In: Energy Resources: Development… ISBN 978-1-61324-520-0
Editor: Enner Herenio de Alcantara,pp.

Chapter 2

BIOENERGY IN CENTRAL EUROPE – RECENT DEVELOPMENTS, INTERNATIONAL BIOFUEL TRADE AND FUTURE PROSPECTS

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ABSTRACT

In order to assess future prospects of bioenergy use, it is essential to have thorough knowledge of the status quo, recent developments and unused primary energy potentials.

To this end, statistical data on the current biomass use and international biomass streams as well as data on biomass potentials in literature need to be reviewed and discussed. In this chapter, this is done for the Central European (CE) region, with a special focus on international biomass trade and the situation in Austria.

The contribution of biomass and wastes to the energy supply in CE countries ranges from 2.8% in Italy to 14.9% in Denmark (2008). Due to European directives and according national support schemes, the share of biomass in the total energy consumption increased significantly in recent years, especially in Denmark (+6% from 2000 to 2008), Germany (+4.8%), Austria (+4.5%) and Hungary (+3.9%). The main progress was achieved in the field of electricity and CHP generation as well as the production and use of transport fuels.

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With regard to the compilation and interpretation of statistics on internationally traded biomass volumes, various challenges need to be addressed.

Statistical data on cross-border trade often do not cover the whole range of biomass used for energy recovery, such as energy crops for biofuel production or biomass which is intended for material uses and ultimately end up in energy production.

Therefore, methodological approaches to gain insight into recent developments and the status quo of biofuel trade are proposed and discussed. Subsequently, it is analysed which Central European countries act as importers and exporters of biomass, and trade streams are mapped.

The main importers of wood fuels in CE are Italy, Denmark and Austria. Cross-border trade of wood pellets has increased significantly in recent years. For Denmark pellets are the most important biomass import stream. Austria, being a net exporter of wood pellets, is importing considerable amounts of wood residues, primarily indirectly in the form of industrial roundwood.

With regard to direct biofuel trade (biodiesel and ethanol), Austria, Italy and Poland are the main importers (primarily biodiesel). Although growing rapidly, cross-border trade related to biofuels for transport is still rather moderate compared to (indirect and direct) trade of wood fuels in CE.

However, there is strong evidence that the CE region is currently becoming increasingly dependent on imports of biofuels as well as feedstock for biofuel production.

For the case of Austria, a detailed assessment of trade streams, including trade streams which are not considered in energy statistics, namely indirect trade of wood-based fuels and energy crops intended for biofuel production is carried out.

The results indicate that the net imports of biomass accounted for up to on fourth of the total bioenergy use in Austria in recent years. This is about three times the quantity that energy statistics suggest.

The results and methodological approaches of studies assessing biomass potentials indicate that there are considerable unused biomass resources available in Austria and other CE countries.

This chapter also provides insight into the (among the considered countries highly inhomogeneous) structure and current exploitation of biomass potentials and the achievable contribution to the total energy supply.

Finally, conclusions about future prospects for bioenergy use with a focus on the EU’s 2020 targets and policy recommendations are derived.

1. INTRODUCTION AND OUTLINE

Among the different renewable energy sources (RES) bioenergy is of crucial importance for the current and future energy supply in Central Europe (CE).[1] Not only because it already has the highest share of all RES, but also due to the vast potentials of biomass and the fact that it can be used in all energy sectors: for heat-only, electricity or combined heat and power generation as well as for the production of transport fuels.

With regard to the “2020-RES-targets” (as defined in the 2009-EU Directive on the promotion of the use of energy from renewable sources; EC, 2009a) the current structure of bioenergy use, recent developments and the availability of environmentally compatible resource potentials are of high interest.

Within this chapter recent developments are discussed, implications with regard to cross-border trade and energy policy targets are analysed. The considered countries include Austria, Czech Republic, Germany, Hungary, Poland, Slovenia and Slovakia as well as Italy and Denmark[2]. The sections of this chapter are organized as follows:

After this introduction, section 2 provides insight into the structure of energy consumption and bioenergy use in CE (sections 2.1. to 2.2.3). A special focus is given to the situation in Austria (section 2.3). The topic of section 3 is international trade of biomass.

After discussing methodological issues of assessing cross-border trade related to bioenergy (3.1), net imports and exports according to energy statistics are analysed (3.2). In section 3.3 trade streams of wood in CE are mapped. For the case of Austria a more detailed assessment of cross-border trade related to bioenergy use is carried out (3.4).

Section 4 deals with prospects for a further increase of bioenergy use, EU energy policy framework conditions and biomass resource potentials in the considered countries. Section 9 includes a discussion, conclusions and policy implications.

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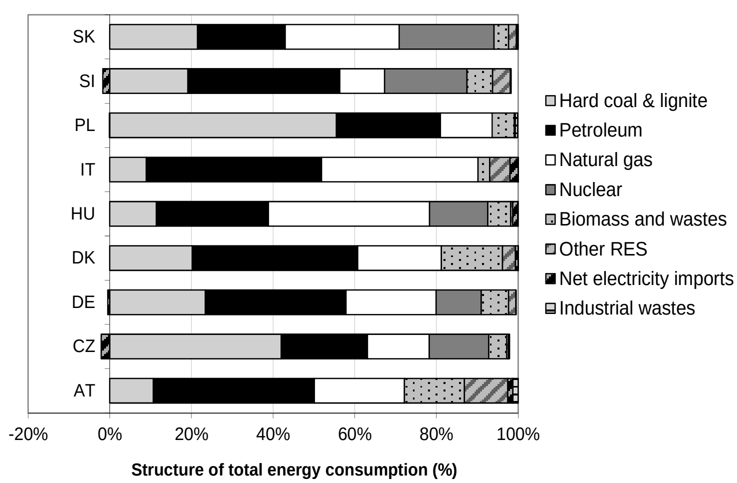
[1]Within this chapter, “bioenergy” is used for all kinds of biomass utilization for energy recovery. “Biofuels” comprise liquid and gaseous biogenic fuels used for transportation, such as biodiesel and bioethanol.

[2]These countries are referred to as “CE countries” in this chapter, even though Italy and Denmark are usually not considered to be part of Central Europe. They have been included primarily because of their significant cross-border trade streams as well as their characteristic biomass consumption profiles.

2. The Contribution of Biomass to the Energy Supply

2.1. The Structure of Energy Consumption in Central Europe

Despite the geographical vicinity of the considered countries, the structures of their primary energy consumption (gross inland consumption; GIC) are quite inhomogeneous (Figure 1). On an average the share of fossil fuels (petroleum, natural gas, lignite and hard coal) accounts for 80% of the total energy sources used, with Slovenia and Slovakia being least dependent on fossil fuels (both about 70%). The share of hard coal and lignite ranges from less than 10% (Italy) to more than 50% (Poland) and the contribution of petroleum from 21% (Slovakia) to 43% (Italy). The share of natural gas is especially high in Hungary's and Italy's GIC (both close to 40%) and relatively low in Poland and Slovenia (both slightly more than 10%). In the Slovak Republic nuclear energy accounts for as much as 23% of the GIC, whereas in Austria, Denmark, Italy and Poland there are no nuclear power plants in operation. There are also significant differences with regard to energy consumption per capita. In Hungary and Poland it accounts for 108 GJ/a, whereas in the Czech Republic it is 182 GJ/a and in Germany 175 GJ/a. In the other countries it ranges from about 125 to 170 GJ/a. (All data refer to 2008.)

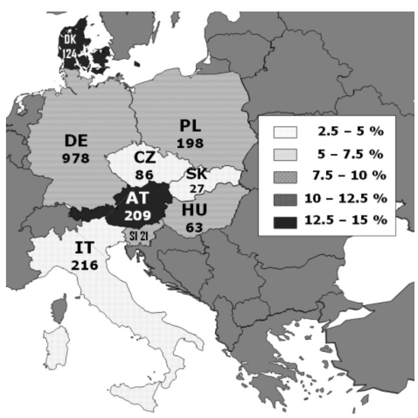


Sources: Eurostat (2010a), own calculations.

Figure 1. Structure of the GIC in CE countries in 2008.

2.2. The Contribution of Bioenergy in Central Europe

The shares of renewable energies in the GIC of the considered countries range from 5% in the Czech Republic to 25.3% in Austria (2008), with biomass and wastes accounting for an average of more than 70% of all renewables.[3] In the Czech Republic, Poland and Hungary biomass and wastes account for more than 90% of all RES. The share of biomass and wastes in the GIC is illustrated in the map in Figure 2. It is highest in Denmark (14.9%) and Austria (14.7%). The high contribution in Denmark is a result of ambitious energy policy measures which led to a significant increase of biomass use in combined heat and power (CHP) and district heating plants (largely based on imported biomass, as will be shown in section 3), especially since the early nineties. For the case of Austria the following reasons for the high importance of biomass have been identified: (i) Austria is a heavily wooded country. Almost 50% of the total Austrian area is forests, which is clearly more than in most other CE countries.[4] (ii) The use of biomass for residential heating is traditionally high in Austria. Especially in the eighties log wood boilers gained in importance due to the oil price shock and in recent years pellet boilers and other modern biomass heating systems have become increasingly popular (partly due to attractive investment subsidies).



Source: Eurostat (2010a)

Figure 2. Bioenergy as share of gross inland energy consumption in 2008 (values in PJ/a).

3The fact that non-renewable wastes are also included in “biomass and wastes” is neglected here.
4Only Slovenia has an even higher share of approximately 60%.

Today more than 20% of the total residential heat demand is met with biomass (Statistik Austria, 2010b). (iii) The prominent role of the wood processing industries in Austria was crucial for the development of the bioenergy sector. First, they provide substantial amounts of wood residues for energy use and second, a high proportion of their energy demand is covered with biomass. Therefore, the bioenergy share in the energy supply of the industrial sector is also exceptionally high.

2.2.1. The Structure of Biomass Use and Recent Developments

In Figure 3. the historic development of the share of biomass and wastes in the total GIC is illustrated for each CE country. The figure shows that in most countries the contribution of biomass increased significantly in recent years. The most notable developments were achieved in Germany and Denmark, but also in Austria, Czech Republic, Hungary and Slovakia the importance of biomass for energy production has been increasing steadily; especially since the year 2000 or so. In Austria the biomass consumption has more than doubled from 1990 to 2008, but due to the rising total energy consumption (about 34% increase from 1990 to 2008), the biomass share only showed an increase of about 60%.[5] In absolute numbers the biomass consumption in CE increased from about 450 PJ in 1990 to 1,950 PJ in 2008. Remarkably, the progress in Germany accounted for more than 50% of this increase. In 2008 about 50% of the total amount of biomass used for energy recovery in CE was consumed in Germany. The biomass consumption per capita is highest in Austria (25 GJ in 2008), followed by Denmark (22.7 GJ), Germany (12 GJ) Slovenia (10.5 GJ).

Figure 4. shows that the main increase in bioenergy use was achieved in the field of electricity and CHP generation. The share of biomass for heat-only production, accounting for about 80% in the nineties has recently gone down to less than 50%. The main reason for the increase in electricity and CHP generation was the implementation of the “EC Directive on electricity production from renewable energy sources” (EC, 2001) and the introduction of according support schemes (e.g. the German Renewable Energy Sources Act).

Among the considered countries the ratio of electricity generation from biomass and wastes to the total electricity consumption ranges from less than 1% in Slovenia to more than 10% in Denmark. In Austria (6.4%), Germany (5.3%) and Hungary (4.7%) the ratio is also relatively high, whereas in Czech Republic, Italy, Poland and Slovakia it is only about 2%. In the early nineties

[5]In most CE countries the energy consumption declined during this period.

only the biomass share in Austria's electricity consumption accounted for more than 2%.

