biomass** for energetic utilisation, the RP already directly or indirectly includes statements with text or drawings.
- For **77 %** of the identified aspects with demand for governing, which result from land use of **bioenergy plants**, the RP already directly or indirectly includes statements with text or drawings.

The figures demonstrate that primarily plants for energy provision can be steered. This can be attributed to the fact that the quality of the plan's statements for buildings and structures is more precise than those for agricultural requirements and thus for the cultivation of biomass. At least, statements are made for almost half of the identified needs for governing resulting from the cultivation of biomass. This is attributed to the fact that the production of biomass in this case hardly causes other environmental impacts and land use conflicts than conventional agriculture for food and fodder production.

Furthermore, the analysis of the Western Saxony RP shows that an additional 10 % of the identified environmental impacts and land use conflicts can be bindingly steered by textual adjustments of existing targets. A possible amendment (highlighted in green) could be implemented as follows: *Objective 4.4.4 in the Western Saxony regional plan "Areas for significant enrichment with hedges and field shrubs" shall be structured primarily by hedges, shrubs and short rotation coppice"*. The possible adjustments largely relate to statements for dealing with short rotation coppice (SRC). In the analysis, SRC turns out to be a special case, not just with respect to the negative effects, but also to the positive synergies which can be related to this cultivation system. It is essential to actively utilise them via regional planning.

At the same time the analysis shows that only 1 % of the identified environmental impacts and land use conflicts is not within the sphere of influence of the RP. This particularly regards legal regulations and delegated legislation on water protection as well as statements in zoning maps. Furthermore, the analysis makes clear that agri-environmental measures and contractual nature conservation are appropriate instruments in particular to reduce environmental impacts. However, such measures currently are beyond the sphere of influence of regional planning. At the same time, the ability to govern could be strengthened via agri-environmental measures when the responsible bodies of regional planning and state planning define areas eligible for subsidisation. This requires increased intra-sectoral as well as intra-regional collaboration, in particular with the State Office of Environment, Agriculture and Geology of Saxony.

Altogether the analysis points out that other special departments have efficient instruments to steer the provision of bioenergy also in terms of sustainable spatial development (see section. 3.5 appendix II). A closer cooperation with regard to comprehensive regional planning, as regulated in § 13 Regional Planning Act /89/, should therefore be strengthened.

Options of regional planning to govern the cultivation of biomass for energetic utilisation (including environmental planning)

The designation of **priority or also restricted areas** for biomass cultivation is technically not justified, because the possible negative ecological impacts and effects on landscape barely differ from those of conventional agriculture. Due to its interdisciplinary role, regional planning is not allowed to take influence over the use of specific crops or types of cultivation. In addition, exerting more influence on agriculture would hardly be able to be realised politically.

For technical reasons, the criterion which currently forms the basis for the designation of the priority areas and restricted areas for agriculture should be adjusted in Western Saxony to the new Saxon **soil assessment instrument** /98/. This would enlarge the areas, which are available for the designation of the priority areas and restricted areas for agriculture. Furthermore it is recommended to apply the Saxon soil assessment instrument on natural soil fertility nationwide. The data basis can be derived from the state soils evaluation (started in the year 1934) and the medium-scale agricultural site mapping (1976 - 1982) (cp. also /5/). The particular state authorities would be responsible for the provision.

An exception in the consideration of the cultivation of energy crops are short rotation coppice (SRC) from a connected area of 50 ha. The designation of areas for large-scale SRC would be reasonable from a professional point of view; however, currently no instrument is available in the regional plan which could meet this demand for governing. The characteristics of **suitable areas** for development would make them a manageable instrument to specifically steer SRC due to their preclusive effect. However, whether the context of the term 'suitable area' could be amended by measures of agricultural and silvicultural production or by special crops should be discussed on a technical and legal basis. A quick debate on the subject of priority areas and restricted areas for SRC from a connected area of 50 ha is recommended.

It should also be considered to designate **'Areas with special options for use'**, on the lines of 'Areas with special requirements for use'. These could include 'Areas with a special qualification for the cultivation of SRC'. Criteria for designation could be very high water storage capacity and high total annual precipitation together with potentially significant positive environmental impacts. Such a designation however presumably would produce little steering effect towards the designated areas. SRC would not be excluded outside of these areas. Due to the analogy to areas specific for options for use in the Western Saxony planning region, it is recommended to consider the implementation of this new spatial category initially for Western Saxony only. In contrast, the integration of objectives and principles for spatial coordination of small-scale strip cultivation of SRC **into existing objectives and principles** and/or other requirements turns out to be of relevance for practical planning due to its positive ecologic impacts (see above). Furthermore, it is recommended to consider SRC from an area of 50 ha on the lines of initial forestation of woods due to their similar ecologic effects and thus to make it a matter of regional planning.

In general, the case study analysis of Western Saxony shows that a large part of the anticipated environmental impacts from biomass cultivation can indeed be managed with the instruments given by the regional plan, and this can definitely be done with differentiation. This is possible due to a qualified special contribution for natural conservation and landscape protection **(landscape framework plan)** which is set up in a broad context, because of the close linking of the landscape framework planning with the regional planning /92/ as well as due to the relatively wide range of possible environment-related provisions of the regional plan specific to the Free State of Saxony.

'Landscape areas with special requirements for utilisation' of all different kinds can be determined beyond priority areas and restricted areas for nature and landscape, including e.g. 'Regional key aspects of archaeological cultural monument conservation' or 'Areas for the conservation and improvement of water retention' (see map 16 of the regional plan; pg. Z 4.1.4 /91/). Due to the special qualification for the integration of contents of the landscape framework plan into the regional plan and subsequently for the management of environmental impacts it is recommended to implement the category ''Landscape areas with special requirements for utilisation' into the planning regions of other federal states. It is not recommended however, to overcharge the landscape framework plan with details on the suitability for the cultivation of specific crops beyond the customary consideration of natural soil fertility. For this purpose, the implementation of specialised agricultural planning would be reasonable (see section 5.3).

For the analysis of the environmental impacts of biomass cultivation, the method developed on the basis of the strategic environment audit (SEA) of the Western Saxony RP proves to be suitable. Since biomass production can have significant environmental impacts, biomass cultivation however does not considerably differ from food and fodder production and thus beyond priority areas and restricted areas for nature and landscape include biomass cultivation, we advise to integrate in the future the priority areas and restricted areas for nature and landscape and/or agricultural production of commodity outputs (food and fodder) into the SEA as detailed object of investigation. Preparatory specialised agricultural planning would be helpful also in this case.

Options of regional planning to govern the distribution of bioenergy plants

At the current state of the analysis, the designation of **suitable areas** for regionally significant bioenergy plants is not recommended. A spatial category cannot meet the multitude of technologies for energy provision and their requirements to the area (infrastructural requirements, demand for land) as well as the heterogeneous appearance of individual plants. Insofar, specific suitable areas should be designated for specific types of plants, which would contradict the actual objective of such designation, namely to have a practicable instrument for decisions. Due to the reasons mentioned, the analogy to the wind energy plants can hardly be applied. Furthermore, the determination of areas requires comprehensive consideration under planning law of all other principles and objectives listed in the RP. This effort is reasonable only if a multitude of construction projects of bioenergy plants is expected and therefore the responsible bodies of regional planning are facing strong pressure to act. **Forecasts** on the development of the number and size of plants are therefore essential for regional planning to be able to flexibly exert influence on a multitude of plants by special area categories, where necessary.

Closer consideration furthermore shows that in particular large-scale industrial bioenergy plants, which with regard to ecological and agricultural effects in fact do not substantially differ from conventional energy supply plants, cannot necessarily be governed by means of designated industrial locations as well as commercial areas. Not any designated priority area and restricted area of industry and commerce can meet the special technological requirements of each plant to infrastructure, supply and demand of energy as well as the need for raw materials. Therefore, an exclusive limitation of bioenergy plants to **priority areas and restricted areas of industry and commerce** would be impermissible. The decision under regional planning law on positive and negative statements in the participation procedure for the approval of regionally significant bioenergy plants shall therefore be made in the individual case. It seems all the more important to have a guideline for the responsible authorising agencies, which, amongst others, furnishes information on energy output, raw materials/substrates which can be used, demand for land, and in particular on the operational effects such as e.g. on the required infrastructure and traffic volume as well as on visual effects of bioenergy supply. The technology chains prepared in the scope of the project offer an initial approach for such a guideline. In the future, informal concepts on biomass production, such as the biomass development concept (BDC) prepared in the scope of the project, could be a suitable basis for evaluation and decision for the participation of the responsible bodies of regional planning as public agencies in the approval procedure of regionally significant plants. The missing binding effect of such a non-formalised planning procedure however currently relativises the steering effect of regional planning.

Biomass development concept (BDC) – Further development of governing approaches

Regional energy concepts have a high significance in the current discussion to implement targets of climate policy and energy policy on the level of the regions. Existing regional energy concepts however are very heterogeneous with regard to context. This is caused by their informal character and missing consistent institutional integration. Accordingly, the reference to the area as well as to the institutions involved varies to a wide extent and consequently the questions that the concepts are facing as well as the need for action they want to address. In the future, the set-up process and the coordination of regionally significant measures and development proposals should be facilitated through the formulation of minimum contents.

In the scope of the project, such minimum contents are developed for the range of 'Biomass', which are to be subsumed under the term biomass development concept **(BDC)**. The BDC can be a future building block for a regional energy concept. Using the example of the Western Saxony planning region, proposals are prepared on which regional information should be provided as a foundation for a decision. These are available in a processed form as **maps** depicting in regional spatial potentials for bioenergy provision (crop-specific growing areas and infrastructural requirements) as well as **technical contributions** 'Nature and landscape', 'Land use' on the spatial effects of bioenergy provision (see section 3.3 appendix II). The technical contributions are composed of different commodity maps, whereas the commodities derive from the technology chains considered in the analysis. The preference of focusing on the commodities and not on the technology chains has two reasons. On the one hand, the number of commodities used for energetic utilization in the scope of this project is less than the number of possible plant types. Therefore, by preparing the commodity maps, the information can be better bundled. On the other hand, the validity of the information can be extended in this way. While bioenergy plants are continuously further developed with regard to technology and thus also place different requirements to the region, such changes are not to be expected for the requirements of commodities. Insofar, a framework for planning as described here seems to be more appropriate than an enunciated static conception.

Next to the determination of spatial potentials and to the technical contributions on the effects, the responsible bodies of regional planning, who are establishing a regional energy concept, should formulate precise objectives for a sustainable regional bioenergy provision in their region. These should be available in the form of a **target system** (see section. 5.2), which finally offers the basis for decision for specifications under regional planning. At the same time, such a target system should collect and bundle the essential social and political interests affected by increased bioenergy provision. Therefore, all stakeholders relevant for the subject should be integrated. These should particularly include farmers, planning engineers and investors as well as representatives of communities, regional networks and the different special fields. An analysis of so-called **biomass**

networks performed in the scope of this project in the Western Saxony planning region (LAEDER-local activity group Delitzscher Land e. V. and Kompetenzzentrum Bioenergie e. V.) shows that only few connecting factors for cooperation are currently seen, both on the part of regional planning and on the part of the network actors. Insofar there is demand for action on the part of regional planning to prepare a higher-ranking target system, which reflects in a strategy for an entire region, to bundle existing activities and integrate them into an overall strategy.

Furthermore, experience from the workshops conducted in the scope of the project shows that a participative **scenario process** can contribute to encouraging in particular the discussion, preparation and formulation of regional objectives. Using this method, regional actors can be integrated early into the planning process, which can provide them with useful insights for possible regional developments. At the same time, the planning process can be amended by further expert and regional knowledge of the particular actors involved. This method enables regional planning to transparently arrange the process of decision-making via possible (un)favourable areas for bioenergy provision to facilitate in this way the acceptance of the relevant actors. A joint agreement on priorities for sub-spatial developments can contribute at the same time to regional consensus. Insofar, the scenario method can be considered as a possible approach to coordinate the bioenergy provision at regional level, provided that regional planning succeeds to address and involve the relevant actors.

Conclusion

As a trans-regional and inter-disciplinary subject, regional planning can selectively coordinate spatial developments to minimise negative effects involved with energetic utilisation of biomass as well as to promote positive synergies. The competences of regional planning should be strengthened in the future to be able to ensure a binding coordination in case of arising or assessable conflicts of land use. Provided that the pressure on regional planning to act is similar to the pressure in the fields of wind energy and exploitation of fossil resources, the statements on spatial manifestation of bioenergy provision made in the regional energy concepts should particularly gain a binding character through the integration of relevant objectives into the RP.

5.2.4 Transferability of the method used and of the test results as well as further demand for research

After the analysis which is strongly focused on the case study of the Western Saxony planning region, we will now demonstrate to which degree the method applied for the case study and the findings obtained from it are of a general character and therefore can also be applied to other planning regions.

At first, the **region's potentials** for bioenergy provision shall be determined for defining the management demand. This is based on environmental data and information on the infrastructure. The availability as well as the quality of the appropriate information is relevant for the assessment of the transferability of the procedure in other planning regions. Both the access to the required environmental data and their quantity and quality is better than average in the Western Saxony planning region and insofar not given in all federal states.

The **scenario technology** as used in the Western Saxony planning region is generally applicable to other planning regions. At the same time, the scenario development in planning practice should be insofar adjusted that areas of resistance are prepared on the basis of the environmental impacts and land use conflicts (i.e. for example to previously exclude from consideration such rooms, where plants are already excluded due to the targets of the RP).

The method used for the analysis of the **environmental impacts**, the ecologic risk analysis, is a method prevalent in environmental planning. Therefore, it can be basically applied to other planning regions. The method is also applicable for the assessment of the land use conflicts. Regional targets are required both for the examination of the land use conflicts and the environmental impacts in order to be able to specifically assess them for a region. Consequently, an updated **RP** and an updated, widely established **landscape framework plan** is a precondition. The document analysis of the RP which are available online throughout the country however shows that part of these significantly differ in the quality and quantity of their statements and finally also in their actuality. They still remain an appropriate basis for evaluation, however with less differentiation. Federal and state objectives then need to be prepared separately in advance for the analysis of the environmental impacts and land use conflicts (see also /126/).

The **technical contributions on the biomass development concept** (BDC) prepared in this project should be amended (e.g. by statements on heat sinks or liquid manure volume) and other technical contributions required for the provision of energetic biomass should be prepared so that all information necessary for the establishment of a regional biomass development concept are available (see section 5.3). This extension should be made already by the integration of corresponding aspects into the preparation of scenarios of and/or the determination of potentials. Next to the database problem (see below), the transferability of the methodology for the preparation of a biomass development concept is determined by its informal character. The transferability of the options under regional planning law particularly on an informal level largely depends on the technical competence, financial equipment and human resources, data inventory and data access as well as also the willingness to approach the subject of bioenergy provision.

The **availability of current data** is essential for all steps. Not all data is available in any region. Bundled information e.g. on heat sinks in the Western Saxony planning region are not available. The methodology used for the project, which basically can be applied to other planning regions, should be adjusted specific to a region depending on the availability and quality of data as well as on the state of planning and knowledge.

Due to the character as a case study, the **results of the analysis**, in particular the options for governing, are largely specific to a region and therefore not directly transferable (see chapter 4 Table 29 appendix II).

The following need for research is derived from the findings from the analysis and from the discussion on the transferability of the method as well as of the results:

- Comparative nationwide analysis on the possible course of action by regional planning in selected planning regions for validation of existing findings,
- Comparative analysis on the possible course of action by spatial planning in other countries of the EU, in particular Great Britain, the Netherlands, Sweden, Denmark, Austria, Poland, Czech Republic,

- Development of information tools for spatial and in particular regional planners for spatial coordination of bioenergy provision as well as further development of the biomass development concept,
- Acceptance research in view of spatial coordination of bioenergy provision: who is addressed? Which governing approaches are appropriate to influence decisions of the addressed entities? Which approaches will be accepted (towards governance vs. guidance)?
- Contribution of renewable primary products for the development and design of cultural landscapes – assessment of the cultural landscape, contribution of renewable primary products to increase the value of an area with regard to cultural landscape, options to steer this via spatial planning,
- Regionalisation of material and eco balances (basic data is available, however is not operationalised in such way that it is applicable on a regional basis),
- Application of verbal-argumentative scenarios, scientific coordination of participative approaches,
- Evaluation of existing management approaches (actual management effects of the RP /regional planning processes using the example of bioenergy).

5.3 Recommendations for increase of the steering effects on a regional level

(ZALF and DBFZ)

The material flow-based potential calculations for Germany result in a technical fuel potential of approx. 1.5 to 1.8 EJ/yr for the year 2020 (see section 5.1). The resource basis to achieve the IEKP targets therefore is given. If the available potentials are widely utilised, an approximate doubling of the bioenergy plants and their extension by innovative technologies (SNG, BtL etc.) is to be expected. The further expansion of bioenergy provision in Germany is associated with spatial effects on the level of regional planning and therefore requires targeted spatial coordination to minimise possible negative effects, but also to promote synergies which may be involved with energetic utilisation of biomass.

For the examined planning region of Western Saxony, the material flow-based potential calculations result in enough biomass potentials to provide the necessary share for the realisation of the IEKP targets for heat and electricity. An increase in the number of bioenergy plants in the future can be expected also in Western Saxony. In general, the analysis exemplified by the Western Saxony planning region shows that regional planning in the range of bioenergy provision already has the competence to spatially coordinate it to a certain degree. Already now, some of the outlined possible courses for action take effect beyond the formal RP. However, this cannot cover the entire demand for governing so that in view of the subject of bioenergy provision, further development of the existing regional planning approaches is proposed (see Fig. 13).

In order to act with more foresight and to adequately prepare for pending development challenges, the responsible bodies of regional planning should be better informed by institutions dealing with questions of futurology on development trends and their possible regional effects. Regional planning which is more flexible due to informal planning approaches seems to be more suitable to continuously face new issues of development, rather than highly formalised regional planning which is restricted in their options for presentation and determination. At the same time, the result of the project does not question the part of the RP as a central instrument of regional planning, it is rather emphasized. As a formal instrument, the RP is the only instrument with a political legitimacy. With all required increased flexibility, the RP represents a reliable framework for development, offering planning reliability for all actors. In addition, it becomes obvious that alternative informal processes rarely develop strategic-conceptual competence in accordance with the RP. Moreover, the RP, exemplified by the Western Saxony planning region, proves to be a good data base in particular for informal processes (see section 5.2.4). The majority of the data required for the development of the scenarios for bioenergy provision and examination of possible environmental impacts and land use conflicts (see section 5.2.2) can so be gathered from the RP and the appropriate technical contribution of nature conservation and landscape protection and/or can be provided by the responsible bodies of regional planning.

However, informal processes are necessary without a doubt to ensure flexibility in response to current development issues, with a focus on implementation and to identify and settle occurring conflicts at an early stage. However, if the RP sets the development framework, as shown above, and the responsible bodies for regional planning have the technical competence to bundle, manage and mediate information in order to balance regional interests. This aspires to increased linkages of formal regional planning with informal (sub-) regional processes. Since informal processes have deficiencies particularly in their short lifespan and a lack of institutional basis, it is recommended to strengthen the responsible bodies of regional planning in their function as managers and facilitators, and also as initiators of informal processes.

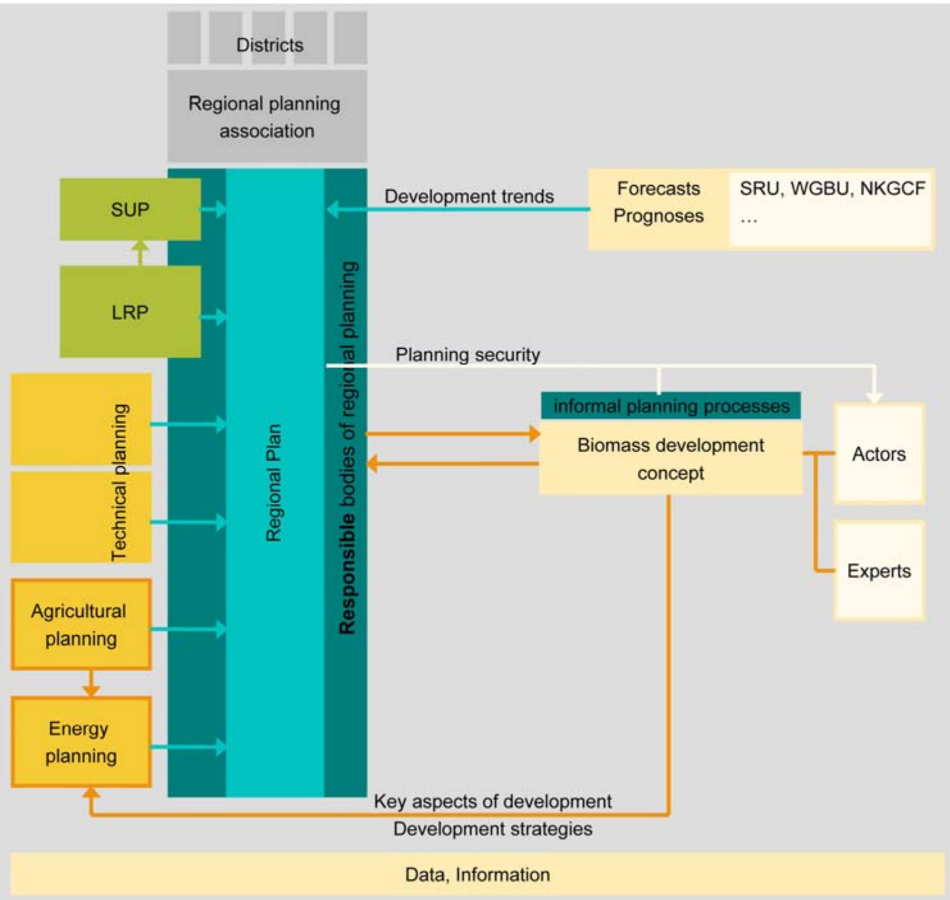

Fig. 13: Recommendation of further development of the existing regional planning approaches (SRU = German Council of Environmental Advisors, WBGU = German Advisory Council on Global Change, *NKGCF = National Committee for Global Change Research, source: ZALF and DBFZ)*

In this way, a planning process (see Fig. 13) can be established, where the informal planning adds to the content of formal planning and makes it more efficient as well as prepares and/or forestalls negotiation processes. The formal planning in return stabilises the informal planning, supports it with regard to context and methodology and legitimates it by adopting contents to the extent appropriate. Such a system corresponds to the often required increased process orientation of planning (see et al. /8/, /57/, /65/, /103/).

The analysis of the regional biomass potentials exemplified by the Western Saxony planning region demonstrates that the integration of agricultural issues into regional planning can be well accomplished with regard to planning methods. At the same time it shows that its integration requires professional preparation. This could be accomplished by an action plan for agriculture (APA). After the abolition of the (informal) agricultural structure development plan in the Free State of Saxony in favour of holistic rural development programmes (ILE (integrated rural development directive)/ LEADER), a gap is existing here. In terms of the context, APA could well be geared to the previous agricultural structure development plan. The planning region should be the reference area. Along with agricultural favourable areas evaluated in the project, APA should provide information on the agricultural structure, on agricultural practice and on trends of agricultural production for the planning practice.

The analysis of both extreme scenarios for the Western Saxony planning region shows that the achievement of the IEKP objectives is not only determined by the available agricultural and silvicultural areas as well as by possible environmental impacts and land use conflicts, but also depends on the selection of the technologies. Therefore, specialised energy planning (EFP) is required in addition to the institutionalisation of action plans for agriculture. This should collect, process and provide information on existing technologies, but also on future technologies (e.g. in the form of project charters as prepared in the scope of the project) as well as data necessary for implementation of regional planning. In parallel to this, the conditions for the legal framework should be established, national objectives defined and guidelines specified for the intended energy supply.

The preparation and implementation of conceptual approaches such as e.g. the biomass development concept (BDC) (see section 3.3.5 appendix II) required a series of data, which should be available in the form of indicators or site-specific information (e.g. in the form of a biomass atlas. Fig. 14 shows some examples of indicators and information which could be of potential relevance for the decision processes. The relevant indicators have to be selected in the scope of a case-specific target discussion and specified and implemented in the importance of their manifestation (e.g. x ha arable land for digestate output per $kW_{electric,}$ biogas plant in consideration of the site-specific conditions, implementation as command variable). The relevance of the indicators can also differ depending on the selected technology chain (see Fig. 14). The necessary information is currently not available for all of the indicators and information listed.

At the same time, the requirement derived from a technical point of view to establish an APA as well as an EFP points out the dilemma which spatial and regional planning are currently facing. If two independent and potent specialised planning institutions are established for the reasons outlined above, this may result in contextual impairment of regional planning. In particular the fields of wind energy planning as well as planning of mining of fossil primary products as previously managed by regional planning would necessarily represent components of EFP and therefore be integrated into this technical planning. The regional planning would lose essential competences and as a result, would lose political and social importance. At the same time, the results of the analysis show that regional planning is absolutely appropriate and currently the only instance to coordinate biomass production on a regional level commensurate with a sustainable spatial development. Due to the partly small financial resources and most of all missing or not processed data (see Fig. 14), the responsible bodies of regional planning are facing the challenge to adequately respond to such developments involved with increased bioenergy provision. The competence of regional planning in this debate should be emphasised, in particular because the institutionalisation of independent specialised planning in the fields of energy and agriculture previously was politically opposed.

Infrastructure	Biomass	Environment
Indicators		
Density railway network/district‡	Agricultural area/district *Δ‡	New sealing by bioenergy plants ha/district *Δ‡
Density road network/district *Δ‡	Forest area/district Δ‡	Land demand for cultivation/district*Δ‡
Density gas distribution system/district ‡	Proportion of grassland on arable land/district*	Planning conformity of cultivation (gfP) *Δ‡
Density power network/district *Δ	Stock farming livestock units/ district *	Erosion-prone area ha/district *Δ‡
Building density and heat demand/residential area *Δ‡	Quantity of biowaste and green waste	Areas for digestate application on land/district *
Site-specific information (e.g. as biomass atlas)		
Harbours	Stock farming/sheds *	Favourable areas *Δ‡
Supply points gas distribution system ‡	Waste collection and processing points	Restricted and excluded areas *Δ‡
Heat supply systems *Δ‡	Machinery syndicates (e.g.harvesters/district) Δ‡	
Freight yards ‡	Tree nurseries with adapted SRC clones Δ‡	
Refineries	Biomass yards	
Industrial plants as raw-material supplier or product purchaser (e.g. heat)Δ‡		
Progress indicators bioenergy provision		
Number of bioenergy plants/ district and plant type*Δ‡	Contribution of bioenergy to power consumption/district *Δ	Rate of CO2 reduction by bioenergy/district *Δ‡
Installed electric power/ district	Contribution of bioenergy to heat consumption/district *Δ‡	Quantity of energetically utilised residues/district
Jobs in the range of bioenergy provision	Produced biofuel quantity/ district	

Fig. 14: Examples of relevant indicators and site-specific information (agricultural biogas plant, Δ biomass gasification with combined heat and power generation, ‡ bio methane on the basis of bio SNG, source: DBFZ and ZALF)*

In summary, the planning approach developed on the basis of scientific finding from the project is a supplementary method to technically and politically prepare existing planning processes, which partly are strongly formalised /42/ and at best, to legitimate them. The objective should be to integrate results from informal participative processes during the update of the formal RP and thus to overall strengthen its function and the function of regional planning as a level of action. This however requires a broader information basis which is necessary to be established.

