Türk-Alman Enerji Forumu
Deutsch-Türkisches Energieforum

Guide of Biomass Utilisation Feasibility

A guidance document based on German expertise to ensure the effective and efficient use of biomass residues

Legal information

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Last updated:
10/2023

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Please cite this publication as follows:
Deutsche Energie-Agentur (Publisher) (dena, 2023) “Guide of Biomass Utilisation Feasibility”

This publication was published within the framework of the Turkish-German Energy Partnership on behalf of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) in cooperation with the Ministry of Energy and Natural Ressources of the Republic of Türkiye by the Deutsche Energie-Agentur GbmH (dena).

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A guidance document based on German expertise to ensure the effective and efficient use of biomass

The direct and indirect promotion of bioenergy has a long history in Germany and is anchored in a multitude of laws, regulations and promotion programs. Türkiye wants to use more of it´s bioenergy potential to untap he benefits of renewable energy solution and waste management combined. For promotion of bioenergy the support mechanisms need to be on point to stimulate development in the contemplated direction. In order to promote the use of bioenergy in Türkiye, the experience of the German funding landscape will be evaluated.

In a first attempt to identify potential exemplary projects, the lack of information regarding biomass, residues and waste in the considered region is a first obstrutance which made a whole new approach necessary. This guidance document shall serve as a collection of information, based on German experience, where and data can be gained and used as a basis for the development of a bioenergy strategy, how biomass logistics are organized and supported and how German regulation and support is structured.

For this purpose, particularly efficient funding instruments and their core elements of the German funding landscape will be described and tried to guide the implementation in existing and to be created Turkish regulations will be carried out. Result of the work is an overview of the most important German promotion instruments and some recommendations to the Turkish legislation.

The long term aim is to create a suitable general funding framework for the establishment of sustainable bioenergy use paths and to develop a biomass strategy based on this.

In two last chapters, technology and stakeholder for bioenergy projects will be described.

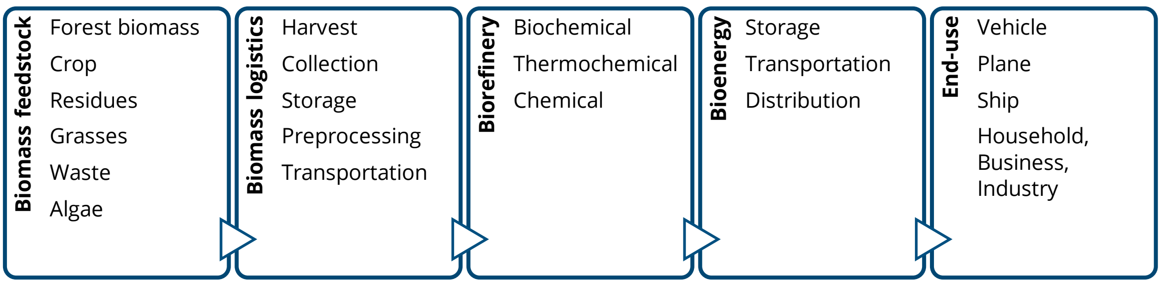

Figure 1: Bioenergy valuation chain

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1 Raw material site analysis

In order to assess potential biomass streams for bioenergy projects and the potential contribution of bioenergy in the energy system it is fundamental to collect and analyze the feedstocks that can be used. This chapter is therefore dedicated to describe the basic methods to asses and monitor biomass raw materials.

1.1 Necessary data for implementing a biomass strategy

As a first step, the analysis of the current land use is important. Here, the forest area as well as agricultural land should be examined in more detail. In Germany, the agricultural land area is determined by the FNR on behalf of the German Federal Ministry of Food and Agriculture (BMEL). The collected data on cultivation and use of renewable raw materials in Germany is published annually in statistical reports.[1]

The data basis for determining the quantities of **renewable raw materials** used are the official agricultural statistics, the official production and foreign trade statistics and the reports to the Federal Office for Agriculture and Food (BLE) on market regulation goods (MVO). The data results are largely dependent on the timeliness and availability of these input data. Due to existing limitations and the effects of the general reduction in statistics, supplementary sources such as expert surveys, current developments in agriculture and the processing industry, sector studies and information from associations and companies are also included in the analysis. Nevertheless, the available information is not always suitable for differentiating clearly between food and non-food and further between material and energy use of agricultural products. For this reason, additional estimates are made on the basis of consumption.

As a result, 14 percent of agricultural land is used for energy crop[2] cultivation in Germany. 60 percent is used for animal feed and 22 percent for food, while 2 percent is fallow and set-aside land. Industrial crops are grown on a further 2 percent. With a few exceptions, there is no targeted cultivation of energy crops. The use of energy crops is often decided after the harvest due to market conditions. This means that surplus quantities or inferior qualities that cannot be used for the food industry are usually used for biogenic energy sources. In the case of biogas, biodiesel and bioethanol, however, one can already speak of targeted cultivation, since the input materials used per plant remain relatively constant over the years.

Those findings made it possible to establish a comprehensive support landscape for agriculture in general as well as bioenergy specificly. Knowledge about processes and drivers of biomass utilization are the precondition for biomass strategies as a whole. How those data are used, is described in the following chapters.

By monitoring the **forest area and the wood supply**, it is also possible to better estimate how much wood can be harvested. Energy wood is often not obtained directly from the forest, but from wood residues according to cascade utilization. An exception is the targeted cultivation of short-rotation plantations for the production of wood chips. In Germany, a Forest Report of the Federal Government is published once per legislative period, to report to the German Bundestag on the situation and development of forestry and the structure of the timber industry in the Federal territory, as well as on the measures required to promote forestry, based on the economic results of the state forestry administrations and the forestry statistics[3] . In addition, the BMEL supports the project "Rohstoffmonitoring Holz" (Raw Material Monitoring for Wood), which aims at complementing the official statistics regarding energetic and material wood use. The project partners INFRO (Information Systems for Raw Materials), the Institute of Wood Sciences at the University of Hamburg and the Institute of International Forestry and Forest Economics of the Thünen Institute established, among other things, a

[1] FNR (2022): Statistikbericht. Online available at https://www.fnr.de/ftp/pdf/berichte/22004416.pdf. Accessed 26.07.2022.
[2] Energy crops are grown with the goal of using their biomass for energy production. However, agricultural products of inferior quality can also be used to produce bioenergy.
[3] BMEL (2022): Waldbericht der Bundesregierung 2021. Online available at: https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/waldbericht2021.pdf?__blob=publicationFile&v=11. Accessed 26.07.2022

continuous monitoring system within the framework of their joint project, which brings together the many isolated studies and surveys on the wood supply of the individual assortments and on wood use.[4]

For **biogenic residual and waste materials,** there are no official statistics that adequately describe the biogenic residual material potential. In addition, the waste and residual materials are often used within the farms themselves, such as the use of cattle manure as fertilizer on the fields. However, many biogenic residues also remain directly on the fields after harvesting for humus formation, as is the case, for example, with straw as a residual material from grain harvest. In general, this issue is regulated in Germany by the Düngemittelverordnung ("Fertilizer Ordinance") and the Stoffstrombilanzverordnung ("Material Flow Balance Ordinance"). The latter states that sustainable and resource-efficient handling of nutrients must be ensured on the farm during agricultural production. In doing so, nutrient losses to the environment are to be avoided as far as possible. To demonstrate compliance with the obligation, the farmer must draw up and evaluate material flow balances for the farm. The quantities of nitrogen and phosphorus supplied to and discharged from the farm within a reference year must be determined.

Certain farms must conduct a nutrient balance according to the Material Flow Balance Ordinance. The material flow balance, also called farm-gate balance, is the comparison of nutrient supply and nutrient removal on the farm as a whole. This includes the purchase of feed and animals and the delivery of animals, milk, eggs and wool. Neither stable and storage losses nor application losses may be deducted from the material flow balance.

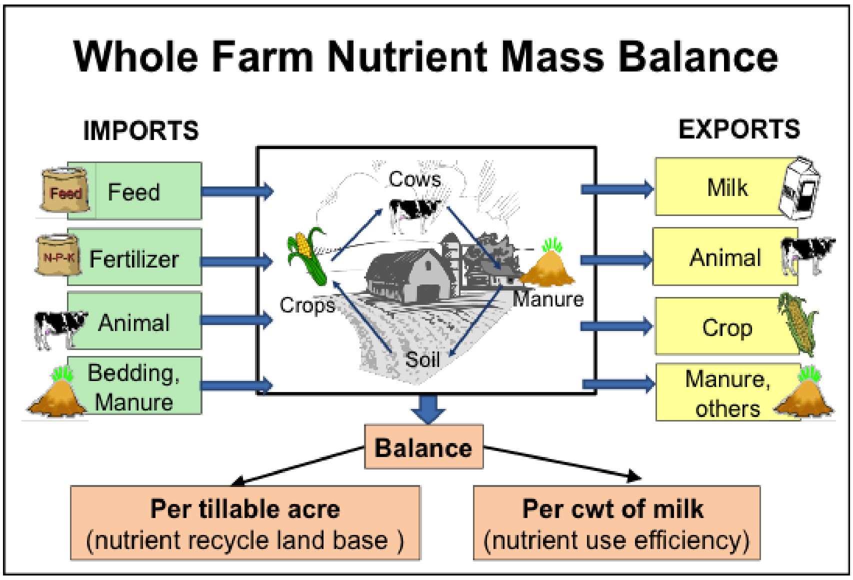

Figure 2: Whole farm nutrient mass balance assessments include accounting for nutrients brought onto the farm as feed, fertilizer, animals and/or bedding/manure, and nutrients exported off the farm as milk, animals, crops, and/or manure[5]

To find out how much waste and residual materials are available for energy use in Germany, the German Biomass Research Center created a resource database for biogenic waste and residues.[6] For the reference year 2015, it was thus possible to determine a theoretical residual material potential from 77 individual biomasses of 199 to 278 million tons of dry matter. Of this, between 66 and 84 percent is already in use. For an increased use of waste and residual materials, additional potentials could be mobilized in the future, especially from cereal straw, forest residues (coniferous), cattle slurry, cattle manure and green waste. An exemplary potential calculation flowchart can be found in figure 4 on page 15.

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[4] Thünen (2018): Rohstoffmonitoring für Holz. Online available at https://www.thuenen.de/de/fachinstitute/waldwirtschaft/projekte-liste/rohstoffmonitoring-fuer-holz. Accessed 12.10.2023.
[5] Cornell (2016): What is the Nutrient Balance of Your Dairy Farm? Online available at: https://blogs.cornell.edu/whatscroppingup/2016/04/20/what-is-the-nutrient-balance-of-your-dairy-farm/. Accessed 14.03.2023.
[6] DBFZ (2019): Ressourcendatenbank. Online available at: https://webapp.dbfz.de/resource-database/?lang=de. Accessed 15.08.2022.

1.2 Methodologies for data collection

1.2.1 Geographical Information system

Since agricultural residues and energy crops are a promising energy resource, using a **geographic information system (GIS),** a system that creates, manages, analyses and maps all types of data, has been successful and is well known in several fields of study, such as resource conservation, ecosystem evaluation, analysis of habitats, planning of land use sites, environmental disaster monitoring, etc. GIS can prove to be a decisive tool for assessing the status and planning of the area's renewable energy assets, and the cost-effective use of such resources. The collected data are useful for assessment of the areas with the help of satellite images taken in high resolution, which increases the preciseness of estimation. Figure 3 shows the methods to apply in GIS for estimating bioenergy potential. Here exemplary for straw usage to electricity production.

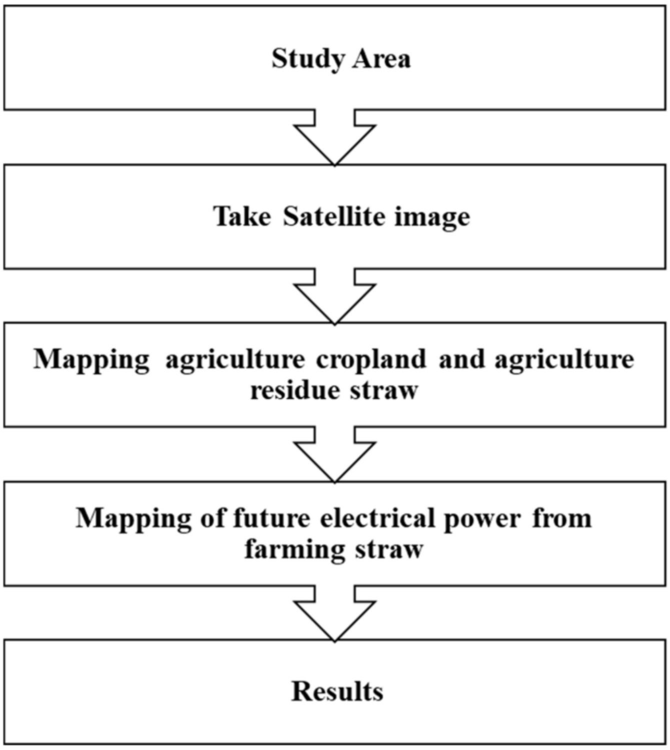

Figure 3: Methods to apply in GIS for estimating bioenergy potential[7]

A GIS intervention for the collection of **agriculture residues** data can be recommended due to the following points:

- varied variations of agro-residues is used for strength feedstocks, therefore preserving their spatiotemporal file about chemical and physical properties, connectivity and storage is more significant.
- GIS offers several benefits which can be accessed later for the efficient raw material collection-cum-management and cost-benefit analysis for bioenergy production.
- confirming the continued supply of feedstock is critical to the power plants. Earlier information on some variations in the source of feedstock would permit the consumer to make the essential arrangements[8] for another supply of feedstock during the lean supply period and can be specified using GIS. In general it is possible to establish a legal infrastructure that secures long-term raw material supply between farmes and energy companies.
- the environmental requirements of residue and economy, harvest constraints, infrastructure, competing for residue use, local socio-political dynamics, civil land use and industrial logistics facilities may also be evaluated with GIS's

[7] Bharti, A.; Paritosh, K.; Mandla, V.R.; Chawade, A.; Vivekanand, V. (2021): GIS Application for the Estimation of Bioenergy Potential from Agriculture Residues: An Overview. Energies 2021, 14, 898. https://doi.org/10.3390/en14040898
[8] Such contracts are called "Anbauvertrag (Cultivation agreement)" for crops or "Vertrag über Abgabe und Aufnahme von Gülle / Gärresten / Jauche / Stallmist (Contract for the delivery and intake of Liquid manure / digestate / slurry / farmyard manure) for residues and manure

geographical supply of agro-residue and effective strategic preparation for the time- and cost-effective selection and storage of residues may be performed.
- Calculation for the optimization of transport routes with ArcGIS software and the associated transport price (examples include the network predictor addition, which can be used to deliver feedstock/biomass, a source-to-sonsumer place for transportation pathways) This enables one to conduct different spatial network-based applications such as shortest path recognition, nearest station, service area and destination origin search.
- When choosing optimal biomass collection, areas that should be considered include current agricultural and geographical area, and the covering locations of distribution and the consumer.
- A GIS method has been developed for assessing techno-economic prospects of biomass for generating power and concluded the documentation for well-organized transport network and best areas of aggregation of biomass.
- The uses of spatial resources such as GIS may address the limitation of conventional methods such as surveys and secondary data analysis.[9]

For calculating the bioenergy potential, the following agricultural GIS technologies can be used:

- Land suitability
- Site search and selection
- Distribution of capital
- Effect assessment
- Location
- Knowledge-based systems

Examples of GIS implementations in bioenergy preparation for agro-residues are shown in Table 1.

Table 1: GIS implementations in bioenergy[10]

Fields	Remark	Reference
Crop residue potential	Sustainable crop residue capacity evaluation focused on GIS in five European regions	Haase, M.; Rösch, C.; Ketzer, D. GIS-based assessment of sustainable crop residue potentials in European regions. Biomass Bioenergy 2016, 86, 156–171.
Agro-forestry residue	Assessment of the production of biomass, techno-economic sustainability and environmental implications of the use of GIS and RETScreen agro-forestry residues	Malico, I.; Carrajola, J.; Gomes, C.P.; Lima, J.C. Biomass residues for energy production and habitat preservation. Case study in a montado area in Southwestern Europe. J. Clean. Prod. 2016, 112, 3676–3683.
Biomass availability and transport logistics	GIS-based calculation of biomass for agro-forestry and shipping logistics	Garcia, D.A.; Sangiorgio, S.; Rosa, F. Estimating the potential biomasses energy source of forest and agricultural residues in the Cinque Terre Italian National Park. Energy Procedia 2015, 82, 674–680.
Agro-forestry biomass	GIS-based approach for the estimation of agro-forestry biomass technological capacity in Portugal	Lourinho, G.; Brito, P. Assessment of biomass energy potential in a region of Portugal (Alto Alentejo). Energy 2015, 81, 189–201.
biomasses availability and biogas plants	GIS-based methodology for determination of potential biomasses and sites for biogas plants in southern Finland	Höhn, J.; Lehtonen, E.; Rasi, S.; Rintala, J. A Geographical Information System (GIS) based methodology for determination of potential biomasses and sites for biogas plants in southern Finland. Appl. Energy 2014, 113, 1–10.
Power plant	Studying the geospatial linkage between rice farms and GIS Power plant	Hu, M.C.; Huang, A.L.; Wen, T.H. GIS-based biomass resource utilization for rice straw cofiring in the Taiwanese power market. Energy 2013, 55, 354–360.

[9] Bharti, A.; Paritosh, K.; Mandla, V.R.; Chawade, A.; Vivekanand, V. (2021): GIS Application for the Estimation of Bioenergy Potential from Agriculture Residues: An Overview. Energies 2021, 14, 898. https://doi.org/10.3390/en14040898.
[10] Bharti, A.; Paritosh, K.; Mandla, V.R.; Chawade, A.; Vivekanand, V. (2021): GIS Application for the Estimation of Bioenergy Potential from Agriculture Residues: An Overview. Energies 2021, 14, 898. https://doi.org/10.3390/en14040898.

To evaluate biomass potential from **energy crops** at regional scale, a GIS-based approach can also be used. Land that can be dedicated to energy crops is identified at local scale through detailed cartography and datasets, considering morphological, pedological and climatic characteristics, administrative borders and current land use. The evaluation of biomass potential from energy crops can be divided into the following sections (Figure 4):

1) **Species selection**: agronomic needs must be defined for each considered crop.
2) **Land suitability:** data are necessary to describe soil characteristics and, thus, to understand where each kind of crop can be grown according to its agronomic needs (cartography).
3) **Land availability:** since not all the suitable land can be converted to energy crops, available land must be identified with the help of current land use data (statistical database) and taking into account political and social constraints.
4) **Land assignment/plant location:** a decision process must be defined in order to determine which crop to grow in each parcel of suitable land available and where to exploit its energy.[11]

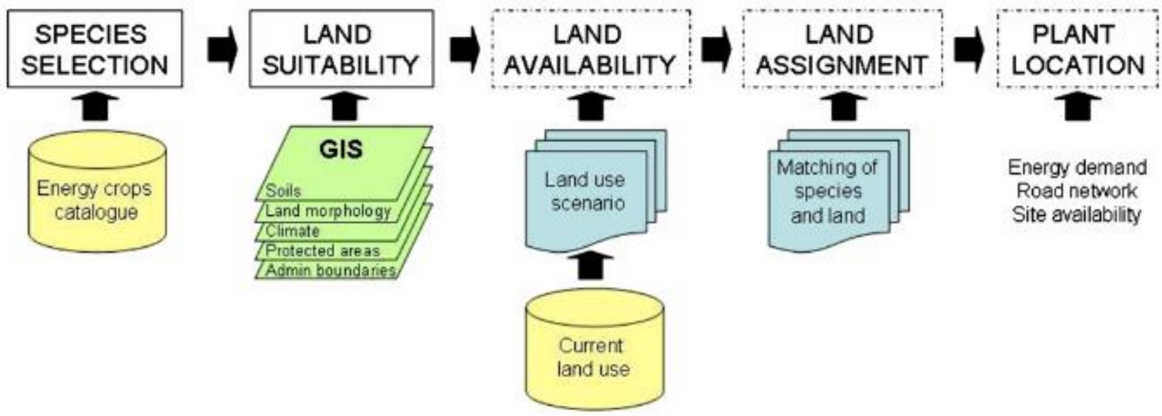

Figure 4: Steps of the proposed method and related databases (Fiorese and Giorgio 2009)

The first step (species selection) consists in identifying promising crops for the area under investigation and the related phytologic characteristics. The second step is to organize a database of cartographic information (land suitability) of the studied area. With the help of GIS tools, all the area is subdivided into parcels (minimum units with uniform attributes, as in Tianhong et al., 2003) that meet one or more of the criteria for the cultivation of the bioenergy crops. The third step is to deduce the availability of suitable land in each parcel for each crop (land availability). This step implies a number of political choices, and specifically the extent to which current agricultural practices may be modified. The fourth step consists in deciding which species to grow in each suitable and available area (land assignment). When more than one crop can be grown on a certain soil, an optimization problem needs to be solved. It is assumed that the objective of such a problem is the maximization of the energy produced. This requires the computation of the energy output from biomass utilization, which means, in turn, that one has to select type, size and location of conversion plants (plant location). The land assignment/plant location optimization problem can be formulated accounting for the net energy produced in the system given by the energy plants' output (that depends on number, size and efficiency of the plants) subtracted the energy needed to transport biomass from fields to plants and the energy needed to grow and harvest energy crops.

The study assumes as decision variables: x_{ijk}, the area, in hectare (ha), in parcel *i*-th, grown with species *k*-th and hauled to plant *j*-th at a distance d_{ij}, and y_j, a binary variable indicating if the plant is built in parcel j (y_j = 1) or not (y_j = 0). The net energy production, to be maximized, is thus

[11] Fiorese, G; Giorgio, G. (2009): A GIS-based approach to evaluate biomass potential from energy crops at regional scale. Environmental Modelling & Software 25. 702–711. doi.org/10.1016/j.envsoft.2009.11.008.

$$\max_{\{x_{ijk},y_j\}} J = \sum_i \sum_j \sum_k \Big[(\eta_j \cdot LHV_k \cdot u_k \cdot x_{ijk}) - (en_{transport} \cdot d_{ij} \cdot u_k \cdot x_{ijk}) - (en_{grow\ k} \cdot u_k \cdot x_{ijk}) \Big] \qquad (1)$$

where:

- u_k is the annual biomass yield of the k-th species, in dry tons/ha. It does not depend on the specific land parcel *i*, since only the most suitable land for growing crop k has been selected in the previous steps.
- h_j is the *j*-th plant efficiency.
- LHV_k is the lower heating value of the *k*-th species, in MJ/dry ton.
- $en_{transport}$ is the annual energy cost, in MJ/dry ton/km, for hauling a unit of biomass over a unit of distance, return trip included.
- $en_{grow\ k}$ is the annual energy cost, in MJ/dry ton, for growing biomass, again assumed to depend only on the species k.

The objective function is subject to the following constraints:

$$\sum_j \sum_k x_{ijk} \le A_i \forall \ i \qquad (2)$$

It imposes that the sum of areas x_{ijk} cultivated with crop *k* in parcel *i*, must be at the most as big as the available land A_i (in ha) in the same parcel, identified in the previous steps of the procedure.

$$CAP_j \cdot \xi^L \cdot y_j \le \sum_i \sum_k LHV_k \cdot u_k \cdot x_{ijk} \le CAP_j \cdot \xi^H \cdot y_j \ \ \forall \ j \qquad (3)$$

It limits the supply to each plant in a range, defined by a lower ξ^L and a upper ξ^H bound of the nominal production capacity CAP_j (in MJ/y), when the plant is actually built in location j (y_j = 1), and sets the supply to zero otherwise (y_j = 0). Working around the nominal capacity of the plant, guarantees that the value *hj* of the conversion efficiency is indeed meaningful and prevents from defining very small plants that may be unjustified from the economical viewpoint.

$$x_{ijk} \ge 0, \ \ y_i = 0, 1 \forall i, j, k \qquad (4)$$

Areas for energy crops must be non-negative, while the presence of a plant in the candidate location is a binary value. Such a problem is a generalization of the much studied capacitated plant location problem, which is known to be NP-hard in computational complexity theory. Here the capacity of each plant is determined by the available biomass, which is also a decision variable. In practical applications, the problem may have thousands of real and hundreds of binary variables, so the study authors developed a procedure to decouple it into two parts: the first is the optimization of land assignment, and the second is a classical plant location/allocation problem, with given information about biomass availability. Once the above problem is solved, GHG flows of the entire crop-to-energy chain can be computed and compared with those of an equivalent fossil fuel system. This is indeed one of the most interesting issues for a regional authority because it clarifies if the optimal biomass exploitation can significantly contribute to curb emissions.

1.2.2 Projections and Calculations

In some cases, resource supply and use can only be calculated or estimated by linking multiple data sources. Such data sources include statistics, literature values, modeling, primary data collection, or expert estimates. A positive example here is the resource database for waste and residual materials from the German Biomass Research Center (DBFZ) mentioned earlier. [12]

The methodology was based on a review of 122 sources. Within that review more than 1,100 dynamic (e.g., statistics) and nondynamic (e.g., literature sources) calculation elements were compiled from existing work. These sources were then organized in a consistent data structure and linked to 77 individual biomasses from five sectors. The very detailed and extensive data merging also includes, among other things, the consistent recording of minimum and maximum values. In this way the uncertainties of corresponding data sources can be taken into account. In addition, the DBFZ resource database enables individual research data on cross-sectoral biomass potentials and their current use.

As a result the DBFZ provides illustrated biomass-specific calculation paths for the potential calculations in flowcharts, so individual biomasses from different sectors can be calculated

Figure 5 gives an example for the projection of the biomass cattle manure. That calculation is based on data from animal counts of the Animal Origin Assurance and Information System (HIT database, an EU-wide traceability and information system for animals based on EU Regulations No. 820/97 and 1760/200).[13]

[12] DBFZ (2019): Ressourcendatenbank. Online available at: https://webapp.dbfz.de/resource-database/?lang=de. Accessed 15.08.2022.
[13] DBFZ (2020): Flowcharts “Potenzialberechnung”. Online available at: https://webapp.dbfz.de/resource-database/static/media/DBFZ_Ressourcendatenbank_Flowcharts_DE.0fd24b5c.pdf. Accessed 15.08.2022.

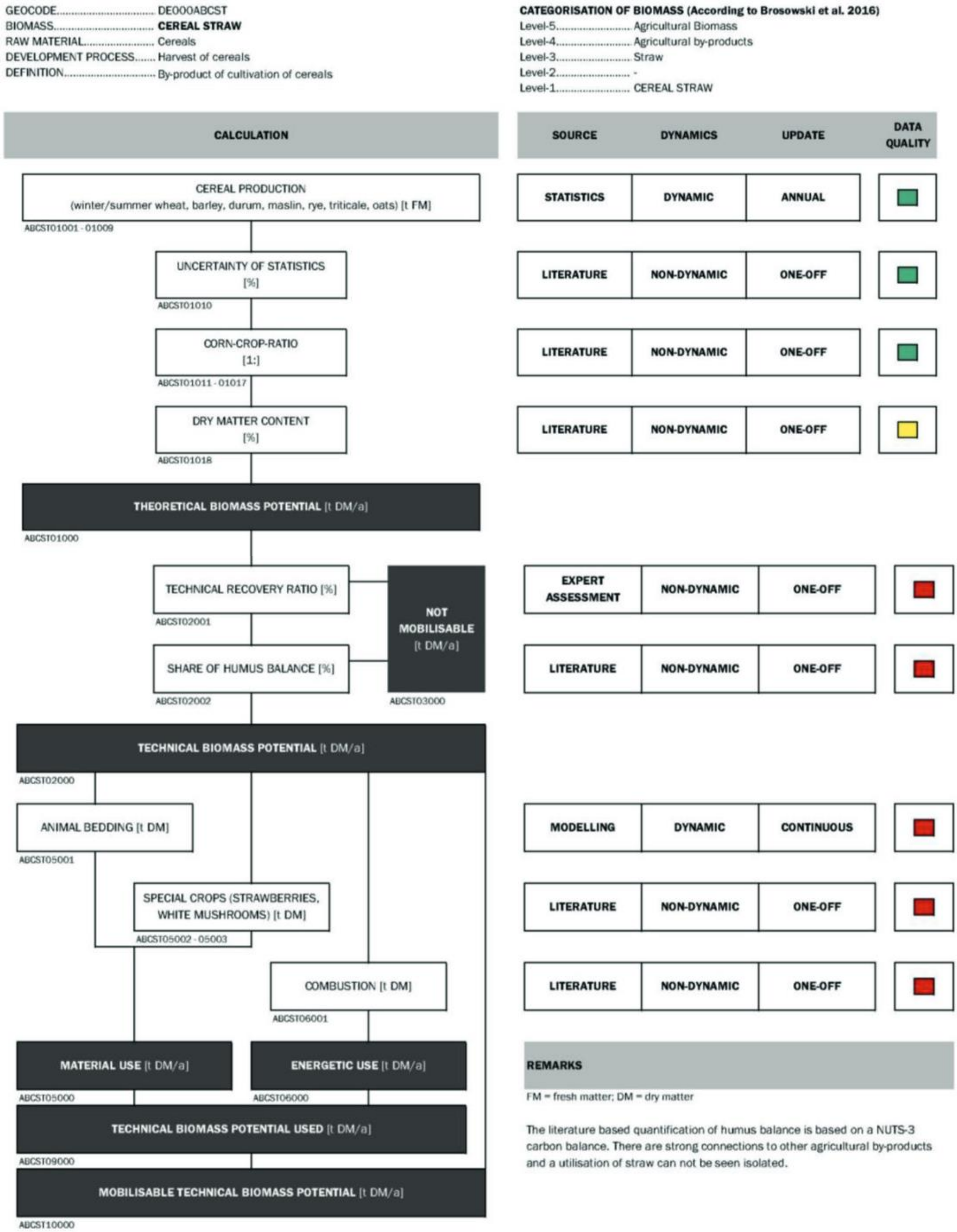

Figure 5: Flowchart for calculating the potential volume of cereal straw in Germany (DBFZ 2020)

1.3 Implementing and use of a biomass monitoring system

The efficient material and energetic use of biogenic residues, by-products and waste offers numerous opportunities to substitute fossil raw materials. However, it is still unclear which raw materials can be understood under these collective terms, which quantities exist across sectors, and what additional contribution can be expected from optimized use. The DBFZ as therefore developed an applicable method with which the technical biomass potential and current use can be continuously balanced and evaluated.[14]

The basis for this is a modular monitoring system that includes, among other things, a multi-level biomass categorization, a regularly updatable network of biomass-specific calculation elements, and a procedure for continuously improving data quality. The monitoring system was tested on the example of Germany and for a consistent reference year.

The methodological approach consists of three parts: **implementation, developing the monitoring system** and **reviewing the data quality**, which will be described in the following chapters.

1.3.1 Implementation

- **Step 1** involves identifying and categorising the biomass types from the different sectors which are to be taken into account in the monitoring system.
- **Step 2** then consists in determining the level of reporting detail.
- **Step 3** brings together an inter-institutional group of experts to work on the relevant topics together, with the aim of setting out clear responsibilities for individual raw materials or sectors.
- **Step 4** involves collecting applicable calculation elements for assessing the biomass potential, and their source data.
- **In Step 5**, the calculation elements which have been gathered are placed in a mathematical relationship to one other. This creates an automated calculation network, which is at the core of the potential calculations.
- **Step 6** consists in visualising the methodological approach in the form of calculation flowcharts
- **In Step 7** the types of biomass potential are contextualised to make it easier to understand their significance in the context of the future use of raw materials.
- **Step 8** involves ensuring that access is provided to the results of the calculations for individual subsequent use by e. g. an online data repository.
- **Step 9** consists in measuring the status quo of reliability, completeness and timeliness. The findings are used to identify gaps in the data and determine the need for research.
- **Step 10** is focused on updating the automatic calculation network by adding, for example, temporal and spatial details or other calculation elements, to come closer to the ecologically sustainable biomass potential.
- **In Step 11**, a structural upgrade can also be used to integrate new types of biomass or other key items of information to describe the material flow into the system.

A visual overview of there eleven steps is also given in Figure 6.

[14] DBFZ (2021): National Resource Monitoring for Biogenic Residues, By-products and Wastes. Online available at: https://www.dbfz.de/fileadmin/user_upload/Referenzen/DBFZ_Reports/DBFZ_Report_41.pdf. Accessed 20.07.2022.

Figure 6: Implementation process for the monitoring system[15]

1.3.2 Developing the monitoring system

The monitoring system consists of a total of **twelve modules,** used to organise the automated data processing and external data provision, which are shown in Figure 7.