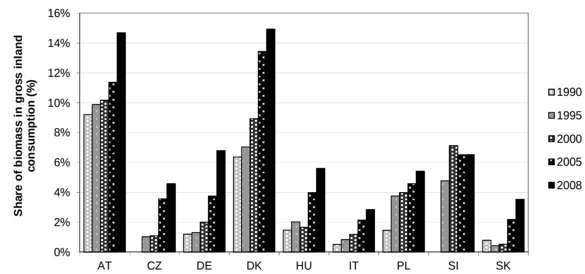
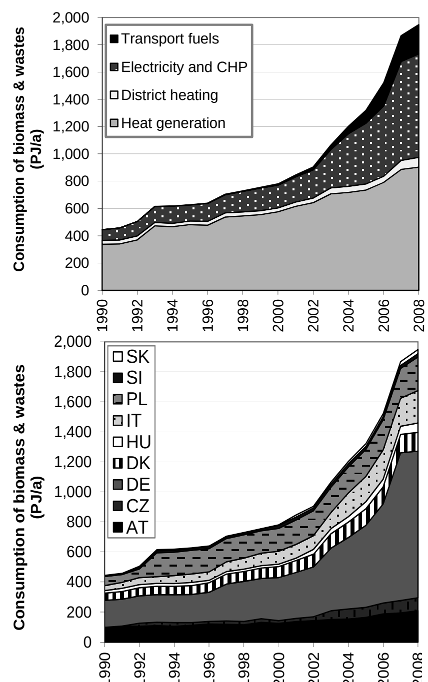


Figure 3. Development of bioenergy as share of GIC from 1990 to 2008.
Source: Eurostat (2010a), own calculations



Source: Eurostat (2010a), own calculations.

Figure 4. Biomass consumption in CE countries from 1990 to 2007 broken down by application (left) and country (right).

2.2.2. Biofuels for Transport

The main progress in the use of biofuels started in 2003, as a consequence of Directive COM 2003/30/EC on the promotion of the use of biofuels for transport (“Biofuel Directive”; EC, 2003). According to the directive, EU Member States are required to establish national targets on the proportion of biofuels in the transport sector.

The following reference values for national targets are stated in this directive: 2% by the end of 2005 and 5.75% by the end of 2010, calculated on the basis of energy values.

The progress in the considered countries according to the national progress reports in the context of the Biofuel Directive (EC, 2009b and EC, 2010a) as well as the national target values are illustrated in Figure 5. The figure illustrates that there are sometimes significant differences between the data according to Eurostat (2010a) (represented by error bars) and the data stated in the biofuel reports, indicating that the consumption of biofuels is partly not captured appropriately in energy statistics. This is particularly true for Slovakia as well as for the 2008-data for Italy and Poland.

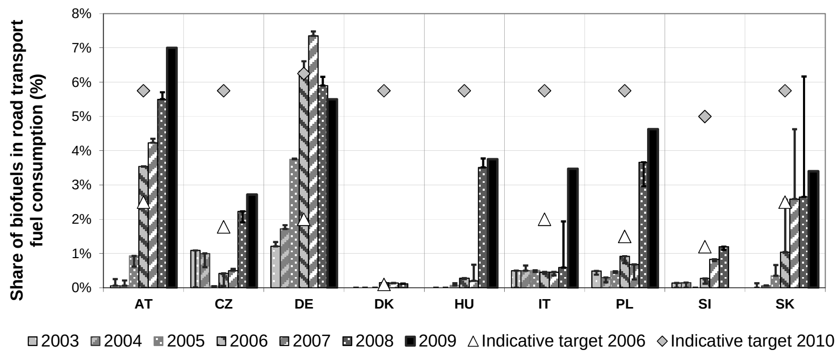
However, progress was very uneven among CE countries. Based on the national progress reports, Austria had the highest share of biofuels in 2009 (7%), followed by Germany (5.5%), Poland (4.63%), Hungary (3.75%) and Italy (3.47%). Up to 2007, Germany was the European leader in the field of biofuels. It had already surpassed its 2010-target of 6.25% in 2006, but in 2009 the share of biofuels had dropped to 5.5% due to an abolishment of the tax exemption for biofuels (see section 2.2.3).

In most other CE countries no appreciable progress was reported until 2008 or 2009. Denmark’s latest report (for the year 2008) indicates a biofuel share of only 0.12%. According to DEA (2009), Denmark aims at achieving the indicative 5.75%-target in 2012, after a gradual phase-in starting in 2010.

Figure 6 shows the historic development of biodiesel and bioethanol production in CE countries. Germany is the major producer of both biofuels. The German biodiesel production accounted for about 50% of the total production in the EU in the years 2002 to 2007.

Thereafter the production in Germany declined and its share in the total production in the EU decreased to about 28% (2009).[6]

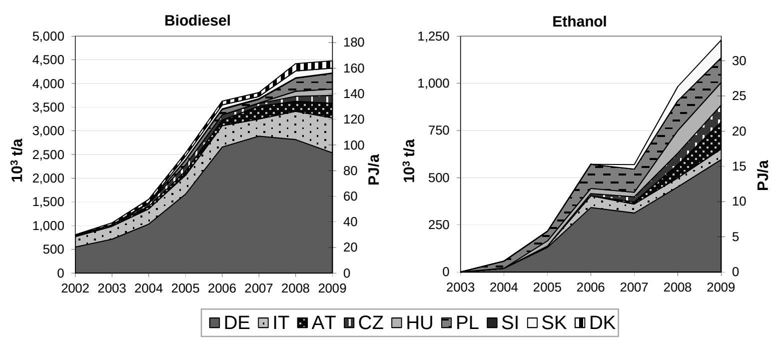
[6]An increase in tax levels for pure biodiesel in Germany in 2007 has severely affected the competitiveness of biodiesel, and numerous production plants have gone out of operation.



Sources: EC (2009b), EC (2010a) (no data for 2009 available for Denmark and Slovenia); error bars: data according to Eurostat (2010a), own calculations.

Figure 5. Share of biofuels for transport and national indicative target values in the context of Directive COM 2003/30/EC.

The capacity of biodiesel and bioethanol production plants being built recently in CE is considerable: From 2007 to mid-2010, the installed biodiesel production capacities increased from 3.8 Million tons per year (Mt/a) to 9.7 Mt/a (EBB, 2011). The bioethanol production capacities installed in CE increased from 1.94 Mt/a in mid-2008 to 3.1 Mt/a in mid-2010 (ePURE, 2011). About 50% of these capacities are located in Poland (0.56 Mt/a).



Sources: EBB (2011), ePURE (2011), own calculations[7].

Figure 6. Production of biodiesel and bioethanol in CE countries (quantity in tons and net calorific value of the fuels produced).

[7]For biodiesel production only aggregated data for Denmark and Sweden are available. The data for Denmark shown in the figure are therefore based on the installed production capacities.

At full capacity, biodiesel and bioethanol plants installed in mid-2010 could produce as much as 7.8% of the total fuel consumption in road transport in CE (2008). Hence, with regard to the available production capacities, the 5.75%-target for 2010 could theoretically be easily achieved. However, actual production figures have been clearly below production capacities and the question of whether or not the target will be achieved remains questionable; especially with regard to the recent developments in Germany. (Throughout the EU-27 the indicative target is very unlikely to be reached according to Resch et al., 2008a).

According to EC (2009b) the self-sufficiency of biofuels for transport of the EU-27 (defined as the ratio of production to consumption) decreased from 109% in 2005 to 73% in 2007. Throughout CE countries, the self-sufficiency of biodiesel was 83% and the one of bioethanol 76% in 2009 (calculation based on EBB, 2011, ePURE, 2011 and preliminary data according to EurObserv'ER, 2010). However, as biofuels are partly produced with imported feedstock, these calculations actually do not bear any information as to what extent the biofuel supply is based on imports. This aspect will be discussed in more detail for Austria and Germany in section 3.

2.2.3. Support Schemes for Bioenergy

In the field of transport and electricity generation from RES, EU directives issued shortly after 2000 resulted in a notable growth in bioenergy use in most CE countries. For heat generation no such directive was issued before Directive 2009/28/EC ("2009-RES-Directive"; EC, 2009a) and policy support was limited to diverse national or regional support schemes. These include investment subsidies (e.g. Austria, Germany, Slovenia), tax incentives (e.g. Austria, Germany), bonuses to electricity feed-in tariffs for the utilization of waste heat from combined heat and power plants (e.g. Czech Republic, Germany), certificate systems (e.g. Italy) and soft loans (e.g. Poland, Slovenia) (Resch et al., 2008b).

The most common instruments to promote biofuels in the transport sector are tax relieves and obligations to blend. According to EC (2009b) all CE countries used tax exemptions as the main support measure in 2005 and 2006. In Austria and Slovakia there were also obligations to blend. Since 2007 this policy instrument has also been adopted in Germany, Czech Republic, Italy and Slovenia, mostly in combination with increasing levels of taxation. For example in Germany the law on biofuel quotas ("Biokraftstoffquotengesetz") which came into force in January 2007 put an end to total tax exemption and established an obligation to blend (4.4% for biodiesel in diesel fuel and 1.2% for bioethanol in petrol).

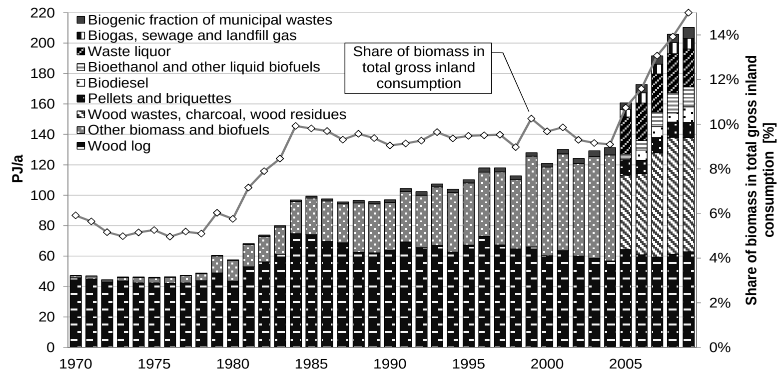
A major indirect support scheme for bioenergy and other low-carbon RES is the EU Emission Trading Scheme for greenhouse gases (EU ETS), which operates in the EU-27 plus Iceland, Liechtenstein and Norway. It was launched in 2005 and covers CO2 emissions from power stations, combustion plants and other industrial plants with a net heat excess of more than 20 MW (EC, 2010b).

2.3. The Development of Bioenergy Use in Austria

This section provides a more detailed insight into the historic development of biomass use in Austria, based on national statistics which are more detailed than the ones available on Eurostat (2010a). Figure 7 shows the development of biomass primary energy consumption broken down by biomass types. From 1970 to 2004, biomass statistics differentiated only between the categories “wood log” and “other biomass and biofuels”. The data for the biogenic fraction of municipal solid wastes are estimates based on the total energy use of wastes and an assumed biogenic share of 20%. More detailed data are available for the years 2005 to 2009, as shown in the figure. The biogenic share of wastes was in the range of 17 to 24% during this period.

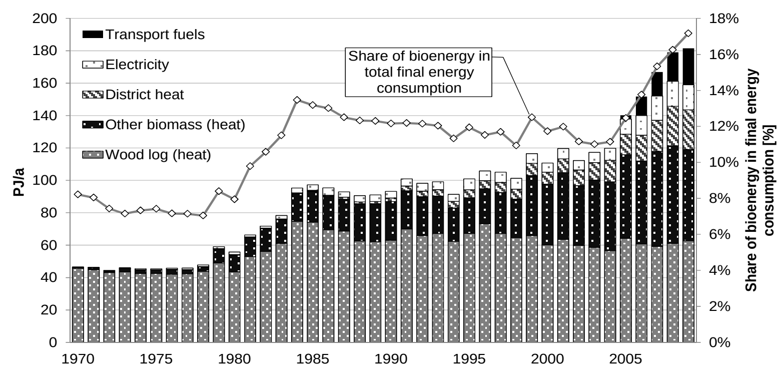
Figure 7 also shows the share of biomass in the total gross inland consumption, which increased from less than 6% (less than 50 PJ/a) during the mid-1970 to 15% (210 PJ) in 2009. The main increase in biomass use took place during the periods 1980 to 1985 and 2005 to 2009. Until the year 1999 the use of wood log for domestic heating accounted for more than 50% of the total biomass use for energy. The rest was primarily wood wastes and residues of the wood processing industries as well as waste liquor of the paper and pulp industry. Especially during the last five years, the different fractions of wood biomass, including forest wood chips, industrial residues and other wood wastes as well as liquid and gaseous biomass have become increasingly important, whereas wood log remained relatively constant at about 60 PJ/a. Hence, wood log accounted for only 30% of the total biomass use in 2009.