Finally, the following recommendations for action are derived from further development of the current understanding of planning as well as from the cognitions gained in the scope of the project:

- The existing competences of spatial planning, in particular of regional planning for governing the bioenergy provision should be more emphasised in the technical, political and social awareness.
- Deficits of governing should be minimised in the short to medium term by the development of actor-oriented and user oriented concepts and strategies, as represented for example by the BDC. Persuasive and initiating planning approaches can increase the acceptance for specific spatial developments in the region. The increased planning effort due to the initiation of participating planning approaches should be regarded in the future for the financial strength of the responsible bodies of regional planning.
- Politically and socially jointly prepared and coordinated results of informal processes should be integrated into existing formal planning rules to increase its steering effect and thus ensure binding coordination of land use conflicts.
- Against the background of increasing importance of the provision of non-commodity outputs by agriculture, a critical discourse on the current privilege of agricultural production of commodity outputs could additionally contribute to the avoidance of future conflicts in connection with energetic biomass production in specified sub-regions.

Finally it must be stated that the **regions' general increase in importance** /1/, /78/ also involves more responsibility to be assumed by the regions for their development. The regions are explicitly requested to establish conditions for sustainable development of the bioenergy provision and to prepare its organisation as regards planning and conception (see section 5.2.3; /99/, /100/). Conflicts resulting from increased bioenergy provision become manifest in regions, but can often be regulated globally. Regional action is considerably determined by national and international decisions and integrated into global developments. Insofar, the results from the global part of the analysis in the following chapter are relevant for the objectives to be identified and formulated in the scope of the international discussion on distribution conflicts for sustainable bioenergy provision on a national and international level, in particular also in view of spatial development. In this process, not only the discourse should take place on the different levels of politics, but also the governing bioenergy provision.

6 GLOBAL BIOMASS POTENTIALS

Bioenergy is the most important renewable energy source not only in Germany, but all over Europe and globally, and is to be further developed in many countries of the world for reasons of security of supply and climate protection.

The material and energetic utilisation of biomass is in competition with the use of food, objectives of nature conservation and numerous other demands of society. Since agricultural and forestry raw materials are mainly suitable for transport and storage and are increasingly tradable on global markets, domestic use of such biomass is always in competition with the export or import of such goods. Furthermore, it is to be expected that the use of agricultural biomass to secure the global food supply will be given priority towards other types of utilisation, both in the markets and in policy making. After all, the world population and thus the global demand for food is strongly increasing at least until the middle of this century, while less growth and stabilization at approx. 10 billion people is expected /40/, /111/. In contrast, damping effects (climate change, soil degradation etc.) have been influencing the supply of agricultural biomass for several years.

Against this background, this chapter shall demonstrate on the one hand, which country-specific technical fuel potentials exist for individual biomass fractions (biomass from agriculture and forestry, residual materials) and could be globally produced and potentially imported to satisfy the domestic demand in Germany to achieve the targets of climate and energy policy with given and possibly changing basic conditions (e.g. objectives of environmental and nature conservation, trend of earnings, see chapter 4). The scope of the analysis covers 134 countries which were selected by means of their relevance according to different criteria, such as e.g. population and arable land. The principle for all calculations is that food supply always takes priority and the countries with land potential for renewable primary products use it only to such extent that the global food supply will remain assured (see section 6.1 to 6.4).

On the other hand it is to be analysed by the combination of remote sensing data and statistical data, whether an improved spatial resolution can be achieved and thus future alternatives can be created which support regular monitoring of area-related biomass resources (see section 6.5). In this work package "Remote sensing", the qualification of the dynamic model "Biosphere Energy Transfer Hydrology (BETHY/DLR)" is analysed for the quantification of energetically usable carbon, whereas remote sensing data is used as input data for current characterisation of plant growth. Furthermore, it is analysed which options exist for monitoring the loss of agricultural areas by e.g. degradation or erosion by means of remote sensing, and change of forest areas into arable land.

6.1 Agricultural biomass

(University of Hohenheim and DBFZ)

The availability of agricultural biomass for the provision of bioenergy depends on future availability of areas, which are not needed for food production (so-called non-food areas) and therefore can be used for energetic biomass production. The estimate of global agricultural biomass potentials starts from the premise of previous utilisation of regional agricultural products in consideration of regional landscape configuration as well as the general economic and political conditions given there. The key influencing factors include factors which change over in the course of time, such as demographic development and demand behaviour of the population as well as productivity of agricultural production. According to the findings to date, climate change has a mainly negative influence on this. Effects of the climate change are partly included in the trend of earnings (see section 4.1.1). The global area potentials and/or technical fuel potentials are calculated for different scenarios (cp. chapter 4) and time points (basis 2002 - 2005, 2010, 2015 and 2020). Although the reliability of the determination of future potentials is significantly less for larger periods of time, an outlook for the area potentials is given for the year 2050.

6.1.1 Approach

The methodology was developed in different previous studies and adapted with respect to the questions in this project (/102/, /104/, /116/, /133/, see Fig. 15). The potential assessment for non-food utilisation is accomplished by means of Excel spreadsheets in comparative-statistical model calculations for purposes of agricultural economics. The so-called GAPP simulation model (Global Agricultural Production Potential) was specially developed for these questions and delivers plausible estimated results. Next to available areas for agricultural primary products, it is also suitable to evaluate raw material potentials for the production of bioenergy sources. These key figures in turn are also assessed and shown as technical potential for individual countries and as global potentials for bioenergy provision of groups of countries and continents.

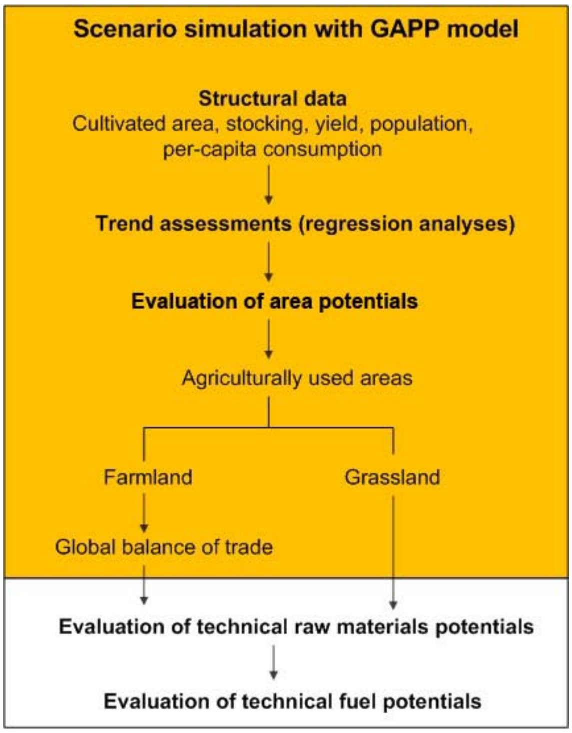

Fig. 15: Flow chart - Methodology for the evaluation of the land potentials (source: DBFZ, Univ. of Hohenheim)

Linear and non-linear functions are tested by means of regression analyses and used according to statistical criteria for the forecast of food demand, yield, offer of agricultural raw materials and many other parameters. It is assumed for the evaluation of the national area potentials that the examined countries can use useful fallow land and that part of agricultural over production for bioenergy sources, which previously was sold in the global market by means of export subsidies. This particularly applies to industrial states, which buy, store and export by means of subsidies surplus of beef, dairy products and partly also maize for prices stipulated by the government. The various databases of FAO, UN and of the German Federal Statistical Office /38/, /39/, /112/ serve as a data basis. It should be noted that all agricultural areas calculated in this chapter quantify the additional areas, which could be available beyond the already existing base areas for biomass production. In Germany for example, renewable primary products for energetic utilisation were already cultivated on approx. 1 million ha of arable land in the base period of 2002 - 2005 /33/. These should be added to the German non-food areas evaluated in this project. On a global basis it can be assumed that approx. 30 million ha were primarily used at the basis for the production of biofuels.

After the assessment of the national potentials for areas used for agriculture (crop land and grassland) which will be released for biomass production, a type of global trade compensation is performed for the global cropland to ensure the basic requirement of "priority for food supply". The raw material quantities and/or the technical raw material potentials are then evaluated for the subsequently still available non-food cropland. In the scenario "Business as usual", the cultivation mix which exists for the particular group of countries is assumed, while for the scenarios "Bioenergy" and "Bioenergy with increased restrictions on environment and nature conservation", the areas potentially available for non-food use are occupied with a kind of energy crop rotation. The energetically useable grassland growth is determined for the grassland which becomes available. The technical fuel potentials are then calculated in a last step.

6.1.2 Results

National potentials of agricultural area

Fig. 16 shows the global sums of the evaluated national land potentials in million ha of agricultural area (arable land and grassland) for the reference period (average 2002 - 2005) and the forecasts until 2050. For the results for the basis should be noted that these are potential areas and not real areas where bioenergy sources can actually be produced. They already could have been cultivated in the basis, if the countries had used fallow land for it and had abstained from exports of soft commodities and foodstuff. Thus, there would have been approx. 2.9 million ha of extra non-food land potential in Germany in the base period in addition to the already existing 1 million ha land for renewable resources for energetic utilisation (altogether approx. 3.9 million ha, see section 5.1).

In general, the results show that a considerable unused global potential would have existed in the reference period (approx. 640 million ha). Although, the global area potential decreases until 2020 due to continuous growth of population and increasing per-capita consumption, substantial national potentials will be available for non-food use in all conceivable scenarios. If the existing basic conditions for agricultural production will principally remain the same to a large extent, (scenario "Business as usual (BAU)"), this can keep pace with the enormously growing global population and the increasing per-capita consumption even until 2050 and comparatively large, but later decreasing potentials for the utilisation of agricultural biomass for energy sources will be available in the near future.

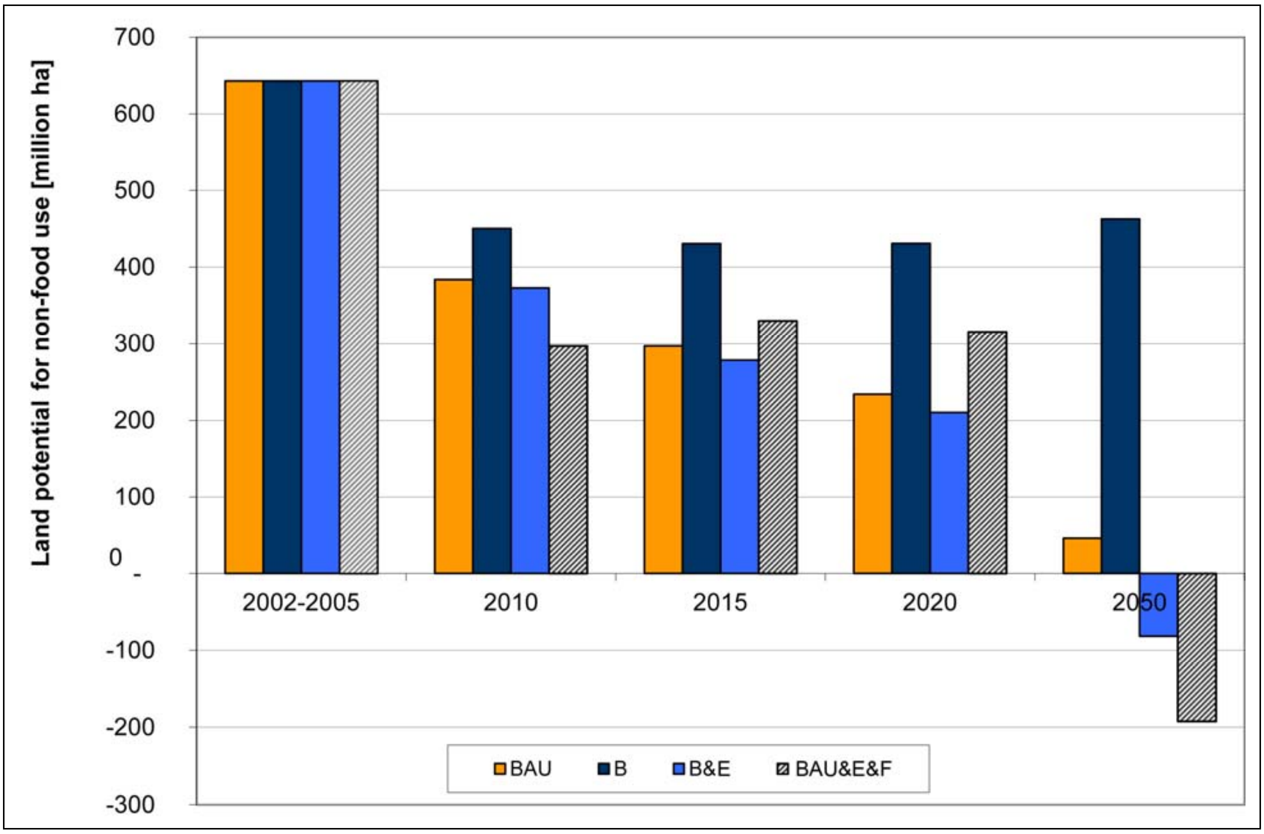

Fig. 16: Global land potential (agricultural area) for non-food use, considering the productivity (source: DBFZ, University of Hohenheim)

The largest area potentials result in the course of the expected development in the CIS states. In Russia alone, around 70 million ha arable land was not used for economic and social reasons. A similar situation is found in the Ukraine. With a rather stagnating population and partly decreasing per-capita consumption as well as increasing expected yield on a relatively low level of production, there will be enormous national land potential. In contrast, the large base land potential in North America will melt off in the course of the time, because there is a significant increase of both the population and the per-capita consumption. Due to especially high growth rates in food demand in consequence of high population growth, the land potential in Asia and Africa is significantly decreasing.

Especially industrial countries with a highly developed infrastructure have land potentials. These countries would also be absolutely able to install and efficiently operate appropriate conversion plants for the production of bioenergy sources. Nevertheless, it should be considered that the import demand for agricultural raw materials will substantially increase particularly in the populous countries in Asia and Africa. The increasing competition between agricultural raw materials for bioenergy provision and food export into import countries can and will lead to price effects, which make the assumptions of the "BAU" scenario rather unrealistic.

The price increase in agricultural raw materials may lead to the fact that still available potentials for the full exploitation of the yield can be additionally developed, in particular in countries on a low level. This situation is illustrated by the "Bioenergy" scenario, where significantly higher agricultural prices can have a stimulating effect on realising an increase in yield of up to 50 % compared to the "BAU" scenario. This increase in yield effectuates significantly higher national non-food land potentials compared to the remaining scenarios. A considerable land potential of approx. 470 million ha of agricultural area would be available even in the year 2050. It is assumed that this scenario represents the range which is to be taken as maximum land potential for the provision of bioenergy.

On the other hand, due to the demand for the objectives of environmental and nature conservation in the scenario "Bioenergy with increased restrictions on environmental and nature conservation", which increasingly raises public awareness, it should be assumed that large-scale forest clearances and ploughing up of grassland will be more limited and could almost come to a halt. The exceeding demand for rededication of land for purposes of nature conservation is of less consequence for the overall land balance. Globally, there is large national land potential also in this scenario until approx. 2020, which however will be drastically reduced and clearly is in a negative range in 2050.

Another fourth pure land scenario was calculated as a small excursus (business as usual with increased restrictions on environment and nature conservation and change in food habits, see chapter 4). On the one hand, the non-food land potential in this scenario is reduced due to increased restriction on environment and nature (e.g. higher share of organic farming), but on the other hand it is increased due to the change in food habits (e.g. less meat, less calories in states with excess nutrition). Only in 2050 there is no more land potential for the provision of bioenergy.

Farmland potentials after global balance of trade

If all countries would use the national potential of agricultural areas for the supply of material and energetic markets, they would no longer be available for exports for food supply into countries in deficit. In order to ensure the basic requirement "Priority of food supply", a kind of trade balance is performed in the next step. The share of available land for biomass cultivation for energetic utilisation results from the quotient of the negative potential arable land vs. the positive arable land of all countries. The quotient therefore expresses, which share of the non-food land potential does not need to be reserved for exports to ensure global food supply and thus is available for the provision of bioenergy (see Table 8).

Table 8: Global share quotients of total national potential for non-food use (source: University of Hohenheim)

	Ø 2002 -2005	2010	2015	2020	2050
Business as usual (BAU)	0.998	0.423	0.172	-0.018	-0.532
Bioenergy (B)	0.998	0.576	0.496	0.462	0.361
Bioenergy with increased restrictions on environment and nature conservation (B&E)	0.998	0.449	0.204	0.008	-0.733
Business as usual with increased restrictions on environment and nature conservation and change in food habits (BAU&E+F)	0.998	0.223	0.250	0.198	-0.694

The quotient from negative and positive potentials of 0.423 in the scenario "BAU" in the year 2010 means that 42.3 % of the land potential of all countries with positive potential may be used for non-food use, while the remaining 57.7 % need to be held available for exports into countries in deficit for food and nutrition supply (see Table 8). The latter will then have a non-food potential of zero. If the quotient of share becomes negative, the land deficits would be globally even higher than the land potentials, i.e. the coefficient of share in the countries with positive potentials is set to zero (no global non-food land potential).

Table 9 shows the farmland potentials (farmland for non-food use) in the scenario "Business as usual": on the left part of the table subject to the requirement that global food supply must be insured prior to the use for bioenergy sources, and on the right side of the table as remaining non-food land potential, wenn the group of countries participate on a pro-rata basis in exports to cover the deficit food supply of the import countries. The data for the "BAU" scenario indicates that no more farmland potentials for non-food use will be globally available from the year 2020. However, there is still grassland for non-food use. Since no more farmland is available for non-food purposes, the big surplus states for agricultural primary products, such as Europe, North America and South America would have to export as of 2020 all agricultural primary products, which are no longer needed for their own food supply, into countries in deficit (mainly Asia and Africa).

Table 9: Land potentials (farmland) for non-food use, scenario "BAU" (source: University of Hohenheim)

	National potential [1,000 ha]					Remaining potential with food security (world) [1,000 ha]				
Country	Ø 2002-2005	2010	2015	2020	2050	Ø 2002-2005	2010	2015	2020	2050
Germany	2,051.4	1,515.5	1,915.3	2,313.5	4,368.4	2,047.4	641.1	328.5	0.0	0.0
EU-27	24,541.2	15,328.4	16,908.8	18,606.2	23,009.0	24,493.3	7,535.4	3,444.2	0.0	0.0
Europe others	92,642.4	87,389.2	98,225.8	108,490.0	148,437.8	92,461.6	36,995.6	16,871.4	0.0	0.0
Europe	117,183.6	102,717.6	115,134.7	127,096.2	171,446.8	116,954.9	44,531.0	20,315.6	0.0	0.0
North America	101,377.0	65,621.0	59,090.3	53,709.8	33,144.6	101,179.1	27,759.1	10,135.1	0.0	0.0
Central America	15,299.2	-3,545.2	-11,764.9	-18,639.8	-41,218.9	15,269.3	1,171,.2	445.9	0.0	0.0
South America	42,886.2	35,786.4	29,132.5	24,170.1	18,066.0	42,802.5	21,182.5	9,364.4	0.0	0.0
America	159,562.4	97,862.2	76,457.9	59,240.2	9,991.7	159,251.0	50,112.7	19,945.3	0.0	0.0
Oceania	42,440.5	33,157.0	28,184.9	23,361.9	-6,416.3	42,357.7	14,026.1	4,834.2	0.0	0.0
Asia	61,664.3	-62,219.6	-113,430.4	-153,786.6	-292,920.8	64,038.6	18,540.0	6,734.0	0.0	0.0
Africa	39,322.8	-56,818.4	-91,310.3	-121,677.1	-322,022.7	39,290.1	6,385.2	3,717.0	0.0	0.0
Total 134 countries	420,173.7	114,698.9	15,036.8	-65,765.4	-439,921.2	421,892.4	133,595.1	55,546.2	0.0	0.0
In consideration of productivity	433,125.1	135,314.8	55,277.1	-6,011.5	-213,557.6	433,125.1	135,314.8	55,277.1	0.0	0.0

If the EU-27 would act selfishly in this scenario (business as usual), i.e. if they would satisfy their own food deficits by balance of trade between EU states, but not participate in safeguarding the global food supply, a lower, but still substantial raw material potential compared to the sum of the national potentials could be used; this amounts to 23 million ha in the year 2050 (see Table 10 below). However, this land would not be available for global food supply. Increases in prices for agricultural primary products would probably result, which would cause the EU-27 to reduce non-food use in favour of food export into global markets. It is relatively unrealistic to assume that a country with a large surplus of agricultural primary products would use their arable potentials in the non-food range exclusively for the production of national bioenergy sources. However, bioenergy from grassland and residual materials would still be available to contribute to a considerable amount.

Table 10: Land potentials (arable land) for non-food use (EU-27), scenario "BAU" (source: University of Hohenheim)

	National potential [1,000 ha]					Remaining potential with food security (EU-27) [1,000 ha]				
Country	**Ø 2002-2005**	**2010**	**2015**	**2020**	**2050**	**Ø 2002-2005**	**2010**	**2015**	**2020**	**2050**
Germany	2,051.4	1,515.5	1,915.3	2,313.5	4,368.4	2,051.4	1,293.8	1,608.5	1,914.7	3,192.7
France	6,482.0	5,011.7	4,499.8	4,038.0	1,951.5	6,482.0	4,278.3	3,778.9	3,341.9	1,426.2
United Kingdom	-161.5	-1,158.5	-1,194.9	-1,267.3	-1,324.9	161.5	0.0	0.0	0.0	0.0
Italy	1,410.8	784.8	924.3	1,106.8	2,402.9	1,410.8	670.0	776.2	916.0	1,756.2
Spain	3,831.4	4,050.0	5,825.3	7,596.1	15,477.4	3,831.7	3,457.5	4,892.1	6,286.7	11,311.6
Poland	1,837.1	-701.8	-1,069.7	-1,398.2	-4,193.3	1,837.1	0.0	0.0	0.0	0.0
Romania	748.0	649.2	642.1	667.7	976.5	748.0	554.2	539.3	552.6	713.7
The Netherlands	49.7	84.9	109.6	134.8	207.4	49.7	72.5	92.0	111.6	151.6
Greece	445.5	-611.1	-806.9	-947.0	-1,552.0	445.5	0.0	0.0	0.0	0.0
Belgium/Luxembourg	28.3	98.8	173.5	247.1	694.5	28.3	84.3	145.7	204.5	507.6
Czech Republic	1,093.2	877.1	931.1	991.7	1,424.2	1,093.2	748.8	781.9	820.7	1,040.9
Portugal	536.5	463.0	692.0	919.3	1,998.3	536.5	395.2	581.1	760.8	1,460.5
Hungary	1,444.5	1,295.1	1,292.3	1,276.8	524.6	1,444.5	1,105.6	1,085.3	1,056.7	383.4
Sweden	490.9	306.6	283.1	258.0	184.5	490.9	261.7	237.7	213.5	134.8
Austria	186.2	92.8	119.1	142.5	218.9	186.2	79.2	100.0	117.9	160.0
Bulgaria	1,121.2	915.4	813.2	699.1	-674.8	1,121.2	781.5	682.9	578.6	0.0
Slovakia	218.7	-123.7	-243.5	-384.1	-1,604.8	218.7	0.0	0.0	0.0	0.0
Denmark	182.9	188.1	254.2	318.6	567.7	182.9	160.6	213.5	263.7	414.9
Finland	301.6	165.4	100.5	40.2	-203.3	301.6	141.2	84.4	33.3	0.0
Ireland	848.0	932.5	1,022.8	1,106.4	674.6	848.0	796.1	859.0	915.7	493.0
Lithuania	490.6	-39.3	19.6	72.2	91.6	490.6	0.0	16.4	59.7	66.9
Latvia	538.8	186.9	238.6	285.6	384.1	538.8	159.6	200.4	236.4	280.7
Slovenia	4.3	1.2	-3.3	-8.7	-50.9	4.3	1.0	0.0	0.0	0.0
Estonia	31.5	-11.2	35.6	79.6	222.0	31.5	0.0	29.9	65.9	162.2
Cyprus	6.5	-15.1	-24.6	-32.6	-57.9	6.5	0.0	0.0	0.0	0.0
Malta	0.0	-1.0	-1.1	-1.0	1.6	0.0	0.0	0.0	0.0	1.1
EU-27	24,541.2	14,957.4	16,548.0	18,255.2	22,708.6	24,541.5	15,040.9	16,705.3	18,450.9	23,658.0
In consideration of productivity	25,413.3	16,121.1	17,261.7	18,495.9	21,549.3	25,413.5	16,121.2	17,261.7	18,495.9	21,549.3

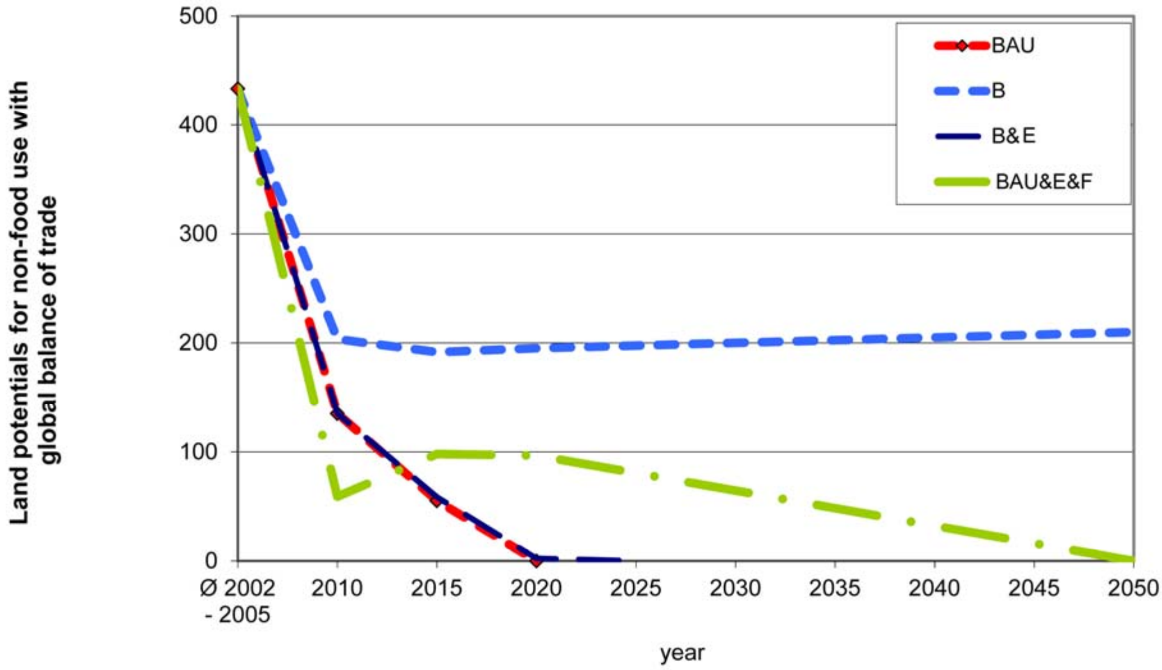

Fig. 17: Global land potential (arable land) for non-food use with global balance of trade (source: University of Hohenheim)

Fig. 17 shows the results on the non-food farmland being released after the global trade balance is performed. While the global agricultural markets were characterized by structural over production during the past 20 years, the future development seems to lead sooner or later to a reversal to deficit markets. More than 400 million ha farm land would still have been globally available in the reference period for renewable primary products in the form of fallow land and land released by reduction of agricultural surplus production. The farmland potential which becomes available for biomass production is rapidly descending in the course of time. While the "Bioenergy" scenario stabilises after 2010 at a relative constant value, there is no more farmland potential for the cultivation of energy crop as from 2020 in the scenarios "Business as usual" and "Bioenergy with increased restrictions on environmental and nature conservation". The farmland potential in the scenario "BAU&U+E" initially declines more compared to BAU, because 2 % of the farmland is dedicated to a nature conservation area already in 2010. After 2010 it increases, because it was assumed that the entire world with excess nutrition will reduce the consumption of food. Due to the increase in population, the farmland potential again declines after 2020 until no more non-food farmland potential exists in 2050.

