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Dieses Projekt wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Programms „Austrian Climate Research Programme (ACRP)" durchgeführt.

A) Project data

Allgemeines zum Projekt	
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Allgemeines zum Projekt	
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B) Project overview

1 Kurzfassung

Der Klimawandel und seine Auswirkungen haben sich speziell in den letzten Jahren zu einer der größten Herausforderungen unserer Zeit entwickelt (NOAA 2014). Hauptverantwortlich dafür sind die stark steigenden Konzentrationen an Treibhausgasen (v.a. CO_2, CH_4, N_2O), die eindeutig auf einen menschlichen Einfluss zurückzuführen sind (laut aktuellstem IPCC-Sachstandsbericht). Für mögliche Maßnahmen zur Reduktion von Treibhausgasemissionen (THG) ist die Kenntnis der Ursachen der Emissionen notwendig, um die klimaintensivsten Aktivitäten identifizieren zu können. Zurzeit erfolgt eine Erfassung von THG in den meisten Ländern anhand eines territorialen Ansatzes, der auf nationale Grenzen beschränkt und somit auf die nationale Produktion fokussiert ist. Auswirkungen im Ausland durch den internationalen Handel (Importe und Exporte) werden hingegen nicht berücksichtigt, wodurch die tatsächlichen Klimaeffekte hinter dem Konsum eines Landes nicht abgebildet werden (Bruckner et al. 2010).

Die Einbeziehung der Treibhausgasemissionen für die Herstellung der Handelsgüter in die nationale Treibhausgasbilanz würde die nationale Bilanz um die Klimarelevanz des österreichischen Konsums erweitern. Demnach müssten THG, die in Verbindung mit importierten Gütern stehen, der nationalen Klimabilanz zugerechnet, sowie THG durch die Herstellung von exportierten Gütern abgezogen werden. Durch einen derartigen Ansatz der THG-Bilanzierung könnte ein transparentes Bild über die Klimawirkungen des österreichischen Konsums dargestellt sowie die wesentlichsten Handlungsfelder für Maßnahmen zur Reduktion von THG identifiziert werden.

Für die Berechnung und Modellierung der konsumbasierten THG-Emissionen von Österreich wird ein produkt- und technologiebezogener Ansatz gewählt, der auf einer physischen Güterflussbilanz hinter der Bereitstellung der in Österreich konsumierten Produkte beruht. Dazu müssen Im- und Exporte mit der inländischen Herstellung verbunden werden. Aus dieser Güterflussbilanz werden mit produktspezifischen Lebenszyklusdaten (vorwiegend aus ECOINVENT und GEMIS) die Emissionen hinter dem Konsum errechnet. Dabei werden speziell der technologische Stand und der jeweils nationale Energiemix über die Emissionsfaktoren für die jeweiligen Exportländer und Importländer berücksichtigt, um auch Unterschiede in den Emissionen zwischen national hergestellten und importierten Produkten darstellen zu können. Darüber hinaus werden Emissionen hinter der Nutzung von Produkten ebenfalls mit berücksichtigt. Um die Vergleichbarkeit der Ergebnisse mit der nationalen Klimainventur zu gewährleisten, wird auch eine Verbindung des gewählten LCA-Ansatzes zu den Inventurwerten hergestellt.

Nach dem produktionsbasierten Ansatz der nationalen Klimainventur beträgt die nationale Emission Österreichs im Jahr 2013 knapp 80 Millionen Tonnen an

Treibhausgasen. Die Ergebnisse bereits durchgeführter Ansätze, die mit monetären Input-Output Modellen die Klimabelastungen hinter dem Konsum in Österreich errechnet haben, weisen Emissionen in der Höhe von etwa 150% der nationalen THG-Emissionen aus.

Die Ergebnisse des vorliegenden Projektes zeigen ebenfalls, dass die Treibhausgasemissionen einer konsumbasierten Betrachtung deutlich über der nationalen THG-Inventur liegen. Nach den Ergebnissen liegen die konsumbasierten THG-Emissionen im Jahr 2013 bei etwa 130 Millionen Tonnen und somit knapp 60% über jenen der nationalen Klimainventur. Dies bestätigt die Ergebnisse der bisherigen Berechnungen und zeigt, dass die Bereitstellung der importierten Produkte einen wesentlichen Teil der Klimabelastungen des österreichischen Konsums ausmacht. Diese Emissionen sind derzeit nur in den nationalen Bilanzen der jeweiligen Exportländer sichtbar, ohne eine Verbindung zu dem Land, von dem sie nachgefragt werden.

Dieses Projekt hat gezeigt, dass die Verwendung eines produkt- und technologiebezogenen Ansatzes einerseits die Identifikation der wesentlichen Emissionstreiber bei den Produkten ermöglicht, sowie andererseits etwaige Mehrbelastungen durch höhere Emissionsintensität der importierten gegenüber national hergestellten Produkten darstellt. Damit können mögliche Reduktionspotenziale und auch Verlagerungen von Emissionen („carbon leakage"), die in der Vergangenheit erfolgt sind oder mit denen in Zukunft zu rechnen ist, aufgezeigt werden.

2 Executive summary

The impacts of climate change have become more and more apparent in recent years (e.g. NOAA 2014). The major causes are the increasing greenhouse gas emissions (GHG) from anthropogenic activities. The knowledge of the sources of emissions is necessary for the reduction of GHG emissions on global level. To accomplish this, most states conduct a greenhouse gas emission inventory on national level (under UNFCCC). This type of a national GHG balance is a production-based approach which focuses on domestic activities and neglects impacts in foreign countries induced by trade (Bruckner et al. 2010). Hence, it is difficult to develop a comprehensive national strategy for global climate protection when essential climate effects of traded materials and products are not considered. As climate change is a global challenge it is not enough to focus on national boundaries only, as this favours the outsourcing of energy intensive production, often to countries with low technical standards and weak climate regulation. So the currently used GHG accounting system results in a blurred picture of national climate impacts because of the lack of the climate effects of imported and exported goods.

This project looks at this topic and aims at complementing the national GHG inventory of Austria with greenhouse gas emissions induced by foreign trade. This shall bring a transparent picture of Austria's climate impacts caused by consumption and shall help to identify the most urgent areas for climate protection measures. The project applies a product-specific and technologic view in a detailed life cycle based approach behind the Austrian consumption. The calculation of greenhouse gas emissions is based on physical material flows behind the supply of consumed products combined with product-specific LCA data and country- and branch-specific technology factors. Additionally, emissions induced by the use of final products will be addressed as well. Finally, a link to national climate inventory data will be provided through an attribution of calculated LCA-based emissions to the sectors used in the inventory to ensure comparability with the results of the national inventory.

The results of this project have shown that focusing on national activities leads to a substantial underestimation of the climate impacts that Austria is responsible for from a consumption-based perspective. The greenhouse gas emissions induced by the Austrian consumption were almost 130 million tonnes (Mt) of CO_{2equ} in 2013 and therefore about 60% higher than the national inventory. Hence, Austria is a net importer of greenhouse gas emissions required to supply the domestic consumption, which have not been accounted for in national climate inventories up to now. These results must be seen as a first attempt to manage the complexity coming from the high level of detail at the product level. Several assumptions had to be made to fill data gaps and to fit the material balances. In order to check the range of variation coming from the assumptions, sensitivity analyses have been applied.

In contrast to previous approaches from environmental economics (based on input-output models), the applied approach shows less aggregation and is decisively more detailed as it directly addresses the impacts of materials and products. This allows for the attribution of emission factors specifically to respective products. Consequently, the climate impacts can be calculated in a more transparent way and the most crucial areas of material and climate intensity, as well as ways how to improve the situation, can be identified. Furthermore, the country- and sector-specific regionalization of emission factors has a large impact on the results as well. This regionalization shows that Austria has a high technological standard and low emission intensity compared to the countries from which and to which Austria imports and exports goods and products respectively.