Figure 8 shows the development of biomass final energy consumption from 1970 to 2009. The data are broken down by fuels used for residential heating or industrial heat production (further broken down by wood log and other biomass), district heat, electricity and transport fuels produced from biomass.[8] In 2009, wood log and other biogenic fuels used for heat generation accounted for 65.6% of the biomass final energy consumption, district heat generated with biomass for 13.5%, electrical energy from biomass power plants for 8.5%, and transport fuels for 12.4%.



Source: Statistik Austria (2010a)

Figure 7. Biomass gross inland consumption in Austria from 1970 to 2009 and biomass share in total primary energy consumption.



Source: Statistik Austria (2010a).

Figure 8. Biomass final energy consumption in Austria from 1970 to 2009 and biomass share in total final energy consumption.

8 "Final energy consumption" covers energy supplied to the final consumer for all energy uses.

3. CROSS-BORDER TRADE OF BIOMASS FOR ENERGY

Well-functioning international biomass markets are considered one of the key factors for mobilizing the global biomass production potential and serving the growing demand for biomass for energy (Heinimö et al., 2007). Heinimö and Junginger (2009) argue that international biomass trade for energy is still in its initial phase and global trade volumes of certain biomass types (e.g. wood pellets, ethanol or plant oil) have already increased significantly in recent years.

Projects studying international bioenergy markets and trade have been launched, such as the international collaboration project entitled "Task 40: Sustainable International Bioenergy Trade: Securing Supply and Demand", which is carried out within the framework of the IEA Bioenergy agreement (see IEA, 2010a and IEA, 2010b). The objective of Task 40 is to "support the development of a sustainable, international, bioenergy market, recognising the diversity in resources [and] biomass applications […] by providing high quality information and analyses for market players, policy makers, international bodies as well as NGOs".

More specifically, one of the core objectives is to "map and provide an integral overview of biomass markets and trade on global level". The analyses presented in this section are intended to contribute to this objective by providing insight in current state of cross-border trade in CE, the impact of increasing bioenergy use on biomass streams as well as by carrying out a critical review of data in statistics and discussing methodological aspects.

3.1. Methodological Aspects

As Heinimö and Junginger (2009) emphasize, no comprehensive statistics and summaries aggregating separate biomass trade flows for energy generation are available and there are several challenges related to measurement of internationally traded volumes of biomass for energy generation.

Many biomass streams are traded for several applications, including both material and energy purposes (e.g. wood chips or oilseeds and plant oil for the production of biodiesel) or they are traded for material uses and ultimately end up in energy production (indirect trade).

Feedstock used for biofuel production is generally not taken into account energy statistics. Table 3 1 gives an overview of the methodological approaches applied in this section, their advantages and drawbacks as well as the biomass types considered and references/databases used. For data from trade statistics the CN codes of the respective commodities are provided (see EC, 2007).

The following methodological approaches are applied: First, the net imports (or net exports) of the following biomass types are analysed on the basis of energy and other statistics[9] (section 7.2): wood and wood waste, wood pellets, biodiesel and bioethanol (direct trade) and wood residues (indirect trade in the form of roundwood in the rough).

These data provide a rough overview about which countries act as net importers and exporters, and on the importance of direct cross-border trade of biomass for energy.

Next, direct trade streams of fuelwood and other wood fractions in the CE region are mapped, in order to identify the main trade streams of wood fuels (section 7.3).

Table 1. Data used and methodologies applied for assessing biomass trade

Short description	Types of biomass, databases/references used, CN codes	Characteristics and features (favourable: +, adverse: –)
Assessment of net imports / net exports based on energy and other statistics	Wood and wood wastes used for energy (Eurostat, 2010a) Wood pellets (Pellet@las, 2010) Indirect trade of wood residues (based on roundwood statistics according to FAO, 2010a) Biodiesel and bioethanol (Eurostat, 2010)	+ Avoidance of error sources related to trade statistics + Trade streams of products with no separate CN codes can be assessed + Volumes which are not covered in trade statistics can be assessed (e.g. blends of biofuels with fossil fuels) – Neglect of the lag between production and consumption as well as stockkeeping results in errors – No information about trade partners – Trade of upstream products (e.g. energy crops for transport fuel production) is not taken into account

[9] Apart from energy statistics (Eurostat, 2010a), data have been obtained from Pellet@las (2010) and FAO (2010a).

Short description	Types of biomass, databases/references used, CN codes	Characteristics and features (favourable: +, adverse: –)
Investigation and mapping of trade statistics	Wood residues (UN Comtrade, 2009; CN codes 4401 2100, 4401 2200 and 4401 3010) Fuelwood (UN Comtrade, 2009; CN code 4401 1000)	+ Use of official data on international trade volumes + Information about trade partners available – Several error sources related to trade statistics, e.g. shipments below declaration limit not included, commodities may be recorded under wrong CN Codes, country of origin or ultimate destination may be unknown in case of transit – No differentiation between energy and non-energy use (no separate CN Codes) – Several biomass types sometimes aggregated under one CN Code (e.g. pellets included in wood residues) – Only quantities of specific products included; trade of upstream products not considered (e.g. trade of oilseeds or plant oil intended for biodiesel production)
Assessment of total cross-border trade related to bioenergy use (exemplary assessment for the case of Austria)	Direct trade: energy statistics (Eurostat, 2010a) Indirect trade with wood-based fuels: statistics of wood processing industries and supply statistics (BMLFUW, 2010, FAO, 2010a etc.) Biofuel statistics (Winter, 2010), supply balances for agricultural commodities (Statistik Austria, 2010c)	+ Provides comprehensive insight into biomass trade relevant for bioenergy use + Indirect trade streams and trade with upstream products (feedstock for biofuel production) can be assessed – High data requirements, data need to be collected from different databases and statistics of industries – Complete assessment of indirect trade streams not possible due to insufficient data availability – Preselection of commodities is necessary; selection is not straightforward and background knowledge of trade streams is required

Assessment of direct and indirect effects of biomass use on trade flows of related products	Biodiesel (impact on oilseed and plant oil trade streams);Databases: EBB (2009); rapeseed production: Eurostat (2010a), UN Comtrade (2009); CN codes 1205, 1514, 1511	+ Suitable for fuels with several upstream products which can be used for energy and other purposes + Indirect and spillover effects can be assessed – Selection of commodities which are taken into account is not straightforward; background knowledge/presumptions on indirect effects required – Only rough conclusions are possible due to uncertainties related to other influencing factors – Information on conversion processes required

However, since the statistical data used for these approaches are fragmentary and do not cover the whole range of biomass trade relevant for bioenergy use, a complete assessment is carried out for the exemplary case of Austria (section 7.4). This includes an assessment of indirect trade of wood-based fuels and of feedstock used for biofuel production. The assessment of indirect trade is based on a comprehensive analysis of international and domestic wood trade flows (i.e. imports and exports of the wood-processing industries as well as trade streams between the industries), in order to capture the total amount of biomass used for energy generation and originating from non-domestic production. Finally, the impact of increasing resource demand for biodiesel production on trade statistics of oilseeds and plant oil is exemplarily analysed for the cases of Germany and Austria (section 7.5).[10]

3.2. Net Imports and Exports of Biomass

Under disregard of the time lag between biomass production and consumption, the difference can be considered as net imports (or net exports, respectively).

[10]For the conversion of trade data given in mass units to energy units, the following LHV are assumed: Fuelwood and wood residues: 14.4 MJ/kg, wood pellets: 18 MJ/kg, biodiesel: 37 MJ/kg, bioethanol: 26.7 MJ/kg.

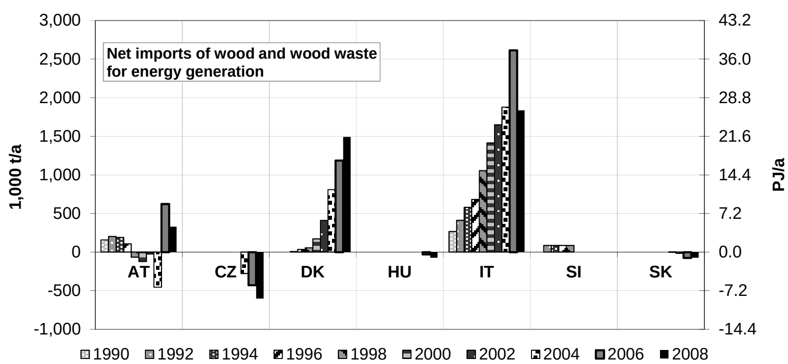
The main advantage of this simple approach is that the numerous error sources related to trade statistics are avoided. Apart from errors caused by neglecting stockkeeping, which can be especially relevant during very dynamic market developments, the main drawback is that no information about trade partners can be obtained.

3.2.1. Wood and Wood Waste

Figure 9. shows the net imports of "wood and wood wastes", based on energy statistics (Eurostat, 2010a).[11] The data indicate that especially the net imports of Italy and Denmark have increased significantly in recent years.

More than 30% of the wood biomass consumption in Italy and about 25% of the consumption in Denmark is based on imports. According to ENS (2009), the net imports of wood chips, wood pellets and fuelwood accounted for 19.5 PJ in 2008 (1.8, 15.5 and 2.2 PJ, respectively).

Austria has turned from net exporter to net importer in recent years, reflecting the increasing demand for wood fuels during this period. Czech Republic on the other hand has been exporting increasing amounts of wood biomass.



Source: Eurostat (2010a); own calculations.

Figure 9. Net imports of wood biomass for energy generation based on energy statistics (no data for Germany and Poland available).

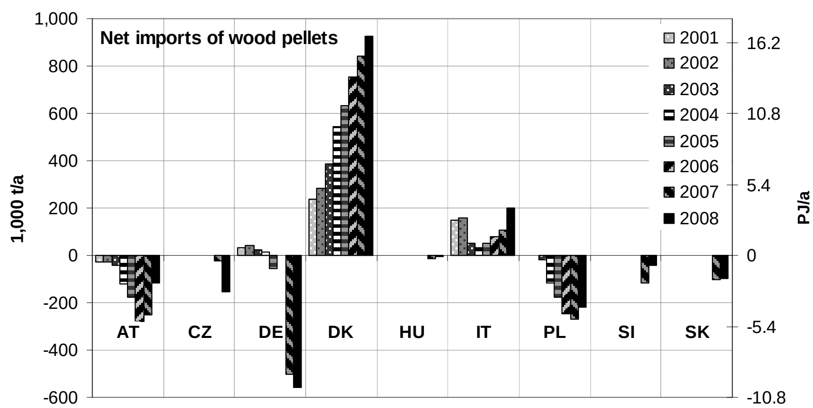
[11] According to the definition by Eurostat, the category "wood and wood wastes" covers "a multitude of woody materials generated by industrial processes or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, black liquor, etc.) as well as wastes such as straw, rice husks, […] and purpose-grown energy crops (poplar, willow, etc.)".

3.2.2. Wood Pellets

Wood pellets are well suited for transportation due to their high density and energy content. Recent policy and market changes have stimulated an increasing demand for wood pellets (Peksa-Blanchard et al., 2007) and given an impetus to international trade with wood pellets. Figure 10 illustrates the net imports of wood pellets from 2001 to 2008. The increase in international trade is especially apparent in the data for Austria, Germany, Denmark and Poland. Denmark and Italy have been importing significant amounts of wood pellets in recent years, whereas the other CE countries are net exporters. It is remarkable that pellets account for the largest single fraction of wood fuels imports to Denmark. With regard to net exports it has to be mentioned that the neglect of the time lag between production and consumption may result in an overestimation.