The results of the “Bioenergy” scenario show that both the global food supply is secured and a limited potential for non-food use can be globally provided in the long term. However, the results of the "B&U" scenario suggest that despite large progress to achieve increased yields, the land potentials are depleted faster due to the realisation of more restrictive environmental targets. If changes in land use would be completely refrained from and a further 2 % of the farmland would additionally be provided for nature conservation, no more non-food areas would be available as from 2020.

Technical fuel potentials

After the assessment of the non-food land being released after the global trade balance is performed (grassland and farmland after balance of trade), the next step is to calculate the technical fuel potentials possible for such areas for the three scenarios "BAU", "B" and "B&U". The technical fuel potential of grassland growth is determined for the grassland areas. The grassland areas being released are evaluated depending on demographic development and per-capita consumption of milk and beef. Since the assumptions for these factors are the same in all three scenarios, the grassland areas and thus the technical fuel potentials of grassland growth are also the same for all scenarios.

In addition, the calculation of the technical fuel potentials results from the farmland still available for biomass production (surplus land) after performance of the global trade balance. It is assumed for the scenario "Business as usual" that the areas are used in the cultivation ratio as found in the reference period (established crop rotation focusing on food production). Since the land potential for non-food use is more and more limited in the course of time, it is all the more important that such energy crops are cultivated on the remaining areas (with ensured global food supply), which comply best with the targets of energy policy and climate policy. Therefore, such energy crops are cultivated in the scenarios "Bioenergy" and "Bioenergy with increased restrictions on environmental and nature conservation", which have a high energetic potential in the particular country or group of countries. Initially, 33 % of the available areas are cultivated with plantations of fast-growing trees (short-rotation coppicing, SRC) in temperate zones and forest plantations in subtropical and tropical regions. Sugar beet and sugar cane are allowed as cultures with the second highest priority up to doubling of the previously cultivated area (comparison with reference period). The ranking continues with silage maize (in the EU states only), followed by the highest yielding type of maize or oil fruit and finally in the tropical countries rice cultivation and also cultivation of oil palms as substitute to deep water rice cultivation.

After calculation of the production volumes and/or raw material potentials, the technical fuel potentials for the agricultural biomass (energy crops from released farmland and grassland growth from grassland for non-food use) were calculated by means of the crop-specific lower heating values. The potentials from the short-rotation coppice and forest plantations are integrated into the calculations of the forestry potentials and are shown in section 6.2.

Table 11 presents the results of the calculations of the technical fuel potentials for the three scenarios. Since no more farmland for non-food use is globally available in 2020 in the scenarios "Business as usual" and "Bioenergy with increased restrictions on environmental and nature conservation", there will be no more considerable technical fuel potentials. In contrast, the technical fuel potentials in the "Bioenergy" scenario increase considerably until 2050 due to the continuously increasing non-food farmland which become available, and already amount to about 16,140 PJ in 2020. This quantity corresponds to approx. 2.5 % of the predicted global primary energy consumption in 2020 (approx. 650,000 PJ, /25/). About 22,120 PJ will be globally achieved in 2050.

Table 11: Technical fuel potential of agricultural biomass 2015, 2020 and 2050, scenario "BAU", "B" and "B&E" with balance of trade (source: DBFZ)

		Technical fuel potential [PJ/yr]								
Year under consideration, scenario		**2015**			**2020**			**2050**		
		BAU	**B**	**B&E**	**BAU**	**B**	**B&E**	**BAU**	**B**	**B&E**
Europe	EU-27	392.9	982.6	383.5	22.8	996.9	34.5	0.0	1,512.3	0,0
	Europe others	755.9	1,655.7	714.9	29.0	1,828.0	57.4	0.0	3,294.4	0,0
	Sum	1,148.8	2,638.4	1,098.3	51.8	2,824.9	91.9	0.0	4,806.7	0,0
America	North America	915.9	3,303.1	1,283.7	3.0	3,357.6	54.6	0.0	3,868.9	0,0
	Central America	83.7	204.9	67.3	1.5	193.4	3.5	0.0	128.4	0,0
	South America	1,628.9	4,472.5	1,810.4	70.7	4,473.0	132.6	0.0	5,931.5	0,0
	Sum	2,628.5	7,980.5	3,161.4	75.2	8,023.9	190.8	0.0	9,928.9	0,0
Oceania		805.1	1,037.3	692.2	115.8	549.8	117.6	0.0	207.3	0,0
Asia		500.7	3,268.4	463.3	21.8	3,568.6	36.7	0.0	4,624.0	0,0
Africa		426.2	1,013.4	396.3	33.1	1,173.2	46.6	0.0	2,552.4	0,0
Total 134 countries		5,509,3	15,938.0	5,811.5	297.6	16,140.4	483.6	0.0	22,119.3	0.0

Fig. 18 itemises the global fuel potentials with respect to the different crop types. It becomes apparent that in particular corn, sugar cane and oil palms contribute to the potentials. In addition, there are large fuel potentials from grassland growth in 2015.

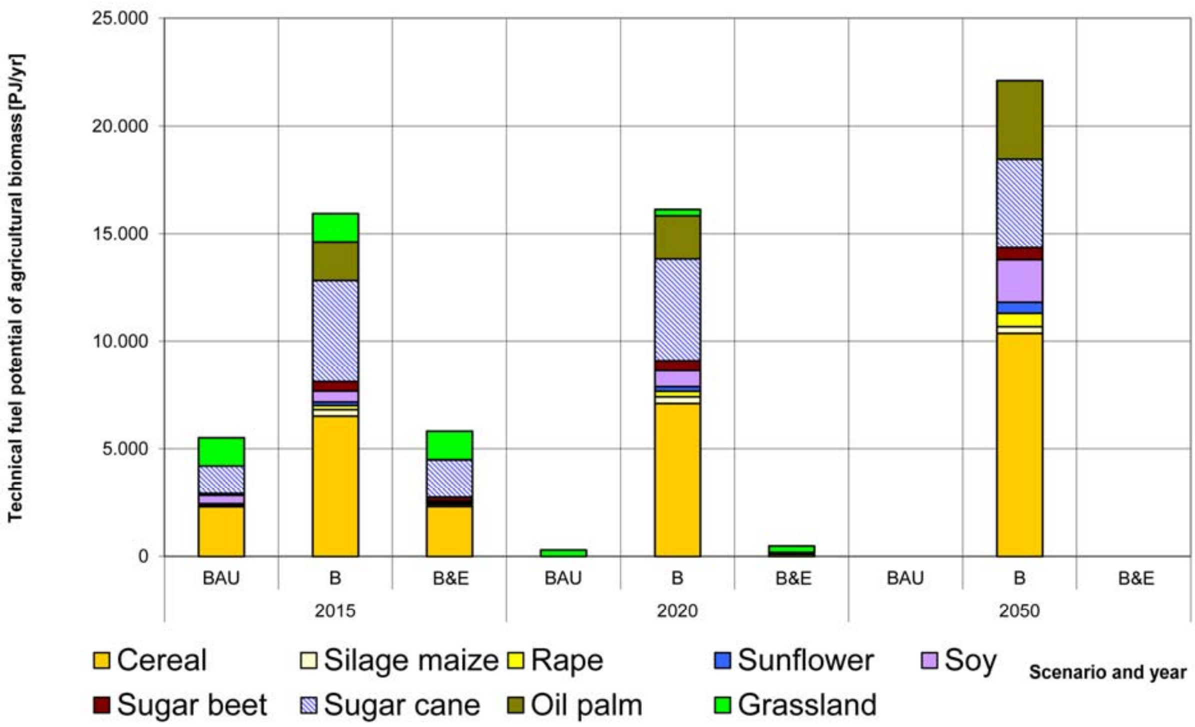

Fig. 18: Technical fuel potential of agricultural biomass 2015, 2020 and 2050, scenario "BAU", "B" and "B&U" with balance of trade, itemised by the different crop types (source: DBFZ)

Since it is the task of the project to determine "hot spots" of biomass production and therefore potential suppliers for import biomass (IEKP 2020), the results for 2020 are presented as specific to the countries and discussed below.

The scenarios "Business as usual" and "Bioenergy with increased restrictions on environmental and nature conservation" result in comparatively insignificant global technical fuel potentials of around 300 PJ/yr and 480 PJ/yr respectively. In the scenario "Business as usual", the fuel potential can be completely attributed to the utilisation of grassland growth, because in 2020 there are no more non-food areas for the cultivation of energy crops. In 2020, technical fuel potentials from grassland are available only in 42 of the examined 134 countries, whereas only Australia (approx. 84 PJ), Argentina (approx. 47 PJ), New Zealand (approx. 32 PJ), South Africa (approx. 25 PJ), Russia and Uruguay (each approx. 18 PJ) show significant potentials.

Also in the scenario "Bioenergy with increased restrictions on environmental and nature conservation", the fuel potentials are largely based on the utilisation of grassland growth (around 298 PJ). Very low potentials of corn still are in the USA (approx. 45 PJ), Russia (approx. 13 PJ) and South Africa (approx. 11 PJ). Sugar cane from Brazil delivers another 48 PJ.

In the scenario "Bioenergy" there is a global technical fuel potential of agricultural biomass of around 16,140 PJ in 2020. By far the largest potentials are in Brazil (approx. 3,800 PJ, mainly sugar cane) and in the USA (approx. 3,150 PJ, mainly corn), followed by Indonesia (approx. 1,800 PJ, mainly from oil palms) and Russia (approx. 1,500 PJ, mainly from corn, see Fig. 19). Even in scenario "B" with its high potentials, e.g. China, India and many other countries of Africa and Central America have no technical fuel potentials due to the high demand for food and thus for land requirements for food.

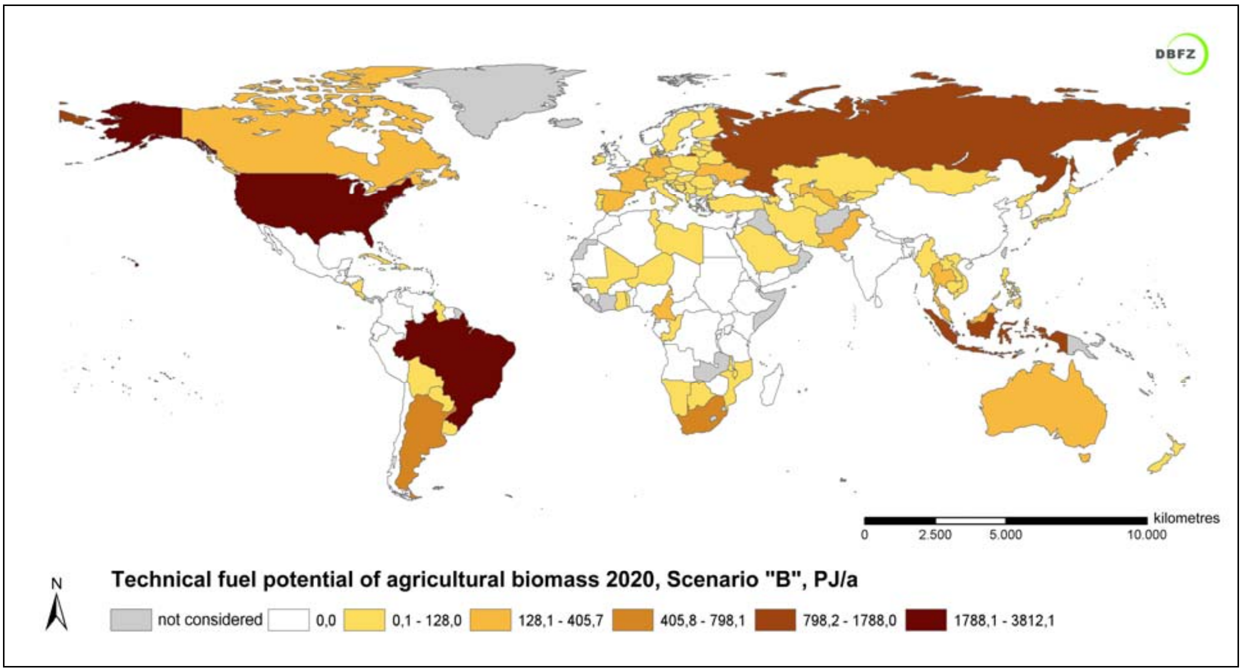

Fig. 19: Technical fuel potential of agricultural biomass in 2020, scenario "B" with balance of trade (source: DBFZ)

6.1.3 Conclusion

The results of the potential assessments for the different scenarios clearly shows that the global potentials for land and raw materials for non-food use primarily depends on the demand for food on the one hand and on the yield increases on limited farmland on the other hand. While the global agricultural markets were characterised by structural over production in the last 20 years and considerable potentials could have been made available for bioenergy, future development can lead to a reversal to deficit markets in the medium and long term.

The potentials of the continents and sub-continents in this process are developing in different directions in all three scenarios: while Europe, North and South America can provide significant and stable land potentials for the production of bioenergy crops, the land for food supply in many countries of Asia and Africa is not sufficient and there is a growing demand for import of food. Under the assumption of a global balance of trade, this results in a calculating land demand for potential bioenergy land in other countries of the world. Their bioenergy potentials will then be correspondingly reduced. This would not result in a global crisis of food security.

According to these assessments, still more than 400 million ha of arable land would have been globally available in the basis (2002 - 2005) for renewable primary products in the form of fallow land and land release by reduction of surplus agricultural production. In 2007/08 however, a global food shortage became apparent for the first time, which may repeat in shorter intervals and, if the trend continues for all relevant determining factors for the agricultural commodity markets, may lead to exhaustion of the resources from 2020 and to their exclusive use for food.

This can be countervailed by extensive exhaustion of the land resources and increasing the agricultural productivity - whereas this does not principally need to lead to loss of sustainability. Essential requirements for this are higher prices for soft commodities, which presumably will automatically develop in the course of further shortages of agricultural commodity supply. The quantification of these effects is difficult. In the "Bioenergy" scenario, which becomes more realistic with higher agricultural and crude oil prices, energy crops with a technical fuel potential of 22 EJ could also be cultivated on approx. 200 million ha of farmland until the middle of the century.

Since the IEKP target in the range of biofuels - with simultaneous compliance with IEKP targets in the fields of electricity and heat - probably cannot be completely realised with biomass in Germany, the significance of import of biomass and/or bioenergy sources will increase in the future. Correspondingly calculations were carried out for the assessment of the import potentials. The "Bioenergy" scenario results in import potentials for Germany of liquid and/or gaseous biofuels of approx. 6.5 EJ/yr for 2020. Approx. 187 million t bioethanol, 31 million t biodiesel and 6.6 billion m^3 biomethane could be provided in addition to the biofuel volume already produced today (triple the amount of that produced in 2008). Key countries of production are Russia, Brazil, USA and Indonesia. In this way, the IEKP targets for the transport sector in the "Bioenergy" scenario could be significantly exceeded. It should be considered however that other countries, which already have formulated targets for biofuel would also like to make use of this potential.

The results of the scenario "Bioenergy with increased restrictions on environmental and nature conservation" indicate that the implementation of further standards of environmental and nature conservation (no direct changes in land use as e.g. ploughing up of grassland and forest clearance, further re-dedication of 2 % farmland for purposes of nature conservation without agricultural use) can substantially reduce the land and fuel potential, if applicable.

Along with the land potentials analysed in this project, there is more potential for the cultivation of energy crops on degraded land. In literature, very different dimensions are quoted (from 6 to 35 million km^2) and they display a very wide range of soil quality and expected yield, previous use etc. Therefore, a general classification of such land potential is impossible in the scope of this project.

However, synergies between land upgrade and biomass production may well be possible, also for the supply of international markets. Careful development of such resources however requires case-specific consideration.

Altogether, the examinations show that the trend assessment is well suitable for the determination of future agricultural biomass potentials. The actual use of the land potential for energy crops however depends on many factors which often are difficult to predict. In particular the general political conditions are of great influence for the further development of the economic environment. Experience from the past years has shown that the agricultural prices can undergo extreme fluctuations within a very short time, which in turn may have a problematic effect on the security of global food supply. It is debatable whether in the case of large hunger crisis e.g. in Africa would really result in a "global trade balance" and if the countries with larger national land potentials therefore would not use it for the provision of bioenergy.

6.2 Forestry biomass

(vTI)

6.2.1 Problem statement

With 3.95 billion ha, forests cover approx. 30 % of the Earth's landmass /36/. They are a habitat for countless species and communities, as well as an important factor in the energy and material balance of the Earth. They influence the local and regional climate and facilitate natural carbon storage; they are a key factor for future development of the global climate. As a source of the renewable resource of wood and other primary products, they also are a major factor of global economy. Wood is materially and energetically used in many ways due to its technical properties. About 3.5 billion m³ of raw wood was globally used in the year 2006 /36/. It may be surprising that not material use, but energetic use of wood prevails with more than 50 %. Wood is generally the most important fuel in the less developed countries of Africa, Asia and Latin America. The global consumption of wood is very likely to increase further over the next years due to the continuously growing population on Earth, as well as the expected increasing demand for biomass for the fulfilment of climate policy goals. Therefore, the question arises as to whether the forests of the world will be able in the future to sustainably satisfy the growing demand without losing their important ecosystem functions for energy, water, material balance and climate, or even if there is the option to increase sustainable energetic utilisation of wood. In the light of proceeding conversion of primary forests into agricultural land for the production of food and biomass as well as more intense utilisation of commercial forests, apprehensions arise that this could not be the case.

Based on specific assumptions on the future development of the forest and plantation areas, growing stocks as well as protection of forests, in the following sections it will be assessed, how big the sustainably available global raw wood potential could be in 2020. In a second step, we will compare the raw wood potential with the raw wood demand by the 46 globally most important states producing and consuming raw wood in order to evaluate the balance of the technical fuel potential of wood fuel (in the following abbreviated with: technical potential of wood fuel) in the year 2020.

A detailed description of the data sources used, of the methodical approach as well as an extensive presentation of the results is found in Appendix IV of this report.

6.2.2 Procedure

The assessment of the global sustainable raw wood potential as well as of the technical wood fuel potential is mainly based on statistics on global development of the forests as well as regional and country-specific information. The global raw wood potential is assessed for three different development scenarios in two transparent steps for 134 countries. The technical potential of wood fuel is evaluated for 46 countries and three different development scenarios in three transparent steps.

At first, the global forest and plantation area is assessed for the year 2020 by assuming their further development based on the average country-specific annual changes of the forest and plantation areas observed since 1990. In a second step it is calculated how large the sustainable raw wood potential from forests and plantations would be in the year 2020. This is done by multiplication by the particular country-specific annual net increase of the growing stock. This derivation of the future sustainable global forestry raw wood potential is based on the classical comprehension of sustainability in forestry, i.e. to use only as much wood as grows back. This definition of sustainability ensures that even with complete utilisation of the potential, no reduction of growing stock and/or no excess utilization would take place in the long term.

Raw wood production and consumption for the year 2020 is assessed for the 46 globally most important countries producing and consuming wood. The calculations are based on the linkage of time series on production and consumption rates with the development of the gross domestic product and the population in the countries under consideration. By subsequent balancing of potential with production/consumption, the potential raw wood exporters and importers can be identified among the 46 countries under consideration and statements can be made on the dimensions and directions of the flow of trade for raw wood in the year 2020. The balancing also serves as being able to make a statement on whether the sustainable raw wood potential, subject to the assumptions taken as a basis, is sufficient in 2020 to satisfy the estimated raw wood consumption of the 46 countries under consideration. Finally, the technical potential of wood fuel is determined and compared with the wood fuel consumption.

6.2.3 Scenarios

The assessment of the future global forestry biomass potential and/or wood fuel potential performed in the scope of this project does not intend to predict exact quantities for the year 2020. This is impossible due to the many unforeseeable events which could influence the raw wood potential. The three scenarios shall rather give an impression of how large the potential of wood fuel would be in the year 2020 if forest and plantation area, net annual growth, raw wood production and consumption would develop until the year 2020 according to the outlined assumptions. A detailed explanation of the scenario assumptions is given in section 4.1.

6.2.4 Results

Commercial forest and plantation area in the year 2020

Considering the development of the global commercial forest area in the scenario "Business As Usual" (BAU), i.e. the scenario which continues the development between 1990 and 2005 until the year 2020, a global decrease of approx. 310 million ha to approx. 3.1 billion ha of commercial forest would have to be expected (see Fig. 20). The strongest decline would be in South East Asia, in particular in Indonesia as well as in South America, especially in Brazil, but also in Africa. The reason for this is the persistent conversion of primary forest into arable land or forest plantations. In contrast, a comparably slight decline would be observed in the other continents as well as EU-27 countries. Also in the year 2020, the largest forest areas would be in Russia, Brazil and Canada. Since the assumptions made in the "Bioenergy" (B) scenario only affect the plantation areas, the commercial forest area will remain unchanged compared to the BAU scenario.

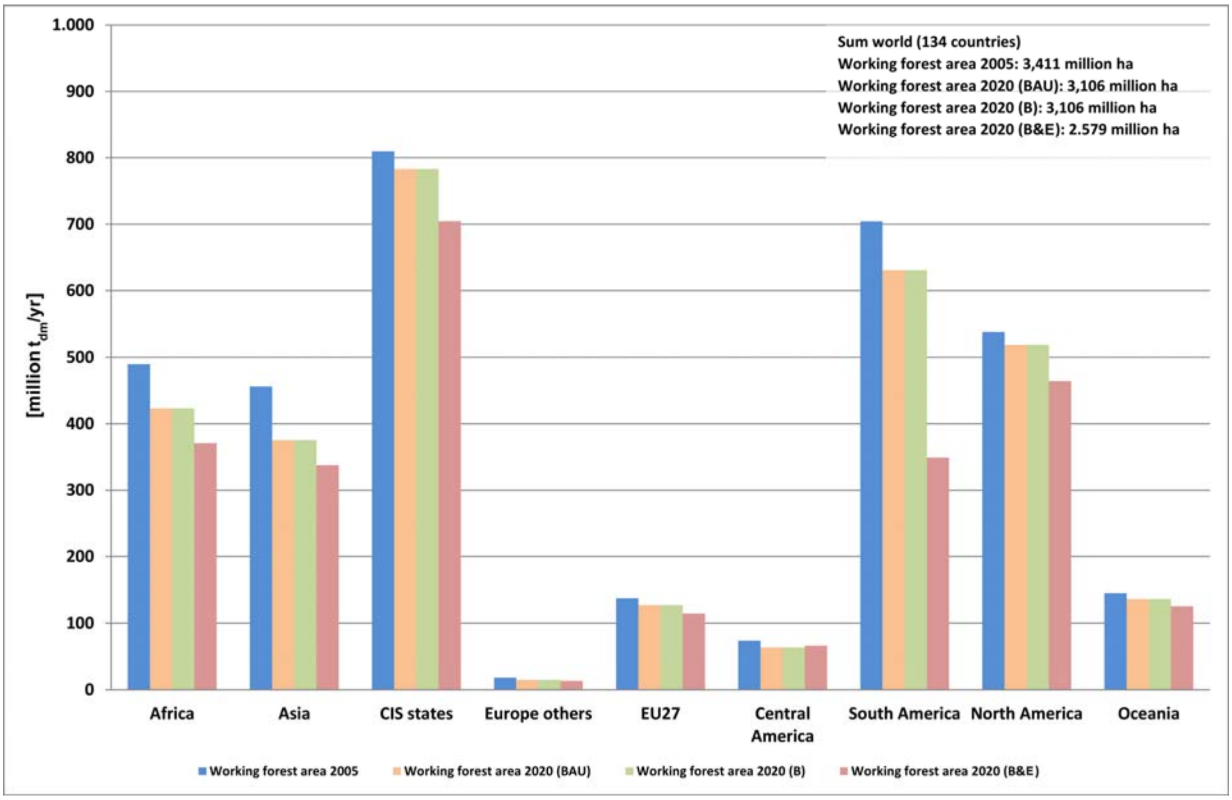

Fig. 20: Development of the commercial forest area in the different scenarios for the period 2005 – 2020 (source: vTI acc. to /36/)

Taking the assumptions of the scenario "Bioenergy with increased restrictions on environmental and nature conservation (B&E) “,as a basis, the decline of the commercial forest area would be much more significant than in the scenario "BAU" and "B". Compared to the year 2005, the area would decrease by approx. 810 million ha to then 2.6 billion ha. This however would be attributed to the large-scale conservation of 50 % of the primary forests in the tropics as well as 10 % of the commercial forest of the temperate and boreal zone as defined in scenario "B&E", and not only to forest conversion. As shown in Fig. 20, the decline of commercial forest area would therefore be especially large in countries or groups of countries with a high share of primary forests such as South America, Asia and Africa. In North America and Europe, where only 10 % of the working forest area would be under protection, far less area would be taken out of production.

The development of the global forest plantation area as well as short rotation coppice area runs contrary to the development of the commercial forest area. In the "BAU" scenario, it would globally increase by approx. 35 million ha to 174 million ha until the year 2020 (see Fig. 20). A strong increase would be expected primarily in Asia, where the forest plantation area already is the largest. In China alone, more than 44 million ha of forest plantations would emerge until the year 2020. The increase in Europe and North America would be less, but still significant. In Africa and South America however, it would be comparatively small. Considering the absolute plantation area, Russia and the USA, next to China, would be the countries with the largest forest plantation areas.

The increase in plantation area would be even stronger if the assumptions of the "Bioenergy" (B) scenario would occur. The additional farmland no longer needed for the production of food and hence available for the cultivation of forest plantations and short rotation coppice would lead to the fact that the global plantation area would increase by slightly more than 100 million ha until the year 2020 (see Fig. 21). 65.5 million ha of this would be areas formerly used for food production. More than 34 million ha of this area could be stocked with forest plantations in Russia, the USA and Brazil alone.