Finally, the results confirm the importance of extending system boundaries and taking into account all climate impacts induced by national consumption. Otherwise a distortion of emissions ("carbon leakage") will be favoured. From a global perspective, it would be beneficial to produce climate intensive materials in countries with the highest technological standard and the lowest emission intensity in order to keep greenhouse gas emissions as low as possible. Of course, this kind of switching to more efficient production sites is not done from one day to the other and the available production capacities with such a technological standard might be a limiting factor. Additionally, it would be reasonable to invest in efficiency improvements and low carbon technologies in foreign countries. However rebound effects (e.g. price changes) and other possible impacts (e.g. added value or jobs) have to be taken into account.

3 Background and objectives

The impacts of climate change are becoming more and more apparent in recent years (e.g. NOAA 2014). The major causes for this are the increasing greenhouse gas emissions (e.g. CO_2, CH_4, N_2O) from anthropogenic activities. This dominant human influence was affirmed in the latest progress report of IPCC (2013). Knowledge of the sources of GHG emissions is necessary to reduce them rapidly at the global level. With this information every state could implement suitable measures and policies to reduce emissions. However, most states conduct a GHG inventory on a national level only. This type of a national climate balance is an activity based approach which focuses on domestic production limited to within national boundaries. Impacts in foreign countries induced by trade (e.g. import) are not considered, so the climate effects behind the consumption of goods by a specific country are not visible (Bruckner et al. 2010). It is difficult, therefore, to develop a comprehensive national strategy for global climate protection. As climate change is a global challenge it is not enough to focus only on national boundaries as this favours the outsourcing of energy intensive production to countries with low technical standards and weak climate regulation and importing the products. Such outsourcing normally results in better GHG balances for the importing country but in reality it often leads to a negative impact on global scale. The differences in system boundaries between the production- and consumption-based accounting approaches is illustrated in Figure 1.

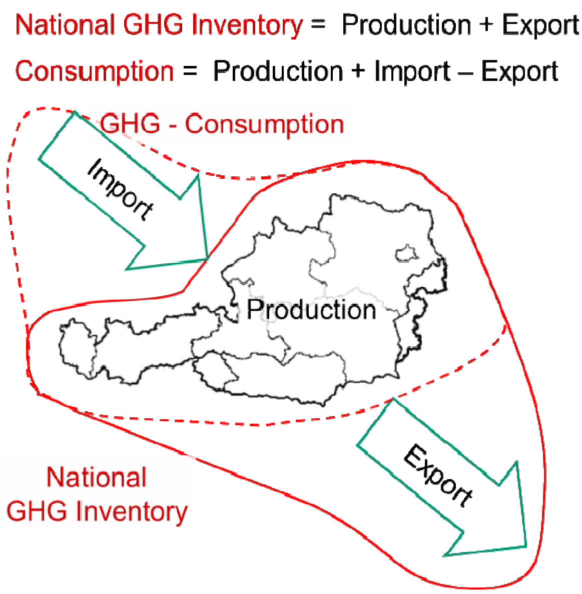


Figure 1: System boundaries of the national inventory and the consumption based emission accounting for Austria

So the currently used GHG accounting systems lead to a blurred picture of national climate impacts because it's missing the impacts of imported and exported goods. For serious climate protection both, the direct (inside national boundaries) emissions of a country and the emissions abroad induced by national consumption have to be considered.

This project aims at extending the national GHG inventory of Austria with emissions from the foreign trade by considering imported and exported goods and products. This shall bring a transparent picture of Austria's consumption-based climate impacts by identifying emissions induced domestically and abroad. Consequently climate impacts outside national boundaries, e.g. imports, which, up to now, have not been addressed to the same extent as those within the national borders, will be visible. This helps to identify negative effects coming from inventory view within national boundaries, where outsourcing of energy intensive production helps to improve national inventory, but increases emissions globally through lower technical standards or weaker climate change regulation in the production countries than in Austria. Thus, those areas for domestic climate protection measures with the largest potential to reduce climate change effects globally will be identified.

The project applies a material- and life cycle based approach to calculate the greenhouse gas emissions induced by the consumption in Austria. The basis is a material flow balance that depicts the whole process chain behind the Austrian consumption in physical units. The consumption is calculated by adding the flows of imports and subtracting those of exports from the national production. Greenhouse gas emissions are further calculated using product-specific emission factors from life cycle assessments, supplemented by technological factors to depict the technological standard in the respective countries of manufacture.

The results will show the crucial areas of material intensity, which are most responsible for climate impact. Additionally possible benefits on global level from the export of products to other countries can be derived as well as possibilities for improving the situation through changing the share or the origin countries of the imported goods. Having in mind the above mentioned intentions the following research topics were addressed during this project:

- Austria's GHG emissions from a production and consumption perspective;
- Relation between emissions induced by domestic activities to those from net-imports;
- Which materials and products are most responsible for the GHG emissions; and
- Consequences of differences in technological standards on global level – investigation of possible benefits (e.g. exports) and disadvantages (e.g. imports).

4 Project content and results

In the course of this project a product-specific and technologic view was applied in a detailed life cycle based approach to calculate the emissions behind the Austrian consumption. The calculation of greenhouse gas emissions is based on physical material flows behind the supply of consumed products combined with product-specific LCA data and country- and branch-specific technology factors. The emissions induced by the use of final products will be addressed as well. Finally, a link to the national climate inventory will be provided through an attribution of calculated LCA-based emissions to the sectors used in the inventory to ensure comparability with the results of the national inventory.

Two approaches were developed and applied during the project in order to address all research questions. First, a detailed and encompassing process chain method was used. The initial focus on commodities was therefore extended up to the whole process chain, as emission factors were available for final products as well and essential information behind the origin of emissions (domestic or abroad) along the whole chain could get depicted. Two years (2005 and 2013) were planned for investigation, however, during the project it turned out to be insightful looking at a whole time series as well. But, as the development of the process chain method was very elaborate and so only applied for one specific year (2013), an abridged version was used to develop an estimate for the extended time under consideration (2000 – 2014). This second method focused on "key" commodities and products to handle the calculation for the whole time series.

To ensure smooth exchange of information and progress throughout this project, four meetings with all partners were held. These meetings were scheduled at the beginning of the respective work package (WP) to plan and discuss the further work. One meeting was held as a video conference to reduce travel. Additionally five project meetings were held between the Austrian partners during the single WPs.

The following section will illustrate the main results of this project, followed by a short discussion how these results can be ranged and interpreted in the scientific and governmental context.

Material flow balance behind the consumption in Austria (WP 2)

The development of a countrywide material flow balance behind national consumption requires on one hand the definition of the scope and the level of detail as well as the development of the process chains behind national consumption (WP 1, Methodology-section). On the other hand the physical data for the national production, imports and exports have to be collected, which are used further as the basis for the calculation of greenhouse gas emissions (WP 2, Methodology-section).

As illustrated in Table 1, Austria imports about 89 Mt of materials and products in 2013 with a value of 130 billion euros[1]. In the same year, the country exports 50 Mt with almost the same value. Thus, Austria's industry adds significant value to the exported materials. Compared to 2005, in 2013, both imports and exports have slightly increased on a mass-basis and significantly increased on a value-basis. Overall imports and exports have been increasing annually since 2005 with the exception of 2009 when a significant drop occurred, caused by the commercial crisis.

Table 1: Austria's imports and exports from 2005 up to 2013

Year	Imports (10^6 t)	Exports (10^6 t)	Imports (10^9 €)	Export (10^9 €)
2005	82	50	97	95
2006	87	53	104	104
2007	91	59	114	115
2008	88	60	119	118
2009	80	51	98	94
2010	87	56	114	109
2011	92	57	131	122
2012	91	56	132	124
2013	89	56	131	126

Figure 2 shows that about 50% of the imports are raw materials, followed by commodities and final products. In contrast, for exports, about 50% belong to commodities. The main material flows within the country are raw materials. The majority of them are directly used as final products, the smaller part is further processed in Austria.