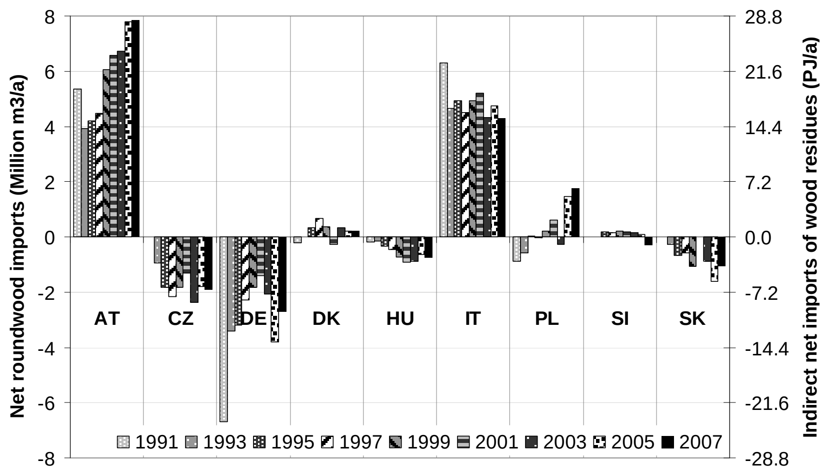
3.2.3. Indirect Imports of Wood Residues

A large percentage of roundwood material in the rough being shipped for the purpose of sawnwood production actually ends up as byproducts (bark, sawdust, wood chips etc.). Due to the vast amounts of roundwood being traded globally, these indirect imports of wood residues are of some significance. Heinimö and Junginger (2009) conclude that indirect trade of biomass through trading of industrial roundwood and material byproducts composes the largest share of global biomass trade.



Source: Pellet@las (2010), own calculations.

Figure 10. Net imports of wood pellets based on production and consumption statistics.



Source: FAO (2010a); own calculations.

Figure 11. Net imports of roundwood (in million m3; left axis) and the according indirect net imports of wood residues (in PJ; right axis).[12].

Figure 11. shows the net imports of roundwood and the estimated indirect net imports of wood residues from 1991 to 2007.[13] Austria and Italy are the main importers of industrial roundwood in CE. While Italy shows a declining trend, Austria's net imports have almost doubled since the mid-1990s. The main exporters of industrial roundwood are Germany and the Czech Republic.

Figure 11. provides a rough overview into the quantities of indirectly traded wood residues, and into which countries are net importers and which are net exporters of roundwood.

However, it needs to be considered that wood residues are not only used for energy recovery but also for material uses, primarily the production of paper, pulp and wood boards. Therefore it is necessary to analyse the trade flows within the countries, in order to gain insight into the quantities relevant for bioenergy use. In section 3.4.3 this is done for the case of Austria.

[12]Based on Heinimö and Junginger (2009) who estimate that 40–60% of roundwood can be converted into forest products, it is assumed that 50% of the industrial roundwood end up as residues.

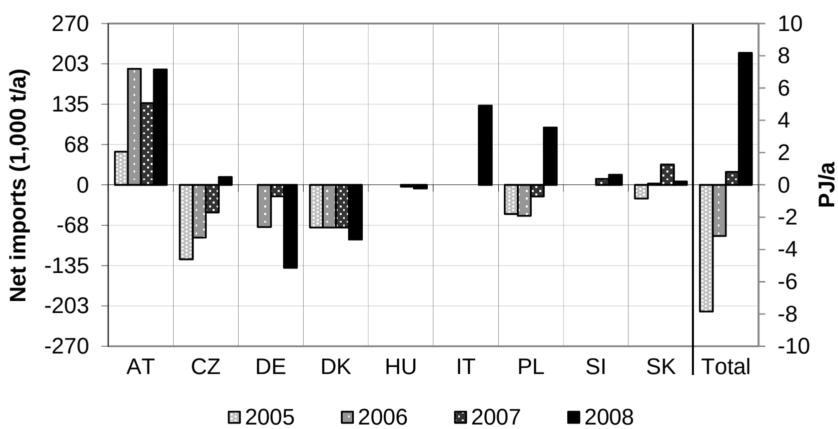
[13]There are several other streams of indirect biomass imports, including for example waste wood in the form of wood products or residues from sawnwood processing. However, cross-border trade of industrial roundwood is assumed to be by far the most significant indirect biofuel stream.

3.2.4. Liquid Biofuels for Transport

With the growing demand for biofuels for transport[14], the volumes of internationally traded biofuels have been increasing strongly in recent years. The total biodiesel imports of CE countries (with trade between CE countries included) increased from 70,000 t in 2005 to about 800,000 t in 2008 and the total exports from 210,000 t to 480,000 t. The total bioethanol imports increased from zero to 420,000 t and the exports from 30,000 t to 190,000 t during the period 2005 to 2008 (Eurostat, 2010a).

The following figures show the development of net imports of biodiesel and ethanol for the CE countries as well as the aggregated data for the CE region. Apparently, Austria was the main net importer of biodiesel in the considered period, whereas Czech Republic, Germany and Denmark stand out as net exporters.

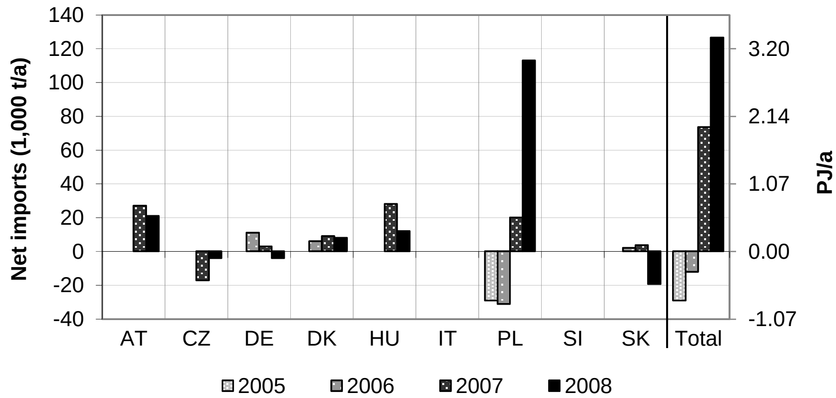
The net trade flows of bioethanol are much lower, except for the case of Poland. With regard to the development during the period 2005 to 2008, which was characterized by substantial increase in biofuel use in CE (see section 2.2.2), it is evident that production could not keep pace with the growing demand. The aggregated data for all considered countries illustrate that despite the rapidly increasing production (see Figure 6) the CE region turned from a net exporter into a net importer of both biodiesel and ethanol.



Source: Eurostat (2010a), own calculations.

Figure 12. Net imports of biodiesel based on energy statistics.

[14]Only biodiesel and bioethanol are considered here. Apart from these biofuels, vegetable oil is of some significance in Germany and Austria (EurObserv'ER, 2010).



Source: Eurostat (2010a), own calculations.

Figure 13. Net imports of bioethanol based on energy statistics.

Analyses of biofuel trade streams (based on UN Comtrade, 2009, for example) prove to be problematic, as statistical compilation of biofuel trade of biofuels for transport is still in the early stages. Only since January 2008, there is a separate CN Code for biodiesel (3824 9091). Before that date, biodiesel had to be classified under a general CN subheading together with other chemical products[15] (Freshfields Bruckhaus Deringer, 2008). Furthermore, the quantities reported under the newly established CN Code are highly incomplete, as only biodiesel shipped in its pure form is included.[16]

Bioethanol is classified under CN code 2207 0000, together with any other sort of “denatured ethyl alcohol and other spirits of any strength”, making it impossible to map trade streams of bioethanol used as transport fuel. Apart from that, like biodiesel ethanol is also shipped in blends of different proportions, further complicating analyses of trade streams.

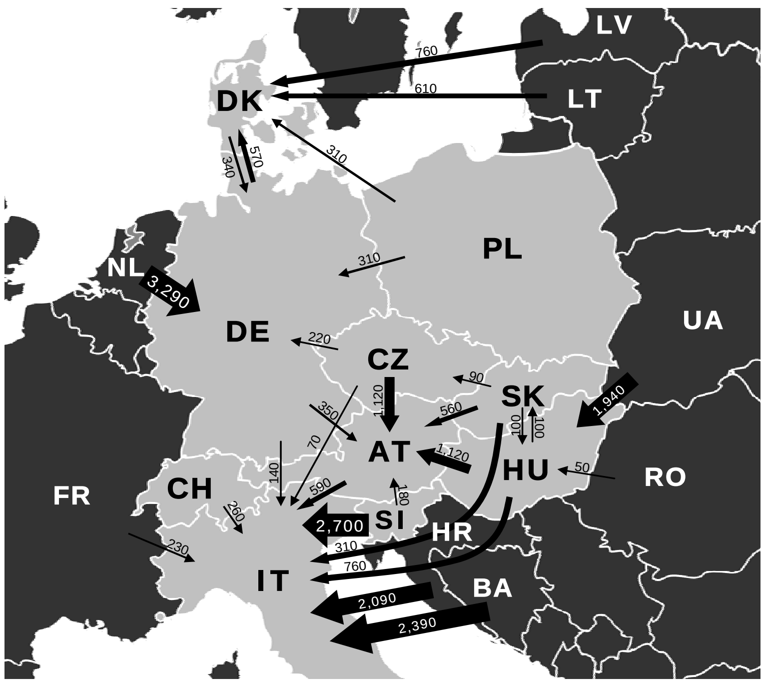
3.3. Streams of Wood Biomass in Central Europe

Based on trade statistics (UN Comtrade, 2009), the following figures show wood biomass streams in the CE region. Figure 14. shows the trade streams of

[15]CN Code 3824 9098 “chemical products and preparations of the chemical or allied industries, including those consisting of mixtures of natural products”.

[16]For example, the biodiesel imports reported by Austria in 2008 account for only 20% of the import quantities according to energy statistics. These incomplete data suggest that Austria imported more than 80% of the total imports from Germany.

fuelwood (CN code 4401 1000 “wood in logs, in billets, in twigs, in faggots or in similar forms”) in the year 2007. With total net imports amounting to 7.4 PJ in 2007, Italy is the main importer of fuelwood. However, Italy’s fuelwood imports in 2007 accounted for only slightly more than 20% of its total imports of wood biomass (cp. Figure 9). More than 50% of Italy’s fuelwood imports come from CE countries. The rest is imported primarily from Croatia and Bosnia-Herzegovina. Further major fuelwood streams are from the Netherlands (i.e. from overseas) to Germany and from Ukraine to Hungary. Austria is also importing noteworthy amounts of fuelwood from Czech Republic, Slovakia and Hungary.

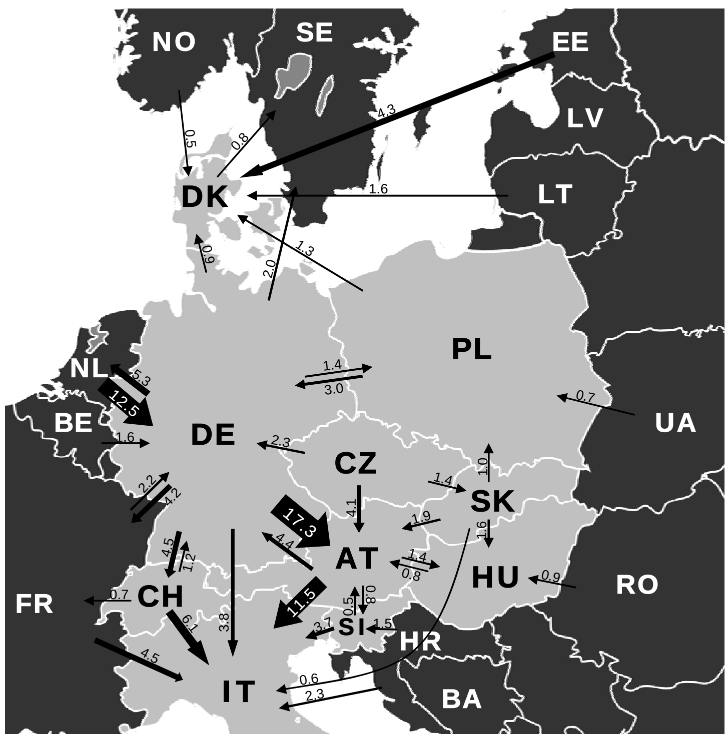


Source: Data obtained from UN Comtrade (2009), own calculations and illustration.

Figure 14. Cross-border trade of fuelwood in Central Europe in 2007 (in TJ/a; flows smaller than 50 TJ/a are not depicted; unlabeled neighbouring countries do not have any relevant trade flows.)[17].

[17]Data reported by the importing and the exporting country often show significant discrepancies; in Figure 14 and Figure 15 always the higher value is shown.

