Climate change and its effect on Austrians cross-border biomass trade: A literature review

Deliverable 3.1 of the project

BioTransform.at

Using domestic land and biomass resources to facilitate a transformation towards a low-carbon society in Austria

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Abstract

Today about ¼ of Austrians import volume is biomass including food and feed, forest biomass for the wood processing industries and solid and liquid biofuels. International trade is discussed to be triggered by simple supply-demand balances and/or the desire for cost-efficiency. In this report we want to analyse if and how climate change will affect Austrians cross-border trade in the upcoming decades. Therefore we perform a literature analysis and summarise and discuss the main findings together with findings from own unpublished work. We find that literature on climate change effects on Austrian cross-border biomass trade is not existent and scientific efforts on analysing global effects focus on trade of food and feed. International trade of biomass for energy and material purposes will face changes rather due to changes in demand and supply quantities (caused by other factors than climate change), technological progress with respect to pre-treatment and conversion technologies, in specific for lignocellulosic biomass, as well as policies regarding biomass trade and respective framework conditions. Effects of specific policies and policy packages like e.g. the end of the EUs sugar management quota and TTIP are however not within the scope of this report.

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1 Introduction

1.1 Background: The project “BioTransform.at”

According to the analysis of current biomass trade carried out within “BioTransform.at” (see Deliverable 2.1), total biomass imports increased from less than 20 million tonnes dry mass (Mt) to more than 27 Mt during the period 2000 to 2013. The most relevant category in imports as well as exports is “wood and articles of wood”. Also, cross-border trade of the paper and pulp industry (i.e. pulp and paper and paperboard) account for considerable shares. Highest net imports in 2013 were also wood and pulp followed by cereals. With regard to net exports, paper and paperboard, dairy products and beverages were the most relevant categories. It is further obvious that a considerable share of industrial wood residues is used for energy and actually (indirectly) originates from imported roundwood. Wood chips, particles and residues imported by the wood industries are either used for energy or material purposes.

1.2 Objective of this deliverable

The objective of this deliverable is to assess, if and how climate change might affect biomass trade flows. According to APCC (2014) the average temperature since 1880 increased by nearly 2°C in Austria, which is more than double the global average (0.85°C increase). Temperature is expected very likely to increase by 1.4°C in the first half of the 21st century. At the same time the precipitation is likely to decrease in the summer months and increase in the winter months. However potential economic impacts are expected (medium confidence) to be predominantly determined by extreme events and weather periods. Further changing parameters that can influence agricultural and forestry production are listed in the discussed report are significant increases (very likely) in landslides, mudflows, rock falls, gravitational mass movements, forest fires, soil erosion and heat tolerant pests. Impacts of climate change will vary by region (1) forests productivity will increase in mountainous areas and in regions that receive sufficient precipitation (high agreement) and (2) in cooler, wetter areas (e.g. northern foothills of the Alps etc.) average potential yield of crops will increase while (3) north of the Danube and in the eastern and south-eastern part of Austria increasing droughts and heat stress reduces the long term average yield potential. Corn and vineyards as examples for warm tolerant crops, are expected to expand significantly (very likely).

1.3 Contents and structure of this report

Based on the previous work in the current and similar projects, possible relevant climate change impacts on trade are discussed for the following biomass uses:

1. Wood based industry
2. Agricultural biomass
3. Biomass dedicated for energy use (bioenergy trade)
4. New applications, primarily advanced biobased materials

Boundaries between these applications are diffuse; some literature discusses several sectors. Scenarios for agricultural and forestry biomass are usually clearly separated while literature focusing on specific end uses (traditional materials, energy, food and fodder as well as advanced biobased materials) do not distinguish between wood and agricultural biomass as feedstock.

Scarce literature on climate change impacts on these sectors in Austria will be broadened by biomass trade scenarios on the global scale as well as scenarios based on other scenario dimensions namely (1) socio economy and political pathways, (2) bioenergy demand development and (3) biobased materials demand development.

In a conclusions section the main findings from the literature review are discussed and implications for the modelling work of the project are outlined.