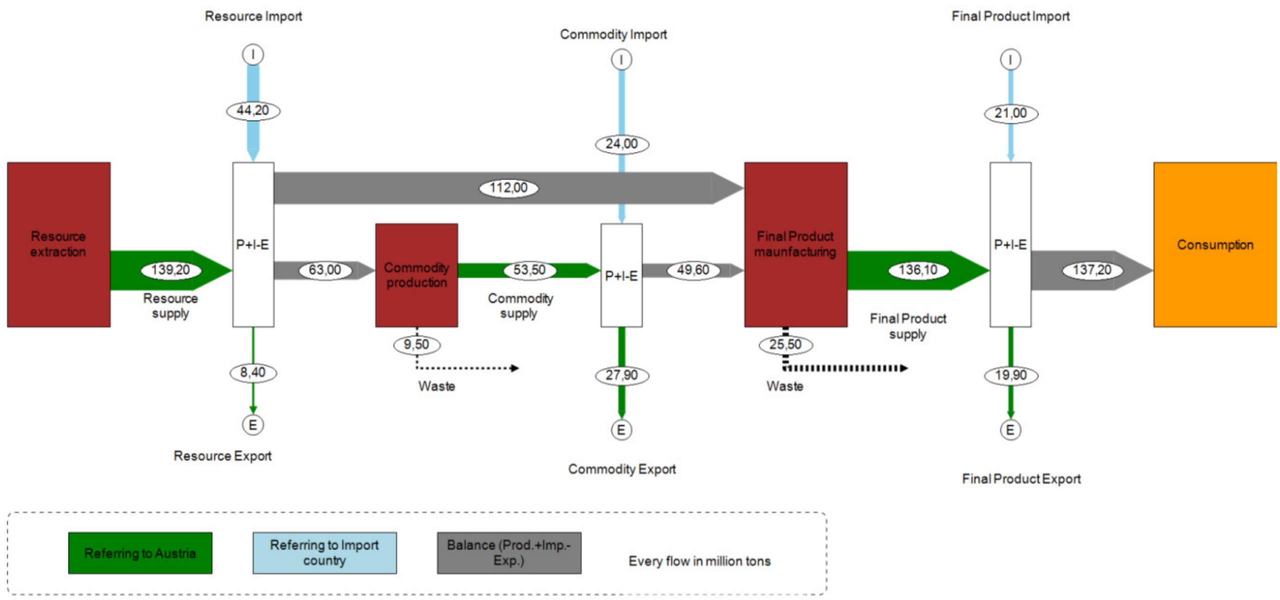


Figure 2: Material flows behind the consumption in Austria in 2013 (in Mio. t)

[1] Billion = 1 × 10^9

The origin of Austria's imports and the destination of its exports are illustrated in Figure 3 and Figure 4. It is clearly obvious that countries inside Europe are the most important trading partners of Austria (both for imports and exports). Additionally, more than one third of the imports and exports are connected to Germany. These are only the first level of imports and exports. For example, if Austria is importing final products from Germany, we assume that the whole process chain of that product takes place in Germany. In fact, Germany might import for the manufacturing of the products, e.g. cars, some commodities e.g. steel plates, from other countries.

This represents one main challenge that could not be solved at the moment, as the foreign trade statistics don't have information about these process chains. Supplementary data on the interlinkage of world economy are envisaged for further improvement. These process chains behind the imports are depicted in MRIO-models and ways to combine it with the respective model might be promising.

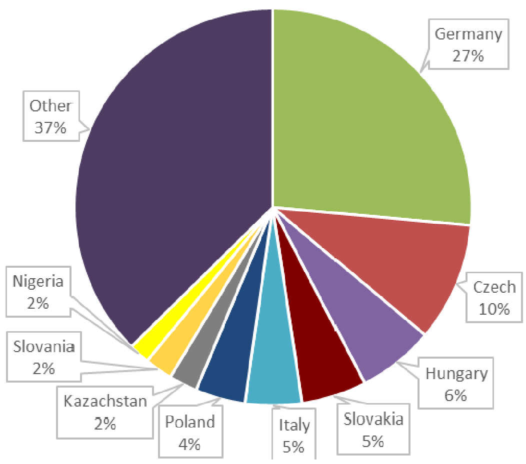


Figure 3: The origin of Austrian imports in 2013

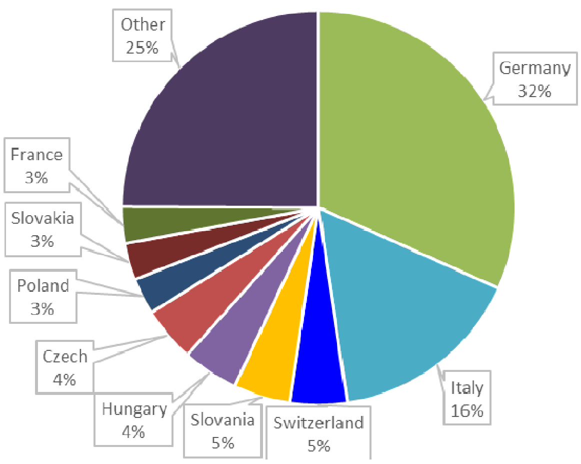


Figure 4: The desitination of Austrian exports in 2013

In Figure 5 and Figure 6 the compositions of Austria's imports and exports are illustrated for 2013. The diagrams show that chemical products (including petrochemical products) as well as metals are Austria's most important imports. For exports the picture is quite similar, differentiating only that timber products are one additional major export.

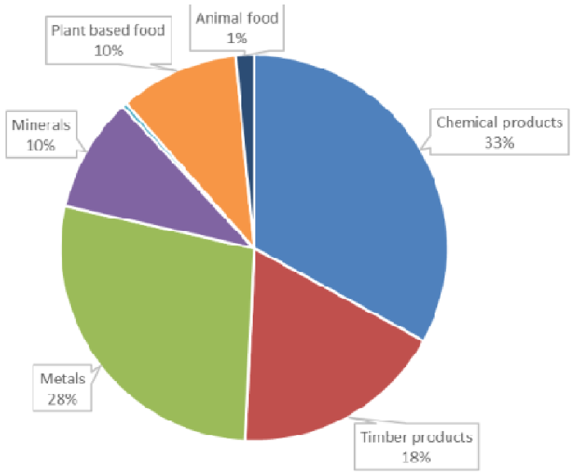


Figure 5: Distribution (by mass) of Austria's imports in 2013

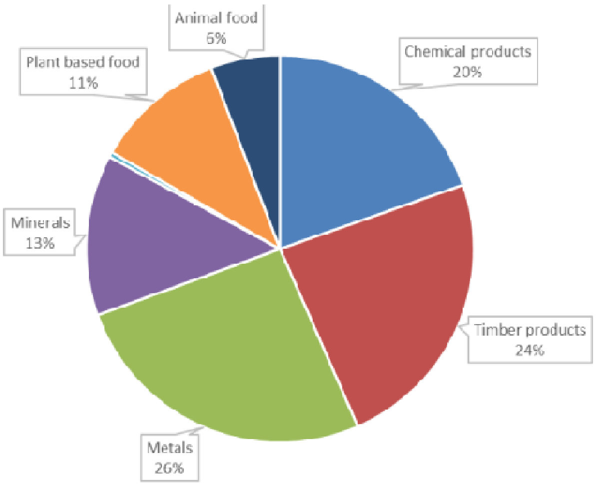


Figure 6: Distribution (by mass) of Austria's exports in 2013

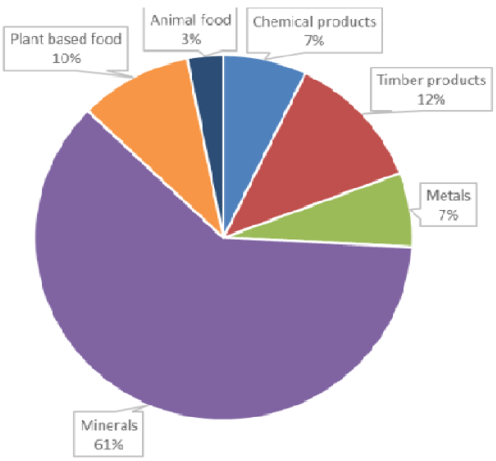


Figure 7: Distribution (by mass) of Austria's national production in 2013

Furthermore it is obvious that at resource level imports and exports are dominated by a few items. In contrast, the product level is not dominated by single products. For example, five raw materials represent nearly 75% of the total import of raw materials. For exports, the same picture can be drawn as five goods amount for almost 67% of all exported raw materials. In contrast, the national production in Austria is clearly dominated by the production of minerals, followed by timber products and plant based food (see Figure 7).