However, in total the net imports to Austria accounted for less than 5% of its total fuelwood consumption in 2007. It has to be noted that the data reported in trade statistics are connected with high uncertainties. This becomes obvious when data reported by the importing country are compared with the respective data reported by the exporting country, which are often highly inconsistent. It is assumed that these discrepancies are due to different regulations concerning the notification of imports and exports, as well as methodologies of data collection. Even though fuelwood cross-border trade among some CE countries has been increasing substantially in recent years (especially imports to Italy, increasing by close to 400% in the last ten years or so according to UN Comtrade, 2010), it is concluded that the trade volumes of fuelwood are rather insignificant in relation to its utilization in CE.



Source: Data obtained from UN Comtrade (2009), own calculations and illustration.

Figure 15. Cross-border trade of wood residues (including wood chips, sawdust, briquettes, pellets etc. for energy and material purposes) in Central Europe in 2007 (in PJ/a; flows smaller than 0.5 PJ/a are not depicted).

Figure 15. illustrates the cross-border trade of wood chips, sawdust, pellets etc. (in the following the term “wood residues” is used for these fractions)[18]. The quantities are clearly higher than those of fuelwood shown above.

However, this category also includes wood which is used for material purposes. It is clear to see that apart from German overseas imports via the Netherlands and Denmark’s imports from the Baltic States, the main streams are Austria’s imports from Germany and Austria’s exports to Italy.

The figures confirm that Austria and Italy are the main net importers of wood residues in CE. For the case of Austria, this is partly due to the high demand of the paper and pulp industry and the board industry, but the share of wood residues being used for energy generation has been increasing significantly in recent years (see section 3.4.3).

From 1996 to 2007 Austria’s total import quantity of wood residues increased from 0.85 Mt to 1.9 Mt. However, clearly larger volumes are imported indirectly through industrial roundwood, as it was shown in section 3.2.3.

3.4. Cross-Border Trade Related to Bioenergy Use in Austria

This section provides a more detailed insight into the importance of biomass cross-border trade for bioenergy use in Austria. Apart from energy statistics (Statistik Austria, 2010a), production and consumption statistics of the wood-processing industries (sawmill industry: FAO (2010a), paper and pulp industry: Austropapier (2010), wood board industry: Schmied (2009), statistical data on wood consumption and trade (FAO, 2010b), supply balances for agricultural commodities (Statistik Austria, 2010c) as well as reports on timber felling (BMLFUW, 2010) and biofuel consumption (Winter, 2010) were used. Hence, the data required for gaining insight into the importance of international trade streams for the bioenergy sector go far beyond energy statistics provided by Eurostat or national statistical institutes, respectively.

3.4.1. Biomass Trade According to Energy Statistics

Figure 16. shows the imports and exports of biomass used for energy production in Austria according to energy statistics, broken down by the

[18] “Wood in chips or particles”: sawdust and wood waste and scrap, whether or not agglomerated in logs, briquettes, pellets or similar forms (CN Codes 4401 2100, 4401 2200 and 4401 3010).

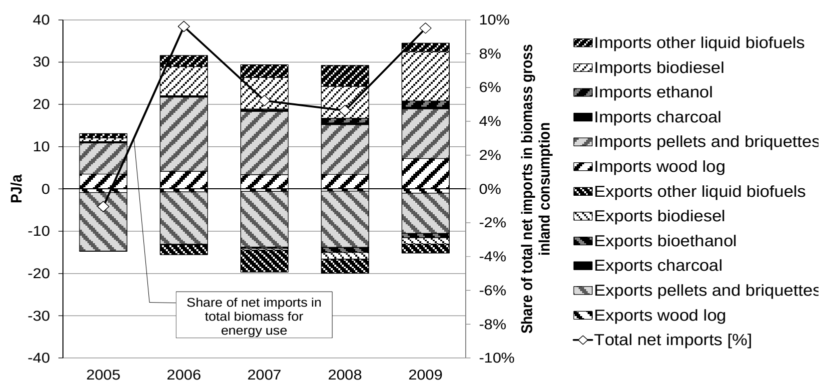
different types of biofuels, pellets and briquettes, wood log and charcoal.[19] Primarily due to the relatively high imports of wood log and biodiesel, the net imports were clearly positive since 2006. In the years 2006 and 2009 they accounted for close to 10% of the GIC of biomass in Austria.

3.4.2. Cross-Border Trade of Biofuels

The increasing use of biogenic transport fuels (biodiesel, vegetable oil and ethanol) in recent years resulted in a significant increase of cross-border trade. Apart from direct trade with biofuels, cross-border trade of feedstock used for biofuel production need to be taken into account.

Biodiesel

Figure 17. shows the development of biodiesel production and direct imports and exports according to the official biofuel reports persuant Directive 2003/30/EC (Winter, 2010). The figure shows that imports accounted for approximately 50% of the inland consumption in the period 2005 to 2009. Close to one fourth of the domestic production of biodiesel, which increased from 70,000 t (2005) to more than 320,000 t (2009) during this period was exported.

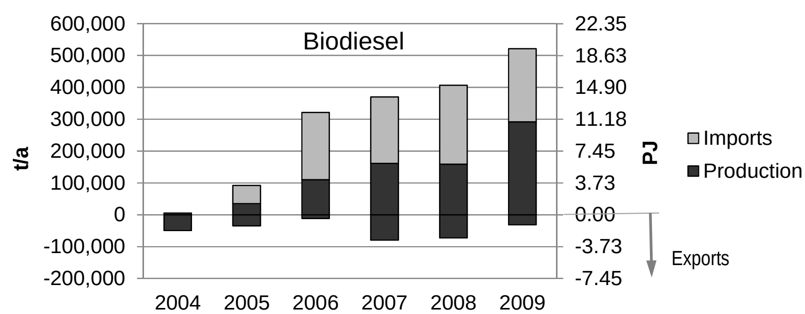


Source: Statistik Austria (2010a), own calculations

Figure 16. Imports and exports of biogenic energy carriers according to energy statistics.

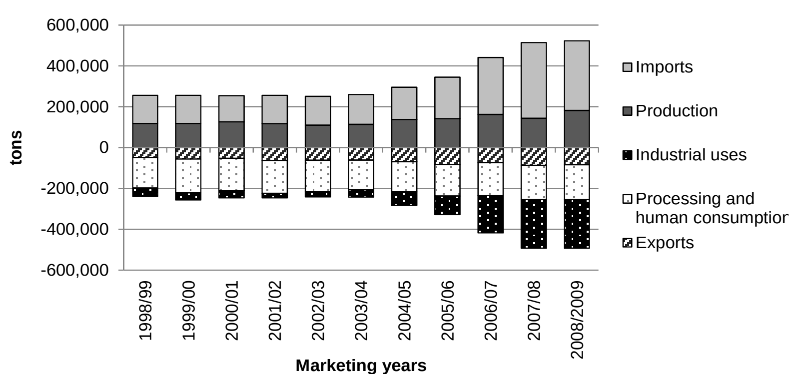
[19]These detailed data are only available for the period 2005 to 2009 (cp. Figure 7 and Figure 8). A comparison with data presented in the previous sections indicates that the category "pellets and briquettes" also includes unrefined wood residues.

With regard to plant oil used for transportation, there are hardly any reliable data, as production volumes in statistics are not differentiated by intended uses and due to largely regional distribution channels. According to Winter (2010), approximately 17,000 to 18,000 t (0.6 to 0.67 PJ) of plant oil were used for transportation annually during 2007 to 2009. It is assumed that at least the quantities which are used in agriculture (approximately 2,700 t or 0.1 PJ in the year 2009) originate from domestic production.



Source: Winter (2010), own calculations

Figure 17. Austrian biodiesel supply from 2004 to 2009 according to the official biofuel report persuant Directive 2003/30/EC (Stockkeeping is neglected.)



Source: Statistik Austria (2010c)

Figure 18. Supply balance for vegetable fats and oils (losses, stockkeeping and animal feed are not shown due to negligible quantities).

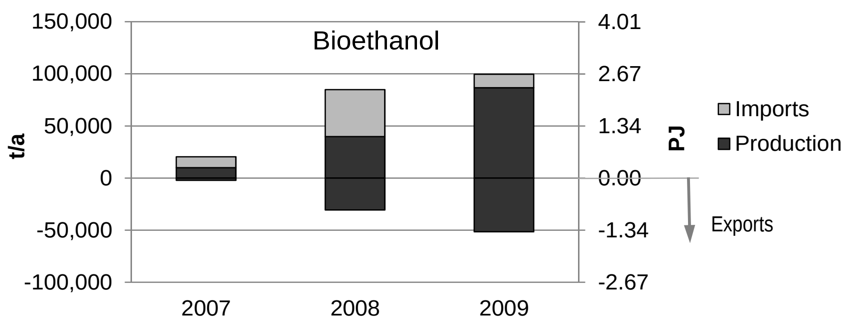
In order to provide insight into the impact of biodiesel and plant oil for energy use on Austria's trade streams, the supply balance for vegetable fats and oils is shown in Figure 18. The supply balance shows “sources” (imports and domestic production) as well as “sinks” (processing and human consumption, exports and industrial uses). It is clear to see that the rapidly increasing industrial use of vegetable oils and fats (i.e. primarily biodiesel production) was facilitated by a significant increase in imports, whereas domestic production remained relatively constant. The self-sufficiency (calculated on the basis of the oil yield from domestic oilseed production) decreased from about 60% (marketing years 1998/99 to 2000/01) to less than 30% (2007/08: 23%, 2008/09: 27%). Today, industrial uses exceed the quantity used for processing and human consumption in Austria.

To conclude, the additional demand for energetic uses of vegetable fats and oils was almost exclusively covered with imports. The most important trade streams are rapeseed oil imports from the eastern neighboring countries and Eastern Europe, respectively, but Austria is also importing increasing amounts of palm oil: From 2000 to 2008 the net imports increased from about 13,000 t to 47,000 t (UN Comtrade, 2009).

Bioethanol

The Austrian production of bioethanol used for transportation is limited to one large-scale plant, located in Pischelsdorf in Lower Austria and operated by the AGRANA holding company. The plant became fully operational in mid-2008 (in 2007 a test run was carried out) and has a capacity of approximately 190,000 t/a (5.1 PJ/a). Figure 19 shows the bioethanol production, imports and exports in Austria from 2007 to 2009. Whereas in 2007 and 2008, Austria was a net importer of bioethanol, the net exports in 2009 amounted to about 28% of the production. The annual feedstock demand at full capacity is reported to account for 620,000 t (75% wheat and triticale, 15% maize and 10% sugar juice). According to Kopetz et al. (2010), the agricultural land used for the production of “ethanol feedstock” in 2007 was 6.749 ha. There are no profound data available on the feedstock supply in 2008 and 2009, but according to the operator’s financial report for the business year 2009/10 (AGRANA, 2010), most originated from domestic production.

The self-sufficiency of cereals varied from 94 to 110% in the marketing years 2003/04 to 2008/09. Despite the additional demand for ethanol production (about 400,000 t), the self-sufficiency in 2008/09 was as high as 105%, because the production quantity in this marketing year surpassed the average of the previous five years by about 1 Mt.



Source: Winter (2010), own calculations

Figure 19. Austrian bioethanol supply from 2007 to 2009 according to the official biofuel report persuant Directive 2003/30/EC.

Hence, it is concluded that (i) the feedstock demand for bioethanol production is relatively moderate, compared to the total cereal production (approximately 5.75 Mt in 2008/09), (ii) based on historical data, general conclusions about the impact of bioethanol production on international trade streams in Austria are not possible, but (iii) the data for 2008/09 suggest that the feedstock demand for the current quantity of bioethanol production can basically be supplied from domestic production without reducing the self-sufficiency.

3.4.3. Indirect Cross-Border Trade of Wood-Based Fuels

As mentioned before, indirect imports of biomass include quantities which are originally imported for material uses but ultimately end up in energy generation. For the case of Austria, the presumably most significant indirect trade streams of wood-based fuels are indirect imports of residues of the sawmill industry (industrial wood residues), bark from industrial roundwood, residues of the wood board industry and waste liquor of the paper and pulp industry.