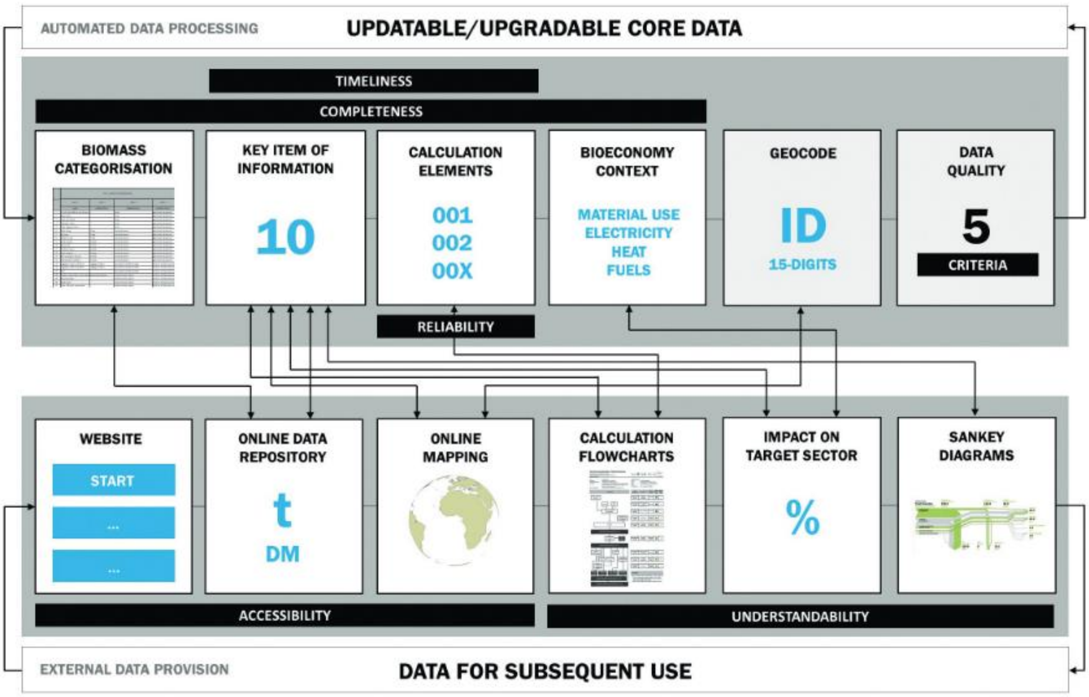

Figure 7: Overview of the twelve modules of the monitoring system, the five criteria of data quality and their connection to one other[16]

[15] DBFZ (2021): National Resource Monitoring for Biogenic Residues, By-products and Wastes. Online available at: https://www.dbfz.de/fileadmin/user_upload/Referenzen/DBFZ_Reports/DBFZ_Report_41.pdf. Accessed 20.07.2022.
[16] DBFZ (2021): National Resource Monitoring for Biogenic Residues, By-products and Wastes. Online available at: https://www.dbfz.de/fileadmin/user_upload/Referenzen/DBFZ_Reports/DBFZ_Report_41.pdf. Accessed 12.10.2023.

The modules are described in more detail below:

- **Modul 1 Biomass categorization:** The biomass is divided into the following five categories
  - Agriculture
  - Forestry
  - Municipal waste and swage sludge
  - Industrial residues
  - Residues from other areas
- **Modul 2 Key items of information:** A total of ten key items of information are defined for communicating findings in a targeted, clearly organised manner. On this basis, the entire material flow is consistently described for each individual type of biomass.
- **Modul 3 Calculation elements:** To calculate the potential in a manner that can be regularly updated and is temporally and methodologically consistent, detailed information is required on the calculation elements which are used.
- **Modul 4 Bioeconomy context and Modul 11 impact on target sector:** The interpretation of the results is made possible by contextualising the key items of information.
- **Modul 5 Geocoding and Modul 11 Online mapping:** To enable the monitoring system to be transferred geographically, the data structure is based on 15-digit geocodes which unambiguously describe countries, regions, all biomass types, sectors, key items of information and biomass-specific calculation elements, both temporally and spatially.
- **Modul 6 Data quality:** The data quality has a decisive influence on how informative and well accepted the findings on potential are. With regard to the requirements posed for the monitoring system, the five criteria of accessibility, understandability, reliability, completeness and timeliness are taken into account.
- **Modul 7 Website and Modul 8 Online data repository:** So that the data can be used subsequently a freely accessible website has been set up at http://webapp.dbfz.de with an online data repository offering access to biomass-specific key items of information and their contextualization.
- **Modul 10 Calculation flowcharts:** To improve the understandability of the biomass potential calculations, the relationships between the calculation elements and the key items of information for every type of biomass considered are each visualised as a calculation flowchart.
- **Modul 12 Sankey diagrams:** The quantitative relationships in the material flow can be visualised in a clearly understandable manner using Sankey diagrams.

1.3.3 Review of data quality

The continuous improvement of the data quality enables the monitoring system to be updated and extended step by step. To enable corresponding adjustments to be made in a targeted, needs-based manner, the status quo of data quality must be known. Five methodological approaches were developed for the three quality criteria reliability, completeness and timeliness.

- **Points-based evaluation of calculation elements:** The calculations of potential include biomassspecific calculation elements based on various sources.
- **Consideration of ecological sustainability indicators:** The aim is to mobilise the biomass potential within ecological limits (Global Bioenergy Partnership (GBEP), Sustainable Development Goals, German Federal Government Sustainable Development Strategy).
- **Dynamics of data sources:** The timeliness of the monitoring findings depends on whether the calculation elements can be updated, and the intervals at which the corresponding data bases are updated. In the monitoring system, a difference was thus made between dynamic and non-dynamic calculation elements.
- **Updating and upgrading the monitoring system**: Temporal and spatial details of important biomass.
- **Integration of further content:** Continuously improved content by updating the content and structure of the monitoring system

2 Bioenergy Analysis

From the available raw material analyzed in chapter 1, a wide range of bioenergy can be generated by considering or not considering different parameters such as technology use, sustainability aspects and regulatory framework. In the following different concepts to analyse the bioenergy potential are presented via using model simulations or a matrix.

2.1 Definition of the bioenergy potential term

To assess bioenergy potentials, system boundaries and conditions need to be defined. Therefore, common terms for potential analysis are "theoretical", "technical", or "economic" potentials.

From theoretical to technical to economic potential, restrictions progressively become tougher and only constitute a portion of the superordinate potential.

The **theoretical potential** is the theoretical energy supply in a given region that can be used physically. It is determined solely by the given physical utilisation boundaries and thus defines the upper limit of the theoretically realisable energy supply. Since the theoretical potential often can only be tapped to a very small degree due to certain restrictions, it is of basically no practical relevance in the assessment of the actual utilisation of the biomass.

The **technical potential** describes the portion of the theoretical potential when taking into account the given technical restrictions (e.g. recovery rates, conversion losses). Additionally, the given structural and legal environmental limitations (environmental, cross compliance, social restrictions) are taken into consideration since they are regarded, similar to the technical restrictions. As a result it describes time and location dependent contribution of the biomass to energy supply from a technical point of view.

The **economic potential** describes the time and location dependent portion of the technical potential that can be tapped economically under the respective economic framework conditions. Since the economic framework conditions are subject to short-term changes (e.g. price wise as well as regulatory wise), the economic potential is subject to considerable temporal fluctuations.

Since the technical potential is considerably influenced by the more long term stable technical framework conditions and considerably less subject to temporal fluctuations. Therefore, the technical potential is quite often presented in studies.[17]

2.2 Model Simulations

The requirements for a future, sustainable energetic biomass use are diverse and should ensure a resource-efficient, climate-compatible, socially accepted and long-term sustainable bioenergy strategy. With simulation models it can be analyzed which technology options are economically advantageous under different framework conditions and which ecological, economic and social impacts result from the biomass demand associated with bioenergy production. From this, a viable and sustainable bioenergy strategy can be identified and recommendations for action derived.

Various computer models can be used to identify the technical and organizational milestones. According to the publication series of the funding program "Energetic Biomass Utilization"[18], a model network was presented, which shows the different framework conditions as economically advantageous and which ecological, economic and social impacts are associated with bioenergy production. Furthermore, input parameters for the models were defined in the german project network via so-

[17] D. Thrän, D. Pfeiffer (Eds.) (2015): Method Handbook - Material Flow-oriented Assessment of Greenhouse Gas Effects https://www.energetische-biomassenutzung.de/en/publications/series-biomass-energy-use/method-handbook-material-flow-oriented-assessment-of-greenhouse-gas-effects. Accessed 12.10.2023.

[18] D. Thrän, D. Pfeiffer (Eds.) (2015): Meilensteine 2030: Elemente und Meilensteine für die Entwicklung einer tragfähigen und nachhaltigen Bioenergiestrategie. Online available at: https://www.energetische-biomassenutzung.de/fileadmin/Steckbriefe/dokumente/03KB065_Endbericht_MS2030_final.pdf. Accessed 12.10.2023.

called modules, and ex post evaluations of the model calculations were carried out. The required data are mentioned in the model introductions below.

The study mentioned has developed a model network consisting of

- a global land use model (LandSHIFT), for area-based sustainability criteria
- a global market model (MAGNET), to simulate commodity prices and demand
- and a Bioenergy Simulation Model (BENSIM) for technology comparison, which was developed especially for this project.

2.2.1 LandSHIFT

Land use, land supply, raw material supply: for a land-based sustainability assessment. It is used for the spatial and temporal simulation of land use changes caused by the cultivation of food, feed and energy crops. It combines GIS and simulation analyses.

2.2.2 MAGNET (Modular Applied GeNeral Equilibrium Tool)

Commodity origin, commodity quantity, commodity price for food security assessment. Simulates the development of commodity prices and commodity demand in a macroeconomic context. In interaction with LandSHIFT, MAGNET shows the total agricultural area and production per country and product. MAGNET is used in the project to estimate the price development and the development of demand for the tradable raw materials relevant for the conversion plants considered in BENSIM. The data basis is volume data of the base year from other statistics. The model is based on the GTAP database, which covers 56 sectors in 140 countries and regions.

To perform an area-based risk assessment for biomass, the results of the interaction of MAGNET (imports) and LandSHIFT (land use) can be used. In addition to the simulation models, food security requirements should also be carried out building on the results of the modeling in MAGNET.

2.2.3 BENSIM (BioENergy SImulation Model)

This simlutaion model includes plant parks and feedstock requirements for the assessment of regional infrastructure. The model calculations provide information on which of the bioenergy technologies will prevail over other bioenergy technologies, when and under which conditions. Required data are data on the costs of the raw materials. These are provided for tradable agricultural commodities through the interface to MAGNET.

The plant fleet calculated in BENSIM, the provision of electricity, heat or fuels associated with it, and the feedstock requirements needed for this can help answer the question of how the plants can be integrated into existing, municipal infrastructures and whether the feedstock requirements can be provided from a municipal logistics perspective. By investigating the regional effects, the probability of individual scenarios as well as the effects on the heating market but also on the role of biomass in the electricity market (balancing of fluctuating RE by biogas) can be fed back. In the ideal case, this in turn allows regionally substantiated conclusions to be drawn about the current scenarios of energy supply in Germany with regard to heat and CHP for a specific biomass scenario.

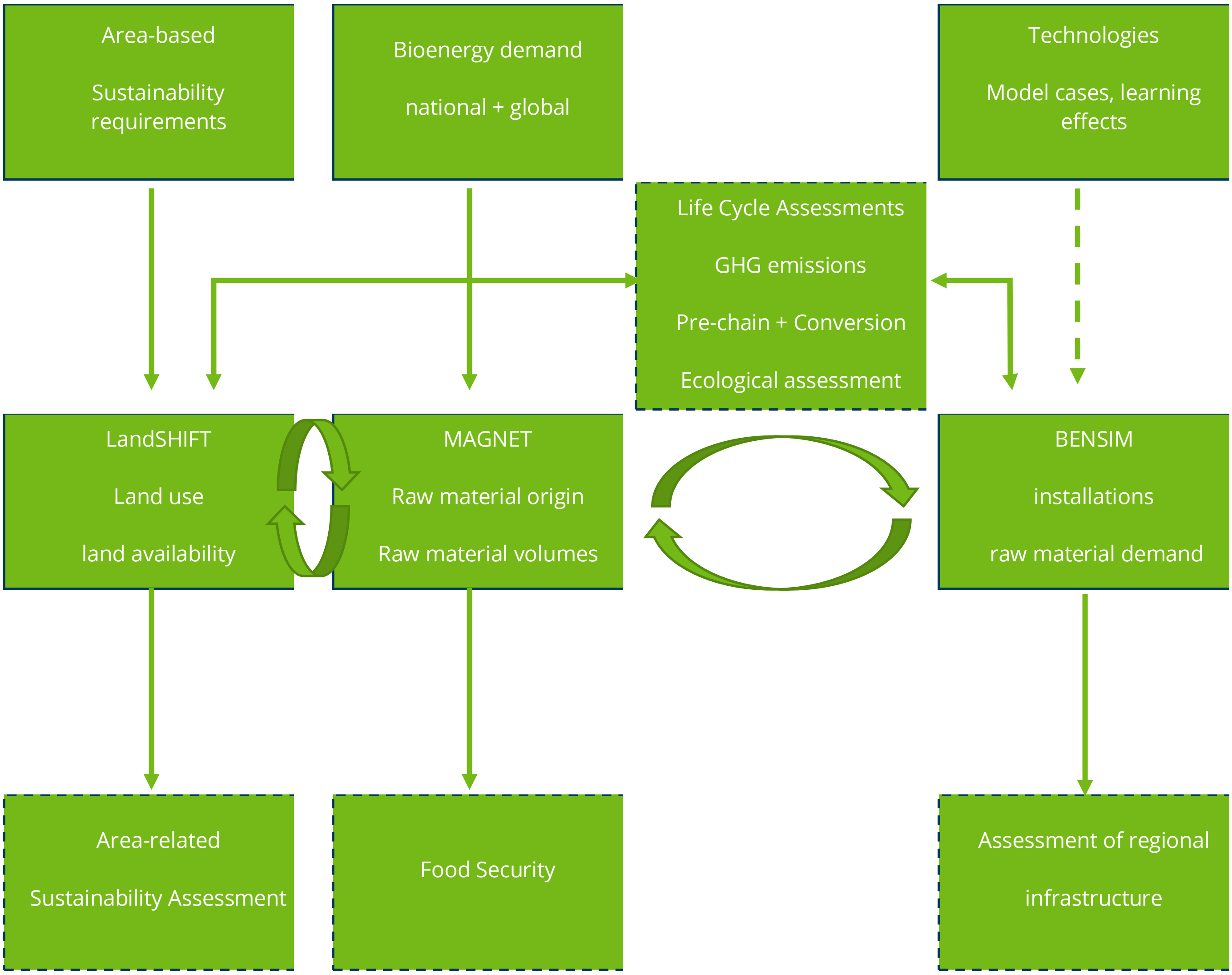

Figure 8: Inputs, interconnections and dependencies of modules

2.3 Evaluation of the deployment paths using a matrix

The biomass demand differs strongly between the conversion technologies, plant outputs, plant types and utilization concepts. In order to identify preferred utilization paths in the electricity, heat and fuel markets, the technical and economic boundary conditions of current and future conversion technologies must be analysed. Beside Model simulations as shown in chapter 2.2, matrix based evaluation is another method of analysing promising deployment pathes for bioenergy. For this purpose the German Environment Agency, has analyzed and evaluated existing and future technological concepts for the production of secondary and final energy sources for bioenergy carriers based on biogenic waste and residues from a process engineering, ecological and economic perspective.[19] According to the study a total of 19 technologies were determined for biomass conversion (Table 2).

[19] UBA (2018): BioRest: Verfügbarkeit und Nutzungsoptionen biogener Abfall- und Reststoffe im Energiesystem (Strom-, Wärme- und Verkehrssektor). Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-09-24_texte_115-2019_biorest.pdf. Accessed 12.10.2023.

Table 2: Overview of conversion technologies and techniques considered[20]

Conversion technology	techniques under consideration
Combustion	wood pellet central heating 15 kW_{th}
	wood chips boiler 500 kW_{th}
	CHP plant 5 MW_{el}
	ORC cogeneration plant 250 kW_{el}
	sewage sludge combustion plant 10 MW
	co-combustion of solid biomass in coal power plant
	municipal solid waste incinerator 50 MW
Gasification	small-scale gasifier 30 kW_{el}
	wood gasifier 10 MW_{el}
	Bio-SNG 25 MW_{SNG}
	BtL 100 $MW_{Biofuel}$
Fermentation (biogas)	Biogas plant 75 kW_{el}
	Biogas plant 500 kW_{el} – wet fermentation
	Biogas plant 800 kW_{el} – dry fermentation
	Biomethane plant 2 MW – wet fermentation
	Biomethane plant 2 MW – dry fermentation
Fermentation (ethanol)	Ethanol plant
Transesterification	Biodiesel plant

Subsequently, the suitability of the selected techniques for each individual waste and residual material type was evaluated using a technical suitability matrix. To create a technical suitability matrix, characteristics of the waste and residual materials were linked to parameters characterizing the conversion techniques. The aim here is to use criteria that are as objective as possible or can be objectified, and that allow an assignment of residual material and specific technique from a purely technical point of view. For example, the water content of the material under investigation can be matched with the technical requirements of a technique in terms of the desired moisture content of the material to be treated.

On the basis of suitable information on waste and residual materials and technical conditions, a selection of criteria for the technical suitability matrix was determined that is as non-overlapping as possible. It comprises the following four criteria:

- Water content
- Gas yield (for fermentation)
- Requirement structure input material
- material purity

The evaluation was carried out using a three-level "traffic light system" (green = good match, yellow = partial match, red = no match). As a rule, a waste/residual material and technology combination is considered suitable if it does not contain any individual assessment marked with "red".

[20] UBA (2018): BioRest: Verfügbarkeit und Nutzungsoptionen biogener Abfall- und Reststoffe im Energiesystem (Strom-, Wärme- und Verkehrssektor). Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-09-24_texte_115-2019_biorest.pdf. Accessed 12.10.2023.

In the second step, it was checked again whether a "red" evaluation can lead to a more favorable individual evaluation by considering a reasonable pretreatment. The selection of whether a pretreatment is reasonable and results in a reasonable optional treatment option was made by expert judgment.

The combinations (application paths) of waste/residual material and conversion technology (with or without modification) available at the end of the first two steps were then subjected to an extended evaluation. This extended evaluation includes the application of the generated energy product. From this, in the third step, an input path matrix was developed, which was applied as follows:

1. Establishment of priority input paths
2. Grouping of similar wastes/residues within a conversion technique
3. Establishment of the input pathway matrix as a starting point for the subsequent evaluation step
4. Selection of input pathways and assignment to energy products and energy applications.

Further differentiation of the input pathways is led by the different energy products generated by the input pathways:

- Electricity;
- Heat in form of various applications such as building heating or process heat, which also need to be further differentiated into piped building heat or individual firing, low or higher calorific process steam (depending on pressure and temperature);
- Fuels, which also need to be further differentiated, such as biofuels for road, marine, or aviation transport.

Some pathways may yield different energy products in the process. Table 3 shows which pathways are associated with which energy products.

In the case of CHP, steam turbines, electricity and heat utilization rates are variable (depending on the design); more electricity coupling means less heat coupling and vice versa; therefore, only the two "extreme cases" are considered for the evaluation:

- Pure heat coupling and use as process heat with low or higher steam parameters (150°C or 300°C, respectively) or
- Pure power coupling.

For some application paths, electricity was thus used as the energy product throughout Table 3. This approach/definition of a product is necessary to keep the evaluation of the input paths comprehensible. To show that heat use is a complementary or additive option, these places in the table are marked with (CHP) in parentheses.

For gas engine plants (biogas CHP), waste heat accrues for use without limiting electricity efficiency. For biogas plants, heat utilization is therefore not an alternative to electricity utilization but basically additive. For the corresponding paths 19-25, therefore, in addition to the maximum possible electricity output, the additional possible waste heat utilization was always included, marked for the list in Table 3 with CHP without brackets.

Table 3: Energy products according to the different conversion techniques and application paths[21]

Nr	waste/residue	conversion technique	electricity	building's heat		process heat		transport fuel		
				pipe	s.b.	l.p.	m.p.	str. p.v.	ship./ av.	Str. truck
1	forest wood	wood pellet central heating 15 kW_{th}			x					
2	Industrial wood, solid industrial substrates	wood pellet central heating 15 kW_{th}			x					
3	Forest wood, industrial wood	wood chips boiler 500 kW_{th}		x		x	x			
4	woody biomass from landscape management and green waste	wood chips boiler 500 kW_{th}		x		x	x			
5	woody residues	CHP plant 5 MW_{el}	X	(CHP)			x			
6	Straw	CHP plant 5 MW_{el}	X	(CHP)			x			
7	forest wood, woody biomass from landscape management and green waste	ORC cogeneration plant 250 kW_{el}	X	(CHP)						
8	Straw	ORC cogeneration plant 250 kW_{el}	X	(CHP)						
9	municipal and industrial sewage sludge	sewage sludge incinerator	X	(CHP)			x			
10	organic waste	sewage sludge incinerator	X	(CHP)			x			
11	woody residues	co-combustion of solid biomass in coal power plant	X	(CHP)						
12	animal meal	co-combustion of solid biomass in coal power plant	X	(CHP)						
13	12 wastes and residues	municipal solid waste incinerator 50 MW	X	(CHP)			x			
14	woody residues	small-scale gasifier 30	X		x					
15	Forest wood, industrial wood, waste wood	wood gasifier 10 Mw_{el}	X	(CHP)						
16	Forest wood, industrial wood, waste wood	Bio-SNG plant 25 MW_{SNG}	X	(CHP)		x			x	
17	Forest wood, industrial wood, waste wood, woody biomass from landscape management	BtL plant 100 $MW_{biofuel}$						x	x	x
18	Straw	BtL plant 100 $MW_{biofuel}$						x	x	X
19	herbaceous biomass from landscape and green waste, slurry and manure	Biogas plant 75 kW_{el} - wet	X	CHP						

[21] UBA (2018): BioRest: Verfügbarkeit und Nutzungsoptionen biogener Abfall- und Reststoffe im Energiesystem (Strom-, Wärme- und Verkehrssektor). Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-09-24_texte_115-2019_biorest.pdf. Accessed 12.10.2023.

Nr	waste/residue	conversion technique	electricity	building's heat		process heat		transport fuel		
				pipe	s.b.	l.p.	m.p.	str. p.v.	ship./ av.	Str. truck
20	harvest residues	Biogas plant 75 kW_{el} - wet	X	CHP						
21	herbaceous green waste, slurry and manure	Biogas plant 500 kW_{el} - wet	X	CHP						
22	harvest residues	Biogas plant 500 kW_{el} – wet	X	CHP						
23	herbaceous green waste, manure, harvest residues black liquor	Biogas plant 800 kW_{el} – dry	X	CHP						
24	Straw	Biogas plant 800 kW_{el} – dry	X	CHP						
25	biowaste	Biogas plant 800 kW_{el} – dry	X	CHP						
26	herbaceous green waste, slurry and manure	Biomethane plant 2 MW – wet	X	(CHP)	x	x	x	x	x	x
27	harvest residues	Biomethane plant 2 MW – wet	X	(CHP)	x	x	x	x	x	x
28	herbaceous biomass from landscape and green waste, manure, harvest residues black liquor	Biomethane plant 2 MW – dry	X	(CHP)	x	x	x	x	x	x
29	Straw	Biomethane plant 2 MW – dry	X	(CHP)	x	x	x	x	x	x
30	Biowaste	Biomethane plant 2 MW – dry	X	(CHP)	x	x	x	x	x	x
31	Straw	LC Ethanol plant						x	x	
32	animal fat, used oils and fats	Biodiesel plant							x	x

**pipe = pipe-based heat for buildings; s.b. = single building; l.p. = low pressure steam, m.p. = medium pressure steam; str. P.v.= street-based for person vehicles; Str. truck= street-based for person vehicles for trucks; ship./av. = fuel for shipping or aviation; x = pathway to be assessed, CHP = heat from CHP additionally included; (CHP): heat from CHP could be an alternatively produced instead of complete electricity production (condensation), on which this assessment is based*

Finally, an overall **utilization concept** was developed on the basis of the biogenic waste and residual material potential that can be exploited for energy, the conversion technologies required for utilization in the energy system, and the technical suitability assessment of combinations of materials and technologies, as well as the ecological assessment of the resulting possible utilization paths.

The evaluation of the 32 use paths, in some cases further differentiated according to different energy products, was based on the following five criteria:

- Energy efficiency
- Greenhouse gas balance
- Cost situation
- Other ecological aspects
- Compatibility with the transformation of the energy system

The total utilization concept looks as follows for Germany as a result: approx. 600 PJ bioenergy in heating sector, approx. 8.2 PJ in electricity sector and approx. 25 PJ transportation sector.

3 Methodologies of raw material collecting

A robust logistics concept must be developed involving all stakeholders in a value chain with a fair distribution of risks between biomass producers and biofuel producers. In particular, it is important to consider that many biomass feedstocks for advanced biofuel pathways, especially crop residues, are seasonal and therefore require intermediate storage, possibly also prior preservation (e.g. drying). Likewise, possible crop failures must be considered, for example, due to extreme weather or pest infestation. Biomass pretreatment to increase energy density may also be indicated for longer transport distances.

Plant operators are faced with the choice of either applying a conversion technology that has the highest possible feedstock flexibility, which is adapted to the biomass types, their availability and the necessary logistics, or - in the case of technologies with low feedstock flexibility - determining a site with sufficient potential of a few, intrinsically homogeneous biomass feedstocks (with relatively narrow specifications, e.g. with regard to water content), which are used in the campaign operation.

3.1 Possible utilization routes for wet, woody and lignin and cellulose rich bio wastes and residues

The transport logistics differ according to the raw material to be used for bioenergy production.

The following section will therefore describe the various transport routes according to the different waste categories.

1. **Forestry by-products**
    - Bark
    - Forest residues (deciduous)
    - Forest residues (coniferous)

The classic feedstock for forest chips (wood chips) are forest residues, mainly from spruce and pine. This includes crowns and crown parts, branches and rotten or broken trunk sections. Depending on the stand, admixtures of hardwood up to 30 percent occur. Increasingly, (coarsely) delimbed trunk sections of poor quality are also being offered for chipping as energy roundwood. Overall, the trend is toward the use of professional chipping contractors. Chipping is generally a process step decoupled from harvesting and skidding. The forest road has become the accepted location for the chipper. Here, due to the low demands on off-road mobility, the use of mobile large-scale chippers and various combinations of machines (including transport vehicles) is possible. Due to their mobility, these powerful machines enable economical chipping operations in the forest without labor-intensive transport of chipped wood.

When used on the forest road, chipping and transport are coupled, as the wood chips are usually ejected directly into transport containers. Forest chips are mainly transported by container trucks when large-scale chippers are used. Usually, truck trains with two containers are used, one of which is parked at a reloading point (e.g. forest parking lot). The forest journey for loading at the chipper then takes place without a trailer. For smaller operations, agricultural trailers on tractors also play a role.

2. **Wood by-products**
    - Waste wood
    - Other industrial wood
    - Sawmill by-products and wood shavings

Waste wood inform of old furniture and the like is picked up free of charge depending on the federal state in Germany or must be brought to the plants for a fee.

Sawdust from sawmills accumulates directly in sawmills and can either be used as material (e.g. in chipboard) or pressed into pellets for energy use.

3. Agricultural by-products

- Straw
- Railroad grass
- Railroad accompanying wood
- Stalks from orchards
- Stalks from landscape maintenance areas
- Stalks from vineyards
- Wood from orchards
- Wood from landscape maintenance areas
- Wood from vineyards
- Roadside greenery
- Roadside wood

The collection and transport of agricultural by-products such as straw is done by large threshers that thresh out the grain as it passes by. What remains is the straw on the field. A baler collects the straw and compresses it into packets or big bales. In this way, the bales can be easily transported by agricultural wagons and stored.

Accompanying grass and wood, however, is more likely to be shredded by chippers and transported in trucks.

4. Animal excrements

- Chicken manure
- Horse manure
- Cattle manure
- Cattle slurry
- Sheep manure
- Pig manure
- Pig slurry
- Goat manure

Animal excrements often have a very high water content, which makes long transport distances uneconomical. Therefore, it is usually only worthwhile to operate a biogas plant in the immediate vicinity of a livestock farm. The decisive factor here is that the farm has a certain size and therefore a certain number of livestock in order to ensure the corresponding requirements for the operation of the biogas plant.

In the case of other excrements, such as horse manure, collection is usually done manually and smaller quantities are produced. Therefore, a transport to the nearest biogas plant is usually not worthwhile.

5. Residues from bioethanol and biodiesel production

- Glycerine from biodiesel production
- Residues from bioethanol production

The residues from bioethanol and biodiesel production accumulate directly at the plants and can be used either as animal feed or in biogas plants, depending on the raw materials used. In the latter case, it makes sense to set up a biogas plant in the immediate vicinity in order to keep the transport distance short. However, it must be noted that the feedstocks for bioethanol and biodiesel consist largely of renewable raw materials. The amount of residual material therefore depends on how much renewable raw material was used.

6. Residues from food industry

- Breweries
- Distilleries
- Bread and bakery products production
- Ready meals production
- Fish processing
- Meat processing
- Feed production
- Vegetable processing

- Grain processing
- Coffee production
- Potato processing
- Milk processing
- Fruit processing
- Starch production
- Tobacco processing
- Sugar production
- Malting plants
- Wineries
- Oil mills

Here too, the residual materials are produced directly in the industrial plants. Therefore, it must be weighed up whether the resulting residual materials would be sufficient for the operation of a biogas plant.

7. Municipal waste and sewage sludge

- Biogenic fraction of sewage, screenings and grit traps
- Biogenic fraction of wastewater
- Biogenic fraction of used textiles
- Biogenic fraction of street sweepings
- Biogenic waste from private households
- Green waste
- Sewage sludge from municipal wastewater treatment plants
- Kitchen and canteen waste

In Germany, municipal waste is either collected separately through the "bio garbage can" for a fee, transported by private individuals to composting plants as compost, or composted in one's own garden if possible. When biomass waste is collected, it is often worthwhile to operate a biogas plant. In this way, the Berliner Stadtreinigungsbetriebe ferments almost 70,000 tons of biowaste into biogas every year at the biogas plant in the Ruhleben district of Berlin. For a bio garbage can for a residential unit of 120 liters, a fee of 12 EUR per quarter must be paid for collection (14-day collection). The collection is carried out by waste collection vehicles.

3.2 State of the art methods for biomass collection, logistics and conversation

The **collection of biomass** occurs on the location of occurance of the biomass. For field fruits, the harvest of the biomass is the first collection step. With wastes and residues, collection of biomass took place before and the remains are stored on site of the previous processing. The appropriate method for biomass collection heavily depends on the nature of biomass and the desired moisture level.

Storage is necessary to synchronize timing of the occurance of biomass with the biofuel production plan. Storage can occur in the fields, in the farms, in centralized storage sites, or before the processes in a biorefinery. It is important to note that storage is a buffer between the occurance and usage in the biorefineries. Suitable storage could reduce dry matter loss and protect biomass against the indoor/outdoor condition.

Preprocessing or pretreatment allows to improve the quality of preservation and handling and to reduce transportation costs by increasing density and reducing degradations. There are many type of pretreatments such as ensilaging, pelletisation, torrefaction, and pyrolysis. These pretreatments aim to reduce moisture, stabilize products and increase its calorific value and yield solid uniform products.

Establishing efficient biomass supply chains can be done by cathegorized decision-making in supply chain management into three levels according to the degree of importance and the planning horizon such as strategic, tactical and operational decisions (Figure 9).

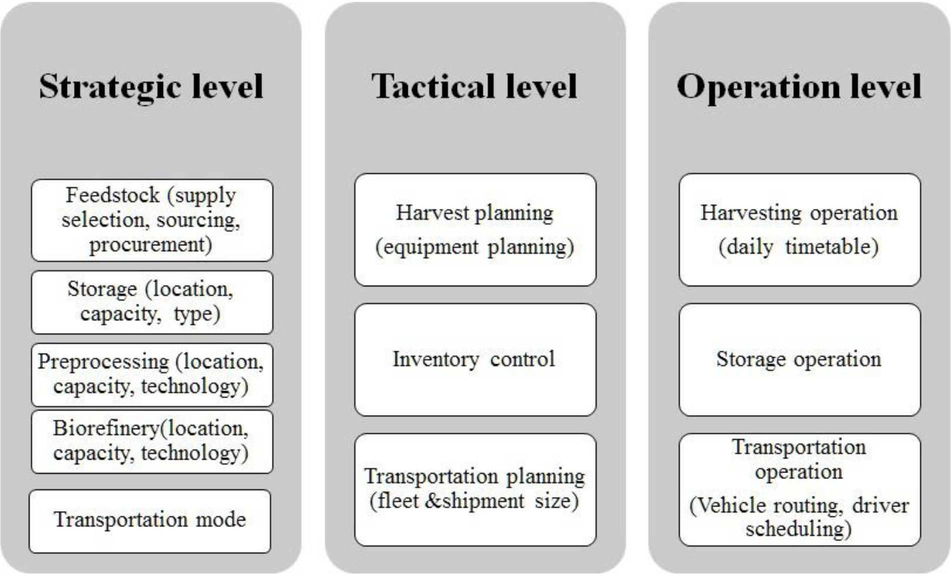

Figure 9: Decicion making categories[22]

The strategic level aims to identify promising production technologies, biomass preprocessing techniques, determining the capacity and location, the optimal configuration of logistics network for specific biomass supply chains. Different approaches have been made using mathematical models based on information of GIS as a main support, as described in chapter 2.

