Chapter 1
Introduction

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Abstract Biomass is the most relevant renewable energy source, with a wide range of possible and established methods to apply biomass for energy generation. In regards to the supply of sustainable energy, not only the provision of technology but also the integration of this technology into the system will be considerably important. This demands a change in bioenergy provision which is comparable to the transition from traditional to modern biomass use. The need for further development in the provision of bioenergy is also underlined by the challenges affecting the biomass resource base, including increasing demands for biomass for food, feed, materials and fuel. Furthermore, this is underlined by the major concerns surrounding factors relating to the land such as soil, nutrients and biodiversity.

Germany has implemented an active policy for the transition of the energy system towards greater use of renewable energy sources more than a decade ago, which has led to a strong increase in the amount of biomass used for electricity, heat and the provision of transport fuel. With relevant shares of electricity from wind and solar the need for better system integration is on the agenda. The situation in Germany can therefore provide interesting insights into the challenges and opportunities of using bioenergy in its new role. This will be elaborated on step by step in this book, starting with issues relating to the market and resource base, then moving on to analysis of the technical options, followed by the modeling of the effects on the German energy system in a case study and in conclusion focusing on the most promising fields as well as the missing elements for a successful transition.

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1.1 Bioenergy Today

The transition of the energy system towards greater use of renewable energy is a precondition for the envisaged reduction of greenhouse gas emission [12], for a sustainable use of the finite resources [4] and for a payable and fair access to energy [1]. The use of renewable energy sources has been increased worldwide over the last decade with biomass as the most important source covering 10 % of the total global primary energy demand [17].

Biomass is a renewable carbon source which uses the process of photosynthesis to generate hydrocarbons. The most relevant biomass resources for bioenergy are energy crops, residues and by-products from forestry, agriculture, the wood and food processing industry, residues from gardening and landscape management as well as organic waste from industry and final consumers. In general, all these renewable hydrocarbon sources can be used to substitute all fossil fuels, including natural gas, liquid fuels and coal. In practice, the effort expenditure needed for this substitution differs greatly due to different chemical structures, inorganic compounds and trace elements in the biobased materials, which affect the conversion unit and can cause corrosion, slagging, lower efficiency and higher emissions [14].

The use of biomass is realized through a number of multi-step pathways, including resource provision, transportation, storage and condition, conversion of the biomass into biofuel and finally conversion into useable energy (Fig. 1.1).

There are thermo-chemical, bio-chemical and physico-chemical conversion systems available to produce solid, liquid and gaseous fuels from biomass. These fuel sources are then combusted to generate heat and power in stationary and mobile applications:

- Thermo-chemical conversion involves the use of a system to transform solid biomass into charcoal, pyrolysis oil, product gas and other intermediates (thermochemically treated solid biomass). The next step sees these intermediates be transformed into dedicated bioenergy carriers (synthetic biofuels, synthetic natural gas (SNG)).
- Physico-chemical conversion is used for oil resources to provide vegetable oil or biodiesel
- Biochemical conversion includes the anaerobic digestion of sugar and starch to produce biogas and the fermentation of sources containing specific sugars to bioethanol.
- All the converted biofuels can be processed further, i.e. product gas to liquid biofuels (“bio-to-liquid”), vegetable oil to hydrogenated biofuels (‘HVO’), so in theory pathways are possible from almost every resource to every energy carrier. In practice, these concepts are still however at the research and demonstration stage.

Today, biomass contributes to the heat and power market as well as for the provision of renewable transportation fuels [17]. Figure 1.2 gives an overview of the relevance of the different fields of application worldwide. The provision of heat through biomass is the most important field. Traditional use of biomass to produce heat requires the highest share of resources. Even if realistic figures of the total use