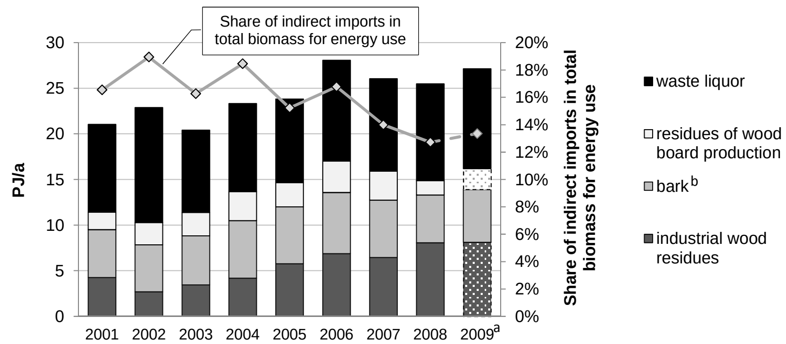
In order to assess the indirect biomass imports used for energy, it is essential to have an idea of the different utilization paths of the various wood fractions, as well as the trade streams between the wood processing industries: The bulk of industrial roundwood is processed to sawnwood by the sawmill industry. The average share of imported roundwood in the consumption of the sawmill industry was about 45% in the last ten years. The paper and pulp industry as well as the wood board industry process roundwood and wood residues of the sawmill industry. Therefore, the sawmill industry acts as an important raw material supplier for the other industry segments. The increasing production of the Austrian sawmill industry in the last years and decades provided favourable framework conditions for the growth of the paper and pulp and the wood board industry. However, in recent years the demand for wood residues for energy generation has been increasing significantly, and the import quantities of these industries segments have also amounted to notable trade streams.

Based on production and consumption statistics of the wood processing industries as well as trade statistics, the quantities of the indirect trade streams mentioned above have been assessed: During the period 2001 to 2009 imports accounted for an average of 42% (between 35 and 52%) of the wood consumption of the Austrian sawmill industry and the share of sawmill residues being used energetically increased from 12% in 2002 to about 40% in 2009 (own calculations based on statistical data of the wood processing industries). Accordingly, the energy quantity of indirectly imported sawmill residues increased from 2.7 PJ in 2002 to 8.1 PJ in 2009. Futhermore, the quantity of bark being imported in the form of roundwood and used for energy production is estimated 5.8 PJ/a (average value of the period 2001 to 2008; no discernible trend during this period). With regard to waste liquor of the wood processing industries, the analysis of statistical data indicates that between 38 and 44% of the total quantity reported in energy statistics can be traced back to imports (directly imported roundwood and wood residues as well as indirectly imported residues). Hence, on an average about 10 PJ of indirectly imported waste liquor were used for energy production annually during 2001 to 2009. Compared to this, the quantities of indirectly imported wood residues of the board industries are relatively low (about 2.6 PJ/a).

The results of the assessment of indirect imports of wood-based fuels in Austria are summarized in Figure 20. In total, indirect imports of wood-based fuels amounted to an energy equivalent of more than 25 PJ/a since 2006. At the same time, the share of indirect imports in the total biomass gross inland consumption in Austria has declined from more than 18% (2002 and 2004) to around 13% (2008 and 2009), as the total biomass consumption has increased more rapidly than the contribution of indirect imports.[20]

Due to the economic crisis in 2009, a downturn of the production quantities of all wood-processing industries could be observed.

[20]The annual fluctuations of indirect imports are partly due to weather conditions and storms, which had a significant impact on the domestic wood supply in recent years (e.g. the storms "Kyrill" and "Paula" in 2007 and 2008, respectively).



Sources: FAO (2010a), FAO (2010b), Austropapier (2010), BMLFUW (2010), Hagauer (2007), Schmied (2009), own calculations.

Figure 20. Development of indirect imports used for energy, and the according share in the total biomass consumption in Austria. a) The data for indirect imports of industrial wood residues and residues of wood board production in 2009 are estimates, as no 2009-data on the wood consumption of the board industry were available at the time these analyses were carried out.b) The share of bark in imported quantities of industrial roundwood is assumed 10%.

However, the relative decrease of sawnwood production (and therefore also the inland supply of industrial residues) decreased more significantly (minus 24%) than the production of the paper and pulp and the board industry (minus 12% and minus 11%, respectively). The paper and pulp industry's consumption of domestically produced industrial residues decreased by more than 30%[21], and the share of imports in the total wood consumption increased to about 30% (compared to an average share of 22% in the previous five years). It is important to note that there are some other indirect biomass trade streams, which are not taken into account here: First of all, streams of wood products like sawnwood, wood panels, paper etc. which usually end up in energy generation, either in dedicated bioenergy plants utilizing waste wood, or in waste treatment plants. There are substantial methodological challenges related to the assessment of these indirect trade streams, including insufficient statistical data on trade volumes, uncertainties about the lifetime of wood products, recycling rates and many more. With regard to wood products Austria a net exporter, which puts the high indirect imports shown in Figure 20 somewhat into perspective.

[21]For the estimated 2009-data in Figure 20 it was assumed that the same shift in the wood consumption structure occurred in the board industry.

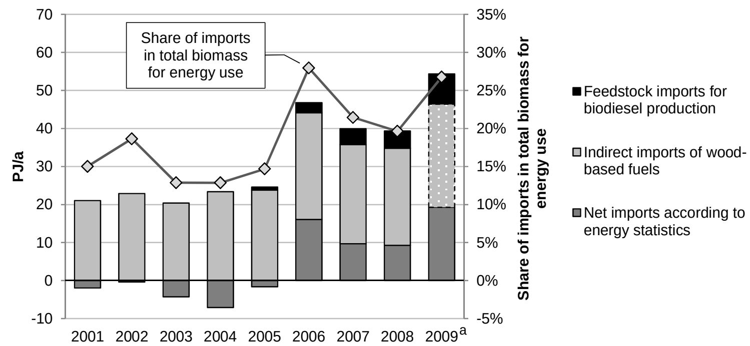


Figure 21. Development of total biomass imports for energy use including indirect imports and feedstock for biodiesel production, and the according share in the total biomass use in Austria, a) The data for indirect imports of wood-based fuels in 2009 are partly based on estimates.

3.4.4. Summary

To sum up, with feedstock for biofuel production and indirect trade streams taken into account, cross-border trade of biomass for energy use is clearly more significant than energy statistics suggest. Based on the assessments described above, it is concluded that the share of imported biomass was between 20% and 30% of the total biomass consumption in Austria during 2006 to 2009 (Figure 21). Indirect imports of wood-based fuels are the most significant fraction, but direct imports of wood fuels, liquid transport fuels and feedstock imports for biofuel production have also become increasingly important in recent years.

3.5. The Impact of Biodiesel Production on International Trade Streams

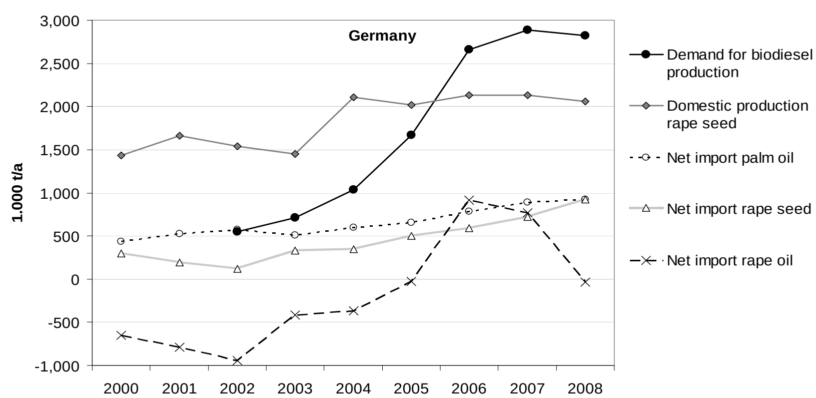
A crucial issue in connection with the increasing demand for biofuels are possible indirect effects and spillover effects, especially on global land use and food markets. There has been growing concern about possible impacts of biofuel production from edible crops on global food security as well as sustainability issues like indirect land-use change (see EC, 2010c).

For example Fischer et al. (2010a) argue that “uncoordinated biofuels development can contribute substantially to short-term price shocks […] and may also result in a stable trend in rising food prices”.

Plant oil and oilseeds are basically more suitable for long-distance transportation than wood biomass due to their higher specific calorific values. In section 3.2.4 it was shown that the rising consumption of biofuels was accompanied by increasing direct cross-border trade.

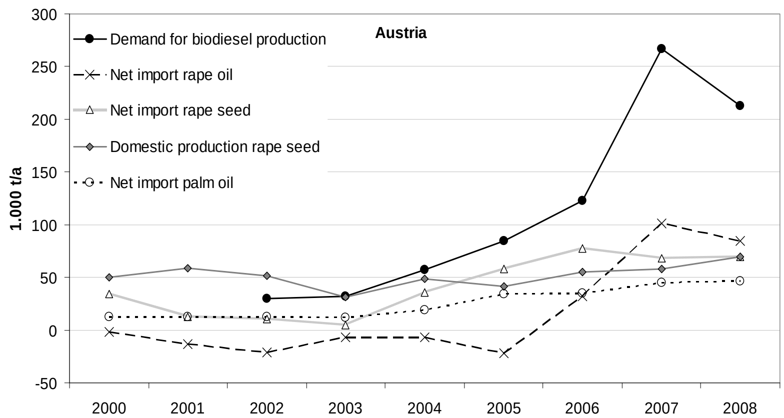
The objective of this section is to analyse the impact of the increasing biodiesel production on trade streams of plant oil and oilseeds. The focus is on the countries which showed the most rapid development in biodiesel production and consumption among CE countries: Germany and Austria.

The basic approach is to convert production data of oilseeds, net imports of oilseeds and plant oil and data on the demand for biodiesel production on a common basis of comparison ("plant oil equivalents") and to qualitatively investigate correlations between the time series (see Table 3 1 for details on the commodities considered, references and CN Codes). Figure 22. and Figure 23. show the data for Germany and Austria, respectively. It is clear to see that in both countries, the growing plant oil demand for biodiesel production primarily resulted in an increase in rape oil net imports, rather than domestic production of rapeseeds. Furthermore, in both countries also a (compared to the rape oil imports moderate but still notable) increase in palm oil imports, primarily from Indonesia and Colombia, took place. Germany's total palm oil net imports increased from 0.44 Mt in 2000 to about 0.9 Mt in 2008 and Austria's net imports from 16,000 to 47,000 t during the same period.



Sources: UN Comtrade (2009), Eurostat (2010b), EBB (2009), own calculations.

Figure 22. Development of plant oil demand for biodiesel production and provision of plant oil in Germany (rape seed production and import converted to equivalent amount of plant oil).



Sources: UN Comtrade (2009), Eurostat (2010b), EBB (2009), own calculations

Figure 23. Development of plant oil demand for biodiesel production and provision of plant oil in Austria (rape seed production and import converted to equivalent amount of plant oil).

This supports the presumption by Rosillo-Calle et al. (2009), who argue that "increasing consumption of domestically produced rapeseed oil for biodiesel uses may have led to a considerable gap in EU food oil demand (which continues to increase), resulting in an increase on imports for other types of oil (mostly edible palm oil)".

We conclude that the increasing biodiesel production in Germany and Austria led to significant shifts in international trade of plant oil and oil seeds. As shown in section 2.2.2, progress in the field of biofuels for transport was very uneven among CE countries. Therefore, the additional crop demand could initially be imported from neighbouring countries with favourable conditions for increasing energy crop production, especially Czech Republic and Hungary.

However, recent data suggest that with the demand for energy crops also increasing in these countries, imports from other European, or especially Non-European countries are getting inevitable. It was already shown in section 3.2.4 that the CE region recently turned from a net exporter of biofuels into a net importer. With regard to the supply of oilseeds, the data are even more striking: The total net imports of rape seed to CE increased from 0.76 Mt in 1996 to about 2 Mt in 2008.[22]

[22]Slovakia was excluded from this calculation due to highly implausible data for 2008 (UN Comtrade, 2009).

4. POTENTIALS AND PROSPECTS FOR AN ENHANCED USE OF BIOENERGY IN CENTRAL EUROPE

4.1. Bioenergy in the Context of Eu Energy Policy

With the implementation of the 2009-RES-Directive (EC, 2009a) an "overall binding target of a 20% share of renewable energy sources in energy consumption […] as well as binding national targets by 2020 in line with the overall EU target of 20%" have been established. The share of RES is calculated as the sum of final energy from RES consumed in the heat, transport and electricity sector, divided by the total final energy consumption, including distribution losses and consumption of the energy sector. In addition to the overall 20% target by 2020, a sub-target for the transport sector (including road and rail transport) in the amount of 10% was defined. Renewable electricity used in electric cars is also taken into account; in consideration of the higher efficiency of electric drivetrains, a factor of 2.5 is applied for electric cars. In order to promote advanced biofuels produced from nonfood cellulosic materials and ligno-cellulosic materials, the amounts of "advanced" biofuels count twice towards the target. Still, the main contribution towards the sub-target is expected to come from biodiesel and ethanol.