2 Projects, models and literature on biomass trade

2.1 Agricultural biomass and lifestock

The Food and Agricultural Organisation of the United Nations recently published the report "Global assessment and implications of climate change for food security and trade" (FAO, 2015). This section is mainly based on this report, as it is the most comprehensive scientific report on this topic. The study comprises a large set of modelling results including mechanistic and empirical models and models that can be classified between these two types, as well as a newer class of models, namely large-area crop models but also bio-/agroeconomic models of agriculture and food systems which apply biophysical model applications within an economic modelling framework. Between the models collaboration and clustering work has been performed with respect to e.g. modelling protocols, databases and results comparisons and summaries. The intergovernmental Panel on Climate Change Fifth Assessment (IPCC AR5) (Pachauri et al., 2014) the Inter-Sectoral Impacts Model Intercomparison Project (ISI-MIP1) (Warszawski et al., 2014) the Agricultural Model Intercomparison and Improvement Project (AgMIP) (Rosenzweig and Hillel, 2015) as well as the Modelling European Agriculture with Climate Change for Food Security project (MACSUR) (von Lampe et al., 2014) can be named as collaborative initiatives of this study.

The comprehensive report illustrates fundamental climate change impacts on global food production patterns, with decreasing crop productivity in low latitude and tropical regions and somewhat positive impacts in high latitude regions. Increased water scarcity in many regions will be a major challenge. Impacts are expected to be more severe for crop yields than for grass yields which would favour for example an increasing number of ruminants in the grazing system "rebalancing in the general trend towards more intensive systems projected without climate change" (Havlik et al., 2014 in (FAO, 2015)).

Focusing on Europe (Chapter 4 of the report), most projected impacts on production and yields of crops indicate gains – especially for northern Europe. The report points out little change for southern Europe with considerable differences in the magnitude of changes between the compared projections. However, changing large-scale variability patterns including, for instance, the North Atlantic Oscillation and the Arctic Oscillation could have stronger influences if occurring. With the most common projections suggesting that these circulation patterns will remain in place, **the expansion of European crop production could have lower environmental costs than anywhere else, thus raising the question if the continent will amplify its contribution to global food security under climate change.** Given demographic development projections and availability of agricultural land reserves for Europe compared to other world regions would support such amplification. Past trends exhibit continuous increments of wheat since the 1980s while barley cultivation decreased in the same time frame. Beside these most widely grown cereals within the EU-27 (with around 38 million hectares) maize cultivation stagnated at around 9 million hectares in the last five decades. Main reductions are noted for the cultivation area for potatoes and a less strong reduction for sugar beet. Barley and wheat yields increments slowed down since the beginning of the 2000s, oat yields stagnated since 1980s and yields for maize and sugar beet have continued their growth nearly linearly. Yield projections are differentiated in the report between (1) effects of climate variable only, (2) additional fertilisation effect of CO_2 and (3) all effects including technological progress. While the effects of climate variable only indicate overall yield losses, ranging from 0 to 10 %, fertilisation effects shift the net impacts into the positive range at European scale. But "technological progress clearly overrules the influence of all other factors." (R. Rötter & J.Höhn in (FAO, 2015)) Regionally higher yields for wheat are projected in Northern Europe and Western Europe and remarkable increases for specific locations in Bulgaria. However, crop yield decreases are expected for an area in northern Italy as well as barley and maize projections which are likely to decrease in Austria, Denmark and Italy. Further research is considered necessary to assess yield impacts of increasing climatic variability along with higher frequencies and graveness of extreme weather events.