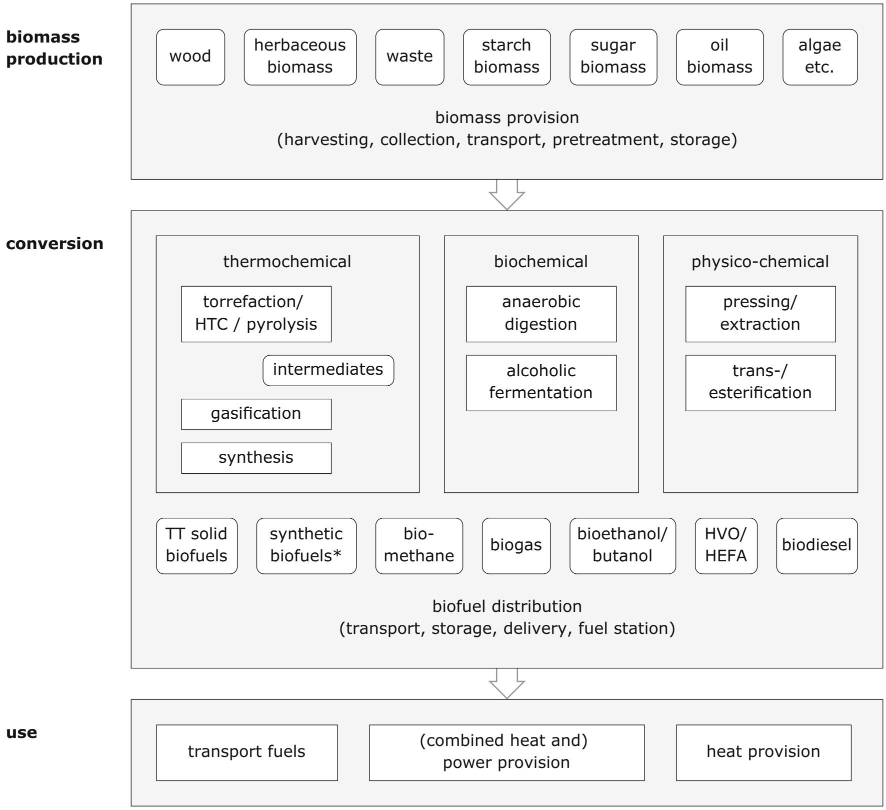
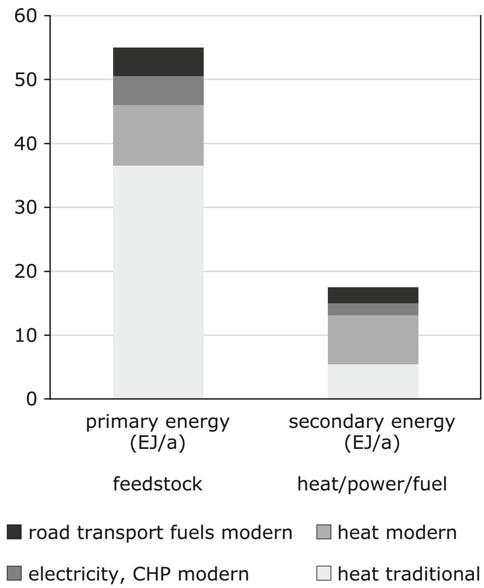


Fig. 1.1 Pathways of technologies for biomass feedstock conversion (*TT* thermochemically treated; * Fischer-Tropsch Diesel, DME, Biohydrogen etc.)

Fig. 1.2 Global biomass flows in 2012 (Primary energy from [17], secondary energy from [3, 17] and own calculation)



of biomass are uncertain due to additional activities in the informal sector, which are normally not reported in the statistics [9], resources are used rather inefficiently in this sector, in comparison: open fire places and stoves for heat provision in the "traditional bioenergy sector" are characterized by conversion rates of 10–20 % [6]. This kind of application is still the major conversion pathway for biomass feedstock to provide energy in the global context (about 35 EJ/a; see Fig. 1.2). Modern biomass uses like, for example, biofuel provisions for transport, combined heat and power provision and modern heat provision in boilers and stoves with a higher energy efficiency rate are applied to about 20 EJ/a of the biomass feedstock. Because of the much higher conversion efficiency of modern biomass, it is able to deliver almost 70 % of the secondary energy.

Electricity, modern combined heat and power (CHP) and biofuels for the transport sector provide a minor contribution, and are used especially in countries committed to the use of renewable energy. Today, these facilities often run for the whole year on full load, producing biofuels or bioenergy regardless of the actual energy demand and supply situation. The transition of the energy system will change this picture dramatically: the increasing use of solar and wind energy requires the provision of electricity from biomass in periods of insufficient wind speed or insufficient sunlight; the use of different renewable sources in combination with one another can also occur in the heating sector, for example the combined use of biomass systems and solar collectors, while in the field of biofuels the combined provision of biofuels and other biomass products will be of higher interest.