Due to the increased restrictions on environmental protection and nature conservation, far less farmland will be released for non-food use in the "B&E" scenario. Only about 765,000 ha of the area formerly used for food production would be additionally stocked with forest plantations or short rotation coppice. Compared to the "BAU" scenario, the plantation area would only increase by this share.

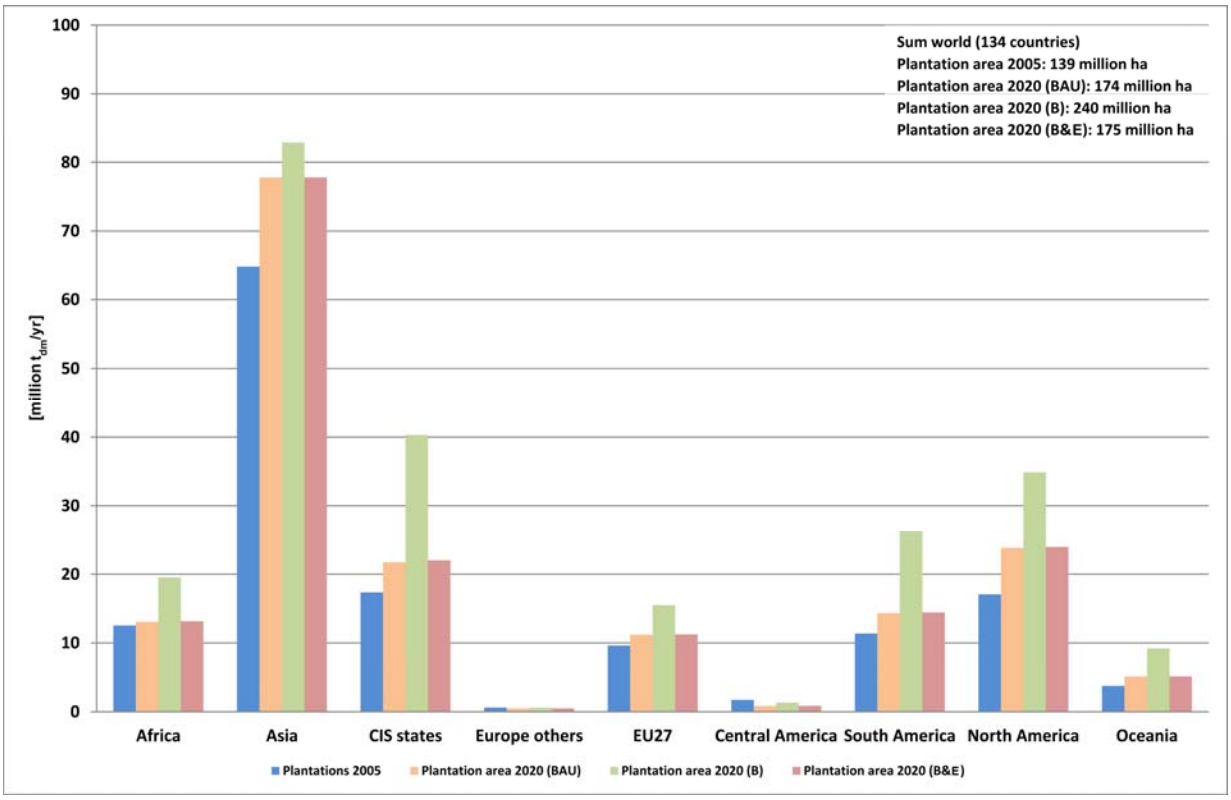

Fig. 21: Development of the forest and short rotation coppice area in the different scenarios in the period 2005 - 2020 in million ha (source: vTI acc. to /36/)

Raw wood potential from forests and plantations in the year 2020

Adding the sustainable raw wood potential from forests and plantations results in the following scene in the year 2020. In the scenario "Business As Usual", about 3.5 billion t_{dm} [tons of dry matter] of raw wood could be sustainably used in 2020. About two-thirds of the potential would come from forests and one-third from plantations (cp. Fig. 22). The largest potentials would be found in North America, the CIS states and South America. Due to the strong increase of forest plantations in China, the potential from plantations in Asia in 2020 would be larger than from forests.

In the "Bioenergy" scenario, the sustainable raw wood potential would have a volume of about 4.2 billion t_{dm}. Therefore, it would be approx. 700 million t_{dm} higher than in the "BAU" scenario (cp. Fig. 22). The increase of the potential exclusively results from forest plantations and short rotation coppice, which would grow on farmland no longer used for food production. In Asia, South America and Oceania, more than 50 % of the raw wood potential would come from forest plantations. Due to the high relative yield compared to forests, which can reach more than 20 t_{dm} per hectare annually, these 700 million t_{dm} would be produced on a comparatively small area of 65.5 million ha. In theory, the same quantity of raw wood could therefore be produced with intensely cultivated forest plantations on just a little more than 10 % of the global commercial forest area.

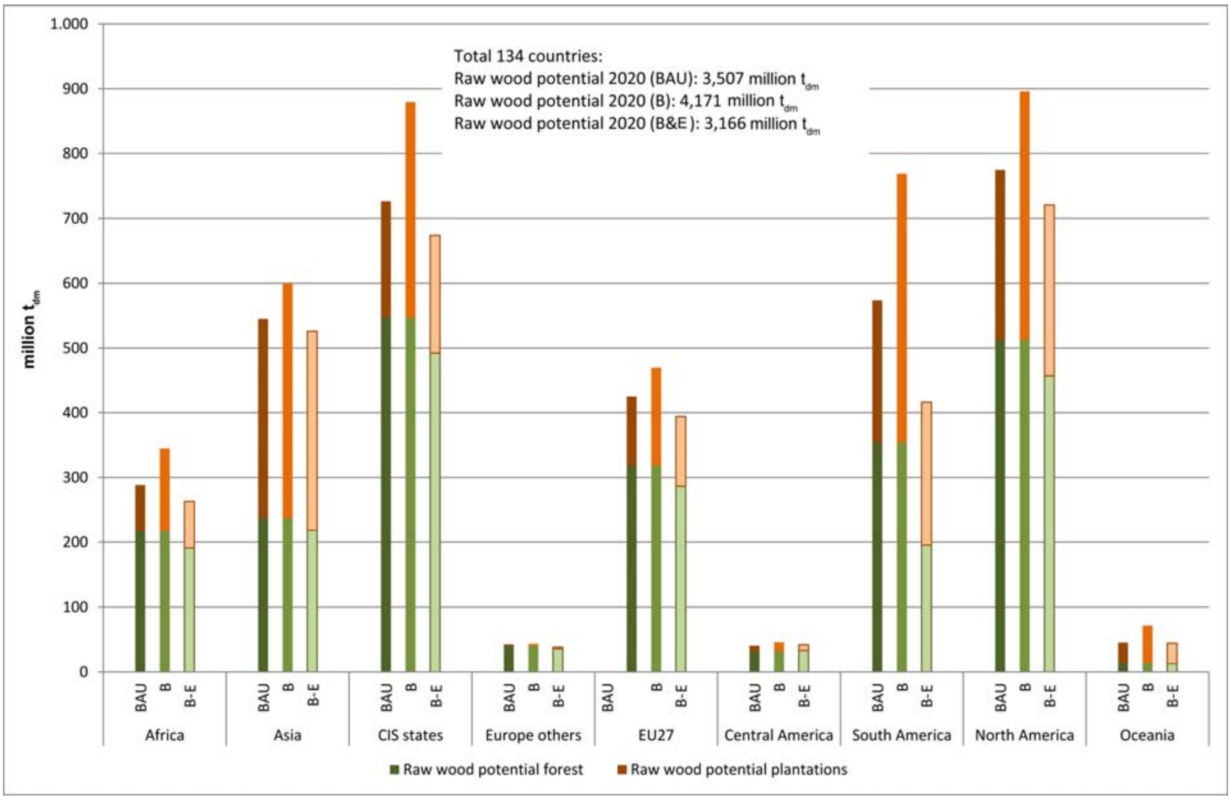

Fig. 22: Sustainably useable global raw wood potential for the three scenarios "BAU", "B" and "B&E" in the year 2020 (source: vTI acc. to /36/)

Notwithstanding the protection of 50 % of the tropical primary forest and 10 % of the commercial forest in the boreal and temperate zones, the sustainable raw wood potential in the scenario "Bioenergy with increased restrictions on environmental protection and nature conservation (B&U)" would only be 300 million t_{dm} less compared to the "BAU" scenario. This is to be explained with the low productivity of the tropical and boreal primary forests, which is on average only between 0.5 and 1 t_{dm} per hectare and year. Despite the comparatively large forest area under protection, the potential would therefore decrease only slightly in comparison (see Fig. 22). This however would be the case only if primary forest would actually be sustainably managed and not be transformed. The results of the "Bioenergy" scenario demonstrate that the cultivation of forest plantations on areas no longer needed for food production would be appropriate to compensate the reduced potential on a comparatively small area in case of extended protection of primary forests.

Raw wood production and consumption in the year 2020

The results of the assessment for raw wood production and consumption in the year 2020 indicate for the 46 countries partly listed in Table 12 a raw wood production of 1.6 billion t_{dm}. Approx. 920 million t_{dm} of this amount would be allocated to round wood for material use and 680 million t_{dm} to wood fuel. Compared to the year 2005, this would be an increase by 227 million dm. The raw wood consumption in the year 2020 would be only 20 million t_{dm} below the value of the production, with almost 1.6 billion t_{dm}. About 900 million t_{dm} of this amount would be used as round and 680 million t_{dm} would be used as wood fuel. The global demand for raw wood - i.e. the consumption - could be completely satisfied by the produced raw wood quantity in the year 2020. The consumption would then be 200 million t_{dm} higher compared to the year 2005.

Table 12: List of the most densely wooded countries and/or largest producers/consumers of raw wood (source: vTI)

Groups of countries/continent	Selected countries
Asia:	China, India, Indonesia, Japan, Malaysia
Africa:	Ethiopia, Dem. Rep. of the Congo, Nigeria, South Africa
Europe:	EU-27, Norway, Russia, Switzerland
North America:	Canada, USA
South America:	Argentina, Brazil, Chile
Oceania:	Australia, New Zealand

Fig. 23 shows the production and consumption values of the 46 countries under consideration for the years 2005 and 2020, classified by continents and/or groups of countries. It is evident that on the basis of the development assumed, the considered European countries have the strongest growth in production and consumption. The production would increase here from 327 million t_{dm} in the year 2005 to 469 million t_{dm}. This corresponds to an increase of more than 43 %. The increase in consumption would be slightly less. The increase would here be of approx. 32 %, from 317 million t_{dm} to 417 million t_{dm}. The largest increase would mainly be in Russia and to a lower extent in Germany, Sweden and Poland. Compared to the development in other countries or groups of countries, this would be based on the simultaneous increase of production and consumption both of round wood and wood fuel. Raw wood production and consumption in the five Asian countries increased by 11 % and 15 % respectively and with values of 433 million t_{dm} and 469 million t_{dm} respectively, would be on a comparable level with the European countries. Production and consumption of both North American countries would be relatively constant during this period of time. Production and consumption would reach 330 million t_{dm}. The production of raw wood for the three South American countries would be 169 million t_{dm} in 2020, an increase of approx. 11 %. The consumption would increase slightly more by 14 % to 172 million t_{dm}. For the five African countries there would be an increase of 20 % each. Production and consumption would be approx. 165 million t_{dm} each. Slight declines are registered for both countries in Oceania. The production would decrease by 1 % to 25 million t_{dm} until 2020. The consumption would decrease more, by 7 % to 21 million t_{dm}.

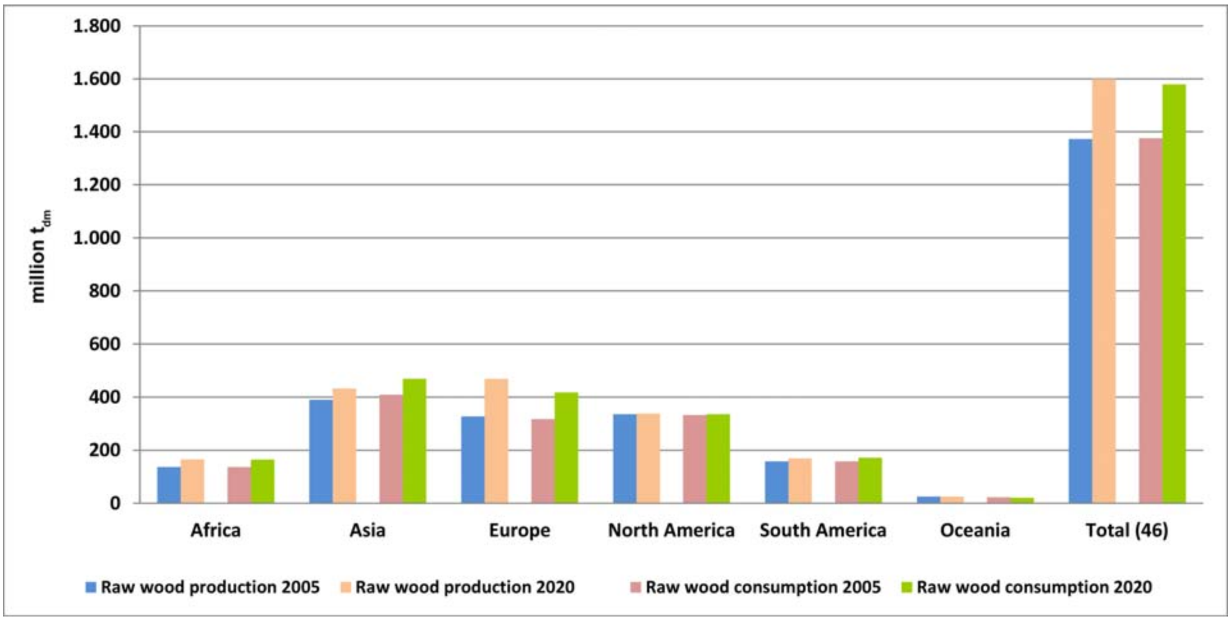

Fig. 23: Production and consumption of raw wood of the 46 selected countries 2005 and 2020 (source: vTI acc. to /54//55/)

Technical wood fuel potential in the year 2020

The technical wood fuel potential, which is calculated as the difference between the raw wood potential and consumption of round wood would be shown as below for the 46 countries under consideration (cp. Fig. 24).

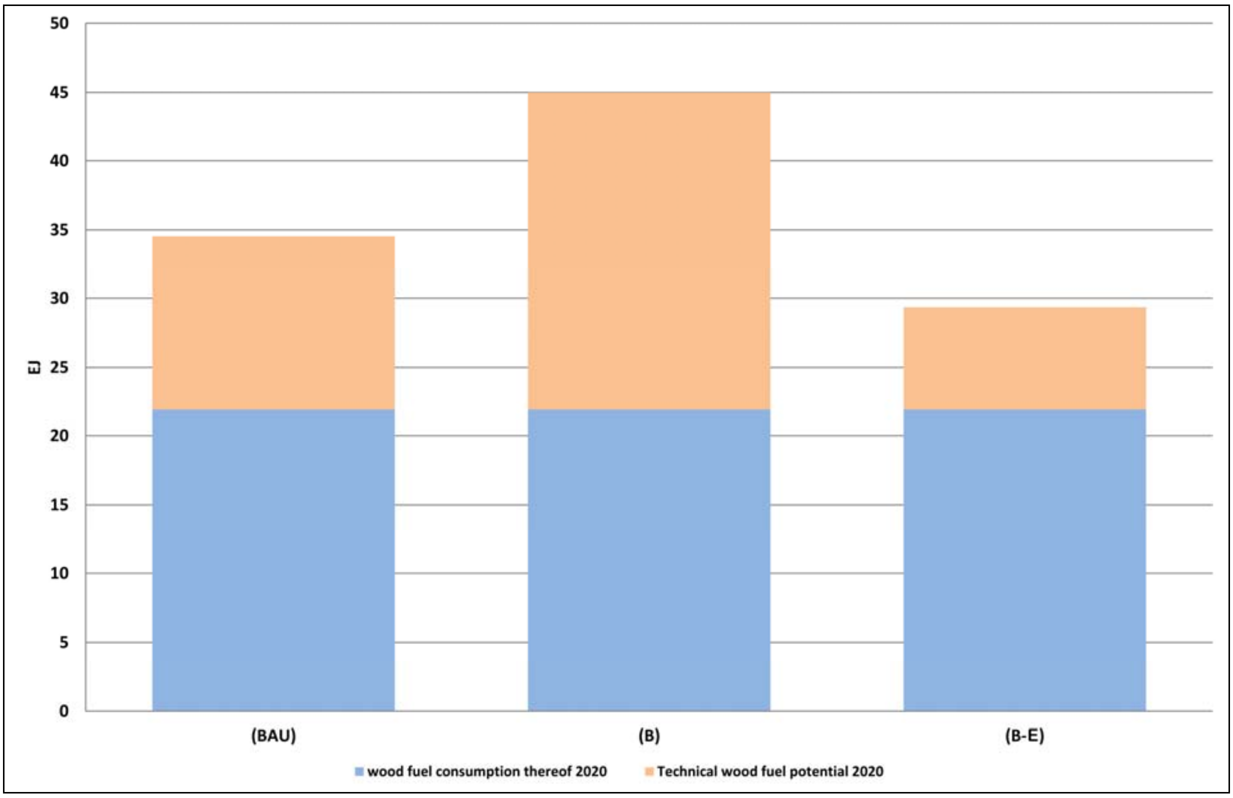

Fig. 24: Technical wood fuel potential of the 46 selected countries in 2020 (source: vTI)

For the scenario "Business As Usual", a total technical wood fuel potential of around 34 EJ is calculated for the year 2020 in the 46 countries under consideration. This could completely satisfy the consumption of wood fuel assessed for the year 2020 to approximately 22 EJ, 12 EJ would be unused and would be additionally available for energetic utilization. In the "Bioenergy" scenario however, the technical potential of wood fuel would be around 10 EJ higher and reaches almost 45 EJ. This would be caused by the large, unused raw wood potential from plantations, which additionally could be used energetically. Compared to the scenario "Business As Usual", around 22 EJ could therefore be energetically used in addition to the assessed consumption of wood fuel. As shown in Fig. 25, the largest technical potentials of wood fuel would be found in Russia (approx. 13,790 PJ/yr), the USA (approx. 8,980 PJ/yr) and Brazil (approx. 7,900 PJ/yr). In the scenario "Bioenergy with increased restrictions on environmental and nature conservation", the technical potential of wood fuel would be the lowest with around 29 EJ, due to the assumed restrictions on environmental protection and nature conservation.

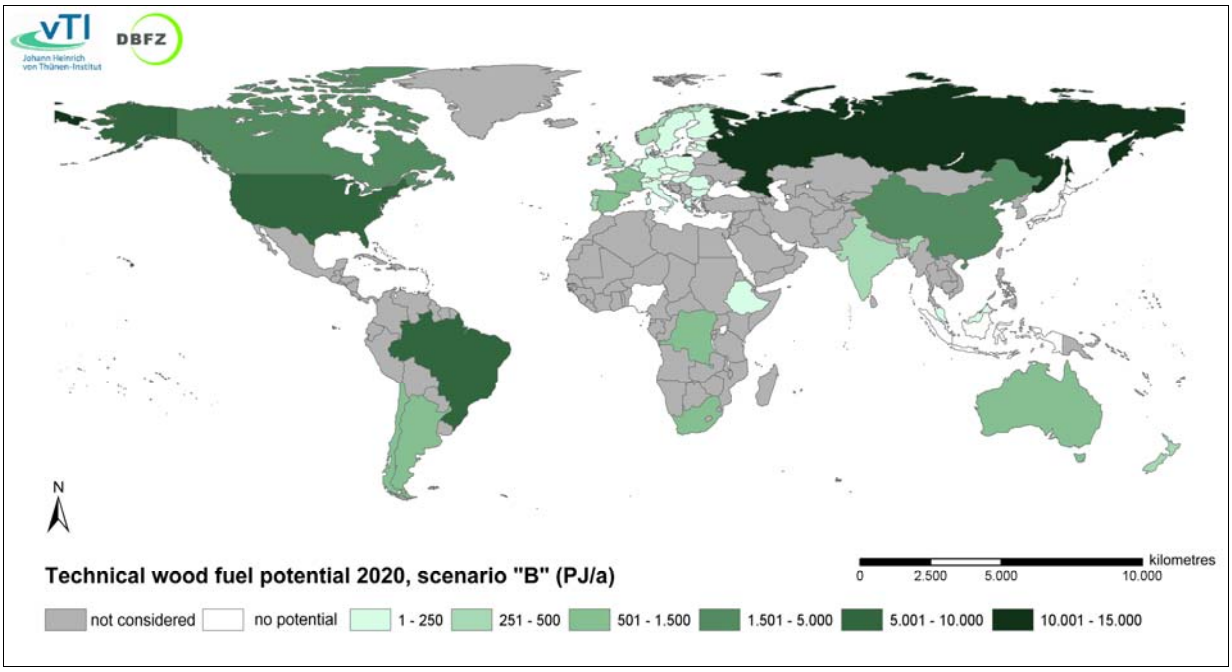

Fig. 25: Technical wood fuel potentials in the scenario "Bioenergy" of the 46 selected countries in the year 2020 (source: vTI, DBFZ)

Assuming that the 46 countries under consideration would satisfy 80 % of the global technical wood fuel potential, the total global technical wood fuel potential would be around 43 EJ in the scenario "Business as Usual", around 57 EJ in the scenario "Bioenergy" and around 36 EJ in the scenario "Bioenergy with increased restrictions on environmental and nature conservation".

6.2.5 Discussion and summary

The results of the method applied here for the assessment of raw wood potential, production, consumption and technical wood fuel potential are based on rough estimates and assumptions. They are rough estimates because it would involve immense effort to identify and quantify the factors which influence the raw wood potential for all countries under consideration. Likewise, it would involve great efforts to evaluate for all of the countries, the differentiated information on the net increase of the different types of forests. Other factors influencing the potential, including the development of infrastructure or technology, are not explicitly considered, however these parameters are implicitly based on the development of consumption and production of round wood and wood fuel assumed until the year 2020. It can only be estimated, how strong their influence is towards production and consumption. For all these reasons, the raw wood and wood fuel potential evaluated for 2020 should always be interpreted keeping these restrictions in mind.

The data quality and data gaps are another weak point of this and other potential assessments. This particularly applies to information on production and consumption of wood fuel. The information which is also included in the statistics used here is based in many cases on estimates or data collections, which illustrate the reality only imprecise and/or in part. Since wood fuel is a commodity to a small percentage, instead regionally marketed and produced for domestic use, the quantities collected in the statistics are significantly below the actual consumption. Although large efforts were taken by the UN Economic Commission for Europe (UNECE) /122/ in the past few years to improve the data base, longer time series with more reliable information on production and consumption are required for better assessment of the future potentials. The same applies to the quantification of the felling. This is often underestimated in official statistics. Therefore, it is essential to improve and globally harmonise data collection to make the results more reliable in the future.

It is quite doubtful, whether more exact results could be obtained through the use of a market modelling exercise, as is often assumed, i.e. a model which is based on the elasticity of price, supply and demand as well as additional parameters, because such a market model is also inevitably based on the existing unsatisfactory data sources. In addition, the complex mechanisms which determine supply and demand of raw wood can only be determined to some extent by a market model. This also applies to unforeseeable incidents (natural catastrophes, regional and global economic crises), which influence the raw wood potential, production, consumption and trade. The results of a market model shall therefore be interpreted with great care, being aware of large inaccuracies.

Altogether it can be stated that the global commercial forest area would decrease by around 300 million ha until the year 2020 in the scenarios "Business as Usual" and "Bioenergy" due to forest conversion. In the scenario "Bioenergy with increased restrictions on environmental and nature conservation", the available commercial forest area would be reduced by around 900 million ha due to the assumed restrictions on environmental protection and nature conservation. The global forest plantation area however would develop inversely. In particular in the "Bioenergy" scenario, the area would increase to 240 million ha and be around 100 million ha larger than in the year 2005. The increase in the two other scenarios to around 175 million ha would be significantly less. Accordingly, the raw wood potential in the "Bioenergy" scenario would be the highest with 4.2 billion t_{dm}. In the scenarios "Business As Usual" and "Bioenergy with increased restrictions on environmental and nature conservation", the raw wood potential would be 3.5 and 3.2 billion t_{dm} respectively in the year 2020. It is apparent that with forest plantations and short rotation coppice an enormous increase is possible on a comparatively smaller area. Potential reductions due to environmental protection and nature conservation could be more than compensated.

The global technical wood fuel potential from forests and plantations in the year 2020 would be around 36 and 57 EJ, depending on the scenario.

Even if the comparison of raw wood potential and consumption for the 46 countries under consideration gives no reason to suspect raw wood shortage for the year 2020 in any of the scenarios, the balance surplus should always be considered against the background of economic and ecologic restrictions. Primarily in Russia, North and South America, these lead to the fact that only part of the potential can be mobilised and will be available for the compensation of regional raw wood shortage. That is to say that regional shortage of raw wood will not inevitably be compensated for by additional mobilisation (production) in the region and/or import of raw wood from other regions and/or more efficient material and energetic utilisation of raw wood, but at the same time adjustment of the regional raw wood consumption.

Despite all the inadequateness, the results of this potential assessment are suitable to localise the global potentials as well as to identify possible development trends and "hot spots". In addition, the results of this study are within the scope of other potential assessments.

6.3 Residues

(DBFZ)

Along with agricultural and forestry potentials, also potentials from ancillary products, residual materials and waste play an important part when considering biomass potentials for energetic utilisation. We understand these so-called residues to be substances of organic origin, accruing during manufacture of a specific (main) product from organic substances and can be used for the provision of bioenergy. Such biomass fractions come, amongst others, from agriculture and forestry as well as from commerce and industry. In addition, they include municipal waste, which also can have a high portion of organic components (see Fig. 26) /62/.

Only few potential assessments exist for ancillary products, residual materials and waste, which are partly afflicted with large uncertainties /50/, /62/, /110/, /130/. In this project, the technical fuel potentials of different fractions of residual materials are determined for 134 countries as well as discussed with respect to the potential development until 2020 and their availability. Except for the municipal waste, all globally accruing residues strongly depend on the development of the respective industries. Since these developments cannot be foreseen on a global basis and in addition, a study by the German Oeko-Institut (Institute for Applied Ecology) (2004) has shown that the potential of residues do not largely differ in different scenarios, no calculations will be made for different scenarios in this project /84/.