The tactical decisions level is related to medium-term decisions such as production planning, logistics planning (number of vehicles and workers), transportation mode and definition of safety stock level. Therefore mathematical models are used calculating optimal transportation routes for minimizing transportation costs, since they can make up 25 to 50 percent of the total logistics costs of a supply chain.[23]

The operational level aims on short-term decision making, such as production and logistic planning on a daily basis. Here too, mathematical models are used combined with geo-spatial analysis.

In general, deterministic optimization models are used to perform complex “what-if” scenarios based on different input conditions, calculated on commercially available solvers such as CPLEX, AIMMS, and AMPL.

3.3 Coupling of material-energetic use of biomass streams

The decision of prefereable future use pathes of biomass in energetic and material use is higly complex and dependend of several factors as shown in the sections before. Future conversion technologies as discussed in chapter 5 “Best available and state of the art technologies of Germany should be highly efficient while avoiding competition with other usages. In general it is not sufficient to optimize single usage pathways, but instead have a deeper look into the various byproducts. Coupling energetic and material use can benefit both uses and avoid use competition. A common concept is the biorefinery.

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[22] Duc Huy Nguyen. Study on biomass supply chain planning and inventory control of perishable products. Other. Université de Technologie de Troyes, 2019.
[23] A New Tactical Optimization Model For Bioenergy Supply Chain, Ba Birome Holo, 2015

A common definition and understanding of such refineries is given by the IEA Bioenergy in Task 42[24]:

Biorefining is the sustainable processing of biomass into a spectrum of marketable bio-based products (BBP) and bioenergy.

In any case, processing involves the separation of material flows, which should not be purely physical. The processing can follow two principles:

On one hand, the separation of the feedstock down to the molecular level, on the other hand, existing structures and bonds can be used. More than one end product with high added value is generated: in addition to the generation of net energy, a main product is also used materially.

The IEA definition includes the following key elements:

- **Sustainable**: maximising economics, socially acceptable, optimal environmental performance
- **Processing**: upstream processing, transformation, fractionation, thermo- chemical and biochemical conversion, extraction, separation, downstream processing
- **Biomass**: residues, crops, algae, gras
- **Spectrum**: multiple product outlets
- **Marketable**: volumes, prices
- **Bio-based Products**: food, feed, chemicals, materials
- **Bioenergy**: fuels, power, heat

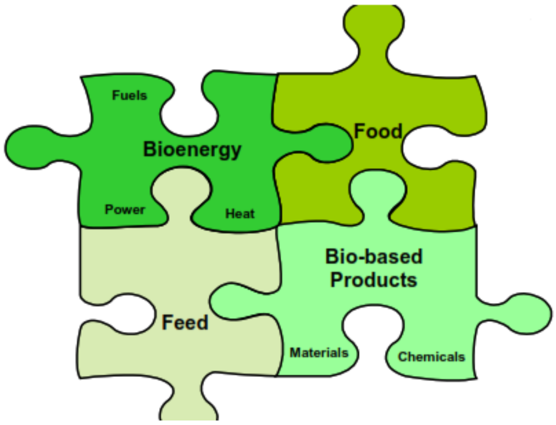

Figure 10: Spectrum of biomass utilization pathways

In general product-driven (PDB) and energy-driven biorefineries (EDB) can be distinguished.

PDB: main goal is the production of one/more bio-based products; process residues are used to produce bioenergy for internal/external use.

EDB: main goal is the production of one/more energy carriers (fuels, power and/or heat); process residues are valorised to BBP to maximise the economic profitability of the overall process.

In context of developing bioeconomy concepts, existing biomass based energy concepts and propably PDBs will have to adopt the valuation process of biomass. This involves a shift from the production of a single product, such as biofuels or electricity, to the production of a range of bio-based products, including fuels, chemicals, and materials. This shift towards a biorefinery concept will result in the utilization of the entire biomass feedstock, including non-food crops and waste streams, to create a range of value-added products.

One major difference in the biorefinery concept is that it is more sustainable and environmentally friendly than traditional energy production methods. By utilizing the entire biomass feedstock, biorefineries can reduce waste and increase efficiency, resulting in a lower carbon footprint. Additionally, the production of a range of products can help to diversify revenue streams and increase profitability.

Existing facilities will need to adapt to the biorefinery concept by upgrading their infrastructure and equipment to accommodate the production of a range of products. This may involve retrofitting existing facilities or building new facilities altogether as well as the need to invest in research and development to identify new products and technologies that can be produced from biomass feedstocks, while still produce energy from waste and residue

[24] IEA Bioenergy (2010): Biorefineries Co-production of Food, Feed, Chemicals, Materials, Fuels, Power and Heat from Biomass. Online available at http://edepot.wur.nl/142932. Accessed 12.10.2023.

Overall, the shift towards a biorefinery concept represents a significant opportunity for biomass-based energy companies to diversify their revenue streams and increase their sustainability by reducing their environmental impact.

Several concepts for comparison and their costs and revenue structures are shown in chapter 3.5.

Further references: BioCouple: Kopplung der stofflich / energetischen Nutzung von Biomasse – Analyse und Bewertung der Konzepte und der Einbindung in bestehende Bereitstellungs- und Nutzungsszenarien, Wuppertal, Oberhausen, Darmstadt, Juni 2011

3.4 Integration of bioenergy systems on municipal level

On municipal level, the integration of bioenergy systems on a different level can be addressed. This applies to field of public services like waste collection and disposal as well as interconnected biomass value chains as mentioned before on the principle of biorefineries.

Waste disposal is governed by a number of European regulations and directives, whereby the former automatically apply to each of the member states, while the latter must be separately transposed into national law by each member state. The basis of this legal framework is the Waste Framework Directive (2008/98/EC), which defines the main waste-related terms, lays down a five-step waste hierarchy, and contains key provisions for German waste disposal law.[25]

The Directive was adopted into german law in the **Energy Industry Act (EnWG)**

In Germany, the Energy Industry Act (EnWG) regulates the framework conditions for the generation, distribution and use of energy. However, there are no specific provisions on the energetic use of biogenic sources such as residual materials from industrial processing and biogenic waste. The legal basis for the use of these sources can be found in other laws such as the Renewable Energy Sources Act (EEG) or the Circular Economy Act (KrWG).

Figure 11: Five step waste hierarchy

The EnWG defines the legal framework for the organization and operation of energy supply networks. It regulates the rights and obligations of network operators, access to networks, security of supply and the expansion of energy networks. The Act ensures that access to the energy supply networks is non-discriminatory and transparent for all market participants.

The EnWG also defines the duties and powers of the energy regulatory authority, which in Germany is the Federal Network Agency (BNetzA). The regulatory authority monitors compliance with the statutory requirements, particularly with regard to network regulation and tariff setting.

With regard to the use of biogenic sources for energy, there are no explicit provisions in the EnWG. However, biogas production and the injection of biogas into the gas grid are indirectly regulated by the EEG and other regulations. The EEG promotes the expansion of renewable energies, which includes biogas, and regulates, among other things, the feed-in tariff for biogas plants. The Gas Network Access Ordinance (GasNZV) regulates the access of biogas to the gas network and sets the framework for cost sharing and bearing of the network connection costs and guarantees non-discriminatory access to the gas network.

In addition, aspects of the energetic use of biogenic sources are also regulated by the KrWG. The KrWG promotes the circular economy and, among other things, defines the framework conditions for the recycling of waste. It may contain regulations that affect the energetic use of residual materials from industrial processing and biogenic waste.

In summary, the Energy Industry Act (EnWG) in Germany establishes the legal framework for the organization and operation of energy supply networks. However, it does not contain specific provisions on the energetic use of biogenic sources such as residual materials from industrial processing and biogenic waste. These are regulated in other laws such as the Renewable Energy Sources Act (EEG) and the Circular Economy Act (KrWG).

[25] European Comission (2022): Waste Framework Directive. Online available at: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en. Accessed 12.10.2023.

3.4.1 Renewable Energy Sources Act

Electricity can be generated from solid, liquid and gaseous biomass. However, gaseous biomass in biogas plants accounts for the largest share of bioenergy generation. Electricity generated this way was first remunerated in 1990 by the Electricity Feed Act. With the introduction of the Renewable Energy Sources Act in 2000, the compensation rates were raised considerably and the priority purchase and compensation of electricity from RE by the grid operator was regulated. Since then, electricity generation from biomass has been subject to a minimum remuneration rate per unit of electricity generated with a guaranteed remuneration period of 20 years from commissioning. This created investment security and consequently led to a continuous expansion of plants. The prerequisite for the remuneration of electricity from biogas is the use of biomass within the meaning of the Biomass Ordinance. This regulates which substances are considered as biomass, which technical processes can be used to generate electricity and which sustainability requirements must be met when generating electricity from biomass. For liquid biomass used to generate electricity under the Renewable Energy Sources Act, the Biomass Electricity Sustainability Ordinance has also applied since 2009. In addition, the **Fertilizer application Ordinance (Düngeverordnung DüV)** regulates professional practice in the application of fermentation products (fermented biogas substrates), which can be used as high-quality organic fertilizers if they are uncontaminated and originate from agricultural biogas plants. Plant operators must also be able to prove through the Fertilizer application Ordinance that farm manure and fermentation residues can be stored temporarily for at least two to nine months (§12 Fertilize application Ordinance), which **increases the pressure** on the storage capacities of biogas plants and the investment volume increased.

With the amendment of the *Renewable Energy Sources Act 2004,* a **biomass bonus** was introduced, which **led to enlargements of the plants in terms of electrical output** as well as to the specialization on "renewable raw materials plants". As a result, a **manure bonus** (an additional bonus if input was 30 percent share of manure) was implemented with the *Renewable Energy Sources Act 2009* and the focus was placed on smaller plants. Furthermore, the maximum compensation was reduced and a **flexibility bonus** was introduced to promote variable plant operation. In addition, the gas processing bonus promoted the processing of gas to natural gas levels. With the *Renewable Energy Sources Act 2012,* the focus shifted mainly to waste and residual materials, so that corn and grain were only allowed to have a maximum share of 60 percent in the substrate mix at that time. In addition, biogas and biomethane plants were required to market their electricity directly if the output was over 750 kW and the plant was commissioned after Jan. 1, 2014. In the *Renewable Energy Sources Act 2014,* the remuneration structure was again reduced and lowered, so that only a basic remuneration was granted. The separate remuneration for biomass (feedstock remuneration classes I and II) and the gas processing bonus were then dropped. The flexibility premium will not be continued for new plants, but there is a flexibility surcharge to provide demand-based electricity generation and to respond to price signals from the electricity market. Overall, the Renewable Energy Sources Act 2012 allowed the share of biomass in electricity generation to increase until the Renewable Energy Sources Act 2014 amendment slowed the increase and expansion of bioenergy plants. In the *Renewable Energy Sources Act 2017* amendment, the EEG was transformed from a fixed remuneration model to a tendering model with overall lower remuneration, with a flexibile system being fundamental. However, the tender volume for biomass was hardly utilized in the last years, due to the short-term introduction of two tender rounds per year and a difficult implementation period of two years for subsidized new plants.

How does the tendering model work?

The Federal Network Agency conducts tenders to determine the value to be applied for electricity from biomass plants. The determined value to be applied serves as the basis for calculating the amount of the payment claim (market premium).

The claiming of a payment for electricity from newly commissioned biomass plants with an installed capacity of 151 kilowatts to 20 megawatts is generally only possible through tenders. Existing biomass plants can also participate with a lower installed capacity. Newly commissioned biomass plants with an installed capacity of 150 kW or less are exempt from the tendering requirement and can be subsidized under the provisions of the EEG 2021. Biomass plants above 20 MW are not eligible for support under the EEG. The conditions for participation in the biomass tender are significantly more complex than for the other renewable technologies - not only because existing plants can also bid. It is therefore much more difficult to calculate at which bid level a successful participation is likely.

For example, the biomass plant operator specifies in its bid, among other things, a precise bid amount (kWh) and a precise bid value (in ct/kWh). Subsequently, it will be decided by the award procedure whether and in which amount an award has been received. The award procedure runs in up to three steps:

1. all bids that comply with the form and deadline are ranked by the Federal Network Agency in ascending order of bid value.
2. If there are two or more bids with the same bid value, the bid with the lower volume shall be awarded first. the bid with the lower volume shall be awarded first.

3. if there are two or more bids with the same bid value and the same volume, the order is decided by lot.

The order is important because bids are accepted only until the bids are accepted until the volume limit - 600 megawatts of capacity to be installed in 2023 - is reached or exceeded.

The current Renewable Energy Sources Act 2021 and more recently 2023 do focus much more on giving existing plants with favourable heat concepts an opportunity to remain in business while sorting out plants with high energy crop usage and poor heat concepts. With the necessity to take part in a tender, the most efficient concepts are in advantage. Additionally amendments focussed on the sharpening of flexibility and grid efficient operation by adjusting flexibility premium, surcharge and cap as well as adjusting support for specific concepts.

In summary, the EEG has been and continues to be a successful tool for technology development and financing to expand RE in the German electricity sector. While tariff rates for photovoltaic and wind could be lowered after a certain funding period, this has not been possible for bioenergy generation. This is due to the fact that bioenergy is coupled with other areas such as landscape management, nature conservation, resource policy, and emission control in addition to pure electricity production. In particular, increased agricultural prices and higher technical and emission control plant requirements led to higher costs. The current framework conditions therefore leave open the question of what options existing plants have after the 20-year remuneration period.

Waste and manure usage in biogas in the framework of the EEG

Waste-to-energy plants are treated as a separate category within the EEG. They generate energy from the incineration or gasification of waste. Biogenic waste was to be increasingly fed into anaerobic digestion instead of composting with the introduction of a separate article and increased remuneration entitlement. High transport costs and worsened conditions, e.g. due to TA Luft requirements, supported this goal. Since waste collection is organized by the municipality and has to be put out to tender at regular intervals, the implementation of a biogas plant is only possible within a long-term strategic support by the municipality. In addition, the amount and quality of waste is subject to seasonal fluctuations, which makes the operation and projected revenues of the plant difficult to calculate.

The special Biowaste remuneration could be achieved by using at least 90 percent of input from the following 3 waste codes:

Waste code number 20 02 01: Biowaste from agriculture and horticulture.

> This includes wastes of plant or animal origin generated on farms or in horticulture. This includes, for example, waste from plant residues, green cuttings, agricultural harvest residues, manure or slurry.

Waste code number 20 03 01: Biowaste from food and beverage production.

> Refers to wastes generated during the production of food and beverages. These can be, for example, organic residues, waste from fruits and vegetables, peels, coffee grounds, tea residues or waste from breweries or dairies.

Waste code number 20 03 02: Wastes from the preparation and processing of meat, fish and other food of animal origin.

> This includes wastes generated during the processing and preparation of meat, fish or other food of animal origin. This includes, for example, bones, fish scraps, animal by-products, offal or unprocessed food scraps.

While manure is part of the waste codes above, an additional bonus outside of the waste remuneration was created to incentivise the use of manure in biogas plants.

The so-called "manure bonus" refers to a special compensation scheme for biogas plants that use manure or other substrates of animal origin to produce biogas.

A promoted concept is the use of at least 30 mass percent of liquid manure in regular biogas plants. If the limit is met, the feed-in tariff for the entire plant is increased. This is a particularly attractive concept for agricultural biogas plants with livestock where manure is produced anyway and must be stored until it is spread.

Another concept is the so called small manure plants. With this concept, plants up to a certain size (150 kWelectric) were especially promoted, which used at least 80 percent agricultural residues. This concept was aimed primarily at small farms such as those in the south of Germany. For the usage of manure in biogas plants several additional ordinances apply.

3.4.2 Fertilizer application Ordinance (Düngeverordnung DüV)

The Fertilizer Ordinance regulates the handling of fertilizers and the use of fertilizers on agricultural land in Germany. It aims to protect water bodies from excessive pollution from nutrients from agricultural sources.

With regard to biogas plants and fermentation residues, the Fertilizer application Ordinance contains specific regulations. Biogas plants produce biogas by fermenting organic substances such as liquid manure, manure, energy crops or other biogenic waste. The regulations relating to biogas plants and digestate mainly concern the utilization and use of digestate as fertiliser.

The Ordinance sets limit values for certain nutrients such as nitrogen and phosphorus, which must be observed when spreading fermentation residues. The fermentation residues may only be applied in a certain ratio to the agricultural land in order to avoid over-fertilization. There are also specifications for the storage and spreading of the fermentation residues in order to prevent nutrients from being washed out into water bodies.

With regard to the consideration of biogenic waste, the ordinance aims to promote the sustainable utilization of biomass. Biogenic waste can be used as fertilizer or soil conditioner. However, they are subject to the same specifications as other fertilizers in terms of their nutrient composition and application quantities in order to ensure environmentally friendly application.

Circular Economy Act (KrWG) (chapter 4.2.2), which is today Germany's main waste disposal statute. For specific types of wastes, specific regulations where made to address disposal of those wastes (for example batteries, electronics and vehicles).[26]

In a federal state like Germany, waste management is a task that can be regulated further by the several states, but only as far as it is not already governed by national law, such as: which entities are subject to waste disposal obligations; authorizing bodies for waste disposal matters and municipal waste disposal ordinances.

Differenciation of waste types:

Household waste:

Household waste is defined as residual waste that accumulates in households and is collected by means of a container system through the municipal household waste collection system and sent for further disposal. The non-recycled residues from sorting, composting and fermentation plants and the disposed residues from the sorting of sales packaging from dual systems are allocated to this fraction.

Commercial waste:

Commercial waste is waste that does not come from households but is generated in the commercial sector. It comes from crafts, the service sector or trade. It is often similar to waste from private households: There is paper, organic waste, residual waste and waste that is disposed of in the yellow bag (plastics). For commercial waste disposal and waste from businesses and industry, hazardous waste is also relevant.

Agricultural waste:

The disposal of agricultural waste must be environmentally sound and sustainable. Usually this waste is used on agricultural land or disposed of properly.

Depending on the type of waste, different regulations apply. Animal waste such as animal carcasses or leftovers may not be spread on agricultural land, but must be disposed of in special facilities.

Plant waste, manure and digestate can generally be used on agricultural land as fertiliser or for soil improvement, provided it meets certain requirements. These are regulated, among other things, in the PflAbfV.

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[26] European Comission (2022): Waste Framework Directive. Online available at: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en. Accessed 12.10.2023.

The difference between the collection of commercial and private waste lies primarily in the responsibility and organisation of disposal. While the disposal of private households is organised by the municipalities, companies have to take care of the disposal of their waste independently and order it from private disposal companies.

3.4.3 Municipal waste disposal law

The collection and recovery of household waste at the municipal level are governed by municipal ordinances concerning matters such as usage and integration into the public system, as well as municipal garbage collection charges.

There is a wide variety of biomass potential from agriculture, forestry and waste management, which are available for the supply side for mobilization and use within decentralized, regional utilization.

However, there is also great biomass potential in the area of biogenic residues, which also accumulates in all municipalities in a wide variety of fractions and can be used energetically for the municipal supply of electricity, heat and fuel, e.g.:

- Biogenic residues from the domestic, commercial and industrial sectors
- Residual forest wood that is produced during the processing of forest wood
- By-products of sawmills (e.g. sawdust, wood chips)
- Waste wood (e.g. wooden storage pallets, old wooden furniture)
- Landscape maintenance materials and municipal green waste
- Nature conservation and landscape maintenance materials
- Crop residues (e.g. straw)
- Animal excrements (e.g. liquid manure, dung)
- By-products and waste from food production (e.g. potato peels, grape pomace)
- Biowaste from the food sector, e.g. catering waste, used fats, etc.)
- Other organic waste (e.g. sewage sludge, municipal waste).

Particularly in medium-sized, larger and urban municipalities biomass potentials could be mobilized and used for sustainable and efficient energy purposes in the sense of sustainable and efficient recycling.

On the other hand, in addition to the opportunities outlined above for municipalities on the supply side also on the demand side in each municipality, there is a wide range of demand of sustainably generated electricity, heat and fuels from biomass. Municipalities thus have the opportunity to free themselves from the cost spiral through of fossile energy which will become more expensive in the future and thus achieve regional CO_2 savings as well as generate local investments and jobs.

Larger municipalities and cities in particular have the opportunity to use the energetic use of existing biogenic residues to reduce their municipal waste disposal costs and generate additional climate-friendly and efficient value.

Experience in Germany has shown, that the main reason for untouched biomass potentials were information and deficits among the relevant municipal decision makers as well as insufficient networking with the necessary bioenergy experts and other municipal decision-makers interested in the topic.

In a project called “BioKommunal - Establishment of a nationwide municipal bioenergy network and mobilization measures for an increased use of bioenergy in municipalities” key factors for a succesfull mobilisation of biomass potentials where identified as follows:

- The remunicipalization of the energy industry is a central challenge of the energy transition.
- Municipalities are an important and decisive success factor for the success of the energy transition.
- A sustainable, environmentally compatible and secure energy supply is one of the most important very central municipal issues.

- There is a huge interest on the part of municipalities and regional institutions in actively shaping the energy transition.
- This requires innovative participation models (new municipal utilities, energy cooperatives, citizen participation models, etc.).
- The energy turnaround and the market expansion of renewable energies and bioenergy must be accompanied by an intensive communication and information campaign at the municipal level.
- At the municipal level, there is a great deal of interest in regional bioenergy projects, but also considerable information deficits.
- At the same time, however, there are also various problems of acceptance and reservations towards bioenergy (justified and unjustified).
- Municipal involvement as well as intensive information and education are the success guarantee for a sustainable social acceptance of the bioenergy market expansion.
- Energy transition, the expansion the renewables energies and new bioenergy projects must be much more intensively communicative accompanied, to ensure social acceptance.
- Biogenic residual material fractions are still insufficiently developed and often not sensibly used.
- Interfaces between energy- and waste management are often inadequate or not available and must therefore be optimized.
- Only with biogenic residual materials the bioenergy expansion targets can not be achieved, agri- and forestry biomass must also be intensively used.
- Efficiency improvements along the entire value chain and sustainable utilization concepts are the key challenges for the bioenergy sector.

3.4.4 Commercial and industrial waste disposal

Commercial and industrial waste disposal usally refers to one of the following waste types:

- Residues from meat processing and rendering (slaughterhouse waste, bone meal, animal fats, animal meal)
- Residues from the food and luxury food industry (pomace from beverage production, slops and whey, press residues from oil extraction, residues from breweries)
- Residues from the water industry (grease separator contents, sewage sludge, other waste from sewage treatment plants)

Due to the wide varity of characteristics of those wastes, not all of them are suitable for transportation and storage for bioenergy purposes.

Table 4: Structure, place and collction of commercial and industrial waste streams

Material stream	Structure and impurities	Accrual	
		Place	Collection
Used grease/waste oil	Liquid	Private household, gastronomy, food industry	Container, grease separator
black liquor	Grain size: fine Sulfur content in lignin, Water content	Pulp production	-
Solid industrial substrates, Husks, dusts, kernels, stalks, Nut shells,	Grain size: irregular, rather coarser potentially microplastics, Soil material, stones	processing industry	Containers and bags

Slaughter by-products (animal meal, animal fat,)	Grain size: fine Wastewater generation in Slaughterhouses can be contaminated to varying degrees by organic substances	By-products from slaughtering and Food industry	Containers and bags
Kitchen and canteen waste or catering waste	Grain size: fine to medium Type of impurity and impurity content: Packaging content	Gastronomy business, companies with canteens	are disposed of - as commercial waste - by the waste is disposed of by the waste producer on his own responsibility, usually by commissioning a company to dispose of it. Shifts to the organic waste bin cannot be ruled out.

3.5 Profitability of selected processes and systems (including the costs for collection, conditioning and transport) for the energetic use of different biogenic residues and waste[27]

In this chapter different types of biorefineries are discussed regarding to their profitability.

Type I: Single-platform (starch) biorefinery for bioethanol and animal feed from starchy grains.

In this type of biorefinery, wheat is processed into bioethanol and animal feed. The process is mature and is used commercially in many plants in Germany. A typical plant (in terms of approximate scale and technical data) is described in Table 5.

Table 5: Scale and technical data of single-platform biorefinery for bioethanol

Technical parameters	Unit	2020	2030
Energy content input	MWh/a	1.112.020	1.112.020
Biomass Input	t/a	236.600	236.600
Energy content output	MWh/a	677.380	722.813
Power Input	MW	139	139
Power Output	MW	85	90
Efficiency in relation to main product	%	61	65
Typical Utilization	h/a	8000	8000
Lifespan	a	20	20
Ethanol	t/a	91.000	97.100
dried distillers grains and solubles	t/a	91.000	97.100

The investment of a plant as described here is estimated at 66 million € for the initial state in 2020. This corresponds to specific investment costs of 775€/kW_{out} for the main product ethanol.

The fixed costs of such a plant are calculated according to the method manual developed in the BMU funding program[28] depending on the amount of the investment. It is assumed that annually for maintenance and cleaning two percent of the

[27] BioCouple (2010): Kopplung der stofflich/energetischen Nutzung von Biomasse – Analyse und Bewertung der Konzepte und der Einbindung in bestehende Bereitstellungs- und Nutzungsszenarien. Online available at: https://www.energetische-biomassenutzung.de/fileadmin/Steckbriefe/dokumente/03KB006_BioCouple_Endbericht.pdf. Accessed 01.12.2022.
[28] Thrän, D., Fischer, E. et al. (2010). Methodenhandbuch: Methoden zur stoffstromorientierten Beurteilung für Vorhaben im Rahmen des BMU-Förderprogramms "Energetische Biomassenutzung". Leipzig, DBFZ.

investment, for administration 0.75 percent, for insurance without construction one percent and for "contingencies" and 0.5 percent of the investment are incurred. The annual personnel costs are calculated at 50,000€/year and a need for 0.25 employees/MW_{out}. For this type of plant, this results in annual fixed costs of approximately 3.8 million € per year. Applied to the main product, this corresponds to approx. 45€/kW*a.

Variable costs, excluding grain costs, are estimated with 5€/MWh and result mainly from the plant's electricity requirements.

For 2030, it is assumed that investments can be reduced to 54 million € and annual fixed costs can be reduced to 2.5 percent of investments. The specific investment costs for ethanol are 750€/kW_{out}. In addition, one worker is saved due to better process automation. This leads to a reduction of the annual fixed costs in 2030 to about 2.5 million €. In relation to the output of the plant (ethanol purchase), this corresponds to 45€/kW*a in 2020 and 19€/kW*a in 2030.

Table 6: Costs of single-platform biorefinery for bioethanol

Costs	Unit	2020	2030
specific investment	€/kW_{out}	775	750
Investment	Mio. €	66	64
Fixed Costs	€/a	3.847.309	2.587.610
Employees	Quantity	21	20
Fixed costs in relation to performance Output	€/kW*a	45,4	18,6
variable costs	€/MWh	5	5

Type II: Single-platform (oil) biorefinery for biodiesel, animal feed and glycerin from oleaginous plant seeds

This generic biorefinery type processes rapeseed into rapeseed methyl ester (biodiesel), crude glycerol and rapeseed cake. This process is also currently already commercially available and is used at many locations in Germany.

Table 7: Scale and technical data of single-platform biorefinery for biodiesel

Technical parameters	Unit	2020	2030
Energy content input	MWh/a	3.924.319	3.924.319
Biomass Input	t/a	576.635	576.635
Energy content output	MWh/a	2.472.248	2.629.294
Power Input	MW	491	491
Power Output	MW	309	329
Efficiency in relation to main product	%	63	67
Typical Utilization	h/a	8000	8000
Lifespan	a	20	20
Biodiesel (Rapeseed methyl ester)	t/a	239.880	255.118
Raw glycerol II	t/a	23.988	27.132
Rapeseed cake	t/a	352.120	374.487

According to a study by the Institute for Economic Research at the University of Munich[29], the investment of such a plant (oil mill and biodiesel production) in relation to the total capacity of the plant amounts to approx. 400€/t biodiesel. For the plant assumed here, this results in investments of 96 million €.

The fixed costs of such a plant are also calculated according to the method manual developed in the BMU funding program[30], depending on the amount of the investment. It is assumed that annually for maintenance and cleaning two percent of the investment, for administration 0.75 percent, for insurance without construction one percent and for contingencies 0.5 percent

[29] ifo (2009). Gesamtwirtschaftliche Effekte der Förderung von Biodiesel. München, Institut für Wirtschaftsforschung an der Universität München

[30] Thrän, D., Fischer, E. et al. (2010). Methodenhandbuch: Methoden zur stoffstromorientierten Beurteilung für Vorhaben im Rahmen des BMU-Förderprogramms "Energetische Biomassenutzung". Leipzig, DBFZ.

of the investment are incurred. The annual personnel costs are calculated at 50,000€/year and a need for 0.25 employee/MW_{out}. For this type of plant, the annual fixed costs amount to approx. 8 million € in 2020. The variable costs result primarily from the costs for the catalyst and the operating material methanol. The catalyst causes approx. two percent of the costs for the rapeseed oil, for the methanol costs of 295€/t are calculated. This results in variable costs without biomass costs of about 22€/kWh.

No reduction of investments over time is assumed, so that these are also estimated at 96 million € for 2030. With regard to the utilization of the plant, 8000 hours per year is also assumed for 2030, resulting in specific investments in the amount of 155 €/KWout for 2030. It should be borne in mind that the utilization rate of biodiesel plants in Germany was only about 56 percent in 2008, which means significantly higher specific investments. It is assumed that the annual fixed costs can be reduced to 2.5 percent of the investments and that the personnel requirement remains constant at 77 employees. This results in fixed costs of 6.2 million euros in 2030.

Table 8: Costs of single-platform biorefinery for biodiesel

Costs	Unit	2020	2030
specific investment	€/kW_{out}	165	155
employees	Quantity	77	77
Fixed costs in relation to performance Output	€/kW*a	25,7	12,7
variable costs o. main input	€/MWh	21,9	21,9

Type III: Single-platform (synthesis gas) biorefinery for synthetic biofuels, electricity and naphtha from residual wood/COP.

The plant presented here processes wood into synthetic biofuels, electricity and naphtha. The process is not yet commercially available; only a demonstration plant is currently in operation in Germany.

Table 9: Scale and technical data of single-platform biorefinery for synthetic biofuels, electricity and naphtha

Technical parameters	Unit	2020	2030
Energy content input	MWh/a	3.885.000	8.000.000
Biomass Input	t/a	1.080.000	2.154.012
Energy content output	MWh/a	1.174.167	4.000.000
Power Input	MW	518	1.000
Power Output	MW	229	500
Efficiency in relation to main product	%	44,1	50
Typical Utilization	h/a	7500	8000
Lifespan	a	20	20
FT-Diesel	t/a	140.250	372.250
Naphta	t/a	28.800	59.300
Electricity	GWh/a	81	300

The investment of such a biorefinery type is estimated at 940 million €. The fixed costs are estimated at three percent of the investments plus personnel costs amounting to annual costs of 50,000 € for 70 workers. Variable costs are influenced by the consumption of catalysts as well as other operating and auxiliary materials and are estimated at 65 percent of the biomass supply costs and thus about 15 €/MWh based on cost calculations by the operator.

As plant size increases, capital expenditures also increase from 940 million € to 1,250 million € in 2030. For the year 2030, 2.5 percent of the investments are assumed for the fixed costs in addition to 60 persons with costs of 50,000 € each. The reduction in personnel requirements results from increasing automation of the plants.

Table 10: Costs of single-platform biorefinery for synthetic biofuels, electricity and naphtha

Costs	Unit	2020	2030
specific investment	€/kW_{out}	4.102	2.500
employees	Quantity	70	60
Fixed costs in relation to performance Output	€/kW*a	138,4	34
variable costs o. main input	€/MWh	15	15

Type IV: Three-platform (hemicellulose, cellulose and lignin) biorefinery for bioethanol and chemicals (phenols) from straw hay ends Automation of the plants.