1.2 The Way Forward: Traditional, Modern and Integrated Bioenergy Provision

The global figures relating to current bioenergy provision clearly indicate that the role of bioenergy and the transition processes towards renewable energy use in different regions of the world vary. The transition from traditional biomass use to modern biomass use guarantees more energy efficiency and can in most cases reduce local emissions [19]. Another transition taking place is that from modern biomass use as a stand-alone concept to biomass having an integrated role in an energy system mainly based on renewable energy sources. The expected new way for bioenergy use is shown in Fig. 1.3. For biomass to have an integrated role, two questions must be addressed: The first question is how to provide bioenergy with efficient technologies. The second question is, which kind of bioenergy is able to best support demands for a secure, cost efficient and climate protective energy system. The provision of flexible bioenergy requires the conversion system to have a greater capacity and a greater number of control units. In many cases, this would mean reducing the full load production of a conversion unit from basic load (8,000 h per year full load) to part load or seasonal operation, or to change the technical concepts to smaller conversion units to be operated in modules. These additional measures need to be beneficial to the overall energy supply, for this reason

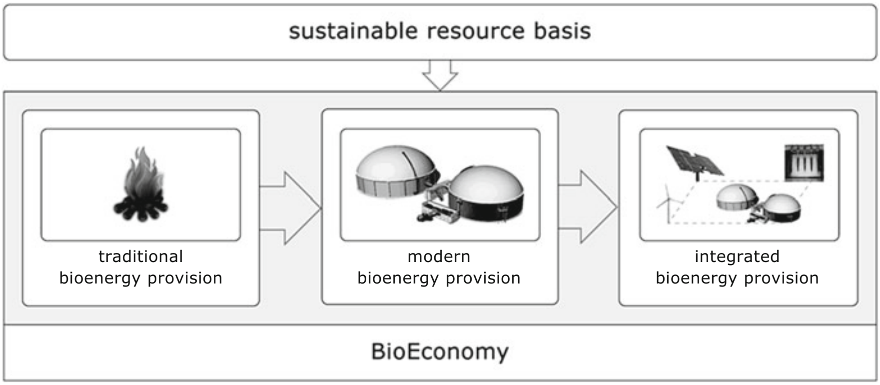


Fig. 1.3 The development of bioenergy as one column of the transition of the energy system

promising solutions can be expected to be different in different countries, i.e. Sweden as a country with high hydropower potential focuses much more on the use of biomass in the transport sector.

Not only demand but also supply is characterised by major changes. In regards to future systems, it is expected that the demand for biomass will increase – for food and feed but also for materials – while different factors will reduce the resource base. Additionally, there is an increasing concern that the direct and indirect effects on bioenergy provision could contradict the intended effect, for example change could occur as a result of energy crop production through direct and indirect land use, through airborne emissions of greenhouse gas relevant substances (methane, nitrogen dioxide) along the process chain, through environmental effects due to the increasing use of by-products from agriculture and forestry [15, 18]. On the other hand, additional potentials on land and biomass are discussed, and there is the chance of increasing the use of marginal land, if the use of biomass is embedded in an integrated approach for sustainable land use [5] (Fig. 1.3). Finally, the major part of the resource basis is provided and used on a local and regional scale; trans-regional transport and trade is only suitable for specific biofuels, such as wood pellets, biodiesel and bioethanol [13].

1.3 The German Transformation: Demanding a New Role for Bioenergy?

Germany has implemented an active policy for the transition of the energy system towards the use of renewable energy more than a decade ago. The development of the renewable energy sector in Germany actively started to gain momentum in 1991 when the electricity feed-in law came into force, which was renamed as the “EEG”–Renewable Energy Sources Act in 2000 and has since undergone several amendments [7, 20]. The EEG aims to enforce technological development in order to introduce renewable energy into the electricity market and integrate it into the energy system. Since 2001, the European energy policy has promoted electricity production from renewable energy sources on the domestic electricity market [8]. Currently 20.3 % of the electricity consumed in Germany is produced from renewable energy that is mainly supported by the EEG, with the fluctuating use of wind and photovoltaic power accounting for one half, and biomass and hydropower accounting for the other [2].

A biofuel policy was implemented in 2003 in the transport sector, introducing a tax exemption for biofuels and transforming the system into a quota system from 2007 onwards [11]. This led to a share of biofuels in the road transport sector of 6.25 % since 2010. Up to now, all renewable energy sources for the provision of the transport sector are derived from biomass [16].

Furthermore, biomass is dominant in the heat sector, accounting for 90 % of renewable heat produced. The heat sector is much more market driven. An increase of biomass use occurred from 2003 due to the consumer reaction to increased prices of fossil fuels. In conclusion, 65 % of the renewable energy provided in Germany is a product of biomass, with the potential to reduce 65 million tons of CO_2-emissions, which is equivalent to the total amount of greenhouse gases emitted in 2012 [2].