GHG emissions behind the consumption in Austria (WP 4)

These physical material flows supplemented by product-specific life cycle based emission factors (WP 3, Methodology-section) are the basis for the calculation of greenhouse gas emissions behind the consumption in Austria. The results will be illustrated in the course of this section.

Detailed process chain method

The results of the calculation of the emissions with the process chain model for the year 2013 are illustrated in subsequent Figure 8. This shows that clearly more emissions are induced by imports than exports. The consumption based GHG emissions of Austria amount to almost 130 Mt CO_{2equ}. Emissions increase in the course of the chain from raw materials up to final products. This is characteristic for a process chain, as it is also described in LCA-data, as all impacts up to the considered good are included respectively. Overall more than 90 Mt CO_{2equ} (71%) are emitted through the provision of goods and only a minor part was emitted by the use of products (e.g. driving a car or heating).

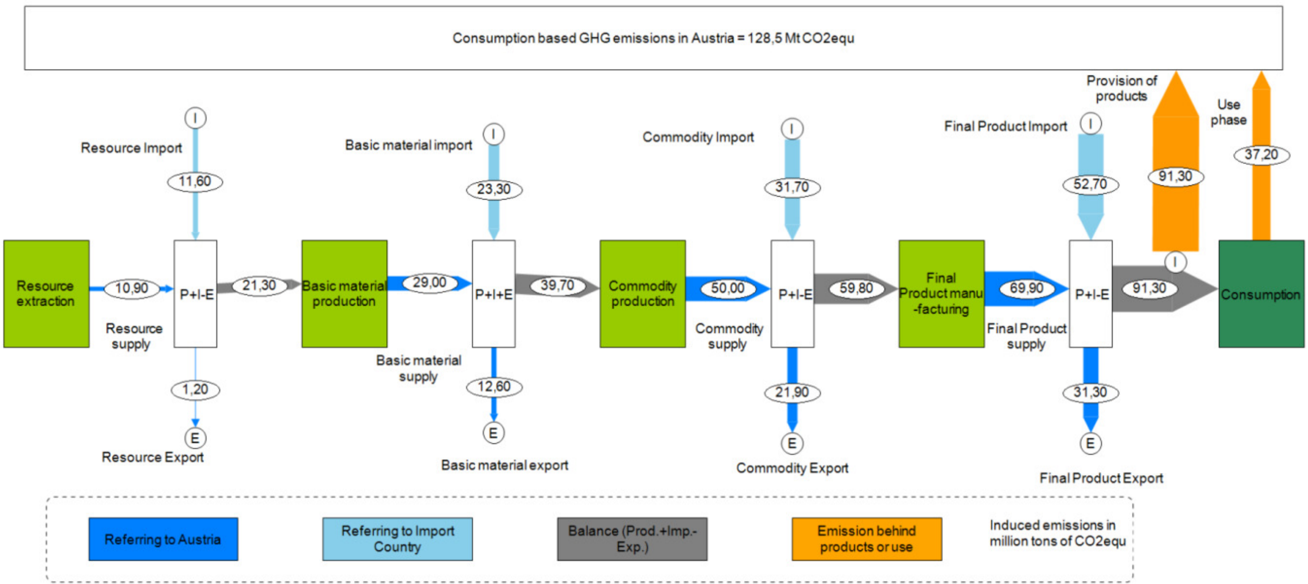


Figure 8: GHG emissions behind the process chains of the consumption of Austria in 2013

Consequently, the consumption based emissions of Austria are about 60% higher compared to the national inventory in 2013. For the purpose of quality control, the national inventory was recalculated based on the developed LCA-based process chain approach.

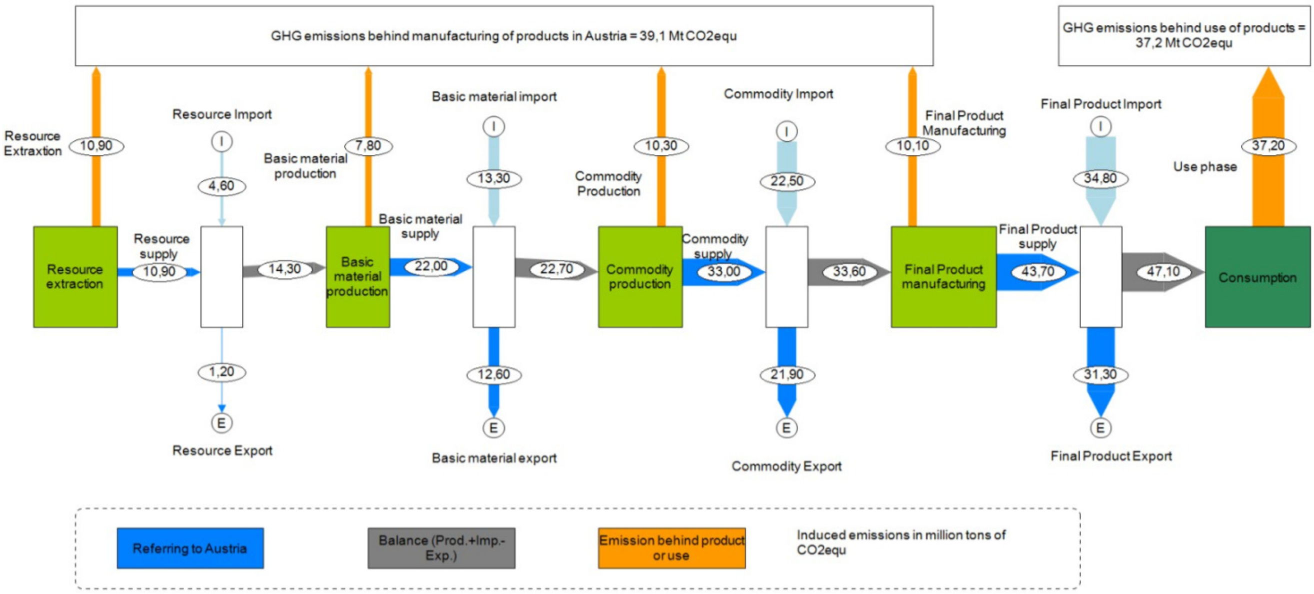


Figure 9: LCA-based national GHG-inventory for 2013

As illustrated in Figure 9, the GHG emissions relevant for the national inventory are those, which are emitted through national activities (illustrated by the orange arrows). Almost 40 Mt CO_{2equ} are emitted through the provision of goods and 37 Mt CO_{2equ} by the use of products. Overall, the LCA-based inventory results in more than 76 Mt CO_{2equ}. For comparison, the inventory reports almost 80 Mt CO_{2equ} for the year 2013 (Pazdernik et al. 2014). The deviation from inventory can be explained with the incomplete inclusion of the waste sector and the incomplete coverage of HFC components.