Table 11: Scale and technical data of three-platform biorefinery for bioethanol and chemicals

Technical parameters	Unit	2020	2030
Energy content input	MWh/a	1.739.965	2.000.000
Biomass Input	t/a	438.278	516.529
Energy content output	MWh/a	750.000	1.000.000
Power Input	MW	232	250
Power Output	MW	100	125
Efficiency in relation to main product	%	43,1	50
Typical Utilization	h/a	7500	8000
Lifespan	a	15	20
Bioethanol	t/a	100.756	134.341
Phenol	t/a	29.628	34.917

This type of plant processes straw into bioethanol and phenolic compounds, which are used as raw materials for the synthesis of duromers. Specific applications are phenolic resin binders for applications in wood-based materials such as MDF, particleboard or plywood.[31] Another possibility for the material use of lignin is, for example, the compounding of polylactic acid (PLA) with a lignin fraction using maleic acid as a coupler. For the generic biorefinery, it is assumed that the steam explosion process is used to pre-treat the straw.

The costs of straw supply strongly depend on the size of the catchment area, which is necessary to supply straw in sufficient quantities. In addition, it must be considered that straw is only produced seasonally, so that high costs for storing the biomass can arise.

The cost of ethanol production from lignocellulosics is particularly influenced by the choice of input material, the size of the ethanol plant, the conversion efficiency, and the level of investment costs.[32] Total production costs were composed of 50 to 55 percent for input material, 30 to 40 percent for investment costs, and 10 percent for variable costs.[33] The variable costs are dominated in particular by the cost of enzymes.

Table 12: Costs of three-platform biorefinery for bioethanol and chemicals

Costs	Unit	2020	2030
specific investment	€/kW_{out}	4.272	3.000
employees	Quantity	50	50
Fixed costs in relation to performance Output	€/kW*a	207	48

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[31] Ehrich, K., J. Michels, et al. (2009). Pilotprojekt "Lignocellulose-Bioraffinerie" Gemeinsamer Schlussbericht zu den wissenschaftlich-technischen Ergebnissen aller Teilvorhaben. Frankfurt am Main, DECHEMA.

[32] Gnansounou, E. and A. Dauriat (2010). "Techno-economic analysis of lignocellulosic ethanol: A review." Bioresource Technology 101(13): 4980-4991.

[33] Gnansounou, E. and A. Dauriat (2010). "Techno-economic analysis of lignocellulosic ethanol: A review." Bioresource Technology 101(13): 4980-4991.

variable costs o. main input	€/MWh	21	15

Type V: Two-platform "green" (organic juices and press cake) biorefinery for electricity, insulation, fiber-reinforced plastics, and fertilizer from grass.

Table 13: Scale and technical data of two-platform biorefinery for electricity, insulation, fiber-reinforced plastics, and fertilizer

Technical parameters	Unit	2020	2030
Energy content input	MWh/a	49.928	49.928
Biomass Input	t/a	45.000	45.000
Energy content output	MWh/a	10.300	11.484
Power Input	MW	6,2	6,2
Power Output	MW	1,3	1,4
Efficiency in relation to main product	%	20,6	23
Typical Utilization	h/a	8000	8000
Lifespan	a	20	20
Fiber-reinforced plastics (FRP)	t/a	2.500	2.500
Insulation materials	t/a	1.410	1.410
Fertilizer	t/a	11.300	11.300
Electricity	GWh/a	10,3	10,3

This generic biorefinery type processes grass into insulating material made from grass fibers, natural fiber-reinforced plastic, fertilizer made from digestate, and electricity and heat from combined heat and power plants. In contrast to the other biorefinery types considered here, this biorefinery type focuses on the material products that are produced from the grass fibers.

The investment of such a plant consisting of grass finishing plant and co-fermentation plant is estimated at 10 million € for 2020 and 7 million € for 2030. Fixed costs are estimated at 625,000 €/year, composed of four employees a 50,000 € plus another 5.25 percent on the investments for maintenance, cleaning, insurance, administration and "contingencies". The variable costs of approx. 160 €/MWh result from the electricity costs as well as costs for PE granulate, which is needed for the production of natural fiber reinforced plastics.

Table 14: Costs of two-platform biorefinery for electricity, insulation, fiber-reinforced plastics, and fertilizer

Costs	Unit	2020	2030
specific investment	€/kW$_{out}$	7.767	5.000
employees	Quantity	4	4
Fixed costs in relation to performance Output	€/kW*a	485	264
variable costs o. main input	€/MWh	158	142

4 Regulation and Support

The energetic use of biogenic resources requires an appropriate regulatory framework ensuring environmentally and economically reasonable use of biomass, which is in accordance with other utilisation options (food, feed, fibre). In the following, corresponding regulation and laws concerning raw material use for energetic purposes in Türkiye and Germany are presented. Existing gaps in regulation and need for further clarifications should be discussed in the next step.

4.1 Turkish regulation, laws and existing funding schemes concerning biogenic resource use for energy production

Investors wishing to participate in the Turkish renewable energy sector have two options: (i) the licensed market which is governed by the Electricity Market Licensing Regulation (the **"Licensing Regulation"**)[34]; and (ii) the unlicensed market for power plants with installed capacities of less than 5 MW[35] which is governed by the Regulation on Unlicensed Generation of Electricity in the Electricity Market (the **"Unlicensed Regulation"**)[36].

During the early stages of the Turkish electricity market, licensed electricity generation constituted an essential part of the entire output. However, along with increased government support and low establishment costs, unlicensed electricity generation gained momentum. Through various incentives including purchase and guarantee mechanisms detailed remarkable investments have been made in the Turkish electricity market. For instance, according to the so-called Installed Power Report[37] by the Turkish Electricity Transmission Corporation ("**TEİAŞ**"), as of December 2022, the number of licensed biomass based power plants (the "**BBPP(s)**") have reached 384 in total which corresponds to an installed capacity of MW 1,921.3. On the other hand, according to such report, 58 unlicenced BBPPs corresponding to an installed capacity of MW 89.9 are operating in the market. It is expected that installed capacities of BBPS will be doubled by 2030 and will reach and overall capacity of GW 7.[38]

4.1.1 Law on the utilization of renewable energy resources for the production of electricity (Law Nr.: 5346)

Purpose

The purpose of the RES Law is to promote the use of renewable energy sources for electricity generation, to incorporate these resources to the economy in a reliable, economical and high-quality manner, to increase resource diversity, to reduce greenhouse gas emissions, to utilise waste, to protect the environment and to develop the manufacturing sector needed to realise these objectives.

Scope

The RES Law sets out the procedures and principles on the establishment and protection of renewable energy resource areas, allocation of land for the purposes of generating electricity as well as introducing the main incentive mechanisms and the certification systems of electrical energy obtained from renewable energy sources.

According to the RES Law, renewable energy sources have been defined as non-fossil renewable energy sources such as hydroelectricity, sunlight, geothermal, biomass, wave, tide and flow energy. Accordingly, any incentive regime applicable to renewable energy sources also applies to BBPPs.

Key points of the RES Law can be summarised as below:

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[34] Published in the Official Gazette dated 2 November 2013 and numbered 28809.
[35] This threshold has been increased from originally 1 MW to 5 MW with the publication of the Presidential Decree dated 9 May 2019 and numbered 1044, published in the Official Gazette dated 10 May 2019 and numbered 30770.
[36] Published in the Official Gazette dated 12 May 2019 and numbered 30772.
[37] Installed Power Report can be accessed through the following link: https://webim.teias.gov.tr/file/a5ec8c53-fad2-4b3d-b056-db93a70a0fa3?download
[38] Güray, B.Ş., Merdan, E. 2022, Türkiye Yenilenebilir Enerji Görünümü 2022, Sabancı University Istanbul International Center for Energy and Climate, pp. 204.

RES Certificate

- According to Article 5 of the RES Law, the Energy Market Regulatory Authority ("**EMRA**") grants a certificate to licensees to monitor the source of the electricity generated by renewable energy sources (the "**RES Certificate**"). The RES Certificate shows that such licensee generates electricity based on renewable energy within the scope of the RES Law and is eligible to benefit from the feed-in tariff support mechanism[39] ("**RES Support Mechanism**" or "**feed-in tariff**") provided by the RES Law.

RES Support Mechanism

- RES Support Mechanism is an incentive introduced with the RES Law in 2005 to make renewable energy investments more preferable for investors. It works as purchase guarantee mechanism being operated by the Energy Exchange Istanbul ("**EXIST**"). RES Certificate holder electricity generation licensees are free to participate in the RES Support Mechanism, nevertheless, once joined, those licensees that have opted to be included in the RES Support Mechanism for a calendar year cannot opt out of such within the same calendar year. While RES Support Mechanism participants still actively engage in electricity sale in the electricity market, their overall income is guaranteed under a fixed tariff (as specified below).
- With the amendments made to RES Law in 2011, the feed-in tariffs and respective local content uplift were determined based on USD cents per kilowatt-hour for a period of 10 years for power plants that commenced operation between 18 May 2005 and 31 December 2015.
- The authority to determine the feed-in tariffs for power plants to commence operations after 31 December 2015 was initially given to the Council of Ministers but with the constitutional amendment made in 2018 then transferred to the President. Accordingly, the feed-in tariff based on USD cents/kWh was extended to power plants that commenced operations between 1 January 2016 and 31 December 2020 by a Council of Ministers decision dated 18 October 2013 and numbered 2013/5625. This situation was also reflected in Article 6 of the RES Law in 2020.
- The decrease in renewable energy investment costs due to technological advances and increased competition in the market as well as other macro-economic factors (such as the devaluation of the Turkish lira) led to a change in policies. Hence, the Presidential Decision dated 29 January 2021 and numbered 3453 (the "**Decision No. 3453**") determined the feed-in tariffs for power plants commencing operations between 1 July 2021 and 31 December 2025 in the local currency (i.e. Turkish lira). A price escalation formula was created to update the Turkish lira denominated feed-in tariffs every three months, coupled with an upper limit in US dollars.
- The most recent change concerning the feed-in tariff, local content uplift and their respective application periods applicable to electricity generation facilities holding a RES Certificate has been made with The Presidential Decision dated 30 April 2023 and numbered 7189[40] (the "**Decision No. 7189**"). According to the Decision No. 7189, generation facilities with RES Certificates that achieve their commercial operation between 1 July 2021 and 31 December 2030 shall benefit from the RES Support Mechanism and local content uplift tariff under Annex-1 and Annex-2 of the Decision No. 7189 (please see Table 2 for the respective tariffs and their application periods). These prices will be updated every three months according to the formula in Annex-2 of the Decision No 7189. The main purpose of the formula is to adapt the new feed-in tariff to increases in investment costs caused by foreign exchange rate fluctuations and inflation to protect investors. One of the key matters of the Decision No. 7189 brought is the introduction of a minimum limit in addition to an upper limit based on USD cents/kWh. This ensures a minimum price guarantee against fluctuations in foreign exchange rates.

Local Content Uplift

- Article 6/B of the RES Law refers to the use of local products in generation facilities that are based on renewable energy sources. To promote the use of domestic equipment in electricity generation facilities based on renewable

[39] Apart from the feed-in tariff and local content uplift, there are certain incentives that do not fall within the scope of electricity sale, i.e. incentives regarding investment period practices and land requirements.
[40] Published in the Official Gazette dated 1 May 2023 and numbered 32177.

energy sources, the principles and procedures regarding the local content uplift to be applied to the feed-in tariff are regulated in the Domestic Equipment Regulation[41] (the "**DER**"). For an applicant to benefit from this uplift, for the equipment specified in Annex-1 of the DER, the aggregate sum in percentage terms of the proportionate value of the integrative parts in the equipment must be at least 55% and, for the equipment specified in Annex-2 of the DER, the aggregate sum of the equipment points must meet at least the minimum score requirement in Annex-2 of the DER (Art. 8(4)(5) of the DER).

Table 15: Feed-in-tariffs by type of generation facility based on RES

Type of Generation Facility based on RES	Feed-in Tariff (TL/MWh)	Feed-in Tariff Application Period (year)	Minimum/ Maximum Feed-in Tariff (USD/MWh)	Local Content Uplift (TL/MWh)	Local Content Uplift Application Period (year)
Landfill Gas / Resources obtained from by-products of waste tire processing	1060	10	49,50/60,50	288	5
Biomethanisation	1730	10	81,1/99	288	5
Thermal Disposal (Municipal wastes, vegetable oil waste, agricultural wastes not suitable for food and feed, non-industrial forest goods except industrial wood, industrial waste sludges and treatment sludges)	1349	10	57,50/80	215,80	5

Table 16: Feed-in-tariffs of the RES Law differentiated by renewable technologies

Type		Feed – in Tariff (TL/MWh)	Duration (Year)	Local Content Uplift (TL/MWh)	Duration (Year)
Hydroelectric	Reservoir	1440	10	288	5
	River Type	1350	10	288	5
	Pumped-Storage	2020	15	384,50	10
Wind	Onshore	1060	10	288	5
	Offshore	1440	10	384,50	5
Geothermal		2020	15	288	5
Solar		1060	10	288	5
Wave/Tide		1350	10	384,50	10
Integrated Electricity Generation Facility to Solar or Wind Power		1250	10	384,50	10

<u>Unlicensed Electricity Generation</u>

- Those electricity market activities that are exempted from the requirement to obtain a generation licence are listed in Article 14 of the Electricity Market Law numbered 6446 (the "**EML**")[42] as follows:

  a) Generation facilities that are not connected to any emergency groups, transmission or distribution systems;

[41] Published in the Official Gazette dated 28 May 2021 and numbered 31494.
[42] Published in the Official Gazette dated 30 March 2013 and numbered 28603.

b) Generation facilities based on renewable energy sources with an installed capacity up to 5 MW[43];

c) Generation facilities, which are established for the use of municipalities' solid waste facilities and the disposal of treatment plants' muds;

d) Micro-cogeneration facilities and cogeneration facilities that meet the productivity rate designated by the Ministry of Energy and Natural Resources (the "**Ministry**") and which fall within the scope of the category determined by EMRA; and

e) Generation facilities based on renewable energy sources that auto-consume the generated electricity without being connected to any transmission or distribution system (i.e. "**off-grid generation**"), whose generation and consumption is measured at the same measurement device.

- The main purpose of the Unlicensed Regulation is to promote power plants that would primarily generate enough power to meet the internal electricity consumption of a facility.
- Regulation on Technical Evaluation of Applications for Electricity Production Based on Biomass Energy (dated 26 January 2023 and published in the Official Gazette No. 32085): This regulation was made to eliminate resource supply problems caused by biomass resource competition. It aims to ensure resource supply without interfering with the existing legislation and market structure. Within the scope of the regulation, it is aimed to establish a match between waste producers and biomass companies and to control the demands on the agricultural waste potential in the region through other relevant Ministries. The process regarding the implementation of the relevant legislation continues.

4.1.2 Overview of the relevant legislation for waste management and biomass in Türkiye

Law/ regulation	General Description	Responsible Authority	Role	Description for biomass from waste and residues
Environmental Law	Ensures the protection of the environment, in line with the principles of sustainable environment and development	Council of Ministers	Monitoring and control Imposing fines and sanctions Prohibition of illegal waste disposal practices	Rules to promote the recovery of waste Source for other laws and programs to promote recovery Emphasis on separate collection of waste at source
Waste Management Regulation	Promotes the recycling of biowaste and ensuring its environmentally Reduces waste generation, the use of natural resources through reuse, recycling and	Minister of Environment, Urbanisation and Climate Change	Designates the responsibility of waste generators Documentation and evidence requirements on the collection and composition of waste as well as information on recycling or disposal	Specifies requirements for bio-drying, composting and biomethanisation plants Sets out the procedures and principles on the management of

[43] This threshold was formerly 1 MW but has been increased to 5 MW with the publication of the Presidential Decree dated 9 May 2019 and numbered 1044, published in the Official Gazette dated 10 May 2019 and numbered 30770.

Law/ regulation	General Description	Responsible Authority	Role	Description for biomass from waste and residues
	recovery of waste and ensuring waste management			separate collection, recycling, and disposal of bio-waste
Regulation on General Principals of Waste Management	Determines the general principles for ensuring the management of wastes from their generation to their disposal without harming the environment and human health	Minister of Environment, Urbanisation and Climate Change	Classification of waste, disposal and recovery methods	N/A
Regulation on Landfilling of Waste	Determines the general rules to be followed in sanitary landfills and the process of disposal of wastes	Minister of Environment, Urbanisation and Climate Change	Classifies the sanitary landfills Determines the standards of the sanitary landfills Sets outs the measures to be taken in sanitary landfills	Specific procedures on the disposal of certain wastes Specific criteria for sanitary landfills, their operations and licencing Landfill gas management in sanitary landfills
Zero Waste Regulation	Sets out the procedures and principles on the establishment, dissemination, development, monitoring, financing, registration and certification of the zero waste management system	Minister of Environment and Urbanisation	Strict rules on waste collection and storage Compulsory implementation requirements on the usage of zero waste management system	Classification and separate collection of waste Primary objective is to promote material recycling and recovery for energy generation
Communiqué on Mechanical Separation, Biodrying and Biomethanisation Plants and Fermented Product Management	Sets out the procedures and principles on management, storage, disposal and recovery of biodegradable waste and technical criteria for mechanical sorting, biodegradation and biomethanisation facilities with material or energy recovery capabilities	Minister of Environment and Urbanisation and Climate Change	General principles, duties, authorities and obligations regarding mechanical separation, biodrying and biomethanisation plants and fermented product management	Provisions on the collection of biogas for the purposes of energy generation
Municipality Law	Assigns duties and authorisations on local administrations regarding	Cabinet of Ministers	Waste collection and construction of sanitary landfill	N/A

Law/ regulation	General Description	Responsible Authority	Role	Description for biomass from waste and residues
	the collection of waste and sanitary landfill			
Law on the Utilisation of Renewable Energy Resources for Electricity Generation	Contains provisions incentivising the expansion of the use of renewable energy sources for the generation of electricity	Cabinet of Ministers	Contains incentives and state support on the allocation of land and other easements for the use of renewable energy sources in electricity generation Imposes sanctions and prohibitions	Defines biomass and includes it as a renewable energy source so that biomass based power plants can benefit from the supports provided therein
Regulation on Technical Evaluation of Applications for Electricity Production Based on Biomass Energy	Determine the procedures and principles regarding the technical evaluation of applications for the establishment of electricity production facilities based on biomass energy.	Ministry of Energy and Natural Resources	Aims to use biomass resources effectively by regulating the resource and technology incoordination with Ministry of Agriculture and Forestry, Ministry of Environment, Urbanization and Climate Change	Defines biomass the same as in the
Regulation on the Control of End-of-Life Tyres	Sets out the technical and administrative principles regarding the establishment of a collection and transport system for the recovery or disposal of end-of-life tyres, the establishment of a management plan and the necessary regulations and standards in the management of end-of-life tyres, restrictions and obligations regarding the import, export and transit of end-of-life tyres	Minister of Environment, Urbanisation and Climate Change	Determines duties, authorisations and obligations Establishes rules and procedures for the collection, storage, disposal and recovery of end-of-life tyres Imposes legal liability	Includes references to energy recovery from end-of-life tyres
Regulation on the Control of Vegetable Waste Oils	Sets out the procedures and principles on the management of vegetable waste oils (from their generation to their disposal)	Minister of Environment, Urbanisation and Climate Change	Determines duties, authorisations and obligations Imposes legal and criminal liability Sets criteria regarding the quality of the wastes	Introduces a specific section for the recovery of vegetable waste oils by producing biodiesel and biogas

Law/ regulation	General Description	Responsible Authority	Role	Description for biomass from waste and residues
Regulation on the Control of Odour-Forming Emissions	Regulates the administrative and technical procedures and principles for the control and reduction of odour-forming emissions	Minister of Environment, Urbanisation and Climate Change	Sets out duties, authorisations and obligations Imposes sanctions and prohibitions	Establishes a gas collection system in landfills accepting biodegradable waste Provisions on the collection of biogas for the purposes of energy generation
Regulation on water pollution control	Sets out the legal and technical principles necessary to realise the prevention of water pollution and optimum utilisation of the groundwater and surface water resources	Minister of Environment, Urbanisation and Climate Change	Regulates the general principles concerning the protection of waters Imposes sanctions and prohibitions	N/A
Regulation on the use of domestic and sewage sludge in soil	Sets out the technical and administrative principles for the controlled use of sewage sludge resulting from the treatment of domestic and urban wastewater in the soil	Minister of Environment, Urbanisation and Climate Change	Imposes restrictions and prohibitions	N/A
Regulation on animal by-products not intended for human consumption	Sets out the procedures and principles on the sanitary rules for animal by-products and their secondary products that are not offered for human consumption	Minister of Agriculture and Forestry	Imposes sanctions and prohibitions	Provisions regarding the recovery of animal by-products into biogas and compost
Regulation on the Incineration of Waste	Aims to prevent and limit the adverse effects of waste incineration on the environment, in particular pollution of air, soil, surface waters and groundwater	Minister of Environment, Urbanisation and Climate Change	Imposes sanctions and prohibitions	The efficient recovery of heat generated during incineration and co-incineration processes

4.1.3 Waste Management Regulation

Purpose

The Waste Management Regulation[44] dated 2 April 2015 and published in the Official Gazette No. 29314 (the "**Waste Management Regulation**") regulates the waste management principles in Türkiye to ensure that the waste is managed without harming the environment and is reduced by way of reuse and/or recycling.

The Waste Management Regulation outlines the procedures and principles aimed at (i) ensuring the environmentally friendly and safe management of waste from its generation to disposal, (ii) promoting waste reduction, conservation of resources, and the adoption of waste management practices like reuse, recycling, and recovery, and (iii) enforcing measures for production,

[44] Published in the Official Gazette dated 2 April 2015 and numbered 29314.

market surveillance, and inspection to ensure compliance with specific criteria and requirements related to environmental and human health for regulated products within the scope of this regulation.

Scope

The Waste Management Regulation extends to (i) waste generated from mining activities, extraction, processing, or storage of minerals, as well as construction and demolition waste, as defined by the waste list provided in Annex 4 of the Waste Management Regulation and (ii) electrical and electronic items, packages, vehicles, batteries and accumulator products managed under extended producer responsibility.

General principles

The Waste Management Regulation grants permission to entities primarily engaged in the utilisation, retention or storage of waste materials for energy generation purposes, as well as those involved in waste transportation, disposal and recycling for profit. These authorised entities are required to comply with the principles outlined in the licenses granted to them under the provisions of the Waste Management Regulation. The collection, disposal and recycling of waste materials are essential activities performed by these entities to ensure effective waste management practices.

The core objective of the Waste Management Regulation is to effectively address the challenges resulting from waste generation and its hazardous nature. To achieve this, the regulation places significant emphasis on the implementation of clean technologies that minimise the utilisation of natural resources. Additionally, it highlights the importance of designing and promoting products in a manner that minimises adverse environmental and human health impacts throughout the entire lifecycle encompassing production, utilisation, recovery and disposal stages. In line with this objective, the regulation promotes the adoption of a product environmental design strategy, focusing on the development of durable, reusable, and recyclable products. This strategy plays a vital role in curbing waste generation and reducing the presence of harmful substances, thereby fostering sustainable waste management practices. By integrating durability and sustainability into product design, the law allows for the effective mitigation of the environmental consequences associated with waste generation, promoting a responsible and eco-friendly approach to waste management.

In light of the Waste Management Regulation, it is important to highlight several key points:

- In cases where waste generation cannot be avoided, it is crucial to ensure appropriate management practices. This involves the recovery, utilisation or proper disposal of waste through processes such as reuse, recycling and other methods aimed at obtaining secondary raw materials. The Republic of Türkiye Ministry of Environment Urbanisation and Climate Change (the "**Ministry of Environment**") shall establish guidelines and principles regarding the utilisation of waste as alternative raw material and additional fuel.
- Furthermore, the separate collection of different types of waste at their source or point of generation, without mixing them with other waste, is important. It is forbidden to collect and separate waste by any method other than the principles determined by the Ministry of Environment.
- Wastes can be reclaimed at their place of generation, given that the conditions outlined in the law are met. The Ministry of Environment has the authority to exempt facilities from the requirement of an environmental license if they recover their own waste, excluding energy recovery, within their own premises where the waste is generated. However, the exempted facilities must include information regarding the quantity and type of waste in their waste management plan, fulfil the necessary notifications through the Environmental Information System, and adhere to the regulations pertaining to waste management. The Ministry of Environment assesses applications for exemption from an environmental license on a case-by-case basis, taking into account both the waste and the facility involved.
- Ensuring that waste is transported to the nearest and most suitable facility from their place of generation or location in the most efficient manner possible is of utmost importance. The waste should be processed using appropriate methods and technologies.
- Furthermore, biodegradable waste should be collected separately at the source through a dual collection system, ensuring they are not mixed with recyclable waste. It is necessary to establish a dual collection system for this purpose.
- Bio-drying, composting and bio-methanisation plants are subject to the following obligations:

a) Adhering to the provisions outlined in subparagraphs (a), (b), (c), (d), (e), (f), (g), (h), and (i) of the first paragraph of the Article 5 of the Waste Management Regulation;

b) Selecting a location for the facility, except those within the boundaries of a sanitary landfill, that maintains a minimum distance of 250 meters from residential areas and designing it in a way that prevents pollution of the receiving environment, soil, surface waters and groundwater;

c) Implementing preventive measures to minimise odours, dust, leachate, gas emissions and any other negative impacts that may arise from the facility;

d) Establishing necessary systems to ensure that the accepted wastes are processed in accordance with the specified criteria;

e) Submitting the operational plan to the Ministry of Environment, obtaining the appropriate approval, and promptly submitting any revised operational plan within one month;

f) Managing the collection, processing, and utilisation of gases produced during operations, including greenhouse gases, in an environmentally and human health-friendly manner;

g) Constructing a closed pre-storage tank that serves as a pre-storage and stabilisation unit for the incoming waste; and

h) Disposing the waste that is unsuitable for processing and the by-products that are unsuitable for use in accordance with the relevant legislation.

Within the scope of the regulation, an attempt is made to match the law No. 5346 on Electrical Energy Production from Renewable Energy Resources by introducing an "8" code indicating that some waste codes are considered "biomass". The management principles of waste in this scope are a little easier. Since the aim of the regulation is waste management principles rather than resource management, in practice it is not possible to fully match the scope of biomass in Law No. 5346.

In summary, the Waste Management Regulation excludes other natural and non-hazardous agricultural or forestry materials, as well as substances used in agroforestry activities or biomass energy generation by processes or methods that do not harm nature or endanger human health.

4.1.4 Zero Waste Regulation

Purpose

The purpose of the Zero Waste Regulation[45] is to establish the general principles and guidelines for the efficient management of raw materials and natural resources, in line with the principles of sustainable development, aiming to protect the environment, human health and all resources in waste management processes, by establishing, promoting, developing, monitoring, financing, recording and certifying the zero waste management system.

Scope

The Zero Waste Regulation covers the principles related to the establishment and monitoring of the zero waste management systems and issuance of the zero waste certificate for (i) local administrations and other places specified in Annex-1[46] of the

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[45] Published in the Official Gazette dated 12 July 2019 and numbered 30829.

[46] Ex: Organised industrial zones, airports, ports, business centres, and commercial plazas (with 100 or more office capacity), shopping malls (with an area of 5000 square meters and above), industrial facilities listed in Annex-1 of the Environmental Impact Assessment Regulation (for industrialists with an industrial registry certificate), educational institutions and dormitories (with 250 or more students), accommodation facilities with 100 or more rooms, healthcare institutions (with a capacity of 100 beds and above), fuel stations, rest areas, residential sites with 300 or more units, and chain supermarkets.

Zero Waste Regulation who are obliged to have in place zero waste systems and (ii) those who voluntarily want to have the zero waste system.

General principles

The Zero Waste Regulation aims to implement a proper waste classification mechanism where the waste is thoroughly separated and collected without mixing with other class of waste. To achieve this, the Zero Waste Regulation mandates local administrations and other places specified in Annex-1 of the Zero Waste Regulation to establish zero waste management systems and sets out the monitoring systems to ensure compliance. As per Article 20/(cc) of the Environmental Law[47], entities obliged to establish zero waste management systems are subject to administrative fines in case of non-compliance with their obligations under the Zero Waste Regulation. Further, Article 29/2 of the Environmental Law sets out that the Ministry of Environment shall implement incentive mechanisms for those who establish the zero waste management system.

The Zero Waste Regulation defines the term "recovery" which is also found in the Waste Regulation as the "*processes listed in Annex-2/B of the Waste Management Regulation, involved in preparing waste to be ready for the use of a beneficial purpose as a substitute for materials used in the market or at a facility*". Annex-2/B of the Waste Management Regulation includes processes such as fuel usage or use in other forms for energy generation, recovery/regeneration of solvents, recycling/reclamation of (i) non-used organic substances (including compost and other biological processes); (ii) metals and metal compounds; and (iii) other inorganic materials, recovery of components used for pollution abatement, regeneration or other reuse of oils and land treatment resulting in ecological improvement or agriculture benefit.

The Zero Waste Regulation prioritises the classification and separate collection of waste. Its primary objective is to promote material recycling and recovery for energy generation. The responsibility for implementing, monitoring, and ensuring continuous compliance with the Zero Waste Regulation lies with the Ministry of Environment, Environment and Urbanization Provincial Directorates, as well as local administrations and authorities.

The Zero Waste Regulation sets out a colour code for each type of waste. Accordingly:

Waste Type (partial separation)	Colour
Paper, Glass, Metal, and Plastic (if collected together)	Light Blue
Other	Dark Grey

Waste Type (full separation)	Colour
Paper	Blue
Plastic	Yellow
Glass	Green
Metal	Light Grey
Biodegradable	Brown
Pharmaceutical	White

4.1.5 Regulation on General Principles of Waste Pre-Treatment and Recycling Facilities

Purpose

The Regulation on General Principles for Waste Pre-Treatment and Recycling Facilities[48] dated 9 October 2021 and published in the Official Gazette No. 31623 (the "**Waste Pre-Treatment and Recycling Facilities Regulation**") regulates the

[47] Published in the Official Gazette dated 9 August 1983 and numbered 18132.
[48] Published in the Official Gazette dated 9 October 2021 and numbered 31623.

procedures and principles regarding the technical criteria of waste pre-treatment and recycling facilities operating for the processing of wastes and the minimum conditions that must be present in these facilities.

Scope

This Waste Pre-Treatment and Recycling Facilities Regulation establishes the guidelines and principles governing the minimum standards and technical criteria for waste pre-treatment and recycling facilities involved in waste processing. It encompasses various types of facilities, including collection and separation facilities, pre-treatment facilities, scrap metal processing facilities, facilities engaged in reuse activities, non-hazardous waste recycling facilities and hazardous waste recycling facilities. However, it should be noted that facilities processing waste types listed in Annex-4 of the Waste Management Regulation are not covered by this regulation. The primary objective is to ensure proper management and processing of waste, while adhering to specified procedures and criteria for waste pre-treatment and recycling activities.

4.1.6 Regulation on Sanitary Landfill of Waste

Purpose

The Regulation on Sanitary Landfill of Waste[49] dated 26 March 2010 and published in the Official Gazette No. 27533 (the "**Regulation on Landfilling of Waste**") regulates the technical and administrative issues and general rules to be followed with waste disposal through the sanitary landfill method.

Accordingly, the Regulation on Landfilling of Waste establishes the technical guidelines for sanitary landfills, along with the procedures, principles, measures, controls, and obligations pertaining to the acceptance and disposal of waste in these landfills. The definition of waste, as outlined in Article 4 of the Waste Management Regulation, is applicable to this Regulation on Landfilling of Waste. Additionally, this Regulation on Landfilling of Waste places significant emphasis on preventing environmental pollution during the waste disposal process, specifically through the use of sanitary landfill methods.

It sets forth the necessary provisions to ensure proper waste management and environmental protection in landfilling practices with the aim of:

a) Minimising the adverse effects of potential leachate and landfill gases on soil, air, groundwater, and surface waters, preventing environmental pollution;

b) Making technical designs of appropriate storage bases according to the type of wastes and construction of sanitary landfill facilities;

c) Accepting waste to landfill facilities;

d) Operating and closing of sanitary landfill facilities and post-closing control and maintenance processes;

e) Preventing adverse effects that may pose a risk to the environment and human health, including the greenhouse effect, during operation, closure and post-closure maintenance processes; and

f) Maintenance of existing sanitary landfill facilities after the improvement, closure and post-closure.

Scope

The Regulation on Landfilling of Waste encompasses the technical principles regarding sanitary landfill facilities, as well as the procedures and principles for the acceptance of waste to sanitary landfill facilities and the measures, inspections, and responsibilities to be undertaken. It outlines the necessary guidelines and obligations to ensure proper waste management and compliance with environmental standards in controlled landfilling practices.