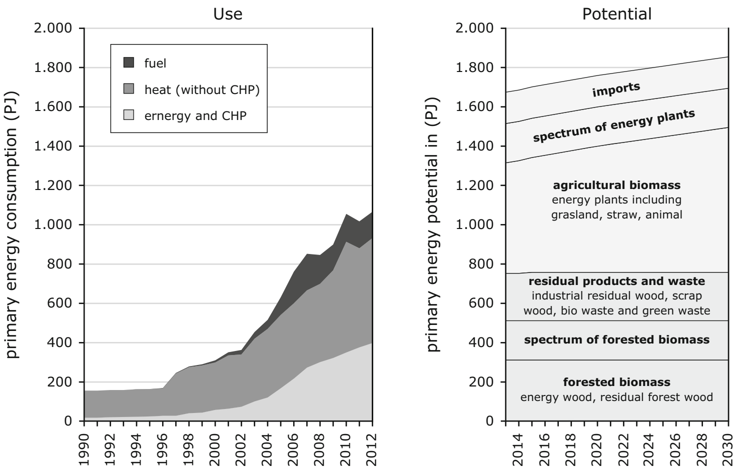
In many respects, Germany is extreme in exploring the new role of bioenergy. It is a densely populated nation with a high energy demand, has a strong agricultural sector and limited access to other continuous renewable resources such as hydro or geothermal energy. The International Renewable Energy Agency (IRENA) has ranked Germany in first position in the categories "*Renewable power per capita (not incl. hydro)*", "*total installation of PV*" and "*total installation of wind power*" and with place 3 in the categories "*total installations of bio-power*" and "*total installations of biodiesel production*" in the REN 21 report 2013 [17].

The development of the biomass input of the different energy carriers in Germany is shown in Fig. 1.4. Germany's renewable energy policy led to a strong increase of biomass use for energy provision in all three sectors over the last decade. Today more than 50 % of residues and the waste stream is used, and energy crops are cultivated on around 2 million ha of arable land [10]. The further additional biomass potential and expansion of the resource base is limited.

For the analysis of the possible new role of bioenergy in future energy systems these frame conditions offer interesting insights. This is the reason Germany has been selected for case study to demonstrate the possible options for a more system oriented provision of bioenergy.

1.4 Set-Up of the Book

In this book the possible new roles of bioenergy are described from a technical perspective while also taking into consideration market expectations. The aim is to find out what are the most promising solutions in the short- and midterm because



Reference
Terms: According to AGEE-Stat 2013 (PEC calculated by efficiency method) potentials: BMVBS 2010 (energy plants, excrement), Zeller et al. 2011 (straw), Destatis (Foreign Trade Statistics 2011), DBFZ 2013 (biowaste and green waste, industrial waste, unpublished) (Note: Missing years were determined by extrapolation of the individual results)

Fig. 1.4 Use of biomass for energy provision in Germany – historical development and expected availability of biomass

increasing flexibility always requires higher effort expenditure to produce certain amounts of energy.

The expected demand from future energy systems is the starting point for this investigation. This includes the question what kind of energy is necessary (power, heat, transport fuel etc.) and under which frame conditions the demand is expected (continuous versus discontinuous demand). In Chap. 2 the different energy markets are therefore analysed, including the status quo of biomass use and expected changes as well as market demands which are resulting from the process of transition of Germany's energy system. Germany is taken as a case study because of the extreme frame conditions for demand orientated provision. Furthermore, there is good data available for comparison as well as some practical experience in this field.

The second big driving force for a change in the role of bioenergy in future systems is the expected biomass potentials under the currently discussed sustainability criteria. This is analyzed in Chap. 3. Due to the complex international interdependencies of biomass potentials, the analysis of the resource base is provided on a global basis, analyzing the relevant driving forces and frame condition and to discuss with them the future availability of biomass.

The options for new concepts and technologies are investigated in the following chapters, referring to power provision from solid biofuels (Chap. 4), power provision from biogas (Chap. 5), heat provision from solid fuels (Chap. 6) and biofuels for the transport sector (Chap. 7). Additionally, the concepts and technologies to upgrade biomass to a better defined intermediate fuel which can be used in more complex conversion technologies are provided in Chap. 8.

Finally, a case study of a German region examines the effects of system optimized power provision from different renewable energy sources with bioenergy as a flexible option to balance the regional power supply system (Chap. 9).

From today's perspective it is very difficult to draw a full picture of the future application of bioenergy. However, the comprehensive analysis of the new challenges of the different markets and the potential technical answers could reveal the options for the transition of bioenergy use in future energy systems with higher share of renewables. This will be summarized in Chap. 10.

A final remark: biomass is a limited resource and at the moment how to satisfy the future demands for energy and materials is questionable; the reduction of the overall demand – by efficiency and sufficiency approaches – seems to be a precondition for the sustainable integration of bioenergy in future systems.

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