Fig. 26: Global residual materials as object of investigation (source: DBFZ)

6.3.1 Straw

Straw is generally considered as stem-like residual from harvesting, accruing in agricultural production e.g. of cereals and oil seeds. Since there are no FAO statistics on straw volume, the production quantities specific to countries and crop type of the examined 134 countries serve as a data source /38/. Based on these data, a five year average value (2003 – 2007) is calculated for the following species: cereals as wheat, oat, maize, rice, soya and sugar cane /49/, /59/, /77/, /79/, /110/. Then the annually accruing straw is calculated in consideration of a region and crop-specific grain-straw relation /70/. However, only part of the accruing straw is available for energetic utilisation because in agriculture, straw is required for the conservation of the humus balance and stock farming (fodder, livestock bedding). The amount of straw which should be retained on the field considerably depends on location, crop rotation and other organic fertilisers added to a soil. A country-specific assessment could not be accomplished in the scope of this project and generally should be specific to a site. Due to aspects of sustainability, a relatively conservative value of 20 % compared to other studies in literature is assumed in the following considerations for the portion of straw for energetic use /52/, /50/, /74/, /84/, /132/. In the last step, the technical fuel potential is calculated via the average lower heating value.

The country-specific results are presented in Fig. 27. Altogether, around 783 million t_{dm} of straw is annually available for energetic utilisation for the examined 134 countries, whereas the largest amounts of straw accrue in the cultivation of maize, sugar cane, rice and wheat. There is a technical fuel potential of 13,317 PJ/yr for the 134 examined counties, with China having by far the largest potential with 2,570 PJ/yr, followed by India, the USA and Brazil.

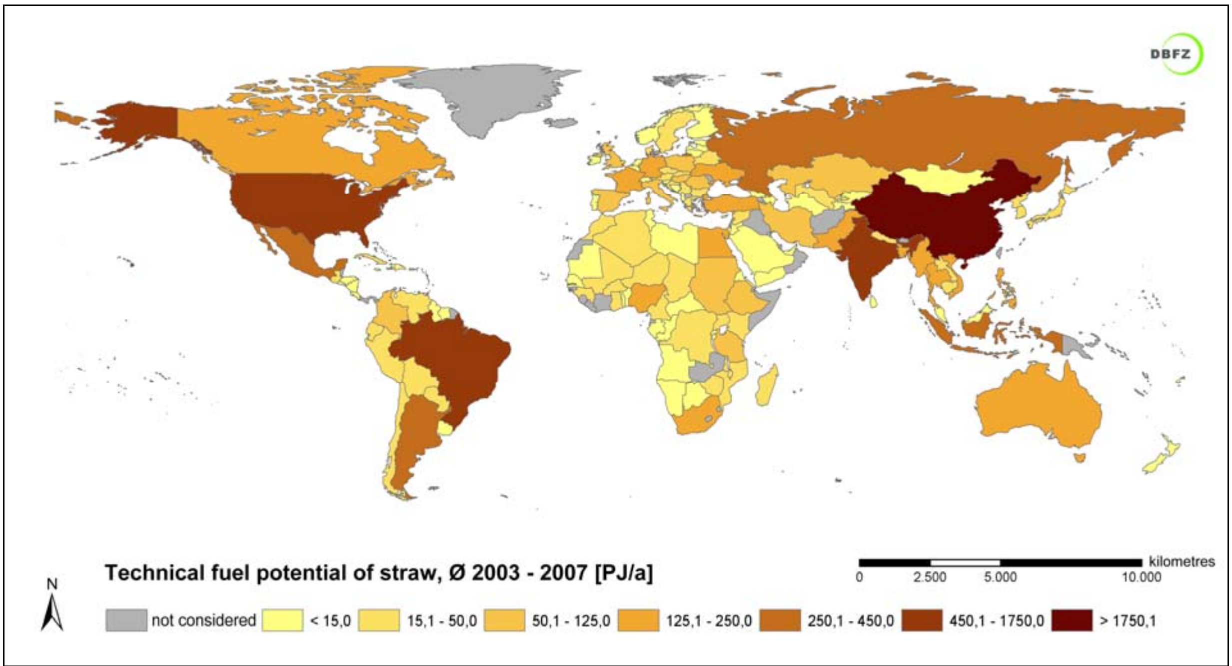

Fig. 27: Technical fuel potential of straw, Ø 2003 - 2007 (source: DBFZ)

Straw currently is energetically utilised to a small amount only and if so, mainly in the form of thermal utilisation. Basically, it can also be used in biogas plants. In the future, straw could serve as a primary product for biofuels of the second generation (e.g. cellulose-based bioethanol and synthetic biofuels such as BtL and biogas SNG). Such motor fuels are currently produced in test and pilot plants only /52/, /61/. It is impossible to assess today, when the procedures can be implemented at a large scale.

6.3.2 Excrement from livestock

Agricultural stock farming produces lots of excrement as liquid or solid manure and slurry, which currently is spread directly on farmland mainly as farm fertiliser for recycling of the nutrients contained therein /84/. Dried animal excrement such as dung however plays an important part as solid fuel already today, globally and in particular in Asia. Liquid manure and droppings contain a high percentage of biomass, which can be energetically utilised by fermentation, whereas the nutrients subsequently are available as farm fertiliser (digestate).

However, for technical and economic reasons not all excrement can be used for biogas generation, for example in the case of pasture management or small quantities of livestock. The calculations therefore include only cattle, pigs and chicken as relevant livestock /106/. The country-specific five-year average (2003 - 2007) of the FAO livestock numbers forms the basis of the calculations /39/. The FAO statistics do not subdivide e.g. for cattle between feeder cattle, dairy cow, mother cow or calf. The conversion into livestock units was performed by means of factors specific for the region. Since there are no global surveys on country-specific livestock breeding, the portion of indoor breeding was assessed by regions based on an FAO study for "landless production" in stock farming /106/. The specific quantity of liquid manure per livestock unit and species and the average biogas yield of the excrement were included as further parameters. The results specific to the countries are shown in Fig. 28.

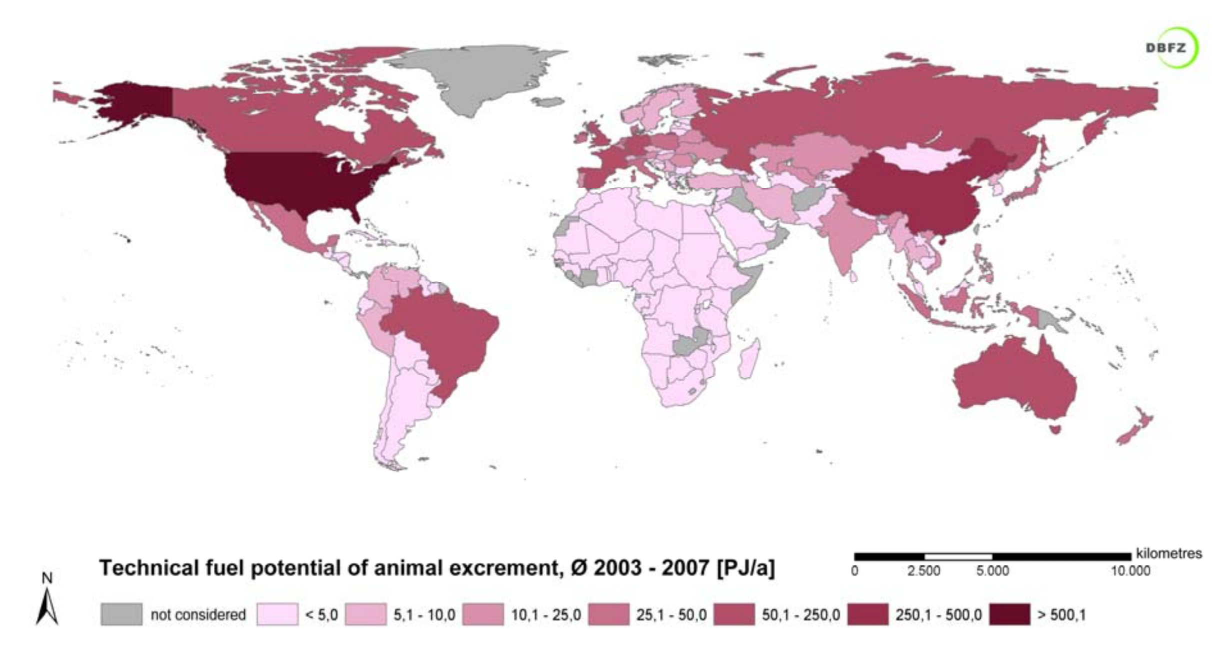

Fig. 28: Technical fuel potential of animal excrements, Ø 2003 - 2007 (source: DBFZ)

For the examined 134 countries, this results in a technical fuel potential of around 2,370 PJ/a, whereas the USA (approx. 600 PJ) and China (approx. 400 PJ) exhibit the largest potentials. Furthermore, Europe, Australia and Brazil have major fuel potentials. The largest fuel potentials in Europe are in France, Germany, Spain, Russia and the United Kingdom (56 – 109 PJ). While in Europe the largest potentials are from cattle breeding, the potentials in Asia and South America are mainly from pig breeding and poultry keeping. Oceania has fuel potentials almost exclusively from cattle breeding. Due to the wide extent of free-range breeding, Africa altogether has an insignificant fuel potential from excrement.

Altogether, it turned out that the data sources for global livestock breeding are very heterogeneous and incomplete. This is caused by a number of uncertainties, which even become vaguer by the considerable spread of information on liquid manure quantities, biogas yield etc. The results for the technical fuel potentials from excrement of livestock breeding should therefore be interpreted as approximate values only.

Missing regionalised data on the type of livestock (e.g. division of cattle into feeder cattle, dairy cow or calf) and on the type of breeding (indoor/outdoor breeding) is the largest problem. Although the FAO information on "landless production" allow for an assessment of the regional type of breeding, they merely are more or less a rough indicator and can largely deviate on national levels. Although the parameter 'liquid manure volume per livestock unit' and 'average biogas yield' may largely vary even within one species, these factors needed to be assumed as a flat rate, which further limits the preciseness.

The potentials from excrement will increase in the future, because cattle breeding will further increase due to growth in population and increasing demand for meat and milk.

6.3.3 Logging residues

The technical fuel potential of logging residues is assessed by means of the estimates on the raw wood production quantities in section 6.1, which is performed for the 46 globally most densely wooded countries and/or most important raw wood producing and consuming countries. Although this selection only represents one-third of the 134 countries, approx. 80 % of the global raw wood production and consumption is gathered.

The technical fuel potential of logging residues is calculated by the individual fractions of harvest loss during raw wood harvesting, percentage of crown mass and merchantable wood and the percentage of brush-wood. The particular country-specific potentials are therefore subject to strongly fluctuating influencing factors such as the composition of tree species, distribution of age categories and growth, which especially determine the fractions of the percentage of crown mass and merchantable wood as well as the percentage of brush-wood. However, as a rule of thumb it can be assumed that almost 30 % of the raw wood harvest without bark represent the theoretical fuel potential of logging residues for a country. 50 % of this quantity is available as technical fuel potential. These general figures however can only be used for the subtropical and tropical areas on the assumption that part of the firewood potential is allocated to the wood, which here is classified as logging residues.

The country-specific results on forest logging residues for 2005 are shown in Fig. 29. In 2005, the 46 countries under consideration have a total technical fuel potential of around 8,050 PJ/yr. The USA have the largest annual potential with approx. 1,370 PJ, followed by India (approx. 970 PJ) and China (approx. 920 PJ). The raw wood production quantities assessed also for 2020 in the section "global forestry biomass potentials" result in a technical fuel potential of forest logging residues of around 9,380 PJ/yr in 2020. In particular for Russia, the potential has doubled from approx. 570 PJ/yr in 2005 to 1,110 PJ/yr in 2020.

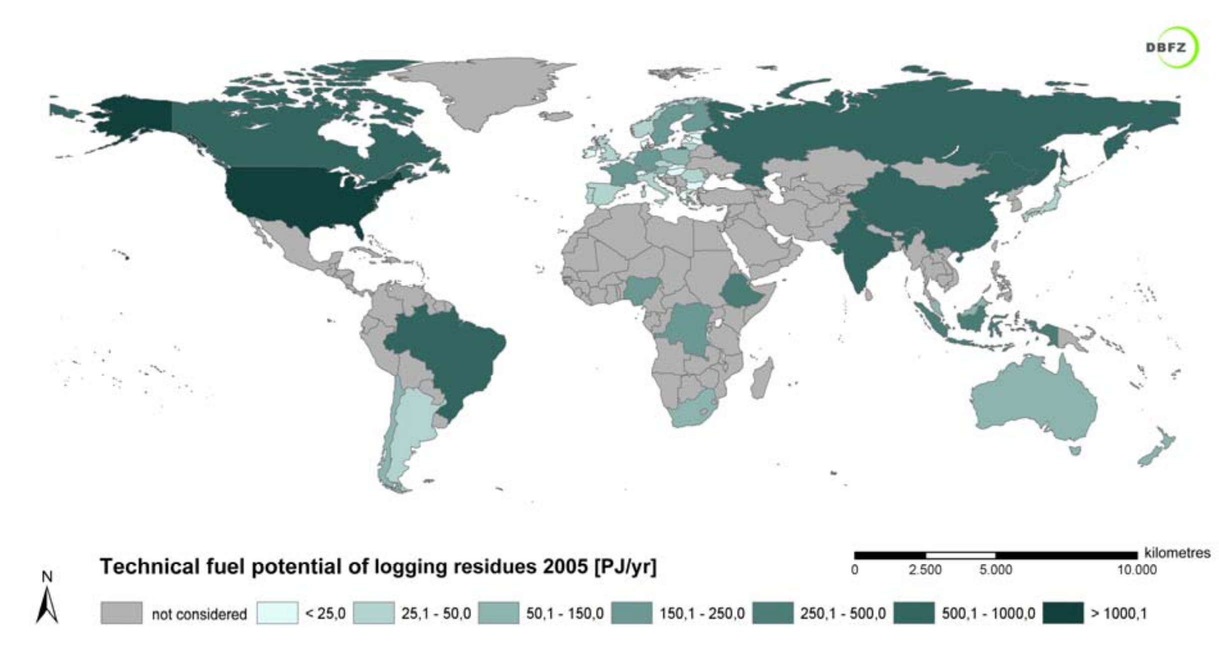

Fig. 29: Technical fuel potential of logging residues 2005 (source: DBFZ)

Since the 46 countries cover approx. 80 % of the global raw wood production and raw wood consumption, this results in a global potential of approx. 10,730 PJ/a for 2005 and of approx. 12,490 PJ/a for 2020.

6.3.4 Municipal waste

According to the definition of the Intergovernmental Panel on Climate Change (IPCC), municipal waste is defined as all waste collected by the communities and/or local administration. It normally includes the waste from households and public greens as well as commercial waste similar to domestic waste /23/. The portions of municipal waste which can be energetically used primarily are food waste (and/or "biowaste") and used wood.

The calculations are based on the population statistics of the FAO /40/ and data on the volume and composition of waste from IPCC /23/. The population statistics were used to form the average value of the years 2003 to 2007. The IPCC data for the year 2000 on the average per-capita volume of municipal waste per inhabitant and year are available party on a national level and partly on a level of the sub-regions, just as the information on the portions of the energetically useable waste fractions. This data is used to calculate the volume of biowaste and used wood per country, whereas an exploitation factor of 75 % is assumed /110/. The technical fuel potentials are subsequently evaluated by means of the biogas yield and/or the lower heating value.

Fig. 30 shows the results specific to the countries. This results in a total technical fuel potential for municipal waste of approx. 2,820 PJ/yr for the 134 countries under consideration (biowaste approx. 1,160 PJ/yr, used wood approx.1,660 PJ/yr)

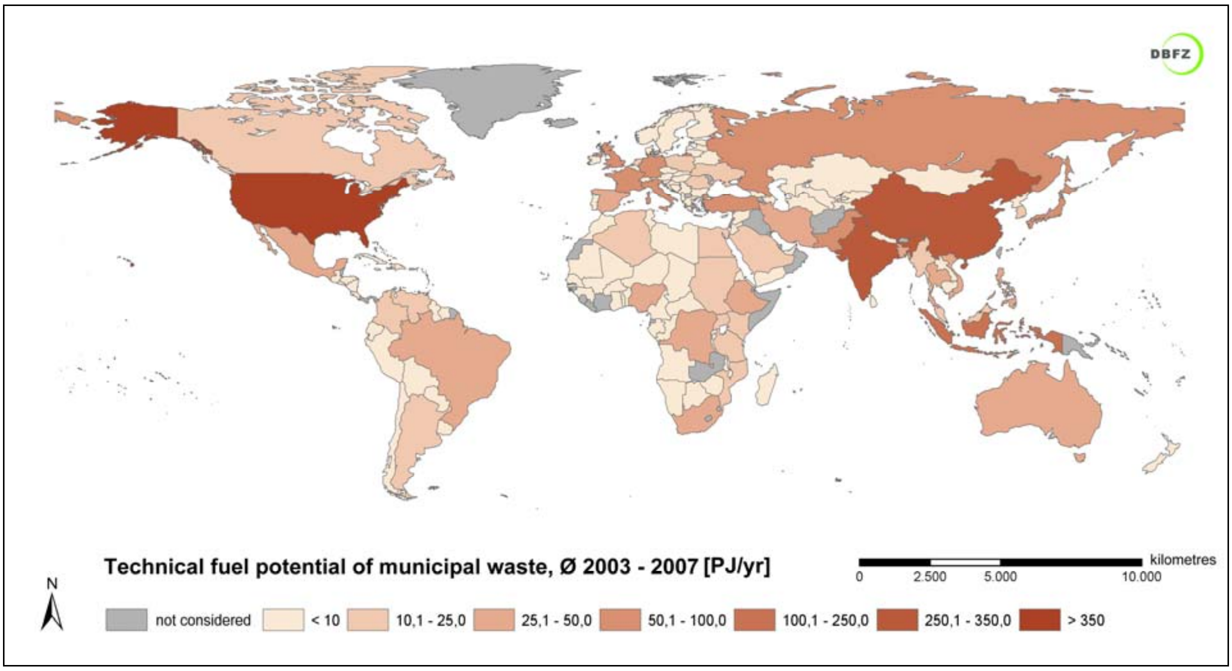

Fig. 30: Technical fuel potential of municipal waste, Ø 2003 - 2007 (source: DBFZ)

As illustrated in Fig. 30, the largest technical fuel potentials both for biowaste and used wood are to be expected in the USA, in China and in India. The USA takes first place with 445 PJ/yr because of their very high waste production rate of 1.14 tons per inhabitant per year /23/. In Europe, the largest fuel potentials accrue in Germany, Russia, France, Italy, Spain and in the United Kingdom (48 – 86 PJ/yr). Therefore, the largest potentials of municipal waste can be found on the one hand in the world's most densely populated countries and groups of countries and on the other hand also in the particularly industrialised countries.

Since the volume and composition of municipal waste is not homogeneous and differs by region, but also by season, the data collected is relatively imprecise /23/, /84/. Furthermore, the IPCC values are not collected for each individual country, but specific countries were taken as examples to generalise for entire groups of countries. For such reasons, the calculations are afflicted with a certain degree of inaccuracies. However, they can serve as an indication for the regional distribution of the potentials.

It is a large hindrance for energetic utilisation of municipal waste that it currently is rarely collected separately and therefore biowaste and used wood mostly are mixed with the residual waste. Such separation is more common only in Central Europe /62/. Landfilling of biodegradable waste is commonly practised in large parts of the world, while in Europe this is possible only to a limited extent. Landfill sites are often problematic, especially in densely populated countries, due to their large demand for space and their emissions, so that energetic utilization of municipal waste offers advantages also in this respect /7/.

Consideration should be given to the thermal utilisation of the used wood, as harmful gases with considerable environmental impacts may occur, depending on the type and degree of treatment (vanishing, wood preservatives, polychlorinated biphenyls (PCB) etc.)

Wood processing industry residues is the umbrella term for different residual wood accruing in different sectors of wood machining and wood processing industry. We use the average of the years 2003 to 2007 of the FAO data on “miscellaneous wood residues" for the calculation of the technical fuel potential of wood processing industry residue. These quantities cover different types of wood residues from industry, for example residues from saw mills as well as boards, edges, trimmings, veneer residuals, saw dust, bark and other residual material from carpenter's workshops and similar enterprises /37/.

The problem here is that the FAO data is not available for all countries. Thus, from the 134 countries considered in this project, only 64 are included in the FAO statistics on "wood residues". Since only a specific portion of the total quantity can be collected due to different restrictions, we assume an exploitation factor of 75 % /58/, /109/, /132/.

The results for the 64 countries under consideration are illustrated in Fig. 31. It becomes apparent that the data situation is insufficient for Africa, large parts of Asia as well as Central and South America. This results in a total technical fuel potential of approx. 700 PJ/yr for the 64 countries, for which data is available. China provides by far the largest technical fuel potential from wood processing industry residues of 101 PJ annually. Also both East Asian states Japan and South Korea have comparably large potentials of up to 54 PJ per year. Canada ranks second in the list of countries with the largest fuel potentials, having around 60 PJ/yr. The largest quantities of wood processing industry residues within Europe, where data series are almost completely available, are found in France, Russia and Finland (48 – 53 PJ/yr, cp. Fig. 31).

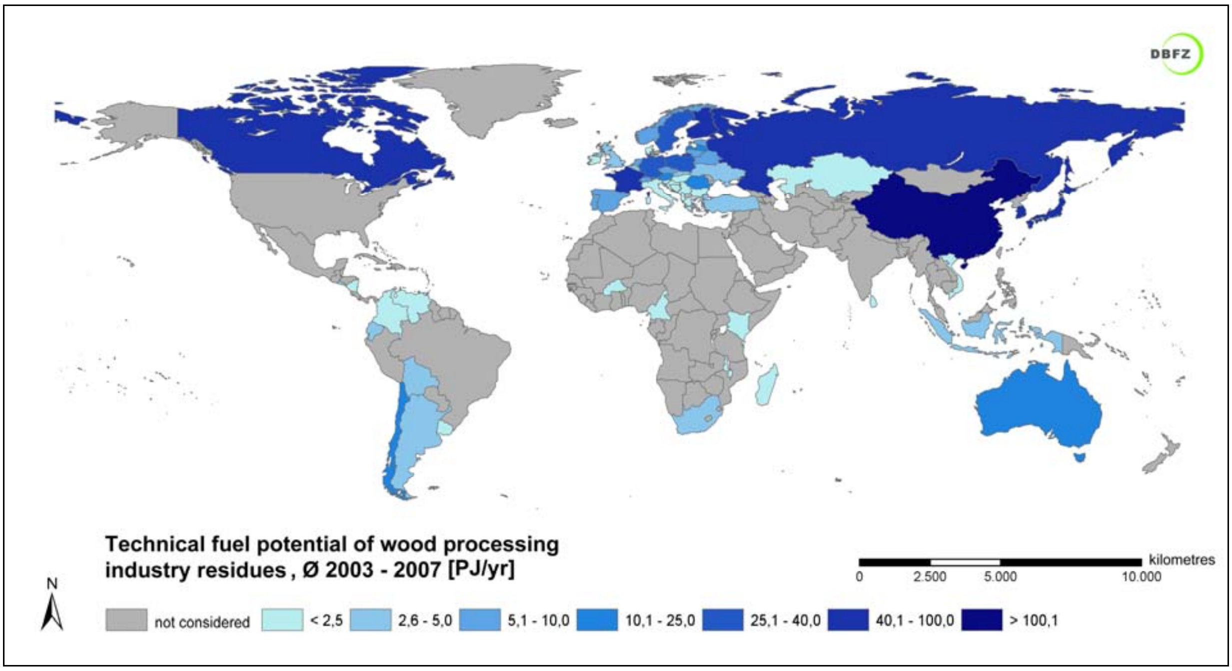

Fig. 31: Theoretical fuel potential of wood processing industry residues for 64 countries, Ø 2003 - 2007 (source: DBFZ).

The FAO data analysed here summarises quite different fractions of wood. Therefore, no rates of residues specific to a product or an industry can be used and no detailed assessments can be made on material utilisation. The calculations based on the FAO data are thus to be considered as rough guideline values only. The technical fuel potential for all 134 countries cannot be completely assessed due to the incompleteness of the data.

Also the future development of the potentials is difficult to assess, since the production of wood products and therefore the quantity of residual material is subject to fluctuations which are hardly foreseeable. In addition, it should be considered for wood processing industry residues that it already is materially utilised to a large extent. Kaltschmitt et al. (2009) suggests that approx. two-thirds of the wood processing industry residues accruing in Germany is materially utilised and only one-third is energetically utilised /62/. A country-specific assessment of material utilisation could not be performed in the scope of the project.

6.3.5 Production specific residuals, ancillary products and waste

Considerable quantities of solids, high viscosity liquids and liquids, which are production-specific wastes accrue in industry and trade. However, there is no global survey on waste and utilisation of such residual matter. Even in Germany, such data is only sporadically available for specific fractions, often in the form of considerations in an individual case. The theoretical fuel potential of specific industrial substrates can be assessed by the proportion of products and residuals, however without consideration of competition in utilisation. The quantity of production-specific organic waste is often characterised by high contents of nutrients and water. Therefore, a large share of such organic substances such as e.g. compressed cakes from vegetable oil production is used as animal feedstuff and is not, or only to a limited extent, available for energetic utilisation /62/. The following production waste is exemplarily analysed in this project: bagasse, the fibrous remains of sugar cane after sugar-making, residual material from palm oil production and coconut processing.

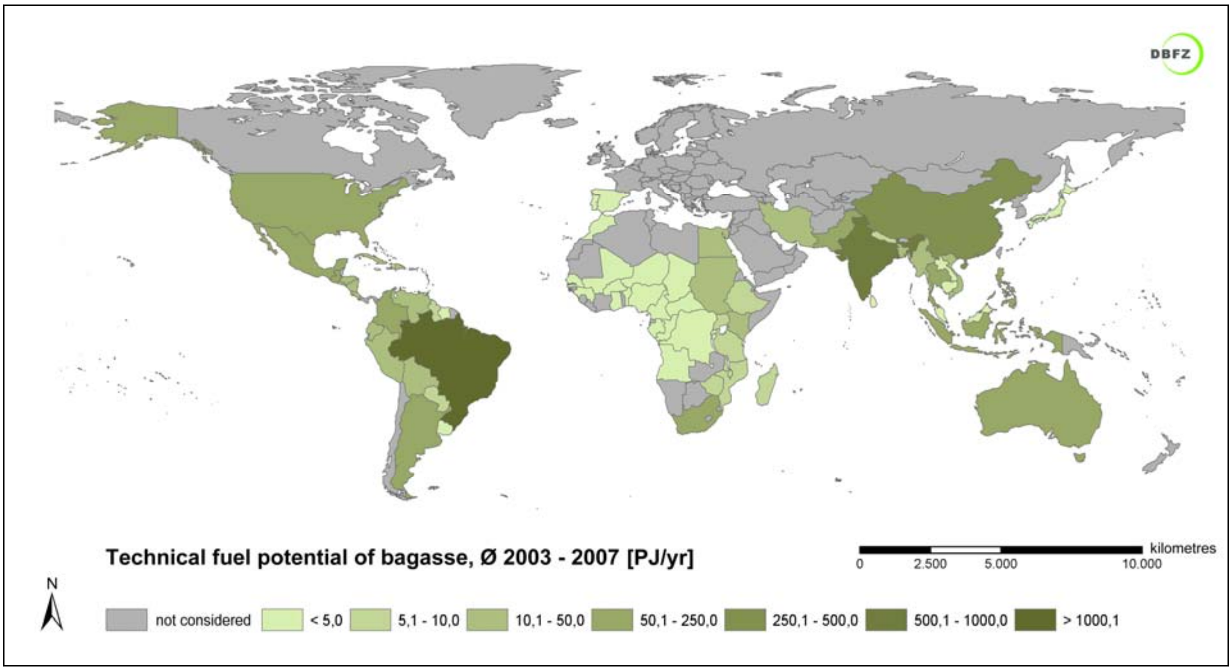

Fig. 32: Theoretical fuel potentials of bagasse, Ø 2003 - 2007 (source: DBFZ)

Fig. 32 shows the country-specific results for bagasse. Relevant cultivation of sugar cane only takes place in 73 of the 134 analysed countries. For these countries, there is a total annual theoretical raw material potential of 210 million t_{dm} for bagasse and a theoretical fuel potential of approx. 3,650 PJ. With approx. 1,190 PJ/yr, Brazil by far has the largest theoretical fuel potential, followed by India (approx. 730 PJ/yr) and China (approx. 250 PJ/yr). Bagasse is currently fired for energetic self-supply of the sugar industry in the manufacturing process or mainly used for the generation of electricity and heat linked to the sugar and ethanol plants and fed into the particular supply grid.