In the overall context, trade as one adaptation strategy under many can play a significant role to stabilise prices and supplies. In 2004 to 2009, wheat and coarse grains were the agricultural commodity with the largest trade volumes globally (about 140 Mt dry mass each for the five year average) followed by oilseeds (about 90 Mt dry mass) and rice (about 30 Mt dry mass). Furthermore about 5% of global meat production and 9% of global dairy production is traded internationally (FAOSTAT, 2013 in (FAO, 2015)). Chapter 10 in FAO, (2015) of the report concludes that economic growth and population growth will continue to drive international trade. Integrated model results for the reference scenario (without climate change) indicate a wheat trade increase of 50% to 230%, 50% to 190% in the case of rice, 80% to 140% for coarse grains and between 90% and 210% for oilseeds until 2050. Exports of rice, coarse grains and oilseeds will be dominated by the same main exporting regions as today, while wheat export from Canada is expected to replace the former Soviet Union in the top three exporters globally. Compared to the reference scenario, including climate change results in a decline in global crop production but a much less reduction of exports - in some models even increase of exports against declining production. (Figure 14, Chapter 10, (FAO, 2015)) This suggests an enhanced role of international trade under climate change. However the effects of extreme weather patterns disrupting supply chains as well as GHG-emissions through trade activity and the effect of climate change on GDP are not accounted for so far.

Further limitations of the discussed study as well as next steps relate to effects of elevated atmospheric CO_2 concentrations on plant growth but also nutrient content, and the complex interaction between carbon, temperature, water and nitrogen. Challenges with regard to data availability are seen in data sets with high resolution in space and time including "daily weather, soil and environmental conditions, crop-specific cultivation areas, irrigation and fertilizer use and local cropping calendars". (Ray et al., 2013 in (FAO, 2015)) To cover sociotechnical changes likely to interact with climate change in the near future Representative Agricultural Pathways (RAPs) consistent with the Shared Socio-economic Pathways (Kriegler et al., 2012 in (FAO, 2015)) and the Representative Concentration Pathways (Vuuren et al., 2011 in (FAO, 2015)) are being developed.

The Austrian Assessment Report 2014 (APCC, 2014) gives a detailed overview on climate change impacts on Austria including the productivity of agricultural plants as already discussed in the introduction. However impact on international trade patterns are not considered so far here.

2.2 Wood based industry

To date no literature is known to the authors focusing on climate change effects of trade for the wood based industry. However, this subsection gives an up-to-date overview on important projects focusing on modelling, scenario discussion and foresight of the wood based industry to consequently outline parameters with possible impacts which are expected to overrule climate change with respect to trade.

In the EFSOS II project (Bali et al., 2011) country-specific projections of consumption, production and trade of forest products including sawnwood, wood-based panels, paper, paperboard and wood energy are listed and combined. The studies cover a time frame from 2010-2030 since “projections of some of the underlying variables used in the study, notably GDP, become increasingly unreliable over longer time periods.” The spatial resolution comprises countries on the European continent without Russia but including Turkey. Furthermore exogenous assumptions about prices and costs developments were incorporated from the EFORWOOD project (Rosen et al., 2011). A *Reference scenario* is modelled and contrasted to quantitative and qualitative *policy scenarios*.

The *Reference scenario* uses an IPCC storyline[1] discussing a world with more local solution to economic, social and environmental problems (B2-Storyline). “It is a world with continuously increasing global population, intermediate levels of economic development, and not so rapid and diverse technological change.“ (Bali et al., 2011) GDP-projections are used to model total consumption for wood products and historical developments in total area of forest and forest area classified as available for wood supply were extrapolated. Furthermore climate change effects on the increment were incorporated accounting for an increment gain of 11% by 2030 compared to no climate change. In order to fulfil an increasing demand from 739 million m³ Roundwood equivalent in 2010 to 853 million m³ in 2030 in the study region a removal increment by 15% in 2030 as compared to 2010 is expected. Furthermore expansion in woody biomass supply outside the forest including landscape care wood, post-consumer wood and industrial wood residues such as sawmill by-products, wood residues from other wood processing industries and black liquor are discussed. The average annual historical growth rate from the period 1993-2008 for global exports of forest products of 6.3% is expected to decline for 2010-2030 to only 3.7% due to a relatively modest development of GDP assumed in this scenario. The average annual growth rate of the countries of the EFSOS-region in the period 1993-2008 was even higher with about 8.2%. In the same time the EFSOS-countries increased their share in world trade from 39% to 50% with about 80% of this trade within the EFSOS-countries itself.

A *Maximising biomass carbon scenario* discusses a strategy to yield highest carbon stock in biomass, while still supplying the required demand. This is only possible with incentives for forest owners to maximise carbon in their forests. As an example subsidy or carbon credits covering extra costs of modified management regimes are mentioned. Subsequently total removals from the forest will stay the same and trade and industry will not be affected by this scenario.