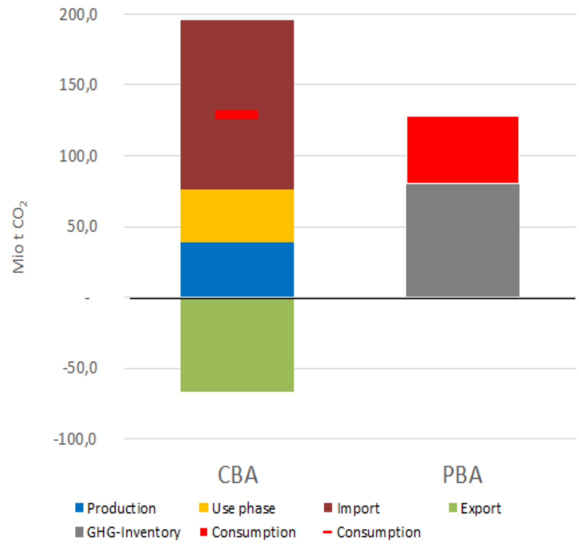


Figure 10: Comparison of consumption (CBA) and production (PBA) based GHG emissions in 2013

Figure 10 shows the consumption based emissions (CBA) of Austria as compared to the national inventory (PBA), for the year 2013 more clearly. As shown, emissions behind imports (brown) dominate and emissions behind the national production (blue) are comparatively small. Anyway, the high technological standard of Austria, compared to those countries from which Austria imports, is a positive contribution to low GHG-emissions. This will be shown in more detail in WP 5. From a consumption based perspective, Austria is responsible for about 60% more emissions than from a production-based perspective (based on the year 2013). Hence Austria is clearly a net-importer of GHG emissions.

Commodities-focused time series method

Figure 11 shows the results from the commodities-focused time series method. Consumption-based emissions have remained relatively constant over the study period (2000 – 2014). The average consumption based emissions are 116.9 Mt CO_2eq (standard error ± 0.7%). For comparison to the *detailed process chain method*, the consumption-based emissions in 2013 using the *commodities-focused time series method* were 114.9 Mt CO_2eq. The national GHG inventory has decreased by 18% since 2005 mostly through policies to promote renewable energy in the residential and industrial sectors. This combination means that the ratio of consumption-based to production-based emissions is increasing. In 2005 the ratio was 1.25 (i.e. 25% additional emissions are a result of imports for consumption). By 2013 the ratio was 1.45. For comparison, Munoz and Steininger (2010), using a top-down MRIO system, estimated that the ratio was 1.44 in 2004.

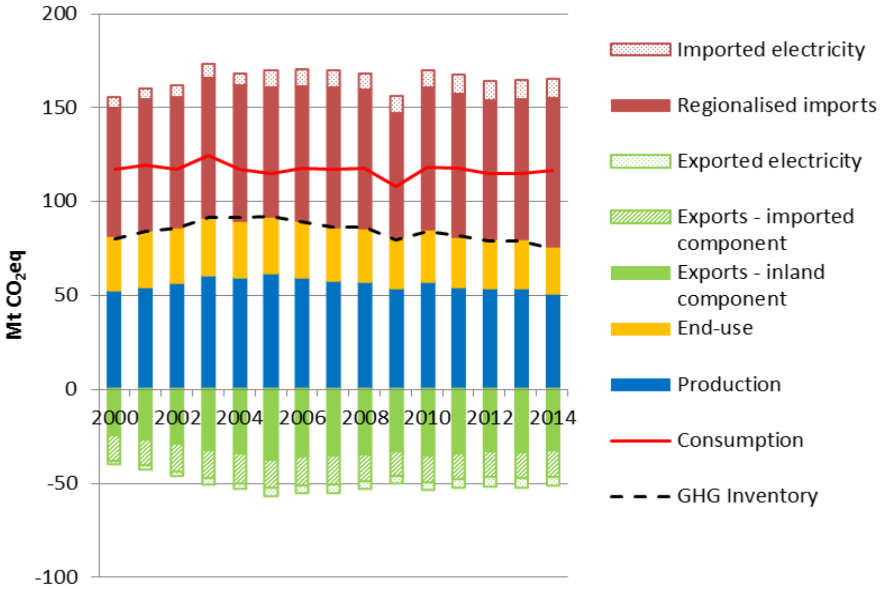


Figure 11: Comparison of consumption and production based GHG emissions for 2000 – 2014 using the commodities-focused time series method

For the second approach a detailed quality control was conducted by comparing an LCA-based estimate of emissions by sector and year to the official national inventory (Figure 12). This shows that the commodities-focused time series method corresponds to the national GHG inventory relatively well. However, there is a trend to underestimate emissions as compared to the national inventory specifically in the industrial sector. The effect of improving energy efficiency on emission factors was included based on estimates from Odyssee, but these values seem to be too optimistic. This analysis highlights the benefits of a time-series approach because individual annual inconsistencies and divergent trends are exposed. This must then either be corrected for or explained.

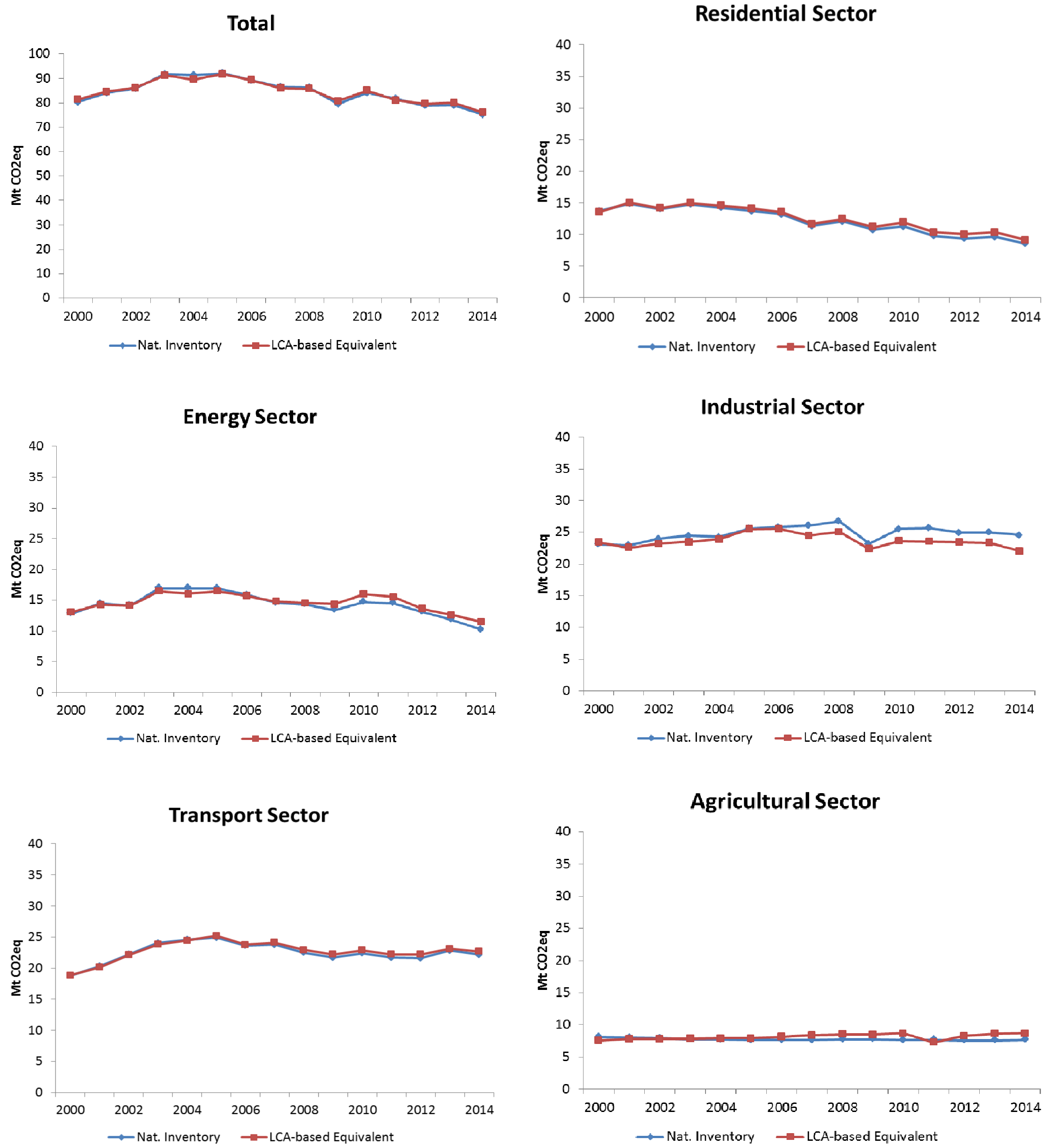


Figure 12: Quality control – a comparison of the national inventory and its LCA-based equivalence by sector using the commodities-focused time series method