Palm oil fruits are produced in only 33 of the analysed 134 countries. The residues from palm oil production (fibres and shells of palm oil fruits) result in a total annual theoretical fuel potential of 1,050 PJ, whereby already 82 % comes half from Malaysia (approx. 450 PJ) and half from Indonesia (approx. 420 PJ). Also the residuals from palm oil production already are partly used for electricity and steam generation in combined heat and power plant mills /93/.

According to the FAO statistics, coconuts are only produced in 44 of the 134 countries. The residues of coconut processing (shells and husks) result in a theoretical fuel potential of approx. 410 PJ/yr. The majority of the coconut residue is found in Indonesia (approx. 130 PJ/yr), the Philippines (approx. 110 PJ/yr) and India (approx. 75 PJ/yr). The residues of coconut processing recently partly remain of the fields as a fertiliser; serve as animal feedstuff or fuel. They are also materially used for numerous products such as door mats or bags made of coconut fibres /3/, /124/.

6.3.6 Conclusion

The analyses on global residual potentials demonstrate that the global data situation overall was quite incomplete and heterogeneous. Cross-national global statistics on the volume of residues do not exist. The volume or residual material therefore had to be evaluated via product-residue ratios from the FAO data on production quantities of e.g. different types of cultivation and log wood, of stock breeding data or inhabitant-specific quantity rates. The technical fuel potentials summarised in Table 13 are more or less a rough approximation.

Table 13: Results for current global technical fuel potential, classified by the different residue fractions (result in the form of the theoretical fuel potential; source: DBFZ)*

Residue fraction		Countries under consideration	Result technical fuel potential [PJ/a]
Straw		All	13,317
Municipal waste - biowaste		All	1,164
Municipal waste – used wood		All	1,660
Excrements from stock breeding		All	2,369
Logging residues		46 countries (global)	8,047 (10,729)
Wood processing industry residues		64 countries	698
Production-specific organic waste	Bagasse	All	3,647*
	Palm oil	All	1,049*
	Coconut	All	409*

In the case of wood processing industry residues, only 64 countries could be analysed due to incomplete data. The evaluation of logging residues is based on the assessments of raw wood production quantities (cp. section. 6.2). Although these were available for one-third of the 134 countries only, the analysed 46 countries represent approx. 80 % of the global raw wood production and raw wood consumption. There is a technical fuel potential from wood residuals of approx. 8,050 PJ/yr for these countries. Extrapolated for the world, this would result in a current potential of approx. 10,730 PJ/yr. Due to missing data on material utilisation, only the theoretical fuel potential was evaluated for the production-specific organic waste.

The comparison of the individual residue fractions in Table 13 shows that large potentials exist in particular for energetic utilisation of straw and logging residues. There is a current global technical fuel potential of around 30 EJ from all residue fractions analysed in this project. Compared to this, the German Advisory Council on Global Change assesses the technical potential from biogenic waste and residues to be approx. 80 EJ per year, whereas the sustainably useable potential is assessed at approx. 50 EJ /130/. The German Advisory Council on Global Change also states that the scientific basis for the assessment of the sustainable global potential of waste and residues is very narrow only and the evaluated value of approx. 50 EJ is to be considered to be rather uncertain.

Due to the existing unsatisfactory data sources, no assessment was made for the potentials in 2020, except for logging residues. The calculations for logging residues are based on the data on raw wood production (see section 6.2) and could therefore be assessed until 2020 (increase to approx. 9,370 PJ/a for the 46 countries and/or 12,490 PJ/a globally). Due to the global growth in population, it can be assumed that for the remaining residues the technical fuel potential will tend to increase further until 2020.

The energetic utilisation of residues is currently increasingly forced, because compared to the utilisation of energy crop, no additional use of land is involved and therefore this does not result in competition with current land use. There will be almost no greenhouse gas emissions from change of land use and cultivation, so that large savings in greenhouse gases are additionally assumed /130/. Residues can have very heterogeneous properties. They normally are characterised by low energy density and are often used locally. Therefore they will not play an important part as import biomass for the IEKP targets.

Despite all the potential data weaknesses, the analyses performed in this project identify the main influencing factors for the residue potential and allow for regional allocation of the potentials within the individual fractions. China, the USA, India and Brazil have particularly high potentials of residues.

6.4 Import biomass for Germany

(DBFZ)

The technical fuel potentials of different agricultural and forestry biomass as well as residues were calculated in sections 6.1 to 6.3 and potential key regions were identified. The direct comparison of the results is possible to a limited extent. The highest potentials for the year 2020 were calculated for the forestry biomass (including short rotation coppice (SRC) and plantations of released farmland). The global technical fuel potential of wood fuel in the scenario "Business as Usual" is approx. 43 EJ/yr, in the "Bioenergy" scenario approx. 57 EJ/yr and 36 EJ/yr in the scenario "Bioenergy with increased restrictions on environment and nature conservation". The current technical fuel potentials for the residual fractions under consideration, totalling approx. 30 EJ, are of similar size. The residual flows tend to further increase until 2020 due to increase in population and increased consumption. Considering the priority of food production in the year 2020, significant high technical fuel potentials from agricultural biomass to the amount of 16 EJ can still be expected only for the "Bioenergy" scenario.

In addition, the options for achievement of the IEKP targets through the import of sustainably produced biomass were to be integrated in the scope of the project. International trade can take place by direct transport of biomass or transport of bioenergy sources. The suitability for transport primarily depends on substrate properties such as the calorific value, transport density and suitability for storage. Furthermore, other basic economic, infrastructural and political conditions must be met for international trade, which however cannot be analysed on a global scale in the scope of this project. The question of suitability for transport was rather derived by means of substrate properties and today's trade flows for different biomass or bioenergy sources (see Table 14).

Table 14: Different biomass fractions and their consideration as import biomass in the scope of this project (source: DBFZ)

Biomass	Suitability for international transport	Import as	In this project …
Residues	not given	no significant import	not considered
Ligneous biomass (forestry)	given	log wood, split logs, pellets	briefly outlined below
Sugar beet, grassland growth, silage maize	not given	biomethane	EU-wide feed into natural gas system
Cereals (e.g. wheat, rice)	given	raw material or bioethanol	considered as bioethanol
Sugar cane	given	bioethanol	considered as bioethanol
plants containing oil (rape, soy)	given	raw material or vegetable oil/biodiesel	considered as biodiesel
plants containing oil (oil palm)	given	vegetable oil /biodiesel	considered as biodiesel

When it comes to the transport of biomass or bioenergy sources, the question of the energetic balance keeps coming up when covering large distances. It is apparent here that the energy consumption of transport is comparatively low and very large distances can be covered before the energy content of the load is depleted (e.g. lorry with 25 t SRC (incl. diesel upstream chain) approx. 11,000 km). Therefore, economic restrictions, rather than aspects of energy consumption, take effect with regard to the transport of biomass.

The results of the calculations for regional biomass potentials for Germany show that the IEKP targets in the range of electricity and heat can already be met with domestic biomass. However, there is a demand for liquid and/or gaseous biofuels in the mobile sector (see section 5.1). The following analysis therefore focuses on import potentials of selected biofuels suitable for transport and/or capable of being supplied (see Table 14).

Table 15 shows the evaluated global quantities of liquid and gaseous biofuels for the different scenarios for the periods relevant for the fulfilment of the IEKP targets 2015 to 2020. It should be considered that these are the quantities which could be produced from the biomass of released non-food areas. In comparison: the quantity of bioethanol and biodiesel already globally produced in 2008 was 52.4 million t and 12.9 million t respectively /41/.

Table 15: Quantities of biofuels for the scenarios "BAU", "B" and "B&E" for 2015 and 2020, classified by the three fuel types under consideration (source: DBFZ)

	Bioethanol (million t)		Biodiesel (million t)		Biomethane (billion m³)	
	2015	**2020**	**2015**	**2020**	**2015**	**2020**
Scenario "BAU"	**57.4**	**0**	**7.4**	**0**	**5.2**	**1.2**
Scenario "B"	**175.1**	**187.5**	**24.1**	**30.7**	**10.6**	**6.6**
Scenario "B&E"	**62.8**	**2.7**	**3.1**	**0.2**	**7.3**	**1.2**

Just as the results of the technical fuel potentials in section 6.1.2 it is apparent that high potentials for energy crops are still available on non-food areas in 2015 in all three scenarios. Due to land availability and the choice of advantageous biomass (so-called energy crop rotation, see section 6.1), the largest fuel quantities could be produced in the "Bioenergy" scenario. Due to the globally increased demand for food and thus for additional farmland, the fuel quantities after 2015 will decrease to such an extent in the scenarios "Business as usual" (BAU) and "Bioenergy with increased restrictions on environment and nature conservation (B&E)" that no significant quantities of additional biofuels (produced from agricultural biomass of non-food areas) would be expected in these scenarios from 2020. Significant quantities of liquid and/or gaseous energy sources could be produced from 2020 only in the "Bioenergy" scenario. Fig. 33 again compares all three scenarios and points out the raw material basis, from which they are produced.

In 2015, the potential of bioethanol, which is produced from grain, dominates in all scenarios. In addition, there are large potentials from sugar cane and oil palms in the "Bioenergy" scenario. The almost insignificant fuel potentials in 2020 in the scenarios "BAU" and "B" either consist of grassland growth (BAU) or grain and grassland growth (B). In the "Bioenergy" scenario, the biofuel potential further increases until 2020, whereas grain, sugar cane and oil palms remain the dominating crop types.

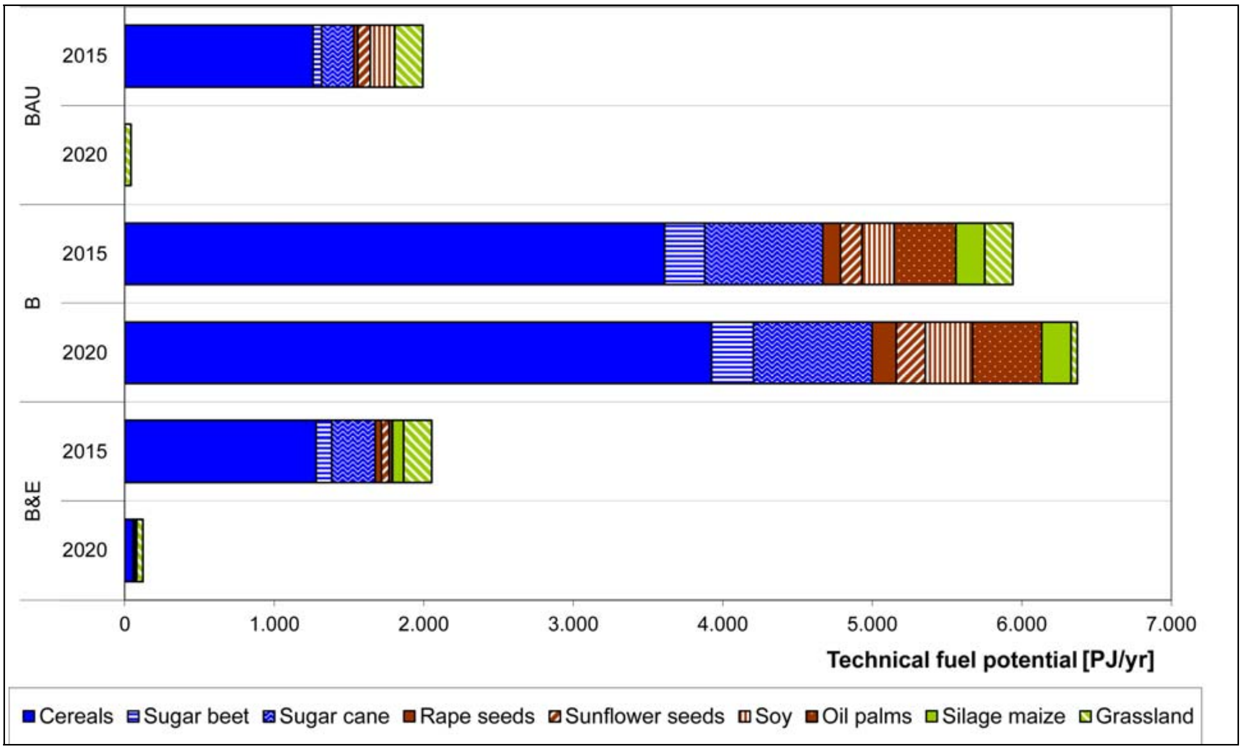

Fig. 33: Technical biofuel potential in the scenarios "BAU", "B" and "B&U" for 2015 and 2020, classified by raw material basis (source: DBFZ)

Fig. 34 shows the country-specific biofuel potentials for the "Bioenergy" scenario in 2020 to identify the potential supplier countries for the import of biofuel to Germany.

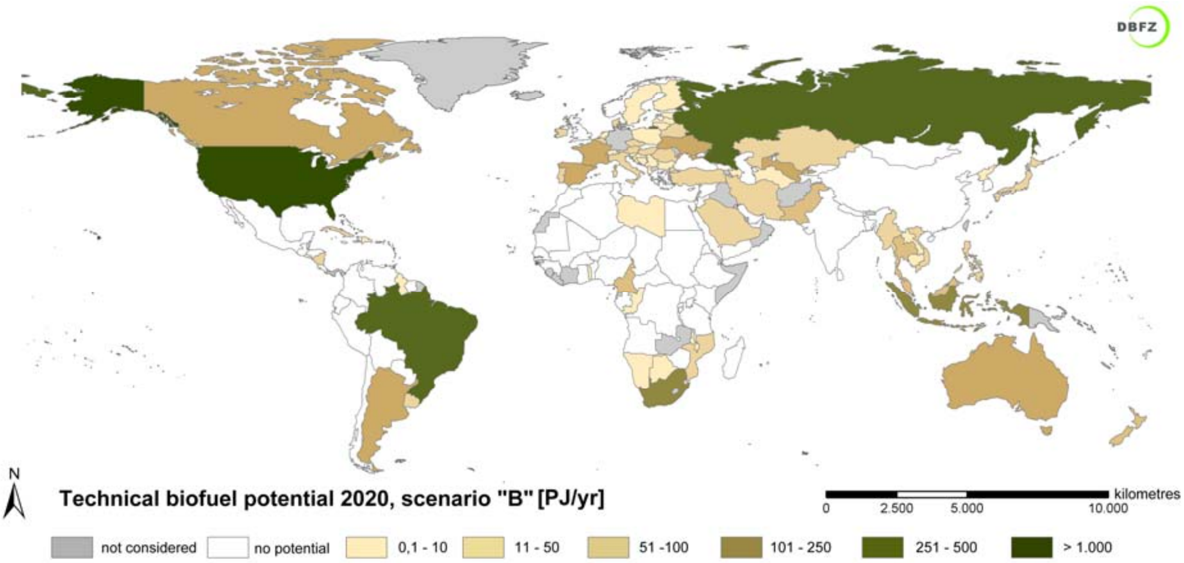

Fig. 34: Technical biofuel potential for the scenario "B" in 2020 (source: DBFZ)

In this scenario, the USA (approx. 1,660 PJ/yr), Brazil (approx. 885 PJ/yr), Russia (approx. 820 PJ/yr) and Indonesia (approx. 390 PJ/yr) are among the largest potential biofuel suppliers. France has the largest potential (approx. 190 PJ/yr) of the EU-27 states. When considering the results it should be noted that along with Germany, the European Union and many other countries have also defined biofuel targets and therefore will also possibly need to import biomass.

Also raw wood is traded internationally, just as agricultural biomass, however to a far lower extent. Key regions of international raw wood trade are North America, Europe and South East Asia. The largest exporters of raw wood are Russia, Canada and the USA. Main importers of this raw wood are the USA, Japan and China. While there is almost no trade with wood fuel in the form of split logs or forest wood chips, global trade with wood pellets has established in the past years. Large production capacities have been built up in Canada and the USA for transportation mainly to the EU. Pellet trade however also takes place inside the EU. The largest pellet markets currently are Sweden, Denmark, the Netherlands and Germany. Due to their technical properties, pellets are an optimal fuel for the generation of heat and/or electricity. The conversion to fuel of the second generation is indeed conceivable; however it cannot be currently assessed, whether this conversion technology will be readily available until the year 2020. It is rather unlikely that the IEKP targets can be achieved in the range of fuels by import of pellets.

Liquid biomass, in particular palm oil, partly was not sustainably produced in the past and partly involved considerable environmental damage (cutting down rainforests, loss of biodiversity, etc.). The import of liquid bioenergy sources in a European context has therefore been bound to the requirements of sustainable production since 2009 /30/. These requirements are specified by means of sustainability criteria for greenhouse gas savings, cultivation areas and cultivation methods in the EU Directive on the development of renewable energies for liquid bioenergy sources /30/. The compliance with such criteria is relevant for the achievement of national targets and for subsidies. Therefore it should be evaluated for the assessment of the amount of the biofuel potentials, to what extent the criteria apply for specific bioenergy sources. Initially, 35 % of the greenhouse gas emissions would have to be saved in the range of greenhouse gas savings compared to fossil energy sources /30/. However, a general statement whether e.g. ethanol based on sugar cane would meet this requirement, is not possible. Greenhouse gas emissions and/or savings always depend on the deposited cultivation and conversion path. Generally it can be noted that the main spheres of influence for greenhouse gas emissions and/or savings potentials are in the cultivation of biomass and its conversion to biofuels. Transport is of rather less importance.

6.5 Remote sensing of biomass resources

(DLR)

6.5.1 Background and objective targets

Satellite remote sensing in the past years has developed to be a successful tool to provide geoinformation on different spatial and temporal scales. Today satellites can deliver data with a spatial resolution ranging from metres (e.g. IKONOS) to kilometres (e.g. MERIS or MODIS) and in a temporal resolution of daily to approx. monthly. After an experimental stage, where satellite data was used only for small areas and for short periods of time, this technology is increasingly used in operational service. Operational service will ensure regular and quality-tested provision of geo-data and information in the long term. This will provide future options to support regular monitoring of area-related biomass resources. The GMES initiative (Global Monitoring for Environment and Security) of the European Commission and the European Space Agency (ESA) is a good example for the establishment and implementation of operational provision of satellite data and products. It is used to create a network for the observation of our environment. GMES is an integral part of the development of a European infrastructure for global spatial information (INSPIRE), which is implemented since March 2007.

Currently, different approaches are known for direct derivation of surface biomass potential from remote sensing data through active and passive optical sensors and through active and passive microwave sensors. A summary of the previously published methods and satellite data used can be found in the 2008 results report /47/. The highest correlation between remote sensing data and biomass ($r^2 = 0.95$) is documented for forest areas /45/. In this process, the average annual normalised difference vegetation index (NDVI) was derived from VEGETATION data. The analyses with the radar system SIR-C /6/, which was experimentally used on the Space Shuttle for a limited time, showed similar results ($r^2 = 0.94$). The literature survey has shown that almost all previously published studies have dealt with the biomass of forests.

In addition, approaches are described in the literature, which use remote sensing data as input data for mechanistic and/or dynamic models /44/, /66/, /88/, /96/, /128/. Global and/or local data on land cover and land use (LCLU) can be derived from remote information, required as input data for models. Time series of the leaf area index (LAI) are other input data for the models, which can be derived from remote sensing data. They describe the phenology of the vegetation. Since most of the models are operated with a time resolution of 1 to 10 days, the LAI time series are generated in the same temporal resolution.

The work package "Remote sensing" analyses the suitability of the dynamic model "Biosphere Energy Transfer Hydrology (BETHY/DLR)" for the quantification of the energetically useable carbon, whereas remote sensing data is used as input data for current characterisation of plant growth. According to the preliminary work in the year 2008, the agricultural and forest biomass potential for Germany and Austria is calculated with BETHY/DLR with a spatial resolution of approx. 1 km x 1 km. The integration of an improved "Bottom-Up" approach for the determination of the biomass potential allows a straw potential for agricultural areas and/or a wood potential for forests to directly derive from the net primary productivity (NPP).

The Final Report 2008 summarised the methods currently used to gather local to continental changes of land cover and/or land use. It was analysed in a literature study in the current project year 2009, which methods exist to identify and possibly map burnt areas (BA) by means of remote sensing data. This analysis was dedicated to the question which options remote sensing offers to detect and capture the conversion from forest to agricultural areas by slash and burn.

The options for monitoring the losses of agricultural areas by e.g. degradation or erosion by means of remote sensing and the conversion from forest to agricultural areas was also analysed in the scope of the literature survey.

6.5.2 Methodology

Next to remote sensing data, BETHY/DLR requires meteorological input data to be able to model the growth of plants depending on weather conditions. The air temperature at 2 m height, the precipitation, the wind speed and the cloud cover are needed as information just as much as the soil water content in the four top layers. Such data is provided by the "European Centre for Medium-Range Weather Forecasts (ECMWF)" with a temporal resolution of up to 4 times a day and a spatial resolution of 0.5° x 0.5° in a rectangular coordinate system. The soil water content is required for the transition phase of the model only. The model then automatically calculates the soil water content according to the hydrological boundary conditions. Analyses of /131/ have shown that a transition phase of one year is normally sufficient to maintain stable starting conditions for the model. In the current version of BETHY/DLR, the stable starting conditions are determined dynamically. The information on high, medium and low cloud cover is used to calculate the solar radiation at the surface according the procedure from /18/ (of /113/).

Data such as e.g. the leaf area index is required for the description of the phenology of vegetation. The leaf area index is defined as the ratio of the entire cumulated leaf area per unit area. For agricultural areas, the LAI typically increases from zero (no leaves per unit area at the time of sowing) to a maximum, which is reached before ripeness. The temporal development of the LAI of agricultural areas reflects the growth of the crop. The LAI can be derived from optical remote sensing data. The global CYCLOPES data developed in the project "Pole d'Observation des Surfaces continentales par TELedetection (POSTEL)" were selected as input data set. They are available globally as so-called 10-day composite.

Also the information on land cover and land use are available in the CYCLOPES data as "Global Land Cover 2000 (GLC2000)“. The Land Cover Classification System (LCCS) of the Food and Agriculture Organization (FAO) of the United Nations was used for the derivation of the GLC2000 land cover categories /4//21/. GLC2000 provides a classification, which differs 22 land cover categories and is representative for the year 2000. The soil was parameterised according to /22/. The global CYCLOPES and GLC2000 data each are available in tiles of 10° x 10° as maps in rectangular projection (lat-long projection) with identification of latitude and longitude (WGS84 date). This provides for complete coverage of the investigation area of Germany and Austria as specified in the project.

In dynamic models such as e.g. BETHY/DLR, the plant growth is parameterised so that in an initial step, the biochemical processes of photosynthesis are modelled on a leaf level according to the ideas of /35/ and /19/. In this process, the enzyme kinetics of photosynthesis of so-called C3 and C4 plants is differentiated. This is important because the photosynthesis and the further path of carbon fixation are significantly different for such two categories of plants (C3 or C4). C4 plants (e.g. millet, maize or sugar cane) can retain more solar radiation and atmospheric carbon dioxide at higher air temperatures than C3 plants (e.g. wheat or barley), whose photosynthesis is saturated in such environmental conditions. Due to the special type of carbon fixation in C4 plants, such plants are better adjusted to warmer climates. In dynamic models, it is extrapolated in a next step from leaf level to crop level, whereby both the structure of a crop and the interaction between soil, atmosphere and vegetation is considered. In particular the energy flow and the water cycle are considered between soil, vegetation and atmosphere. Due to the differentiation of the photosynthesis in C3 and C4 plants, the model BETHY/DLR is based on another internal classification of vegetation than GLC2000. In the following, these model-internal categories of vegetation will be referred to as "vegetation types", in contrast to the "land cover categories" of GLC2000. Currently 33 different vegetation types are differentiated in BETHY/DLR. In BETHY/DLR, a difference is made between C3 and C4 grassland, while GLC2000 differentiates the grassland according to its degree of cover (open to closed or sparsely). In the BETHY/DLR model each vegetation type is allocated photosynthesis parameters such as e.g. the maximum electron transport or the maximum rate of carboxylation /66/. These values are taken from the appropriate literature and are based on leaf measurements.

Since the categories of GLC2000 do not match with the vegetation types of BETHY/DLR and since e.g. for the category GLC2000 "cultivated and worked areas" no division into cultivated crops is possible, an adaptation and generalisation of the GLC2000 categories to the BETHY/DLR vegetation types are required. Along with the characterisation in C3 and C4 plants it is also possible in

BETHY/DLR to define two vegetation types with an appropriate weighting for each model cell (pixel). So it is possible e.g. to define the GLC2000 category "mixed forest" as both BETHY/DLR vegetation types of "temperate broad-leaved deciduous forest" and "evergreen coniferous forest" with the weighting factor 0.5. This option was used for six categories of GLC2000 in the scope of this analysis. Both GLC2000 categories "Cultivated and managed areas (16)" and „Mosaic: cropland / shrub or grassland (18)" are of special and great interest in modelling agricultural areas in Germany and Austria, because they include the energy crops and grasses. Next to the fixed allocation of the weighting factors for both agricultural categories, the MODIS product "Vegetation Continuous Fields (MOD44B or MODIS-CF)" is used for the four forest categories. The MODIS-CF product includes the percentage cover of a pixel for the category forest, non-forest and open soil. The cover rate for the forest category is used for the transformation of the GLC200 categories into the BETHY/DLR vegetation types with annual resolution. The allocation of the GLC200 categories to the BETHY/DLR vegetation types is presented in Table 16. The corresponding static and/or dynamic weight factors are also stated.