However, it should be noted that the provisions of this Regulation on Landfilling of Waste (please see above 1.1.2 for further information), may not apply to certain cases, provided that they do not contradict the Waste Management Regulation. These exceptions include the use of soil for fertilisation or soil improvement purposes in accordance with the Regulation on the Control of Soil Pollution[50], utilising inert wastes for construction purposes in landfill facilities, filling non-hazardous sludge in surface waters, etc. These exceptions are applicable in specific sanitary landfill facilities, particularly those located in isolated settlements solely designated for the disposal of non-hazardous and inert wastes generated within these settlements, as well as underground storage sites and the storage of inert wastes resulting from quarry activities.

4.1.7 Biomass and Bioenergy Potential: Current Status

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[49] Published in the Official Gazette dated 26 March 2010 and numbered 27533.
[50] Published in the Official Gazette dated 31 May 2005 and numbered 25831.

Türkiye has favourable solar, agricultural, water resources and climate conditions for biomass energy generation. Pursuant to 2020 data, Türkiye's biomass resources consist of agricultural, forest, animal, organic urban waste, and similar materials, and the distribution of biomass energy potential is shown in the illustration[51] below.

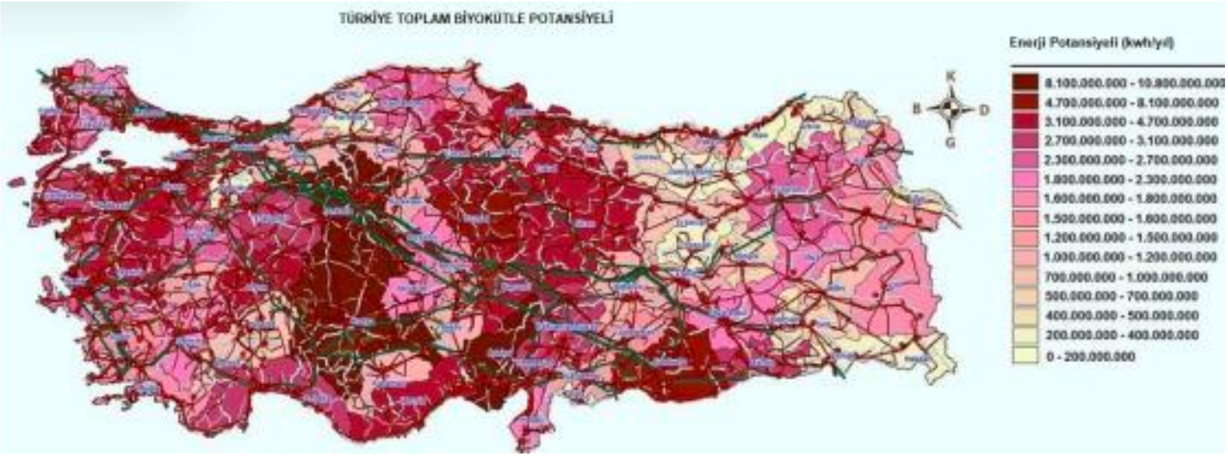

Figure 12: Biomass and Bioenergy Potential in Türkiye

The "Turkish-German Biogas Project" was initiated in 2010 in co-operation with the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety and the Ministry of Environment and Urbanisation of the Republic of Türkiye. The project's objective was to determine Türkiye's biogas potential through poultry, organic waste and food industry waste.[52] Within this project, studies have been conducted to determine Türkiye's biogas potential according to different source types.[53] Accordingly to this study, the theoretical biogas potential of cattle in Türkiye is 2.77 million TOE/year, and the technical biomass potential is 1.13 million TOE/year.[54] The theoretical biogas potential of poultry is 874,175 TOE/year, and the technical biogas potential is 864,462 TOE/year. Further, the total technical biogas potential's energy value is 2 million TOE/year[55]. BEPA (Biomass Energy Potential Atlas, https://bepa.enerji.gov.tr/) prepared by the Ministry of Energy and Natural Resources is another data source. It contains some differences with the study carried out by the Ministry of Environment, Urbanization and Climate Change due to methodology. According to the methodology in BEPA, the approximate economic potential of plant, animal, urban and forest waste is estimated as 4 Million TOE/ year (with forest residue potential). When the resource in question is biomass, usual, especially in studies based on statistical data. Approaches based on Geographic Information Systems (GIS) offer opportunities in reducing these differences. There is a need to integrate Turkey's GIS databases in this context into biomass potential studies.

In order to utilise this existing potential Türkiye has set precise targets for renewable energies, including biomass, and included them in its strategy plans, action plans, development plans.

By way of illustration, according to the Electricity Market and Supply Security Strategy published by the Ministry in May 2009, the share of renewable sources in Türkiye's electricity generation was planned to reach at least 30% by 2023.[56] The purpose of this strategy paper was to support the development of renewable sources such as biomass, wind, solar and hydro by the European Union ("**EU**") Commission, and for Türkiye to actively continue its EU membership process during that period.

The following national policy that drew attention to biomass was the Strategy Document and National Renewable Energy Action Plan, prepared in collaboration with EBRD and Deloitte which was published in December 2014. This plan focused on researching the potential of agricultural by-products and waste, as well as household organic waste, to generate biomass energy. The United Nations Industrial Development Organization worked with the Turkish government to strengthen existing incentives designed to accelerate the use of biomass as an energy resource.

On 20 September 2015 Türkiye submitted its Intended Nationally Determined Contribution ("**INDC**") to the United Nations Framework Convention on Climate Change (the "**UNFCCC**") as part of its commitment to the Paris Agreement. Based on INDC,

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[51] İlleez, B., 2022, Türkiye Yenilenebilir Enerji Görünümü 2022, Sabancı University Istanbul International Center for Energy and Climate.
[52] *Ibid*.
[53] *Ibid*.
[54] *Ibid*.
[55] *Ibid*.
[56] *Ibid*.

biomass-related targets such as the use of agricultural biomass for energy generation, increasing the use of biofuels and refuse-derived fuel in industrial facilities are included in Türkiye's 2030 goals.

Türkiye has recently announced its new energy action plan, named "Türkiye National Energy Plan,"[57] dated 2022 and published by the Ministry. As part of the Türkiye National Energy Plan, Türkiye is committed to revising its biomass policy by placing a strong focus on increasing the share of intermittent renewable energy sources, including biomass, wind and solar. In alignment with the action plan's objectives, Türkiye aims to enhance the installed capacity of other renewable energy sources as well. The plan targets 35.1 GW of installed capacity in hydroelectric power plants and 5.1 GW in geothermal and biomass power plants.[58] Highlighting the significance of biomass within the energy strategy, the "biomass module" is one of the key frameworks in the Türkiye energy module, alongside three other modules. The biomass module focuses on meeting the demand for bioenergy products, such as solid biomass, biofuels, and biogas, by collaborating with the demand module and the power and heat module. This collaborative approach ensures a comprehensive modelling process for bioenergy pricing, resulting culminating its updated tariffs for bioenergy products. The biomass module's outputs will then be fed into both the demand module and the power and heat module, thereby strengthening the integration and optimisation of biomass within the national energy framework.

Although many positive actions have been carried out, need further actions to toward the intended goals. The current status of Türkiye's biomass potential is below its actual capacity as it is not used with modern methods and planning, meaning that Türkiye does not the vast majority of its existing biomass potential in accordance with the current technologies, utilisation areas and waste status.[59]

4.1.8 Funding

Bilateral Agreements

Article 3(1)(j) of the EML defines bilateral agreements as "*commercial agreements between real and legal persons for the purchase and sale of electrical energy and/or capacity subject to the provisions of private law and not subject to the approval of the Energy Market Regulatory Board*". As stated in the definition, these agreements are private law agreements. Therefore, the parties are free to determine their terms and conditions. Although the conditions for the sale and purchase of electricity can be freely determined by the parties, pursuant to Articles 87 and 88 of the Electricity Market Balancing and Settlement Regulation (the "**BSR**")[60], all amounts that are agreed to be sold and purchased under bilateral agreements should be notified by the market participants to the EXIST through the Market Management System. Furthermore, pursuant to Article 88(3) of the BSR, the notifications of bilateral agreements subject to settlement must be made jointly by both market participants (i.e. the seller and the purchaser) and there needs to be a match between these notifications. In other words, the amounts need to match for notifications to be valid. A notification made by a single market participant or non-matching notifications are deemed invalid.

Markets within the Scope of the Balancing and Settlement Mechanism

a) Spot Markets

a. Day-ahead Market:

The day-ahead market is an electricity market established and operated by the EXIST to balance the generation and consumption based on the settlement period forecasted one day ahead of real time. The day-ahead market provides TEİAŞ with a day-ahead balanced system and gives market participants the opportunity to buy and sell energy for the following day.

b. Intra-day Market:

The intra-day market is the electricity market where electricity is traded until the intra-day gate closure time. The intra-day market contributes to the reduction of energy imbalances and provides the EXIST with a balanced system prior to real-time balancing.

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[57] Republic of Türkiye Ministry of Energy and Natural Resources, 2022, Türkiye National Energy Plan, https://enerji.gov.tr/Media/Dizin/EIGM/tr/Raporlar/TUEP/T%C3%BCrkiye_National_Energy_Plan.pdf (Accessed 29 July 2023).
[58] *Ibid*.
[59] *Ibid*.
[60] Published in the Official Gazette dated 14 April 2009 and numbered 27200.

b) Real Time Markets

a. Balancing Power Market

Although TEİAŞ is provided with a balanced market in terms of generation and consumption amounts through the day-ahead market and the intra-day market, there may still be deviations in real time. This could be due to a power plant malfunction or a sudden start/stop of a consumption facility. Such unexpected developments disrupt the balance in the system. The purpose of real-time markets is to balance the supply and demand for electricity in real time. Accordingly, the balancing power market provides the EXIST with spare capacity that can be activated within a maximum of 15 minutes for real time balancing purposes. Market participants in the balancing power market are obliged to comply with the instructions notified to them by the National Load Dispatch Centre of TEİAŞ. In this respect, the balancing of the system is ensured by loading and de-loading instructions. A loading instruction means that a balancing unit sells electricity to the system by increasing its generation or decreasing its consumption in accordance with the instructions given by the EXIST; a de-loading instruction, on the other hand, means that the balancing unit withdraws electricity from the system by decreasing its generation or increasing its consumption. Market participants who have at least one settlement aggregation entity registered in their own name and who meet the conditions for being a balancing unit are obliged to participate in the balancing power market.

RES Support Mechanism

As described above in Section 1.1.1., entities involved in electricity generation and those eligible to benefit from RES Support Mechanism engages in the electricity markets specified above, however with an electricity purchase guarantee system. The electricity generated by participants holding RES Certificates is purchased at a fixed price (please see Table 1 for the relevant price list).

The RES Support Mechanism operates as follows:

EXIST announces the total renewable energy support quantity, allocates such quantity for offtake and designates the payment obligation of each supplier for a portion of such allocation, for each invoicing period. Electricity generated from renewable energy sources within the scope of the RES Law but sold in the free market without being subjected to the RES Support Mechanism will not be included. The amount that each supplier is obliged to pay is determined and invoiced to the relevant supplier and the payment collected is then paid to those legal entities that participate in the RES Support Mechanism in proportion to their shares (Art. 7(8) of the RES Law). Feed-in tariff payments are reflected in the electricity prices paid by the end-users.

4.1.9 Twinning and Comparison

a) Need for a nationalised strategy[61]

Directly reflecting the EU framework in Türkiye would be counter-productive as new strategies have to fit the local needs and take into account local circumstances. While there have been efforts to increase biomass usage through various strategies, the generation of energy from biomass has not reached its full potential. Looking at Germany, it is notable that as an EU member, Germany has its own National Biomass Strategy (NABIS) in place. Therefore, there is a need in Türkiye to identify short, mid and long term strategies and action plans regarding the usage of biomass and related therewith energy generation. When developing such strategies and action plans specifically for biomass, EU requirements should be considered but also Türkiye’s needs and realities.

Since Türkiye is not a EU member state, its commitments to sustainable development may not be aligned with the goals set by the EU. Consequently, Türkiye's approach to sustainable development, including national strategies concerning biomass utilisation, must be appropriately tailored and regulated. However, Türkiye can reflect and/or use EU guidelines as a basis for its own national strategy.

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[61] Please see the following link for Türkiye National Energy Plan: https://enerji.gov.tr/Media/Dizin/EIGM/tr/Raporlar/TUEP/T%C3%BCrkiye_National_Energy_Plan.pdf

Additionally, the electricity market conditions in Türkiye coupled with the specific economic situation of the country, must be thoroughly evaluated when considering the adoption of support mechanisms. These mechanisms, such as feed-in tariffs, feed-in premiums, quotas (TGC) and state subsidies/grants need to be adaptable and maintainable to address the intricacies of the local economy. For instance, as outlined in Section 4.1.1, Türkiye found it necessary to shift from USD-based feed-in tariff structures to its national currency Turkish lira. This strategic adjustment escalated financial pressures on electricity suppliers (with an impact on existing financings of such projects and their financial model). Consequently, this financial strain had a direct impact on the billing structure for end-users.

Furthermore, the divergence between the Turkish electricity market and the European electricity markets must be taken into careful consideration when devising and directly implementing strategies developed by the EU.

On the other hand, the strategies proposed must be closely aligned with Türkiye's capacity to generate and utilise affordable and sustainable sources of agricultural biomass, forest biomass and renewable waste.

It is vital that sustainable development strategies must be developed with a view to also recognize the realities of the locations where they are planned to be implemented. Otherwise, strategies that exceed the upper limits of possibilities may result in non-compliance in practice, leading to unsustainable practices and, consequently, increased emissions.

b) Need for framework legislation

As evident from Section 4.1.2, Turkish waste management legislation encompasses a diverse range of regulations that address various categories of waste. Along with the evolution of waste management systems and the evolving needs of the country, the enactment of new legislation has become imperative. However, this approach inadvertently gives rise to significant hurdles during the implementation phase, primarily due to the complicated nature and system of the current regulations governing different facets of collected waste.

From a legislative standpoint, the adoption of a non-uniform set of rules and regulations is counterproductive, as it undermines the coherence essential for practical application. On the other hand, waste management legislation introduces civil, administrative and criminal measures. Consequently, such laws must be transparent, maintainable and user-friendly to ensure their continued application. Thus, while keeping the current secondary legislation in place, a primary framework legislation with regards to waste management may simplify the application of the secondary legislation by addressing the relevant legislation specific to waste categories.

Without a systematic approach, the task of identifying pertinent regulations within a waste management scenario remains a challenge. Therefore, it is paramount to embrace a holistic methodology that not only aligns regulatory frameworks but also facilitates the effective execution of waste management strategies.

c) Need of a centralised organisation

Due to the intricate nature of biomass, the recovery process involves the participation of numerous state institutions and local administrations. Additionally, as evident in Section 4.1.2, various legislation rule on biomass. However, these different legislative pieces jeopardise a smooth and conflict-free implementation. Moreover, the involvement of multiple state institutions with authorisation in different aspects of biomass at its different stages can lead to inefficiencies in organising, planning, coordinating and monitoring initiatives and strategies.

As stated above, to overcome such challenges, Türkiye should adopt a comprehensive national biomass strategy. This strategy should encompass the organisation and implementation of rules and regulations, with monitoring authority overseen by one institution that includes representation from all authorised institutions. Accordingly, the goal would be to have a coordinated and cohesive approach to be established, facilitating effective governance, enhanced planning and a streamlined approach towards bioenergy initiatives and strategies.

In Germany Umweltbundesamt (UBA) fulfilles such a role. Türkiye also houses several organisations that undertake similar responsibilities. However, it is important to mention that the mandates of these Turkish counterparts are not as extensive as of UBA's. In addition to the Ministry's oversight, there is no separate official entity entrusted with a monitoring role.

Establishing an independent institution separate from the Ministry might not be necessary. Nonetheless, proposing the establishment of a dedicated department within the Ministry, specifically focused on this area might be an option. This approach would guarantee the alignment with international regulations and the continuous monitoring of legislative updates. Moreover, it would establish a body responsible for tracking emerging technologies, tailoring such for local needs and rectifying any legislative gaps during the adaptation process.

d) Need to have a flexible approach to YEKDEM incentives for bioenergy

As indicated in Table 1, the scope of YEKDEM incentives for biomass is confined to the specified electricity generation types. While contemporary technologies – as those layed out in chapter 5 - may not currently offer alternatives for electricity generation via biomass, it is imperative that the YEKDEM tariffs adopt a flexible approach, accommodating potential novel methods of electricity generation to fully leverage the benefits of YEKDEM incentives.

e) Need to increase bioenergy resources

While Türkiye possesses a high capacity of biomass energy sources, there is still a need for further resource expansion. To achieve this, a well-structured biomass program, including planned energy agriculture is essential. Implementing suitable strategies and action plans is crucial to achieve the goals. One effective approach could be incentivising oilseed crop cultivation through state support, as it can significantly contribute to increasing bioenergy resources. By fostering such initiatives and implementing targeted policies, Türkiye can unlock the full potential of its biomass energy and pave the way towards a more sustainable and energy-efficient future.

Türkiye is already a significant producer of oilseeds, and the concept of biorefinery is also relevant here. This concept, similar to the principles in RED II and the biorefinery approach in Europe, seeks to find a balance between promoting renewable energy from biomass and addressing environmental and social concerns. However, the concept of biorefinery is still relatively new in Türkiye. Recent research in this field has yielded data indicating that the implementation and commercialisation of next-generation biofuel technologies and biorefineries have been recognised as key mid-term milestones.

Furthermore, in the context of biorefinery, there exists a collaborative research and development initiative known as INDEPENDENT, involving both the European Union and Türkiye. This program seeks to promote sustainable development aligned with the principles of the bioeconomy. Its primary objective is to establish a biorefinery facility, fostering a supportive platform for small and medium-sized enterprises (SMEs) by advancing biorefinery research and development capabilities, enhancing the 'know-how' capacity. This, in turn, will facilitate the broader adoption of more sustainable and cost-effective biomass products. The ultimate aim is to reduce dependence on fossil-based resources while increasing the utilization of both renewable resources, across various sectors such as energy, food, environment and health.

f) Need of incentives regarding the alternative fuels

Necessary state support must be directed towards research, development and implementation of alternative fuels, drawing inspiration from successful funding programs like Germany, specifically focusing on the use of advanced biofuels in the entire logistics sector.

The European Union's RED is a binding framework designed to promote the use of renewable energy sources within its member states. However, as Türkiye is not a EU member, it is not obligated to adhere to RED. While the directive and its minimum consumption quotas could have been preferable for Türkiye if it had been an EU member, Türkiye currently operates under its own energy strategy outlined in the "Türkiye Energy Plan 2022" published by the Ministry of Energy and Natural Resources.

Implementing a sub-quota similar to the RED II subquoata for advanced fuels, poses challenges for Türkiye, given its relatively recent entry into the biomass industry. The existing conditions in Türkiye needs detailed research to making investments in this sector, and empower to institutional background to formalise any commitments.

On the other hand, the main framework of the Türkiye Energy Plan ("TEP") is composed of four modules to achieve market equilibrium. One of the modules is the biomass module, which focuses on meeting the demand for bioenergy products such as solid biomass, biofuels and biogas. This module includes a specific modeling process to establish bioenergy pricing, ensuring a systematic approach to bioenergy utilisation. However, it is important to note that TEP outlines our strategic energy targets and approaches. Hence, it is not binding or enforceable by any other third party entity.

State-funded initiatives will not only drive innovation but also positively impact the economy by creating job opportunities in the green technology sector. Moreover, it is crucial to incentivise sector players to embrace biomass as an energy source. This can be achieved through a well-defined legal framework and "soft law" incentives that support investors.

As referred under Section 4.3.4., to our understanding, the guide program led by VDI/VDE Innovation + Technik GmbH for the development of regenerative fuels issued by the German Federal Ministry of Digital Affairs and Transport (BMDV) can be given as an example.

Additionally, the "Energie- und Klimafonds und der Nationalen Wasserstoffstrategie" of the BMDV can serve as another example of a state-supported advanced fuel funding program.

g) Need for monitoring mechanisms

There is need for a more effective monitoring mechanism and enhanced supervision in the biomass sector in Türkiye. While some regulations, such as the Zero Waste Regulation, have general rules in place, there is nearly no specific monitoring mechanism tailored to biomass energy generation. As the utilisation and promotion of biomass increase, it is essential to implement more comprehensive monitoring. Generating energy from biomass requires skilled workmanship, necessitating the establishment of a robust monitoring mechanism to ensure adherence to quality standards. Simultaneously, there should be a deterrent in place to avoid non-compliance. Striving for a well-regulated and effectively monitored biomass industry will contribute to its sustainable growth and align with the broader goals of energy efficiency and environmental conservation.

General monitoring may be conducted by the Ministry. However, as an independent regulatory authority, EMRA could also assume responsibility for such monitoring. Ideally, establishing a specialised department for bioenergy would be preferable to ensure coherence in practice.

h) Need for advancing research and development

Currently, there are only a few R&D programs dedicated to biomass, with one notable initiative being the "Biomass Energy Systems and Technologies Application and Research Centre" at Ege University. This centre focuses on providing national and international standard testing, analysis, geographic information system, data collection, vocational training and certification services in the field of biomass energy systems and technologies. It aims to serve as a pioneering and exemplary centre, encouraging and supporting investors, industrialists and legal entities not only in İzmir but also throughout Türkiye. As a state-funded R&D program, it stands as one of the few of its kind. However, there is a need for more programs like this to be supported by the state to further advance research and development incentives in the biomass energy sector.

According to Article 31 of Regulation On The Implementation And Supervision Of Support For Research, Development And Desıgn Activities, R&D and innovation or design projects shall be supported by the public institution or organisation to which the application is made and foundations that are established by law or that use funds or loans from international institutions or public institutions and organisations to support R&D projects within the scope of technology development project agreements. This backing aims to promote R&D projects under the umbrella of technology development agreements, all in accordance with their respective legislations.

Typically, specific legislative frameworks are established for relevant R&D programs in alignment with R&D laws, which implies the possibility of various other institutions providing support for R&D initiatives within this domain. Nevertheless, the aforementioned institutions generally constitute the primary entities responsible for endorsing R&D programs.

4.2 German regulation, laws and existing funding schemes concerning biogenic resource use for energy production

Concerning bioenergy a lot of laws and regulations are in place in Germany. Laws are made by the parliament, the legislature. A regulation, however, is issued by the executive power, by the administration. Laws thus determine what is to happen; ordinances determine how laws are to be implemented.

Proposals for a new law can come from members of the Bundestag, from the Bundesrat or from the federal government. In practice, the impetus for most new laws comes from the government. The federal ministry, initially prepares a draft for a new law or for an amendment to existing laws on behalf of his or her minister. It obtains comments from interest groups and consults with other ministries. Afterwards the finished draft is sent to the minister, who reviews it and then submits it to the cabinet, i.e., the entire federal government. If the cabinet approves the draft, it is forwarded to the Bundesrat and then - with the Bundesrat's opinion - to the Bundestag.

Once the law has passed through the Bundestag and Bundesrat, it is forwarded by the federal government to the federal president, who signs it and promulgates it in the Federal Law Gazette. Only then does it enter into force.

At the moment, there exist 15 federal ministries in Germany, whereby for bioenergy legislation the first 3 are of importance.

1. **Federal Ministry of Economics and Climate Protection (BMWK)**
2. **Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)**
3. **Federal Ministry of Food and Agriculture (BMEL)**
4. Federal Ministry of Finance
5. Federal Ministry of the Interior and Community
6. Federal Foreign Office
7. Federal Ministry of Justice
8. Federal Ministry of Labor and Social Affairs
9. Federal Ministry of Defense
10. Federal Ministry for Family Affairs, Senior Citizens, Women and Youth
11. Federal Ministry of Health
12. Federal Ministry of Digital Affairs and Transport
13. Federal Ministry of Education and Research
14. Federal Ministry for Economic Cooperation and Development
15. Federal Ministry of Housing, Urban Development and Construction

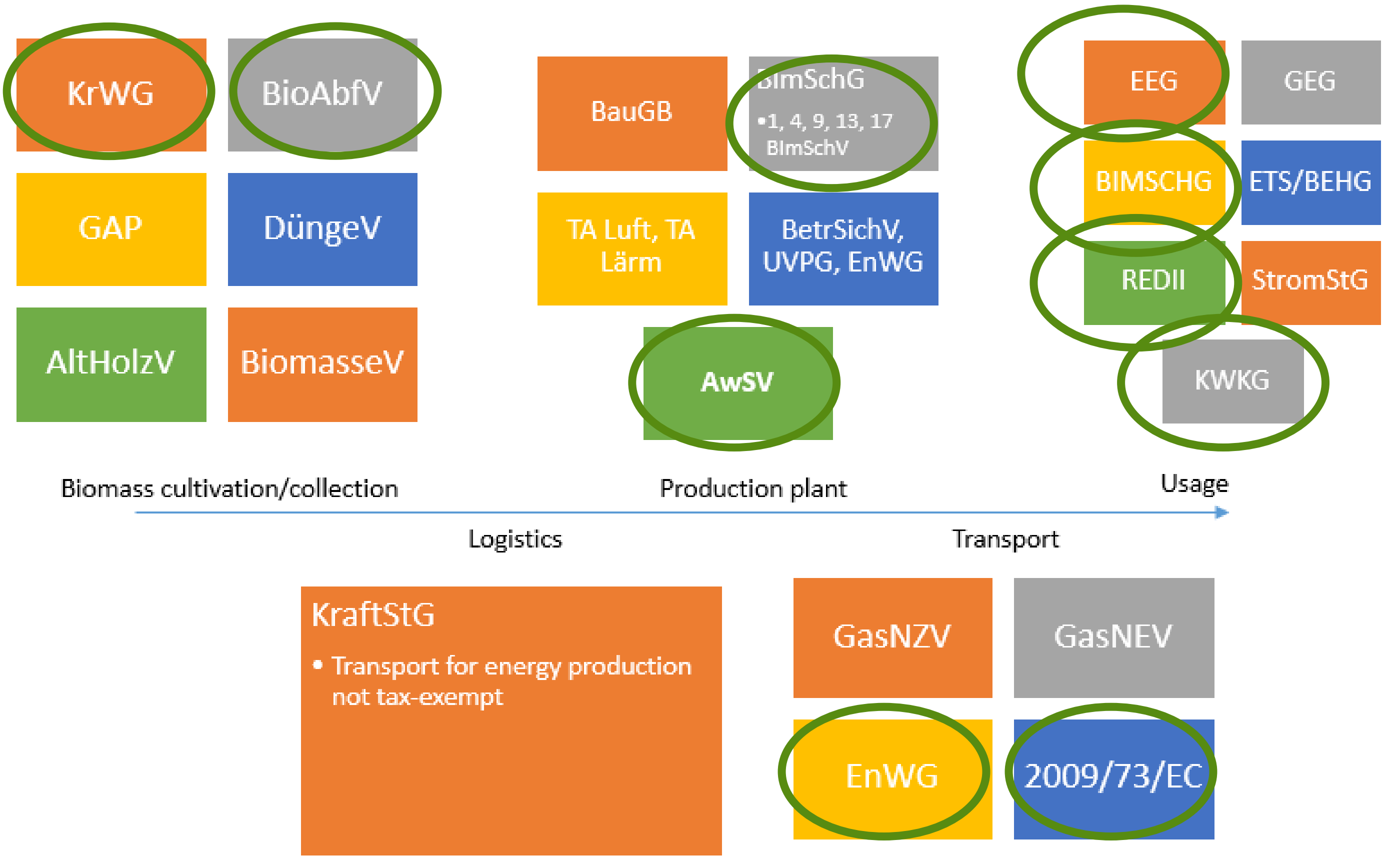

Figure 13: Overview of relevant regulation for bioenergy in Germany

Law/ regulation	General description	Federal responsibility	Classification (promotion, obligation, regulatory law)	Description for biomass from waste and residues
Circular Economy Act (KrWG)	Increase resource efficiency, reduce waste, regulates waste management, promote recycling, and prevent waste.	BMUV	Monitoring and control Fines and sanctions Prohibition of illegal waste disposal practices	Rules for separate collection, recovery and disposal of biological wastes sets requirements for operations (e.g., emission limits) to ensure that the use of biomass for energy is environmentally sound. related to other laws and programs to promote renewable energy (e.g. EEG) aims to simplify and accelerate approval procedures for bioenergy facilities
Ordinance on the prevention and recycling of biowaste (BioAbfV)	was issued within the framework of the KrWG promoting the recycling of biowaste and ensuring its environmentally sound recovery	BMUV	concrete requirements for the separate collection, recycling and disposal of bio-waste	concerns biogenic waste, such as kitchen waste, food waste, garden and park waste, and agricultural waste Regulation of separate collection of bio-waste (minimum requirements for containers, color design and labeling) Requirements for the quality of collected biowaste Recycling targets for biowaste (in percentages by material recycling, such as

				composting, and energy recycling, such as fermentation Documentation and evidence requirements on the amount and composition of biowaste as well as information on recycling or disposal.
Federal Immission Control Act (BImSchG)	legal basis for environmental protection with regard to air quality, noise pollution, odor emissions and other environmental concerns	BMUV	Approval procedure Emission limits Monitoring and control Sactions and fines	Establishes mandatory emission limits for various pollutants that occur during biomass combustion or biogas production (e.g., nitrogen oxides (NOx), sulfur oxides (SOx), dust, and carbon monoxide (CO) Bioenergy facilities must have appropriate exhaust gas cleaning systems (filters, catalysts, or other technologies) to clean exhaust gases Plant operators must apply for permits and demonstrate that their plant complies with legal requirements, including emission limits and technical standards. Permits may be subject to requirements and conditions. Operators are also required to submit regular measurements and reports on their emissions. The competent authorities carry out inspections and controls. The competent authority for monitoring and control is the respective state office for the environment, environmental agency or the competent authority of the respective federal state
AwSV Wastewater Ordinance (AwSV)	protect waters from harmful effects caused by the discharge of wastewater	BMUV	Binding requirements e.g. for wastewater treatment, discharge of wastewater into water bodies, handling of hazardous substances in wastewater and safety of wastewater facilities Approval procedures Monitoring and control Sanctions and fines	§§ 62 - 68 AwSV: specific regulations for the application of manure and other organic fertilizers §§ 59 to 61 of the AwSV:Utilization of fermentation residues The recycling certificate is to be drawn up AwSV defines requirements and specifications for recycling processes, pollutant content and application technology
Renewable Energy Sources Act (EEG)	Expansion of renewable energies Climate protection and emissions reduction Promotion of innovation and Technology development to create a reliable planning basis for investments	BMWK	Feed-in tariff for the electricity generated from renewable energies Grid operators are required by law to purchase and remunerate electricity from renewable energy producers at a fixed price. This ensures preferential feed-in of renewable electricity into the grid and creates	Definition of waste and residual materials. Feed-in tariff for bioenergy from waste and residual materials (amount of tariff depends on type of plant, installed capacity and biomass used). Sustainability criteria for waste and residual materials (biomass must demonstrably come from certified and sustainable sources in order to meet environmental and social standards)

			planning security for producers. Operators can also feed electricity into the market instead of receiving the feed-in tariff. This is done via the so-called market premium model, in which the difference between the market price for electricity and the fixed feed-in tariff is paid to the producers as a market premium.	
Renewable Energy Directive II (RED II)	Sets binding targets for the share of renewable energies in total EU energy consumption (at least 32 percent by 2030)	European commission national implementation BMKW and BMUV	EU member states are required to transpose the directive into national law and to meet the goals and targets set out in it. Member states must draw up national action plans in which they set out their targets and measures for promoting renewable energies. Binding expansion targets for renewable energies are set, which must be achieved by the member states. Sustainability criteria for the use of renewable energy must be met Biomass in particular must meet certain environmental and social standards to be recognized as sustainable. Mandatory reporting and monitoring by member states. European Commission monitors implementation and can take legal action in case of non-compliance. Member states must take the necessary legal and administrative measures to ensure implementation of RED II (e.g., establish remuneration systems, introduce tendering	EEG is used as a national instrument to implement the requirements of RED II in Germany Bioenergy from wastes and residues is recognized as a renewable energy source and can contribute to meeting member states' renewable energy targets Sustainability criteria must be met (greenhouse gas emissions, avoidance of indirect land use change and protection of biodiversity) Cascade use and waste hierarchy must be respected Support mechanisms to promote the use of biomass from waste and residues must be introduced (financial incentives, feed-in tariffs or tendering procedures) Reporting on the amount of biomass used, greenhouse gas emissions saved and compliance with sustainability criteria.

			procedures, create regulatory environment for RE expansion).	
Combined Heat and Power Act (KWKG)	regulates the promotion of combined heat and power (CHP) plants. to increase the efficiency of energy generation and to promote the use of cogeneration plants for the generation of electricity and heat	BMWK	central provisions and regulations for the support, remuneration and requirements for CHP plants CHP plants receive a statutory remuneration and a CHP surcharge for the electricity generated (the amount depends on the plant size, fuel, efficiency, etc.) Technical requirements for CHP plants notification and reporting obligations control and monitoring mechanisms, sanctions	Increased CHP surcharge received Establishment of sustainability criteria Environmental aspects (e.g. avoidance of emissions) that must be complied with in the energy recovery of waste and residual materials Specifications for sorting, processing or treatment of the waste
Energy Industry Act (EnWG)	regulates the energy market, grid infrastructure, regulation of grid operation and the promotion of renewable energies	BMWK	Regulates access to the energy market (network operators must provide other market participants with non-discriminatory access to their networks). Establishes framework conditions for the operation of electricity and gas networks (responsibilities of network operators, obligations to ensure reliable network operation, conditions for network expansion) Regulates the relations between energy suppliers and consumers Defines the tasks and powers of the Federal Network Agency, which is responsible for regulating the energy market. Federal Network Agency	No specific provisions on bioenergy from waste Detailed provisions and remuneration for the promotion of renewable energies are set out in the eeg

			monitors compliance with statutory provisions, regulates network charges, and makes decisions to ensure an efficient and competitive energy market Contains provisions on the promotion of renewable energy, sets the framework for the expansion of renewable energy and regulates the remuneration of electricity from renewable sources, feed-in conditions and grid access for renewable energy installations	
Gas Directive 2009/73/EC of the European Parliament and of the Council	regulates the liberalization and cross-border trade of natural gas in the EU	Responsibility for implementing Directive lies with various authorities at federal and state level, such as the BMWK and the state regulatory authorities	Liberalization of the gas market Unbundling of network and supply Transparency and regulation Network access and capacity allocation Security of gas supply	Establish general principles for all gas supplies, regardless of the type of fuel used These include transparency, access to the network, tariff setting, and security of gas supply. These principles apply to all market participants, regardless of whether they supply conventional natural gas, biomethane, or other gases from renewable sources.