In a *Priority to biodiversity scenario* the protection of biological diversity is discussed to be enforced by designating additional 5% of the forest area for biodiversity conservation and increasing rotation periods. As a result, the amount of carbon stored in forests shows a significantly positive trend. On the other hand the supply would fall short of meeting the projected demand in 2030 by 176.2 million m³ through the absence of extraction of residues.

The *Promoting wood energy scenario* targets for renewable energy by 2020 are reached and the trend continues until 2030 reaching about 860 million m³ of wood for energy, which is nearly double the figure of 435 million m³ for 2010. This would account for 60% of total wood use, compared to 45% in 2010. The additional demand is expected to be covered by

[1] http://sedac.ipcc-data.org/ddc/sres/

increasing stemwood harvest, extended use of forest residues and supplies of wood from less conventional sources (landscape care wood) as well as increments in net imports of wood from other regions from about 12 million m³ wood equivalents to 33 million m³.

A qualitative *Fostering innovation and competitiveness scenario* discusses 1) product, 2) process, 3) marketing and organisational innovation implementing best available technologies (BAT), technologies that are likely to be commercially available until 2020 and breakthrough technologies that are still with no prototypes and pilots in place. The report addresses innovation in the sawnwood and panels sector such as Engineered Wood Products, innovation in the pulp and paper sector and in forest management but also bio-refineries and other non-traditional approaches.

The European Forest Institute (EFI) is expected to publish results of their study "Outlook for European wood products markets and trade"[2]. Recent publications from the study's lead author (Hurmekoski et al., 2015 & Hurmekoski and Hetemäki, 2013) indicate the recent study to build upon the EFSOS II results with major advancements like e.g. covering structural changes in climate and energy policies but also structural changes in the correlation between GDP growth and newspaper print developments, increments in wood-based multi storage construction and the differentiation between gross value added in industry and services. No indication if detailed climate change impacts, and subjacent changes in trade can be expected as part of the new report can be outlined.

2.3 Trade outlook for bioenergy and upcoming bioeconomy sectors

The IEA (International Energy Agency) Bioenergy Implementing Agreement, specifically the IEA Task 40 but also UNCTAD (United Nations Conference on Trade and Development) as well as REN21[3] are main institutions analysing and discussing the development of bioenergy trade. Even though main drivers for bioenergy trade can be identified to be policies targeting GHG-emission mitigation, the direct effects of climate change have not been investigated systematically so far.

While requirements for international trade with gaseous bioenergy carriers (e.g. bio-methane through the natural gas grid) have just been established in the past years (Thrän et al., 2014), modern liquid and solid biofuels experienced already strong international trade growth since the second half of the last decade (UNCTAD, 2014) and the beginning of this century respectively (Junginger et al., 2014). Global liquid biofuel production accounted for about 110 billion litres in 2013. The ratio between bioethanol and biodiesel was about 80/20; international bioethanol and biodiesel trade in 2012 is estimated to be about 12 billion litres and 2 billion, respectively. The most relevant trade partners are the USA, Brasil and the EU (UNCTAD, 2014). Solid bioenergy carriers include wood waste, roundwood chips, fuelwood (in logs) and wood pellets. Wood pellets trade has become the most relavant biomass trade flow for bioenergy during the last decade. About 25 million tonnes of wood pellets have been consumed globally in 2014, 74% of which in the European Union. The EU is furthermore the largest wood pellet importer with 5.2 million tonnes of imports from North America and 1 million tonnes from Russia in 2014. (AEBIOM, 2015)

Available bioenergy trade models simulate the gap between regional bioenergy demand and supply. Matzenberger et al., (2015) compared 22 model results for a 2030 and 2050 outlook. Bioenergy consumption is expected to increase from about 5 EJ in 2014 (EUROSTAT, 2016)