Scenario development, scientific discussion and expert workshop for recommendations (WP 5)

Detailed process chain method

The results of this product-based approach have shown that Austria's consumption-based emissions are much higher than from a production-based perspective. Although this detailed approach has many advantages, e.g. the calculation on individual product level, use of physical material flows, it is simultaneously faced with some challenges as well. For instance, the results are very sensitive to many of the used methodological steps and thus they have to be applied carefully. The method starts with the complete collection of physical material flows to calculate national consumption via production plus imports minus exports. Another main aspect is the development of process chains behind the consumption, as goods have to be attributed to the correct steps along the chain. Otherwise the results would be incorrect. A check with the inventory showed sufficient validity. The collection of LCA-based emission factors is of main importance as well, as the choice of wrong factors can lead to biased results. Finally, the results were highly sensitive to the regionalization of these emission factors which depict the technological standards in the respective countries of origin. On the other hand there is a broad variation among the technological standard of the different sites in the countries and a continuous increase in energy efficiency, which was not depicted in the data.

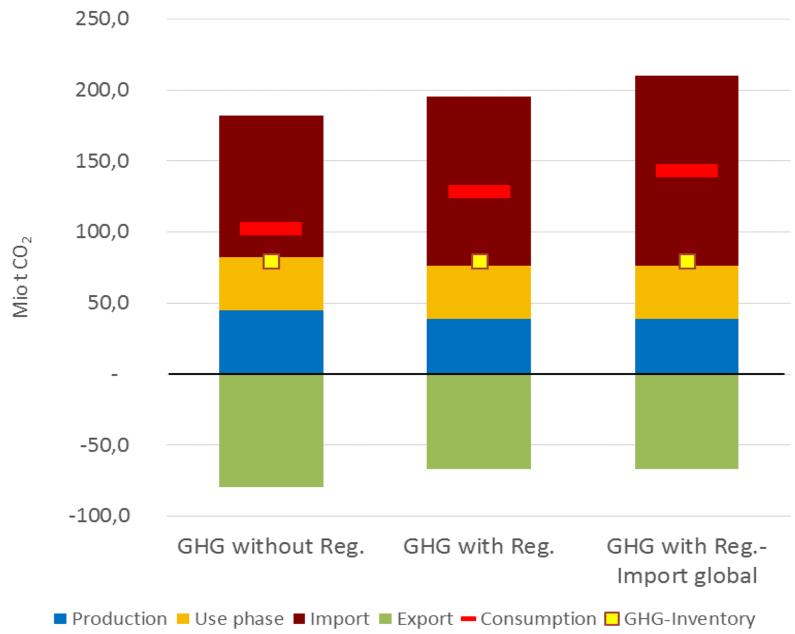


Figure 13: Sensitivity analysis for the consumption based emissions in 2013

These influences should be shown with sensitivity analyses to illustrate the range and the uncertainty of the results. Figure 13 illustrates the results for three different approaches: the first one (GHG without Reg.) was calculated via emission factors as they are available in databases. The results show that CBE are much lower in this case than those with a regionalization of emission factors (GHG with Reg.). This second approach corresponds to the results in WP 4 (see Figure 10). The last approach (GHG with Reg. - Import global) shows the possible effect of one disadvantage of this methodology, the lack of interlinkage in world trade with commodities. If a product is imported from Germany, the regionalization assumes that the whole process chain takes place in Germany. In fact, the process chain of a passenger car may comprise imports of raw materials or commodities from countries with higher emission intensities. As the main part of Austria’s imports come from Europe, the emissions might be underestimated. The last approach shows the effect of such a worldwide trade with commodities by applying emission factors for “rest of the world” for all imports of raw materials and commodities. It results in an increase of CBE up to 80% above the national inventory.

As the sensitivity analysis has shown, the regionalization of emission factors is a very important step in order to depict correctly the technological standard in the origin countries of our imports. Furthermore, both scenarios developed in the course of this project address the technological differences especially between Austria and those countries Austria is importing from and exporting to respectively.

Figure 14 shows a purely theoretic scenario if imported materials and products would be produced with an equivalent emission standard as Austria. For imported raw materials for instance, more than 11 Mt CO_{2equ} are imported (4.6+7.0) in 2013. If all of these resources were provided with Austrian standard, the emissions would decrease from more than 11 to almost 4.6 Mt CO_{2equ}, because of the lower emission intensity in Austria as compared to countries abroad. Overall, up to 40% of the imported emissions could get reduced globally by reintegrating production to Austria or applying a similar high technological standard and low emission intensity. However, this shall mainly illustrate the effects of different production standard and cannot be seen as a realistic scenario, as raw material availability and production capacities are not verified. Additionally, as the national inventory and current reporting obligations are based on a production perspective, all reintegration perspectives would increase national emissions and oppose to the achievement of national climate targets.

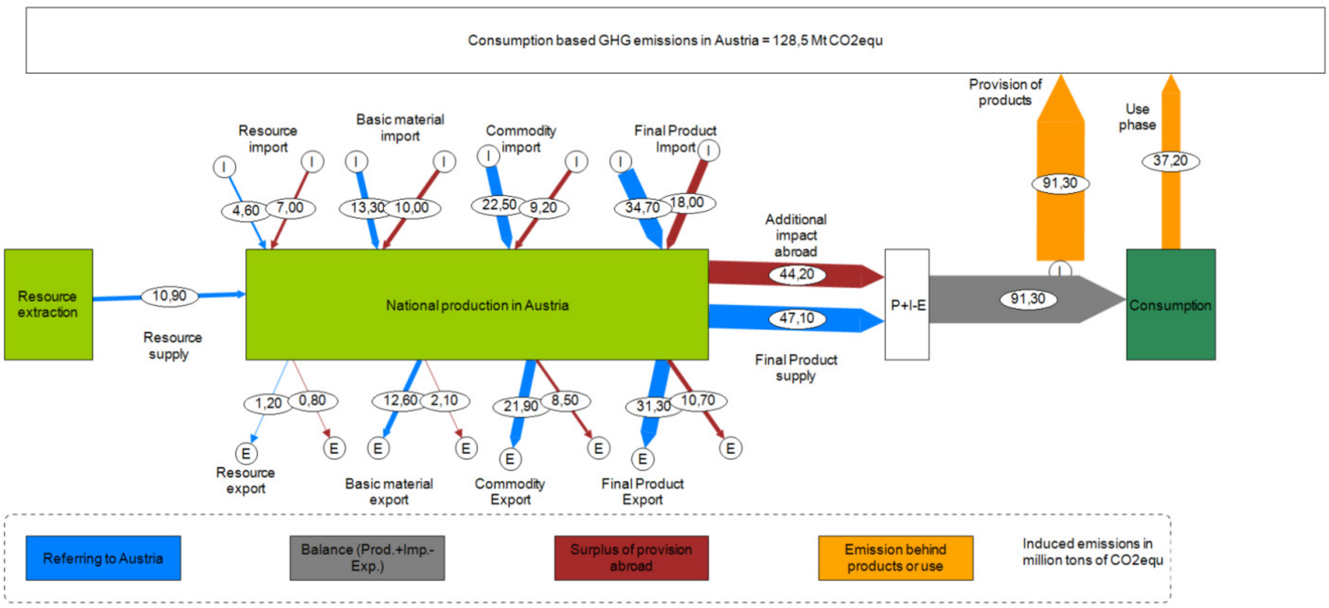


Figure 14: Technological differences between domestic and foreign production in 2013

On the other hand the possible relocation of Austrian production sites ("carbon leakage") is positive for the national inventory, as domestic activities are reduced, but may result in clearly higher GHG emissions from a global perspective.