4.2.1 National Biomass Strategy

In its coalition agreement of 2021, the German government set itself the goal of developing a National Biomass Strategy (NABIS), which is currently being developed on an interdepartmental basis (BMEL, BMWK and BMUV). The need for a biomass strategy arises from the imbalance between a high and growing demand for plant and animal raw materials and a limited supply of biogenic waste and residual materials as well as a limited availability of land for the sustainable production of renewable raw materials. The aim of the biomass strategy is to contribute to the medium- and long-term sustainable use of resources as well as to climate and biodiversity protection and to create the corresponding framework conditions in Germany. The National Biomass Strategy is to be adopted and published in the fall of 2023.

The strategy is intended to form the substantive basis for the German government's future biomass-related policy. The focus is on the development of guiding principles for the sustainable use of biomass, the design of policy instruments, and the development of concrete measures, taking into account the connectivity to the overarching EU framework.

Current guiding principles include prioritizing material use, multiple use and the use of biogenic waste materials. In addition, the strategy will analyze the sustainably available biomass potential, different application areas and the current political framework conditions.

4.2.2 Energy Industry Act (EnWG)

In Germany, the Energy Industry Act (EnWG) regulates the framework conditions for the generation, distribution and use of energy. However, there are no specific provisions on the energetic use of biogenic sources such as residual materials from industrial processing and biogenic waste. The legal basis for the use of these sources can be found in other laws such as the Renewable Energy Sources Act (EEG) or the Circular Economy Act (KrWG).

The EnWG defines the legal framework for the organization and operation of energy supply networks. It regulates the rights and obligations of network operators, access to networks, security of supply and the expansion of energy networks. The Act ensures that access to the energy supply networks is non-discriminatory and transparent for all market participants.

The EnWG also defines the duties and powers of the energy regulatory authority, which in Germany is the Federal Network Agency (BNetzA). The regulatory authority monitors compliance with the statutory requirements, particularly with regard to network regulation and tariff setting.

With regard to the use of biogenic sources for energy, there are no explicit provisions in the EnWG. However, biogas production and the injection of biogas into the gas grid are indirectly regulated by the EEG and other regulations. The EEG promotes the expansion of renewable energies, which includes biogas, and regulates, among other things, the feed-in tariff for biogas plants. The Gas Network Access Ordinance (GasNZV) regulates the access of biogas to the gas network and sets the framework for cost sharing and bearing of the network connection costs and guarantees non-discriminatory access to the gas network.

In addition, aspects of the energetic use of biogenic sources are also regulated by the KrWG. The KrWG promotes the circular economy and, among other things, defines the framework conditions for the recycling of waste. It may contain regulations that affect the energetic use of residual materials from industrial processing and biogenic waste.

In summary, the Energy Industry Act (EnWG) in Germany establishes the legal framework for the organization and operation of energy supply networks. However, it does not contain specific provisions on the energetic use of biogenic sources such as residual materials from industrial processing and biogenic waste. These are regulated in other laws such as the Renewable Energy Sources Act (EEG) and the Circular Economy Act (KrWG).

4.2.3 Renewable Energy Sources Act

Electricity can be generated from solid, liquid and gaseous biomass. However, gaseous biomass in biogas plants accounts for the largest share of bioenergy generation. Electricity generated this way was first remunerated in 1990 by the Electricity Feed Act. With the introduction of the Renewable Energy Sources Act in 2000, the compensation rates were raised considerably and the priority purchase and compensation of electricity from RE by the grid operator was regulated. Since then, electricity generation from biomass has been subject to a minimum remuneration rate per unit of electricity generated with a guaranteed remuneration period of 20 years from commissioning. This created investment security and consequently led to a continuous expansion of plants. The prerequisite for the remuneration of electricity from biogas is the use of biomass within the meaning of the Biomass Ordinance. This regulates which substances are considered as biomass, which technical processes can be used to generate electricity and which sustainability requirements must be met when generating electricity from biomass. For liquid biomass used to generate electricity under the Renewable Energy Sources Act, the Biomass Electricity Sustainability Ordinance has also applied since 2009. In addition, the **Fertilizer application Ordinance (Düngeverordnung DüV)** regulates professional practice in the application of fermentation products (fermented biogas substrates), which can be used as high-quality organic fertilizers if they are uncontaminated and originate from agricultural biogas plants. Plant operators must also be able to prove through the Fertilizer application Ordinance that farm manure and fermentation residues can be stored temporarily for at least two to nine months (§12 Fertilize application Ordinance), which **increases the pressure** on the storage capacities of biogas plants and the investment volume increased.

With the amendment of the *Renewable Energy Sources Act 2004*, a **biomass bonus** was introduced, which **led to enlargements of the plants in terms of electrical output** as well as to the specialization on "renewable raw materials plants". As a result, a **manure bonus** (an additional bonus if input was 30 percent share of manure) was implemented with the *Renewable Energy*

Sources Act 2009 and the focus was placed on smaller plants. Furthermore, the maximum compensation was reduced and a **flexibility bonus** was introduced to promote variable plant operation. In addition, the gas processing bonus promoted the processing of gas to natural gas levels. With the *Renewable Energy Sources Act 2012*, the focus shifted mainly to waste and residual materials, so that corn and grain were only allowed to have a maximum share of 60 percent in the substrate mix at that time. In addition, biogas and biomethane plants were required to market their electricity directly if the output was over 750 kW and the plant was commissioned after Jan. 1, 2014. In the *Renewable Energy Sources Act 2014*, the remuneration structure was again reduced and lowered, so that only a basic remuneration was granted. The separate remuneration for biomass (feedstock remuneration classes I and II) and the gas processing bonus were then dropped. The flexibility premium will not be continued for new plants, but there is a flexibility surcharge to provide demand-based electricity generation and to respond to price signals from the electricity market. Overall, the Renewable Energy Sources Act 2012 allowed the share of biomass in electricity generation to increase until the Renewable Energy Sources Act 2014 amendment slowed the increase and expansion of bioenergy plants. In the *Renewable Energy Sources Act 2017* amendment, the EEG was transformed from a fixed remuneration model to a tendering model with overall lower remuneration, with a flexibile system being fundamental. However, the tender volume for biomass was hardly utilized in the last years, due to the short-term introduction of two tender rounds per year and a difficult implementation period of two years for subsidized new plants.

How does the tendering model work?

The Federal Network Agency conducts tenders to determine the value to be applied for electricity from biomass plants. The determined value to be applied serves as the basis for calculating the amount of the payment claim (market premium).

The claiming of a payment for electricity from newly commissioned biomass plants with an installed capacity of 151 kilowatts to 20 megawatts is generally only possible through tenders. Existing biomass plants can also participate with a lower installed capacity. Newly commissioned biomass plants with an installed capacity of 150 kW or less are exempt from the tendering requirement and can be subsidized under the provisions of the EEG 2021. Biomass plants above 20 MW are not eligible for support under the EEG. The conditions for participation in the biomass tender are significantly more complex than for the other renewable technologies - not only because existing plants can also bid. It is therefore much more difficult to calculate at which bid level a successful participation is likely.

For example, the biomass plant operator specifies in its bid, among other things, a precise bid amount (kWh) and a precise bid value (in ct/kWh). Subsequently, it will be decided by the award procedure whether and in which amount an award has been received. The award procedure runs in up to three steps:

4. all bids that comply with the form and deadline are ranked by the Federal Network Agency in ascending order of bid value.
5. If there are two or more bids with the same bid value, the bid with the lower volume shall be awarded first. the bid with the lower volume shall be awarded first.
6. if there are two or more bids with the same bid value and the same volume, the order is decided by lot.

The order is important because bids are accepted only until the bids are accepted until the volume limit - 600 megawatts of capacity to be installed in 2023 - is reached or exceeded.

The current Renewable Energy Sources Act 2021 and more recently 2023 do focus much more on giving existing plants with favourable heat concepts an opportunity to remain in business while sorting out plants with high energy crop usage and poor heat concepts. With the necessity to take part in a tender, the most efficient concepts are in advantage. Additionally amendments focussed on the sharpening of flexibility and grid efficient operation by adjusting flexibility premium, surcharge and cap as well as adjusting support for specific concepts.

Flexibility in bioenergy?

The flex premium and the flex bonus are instruments that are used in the context of renewable energies to promote the flexibility of systems and to reward their contribution to stabilizing the electricity grid.

The flex premium is a financial payment that is paid to biogas plant operators if they operate their plants flexibly. In this context, flexibility means that the biogas plant can adapt its power generation to the needs of the power grid. This is particularly important to balance the fluctuating power from renewable energy sources such as wind and sun.

The flex bonus, on the other hand, is an additional payment for biogas plants that are able to feed electricity into the grid within a certain period of time on request. The bonus is ment to cover additional costs of the needed capacity expansion.

These mechanisms have changed biogas plant design and concepts in several ways:

Technical adjustments: Biogas plants must now have state-of-the-art technologies and control systems in order to be able to react flexibly to the requirements of the electricity grid. This includes, for example, the use of powerful gas storage facilities, more efficient gas processing plants and advanced control systems.

Increase in efficiency: The flex premium and the flex bonus have created an incentive to increase the efficiency of biogas plants. Thanks to the flexible operation, plants can make better use of their generation peaks and optimize the feeding of electricity into the grid. This contributes to the economic profitability of the systems.

Grid usefulness: Biogas plants are now able to make an active contribution to grid stability by being able to quickly feed additional electricity into the grid or throttle their generation if required. This is particularly important to optimize the interaction of different renewable energy sources and to protect the power grid from overload.

Market integration: Biogas plants are integrated into the electricity market through the flex premium and the flex bonus. They can now react specifically to fluctuations in electricity prices by increasing their generation when prices are high and reducing them when prices are low. This improves the profitability of the plants and contributes to the stability of the electricity market.

Overall, the flex bonus and the flex bonus have significantly advanced plant construction and concepts for biogas. Biogas plants are now technologically more sophisticated, more efficient and can make a greater contribution to the energy transition and to stabilizing the power grid.

In summary, the EEG has been and continues to be a successful tool for technology development and financing to expand RE in the German electricity sector. While tariff rates for photovoltaic and wind could be lowered after a certain funding period, this has not been possible for bioenergy generation. This is due to the fact that bioenergy is coupled with other areas such as landscape management, nature conservation, resource policy, and emission control in addition to pure electricity production. In particular, increased agricultural prices and higher technical and emission control plant requirements led to higher costs. The current framework conditions therefore leave open the question of what options existing plants have after the 20-year remuneration period.

Waste and manure usage in biogas in the framework of the EEG

Waste-to-energy plants are treated as a separate category within the EEG. They generate energy from the incineration or gasification of waste. Biogenic waste was to be increasingly fed into anaerobic digestion instead of composting with the introduction of a separate article and increased remuneration entitlement. High transport costs and worsened conditions, e.g. due to TA Luft requirements, supported this goal. Since waste collection is organized by the municipality and has to be put out to tender at regular intervals, the implementation of a biogas plant is only possible within a long-term strategic support by the municipality. In addition, the amount and quality of waste is subject to seasonal fluctuations, which makes the operation and projected revenues of the plant difficult to calculate.

The special Biowaste remuneration could be achieved by using at least 90 percent of input from the following 3 waste codes:

Waste code number 20 02 01: Biowaste from agriculture and horticulture.

> This includes wastes of plant or animal origin generated on farms or in horticulture. This includes, for example, waste from plant residues, green cuttings, agricultural harvest residues, manure or slurry.

Waste code number 20 03 01: Biowaste from food and beverage production.

> Refers to wastes generated during the production of food and beverages. These can be, for example, organic residues, waste from fruits and vegetables, peels, coffee grounds, tea residues or waste from breweries or dairies.

Waste code number 20 03 02: Wastes from the preparation and processing of meat, fish and other food of animal origin.

> This includes wastes generated during the processing and preparation of meat, fish or other food of animal origin. This includes, for example, bones, fish scraps, animal by-products, offal or unprocessed food scraps.

While manure is part of the waste codes above, an additional bonus outside of the waste remuneration was created to incentivise the use of manure in biogas plants.

The so-called "manure bonus" refers to a special compensation scheme for biogas plants that use manure or other substrates of animal origin to produce biogas.

A promoted concept is the use of at least 30 mass percent of liquid manure in regular biogas plants. If the limit is met, the feed-in tariff for the entire plant is increased. This is a particularly attractive concept for agricultural biogas plants with livestock where manure is produced anyway and must be stored until it is spread.

Another concept is the so called small manure plants. With this concept, plants up to a certain size (150 kWelectric) were especially promoted, which used at least 80 percent agricultural residues. This concept was aimed primarily at small farms such as those in the south of Germany. For the usage of manure in biogas plants several additional ordinances apply.

4.2.4 Fertilizer application Ordinance (Düngeverordnung DüV)

The Fertilizer Ordinance regulates the handling of fertilizers and the use of fertilizers on agricultural land in Germany. It aims to protect water bodies from excessive pollution from nutrients from agricultural sources.

With regard to biogas plants and fermentation residues, the Fertilizer application Ordinance contains specific regulations. Biogas plants produce biogas by fermenting organic substances such as liquid manure, manure, energy crops or other biogenic waste. The regulations relating to biogas plants and digestate mainly concern the utilization and use of digestate as fertiliser.

The Ordinance sets limit values for certain nutrients such as nitrogen and phosphorus, which must be observed when spreading fermentation residues. The fermentation residues may only be applied in a certain ratio to the agricultural land in order to avoid over-fertilization. There are also specifications for the storage and spreading of the fermentation residues in order to prevent nutrients from being washed out into water bodies.

With regard to the consideration of biogenic waste, the ordinance aims to promote the sustainable utilization of biomass. Biogenic waste can be used as fertilizer or soil conditioner. However, they are subject to the same specifications as other fertilizers in terms of their nutrient composition and application quantities in order to ensure environmentally friendly application.

4.2.5 Circular Economy Act (KrWG)

Purpose

The purpose of the Act is to promote circular economy in order to conserve natural resources and to ensure the protection of human health and the environment in the generation and management of waste.

The Act is furthermore intended to promote the achievement of the targets under European law enshrined in Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

Scope

The provisions of the present act shall apply to
1. the prevention of waste,
2. the recovery of waste,
3. the disposal of waste, and
4. other activities of waste management.

The law contains a provision concerning the distinction between waste and byproducts that do not fall within the scope of the law. A byproduct is a substance that is produced in connection with the manufacture of another substance or product, and is thus not the main focus of the manufacturing process. In order for an element to qualify as a byproduct, it must also meet the following criteria:

- must be possible to reuse the element
- Preprocessing exceeding the normal industry standard scope is unnecessary
- Production of the element is inherent to a manufacturing process
- Reuse of the element complies with all applicable laws concerning product, environmental and health protection requirements and not being an environmental or health hazard[62]

A substance no longer qualifies as waste (end-of-waste-status) insofar as the following criteria are met:

- A recycling and/or reclamation process has been carried out
- The substance is used for a specific purpose
- There is demand or a market for the substance
- Specific technical and legal requirements are met
- Use of the substance engenders no harm

One of the core provisions of the Circular Economy Act (KrWG) is the five-step hierarchy, according to which the following ranking of waste management measures applies:

- Prevention
- Preparation for recycling
- Recycling
- Other types of recovery, particularly use for energy recovery
- Disposal

Based on this hierarchy, the waste management measures are to be used that best protect human health and the environment, in light of the relevant technical, economic and social factors. Having regard to recovery/reclamation options (preparation for reuse, reclamation and/or recycling), a given recovery measure may receive higher priority or equal priorit as well as requirements concerning the prioritizing of recovery for specific types of waste may be foreseen and, are to be governed by specific regulations.

Since 2015, sorting is mandatory for organic waste, as well as for paper, metal, plastic and glass. With a view to promoting recycling, Article 14 sets so called recovery rates that will become mandatory in 2022.

According to the KrWG, there is a general obligation to collect biowaste separately. This means that biowaste must be recorded and collected separately from other waste streams to enable high-quality recycling. Biowaste includes organic waste that is biodegradable. This includes, for example, kitchen and food scraps, garden waste, vegetable waste, but also compostable packaging such as bioplastics or compostable paper. The public waste management authorities are responsible for ensuring the separate collection and recycling of biowaste in their area of responsibility. They must set up and operate appropriate collection systems.

Article 17(1) stipulates that household waste and waste of other origins are to be handed over to public sector garbage collection companies with exemption of the use in home composters. Article 17(3) states that exemptions to the handover requirement may be granted for commercial refuse collection, insofar as such exemptions are not in conflict with public interests. Article 18 promulgates a new notification procedure for such public and commercial sector refuse collections.

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[62] The Federal Government is herewith empowered, after consulting the parties concerned, by means of a statutory ordinance with the consent of the Bundesrat, in accordance with the requirements, to determine criteria according to which specific substances or objects are to be regarded as by-products, and to establish requirements for the protection of human health and the environment

In particular, the regulations in Article 11 (Requirements for biowaste treatment plants) and Article 12 (Quality standards for composts and fermentation products) are relevant for biowaste fermentation plants.

Article 11 regulates the requirements to ensure hygienic, environmentally sound and efficient recycling of biowaste. The exact provisions can be defined by legal ordinances, such as the Biowaste Ordinance.

Hygienic requirements: Biowaste treatment plants must take measures to ensure hygienic conditions. This includes, for example, specifications for temperature monitoring, the prevention of odor emissions and the prevention of the spread of pathogens.

Environmental impact: facilities must take measures to minimize environmental impacts, such as protecting water and soil. This includes requirements to limit emissions of odors or pollutants.

Technical equipment: biowaste treatment plants must have the necessary technical equipment to efficiently carry out the recycling of biowaste. This includes, for example, plant components such as composting or fermentation technologies, as well as storage facilities for biowaste.

Article 12 of the KrWG sets quality standards for composts and fermentation products obtained from biowaste recycling. These standards can also be further specified by legal ordinances. The quality standards can relate to aspects such as the content of pollutants, nutrient contents or other relevant parameters.

4.2.6 Biowaste Ordinance (BioAbfV)

In 14 paragraphs and four annexes, the Biowaste Ordinance aims at the proper examination, treatment and recycling of biowaste and mixtures. It is aimed at waste disposal companies, producers, owners, treaters and manufacturers of biowaste and mixtures.

The Biowaste Ordinance also imposes differentiated restrictions, prohibitions and requirements on the application of biowaste to agricultural, horticultural and forestry soils, permanent grassland, field fodder and field vegetable cultivation areas, distinguishing between the soil types clay, loam and sand.

4.2.7 Federal Immission Control Act (BImSchG)

In Germany, the Federal Immission Control Act (BImSchG) regulates protection against harmful effects on the environment that may be caused by certain installations, emissions and immissions. The BImSchG also contains provisions on the use of biogenic sources for energy.

In connection with the energetic use of biogenic sources, the BImSchG regulates in particular the licensing requirement for plants for the generation of electricity, heat or cooling from biomass. These plants are referred to as "biogenic plants" and are subject to the regulations of the BImSchG to ensure that environmental impacts are minimized.

The relevant ordinances related to the use of biogenic sources for energy are:

- **The Ordinance on Plants Requiring a Permit (4th BImSchV):** This ordinance contains specific regulations for bioenergy plants in Germany. It aims to limit emissions from these plants and ensure the protection of people and the environment.
    - Approval procedure: The ordinance sets out requirements for the approval procedure for bioenergy plants. Submission of application documents, site conditions and environmental impacts to be taken into account, and public participation.
    - Emission limits: The 4th BImSchV sets emission limits that must be met by bioenergy plants, e.g. nitrogen oxides (NOx), carbon monoxide (CO), dust, organic compounds and odor emissions.
    - Measurements and monitoring: Obligation of regular measurements and monitoring of emissions.
    - Specific regulations for certain types of bioenergy plants, such as biomass combustion plants or biogas plants, e.g. additional requirements regarding technical equipment and fuel quality.

- **The Ordinance on Plants for the Biological Treatment of Waste (AbfKlärV):** This ordinance concerns plants in which biogenic waste is treated and used for energy generation. It contains requirements for the technical equipment and operation of such plants.
    - It specifies requirements for the technical equipment and operation of such plants.
    - Criteria are defined for the quality of the waste used.
    - The ordinance contains specifications for the storage, processing and treatment of the waste.
    - It ensures that the environmental impact of the plants is minimized and that the protection of people and the environment is guaranteed.
- **The Ordinance on Plants for the Incineration of Certain Wastes (17. BImSchV):** This ordinance concerns plants in which biogenic waste is used to generate energy by incineration. It regulates the requirements for incineration technology, emission control and the operation of such plants.
    - It regulates the technical requirements for incineration technology and emission limitation in order to minimize harmful environmental effects.
    - It sets limits for pollutant emissions that plants must comply with.
    - The ordinance also contains regulations for the operation, monitoring and maintenance of the plants.
- **The Ordinance on the implementation of the biofuel quota regulations (36. BImSchV**): This ordinance aims to promote the use of biofuels and increase their share of total fuel consumption.
    - The ordinance stipulates that biofuels produced from wastes and agricultural residues are counted more heavily than biofuels from other sources when meeting the biofuel quota. This is intended to create incentives to use waste and residues sensibly and to better exploit their energy potential.
    - The 36th BImSchV also contains sustainability criteria for the production of biofuels. These criteria ensure that no negative impacts on the environment, social and working conditions, and land use occur during production. The use of waste and agricultural residues can help to meet the sustainability criteria, as they reuse waste and help to avoid land use conflicts.

4.2.8 Recommendation for twinning

Since bioenergetic use of waste and residues in Turkiye still needs to be developed, first priority should be to build an environment of long term political support and build a basis for a sustainable market for bioenergy. The following steps are recommended for twinning German

Establishing a common understanding what types of biogenic ressource belongs in what category.

- ➔ Definition of biowastes and residues similar to Biowaste Ordinance and Fertilizer application Ordinance
- ➔ Set up quality criteria for residues of energetic use of biogenic inputs to ensure usage as fertilizer on farmland

Establish rules for examination, treatment and recycling of biowaste and mixtures

- ➔ It is conceivable to establish the fermentation of municipal biowaste in an act as an efficient recycling method, in conjunction with the requirement to use the fermentation residues as a digestate fertilizer or growing medium, as long as there are no excessive levels of pollutants.
- ➔ Defining waste hierarchies (like in the german KrWG) can guarantee efficient resources use and ensure that waste streams can be steered towards energetic use without competing use.

Develop a support mechanism to foster investments in technology and value chains with elements that allow to steer and adjust within the progress made.

- ➔ In general a financial support mechanism like the renewable energy sources act has proven to be an efficient starter for a bioenergy market.

➔ Bonuses can be beneficial to support specific plant concepts over others.

4.3 German funding and research support

4.3.1 Funding program "Renewable Resources"

The funding program of the Agency for renewable raw materials (FNR) named "Renewable Resources" is intended to support the further development of the sustainable bioeconomy and open up new opportunities and perspectives for Germany as an industrial location and for the development of rural areas. On the one hand, it supports the development of innovative, internationally competitive biobased products as well as processes and technologies for their production and, on the other hand, the development of concepts aimed at improving the sustainability of the biobased economy and taking into account societal expectations.

The demand for sustainably produced biomass will continue to grow. The funding program takes this into account and prioritizes funding for research, development and demonstration projects in the following areas:

- Sustainable production and supply of renewable resources
- Raw material and residue preparation and processing
- Bio-based products and bioenergy sources
- Overarching topics
- Social dialogue.

Additional funds for research and development in the bioenergy sector are available from the special "Climate and Transformation Fund" (KTF). KTF projects on bioenergy are managed by the FNR on behalf of the German Federal Ministry of Food and Agriculture. It implements the funding on the basis of the "Renewable Resources" funding program and the application procedure applicable to it. 86.5 million euros are available from the 2023 federal budget to implement the program.[63]

An example of a project with a logistics focus is the joint project: **Supply chain wood, IT and from road to rail; Subproject1: Project coordination and logistics, information technology research and processing - Acronym: VEHIT.** The project aims to improve the wood supply chain through the systematic use of IT (VE-HIT) and to develop an intelligent supply chain concept leading to increased rail transport. Transport policy solutions, such as increasing the permissible truck weight to 44 t, are insufficient for the overall problem, so that the timber supply to the market is increasingly at risk. An additional problem is large volumes of damaged timber as a result of climate change. The problem is only achievable by changing the means of transport and means a systematic shift of timber transport from truck to rail. New supply chain concepts must be designed to compensate for the systemic disadvantages of rail in order to take advantage of the special strengths of the rail system. Special loading stations, so-called 'timber ports', are needed for this purpose. These timber ports are modeled as 'digital twins' in the VEHIT project. The analysis focuses on the question of suitable locations that have the potential to continuously supply Timberports with logs. Furthermore, Timberports are to be integrated into the systemic networking of the actors (forestry, truck or rail transport, timber industry) by means of IT. In order to create the conditions for practical site realization, viable business models and suitable operating concepts must be developed to ensure the economic viability of the entire timber supply chain.[64]

4.3.2 Forest and Climate Fund

The Federal Ministries of Food and Agriculture and of the Environment, Nature Conservation, Nuclear Safety and Consumer Protection use funds from the Forest Climate Fund to support measures to preserve and expand the CO2 reduction potential of forests and wood and to adapt forests to climate change. The Forest Climate Fund and its funding guidelines for maintaining and expanding the CO2 reduction potential of forests and wood and for adapting forests to climate change are an integral part of the Climate and Transformation Fund and serve its purpose and objectives without restriction.[65]

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[63] FNR (2023): Förderprogramm Nachwachsende Rohstoffe. Online available at: https://www.fnr.de/projektfoerderung/foerderprogramm-nachwachsende-rohstoffe. Accessed 15.06.2023.

[64] FNR (2023): Projektverzeichnis Details. Online available at: https://www.fnr.de/index.php?id=11150&fkz=2220NR009A. Accessed 15.06.2023.

[65] Waldklimafonds (2023): Waldklimafonds in Kürze. Online available at: https://www.waldklimafonds.de/hintergrund-und-ziele/waldklimafonds-in-kuerze. Accessed 15.06.2023.

One project example is the joint project: **Blockchain technology as a driver for the digitalization of forestry; Subproject 1: Acronym: Potential study.** Blockchain technology offers the possibility to map information processes and data structures in a logged, traceable, unchangeable and decentralized manner. This technology therefore appears suitable to be used for process steps and products in wood logistics, but also, if necessary, in principle for the documentation and mapping of digital data and services in forestry. The proposed project will analyze the potential and possible restrictions of blockchain technology and identify possible applications in forestry.[66]

4.3.3 Fermentation of farm manure

Increased fermentation of farm manure in biogas plants is an important measure of the German government's Climate Protection Program 2030 for the agricultural sector to reduce emissions from livestock farming. To implement these goals, the BMEL is funding the following measures through the FNR project management agency:

- Research and development projects for the energetic and emission-reducing use of farm manure in biogas plants.
- Model and demonstration projects to increase the share of manure in biogas plants
- Investments in emission-reducing measures for the fermentation of manure.

The program funds are provided by the special fund "Climate and Transformation Fund" (KTF) and amount to € 58.55 million in 2023.

4.3.4 Regenerative Biofuels

Together with the project management organization VDI/VDE Innovation + Technik GmbH, the FNR oversees the funding guideline for the development of regenerative fuels issued by the German Federal Ministry of Digital Affairs and Transport (BMDV). The guideline is primarily aimed at research, demonstration and pilot projects; within its framework, the market ramp-up of advanced biofuels is also supported.[67]

One example is the project **"Development of electricity-based fuels and advanced biofuels for maritime applications".** Funding is provided for individual and collaborative projects in which concepts, technologies and process chains for sustainable renewable marine fuel production are further developed.[68]

4.3.5 Energetic Biomass Utilization

Research Program "Energetic Biomass Utilization" of the BMWi uses this program to fund research and development projects for the efficient and sustainable use of biomass for energy production. The funding covers various topics such as

- Development of biogenic residual and waste materials
- Technologies and concepts for system integration
- Technologies and concepts for sector coupling
- Technologies for electricity and heat generation and their combined use
- Production of sustainably produced liquid and gaseous biofuels.

The promotion of energetic biomass use was initiated in 2008 by the German Federal Ministry for the Environment with the program "Promotion of research and development for climate-efficient optimization of energetic biomass use". In 2014, the program moved to the responsibility of the BMWi. Since September 2018, the new funding area "Energetic use of biogenic residual and waste materials" has been funded in the 7th Energy Research Program "Innovations for the energy transition" (Section 3.7).[69]

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[66] Kompetenz- und Informationszentrum Wald und Holz (2023): Projekte – Details. Online available at https://www.kiwuh.de/index.php?id=13475&fkz=2221NR077A. Accessed 15.06.2023.
[67] NOW (2023): Entwicklung regenerativer Kraftstoffe. Online available at: https://www.now-gmbh.de/foerderung/foerderfinder/entwicklung-regenerativer-kraftstoffe-08-2021/. Accessed 12.10.2023.
[68] NOW (2023): Förderaufruf Strombasierte Kraftstoffe für maritime Anwendugen. Online available at: https://www.now-gmbh.de/wp-content/uploads/2022/12/Foerderaufruf-strombasierte-Kraftstoffe-fuer-maritime-Anwendungen.pdf. Accessed 15.06.2023.
[69] Energetische Biomassenutzung (2023): Förderung. Online available at: https://www.energetische-biomassenutzung.de/foerderung. Accessed: 15.06.2023.

Renewable raw materials in industry

The German Federal Ministry of Education and Research (BMBF) funding initiative "Renewable raw materials in industry" aims to promote the sustainable use of renewable raw materials, including biomass for energy production. Within the framework of this initiative, projects are supported that deal with the potential analysis of various biomass resources and the logistical challenges in the provision and utilization of biomass.[70]

The following projects are included in the funding initiative:

"Bioeconomy International" funding program of the BMBF promotes international research cooperation for the development of a sustainable bioeconomy. It also includes projects on potential analysis and logistics in the field of bioenergy. The aim is to develop innovative approaches for the sustainable production, use and utilization of biomass and to overcome its logistical challenges. The duration of the projects to be funded is generally up to three years. The amount of funding per project is based on the requirements of the project applied for within the limits of the available budget, but may not exceed 500,000 euros per network.[71]

"SME-innovative Bioeconomy" of the BMBF: Funding is provided for technologically demanding, high-risk projects that combine the efficient use of biological knowledge with innovative solutions and can be assigned to the bioeconomy in a comprehensive sense. The focus is on the development and manufacture of future-oriented, climate-neutral products from biogenic resources while minimizing environmentally harmful emissions and waste, or their return to natural cycles or value chains.[72]

4.3.6 Investment programs of the Kreditanstalt für Wiederaufbau (KfW)

Investment program for renewable energies (loan 270) of KfW Bank offers various loan programs for the promotion of bioenergy projects. The "Renewable Energies - Standard" program supports investments in renewable energies, including bioenergy.