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[2] Project schedule: 01.2012-12.2015 http://www.efi.int/portal/research/projects/?todo=3&projectid=200
[3] http://www.ren21.net/about-ren21/about-us/

to over 10 EJ and up to 20 EJ in 2030 and 2050 respectively. In EUROSTAT, (2016) about 3.8 EJ in 2014 are indicated as solid biofuels (excl. char). Taking into account 0.3 EJ[4] in 2014 to be supplied via pellets (AEBIOM, 2015) the vast majority of European bioenergy consumption today is supplied using unrefined wood logs & waste which are traded less internationally due to energy density constraints (high water content, low carbon content and density of freshly harvested and undesified biomass). In total we estimate the todays 5 EJ consumption of the EU28 to equal about 300 million tonnes of bioenergy carriers[5]. However we expect a non-linear relationship between growing bioenergy demand expressed in energy and mass terms: The market diffusion of modern biomass pre-treatment and densification technologies will increase the average energy content of consumed bioenergy carriers. The rapid expansion of the international wood pellet market can be expected to be complemented with torrefied pellets trade based on different raw materials (Thrän et al., 2016). The expending liquid biofuels market will be broadened by pyrolysis oil as energy carrier for different purposes including space heating and refinery input. In summary densification technologies will continue to increase tradability of biomass substantially over the upcoming decades.

The production of advanced biobased materials like e.g. polymers, lubricants and bitumen can contribute to another 25-65 million tonnes of bio-products in the EU28 by 2050 (Schipfer et al., submitted). So far a direct substitution of fossil based materials with biobased materials is assumed with main bio-refineries being located in the today's most important chemical production Member States. In this case main biobased material producers will be located in Germany, France, Italy, the Netherlands and Belgium. First bio-polymer producers can be found already in Germany, France, the Netherlands and Italy, partly also retrofitting old chemical refineries with direct port access[6]. Economies of unit scale will most likely either lead to the continuation of this trend and/or make future bio-refineries more dependent on densified biogenic carbon carriers and intermediaries that could be similar or even equivalent with wood pellets, straw pellets, torrefied pellets and pyrolysis oil from various feedstocks.

In summary, international trade with biogenic carbon, for energy and material purposes, will play a key role for realizing the EU's aim to establish a bioeconomy until 2050. However the relatively low biogenic carbon content and density of freshly harvested biomass makes international trade for bioenergy and advanced biomaterials purposes less economic and ecological. Commercially available densification and conversion technologies for fresh biomass produce considerable amounts of biogenic carbon carriers with increased tradability. In an increasing order with regard to traded volumes, carriers include biogas, biomethane, bio-diesel, ethanol and wood pellets. Furthermore we expect densification technologies for woody biomass in the pre-commercial phase namely torrefaction (for the production of pellets with higher carbon contents) and pyrolysis (for the production of pyrolysis oil) as well as gasification as a conversion technology for all types of biomass to become a cost- and emission effective way to increase cross-border trade of biogenic carbon for energy and material purposes in the upcoming decades. With lingo-cellulosic biomass on the main agenda in these sectors according to the iLUC-directive (EU, 2015) climate change effects on Austrians cross border trade will be highly linked to the climate change effects in the traditional wood based industry (see section 2.2) for which no literature is known to the

[4] 18.8 Mt wood pellets with 17 GJ/tonne

[5] 18.3 Mt liquid biofuels are indicated in the statistics, 13 GJ/tonne are estimated as a weighted average for solid biofuels

[6] See e.g. http://www.matrica.it/agenda.asp?ver=en#.V2QC-KIaSvQ

author assessing these effects. The climate change effects include: 1) higher CO_2 fertilisation rates and thus especially higher productivity of managed forests 2) elevation of the timberline in the Alps increasing Austrians forest areas and 3) increasing occurrence of dry periods leading to increased forest fires in Austria and neighbour countries and thus increased importance of trade in securing supply.Technological progress and policies aiming for the cost-effective reduction of GHG-emissions are, however, expected to have a higher impact on international biomass trade than any climate change effects in the coming decades.