In the European Biomass Action Plan (EC, 2005) it is recognized that bioenergy is of major importance for increasing the share of renewable energies and reducing dependence on energy imports. The projections made for the Renewable Energy Road Map (EC, 2006) suggest that the use of biomass can be expected to double and to contribute around half of the total effort for reaching the 20% target.

The "strengthened national policy scenario" in Resch et al. (2008a) gives an impression of to what extent bioenergy can contribute towards fulfilling the 2020-targets in CE.[23] The scenario is based on the following core assumptions: The implementation of "feasible" energy efficiency measures (leading to a moderate development of the future overall energy demand as projected in the

[23]The scenarios have been compiled with the simulation tool Green-X. This model simulates future investments in renewable energy technologies for heat, electricity and transport fuel production, based on a myopic economic optimization. The availability of biomass resources, cost and price developments, the energy demand and its structure, diffusion and other influencing parameters as well as energy policy instruments are considered within the simulation runs.

PRIMES target case (Capros et al., 2008). Support conditions for RES are improved, leading to the fulfillment of the EU-wide 20%-target by 2020.

This simulation confirms that biomass is of crucial importance for meeting the 2020-targets. In all CE countries more than 50% of the growth in RES until 2020 is made up by bioenergy.

In the Czech Republic, Hungary, Poland and Slovakia bioenergy even accounts for more than 75% of the growth. The consumption of biomass as share of the total GIC according to this scenario range from 7.6% in Italy to 25.3% in Denmark.

Table 2. shows a summary of the share of biomass and all RES in the total energy consumption in the reference year 2005 and 2007 (the latest year available in statistics), the national targets according to the 2009-RES-Directive and the contribution of biomass according to the "strengthened national policy scenario" in Resch et al. (2008a).

Table 2. Summary of the current state, targets and prospects for the share of biomass and RES in CE countries (all values in %)

Concept	Reference	Fraction, year	AT	CZ	DE	DK	HU	IT	PL	SI	SK
Final energy consumption	EC (2009a)	RES, 2005	23.3	6.1	5.8	17.0	4.3	5.2	7.2	16.0	6.7
		RES Target, 2020	34.0	13.0	18.0	30.0	13.0	17.0	15.0	25.0	14.0
Gross inland consumption	Eurostat (2010a), own calculations	RES, 2005	21.7	4.0	5.1	16.4	4.4	6.5	4.8	10.6	4.3
		RES, 2007	23.8	4.7	8.3	17.4	5.3	6.9	5.1	10.0	5.5
		Biomass[a], 2005	11.1	3.5	3.4	12.4	3.9	1.9	4.6	6.5	2.1
		Biomass[a], 2007	13.3	4.2	5.7	13.2	4.6	2.2	4.8	6.2	3.2
	Resch et al. (2008a)	Biomass scenario 2020	22.0	9.0	10.2	25.3	11.2	7.6	13.5	15.1	9.6

a)Non-renewable wastes have been deducted based on Eur'ObservER (2010)

4.2. Review and Discussion of Biomass Potentials in Literature

Assessments of biomass supply potentials are numerous and the results vary widely. There are different concepts of potentials like "theoretical", "technical" or "environmentally compatible" potentials (see Rettenmaier et al., 2008). Potentials in literature are usually qualified according to these definitions. Yet methodological approaches, assumptions and constraints of potential assessments differ from study to study.

The following analyses are based on three studies (EEA, 2006; Thrän et al., 2005 and de Wit and Faaij, 2010) which have been chosen for the following reasons: Uniform methodologies have been applied, they comprise all types of biomass resources (with the exception of non-agricultural residues not being considered in de Wit and Faaij, 2010) and results are available for all CE countries, broken down by country and biomass type. The main features of the methodological approaches applied and databases used are summarized in Table 3.

According to the Eurostat definition of "biomass consumption", biofuels for transport are represented with the calorific value of the fuel (and not with the amount of biomass used to produce the fuel). Due to the relatively low conversion efficiencies (e.g. typically 55% for ethanol and 57% for biodiesel[24]; cp. AEBIOM, 2007) the energy content of the quantity of feedstock used for the production (primarily energy crops) is clearly higher than the consumption according to energy statistics (and shown in Figure 4). This needs to be taken into account when comparing statistical data with data on biomass supply potentials.[25]

The methodological approaches of the considered studies are basically quite similar. The most significant differences include environmental restrictions considered, scenario assumptions and influencing factors which are taken into account as well as assumptions about energetically usable fractions of certain biomass resources. Figure 24 shows a comparison of the results. The biomass production and consumption in the year 2007 are also included.

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[24] The conversion efficiencies stated here are defined as the ratio of the energy content of the biofuel to the primary energy content of the feedstock used, with by-products (which can be used for energy recovery, for feed or material uses) not taken into account.

[25] That biofuels for transport are represented with the calorific value of the fuel and not with the primary energy required for the production of the biofuel is still justified by the following facts: First, this allows for a direct comparison of fossil fuel and biofuel consumption and second, the above mentioned by-products are thereby rightly excluded from the statistics.

Table 3. Summary of features, references/databases used and methodologies applied for assessing biomass potentials in Thrän et al. (2005), EEA (2006) and De Wit and Faaij (2010)

	Thrän et al. (2005)	EEA (2006)	De Wit and Faaij (2010)
Type of potential	Technical potential with consideration of structural and ecological restrictions	Technical potential with consideration of environmental criteria ("Environmentally-compatible potential")	"Supply potential" (forest biomass: sustainable potential)
Reference years	2000, 2010, 2020	2010, 2020, 2030	2030
Methodological approaches and main references/databases			
Methodology for assessing forest biomass potential	Comprises potential from current use (felling residues) and potential from annual increment (annual growth minus fellings) Base year: 2000 2010 and 2020: Increasing demand for wood products according to UNECE (2000) Main databases: FAO (2010c), FAO (2005), UNECE (2000)	Comprises "residues from harvest operations normally left in the forsest ("felling residues") and complementary fellings" Complementary fellings describe difference between maximum sustainable harvest level and actual harvest needed to satisfy roundwood demand Environmental considerations include biodiversity, site fertility, soil erosion, water protection Criteria to avoid increased environmental pressure applied Databases: FAO (2010c), OECD Europe (projections for wood demand)	Comprises "difference between actual felling and felling residues and the net annual increment" (including stems) Main database: Karjalainen (2005)
Methodology for assessing potential of biogenic wastes and residues	Comprises only residues which are not usable for material uses Exemplary proportions assumed to be available for energy recovery: sawmill residues 10%, bark 80%, waste wood 75% (estimated on basis of per capita production), straw 20% of total production Other potentials based on scenarios and assessments in literature as well as estimates: e.g. manure based on livestock scenarios and assumptions about husbandry conditions, black liquor based on rough assessments and other studies, food processing industries also considered Databases: FAO (2010c), Eurostat (2010b)	Comprises solid and other agricultural residues, manure, biogenic fraction of municipal solid waste (MSW), black liquor, wood-processing waste wood, construction and demolition wood, other waste wood, sewage sludge and food processing wastes Environmental criteria assumed: waste minimization, no energy recovery from waste currently going to recycling or reuse (estimated proportions), production of timber and wood products declines, extensive farming practices etc. Projections for waste fractions based on different scenarios in literature (e.g. FAO, 2005; Skovgaard et al., 2005)	Comprises only agricultural residues obtained during production of food and feed Crop-specific ratio of crop residue to crop main produce applied Assumed "residue use factor": 50% Main database: FAO (2010c)

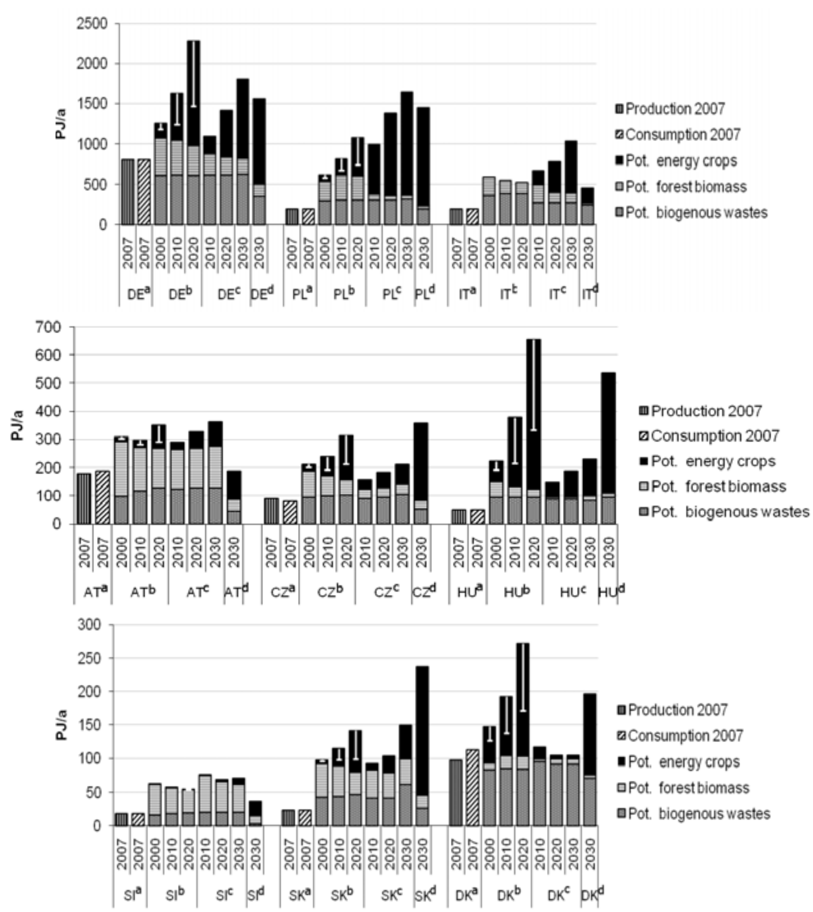
Table 2. (Continued)

	Thrän et al. (2005)	EEA (2006)	De Wit and Faaij (2010)
Methodology for assessing potential of dedicated energy crops	Base year: 2000 (average over 3 to 5 years) Evaluation of surplus arable land and grassland available for dedicated energy crop production Reduction of production surplus and related exports assumed Considered influencing factors: population scenarios, reduction of agricultural land, yield increases, increasing efficiency in livestock breeding Assumed distribution of energy crops Databases: FAO (2010c), Eurostat (2010b)	Evaluation of released and set-aside land under assumption of further reform of common agricultural policy (based on EuroCare, 2004) Competition effect between bioenergy and food production are only taken into account for Germany Assumption of site-specific environmentally-compatible crop mixes Increase in crop yields according to EuroCare (2004) Environmental criteria assumed: 30% of agricultural land dedicated to environmentally-oriented farming, 3% set aside land, extensively cultivated agricultural areas are maintained, bioenergy crops with low environmental pressure are used	Evaluation of surplus arable land and grassland available for dedicated energy crops Projected changes in land area requirements (population size, dietary habit, agricultural productivity, self-sufficiency ration of Europe) Assumption: Europe maintains current food and feed self-sufficiency of about 90% Different assumptions for yield increases and different sustainability criteria assumed Databases: Fischer et al. (2010b)

Basically it can be concluded that there are substantial unused biomass potentials in all CE countries. While forest biomass and biogenic wastes remain fairly constant, the potential of dedicated energy crop production is assumed to become increasingly important.

The potentials of biogenic wastes are the most consistent throughout the studies. This is unsurprising since they are based on current production statistics and often the same databases were used. However, it should be considered that the potentials of waste and residues are essentially based on estimated “use factors”.