Figure 14 shows further the positive contribution through Austrian exports. If these materials and products were produced abroad, the GHG emissions would be clearly higher, especially for commodities and final products. Of course, the national inventory would be reduced, but emissions on global level would rise.

Commodities-focused time series method

LCA-based emission factors are inherently produced for a given country and year. The factors are influenced by energy efficiency of the system, electrical emission intensity, and energy mix for other energy. In the *commodities-focused time series method* a system has been developed whereby the emission factors are decomposed by sector, corrected for electrical emission intensity, and sector-based time and country dependent efficiency and energy mix. Figure 15 shows the effect of this adjustment with respect to the consumption-based emission estimate. In Austria's case assuming dynamic EFs makes a large difference to the national inventory but a smaller difference to the consumption-based emissions. This can be explained as much of Austria's production is exported and hence affects the consumption-based emissions less than national inventory. Regionalisation of imports however has a large impact on the consumption-based emissions.

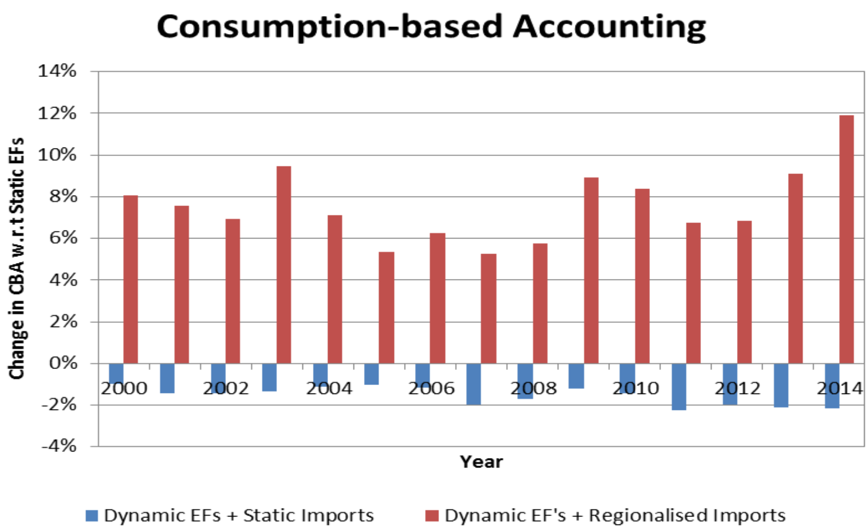


Figure 15: Sensitivity of CBA to type of emission factors and imports

Error estimation and quality aspects

The methodological approach cannot capture all processes and products involved in Austria's consumption. However, the project included an IPCC key-category type analysis to identify products that should be modelled in detail to reduce the potential truncation error to an acceptable minimum. Much of the reported variability in published LCA emission factors is due the country and year for which the analysis was undertaken. In the course of the project, the project team developed a method to adjust values from available databases to a specific country's technology, energy mix and electrical energy intensity. This allowed for the assessment of the emissions from typical "Austrian consumers" and their consumption of specific goods and services. As the method uses a combination of statistical data with LCA data and LCA databases do not include uncertainty ranges no detailed error analysis was done, however a validity check and sensitivity analyses was exercised as described below.

A detailed sensitivity analysis was made for the first method (see Figure 13, publizierbarer Endbericht) to illustrate the range and the uncertainty of the results. Furthermore, a validity check with the national inventory was done, as a life cycle based inventory was recalculated for the purpose of quality control (Figure 9). For the second approach a detailed quality control was conducted by comparing an LCA-based estimate of emissions by sector and year to the official national inventory. While this does not guarantee that imported emissions are correct, it does demonstrate that internally, at least, the method provided equivalent estimates (see Figure 12).

Discussion of the results

Summarizing, Austria's consumption based emissions are clearly higher than those of the national inventory. The two methods applied throughout this project have shown different results. The *detailed process chain method* calculated consumption-based emissions in the amount of almost 130 Mt CO2equ in 2013 (= about 60% higher than the national inventory). The *commodities-focused time series method* resulted in CBE for 2013 at about 115 Mt CO2equ. The lower results can be explained by the consideration of a limited number of "key" commodities and products, as it developed a time series to show the development during the recent years. In contrary the first method provides a detailed picture of one year, taking into account all goods and products behind national consumption but may include double counting, even though all steps possible were attempted to reduce this possibility.

The results of this project, applying for the first time a detailed product based approach ("bottom up"), are also similar to previous input-output based analysis of consumption based emissions of Austria as well. Steininger et al. (2016) report CBE which are approximately 50% higher than the national inventory. Bruckner et al. (2009) came to a similar result for the year 2005, as the emissions induced by national consumption were 58% above the production based emissions.

Furthermore, a workshop (Expert workshop on Consumption based emission accounting) was held in Vienna on Nov. 27th 2015 at which early concepts and results were discussed with a selected team of experts. Their feedback was important for the team to focus its research directions. At this meeting and at subsequent smaller meeting with members of University of Graz, the advantage and disadvantages of bottom-up approaches, as presented by the climAconsum team, as compared to top-down multi-regional Input-Output (MRIO) were discussed. A second expert meeting (Consumption Based GHG Accounting: CCCA – Workshop) was organised in Graz on Oct. 5th, 2016 when results from the climAconsum team were being finalised. Many of the experts in the first meeting also attended the second expert workshop. Finally, an interesting stakeholder discussion (Stakeholder Dialog) was held on March 7th, 2017 in Vienna. At this meeting many excellent suggestion were made by the stakeholder group (e.g. identification and allocation of “tank-tourism” as an export and human tourism to imports and exports). These recommendations were adopted by the climAconsum team.

5 Conclusions and recommendations

Project results

During the project the consumption based emissions were calculated on detailed product level by combining physical material flows with LCA-based emission factors, considering the technological standard in the respective countries of origin as well for the first time. The applied approaches provide in general more detail than previous input-output methods because of more disaggregation and higher accuracy in calculating climate impacts behind national consumption

From the results of this project it is visible that consumption-based GHG emissions are 1.5 to 1.6 times higher than the GHG inventory. This range of surplus of emission corresponds generally well with similar calculations, based on economic input-output models. The results show properly the impact of Austrian consumption, whereby the majority of the emissions comes from the provision of products (see Figure 11), which is clearly higher than from the use of energy carriers (oil, gas, fuel). The most relevant consumption areas are mobility, goods for industrial and private use and food (Figure 16).

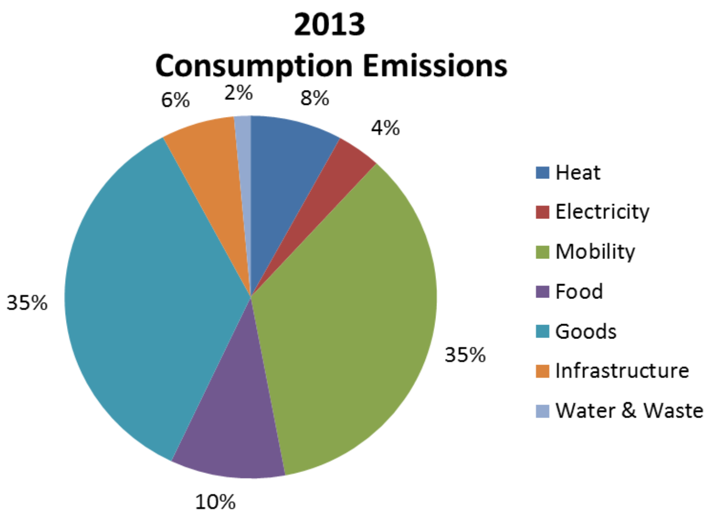


Figure 16: Distribution of consumption based emissions to consumption areas

Recommendations

From the calculations on a product level with adaptation of the emissions to the national situation in the producing countries it became evident, that the technological standard and the emission intensity of the respective energy mix in the countries play an important role for the total emission behind national consumption. It emerged that Austria performs well due to advanced technology, high energy efficiency and low emission intensity coming from a clean energy mix and a high share of hydro power in electricity production. So consumption of products made in Austria leads generally to lower emissions than imported products due to the favourable emission conditions and lower transport distances.