3 Conclusions for Biotransform.at

In this report we summarised literature with the aim to give insights in potential effects of climate change on Austrian cross-border biomass trade. According to APCC (2014) precipitation in Austria will increase during the winter and decrease during the summer months, economic impacts will be dominated by extreme weather events & periods and forest and agricultural yields are going to increase in the alps, north of the alps but decrease in the north of the Danube. No detailed analysis on how these changes will effect cross-border biomass trade for Austria in specific could be identified.

On a global scale we can expect decreasing crop yields in lower latitudes and somewhat increasing yields in higher latitudes with higher impacts on crop than on grass yields (FAO, 2015). Together with increasing water scarcities this will have a substantial impact on global food production patterns. Considerable scientific efforts have been made to estimate these impacts: While demand for meat and milk will double in the first half of this century (mainly due to increasing consumption in Southeast Asia, South Asia and Sub-Saharan Africa) and consumption in general will be driven by economic and population growth, global production could decline by up to 80 million tonnes dry mass due to climate change compared to the reference scenarios (FAO, 2015). This outlines the increasing importance of trade for securing supply. Meanwhile Europe will face yield growths in northern parts and little change or low losses in the southern part. In contrast to the rest of the world, demographic development in Europe is expected to lead to declining consumption. CO_2 fertilisation effects and – more importantly – technological progress will most likely result in higher wheat production in the northern & western part of the EU and specifically also in Bulgaria. Slight decreases in crop production are expected in northern Italy, as well as for barley and maize in Austria, Denmark and Italy. **The EU's potential role as an increasingly important crop exporting region is therefore discussed in FAO (2015) and other publications.** Beside the extensive work done for the compilation of the cited report, the scenarios do not include changes in Atlantic and Arctic oscillations nor the effect of extreme weather events.

For the traditional wood industry, as well as for bioenergy and advanced biobased materials (like e.g. polymers, lubricants and bitumen) no studies about the effect of climate change on international trade, globally or for Austria, could be identified. It is expected that the following three factors will will have a higher impact on future changes of trade flows than climate change: (1) Changing demand/supply balances, (2) technological progress and (3) policies regarding trade and related framework conditions, in these sectors. The traditional wood processing industry is expected to face increasing competition from the bioenergy and advanced biomaterials sectors in the coming decades.

In the previous section we discuss that the focus of these growing sectors is on the cost- and emission effective utilisation of the biogenic carbon contained in the wood. With regard to international biomass trade, the following two aspects are considered crucial:

(1) **Conversion technologies** will be of high importance. Besides already commercial densification and conversion technologies (like pelletisation production of liquid biofuels via fermentation etc.), more advanced technologies like torrefaction, pyrolysis and gasification are expected to play a major role for increasing tradability and utilisation of biomass for energy and advanced biomaterials. For the specific case of Austria, market diffusion of these technologies could lead to increasing cross-border trade of biogenic carbon – in the form of energy carriers (e.g. pellets, torrefied pellets, pyrolysis oil) as well as advanced biobased

materials (e.g. biopolymer resins or products based on biopolymers). Cross-border trade of biomethane injected into the grid could also become of some significance on the longer term.

(2) **Long-term stability of framework conditions** for international trade and **certification of sustainability** are considered crucial. The BioTrade2020plus project published a report summarising the discussion based on a survey on opportunities, risks and barriers of international biomass trade (EC, 2015): A highlighted risk that could influence trade for the importing regions is "the lack of long-term stability in terms of policies and prices". A high variation is perceived for risks depending on the sourcing regions, however with the main theme of "overexploitation" and "unstable EU policy" for most regions. Furthermore and in general "the bad public image due to claims of unsustainable practices for biofuels and a lack of knowledge of public, media and policy makers are seen as the most important barriers for trade". Therefore, and as a key principle, biomass trade "should be based on sustainable and legally acquired biomass sourcing (traceable and verifiable)" including "the full value chain" as a "basis for performance assessment". Following this principle the report indicates the opportunity of biomass trade to cost-efficiently supply regions with limited domestic potential while fostering economic development and job creation of sourcing regions.

Investigations of the effects of the EUs sugar quota management[7] as well as of the Transatlantic Trade and Investment Partnership (TTIP) on biomass trade should be a focus of further research.

[7] http://ec.europa.eu/agriculture/sugar/index_en.htm

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