- Loan from 4.75% effective annual interest rate
- For power and heat generation plants, grids and storage facilities
- For photovoltaics, water, wind, biogas and much more
- For private individuals, companies and public institutions[73]

Other loan programs that support the use/production of bioenergy include:

- Federal funding for efficient buildings credit - Residential building (loan 261)[74]
- Federal funding for energy and resource efficiency in the economy (loan 295)[75]

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[70] BMBF (2023): Nachwachsende Rohstoffe in der Industrie. Online available at: https://www.bmbf.de/bmbf/de/forschung/energiewende-und-nachhaltiges-wirtschaften/biooekonomie/industrielle-biotechnologie/nachwachsende-rohstoffe-in-der-industrie.html. Accessed 15.06.2023.

[71] BMBF (2023): Bekanntmachung. Online available at: https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2023/03/2023-03-03-Bekanntmachung-Bio%C3%B6konomie.html. Accessed 15.06.2023.
PtJ (2023): Bioökonomie International. Online available at: https://www.ptj.de/projektfoerderung/biooekonomie/biooekonomie-international. Accessed 15.06.2023

[72] PtJ (2023): KMU-Innovativ Bioökonomie. Online available at: https://www.ptj.de/projektfoerderung/biooekonomie/kmu-innovativ-biooekonomie. Accessed: 15.06.2023.

[73] KfW (2023): Erneuerbare Energien Standard. Online available at: https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/F%C3%B6rderprodukte/Erneuerbare-Energien-Standard-(270)/. Accessed 16.06.2023.

[74] KfW (2023): Bundesförderung für effiziente Gebäude. Online available at: https://www.kfw.de/inlandsfoerderung/Unternehmen/Wohnwirtschaft/F%C3%B6rderprodukte/Bundesf%C3%B6rderung-f%C3%BCr-effiziente-Geb%C3%A4ude-Wohngeb%C3%A4ude-Kredit-(261-262)/. Accessed 16.06.2023.

[75] KfW (2023): Bundesförderung für Energie- und Ressourceneffizienz in der Wirtschaft. Online available at: https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/F%C3%B6rderprodukte/Energieeffizienz-und-Prozessw%C3%A4rme-aus-Erneuerbaren-Energien-(295)/. Accessed 16.06.2023.

- Investment credit for municipalities - urban energy refurbishment - Neighborhood supply (loan 201)[76]
- Investment loan for municipal and social enterprises Energy-efficient urban redevelopment - neighborhood services (loan 202)[77]

4.3.7 Federal subsidy for efficient buildings

With the new federal subsidy for efficient buildings (BEG), one of the core elements of the National Climate Protection Program 2030, the German government has been reorganizing energy-related building subsidies since January 1, 2021 by combining the former subsidies from KfW and BAFA. Through the BEG, for example, heating systems in newly constructed residential and non-residential buildings and biomass heating systems are subsidized.

In addition, the BEG promotes the construction or expansion of a building network for the exclusive self-supply of at least 2 to a maximum of 16 buildings on one or more plots of land of an owner as well as their connection to a building or heating network. Thus, in contrast to the federal subsidy for efficient heating networks (BEW), the focus here is on the direct supply of energy to buildings. The prerequisite for the subsidy is that at least 25 percent of the heat is generated by RE and no oil is used as fuel. If at least 25 percent RE is used, the subsidy rate is 30 percent. If at least 55 percent RE is used, the quota increases to 35 percent (plus, if applicable, oil exchange bonus as well as innovation bonus for biomass). The budgetary funds provided by the federal budget for the BEG were exhausted at the beginning of the year, which is why KfW decided to freeze applications and commitments for BEG funding. The BEG is financed from the Climate and Transformation Fund.[78]

4.3.8 Regional funding programs

Regional funding programs for bioenergy projects were offered in various German states and municipalities. These included grants and loans for the construction and modernization of biogas plants, the use of biomass for heat and power generation, and the establishment of local heating networks.

An example is the **"Competence Center Forest and Wood 4.0":** The Competence Center Forest and Wood 4.0, coordinated by RIF Institut für Forschung und Transfer e. V., transfers modern methods of digitalization to forestry and thus helps to make optimal and sustainable use of the renewable raw material wood. Analogous to the Industry 4.0 concept, all actors and components in the Forest and Wood cluster can be digitally networked and interlinked in the future. Machines and devices will become intelligent and decentral acting components. The linkage with new services supports the people in the forestry sector. Tasks such as inventory, planning, timber harvesting, timber trade or logistics can be designed in an integrated manner. This can improve the entire value chain. In addition, the intelligent use of the collected data makes it possible to meet the current challenges of ecology, economy and climate change in a sustainable manner.
This project was supported by the state of North Rhine-Westphalia with funding from the European Regional Development Fund (ERDF).[79]

4.3.9 Recommendation for twinning

It has shown that the most efficient way to support research in such a specific and broad topic like bioenergy is being done by having a central institute provided with a specific budget to manage. This way the most efficient use is guaranteed and the same topic is not covered several times in different research programmes.

Low-threshold financing programs for investments in infrastructure and generation like KfW loan programme have shown very strong outcomes in terms of effect on investment activities. In the field of electricity production, the renewable energy

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[76] KfW (2023): IKK Energetische Stadtsanierung – Quartiersversorgung. Online available at: https://www.kfw.de/inlandsfoerderung/%C3%96ffentliche-Einrichtungen/Kommunen/F%C3%B6rderprodukte/Energieeffiziente-Quartiersversorgung-Kommunen-(201)/. Accessed 16.06.2023.
[77] KfW (2023): IKU Unternehmen Energetische Stadtsanierung – Quartiersversorgung. Online available at: https://www.kfw.de/inlandsfoerderung/%C3%96ffentliche-Einrichtungen/Kommunale-Unternehmen/F%C3%B6rderprodukte/Energieeffiziente-Quartiersversorgung-kommunale-Unternehmen-(202)/. Accessed 16.06.2023.
[78] BAFA (2023): Förderprogramm im Überblick. Online available at: https://www.bafa.de/DE/Energie/Effiziente_Gebaeude/Foerderprogramm_im_Ueberblick/foerderprogramm_im_ueberblick_node.html. Accessed 16.06.2023.
[79] RIF (2023): Kompetenzzentrum Wald und Holz 4.0. Online available at: https://www.rif-ev.de/artikel/kwh-40. Accessed 16.06.2023.

installations co-financed through the RE Standard programme reached shares of 32.8 % and 33.4 % of total RE electrical power installed in Germany in the years 2019 and 2020 (excluding offshore wind energy plants).[80]

4.4 Twinning and Comparison, gap analysis of Turkish Regulation in terms of scope of the Energy, Environment, Financing /Banking

4.4.1 Identification of key role regulations and recommendation of potential German experts/ twinning partners

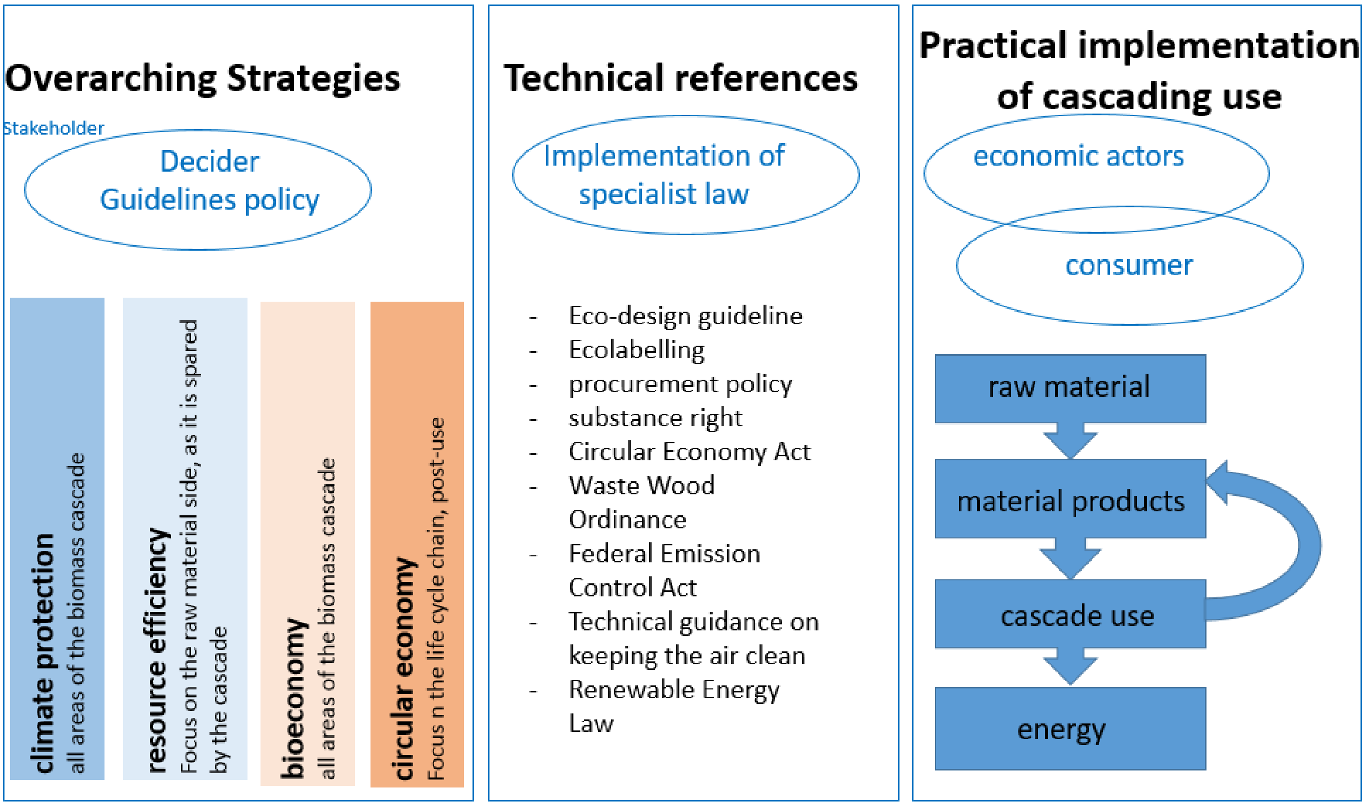

Figure 14: Strategic cornerstones for increased cascade use of biomass and connection of concerned areas of action fields and stakeholder groups[81]

[80] Assessment of environmental and social impacts of the KfW loan programme "Renewable Energies – Standard" for the years 2019 and 2020; https://www.kfw.de/%C3%9Cber-die-KfW/Service/Download-Center/Konzernthemen/Research/Evaluationen/Evaluationen-Erneuerbare-Energien/
Accessed 20th June 2023

[81] UBA (2017): Biomassekaskaden Mehr Ressourceneffizienz durch Kaskadennutzung von Biomasse – von der Theorie zur Praxis. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2017-06-13_texte_53-2017_biokaskaden_abschlussbericht.pdf. Accessed 12.10.2023.

5 Best available and state of the art technologies of Germany

In this chapter the best avaible and state of the art technologies of Germany will be discussed. Fuel can be generated from different types of biomass with various conversion technologies. In the following agricultural wastes and residues as well as industrial and domestic wastes and residues are described as well as the conversion technologies fermentation, anaerobic digestion, liquefaction, pyrolysis and gasification. The energy carriers can be produced by these processes in solid liquid or gaseous aggregate states (Figure 15)

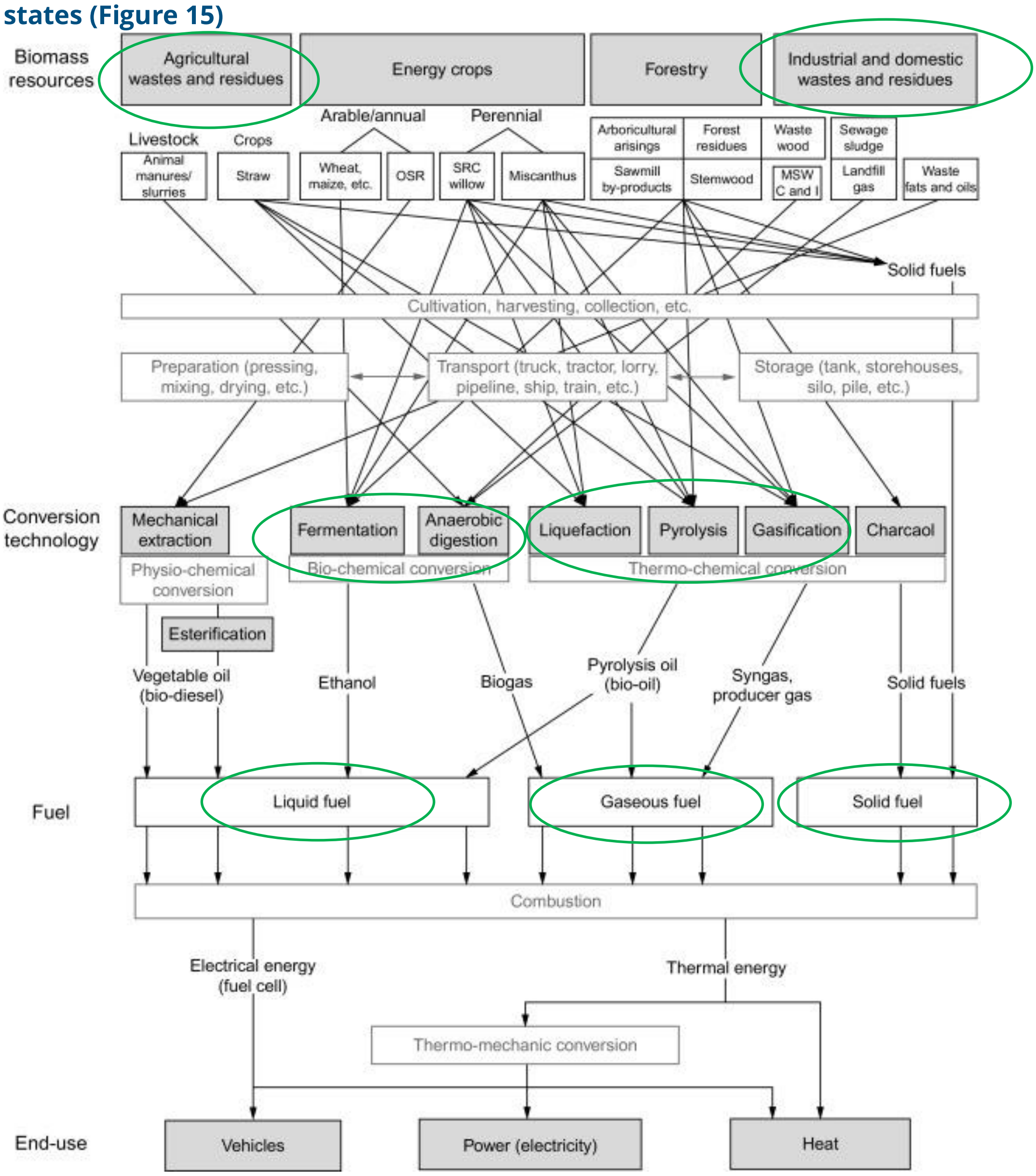

Figure 15: Overview of considered resources and conversion technologies[82]

[82] Adams, P., Bridgwater, T., Lea-Langton, A., Ross, A., Watson, I. (2018): Greenhouse Gas Balances of Bioenergy Systems. Online available at: https://www.sciencedirect.com/science/article/pii/B9780081010365000082. Accessed 01.12.2022.

5.1 Fermentation[83]

Organic materials' glucose is broken down by fermentation, which is an anaerobic process. Sugars are changed into alcohol or acid by a sequence of chemical reactions. The biomass material is mixed with yeast or bacteria, which eat the sugars to create ethanol and carbon dioxide. To acquire a higher concentration of alcohol and the necessary purity for use as motor fuel, the ethanol is distilled and dehydrated. In the case of sugar cane, the solid byproduct of the fermentation process can be used as animal feed or as a fuel for boilers or further gasification.

Fermentation of forest and industrial residues

As substrates for fermentation, raw materials that contain sugars or can be converted into sugars can be employed. Directly fermentable sugary resources, starchy, lignocellulosic materials, and industrial wastes can all be classified as fermentable raw materials. When converting materials into fermentable substrates, sugar-containing materials require the least expensive pretreatment compared to starchy, lignocellulosic, and urban wastes.

Fermentation of agricultural wastes

Due to their primary use as food and feed as well as environmental concerns (high yield factor) conventional crops like corn and sugarcane cannot supply the need for bioethanol production on a worldwide scale. As a result, lignocellulosic materials like agricultural waste are desirable feedstocks for the generation of bioethanol. Agricultural wastes are cheap, abundant, and renewable. The production of bioethanol from agricultural waste has the potential to be a promising technology, but there are a number of obstacles and restrictions in the way of biomass handling and transportation as well as effective pretreatment techniques for complete lignocellulosic delignification. After enzymatic saccharification, appropriate pretreatment techniques can boost quantities of fermentable sugars, enhancing the effectiveness of the entire procedure. To make the entire process cost-effective, new fermentation technologies are required for the conversion of xylose and glucose to ethanol. The objectives of a successful pretreatment procedure are:

- formation of sugars directly or subsequently by hydrolysis
- to avoid loss and/or degradation of sugars formed
- to limit formation of inhibitory products
- to reduce energy demands
- to minimize costs.

5.2 Anaerobic Digestion[84]

Anaerobic digestion is the process of breaking down complex organic molecules with the aid of microorganisms in the absence of oxygen. It is also known as biological oxidation of biodegradable waste by microbes in anaerobic conditions. This product's final byproduct contains significant amounts of carbon dioxide and methane. As a biochemical process, anaerobic digestion mostly uses substrates high in organic matter, such as sludge, household waste, sewage, and waste from a cow feedstock.

Anaerobic Digestion Process

Methanogens and acetogens, a type of anaerobic bacteria that do not use oxygen as an electron donor but instead absorb electrons from acetate and methane for their energy synthesis, are the primary anaerobic bacteria that perform anaerobic decomposition in anaerobic digesters. Anaerobic digestion involves four key processes, which are as follows:

1. Hydrolysis - The liquefaction of complicated molecules is another name for it. Complex molecules contain intricate architectures made up of several chains. Hydrolysis is the process of dissolving chains with the aid of hydrolyzing enzymes. The breakdown of high molecular weight polymeric components yields simple sugars and monomers that are easily accessed by bacteria. These processes result in the production of acetate, hydrogen, and certain VFAs (Volatile Fatty Acids). The microorganisms cannot directly use VFAs, thus they must first be catabolized into smaller compounds that the bacteria can use.

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[83] European Biomass Industry Association (2022): Fermentation. Online available at: http://www.eubia.org/cms/wiki-biomass/fermentation/. Acessed 30.11.2022.
[84] European Biomass Industry Association (2022) Anaerobic Digestion. Online available at: https://www.eubia.org/cms/wiki-biomass/anaerobic-digestion/. Acessed 30.11.2022.

2. Acidolysis - It is the process of breaking down complex molecules and oligo polymers into smaller, simpler molecules. Acidogenesis is a process carried out by acidogenic bacteria. Ammonia, carbon dioxide, hydrogen sulfide, and other byproducts are produced during this reaction.

3. Acetogenesis - Acetogens are used in the process of acetogenesis, which produces acetic acid. Carbon dioxide and hydrogen are the principal byproducts of this process.

4. Methanogenesis - The process of anaerobic decomposition ends here. It's a pH-sensitive process that takes place between pH 6.5 and pH 8. Methane, carbon dioxide, and hydrogen are produced in this stage using the intermediate product from earlier phases.

5.3 Liquification/Biomass to Liquid

Biomass to liquid (BtL) refers to a process chain that converts biomass into synthesis gas via thermochemical gasification and its subsequent synthesis into liquid hydrocarbons. The biogenic hydrocarbons produced in this way can be upgraded to marketable fuels such as diesel or gasoline using known petroleum refining processes.

In principle, any plant biomass can be used to produce BtL fuels. Particularly suitable is cellulose-rich, dry residual biomass such as:

- Straw
- Residual wood
- Energy crops (SRC, Miscanthus...)
- Landscape wood
- Biowaste

While for conventional biofuels often only parts of the plant - mostly the seeds - serve as raw material, the entire plant can be used for the production of BtL fuels.

Production

Different processes are currently being developed for the production of BtL fuels on a research and pilot scale in various companies and research facilities. As a result, the production process also varies in detail.

In principle, however, the following four process steps are necessary for the production of BtL fuels.

1. Gasification: To produce a liquid fuel from biomass, the raw materials must first be converted into a synthesis gas. This is done in a reactor. There, the solid biomass is converted into a gaseous state by heat, pressure and a gasification agent (e.g. oxygen). The process is also called thermochemical gasification. The synthesis gas consists of hydrogen (H_2), carbon monoxide (CO) and carbon dioxide (CO_2), sulfur and nitrogen compounds, and other components.

2. Gas purification: In order to be able to use the synthesis gas, various harmful components (e.g. sulfur and nitrogen compounds) must be removed, as these can damage the catalysts in the subsequent synthesis process. In addition, the hydrogen content in the gas is increased by CO shift and carbon dioxide is separated.

3. Synthesis: In the synthesis step, the gas mixture is processed into liquid hydrocarbons. This is usually done by Fischer-Tropsch (FT) synthesis or by the Methanol-to-Gasoline® (MtG) process.

4. Processing: In processing, a selection into heavy, medium and light fractions takes place. These are then specifically refined and adapted to the desired fuel properties.

BtL fuels are produced synthetically. Their properties can be specifically influenced and optimized for special applications and combustion processes. The fuels can be specially adapted in response to further developments in the engine sector.

All BtL fuels have in common a high cetane content, freedom from sulfur and aromatics, and significantly reduced pollutant emissions (e.g. nitrogen oxides NO_x and particulates). Compared to fossil diesel they reduce CO_2 emissions to 90 percent.

5.4 Gasification[85] [86]

The gasification process gains importance especially because of the opportunities it provides in the disposal of wastes, where emission management is diffucult and efficiency is critical. There are various processes of biomass gasification, i.e. the production of combustible gases by thermochemical processing of biomass, especially wood. The basic principle is converting biomass at an elevated temperature (usually several hundred degrees Celsius) in the absence of oxygen. Thus, not all organic components are oxidized with the release of heat, but a significant proportion of combustible substances such as hydrogen (H_2), methane (CH_4) and carbon monoxide (CO) remain in the gas produced. That type of synthesis gas that can be used either energetically or materially:

- For example, a gas engine can be operated in a combined heat and power plant to generate electrical energy.
- Another example is biofuel, which can be produced from synthesis gas. The plants needed for this, which combine biomass gasification with Fischer-Tropsch synthesis, for example, as well as further refining of the products, would be called biorefineries.

Raw materials suitable for gasification

Raw materials suitable for gasification can be forest wood, e.g. from short-rotation plantations, but also forest residues and wood residues from wood processing processes. Also suitable for gasification are various agricultural residues rich in lignocellulose, such as straw. The use of manure and sewage sludge is also possible.

In many gasification processes, it is necessary to dry the biomass first. Often, mechanical pretreatment is also necessary, especially shredding.

Different gasification agents; autothermal and allothermal gasification

When gasification is carried out without the addition of a gasification agent, it is referred to as pyrolysis (thermal decomposition). In this case, the yield of gases is relatively low, and a substantial part of the carbon from the biomass accumulates as a kind of pyrolysis coke. In addition, a lot of heavy hydrocarbons are produced, which form a tar that condenses out of the gas produced when it cools down.

In most cases, air is added to the biomass as a gasification agent - but much less than would be needed for complete combustion. Thus, incomplete combustion takes place, which provides the required process heat. The gas obtained contains a lot of carbon monoxide, but also nitrogen from the air, as well as considerable amounts of water vapor. Because of the high nitrogen content, the specific calorific value of the gas is low - much lower than that of natural gas, for example. This is why it is referred to as lean gas.

In hydrothermal gasification, water vapor is used as the gasification agent. The process is then no longer autothermal, but allothermal: the required process heat is not generated in the process itself, but must be supplied from outside. This heat is usually obtained by burning some of the biomass together with the solid and liquid residues of the gasification plant (coke and tar).

In the future, high-temperature fuel cells (SOFC[87]) could be used for power generation. Their waste heat could be used for allothermal gasification via heat pipes. This could enable electricity generation with electrical efficiencies above 50 percent.

Types of biomass gasifiers

There are different types of gasifiers for biomass:

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[85] DBFZ (2022): Biomassevergasung. Online available at: www.dbfz.de/projektseiten/smarkt/ergebnisse/vergasung. Accessed 30.11.2022.
[86] Paschotta, Rüdiger (2022): Biomassevergasung. Online available at: https://www.energie-lexikon.info/biomassevergasung.html. Accessed 30.11.2022.
[87] A solid oxide fuel cell (SOFC) is a high-temperature fuel cell that is operated at a temperature of 650-1000 °C. It is an electrochemical conversion device that produces electricity directly from oxidizing a fuel. Fuel cells are characterized by their electrolyte material; the SOFC has a solid oxide or ceramic electrolyte. Especially for industries the achievement of a high temperature level with renewable energies is particularly important.

- Fixed-bed gasifiers are suitable for small wood gasification plants (below 1 MW).
- Fluidized-bed gasifiers operate on the principle of a fluidized-bed combustion system, which is operated with a lack of air. They are suitable for outputs in the range of several megawatts.
- In entrained-flow gasifiers, gasification takes place in a dust cloud fed with highly crushed material that flows through the gasifier relatively quickly. This process is suitable for very large plants (usually over 100 MW) and produces a low-tar gas.
- There are also processes of staged gasification, where the biomass is first sent to a pyrolysis reactor, for example, and then to a steam reformer where further gas is produced. This allows the ratios in the various stages to be optimized separately.

In each case, the gasifier is the central element of a gasification plant, which can, however, contain many other components for the pretreatment of the biomass and the post-treatment of the products.

In the future, plants that have outputs between a few megawatts and a few hundred megawatts are likely to be advantageous. (The power here is related to the energy content of the products produced). Plants that are as large as possible are likely to be more economical to operate, especially for biofuel production: For example, Fischer-Tropsch synthesis is only economical in large units. However, the transport costs for the biomass are then greater.

Preparation of the products

From the gas produced, water and a number of other substances condense as a result of cooling. These substances are produced as residual materials and must be disposed without causing any harm (see below). The remaining gas must be further processed and purified, especially for material use:

- To obtain as much hydrogen as possible, a water gas shift reaction (CO shift) with further water vapor can take place in a separate reactor: Carbon monoxide (CO) is oxidized to carbon dioxide (CO_2), while water vapor is reduced to hydrogen (H2).
- The gas usually contains a relatively large amount of dust and portions of tar. Depending on further utilization, these must be more or less completely removed. Dust can be separated in a cyclone. The tar content can be reduced by thermal cracking, steam reforming, hydrogenation or partial oxidation (with or without catalyst) while increasing the gas yield.
- Further purification of the hydrogen can be achieved by pressure swing adsorption (PSA). This produces a combustible purge gas which can feed a gas engine, for example.
- Biofuel can be produced from the synthesis gas (mainly CO and H2), e.g. by the Fischer-Tropsch process.
- Another option is methanation for the purpose of producing biomethane.
- Methanol can be produced either directly by dry distillation of wood or by methanol synthesis from syngas.

Often, the gas produced still needs to be compressed, for example for storage in tanks. In some cases, liquefaction by cryogenic cooling is also necessary.

Treatment of solid and liquid residues

A considerable part of the biomass cannot be gasified, but accumulates in solid or liquid form. The solids are not only ash (largely mineral substances), but also certain amounts of carbon, for example in the form of a coke. The residual energy content of such materials can still be utilized by burning, although the exhaust gas must be cleaned. In large-scale applications, it is highly desirable for the mineral substances to be in a form suitable for use as fertilizer, so that closed nutrient cycles are possible.

The water vapor portion of the gas obtained can be condensed, with various substances other than tar oil also condensing. The wastewater obtained (referred to as wood gas condensate in the case of wood gasification) can be acidic or alkaline, depending on the process, and contains a variety of pollutants such as carcinogenic phenols and various sulfur and nitrogen compounds. It must therefore be purified more or less extensively in a suitable wastewater treatment plant. Incineration of the organic substances or refeeding them to the gasifier is favorable, but first requires separation from the water. The treatment of such waste is complicated by its variable composition, which depends on the composition of the biomass, but also on the exact process conditions.

Utilization of waste heat

Depending on the gasification process, waste heat can occur at different temperature levels - for example, at high temperatures (occurs when the gas is produced), or at low temperatures (occurs as waste heat of a steam turbine for electricity generation). Some of the heat generated is usually required for specific process steps, e.g., drying the biomass before gasification, but some may remain.

If it is possible to use such waste heat, e.g. for heating systems, the overall energy balance is improved accordingly. If there are no suitable heat consumers on site, there is the possibility of electricity generation for waste heat at a sufficiently high temperature level.

Importance of biomass gasification; comparison with other processes

The technology is relatively complex, since apart from the actual gasification, several other steps have to be mastered, and this for different compositions of the biomass. However, if the processes are further improved, they could well become very important in the future, as they can offer advantages over other methods of utilizing biomass:

While pure combustion only provides heat and, if necessary, electrical energy, gasification also yields gaseous fuels and, through further processing, second-generation liquid biofuels. This makes biomass usable not only for heat and power generation, but also for transportation, for example. Since electrification offers limited opportunities in this sector, biomass gasification is likely to become essential for a full supply of renewable energy.

Even if the goal is only electricity generation, gasification can be advantageous by enabling higher electrical efficiency (e.g., 35 percent) despite small plant capacities (e.g., a few megawatts or even less). Especially if fuel cells become widely applicable, this efficiency advantage could become even greater. As long as this is not the case, electricity generation in large power plants (e.g. by co-firing in coal-fired power plants) can be more efficient in terms of energy than in small power plants with wood gasification, if no waste heat utilization is possible in the latter. However, this then also requires longer transport routes.

Another objective is the realization of CO2 capture and storage in so-called IGCC (Integrated Gasification Combined Cycle) power plants. Here, gasification is carried out with pure oxygen in order to obtain the CO_2 in a higher concentration and thus to be able to separate it easily. The nitrogen produced during air separation (separation of oxygen from the air) is added to the hydrogen-rich gas before combustion to minimize nitrogen oxide emissions. Compared to the production of vegetable oils and biodiesel (rapeseed methyl ester), biomass gasification results in a much higher energy yield, since the cellulose of the plant parts is also used. For this reason, biomass gasification appears to be much more advantageous than previous processes, especially in the production of liquid fuels, and is likely to become very important in this area.

On the other hand, biomass gasification is technically very compley and the processes developed so far need to be further improved. [88]

Biomass gasification could also play an important role in the context of a hydrogen economy: Instead of hydrogen being produced relatively lossy by electrolysis using electrical energy, it could be produced from biomass. However, the productivity per unit area of biomass is relatively low because it relies on photosynthesis, which is not very efficient; while it is slightly better for gasification than for bioethanol and biodiesel, it is significantly worse than for biogas and much worse than for electrolysis hydrogen using solar or wind power. This limits the potential of this method more than for the electric production pathway.

Example: Industrial research project „PlasmaGas" – Plasma-assisted biomass gasification[89]

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[88] Energetische Biomassenutzung (2022): Forschungsvorhaben zu Biomassevergasung. Online available at: https://www.energetische-biomassenutzung.de/projekte-partner/projektsuche?no_cache=1&tx_ebproject_showfilter%5Baction%5D=list&tx_ebproject_showfilter%5Bcategory%5D=12&tx_ebproject_showfilter%5Bcontroller%5D=Filter&tx_ebproject_showfilter%5Bfilter%5D=1&cHash=e695e901b74a37bceb14e199dbb08eeb. Accessed 01.12.2022.

[89] FAU (2022): Industrielles Forschungsprojekt „PlasmaGas" – Plasma-gestützte Biomassevergasung. Online available at https://www.evt.tf.fau.de/forschung/forschungsschwerpunkte/verbrennung_vergasung/plasmagas/. Accessed 01.12.2022.

This is an example of a technology that is not yet ready for the market. In the research project "PlasmaGas", biomass gasification with and without non-equilibrium plasmas (non-thermal plasma) is investigated in order to produce synthesis gases (CO and H2) efficiently and without complex purification processes from biomass.

Allothermal gasification is a key technology for the production of hydrogen, SNG and chemicals from biomass in the global energy transition. Compared to conventional thermal gasification, plasma-assisted biomass gasification enables improved reaction kinetics by providing free radicals and particles of high temperature.

Thermodynamic non-equilibrium plasmas, in which no thermal equilibrium is established, are particularly promising. Here, the light electrically charged electrons are heated by an electric field to mean energies far above those of neutral gas molecules, whose gas temperature increases by only a few 10 to 1000 K, depending on the operating conditions of the NTP.

The dynamic flexibility of the plasma generator lends itself to the use of excess electricity from renewable sources. Thus, fluctuating electrical energy can provide the reaction enthalpy of endothermic gasification reactions in allothermic steam gasification. Electrical energy is converted into chemically bound energy and stored in syngas or, via subsequent syntheses, liquid or gaseous secondary energy carriers. The influence of the plasmas on the reaction kinetics of **biomass** gasification is investigated.