Table 16: Allocation of GLC2000 to the vegetation types of the model BETHY/DLR with respective weighting (source: DLR)

LCC of GLC2000	Vegetation types: BETHY/DLR	Weight
Cultivated and managed areas (cat. 16)	Arable crops (type 15)	100 %
Mosaic: cropland/shrub or grassland (cat. 18)	Arable crops (type 15)	50 %
Deciduous, broad-leaved forest, closed (cat. 2)	Temperate deciduous broad-leaved forest (type 4)	MODIS-CF
Deciduous broad-leaved forest open (cat. 3)	Temperate deciduous broad-leaved forest (type 4)	MODIS-CF
Evergreen coniferous forest (cat. 4)	Evergreen coniferous forest (type 5)	MODIS-CF
Mixed forest (cat. 6)	Temperate deciduous broad-leaved forest (type 4) Evergreen coniferous forest (type 5)	MODIS-CF / 2 MODIS-CF / 2

6.5.3 Results

The modelling results of agricultural and forest areas in Germany and Austria are shown below. Originally the model BETHY/DLR was developed to analyse the global carbon cycle between atmosphere, vegetation and soil. Therefore, the model delivers as one result the amount of assimilated carbon from the atmosphere by the vegetation per unit area and time unit, which is referred to as "Gross Primary Productivity (GPP)". Since each plant releases carbon in the form of CO_2 to the atmosphere called "autotrophic" respiration, less carbon is fixed in the plant as biomass than calculated by GPP. The fixed carbon in the plant is referred to as "Net Primary Productivity (NPP)". The NPP can be converted to biomass potentials by means of conversion factors. The results shown in Fig. 35 illustrate the spatial distribution of NPP for the year 2000 for agricultural and forest areas in Germany and Austria. The distribution of the biomass potential of agricultural and forestry areas is validated with statistical data. Statistical data such as e.g. the yield of different crops per district was used for the validation of the modelled agricultural NPP. The methodology for the conversion of the agricultural NPP into yield will also be shown below. The data of the second national forest inventory (NFI[2]) was used for the validation of the modelled forest NPP. A "Bottom-

Up" approach was developed, to convert the results of the NFI[2], which normally are available as increases of the timber wood in m^3 per unit area and unit of time.

Agricultural and forest net primary production

The result of the modelled NPP for agricultural and forest areas of Germany and Austria for the year 2000 is shown in Fig. 35. The spatial resolution of the NPP map is approx. 1 km x 1 km.

The colour scale was selected so that low NPP values are shown by red, medium by sandy and high values by green colours. White areas represent masked GLC2000 categories, i.e. all such pixels, which do not belong to the agricultural and forest GLC2000 categories 2, 3, 4, 6, 16 or 18. The results of the modelling show that the forest areas such as e.g. the Black Forest, the Bavarian Forest or also the Harz mountains with an NPP of up to max. 200 tons of carbon per km^2 and year assimilate significantly less carbon than productive agricultural areas. With good meteorological conditions, agricultural plants can assimilate up to 400 tons of carbon per km^2 and year. The highest NPP is achieved in Upper and Lower Austria, with approx. 550 tons of carbon per km^2 and year. The lowest NPP is found at the border of Thuringia and Saxony Anhalt and in the Austrian Alps. In Fig. 35, a chequered pattern is visible in the region of Thuringia, Saxony and Saxony-Anhalt, which correlates with the distribution of the meteorological data of ECMWF. This data is provided in a resolution of 0.5 x 0.5° so that local, spatially limited weather events are not considered. An analysis has shown that in this area, in the summer months during the phase of ripening of most agricultural fruits, the precipitation of two adjacent ECMWF tiles differs by the factor 2.

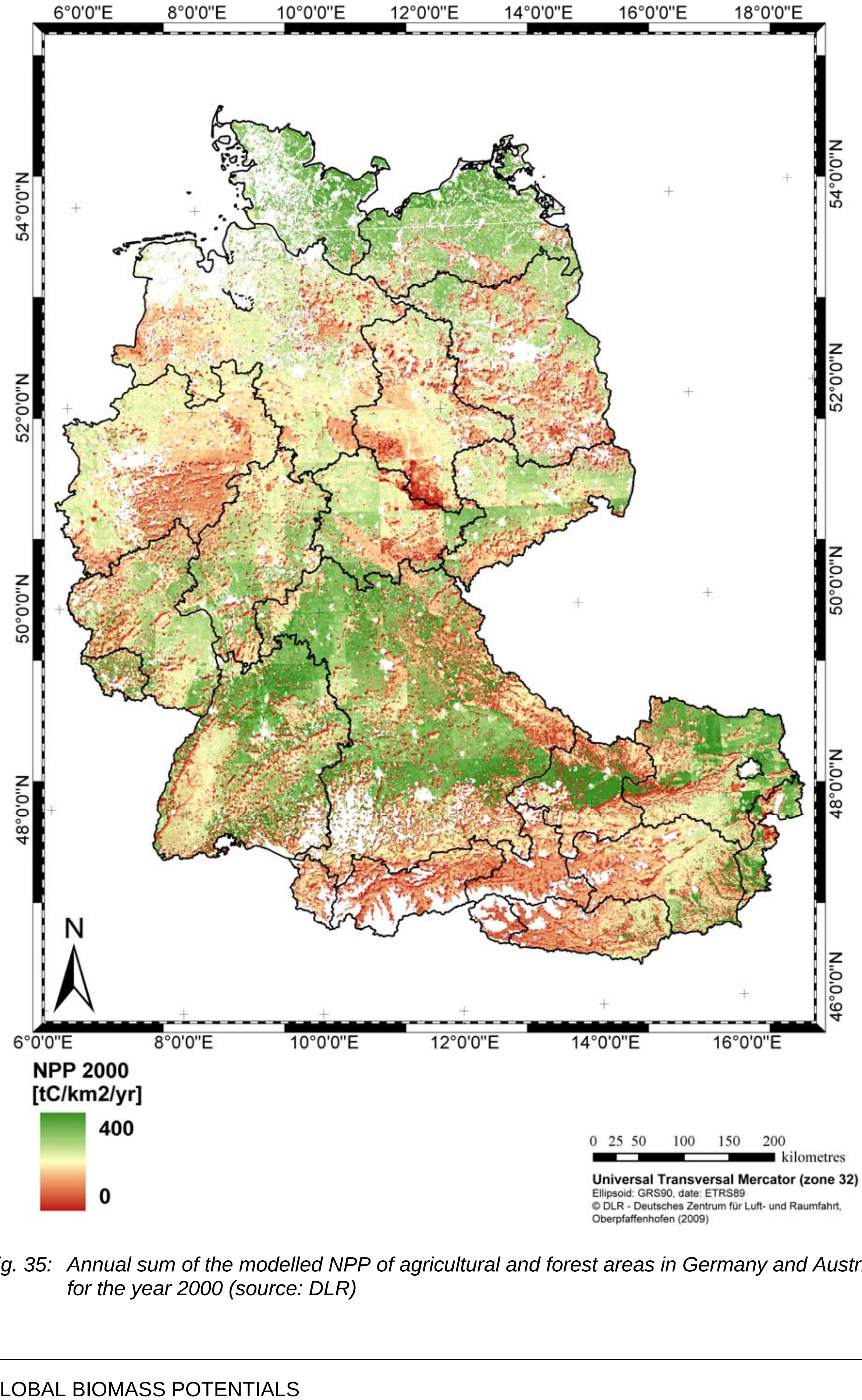

Fig. 35: Annual sum of the modelled NPP of agricultural and forest areas in Germany and Austria for the year 2000 (source: DLR)

Validation of the modelled net primary production

A "Bottom-Up" method was developed for the validation of the modelled NPP of agricultural and forest area using the official yield and/or growth statistics of state or federal offices, to calculate the NPP from such data. For Germany the information on the agricultural yield comes from the Federal Statistical Office in Wiesbaden and for Austria from the Federal Agency STATISTIK AUSTRIA in Vienna. The agricultural yield data of the main crops are available for Germany and Austria on a district and/or regional level (NUTS-3 level) annually. The data on forest growth of timber wood, on forest area, on age distribution of forests, but also on the types of cultivated trees for Germany are taken from the second federal forest inventory (NFI^2). The objective of NFI^2 is to initially provide current and statistically ensured information on the forest conditions in Germany for the old and new federal states. The results of the NFI^2 were collected for each federal state (NUTS-1 level) and are freely available. The data for the NFI^2 is based on statistical surveys and is representative for the years 2001 and 2002.

The agricultural statistics show an average crop yield per NUTS-3 level for each crop cultivated in a district and/or region. By taking into account the designated cultivation area per NUTS-3 level, the overall yield of each crop can be evaluated per NUTS-3 level. By taking into account the typical dry weight and the average carbon content of the harvested crops, the total carbon can be calculated for each harvested product per NUTS-3 level. Since the harvested product, e.g. the grain yield, is only part of the entire plant, additional assumptions need to be made on the grain/straw or beet/leaf ratio to assess the above-ground carbon content. Typical grain/straw or beet/leaf ratios are collected in Table 17. They are taken from /68/. In addition, the maximum and minimum values are stated for the particular grain/straw or beet/leaf ratios found in literature. In order to get a reference value for the modelled agricultural NPP it is necessary to know and consider the surface/subsurface biomass ratio for each crop.

*Table 17: Grain-straw and/or root/corm-leaves ratios for selected crops (source: DLR according to * /68/, + /72/, # /70/)*

Crop	Grain-straw and/or root/corm ratios		
	Used	Maximum	Minimum
Wheat	1.1	1.1 *	0.9 +
Barley	1.1	1.1 *	1.0 *
Rye	1.3	1.6 +	1.0 #
Oat	1.1	1.2 +	1.0 #
Maize	0.8	1.3 +	0.8 *
Rape	2.0	2.0 *	1.7 +
Sugar beet	0.7	0.8 +	0.5 #
Potato	0.2	1.0 #	0.2 *

A similar approach was already described by /9/ for the evaluation of carbon transfer of agricultural areas into the soil by harvesting residues such as e.g. stalks (stubble) and root. This includes information on the surface vs. subsurface ratio for numerous crops. Conversion factors for the grain-straw ratio and the dry weight can be found in literature, e.g. in the reports of the "Kuratorium für Technik und Bauwesen in der Landwirtschaft" (Association for Technology and Structures in Agriculture) /72/ or in /68/, the data of which was used in this study. These values are to be considered as ratios and suggest e.g. for winter wheat that a grain yield of 10 tons would involve an ancillary yield of 11 tons of straw.

For the comparison of the modeled NPP of agricultural areas with the NPP assessed from the yield data it is necessary to aggregate the modeled NPP values to NUTS-3 level. For this purpose, the overall NPP of all pixels designated as category 16 (cultivated and worked areas) in the GLC2000 is added for each NUTS-3 unit. In addition, the modeled NPP of the pixels identified as category 18 (mosaic: farmland / bush or grassland) in the GLC2000 is taken into account according to the weight factor.

The result of the validation of the modelled NPP of agricultural cultures in Germany for both years 2000 and 2001 is shown in Fig. 36. With a coefficient of determination (r^2) of approx. 0.67 and a slope of approx. 0.83 it is shown that the NPP modelled with BETHY/DLR correlates well with the statistical yield data on a district area. With the selected plant-physiological data, which along with the meteorological conditions and the soil conditions determine the growth of plants, the model underestimates the actual agricultural yield by approx. 17 %.

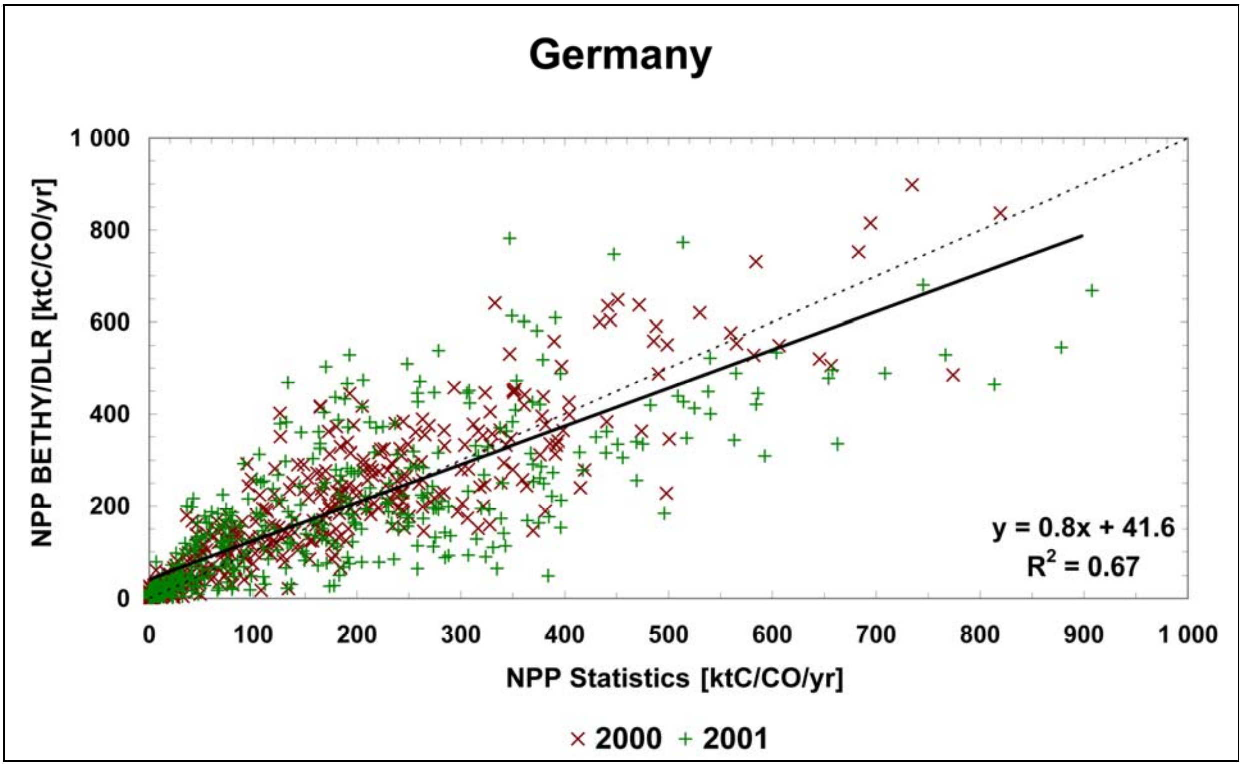

Fig. 36: Validation of the modelled NPP of agricultural areas in Germany for the years 2000 and 2001 with the NPP assessed from statistical yield data. The linear correlation shows a coefficient of determination of approx. 0.67 and a slope of approx. 0.83. (source: DLR)

The "Bottom-Up" approach for the validation of NPP of forests requires statistical data on the increase of the stock, which is given as volume of wood of all trees per unit area and time unit [m^3 ha^{-1} yr^{-1}]. The stock is defined as the currently available merchantable wood of a population or a sum of populations, measured in stock cubic metres or harvest cubic metres. Timber wood (log wood) means the above ground wood mass and/or the volume of above ground wood, which has a diameter of more than 7 cm at breast height. When measuring the diameter, the bark is taken into consideration. Trees below 7 cm diameter at breast height are not considered as timber wood just as the brush-wood and leaves/needles. Information on the increase of timber wood for the old federal states of Germany is available in NFI[2], for which 1 October 2002 is the effective date. The NFI[2] provides the increase of timber wood for individual tree species or individual groups such as "all deciduous trees" depending on the tree age. It can be seen from the NFI[2] that e.g. the average increase in timber wood of all deciduous trees in Bavaria is 10.48 [$m^3ha^{-1}yr^{-1}$], while the average increase in Rhineland Palatinate is only 9.1 [$m^3ha^{-1}yr^{-1}$]. Such differences are explained by the age distribution of the cultivated trees. Apart from this, the NFI[2] shows the area for the cultivated trees for each federal state.

Based on the information of the NFI[2], the DBFZ has calculated in the scope of this project for each federal state the overall forest increase of timber wood, brush-wood and leaves/needles with regard to tree species and age distribution and provided this as increase of the above ground biomass and/or increase of timber wood (in m³ per unit area and time unit) for the validation of the modelled NPP (see section 5.1.2).

In order to compare the modelled NPP with the increase of the ground biomass and/or the timber wood it is required to convert the modelled annual NPP per unit area into the increase of surface biomass per unit area and/or timber wood per unit area. According to /87/, the annually accumulated carbon increase in living biomass can be calculated, if along with the increase in timber wood, also the density of the wood (separated by wood density of the bole and the branches), the ratio of below ground vs. above ground biomass, the conversion factor for carbon in dry matter and a so-called biomass expansion factor will be considered. The biomass expansion factor (BEF) describes the proportion of crown development vs. bole development and depends on the species of tree and the age of the trees. In his dissertation, /87/ developed a new approach for the description of the crown in relation to the bole and implemented a volume expansion factor (VEF), which describes the ratio of tree wood volume vs. log wood (timber wood) volume. By performing intense measurements to deciduous trees and conifers of different ages, the volume expansion factor could be parameterised as a linear regression of the volume of timber wood. Thus, /87/ had found an easy way to calculate the carbon increase (and therefore the NPP) against the increase in timber wood.

Fig. 37 shows the validation of the modelled increase of timber wood of deciduous trees and conifers for Germany for both analysed years 2000 and 2001. A strictly linear correlation can be seen with a coefficient of determination of approx. 0.94. The slope of approx. 0.54 indicates that the model systematically underestimates the increase in timber wood approx. by the factor 2. It is assumed that this underestimation of the increase of timber wood is caused by the selected plant-physiological parameters. Since the average age of the German forest is approx. 65 years, the average increase for conifers has reached the maximum with approx. 19.1 $m^3/ha^{-1}yr^{-1}$ and also the average increase of deciduous trees with approx. 12.1 $m^3/ha^{-1}yr^{-1}$ is at the maximum according to data from NFI[2]. Therefore German forest has the maximum possible increase due to its age structure. The modeled increases are about half of the values shown above. It is therefore assumed that BETHY/DLR models an old forest with a highly reduced increase of timber wood.

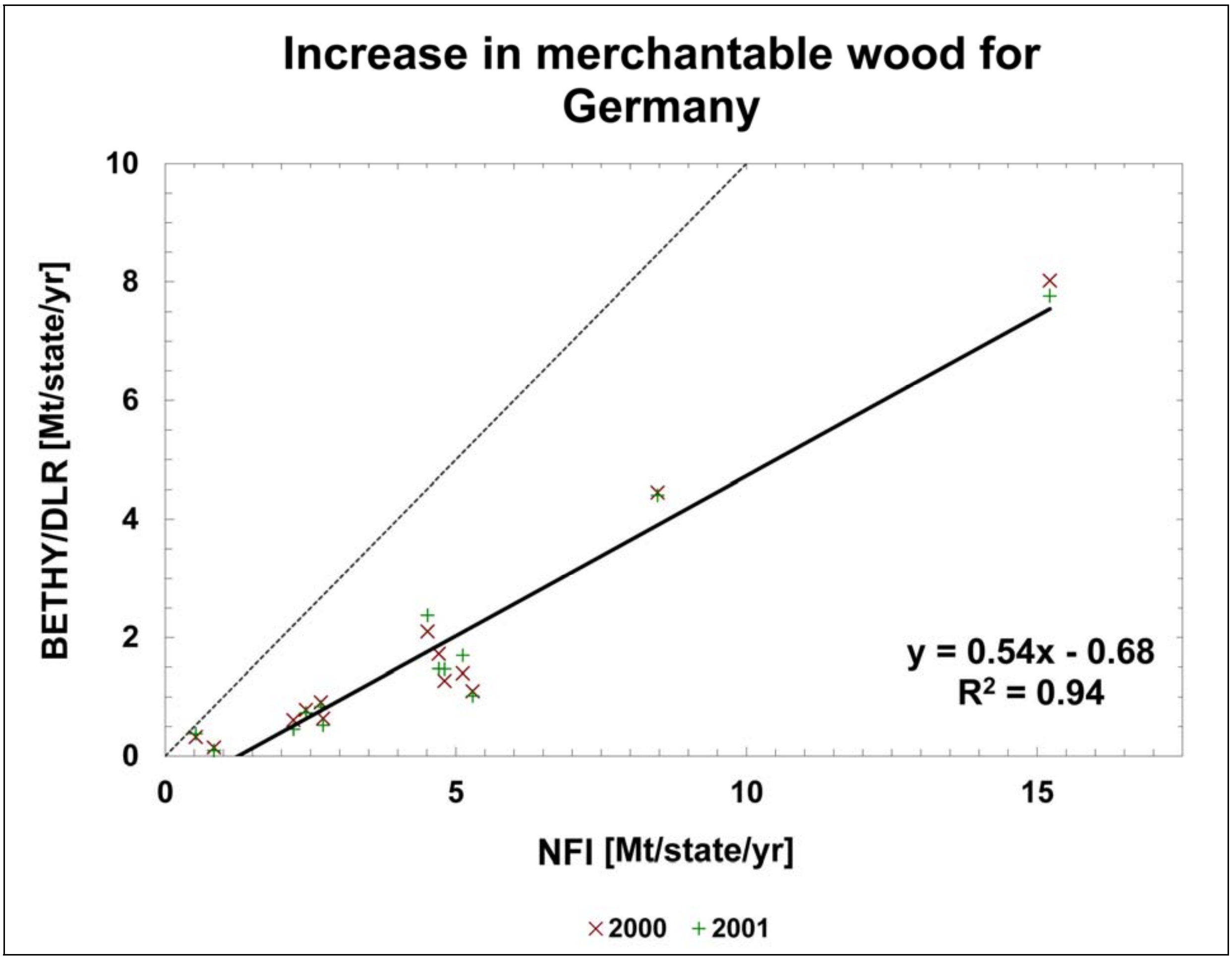

Fig. 37: Validation of the modelled NPP of forest areas in Germany for the years 2000 and 2001 with the NPP assessed from the federal forest inventory (BWI^2). The linear correlation shows a coefficient of determination of approx 0.94 and a slope of approx. 0.5. (source: DLR)

Agricultural and forest biomass potentials

The validation of modelled NPP for agricultural and forest areas described in the previous chapter has shown that there is a linear correlation between the modelled NPP and statistically collected yields and/or the increase of timber wood. In order to transform the modelled NPP into a biomass potential in the form of theoretically available energy, the calorific values for timber wood from deciduous trees and conifers were derived for each federal state in cooperation with the DBFZ. In doing so, the relative distribution of the cultivated trees and their age structure was considered for each federal state. The calorific values for deciduous trees and conifers were taken from /60/. Fig. 38 illustrates the distribution of the theoretically available energy of timber wood for the year 2000 for Germany.

The NPP modeled with BETHY/DLR was used for the derivation of the useful energy, without correcting the underestimation identified by the validation. Furthermore, a sustainable utilization of the forest biomass was assumed. This means that only the annual increase of timber wood is used for energy substitution.

For the derivation of the increase in timber wood in energy units, which is theoretically available under aspects of sustainability, the DBFZ has calculated and made available an average energy yield (in energy unit per unit area and time unit) for each federal country regarding tree species and age distribution for the main tree species (deciduous, conifer and mixed forest). This estimation was performed in line with the determination of the increase of surface biomass and/or timber wood.

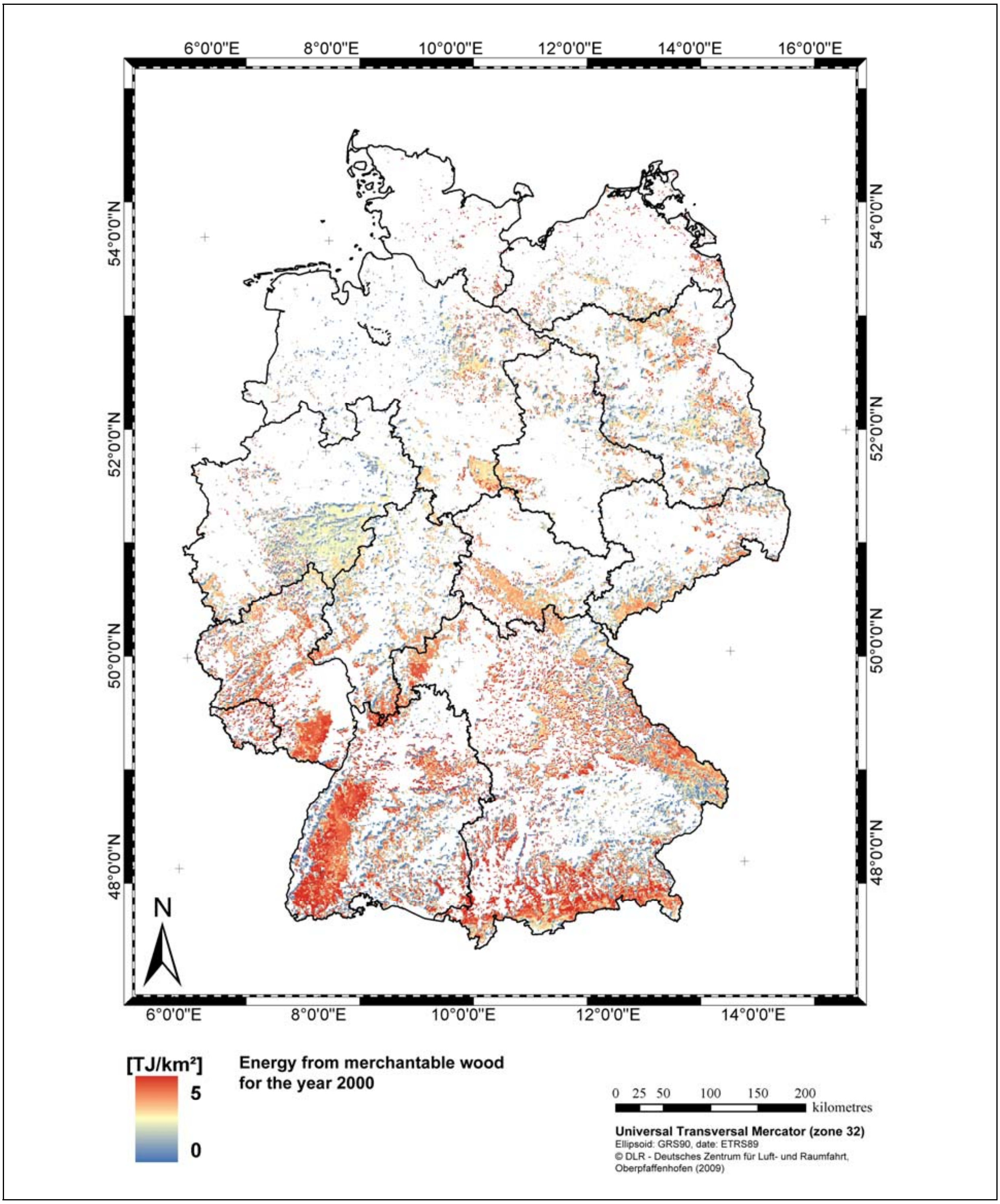

Fig. 38: Sustainable theoretically available timber wood in energy units of forest areas for 2000 for Germany. No correction was performed to the underestimation of the modelled results (source: DLR)

Changes of land cover and/or land use by fire

In the scope of a literature survey it was analysed, which data and algorithms are used to identify and quantify the change in land cover and/or land use by fires on a global scale. The analysis showed basically four global activities working on the land cover changes by fires, the GLOBSCAR /31/, /86/, /108/, the GBA2000 /114/, the GlobCarbon and the "MODIS Burnt Area" project /95/. All projects attempted to determine the time and place of the fires as well as to collect the quantity of the burnt areas. Except for the MODIS project (500 m x 500 m), the spatial resolution of the burnt area products is 1 km x 1 km. Currently not all projects are finished. The results already available show burnt areas for the year 2000 of 2 x 10^6 km² (GLOBSCAR) up to 3.5 x 10^6 km² (GBA2000) /10/ and/or 3.8 x 10^6 km² (L3JRC). The L3JRC product results from the expansion of the investigation period and a modification of the algorithms, which were used for the GBA2000 project /115/. The data of the sensor SPOT-VEGETATION for the period from 2000 to 2007 were used for this purpose. In contrast to the GBA2000 project, a regional algorithm was modified here so that it could be globally used.