In the case of straw, this use factor is assumed 20% in EEA (2006) and 50% in de Wit and Faaij (2010). As the latter point out, the amount of straw which can be removed and used energetically without causing adverse environmental effects is actually site-specific and depends on numerous factors. Highly aggregated assessments of biogenic wastes can therefore only be seen as rough estimates. In order to derive profound data, detailed bottom-up approaches are required, carried out in the course of regional energy concepts, for example. Another aspect to be considered in connection with the assessment of waste and residue potentials based on production statistics is that they sometimes include significant amounts of indirectly imported biomass. For example in Austria the potential of wood processing residues is to a large extent based on imported roundwood (see section 3.4.3). Strictly speaking, this fraction cannot be considered a domestic biomass potential.



Sources: a) Eurostat (2010a), b) Data obtained from Thrän et al. (2005) (error bars represent results for the environmentally-oriented scenario), c) Data obtained from EEA (2006), d) Data obtained from de Wit and Faaij (2010) (baseline scenario; biogenic wastes comprise only agricultural residues).

Figure 24. Comparison of biomass production and consumption in 2007 with biomass potentials ("Pot.") according to three studies.

The increasing potentials of energy crops are on the one hand due to assumed yield increases in both energy crop and food and feed production, and on the other due to scenario assumptions for the future development of agricultural production in Europe. Model-based simulations of the agricultural developments in the EU (e.g. of the CAPSIM model used in EEA, 2006) indicate that with continuing reforms of the common agricultural policy resulting in gradual liberalization of agricultural markets and a reduction in subsidized exports, agricultural productivity can be increased significantly and the current self-sufficiency for food and feed products maintained with clearly less agricultural land. Thus, surplus land is assumed to be made available for energy crop production.

To what extent the consideration of different environmental criteria influence the supply potentials of energy crops is illustrated by the environmentally-oriented scenario according to Thrän et al. (2005), represented by the error bars in Figure 24. The Low and High estimate scenarios in de Wit and Faaij (2010) illustrate that assumptions about yield increases have a huge impact on energy crop potentials. Furthermore, especially with regard to the energy crop potentials in Poland, Italy, Hungary and Denmark there are also significant inconsistencies which cannot be explained easily, indicating that there are substantial uncertainties connected with the future potential of energy crops. The potential of forest biomass primarily depends on the currently unused annual growth. Furthermore, scenarios for the demand of wood products and the development of the wood-processing industries have a major impact. A comparison between EEA (2006) and Thrän et al. (2005) indicates that the additional environmental criteria considered in the former result in a significant reduction of the forest biomass potential. Regardless of the uncertainties related to potential assessments, the following conclusions are drawn: Only in Germany, Austria and Denmark more than half of the biomass supply potential was actually utilized in 2007. The structure of biomass potentials is highly inhomogeneous. According to these studies, especially Germany, Poland and Hungary are capable of increasing the energy crop production substantially, while maintaining the current self-sufficiency for food and feed. The potential of forest biomass is generally rather limited, partly due to the increasing wood demand of the wood-processing industries. Biogenic wastes and residues, including waste wood, wood processing and agricultural residues as well as residues from food processing are a considerable potential. The figures indicate that in several CE countries, the potential of wastes and residues even surpass the total biomass production in 2007.

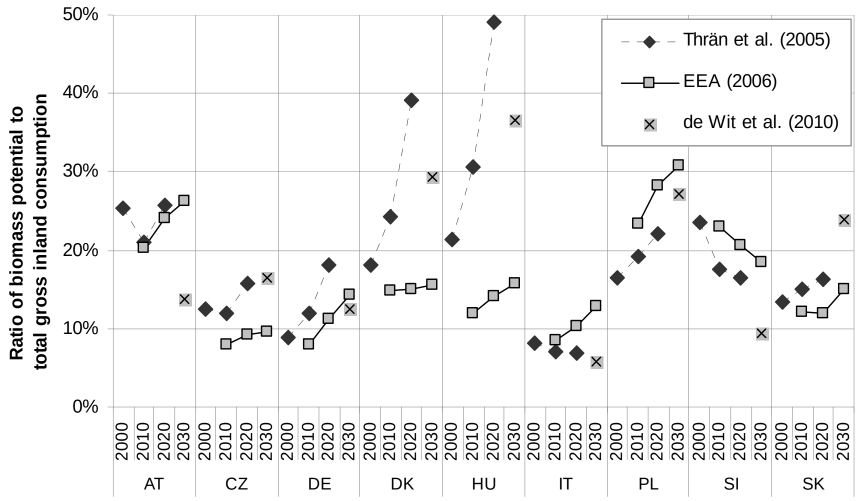


Figure 25. Ratio of biomass supply potential according to Thrän et al. (2005), EEA (2006) and de Wit and Faaij (2010) to total gross inland energy consumption (scenario according to Capros et al., 2008; "PRIMES target case").

Figure 25. shows the biomass potentials of the considered studies as shares of the GIC (projections according to Capros et al., 2008). A comparison with Table 2 (scenarios according to Resch et al., 2008a) reveals that Poland could act as the main exporter of biomass in CE. Even if Poland's 2020-target is primarily achieved with biomass (as projected in Resch et al., 2008a) the unused biomass potential accounts for approximately 500 PJ. In most other countries the domestic biomass potential needs to be utilized to a large extent to fulfil the 2020-targets. With regard to Germany, Italy, Denmark and Hungary no definite conclusions can be drawn due to big uncertainties as to what extent the supply potential of biomass can be extended with the production of energy crops.

5. Discussion, Conclusion and Policy Implications

5.1. Recent Developments in Bioenergy Use in CE

Bioenergy is currently the most important source of renewable energy in CE. The contribution of biomass and wastes to the total energy supply (gross inland consumption) in CE countries ranges from 2.8% in Italy to 14.9% in Denmark (2008).

European directives and according national support schemes have already led to significant progress in recent years. Progress was very uneven in the considered countries. The CE countries with the highest growth of biomass as share of the GIC from 2000 to 2008 were Denmark (+6%), Germany (+4.8%), Austria (+4.5%) and Hungary (+3.9%). It is remarkable that the countries which already had the highest bioenergy shares in 2000, namely Austria and Denmark, are among these countries. It is therefore concluded that at least in recent years, the crucial barriers for an increase in bioenergy use was not the availability of biomass resources in the CE region but the typical barriers for upcoming technologies, such as know-how, capacity building of equipment etc. In absolute numbers, Germany showed by far the highest increase in bioenergy use. In 2008 Germany was accountable for more than 50% of the total biomass consumption and production in the considered countries, and therefore dominates the structure of the energetic biomass use in CE.

Even though heat generation is the oldest and often most competitive utilization path for biomass, EU Directives as well as national support schemes were focused on the electricity and transport sector in recent years. As a result, the annual increments in biomass-based heat generation have been relatively stable since 1990, whereas in the field of power and CHP generation and the production of transport fuels, growth rates increased considerably after the year 2000. It is assumed that as a consequence of the 2009-RES-Directive (EC, 2009a), in which national targets for the share of RES in the final energy consumption are defined, more attention will be paid to biomass use in the heat sector in the years to come.

5.2. International Biomass Trade

The challenges related to mapping international trade streams of biomass for energy are numerous, and assessing the impact of the growing bioenergy use on trade streams is not straightforward. To this end, specific methodologies need to be developed, especially when it comes to assessing indirect effects like spillover effects or indirect land-use change.

Based on the approaches applied in this work, it is concluded that the main importers of wood fuels in CE are Italy, Denmark and Austria. Cross-border trade of wood pellets has increased significantly in recent years and is already of high importance for the Danish bioenergy sector. (Pellets represent by far the most important fraction of biomass imports to Denmark.) Austria, being a net exporter of wood pellets, is importing considerable amounts of wood residues, primarily indirectly in the form of industrial roundwood.

The comprehensive assessment of biomass trade related to bioenergy carried out for the case of Austria indicates that indirect net-imports of wood-based fuels are more significant than direct trade, and that feedstock imports for biofuel production are roughly as important as direct biofuel trade. Hence, it is clearly insufficient to rely only on energy statistics (which do not include indirect trade streams and cross-border trade of feedstock used for biofuel production) when assessing international trade related to bioenergy use.

With regard to direct biofuel trade, Austria, Italy and Poland are the main importers (primarily biodiesel). Although growing rapidly, cross-border trade related to biofuels for transport is still rather moderate compared to (indirect and direct) trade of wood fuels in CE. Still, as more and more (Central) European countries aim at achieving their biofuel targets, it is either necessary to mobilize domestic resource potentials or further increase imports from Non-European countries. There is strong evidence that the CE region is currently becoming increasingly dependent on imports of biofuels as well as feedstock for biofuel production. There is also evidence that in Germany and Austria (which are most advanced in biofuel use), the growing demand for plant oil for biodiesel production primarily resulted in an increase in imports rather than the mobilization of domestic potentials (also palm oil imports have been increasing, albeit to a rather limited extent). Thus, in order to avoid adverse effects of the enhanced use of biomass (especially indirect land-use change), the need for obligatory certification schemes for sustainably produced biomass is becoming increasingly urgent. The enhancement of international biomass trade often seen as a key factor for mobilizing the (global) biomass supply potential, avoiding short-term regional supply problems and providing the framework conditions required for steady growth of bioenergy use. However, concerns about sustainability issues of globally traded biomass resources have to be taken seriously, and in order to enhance the security of supply and facilitate domestic income, a main focus of national biomass action plans should be put on the mobilization and use of regional biomass resources.

5.3. Resource Potentials

It is apparent that there are numerous aspects and barriers for an enhanced use of biomass, which cannot be considered in highly aggregated assessments of biomass potentials. Therefore, the assessment of locally available residues and wastes as well as specific measures for their utilization should be promoted in regional energy concepts and action plans. Increasing biomass imports to countries with a rapid growth of the bioenergy sector on the one hand, and evidence of unused domestic resource potentials on the other indicate that the supply with regional biomass has not been given enough attention within energy policy strategies, according support schemes and incentives. In particular, it should be investigated whether the cost of regional supply chains can be decreased with logistical improvements, the enhanced use of conversion technologies (e.g. pelletizing, torrefaction) and removal of organisational barriers. Results of studies on biomass resource potentials indicate that there are vast unused potentials in most CE countries. According to EEA (2006) the environmentally compatible potential in the year 2010 in the considered countries is about two times higher than the current utilization (2007), and the potential in 2030 even three times higher. The results of other studies show even higher supply potentials. The consideration of different environmental criteria has a significant impact on the amount of agricultural and forest biomass potentials, indicating that there is a considerable risk that uncoordinated growth of bioenergy use results in additional pressure on the environment. The consideration of environmental criteria in the design of bioenergy support schemes (especially promoting the mobilization of biomass resources) is therefore of crucial importance. To what extent the biomass potentials are already utilized is highly diverse among CE countries: In Denmark, Germany and Austria the currently unused resource potential is relatively small, whereas countries like Poland, Italy and Slovakia only use a very low proportion of their biomass potential. Especially agricultural resources (including energy crops as well as residues and wastes) are assumed to constitute a substantial potential that is hardly tapped yet. It is assumed that to some extent, the very uneven progress in biomass use (primarily resulting from diverging energy policies, support schemes and as a consequence diverging biomass price developments) encouraged cross-border trade between European countries. Increasing efforts in the field of bioenergy throughout all EU countries are likely to result in a further shift of trade flows towards international (trans-continental) biomass trade.

5.4. Towards the 2020-Targets

The importance of bioenergy for reaching the 2020-targets defined to the 2009-RES-Directive is undisputed. Scenarios by Resch et al. (2008a) indicate that among the renewable sources of energy, biomass can be expected to bring the biggest contribution to the achievement of the 2020-targets. Special attention should therefore be attributed to the design of support schemes promoting bioenergy use. Aspects which should be considered within national biomass action plans include the following: Biomass can be used in all energy sectors (heat, electricity and transport) and the economic and environmental properties of the different bioenergy utilization paths often vary widely. Clear strategies and targets for the development of the bioenergy sector, designed with consideration of technological, economic and ecological criteria are essential (see Kalt et al., 2010).

Finally, it has to be taken into account that increasing competition for biomass resources between the different types of biomass use (both for energy and material uses) are expected with the progressing exploitation of biomass potentials. In order to facilitate the diffusion of the most efficient utilization paths, bioenergy policies should be designed to counteract resource competition as far as possible; both with supply-side measures and clear priorities for the most beneficial technologies and utilization paths.

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