5.5 Pyrolysis[90]

Despite the difficulties of squeezing the process into a narrow framework, however, low-temperature pyrolysis (500 - 700°C) and high-temperature pyrolysis (above 700°C) can be distinguished from each other according to the parameter of temperature. And depending on the process structure, rotary tube pyrolysis is distinguished from fluid bed pyrolysis.

The aim of the process is to break up the long hydrocarbons of the biomass into shorter ones by means of a high temperature. The idea is therefore similar to that of cracking in oil refineries, but less complex in structure. In this process, the biomass is hermetically sealed in an appropriate reactor and heat is then supplied from the outside. The anaerobic situation prevents the combustion (chemical change) of the organic components and the compounds are broken. There are also special processes in which the high energy of combustion (with oxygen) is used, but the amount of oxygen allowed is too low to allow complete combustion to take place. The partial combustion is used as a heat source.

The resulting hot exhaust gases are then used to generate energy (e.g. with the help of steam generation) and the solid residues can be used as high-quality carbon sources (activated carbon -> soil improvement) or refined into oils.

5.6 New Technologies for waste management

In the following technologies will be presented that are prioritizing for the management of wastes in cities. That way the best practice technologies can be transferred to Türkiye.

Background[91]

Since the creation of cities, urban populations have continued to rise. Some urban areas with populations that are so high (> 10 million), the term "megacity" is used. Megacities now have a greater environmental impact than ever before in human history. The regional and global environments have suffered as a result of rising resource and energy use and waste production.

In many cities, sustainability is being undermined by improper solid waste management, overuse of natural resources, and air and water pollution. For instance, according to estimates from the UN, cities use over 75 percent of the world's energy production and contribute 70 percent of all anthropogenic greenhouse gas emissions.

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[90] BiomassMuse (2022): Steckbrief der Pyrolyse (Holzvergasung). Online available at: https://www.biomasse-nutzung.de/steckbrief-der-pyrolyse-holzvergasung/. Accessed 01.12.2022.
Rösch, C.; Wintzer, D. (1997): Vergasung und Pyrolyse von Biomasse. 2. Sachstandsbericht zum Monitoring "Nachwachsende Rohstoffe". Online available at: https://www.tab-beim-bundestag.de/projekte_vergasung-und-pyrolyse-von-biomasse-monitoring-nachwachsende-rohstoffe.php. Accessed 01.12.2022.
[91] Scientific American (2018: Sustainability Solutions for Megacities. Online available at: https://blogs.scientificamerican.com/observations/innovavations-from-the-energy-and-environmental-sustainability-solutions-for-megacities-program/. Accessed 12.10.2023.

By 2050, when two thirds of the world's population is anticipated to reside in cities, the issues are anticipated to worsen. Sustainable urban solutions are therefore necessary.

A collaboration between Shanghai Jiao Tong University, in China, and the National University of Singapore have conducted research and data collection in two cities of different size and complexity, the megacity of Shanghai and land-scarce Singapore.

Food waste incineration, which accounts for more than 22 percent of incinerable garbage but just 16 percent of waste recycled in Singapore, is a significant issue in both cities. E2S2 (Energy & Environmental Sustainability Solutions for Megacities) came up with approaches that connected the issue of waste management with the production of energy and materials. These include a high-efficiency, three-stage anaerobic digester (AD), which produces biogas from food waste, and a high-solids, water-efficient AD.

Other solutions include wireless air-quality sensor networks, low-quality waste heat utilization technologies for adsorptive cooling and dehumidification, and water drone networks for real-time reservoir contamination monitoring. Studies on toxicological and risk evaluations for contaminants in the city's air, water, and land environments were also conducted. The clean, healthy urban environment that these sustainable solutions give may be provided for Singapore and other megacities in Asia and around the world while maintaining environmental sustainability.

Innovations in Recycling for Sustainable Management of Solid Wastes

There are countless additional procedures for treating various biomass substrates, in addition to these "conventional" methods for treating biowaste. The environmental relief effects achieved by the separate collection and recycling of the increasing quantities of biowaste depend to a large extent on the recycling process used, its operation in accordance with good professional practice, and the best possible use of the waste properties and the products generated.

Alternative recovery options include

- hydrothermal carbonization (HTC)
- pyrolysis
- hydrothermal liquefaction (HTV)
- transesterification
- HEFA process
- lactic acid fermentation
- ABE fermentation
- Process of the soldier fly larve (Hermetia Illucens).

On the basis of the operational data for biowaste/biowaste-like-biomass, none of these processes can achieve or surpass the environmental relief effects of the standard processes for biowaste collected separately near households. The situation is different for used cooking oils, where transesterification achieves reductions that even exceed the values of the conventional processes.

Overall, the **HTC process** has very low loadings and, especially in case of particularly moist biomass types, may possibly have advantages at least over composting in a direct comparison. A more favorable evaluation may possibly be achieved if it is possible to produce an HTC char that can be used in a high-value material application. However, a comprehensive evaluation is not possible at the current stage of development. Experience on the purification of exhaust air and wastewater is not yet available, nor is experience from continuous large-scale long-term operation.

Pyrolysis of woody material can be considered high value if it can be used to produce materially useful products, as modeled by life cycle assessment in this study. This assessment is subject to the provison that satisfactory availability of the plants and disposal of the condensates can be ensured.

Under the general conditions of the present balance, **hydrothermal liquefaction** can only show reductions in the environmental criterion fossil resources due to the high electricity requirement and the use of crude oil as a substitute, and does not represent a high-quality recycling process for biowaste under these general conditions.

The **transesterification** of used cooking oils is an established process that, under the balance sheet framework applied here, predominantly leads to relevant reductions and can therefore be classified as a high-quality process for this fraction.

The **HEFA process** is also established, but does not have the same life cycle assessment advantages in direct comparison to transesterification due to the significantly higher electricity requirement. In particular, the results with regard to the climate change category should be mentioned here. The high value, taking into account the life cycle assessment, can only be determined for the HEFA process on a case-by-case basis.

Lactic acid fermentation from waste biomass for the production of "regenerative" plastics (PLA) is an interesting alternative to plastic production based on fossil raw materials or substrates grown specifically for this purpose. Whether biowaste from the organic waste garbage can will be suitable for this is still unclear. For certain biomass fractions, the process could represent a reasonable perspective if the high electricity demand, which currently still leads to corresponding burdens for most environmental categories, can be reduced.

Similar considerations apply to the **ABE fermentation** process with respect to the "regenerative" production of acetone, butanol and ethanol. However, the high electricity and heat requirements lead to poor LCA results and limitations in economic viability. From an LCA point of view, the evaluation of high value therefore depends on whether waste heat is available and whether the electricity requirement can be reduced.

The **soldier fly** for the production of protein feed from different biomass streams is considered a promising process especially if the demand for high quality compost is low and if the high heat demand can be provided by waste heat that cannot be used elsewhere. Since the required temperature level is low, the chances are high to find sites where heat is available for which there are otherwise no possible applications.

In the case of all the other processes mentioned, it can be assumed that the specific consumption and costs can be reduced (in some cases considerably) through technical optimization and scaling of the plant technology. This would have corresponding consequences for the fossil energy demand and thus also for the life cycle assessment that depends on it. Due to reduced costs, the process products could also represent interesting substitution possibilities for other (material) uses, which would also have an impact on the life cycle assessment. At the same time, for almost all of the processes investigated, the balanced results are still subject to the provison that these (or similar) results can also be achieved in an economically feasible normal operation. Exceptions to this are transesterification and the HEFA process for used cooking oils and pyrolysis for woody material, which are already established processes.

In order to enable further optimization of the other processes investigated here - but also other innovative process approaches that were not investigated in depth here - framework conditions should be created that permit and promote further research into processes and innovations in the field of biowaste utilization.

Overall, it is true that energy processes can perform more favorably in individual cases if particularly unfavorable fuels, especially hard coal and lignite, can be replaced 1:1. However, the phase-out of coal use means that this credit can be credited at most during the transition period, and thus these processes must pursue other utilization concepts in the long term. Conversely, the processes that tend to use energy will become less expensive in the course of the transition to renewable energy. However, competition for renewable electricity is expected to be very high in the future due to numerous new applications, so that a high electricity demand will remain a relevant criterion in the comparative evaluation of processes, regardless of the type of electricity supply.

5.7 Identification of most superior technologies for specific conversation paths according to selected criteria (e.g. availability, complexity, price/performance ratio, scalability)

Konver- sion Conversion	Technologie-Cluster (Anlagenart) Technology cluster (type of plant)	Rohstoff / Brennstoffquelle Feedstock/ Fuel source	Haupt*- und Neben- produkt(e) Main* and by- product(s)	Modellfall Model case	Effizienz 2010 in kg_{TM}/GJ_{out} (GJ Haupt- produkt) Efficiency 2010 in kg_{DM}/GJ_{out} (GJ main product)	Effizienz 2050 in kg_{TM}/GJ_{out} (GJ Haupt- produkt) Efficiency 2050 in kg_{DM}/GJ_{out} (GJ main product)	Invest in $€_{2010}$/kW (Haupt- produkt) Investment in $€_{2010}$/ kW (main product)
Verbrennung Combustion	Wärme < 30 kW Heat	Holz (Scheitholz / Waldstammholz) Wood (firewood / trunk wood)	Wärme Heat	Einzelraumfeuerung [8 kW] Single room heater	85	65	200
	Wärme < 0,3 MW Heat	Holzpellets (zumeist [90 %] Sägewerksneben-produkte) Wood pellets (mostly [90 %] sawmill by-products)	Wärme Heat	Holzpelletkessel (Zentralheizung, [15 kW]) Wood pellet boiler [central heating]	75	61	1 000
	Wärme < 2 MW Heat	Holzhackschnitzel Woodchips	Wärme Heat	Automatische Kleinfeuerungsanlage (Holzhackschnitzelkessel [500 kW] bivalent) Automatic small solid fuel boiler system (woodchip boiler [500 kW] bi-valent)	71	65	1 500
	KWK < 200 kW_{el} CHP	Holzpellets Wood pellets	Strom + Wärme Electricity + heat	Mikro-KWK (Stirling [3kW_{el}]) Micro-CHP (Stirling)	425	280	10 000
	KWK < 1 MW_{el} CHP	Holzhackschnitzel Woodchips	Strom + Wärme Electricity + heat	ORC-Heizkraftwerk [250 kW_{el}] ORC cogeneration system	380	275	12 350
	Pflanzenöl-KWK < 5 MW_{el} Plant-oil CHP unit	Pflanzenöl (Raps) Plant oil (rape)	Strom + Wärme Electricity + heat	Pflanzenöl-BHKW [2 MW_{el}] Plant-oil fueled CHP unit [2 MW_{el}]	63	60	1 100
	KWK > 5 MW_{el} CHP	Holzhackschnitzel Woodchips	Strom + Wärme Electricity + heat	GuD-Heizkraftwerk (Dampfturbine [6 MW_{el}]) Gas and steam cogeneration plant (gas turbine)	168	150	4 300
Anaerobe Vergärung Anaerobic digestion	Biogas klein < 150 kW_{el} Biogas small	Gülle (85 %), Liquid manure Grassilage (10 %), Grass silage Mais (5 %) Maize	Strom + Wärme, Gärrest Electricity + heat, digestate	Landw. Biogasanlage [80 kW_{el}] Agricultural biogas plant	377	211	7 000
	Biogas-Nawaro > 150 kW–ca. 20 MW_{el}) Nawaro biogas plant > 150 kW–approx. 20 MW_{el}	Mais 70 %, Maize Gülle Rind 20 %, Bovine liquid manure Grassilage 5 %, Grass silage GPS 5 % WCS	Strom + Wärme, Gärrest Electricity + heat, digestate	Biogasanlage [500 kW_{el}] Biogas plant	265	141	5 250
	Biomethan > 350 $m^3_{LN}/h_{Biomethan}$ Biomethane > 350 $m^3_{LN}/h_{biomethane}$	Mais (80 %), Maize GPS (15 %), WCS Gülle (5 %) Liquid manure	a) Strom + Wärme, Gärrest Electricity + heat, digestate b) Biomethan (Kraftstoff) Biomethane (fuel)	Biogasaufbereitung / -einspeisung Biogas processing / feed-in [700 Nm³/h] a) BHKW 2 MW_{el} bzw. Flex: 4,8 MW_{el} CHP plant 2 MW_{el} or flex: 4.8 MW_{el} b) ca. 7 MW Biomethan approx. 7 MW biomethane	a) 251 b) 100	a) 134 b) 80	a) 4 500 b) 1 700
	Bioabfall Biomwaste	Bioabfälle (90 %), Biowaste Grassilage (10 %) Grass silage	Strom + Wärme Electricity + heat	Bioabfallvergärung [800 kW_{el}] Biowaste digester	250	133	8 750

Konver-sion Conversion	Technologie-Cluster (Anlagenart) Technology cluster (type of plant)	Rohstoff / Brennstoffquelle Feedstock/ Fuel source	Haupt*- und Neben-produkt(e) Main* and by-product(s)	Modellfall Model case	Effizienz 2010 in kg_{TM}/GJ_{out} (GJ Haupt-produkt) Efficiency 2010 in kg_{DM}/GJ_{out} (GJ main product)	Effizienz 2050 in kg_{TM}/GJ_{out} (GJ Haupt-produkt) Efficiency 2050 in kg_{DM}/GJ_{out} (GJ main product)	Invest in $€_{2010}$/kW (Haupt-produkt) Investment in $€_{2010}$/kW (main product)
Alkoholische Fermentation Alcoholic Fermentation	Zucker Sugar	Zuckerrübe Sugarbeet	Bioethanol +Vinasse dried pulp	130 000 m³ Ethanol/a	103	93	800
	Stärke Starch	Weizen Wheat	Bioethanol + DDGS	200 000 m³ Ethanol/a	123	111	1 390
	Lignozellulose Lignocellulose	Weizenstroh Wheat straw	Bioethanol + Lignin, C5-Sirup	73 000 m³ Ethanol/a	250	119	2 600
Umesterung Transesterification	Biodiesel (FAME) a) zentral centralised > 100.000 $t_{Biodiesel}$/a	Raps (zentrale Ölmühle), used cooking oil (10%) Rapeseed (centralised oil mill), used cooking oil	Biodiesel + Glycerin + Extraktions-schrot Biodiesel + glycerin + extraction meal	200 000 $t_{Biodiesel}$/a	63	61	245
	Biodiesel (FAME) b) dezentral decentralised < 100.000 $t_{Biodiesel}$/a	Raps (dezentrale Ölpresse) Rapeseed (decentralised oil press)	Biodiesel + Glycerin + Rapspress-kuchen Biodiesel + glycerin + rapeseed cake	30 000 $t_{Biodiesel}$/a	73	70	245
Hydroprocessing Hydroprocessing	HVO / HEFA Bio-HVO / HEFA	Pflanzenöl (Raps) Plant oil (rape)	HVO + Butan / Propan, Naphtha HVO + butane / propane, naphtha	HVO (ca. 297 MW_{KS}) (200 000 t_{KS}/a)	65	62	780
Vergasung Gasification	Kleinvergaser < 3 MW Small-scale gasifier	Holzhackschnitzel Woodchips	Strom + Wärme Electricity + heat	(0,038 MW_{el})	268	147	5 000
	Vergaser < 100 MW Gasifier	Holzhackschnitzel Woodchips	Strom Electricity	(10,8 MW_{el}, 44 000 t_{FM}/a Holzeinsatz, ORC-Nachverstromung) (wood input, ORC power generation)	151	106	6 600
	Bio-SNG < 100 MW Bio-SNG	Holzhackschnitzel Woodchips	Biomethan Biomethane	(25 MW_{SNG}) (121 000 t_{FM}/a Holzeinsatz) (wood input)	96	77	3 500
	BtL > 100 MW BtL	Holzhackschnitzel Woodchips	FT-Diesel + FT-Kerosin; FT-LPG, FT-Naphtha FT diesel + FT kerosene; FT-LPG, FT-naphtha	(500 MW_{FWL}, 1 433 000 t_{FM}/a Holzeinsatz, wood input 177 MW_{out} [FT-Kerosin und FT-Diesel) [FT kerosene and FT diesel)	157	126	3 850

Figure 16: Classification of the selected model cases with regard to feedstock source, product(s), efficiency and investment costs[92]

[92] DBFZ (2016): Conversion pathways towards biomass energy use in the 21st century.

6 Stakeholder for project development and realization of flagship projects

In the following an overview of relevant companies with references, technology and contacts is listed.

Table 17: Overview of relevant companies for biomethane and biogas plants

Name	Technology	Specific product	Activity	References	Contact
agriKomp GmbH	Biogas plants Biomethane plants	pre-assembled modules, turnkey technology and CHP containers	Planning and construction	https://agrikomp.com/de/referenzen/	D Energiepark 2 91732 Merkendorf +49 9826-65959-0 www.agrikomp.com
AAT Abwasser- und Abfalltechnik GmbH	Biogas plants	Specialized in organic waste and purification of highly polluted wastewater	Planning and construction	https://www.aat-biogas.at/de/referenzen	Austria 6960 Wolfurt Konrad-Doppelmayr-Str. 17 + 43-5574-65190-0 www.aat-biogas.at
AEV Energy GmbH	Biogas plants	classic biogas plants and waste fermentation plants	Planning and construction	Built 130 plants and worked in more than 20 countries on 4 continents	D 01187 Dresden Hohendölzschener Str. 1a +49 351-467-1301 www.aev-energy.de
Agraferm GmbH	Biogas plants Biomethane plants Waste utilization plants	Highest gas yield with low vessel volume	Planning and construction	http://www.agraferm.com/de/referenzen.html	D 85276 Pfaffenhofen/Ilm Färberstr. 7 +498441-8086-100 www.agraferm.com
APROVIS Energy Systems GmbH	Biomethane plants	Biogas processing	Planning and construction	https://www.aprovis.com/ueber-aprovis/referenzen-projekte/	D 91746 Weidenbach Ornbauerstr. 10 +499826-6583-0 www.aprovis.com
Aqualimpia Engineering e.K.	Biogas plants	continuous-flow stirred tank reactor, covered lagoon digester, steel tank biogas plants, tropicalized industrial digesters and UASB reactors	Planning and constrcution	https://www.en-aqualimpia.com/references/	D 29525 Uelzen Niendorfer Str. 53 b +49581-3890550 www.aqualimpia.com

Arcanum Energy Systems GmbH & Co. KG	Biogas plants Biomethane plants Bio-LNG plants H2-electrolyser		Planning and construction	41 Plants under support	D 59439 Holzwickede Rhenus-Platz 3 +492303-96720-0 www.arcanum-energy.de
bwe Energiesysteme GmbH & Co. KG	Biogas plants		Planning and construction	https://www.bwe-energie.de/biogas	D 26169 Friesoythe Zeppelinring 12-16 +494491-93800-0 www.bwe-energie.de
Beck Naturgas GmbH	Biogas plants	independent planning and engineering office	Planning and construction		D 89185 Hüttisheim Lindenstr. 19 +497305-927678 www.beck-naturgas.de
BeWo Anlagentechnik UG (haftungsbeschränkt) & Co. KG	Biogas plants		Planning and construction	https://bewo-anlagentechnik.de/#bewertungen	D 91802 Meinheim Schellenbuck 1 +499146-6725548 www.bewo-anlagentechnik.de
BEKON GmbH	Biogas plants Biomethane plants	Dry fermentation	Planning and construction	https://www.bekon.eu/referenzen/	D 85774 Unterföhring Feringastr. 7 +4989-9077959-0 www.bekon.eu
BioBG GmbH	Biogas plants		Planning and construction		D 26655 Ocholt Webers Flach 1 +494409-666720 www.biobg.de
BioConstruct GmbH	Biogas plants Biomethane plants Wind turbines PV plants	Own software Substrate heat exchanger made of stainless steel or wall bushings	Planning and construction	https://www.bioconstruct.de/referenzen/	D 49328 Melle Wellingstraße 66 +495226-5932-0 www.bioconstruct.de
Bioenergy Concept GmbH	Biogas plants Pyrolysis PV plants	independent planning and engineering office	Planning and construction	https://bioenergy-concept.com/projects/	D 21335 Lüneburg Munstermannskamp 1 +494131-75727-15 bioenergy-concept.com
Biogas Service Tarmstedt GmbH	Biogas plants Biomethane plants		Planning and construction		D 27412 Westertimke Am Falkenlager 15-17 +494289-4005-0 www.bs-tarmstedt.de
Biogasvertrieb Nord AN GmbH & Co. KG	Biogas plants Heat grids		Planning and construction	https://www.biogasvertriebnord.de/referenzen/	D 91629 Weihenzell Bergstr. 11 +499802-9531010 www.biogasvertriebnord.de
BTA International GmbH	Biogas plants	waste containing impurities	Planning and construction	https://bta-international.de/bta-referenzen/referenzen	D 85276 Pfaffenhofen Färberstraße 7 +498441-8086-100 www.bta-international.de/

Consentis Anlagenbau GmbH	Biogas plants		Planning and construction	https://www.consentis.de/de/referenzen/referenzen_-_biogasanlagen.html	D 49835 Wietmarschen Am langen Graben 13 +495925-9986-0 www.consentis.de
elbe bioenergie GmbH	Biogas plants local heat supply		Planning and construction	https://elbe-bioenergie.de/referenzen/	D 39576 Stendal Rathenower Str. 29 +49 03931258200 www.elbe-bioenergie.de
Elemco GmbH	Biogas plants	75-kw plants Farm systems small systems	Planning and construction	http://www.elemco.de/biq-biogas-hersteller-75kw.html	D 89355 Großaitingen Hauptstraße 38 +498224-8003 849 www.elemco.de
EnviTec Service GmbH	Biogas plants Biomethane plants Bio-LNG plants		Planning and construction	https://www.envitec-biogas.de/referenzen	D 49393 Lohne Industriering 10a +494442-8016-7100 www.envitec-biogas.de
GICON - Großmann Ingenieur Consult GmbH	Biogas plants Waste MG Wind turbines PV plants		Planning and construction	https://www.gicon.de/aktuelles/artikel/items/gicon-receives-planning-order-for-biogas-plant-based-on-the-gicon-biogas-process	D 01219 Dresden Tiergartenstr. 48 +49351-47878-0 www.gicon.de
GTP Solutions GmbH	Biogas plants Natural gas		Planning and construction	https://gtp-solutions.com/de/references.html	D 41372 Niederkrüchten An der Beek 255 +492163-579829-7 www.gtp-solutions.com
Hitachi Zosen Inova AG	Biogas plants Biomethan plants Power-to-Gas		Planning and construction	https://www.hz-inova.com/de/references/	Switzerland 8005 Zürich Hardturmstrasse 127 +41-44-2771-628 www.hz-inova.com/anaerobic-digestion
Ingenieurbüro Rückert GmbH	Biogas plants LNG plants	special stirrers	Planning and construction	https://www.ingenieurbuero-rueckert.de/dev/rueckert-naturgas-verfahren/	D 91207 Lauf / Pegn. Marktplatz 17 +499123-7899-0 www.rueckert-naturgas.de
INNIO Jenbacher Deutschland GmbH	Biogas plants	gas engines	Planning and construction	https://www.energas-gmbh.de/referenzen/	D 88213 Ravensburg Wilhelm-Brielmayer-Straße 7 +49751-8883333-0 www.energas-gmbh.de
LIPP GmbH	Biogas plants	Steel tank construction	Planning and construction	https://www.lipp-system.de/systemloesungen/biogasanlagen/	D 73497 Tannhausen Industriestr. 27 +497964-9003-0 www.lipp-system.de
North-Tec Maschinenbau GmbH	Biogas plants		Planning and construction	https://www.north-tec-biogas.de/unternehmen/projekt-des-monats/januar-2018-instandsetzung-einer-envitec-biogasanlage/	D 25821 Bredstedt Oldenhörn 1 +494671-92798-0 www.north-tec-biogas.de

NQ-Anlagentechnik GmbH	Biogas plants		Planning and construction	https://www.nq-anlagentechnik.de/grossanlagen/	D 86733 Alerheim-Rudelstetten Pflegweg 13 +499085-96003-0 www.nq-anlagentechnik.de
Ökotec Anlagenbau GmbH	Biogas plants		Planning and construction	http://www.oekotec-anlagenbau.de/referenzen/	D 04808 Thallwitz Bahnhofstr. 13 +493425-856580 http://oekotec-anlagenbau.de/
ÖKOBIT GmbH	Biogas plants Biomethane plants		Planning and construction	https://www.oekobit-biogas.com/biogasanlagen/referenzen/	D 54343 Föhren Jean-Monnet-Str. 12 +496502-93859-0 www.oekobit-biogas.com
PlanET Biogastechnik	Biogas plants		Planning and construction	https://planet-biogas.de/referenzen/	D 48712 Gescher Schildarpstraße 75 +492542-86956-0 www.planet-biogas.de
Rotaria Energie - und Umweltechnik GmbH	Biogas plants Water treatment		Planning and construction	https://www.rotaria.com/referenzen/biogasanlagen/	D 18230 Rerik Kirchweg 21 +4938296-748-0 www.rotaria.com
Sauter Biogas GmbH	Biogas plants	sprinkling instead of stirring	Planning and construction	https://sauter-biogas.de/referenzen/	D 01665 Wildberg Am Berg 1 +49351-658774-0 www.sauter-biogas.de
Schwelm Anlagentechnik GmbH	Biogas plants Biomethan plants CNG/LNG H2 electrolyzer		Planning and construction	https://www.schwelm-at.de/referenzen/beispielprojekte.html	D 58332 Schwelm Loher Str. 1 +492336-809-0 www.schwelm-at.de
Seiler GmbH	Biogas plants		Planning and construction	http://www.seiler-gmbh.com/de/biogasanlagen	D 88696 Owingen Henkerberg 11 +497551-9197-0 www.seiler-gmbh.com
Wärtsilä Deutschland GmbH	Biogas plants Biomethane plants Bio-LNG plants		Planning and construction	https://www.wartsila.com/marine/products/gas-solutions/biogas-solutions	D 21107 Hamburg Schlenzigstrasse 6 https://www.wartsila.com/marine/products/gas-solutions/biogas-solutions
WEHRLE-WERK AG	Biogas plants		Planning and construction	https://www.wehrle-werk.de/de/umwelt/anwendungen/biogaserzeugung	D 79312 Emmendingen Bismarckstr. 1-11 +497641-585-0 www.wehrle-werk.de
WHG Anlagenbau GmbH & Co. KG	Biogas plants		Planning and construction		D 95488 Hummeltal Otto-Hahn-Str. 2 +49921-348999-50 www.whg-anlagenbau.de
WELtec BioPower GmbH	Biogas plants	stainless-steel biogas	Planning and construction	https://www.weltec-biopower.com/info-center/reference.html	D 49377 Vechta Ann Börries

		plant construction			Zum Langenberg 2 Tel.: 04441 / 999 78-0 www.weltec-biopower.de
Wolf Power Systems GmbH (WPS)	Biogas plants LNG plants		Planning and construction	https://www.wolf-ps.de/de-de/referenzen	D 29475 Gorleben Streßelfeld 1 +495882-9872-0 www.wolf-ps.de

Table 18: Overview of relevant companies for wood gasifier CHP

Name	Technology	Specific product	Activity	References	Contact
Biotech Energietechnik GmbH	Wood gasifier CHP Pellet, wood chip and log heating systems		Manufacturer		Austria 5303 Thalgau Plainfleder Straße 3 +49 151 58726272 www.biotech-heizung.com
BR Energy Group	Wood gasifier CHP	gasification reactor Waste wood suitability, complete ash burnout	Manufacturer and construction		Switzerland 6362 Stansstad Schützenmatte B 13 +41 44 58 68 782 www.br-eg.com
Burkhardt	Wood gasifier CHP Sewage sludge drying plants	Container solution for wood gasifier	Manufacturer, planning and construction	https://burkhardt-gruppe.de/de/gebaeudetechnik/referenzen/	D 92360 Mühlhausen Kreutweg 2 +49 9185 9401 www.burkhardt-gruppe.de
Glock Ökoenergie	Wood gasifier CHP	For hotel and hospitality establishments	Manufacturer	https://www.glock-ecoenergy.com/en/references	Austria 9112 Griffen Bengerstraße 1 +43 2247 90300-600 www.glock-oeko.at
Holzenergie Wegscheid / ENTRENCO	Wood gasifier CHP	staged process management	Manufacturer, planning and construction	https://www.bioenergie-wegscheid.de/use-cases-old	D 94164 Sonnen Haselberg 3, +49 8584 98861-0 https://www.bioenergie-wegscheid.de/old-home
LiPRO Energy	Wood gas plant	staged process management	Manufacturer, planning and construction	https://www.lipro-energy.de/referenzen/	D 26203 Wardenburg Westerburger Weg 40 +49 4484 202 36 40

					www.lipro-energy.de
ReGaWatt	Wood gas power plant Pyrolysis oil plants	due to countercurrent gasification insensitive to to different fuel qualities	Manufacturer, planning and construction	https://regawatt.de/referenzen/	D 93326 Abensberg An den Sandwellen 114 +49 9443 929 0 www.regawatt.de
SynCraft	Biomass and wood gasifier CHP	automation technology	Manufacturer, planning and construction	https://www.syncraft.at/referenzen/alle-referenzen	Austria 6130 Schwaz Münchnerstr. 22 +43 5242 62510 www.syncraft.at
Meva Energy	Gasification systems for CHP or industrial process gas applications	Uses ean burn CHP engines with wood-based feedstock or agricultural residue	Manufacturer	https://mevaenergy.com/meva-energy-signs-green-energy-agreement-with-ikea-industry-to-produce-long-term-renewable-power-from-wood-residue-using-new-patented-energy-technology/	Sweden 42246 Hisingsbacka, acka Bergögata 18, +46 706248493 www.mevaenergy.com
Spanner Re²	wood gasifier CHP pellet heating	Wood gasifier operable in cascade	Manufacturer, planning and construction	https://www.holz-kraft.com/de/referenzen/referenzen-nach-laender.html	D-84088 Neufahrn Niederfeldstr. 38 Telefon +49 8773 70798 162 www.holz-kraft.com
URBAS Maschinenfabrik	wood gasifier CHP		Planning and construction	https://www.urbas.at/wp-content/uploads/2020/09/URBAS_DE_KWK_7.8.web_WF.pdf	Austria 9100 Völkermarkt Theodor-Billroth-Str. 7 +43 664 123 59 23 www.urbas.at

Table 19: Overview of relevant companies for bioethanol and biodiesel plants

Name	Technology	Specific product	Activity	References	Contact
Vogelbusch Biocomodities	Bioethanol plants	Bioprocess plants for the production of alcohol, starch sugars, yeast, vinegar and organic acids	Planning and construction	www.vogelbusch-biocommodities.com/referenzanlagen/	Austria, 1051 Wien Blechturmgasse 11 +43 1 54 661-0 www.vogelbusch-biocommodities.com
Julius Montz GmbH	Bioethanol plants		Planning and construction	www.montz.de/referenzen	D-40723 Hilden Hofstraße 82 +49 2103 - 894-0 www.montz.de
Helmes Apparatebau und HL	Biodiesel plants	Heaters and evaporation			D-48231 Warendorf Daimlerstraße 8, +49 25 81 / 78 58 20

Anlagentechnik		plants for biodiesel			www.helmes-apparate.de/anwendungen/bio-diesel/
Schwarz & Schmidhofer Industrieanlagenbau GmbH	Biodiesel plants Pipeline construction			https://sus-industrie.de/projekte/referenzenprojekte/	D-67227 Frankenthal Carl-Benz-Straße 16 +49 62 33 – 34 51- 0 www.sus-industrie.de
AT Agrar-Technik Int. GmbH	Biodiesel plants		Planning and construction	https://at-agrartechnik.de/referenzen	D-72070 Tübingen Lichtenberger Weg 8 +49 (0)7071 539 22 20 www.at-agrartechnik.de
HPF Biokraft Hirtl GmbH	Biodiesel plants	based on residual and waste materials such as used cooking oil			Austria 8350 Fehring Grüne Lagune 1 +43 3155 20 920 www.hpf-biokraft.at
Christof Industries Global GmbH	Biodiesel plants			www.christof.com/branche/biodiesel-anlagen/	Austria 8051 Graz Plabutscherstraße 115 +43 502080-0 www.christof.com
Umwelttechnik Anlagenbau Plauen	Biodiesel plants		Planning and construction		D-08527 Plauen / Vogtland Messbacher Straße 50 +49 37 4121 09-0 www.uap-plauen.de
RMEnergy Umweltverfahrenstechnik GmbH	Biodiesel plants	Container plants for decentralized biodiesel production		hwww.rmenergy.de/referenzen/	D-85416 Langenbach Grünseiboldsdorfer Weg 5 +498761/7216256 www.rmenergy.de/biodieselanlagen/