The "Climate Change Initiative (CCI)" of the ESA was published on 11 November 2009. Its objective is to prepare global time series of so-called Essential Climate Variables (ECV) from remote sensing data. By means of the ECVs it should be possible to support the work on the UN framework convention on climate change (UNFCCC) in terms of systematic observation. One ECV which is to be prepared is the identification and topographical survey of burnt areas (BA). This parameter can be used to quantify the damage and/or conversion of forest areas into agricultural areas. The ESA initiative on climate change is designed as a three-stage programme with a term of six years and shall combine the European activities and international experiences described above to a consistent "Burnt Area" product. Using this data set, it will be possible in the future to globally quantify the loss of forest area due to slash-and-burn and/or forest fire and therefore to be able to better assess the actual forest area with updated information.

Land degradation and erosion

Based on the literature study it can be noted that mapping of degradation and erosion with methods of remote sensing is still an issue of current research. Operational and/or global applications are not known. This lack of knowledge is due to the necessary measuring technology and the required spatial resolution. The degradation of agricultural areas e.g. by water erosion after severe precipitations can be mainly observed in semi-arid areas with sparse vegetation. The reflectance received at the satellite is determined by the amount of vegetation and soil within the area of interest (pixel). Therefore no unique spectral signature of vegetation or soil is measured, but a mixed spectral signature. Un-mixing procedures can retrieve the fractions of vegetation and soil. The higher the spatial resolution, the better are the un-mixing results /76/. The un-mixing algorithms are additionally improved if the spectral resolution increases. Therefore, airborne hyper-spectral data is currently used for un-mixing and deriving degradation and thus allows only local analyses. /48/ were able to show with Landsat data with a spatial resolution of 30 m that land degradation can be classified by spectral indicators such as intensity, colour index and shape index. They also showed that land degradation in the Mediterranean area can be mapped with un-mixing technologies. The requirement however is the measurement of local ground spectra which are used as reference spectra. These methods of remote sensing can be used to assess the risk of erosion, if additional geomorphometric attributes are known such as gradient and vertical and horizontal curvature of the terrain. Principally such information can be derived from digital terrain models. However it also becomes clear that the global estimation of the risk of erosion is of little relevance with a spatial resolution of approx. 1 km x 1 km.

6.5.4 Overall evaluation and conclusions

The results shown for the derivation of the biomass potential of agricultural and forest areas in a spatial resolution of approx. 1 km x 1 km make it clear that the use of remote sensing data as input data for complex plant growth models lead to quantitative maps of theoretical available bioenergy. The validation of the model results for agricultural and forest areas have shown that a linear correlation exists between the modelled NPP and statistically collected crop yields and/or timer wood increases. The coefficients of determination are very high, reaching r^2 to 0.94. It also turned out however that the model underestimates the increase in timber wood by the factor 2. Since the average mean of the German wood forests is approx. 65 years and the maximum possible growth rates can be expected here, the reason for the systematic underestimation of the modelled results is due to the fact that an older or well established forest was modelled using plant-physiological parameters. The underestimation found for the agricultural areas in Germany was not quite as large (17 %) and a 1:1 slope was even found for Austria. Therefore the theoretical bioenergy potential for agricultural areas and the timber wood increases of forests is reliably represented by the combination of remote sensing data and a vegetation model. By using remote sensing data with a spatial resolution of 1 km x 1 km, it is thus possible to assess biomass potentials in the same spatial resolution with a high accuracy. The statistically collected biomass potentials which are available in Europe on the basis of districts (NUTS-3 units) and globally normally on the level of countries can be spatially resolved with the new procedure in a higher resolution. Therefore it can be expected that biomass potentials can be assessed with a high spatial resolution also for those countries of the world, for which no statistical data is available. A work effort of approx. 2,000 working days is to be expected for a global assessment of the biomass potential at a resolution of 1 km x 1 km. In this process, we assume the configuration of the model and the data processing as currently used.

6.5.5 Recommendations for action

The results of our modelling approach and their validation with statistical data have shown that input data with a higher spatial resolution, in particular the remote sensing data, is desirable. It will be possible to improve the classification of land cover and use when data of a higher spatial resolution are applied, allowing the identification of small-scale spatial structures such as e.g. forests with an area below 1 km². Such small-scale spatial structures can be increasingly found in the federal countries of Schleswig-Holstein, Lower Saxony and Mecklenburg-West Pomerania. With the previously used remote sensing data however, such areas are classified as agricultural areas. Apart from this it can be expected that with the higher spatial resolution, more categories can be collected and e.g. a separation will be possible of the "conifer forest" class into subclasses as e. g. spruce and pine. It would be reasonable if the land use class "agricultural areas" could also be divided into individual crop types such as maize, wheat or sugar beet. With a higher spatial resolution it is also expected that the time series of the LAI will be improved by reducing the problem of mixed pixels. With a resolution of 1 km x 1 km it is assumed that almost any pixel in Germany represents a mixed pixel. This means that the classified vegetation is not homogeneously distributed within a pixel but that at least two categories contribute to the spectral signature, and thus also to the LAI.

We encourage that the land classification will not only be improved but also be updated on an annual basis. This requires regular monitoring, which can only be accomplished area-wide and globally by means of remote sensing methods.

The data from NFI[2] that is available for general use on the level of the federal states only, was used for the validation of the forest biomass. It is recommended that data on the increase of forest areas will be also be available on a NUTS-3 level in the future (possibly with the planned federal forest inventory NFI[3], to be performed in the years 2011 and 2012).

The results of the project have shown that the modelling of the NPP of forest areas is systematically underestimated. The data of the NFI[2] clearly demonstrates that the timber wood increase strongly depends on the age of the trees, which is not taken into account in the current version of BETHY/DLR. Therefore it is recommended to formulate the modelling of the NPP dependent on the age of trees. This requires a new input data set, which currently is not available as a map. We recommend the development of this data set.

When the national biomass plan was adopted by the federal cabinet on 29 April 2009 it was determined that future utilisation of bioenergy and in particular the cultivation of the required plants must be efficiently and sustainable. It was particularly decided that domestic or imported bioenergy products must not come into conflict with food security and environmental protection. A certification system was demanded and already enacted to check these requirements. It is therefore recommended to support the certification system by means of remote sensing procedures. For this purpose, operational procedures are developed in the scope of the ESA CCI and be available in the near future.

7 CONCLUSIONS

According to the Integrated Energy and Climate Programme of the federal government (IEKP), the rate of energy supply from biomass is to be significantly increased until 2020. Approx. 1.1 – 1.5 EJ/yr of biogenic fuels need to be used to cover the energy demand involved. On the one hand, the regional and global distribution of the biomass potentials suggests a significant potential, on the other hand it also shows that in some fields there is a demand for discussion and control to reach the IEKP objectives:

The **material flow-based potential calculations for Germany** result in a technical fuel potential for 2020 of approx. 1.5 to 1.8 EJ/yr. The raw material basis to meet the IEKP targets is therefore basically given. Subject to the assumptions made, the IEKP targets for electricity and heat with domestic biomass are exceeded (in 2020 approx. 16 – 20 % share of biomass in the overall electricity consumption and approx. 22 – 26 % in the overall heat supply) in all three scenarios analysed (Business as usual, Bioenergy, Bioenergy with increased restrictions on environmental and nature conservation). Approximately two thirds of the fuel target of 12 % can be met. This is based on the assumption on the mix of energy crops in the scenario, which provides for raw materials for biofuel production (currently mainly rape, grain and sugar beet) on max. 1.7 million ha of farmland (this approximately corresponds to half of the potential area for the cultivation of energy crops in Germany). If the available potentials will be further used, a doubling of the pool of bioenergy plants in Germany is possible as well as its enhancement by innovative technologies (SNG, BtL etc.). Regional connecting factors rather apply also for the realisation of electricity and heat supply from biomass, while the supply of biofuel takes place on a nationwide basis both for the raw material supply and product distribution.

The development of bioenergy utilisation provided in the scope of IEKP therefore has significant effects in the area and by the import of biofuels and also affects international markets:

The realisation of the IEKP targets by means of domestic biomass can cause conflicts on the regional level, if the requirements for bioenergy supply are opposed to other social, economic and ecological targets. The analysis of the **spatial interactions** exemplified by the Western Saxony planning region shows that both negative and positive environmental impacts result from the energetic utilisation of biomass on the one hand, as well as land use conflicts, but also spatial synergies on the other hand. The manifestation of the spatial interactions is significantly determined by the local circumstances of the particular landscape in the individual regional sub-areas as well as by the technological requirements of bioenergy provision. The definition of favourable areas, restricted areas and excluded areas both for specific crops and/or cultivation systems and favourable areas for facilities proves to be a suitable instrument for regional planning to spatially govern the provision of bioenergy for a specific area. Individual special contributions of regional planning can depict this information e.g. for the fields of nature conservation and landscape preservation, land management and technical infrastructure and bundle it in the form of a biomass development concept, which in turn can be a component of a regional energy concept.

The strengths of such a biomass development concept lie less in its controlling effect, which, as an informal instrument with no binding effect for authorities, is to be rather limitedly assessed, but rather due to the region-specific data processing and availability and the flexible and manageable basis for regional planning in order to evaluate and decide on spatially important measures and projects, which form the basis of an overall process of spatial consideration.

The analysis of the Western Saxony RP shows that the regional plan makes statements on essential parts of the identified demand for governing, although no separate statements are made for bioenergy provision with regards to text or drawings. This does not only include aspects for spatial coordination of bioenergy plants, but also those which influence the agricultural use in the individual sub-areas. However, the strongly formalised RP reaches two limits. In the short term, it is too static to react to "new" development (technologies, cropping systems, market developments etc.). It is also limited in the quantity of its contents to ensure its readability and thus its manageability.

As the IEKP target in the range of biofuels is expected to be realised only to a limited extent with biomass from Germany, the significance of the **import of biomass and/or bioenergy sources** will increase in the future. Accordingly, the biomass potentials expected globally in the future are to be classified as follows:

- **Biogenic ancillary products, residues and waste (briefly referred to as residues)** result in a global potential of approx. 30 EJ/yr, with the fractions of straw and logging residues having the largest potentials (approx. 13 and 10 EJ/yr). Due to global population growth, the volume of residues will tend to increase further in the period of investigation until 2020, however the import of residues and/or bioenergy sources from residues will only play a minor part due to their small energy densities and partly unfavourable substrate properties. Normally, on-site utilisation is more reasonable from an economic and ecologic point of view.
- The different alternative scenarios clearly show that for **agricultural biomass**, the global land and fuel potentials basically depend on the demand for food and on the increased yield on limited farmland. While the global agricultural markets were characterised by structural overproduction in the last 20 years, the future development could sooner or later lead to a reversal towards deficit markets. The continents and sub-continents are developing in different directions across the scenarios: while Europe, North America and South America can provide considerable and stable potentials of land for the production of bioenergy crops, Asia and Africa have a growing demand for the import of food, which under the assumption of global balancing of trade will also require an calculated land demand for the potential bioenergy areas in other regions. At the same time, the possibly expected shortage will lead to price effects that support the increase in production. The quantification of these effects is difficult - according to a corresponding "Bioenergy" scenario, a global land potential of 200 million ha/yr (farmland for the cultivation of energy crops) can be expected. This is derived from import potentials of liquid and/or gaseous biofuels in 2020 of approx. 6.5 EJ/a. Approximately 187 million t bioethanol, 31 million t biodiesel and 6.6 billion m³ biomethane (three times the amount produced in 2008) could be annually provided in addition to the quantities of biofuels produced already today. Key countries of production would be Russia, Brazil, USA and Indonesia. The implementation of further standards for environmental and nature conservation (no direct changes of land use such as e.g. ploughing of grassland and clearing of primary forests, further rededication of 2 % farmland for purposes of nature conservation without agricultural use) will considerably reduce this potential, if applicable.
- The cultivation of energy crops on **degraded areas** is mentioned as another potential. These are stated with a very different extent (from 6 to 35 million km²) and they have a very wide range of soil quality and expected yield, previous use etc. Therefore, a general classification of such areas is not possible. Synergies between upgrading of land and biomass production (also for the provision for international markets) however may well be possible.

- The results in the range of **forestry biomass** show that the global forest areas will further decrease until 2020, while the plantation areas will further increase. The global raw wood potential in the year 2020 is assessed to be 3.2 to 4.2 million t_{dm} depending on the scenario selected. A comparison with the global consumption of raw wood shows that total raw wood potential would not be depleted in the year 2020, even after subtraction of the material utilisation and would be additionally available for energetic utilisation. The raw wood consumption would only be above the sustainably available raw wood potential in some African, Asian and European countries. In order to cover the raw wood consumption calculated for the year 2020, these countries would either have to import more wood or use more raw wood from domestic countries that is sustainably available. This would lead to a reduction of the wood stock in the short term; the degradation of the forest would be the result in the medium or long term. Large potentials of raw wood in Russia, North America and Brazil should not hide the fact that their mobilisation would present a big challenge (economically and ecologically). Depending on the scenario, there will be a global technical fuel potential of 36 to 57 EJ/yr. These fuels basically are a promising primary product for future biofuels such as BtL or SNG; however this would only result in a small import potential for fuels of the second generation in 2020 because of periods for development and market launch still to be expected.

The demand for sustainable and efficient land management is of higher priority against a background of globally declining land resources. By developing sustainability standards and certifications for biofuels, established approaches from the forestry sector are currently transferred to the field of of energy crop cultivation. The application of certification schemes for food, fodder and material production will be possibly prepared, too. Monitoring systems for early recognition of changes in land use must accompany the expansion of global biomass markets. Such a land screening in the km range could be realised by means of **remote sensing data** and their processing in a vegetation model (BETHY/DLR). Since linear correlations between remote sensing data and statistical information could be shown in this project (for forest areas of up to 94 % and for agricultural areas up to 74 %), the development of such a land screening tool should be possible in the upcoming three to five years - corresponding development activities are currently put in motion by the Climate Change Initiative of the European Space Agency. Furthermore, remote sensing can improve the data basis for the assessment of agricultural and forest biomass potentials in the medium term, in particular in such countries, where the statistical data basis is incomplete (e.g. forestry data in Africa and Asia) as well as identify regional "hot spots" of the biomass resources.

The results of the project make it clear that the IEKP targets of the federal government until 2020 can be achieved with respect to the utilisation of bioenergy and thus, noticeable climate savings can be expected. However, interactions of global and regional effects are also induced. This includes uncertainties in the availability of future land potentials under the postulate of food security, the requirement of efficient utilisation systems as well as the general debate on the limitation of primary products and the distribution of problems involved. For a sustainable regional provision of bioenergy this results in the requirement of more flexible systems, which the approach and the instruments of IEKP previously have only to a limited extent. This will also present new challenges for regional spatial planning.

8 RECOMMENDATIONS FOR ACTION

The effects of energetic biomass utilisation therefore show both global and national and regional effects. Accordingly, recommendations for action are considered on all three levels.

1. Further developing the target system of bioenergy utilisation

The IEKP targets for Germany can be achieved arithmetically, however with respect to biofuel use, they can be developed in the domestic market only to a limited extent and can hardly be incorporated in the regions. At the same time, biofuels contribute comparatively less to climate protection than the use of biomass for the supply of electricity and heat. However, as the only substitute for fossil fuels available in the market, they offer a high potential for questions of the security of supply. In particular in air traffic, they are the only alternative to fossil energy supply. These conflicts of objectives need to be discussed and weighted on a social level against the background of diminishing resources and increasing dependency of energy supply on export. Greenhouse gas balances can support but not replace such a process, because questions of security of supply with food and energy are also basic paradigms. A round table on "Bioenergy" could be the starting point for such a social discourse on the IEKP targets on a national level. The IEKP targets should be further developed in this process of weighting and conciliation. For their reasonable implementation it is further recommended:

2. Laying the foundations for comprehensive development of residual potentials

The energetic utilisation of biogenic residues normally involves comparatively favourable environmental impacts. The development of these quite different material flows however is made difficult partly by their local production, the heterogeneous and partly unfavourable fuel properties and the partly limited available conversion plant technology. This is accompanied by the incomplete data that is available. Preconditions for improved development of the residuals can be established with systematic information, e.g. by so-called biomass supply curves and by targeted development instruments. The information should be presented with an appropriate spatial resolution so that it can be incorporated in the regional planning processes. The provision of corresponding systems (e.g. guideline, manual and/or web-enabled calculation tool) would be helpful for the determination of the residual potentials.

3. Supporting all options of sustainable agricultural production and forest management

Biomass from farmland will be in particular globally available in the medium term, if agricultural production in wide regions of the world uses all sustainable agricultural potentials for production. Even if the requirements involved need to take effect in agriculture and forestry policy (and bioenergy policy can only refer to these requirements). We would like to point out fundamental aspects for the connected fields of action: intensification and systemisation of agricultural research to achieve substantial progress in yield, preventing and avoiding forest clearance, afforestation of degraded areas, transfer of technology as well as consistent water and land management to establish efficient agricultural management systems, systematic analysis and reduction of agricultural greenhouse gases, securing of land rights and participation of the general public on site, orientation of energetic utilisation of agricultural and forestry biomass towards achievable greenhouse gas savings. Policy can also work towards a change of food patterns in the medium to long term. The agricultural production in Germany can primarily respond to the pending uncertainties by contributing to food security and security of energy supply.

4. Adapted mechanisms to achieve the IEKP targets

If in general the political framework conditions remains the same, the German biofuel demand will significantly come from the global market. These are markets which can be characterised by short-term and large price fluctuations, even without the demand of the biofuel sector when it comes to the emerging uncertainties of global food supply. Through the IEKP approach with defined targets for individual segments (such as biofuels) and the EU targets for biofuel, which also involve the demand for specific quantities, possible shortages could be stirred up, if also biofuel producers demand these scarce foodstuffs as biofuel feedstock, in addition to and independent of the price situation. This results in debates ("food plate or petrol tank") and intensifies production with ecological risks, possibly attributable to the utilisation of biofuels. Independent of whether the degree of interrelation is to be discussed controversial approaches for control should be sought to support a stabilisation of food supply. Such instruments should be as flexible as possible and be initiated in a European context. For this purpose, the measures, which have a very complex effect on an international level, need to be identified and understood and the efficiency of the market control, as it was practised with the biofuel rate in the past, needs to be challenged. Any further development of possible instruments should by all means include a higher flexibility, e.g. high demand for primary products on the part of biofuel production with over supply of primary products (low agricultural prices) and small demand with shortage (high agricultural prices). Therefore, there is considerable demand for research for further development of the instruments.

5. More consistent realisation of sustainable land cultivation

Compared to the situation today, areas for agricultural production will be a short resource in the medium term. The energetic utilisation of biomass in the form of the cultivation of energy crops increases the pressure on land use in addition to food and fodder production. The overall impending shortage of primary products requires targeted use of resources, both with respect to general land use and towards the provision of bioenergy and prevention of greenhouse gas.

Generally, sustainable land management could be a possible strategic approach. Areas with a high land value index for example in urban neighbourhoods or in between densely populated districts should be excluded from soil sealing to prevent further agricultural demand.

The standards of sustainability have established initial approaches for the provision of bioenergy and require a provision of primary products which is efficient to greenhouse gas and landscape conservation. Areas with a high carbon storage capacity and a large variety of species are excluded from the production of energy crops in the future. Previously, only a partial system of agriculture is integrated in this system and therefore, alternative reactions of other agricultural areas of production are expected for the sensitive areas. The certified areas are expected to show an increase of efficiency for biomass cultivation in the medium to long term.

6. Regionally based energy concepts as a building block for the security of supply

The global uncertainties of supply are expressed in stronger fluctuating agricultural prices, which also influence the planning security for bioenergy plants in Germany. This situation can be regionally responded to by plant concepts with the participation of the primary product producers and the energy suppliers and/or the final energy consumers. In this way the long-term agreement supporting the continuity of production is ensured, also promoting the reduction in fluctuations of agricultural prices and speculative windfall gains. Local energy concepts, based on regionally established bioenergy plants can therefore essentially contribute to security of supply. Regionally established concepts should also include urban areas, because significant heat sinks are found here. Appropriate resources and information are to be provided for the conception and implementation. This includes amongst others;

- the operationalisation of national or international target systems and scenarios (among them also IEKP),
- the availability of technical conceptual information on bioenergy plants and the options for utilisation of the generated bioenergy also against the background of the changing requirements for energy supply,
- information with spatial resolution on regional heat supply structures and heat sinks, and
- the implementation of evaluation parameters specific to climate protection into regional evaluation instruments (e.g. contribution to climate protection as a regional environmental effect for environmental audit).

The form of implementation can be different, whereas tight linkage to the RP may have pros and cons (see 7th recommendation for action).

7. Stricter control effect by regional planning

For the implementation of site-specific requirements for bioenergy provision, the formal regional planning should be amended by informal planning approaches. Sub-concepts of regional energy concepts can offer an appropriate basis for assessment and decision to govern biomass utilisation for purposes of energy supply compliant to the region, even if used in the short term. At the same time, a planning process which involves participation is better able to legitimatise the actions of regional planning with regard to social and political issues. The target should finally integrate relevant informal statements in the future scope for updating the RP, subject to weighting of existing objectives and principles. The insufficiencies with data could be improved by the institutionalization of professional agricultural planning as well as professional energy planning. This could provide the relevant information for the implementation of the described planning process. This however would restrict the scope of regional planning and weaken their overall function and competence in the medium term. Political decisions on the provision of basic data on agricultural use, as well as energetic development (which in part are currently not available) are relevant for the future role of regional planning in Germany.

8. Strengthening of international cooperation

Parallel to strengthening sustainable land use on a regional basis, such approaches should be moved forward also bilaterally in international cooperation. The Renewable Energies Directive and the Bioelectricity Sustainability Act principally provide good requirements which can be used (demand for raw material provision in a way which is efficient to greenhouse gas). This provides chances on different levels:

- The increasing global markets for biomass and bioenergy sources are currently still characterised by a series of technical and organisational restraints. International standards for the quality of bioenergy sources, but also questions of transport and logistics such as e.g. the technical requirements for input of biomethane to the natural gas distribution system support the development of such markets and also facilitate access to the market especially for smaller players.
- The production of bioenergy sources for potential import to Germany or Europe offers the chance for development in particular of agricultural areas in emerging and less developed nations (transfer of technology and knowledge), if a reasonable linkage with the development of infrastructure and energy supply can be locally achieved. The question of whether and how the joint provision of energy for the local and international market can be successfully realised requires experience in selected model projects of economic cooperation.
- The use of degraded areas is a promising issue for research. If the sustainable production of energy crops on degraded areas is successful, it is associated with the chance of improving the productivity of such locations. These resources however need to be developed with great care, because challenges exist with regard to economic efficiency and social implications of the utilisation of such cultivation systems.
- The promotion of international model projects provides the chance to gain information to cope with this challenge and implement it in countries with a large potential of land. In general, particularly the cooperation with Eastern Europe offers good chances because large agricultural land potential is expected in the future and because there already exists suitable technical infrastructure (amongst others, gas distribution systems for methane input).

9. Establishment of monitoring systems

Increasing capacities for the provision of bioenergy are to be expected internationally, nationally and regionally. The question posed, from which biomass the bioenergy is provided, will primarily decide the sustainability of utilisation in this process. Monitoring, by means of remote sensing helps to identify regional "hot spots" of biomass production and to evaluate changes in land use. Indicators can help on a regional basis to describe the state of implementation and any further potential of bioenergy utilisation to receive targeted evaluation parameters for the regional strategies and approaches for action from of the multitude of regionally available information. Even if indicators can already be specified in individual cases, a systematic derivation is only possible on the basis of a coordinated target system (see 1st recommendation for action).

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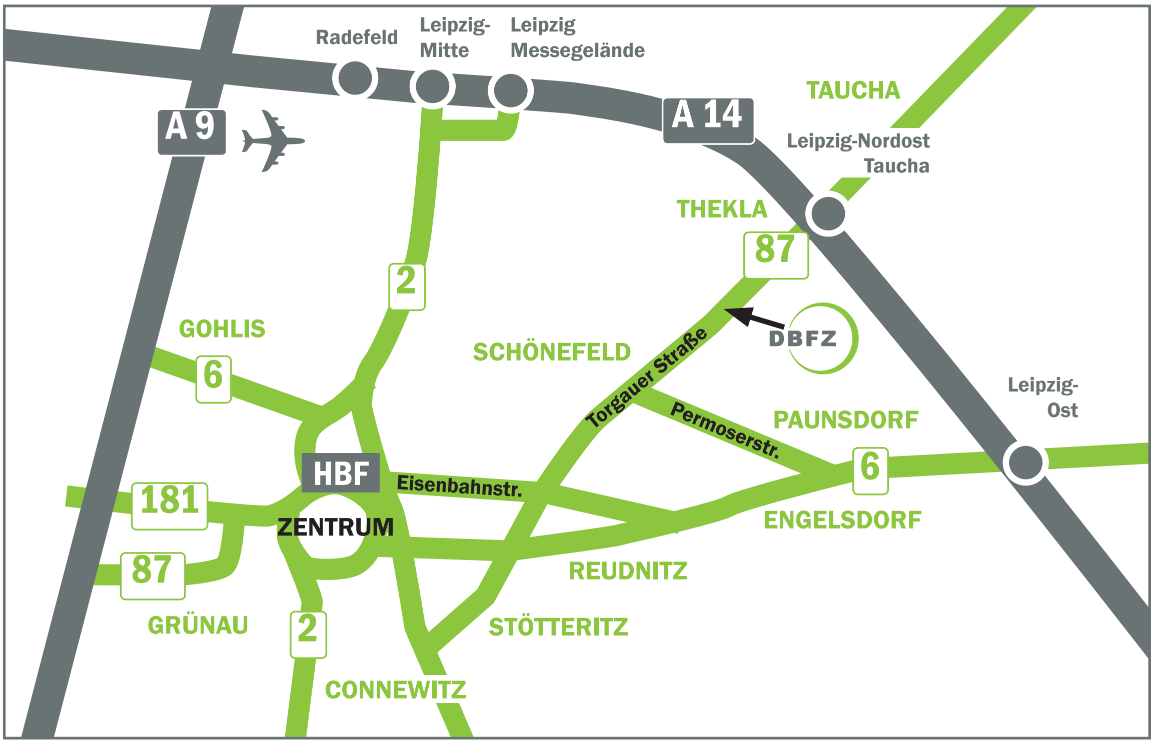

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