In future, the comparative advantage and the favourable position of Austria could decrease since for countries with less efficient technologies it is far easier to make improvements than in developed ones. In addition, as mentioned above, renewable energy sources are limited and in many cases an increase in production will lead to the import of additional electricity with higher emission intensity from neighbouring countries.

Of course, in practice the potential for such shifts in production structure are limited as different aspects have to be considered. So the following questions have to be obeyed: which resources would be available nationally, how would the supply chains for resources and commodities look like, which industries allow further extension of the production capacity or could the then required energy amounts be provided as clean as nowadays.

However, the emissions in the national inventory which is relevant for national report obligations would increase when the national activities are extended although it might result in a reduction of emissions on global level. Furthermore, Austria´s exports reduce greenhouse gas emissions in the importing countries, when they would produce with a lower technological standard and higher emission intensity. In this case export of Austrian products would be also a contribution to emission reduction on global level.

Besides changes in the provision structure, which embody distinct challenges, changes in consumer behaviour seem to be much easier to attain, but require the improved user awareness. Generally it results in a different product pattern and use pattern, meaning less emission intensive products and longer or less intensive use of them.

With the developed product based methods these changes can be described and the effects analysed, even if they concern another production country, products substitution or longer use time meaning a reduction of the consumed amounts. The methods allow one to calculate the effects of the consumption of less emission intensive products or forced consumption of regional products made in Austria both on national emission balance and on global level.

Method improvements

As the detailed product based approach has a high complexity on such a disaggregated level, there were many challenges to handle in the course of the work. It turned out that it is quite time-consuming and much effort was required to construct the correct process chains and to attribute the correct LCA-factors. On the other hand we see now, that the initial development of this methodology had such high effort and a periodic annual updating would be much easier if the number of products could be reduced as it was shown with the time series approach. To facilitate the calculation of time series with the detailed process chain method it would help to functionalize the data-links. However the detailed approach with its high number of products allows the attribution of emissions factors very specifically. This avoids the calculation of emissions with average emission factors per unit value at the sector level which is a characteristic of the high aggregation of the IO-methods.

One crucial consequence of the detailed approach is the importance of the correct process chains to avoid double counting, especially relevant for the use of LCA-data as the whole supply chain up to the considered good is comprised. During their development it is therefore quite important to attribute all goods to the correct steps in the chains.

Moreover the presented methods are based on foreign trade data, that do not fully reflect the real origin of the products. For instance, if products are imported from Germany, the applied regionalization assumes that the whole supply chain necessary to produce that product is performed with Germany's emission intensity. However, some parts of these process chains might occur in other countries, so steel could come from India, which is not visible in foreign trade date, although they are origin oriented. Multi regional IO-data might have a better picture of the situation at least in monetary values. Thus, a hybrid of the product based and the economic method in this respect will be discussed.

A further consequence concerns, for instance, the sector- and country-specific regionalization of emission factors. The use of the national emission intensities in the different branches calculated with the industrial energy mix was successfully applied in the detail product chain method. But the regionalization assumes that all facilities within one branch use the same energy mix, which will not hold true for single facilities. So a more detailed look at the specific situation including the efficiency situation will be appropriate.

C) Project details

6 Methodology

A detailed review of current scientific literature has shown that the interest in consumption based greenhouse gas emission accounting has grown significantly. Economic input-output (I-O) models have been the most common approaches to account for climate impacts from a consumption based perspective up to now (Lenzen et al. 2006, Wiedmann 2009, Bruckner et al. 2009, Lutter et al. 2016). The database of such models includes a set of national input-output (IO) tables that are interlinked by bilateral trade data. I-O tables depict the flow of goods and services within countries in monetary units. The set of IO tables is further extended with sectoral data on energy use, greenhouse gas emissions or other environmental impacts. The models allow production chains triggered by consumption in one country across country borders to be traced and the induced environmental impacts in all other countries to be calculated. Thus, it is possible to determine how many inputs (from various sectors and countries) are necessary to produce the required output for the respective sectors (see e.g. Wiedmann 2009, Bruckner et al. 2009, Lininger 2015, Lutter et al. 2016).

However, there are some challenges and sources of uncertainty that have to be taken into account, e.g. coming from the high level of sector aggregation. This kind of aggregating products of low and high emission intensity together in one sector leads to a significant increase of uncertainty. These approaches are therefore suitable to deliver information for country-level or regional analysis, but are not able to provide accurate data for single products. Furthermore, another source of uncertainty is the prevailing use of monetary structures of sectors to calculate environmental impacts, as monetary data are not as suitable for the calculation of greenhouse gas emissions as physical data are (Wiedmann 2009, Lininger 2015, Lutter et al. 2016).

This project applies a product-specific and technologic view in a detailed life cycle based approach to calculate the climate impacts behind the Austrian consumption. The calculation of greenhouse gas emissions is based on physical material flows behind the supply of consumed products combined with product-specific LCA data and country- and branch-specific technology factors. In contrast to previous approaches from environmental economics (based on input-output models), the applied approach shows less aggregation and is decisively more detailed as it directly addresses the impacts of materials and products. This allows to attribute emission factors very specifically to the respective products. Consequently, the climate impacts can be calculated in a more transparent way and the most crucial areas of material and climate intensity can be identified as well as ways how to improve the situation.

The following section explains the applied approach in detail by describing the respective project steps:

Categorization of Austrian imports and exports (WP 1 and WP 3)

Definition of the scope and the level of detail

The first step in the course of this project was to define the scope and level of detail of goods and products for the analysis. The foreign trade statistics for Austria were therefore briefly considered at first for getting a short insight and impression of the amounts Austria is importing and exporting. A classification scheme for compiling imports and exports had to be selected in a next step. Two different product classifications were potentially possible, the SITC (Standard International Trade Classification) and the CN (Combined Nomenclature) classification. The CN was chosen in the end as it is more focused on materials and has also a better structure according to different material and product types. For illustrating all different product-groups, the statistical data were investigated at the most aggregated level at first, resulting in about 100 different 2-digits of different product groups (see Table 2).

Table 2: Excerpt of product categories in the CN classification (Statistics Austria 2017)

Code	Title
01	LIVE ANIMALS
02	MEAT AND EDIBLE MEAT OFFAL
03	FISH AND CRUSTACEANS
04	DAIRY PRODUCE; BIRDS' EGGS; NATURAL HONEY
05	PRODUCTS OF ANIMAL ORIGIN
06	LIVE TREES AND OTHER PLANTS
07	EDIBLE VEGETABLES AND CERTAIN ROOTS AND TUBERS
08	EDIBLE FRUIT AND NUTS; PEEL OF CITRUS FRUIT OR MELONS
09	COFFEE, TEA, MATÉ AND SPICES
10	CEREALS
11	PRODUCTS OF THE MILLING INDUSTRY
12	OIL SEEDS AND OLEAGINOUS FRUITS
13	LAC; GUMS, RESINS AND OTHER VEGETABLE SAPS AND EXTRACTS
14	VEGETABLE PLAITING MATERIALS
15	ANIMAL OR VEGETABLE FATS AND OILS AND THEIR CLEAVAGE PRODUCTS
16	PREPARATIONS OF MEAT, OF FISH OR OF CRUSTACEANS
17	SUGARS AND SUGAR CONFECTIONERY
18	COCOA AND COCOA PREPARATIONS
19	PREPARATIONS OF CEREALS, FLOUR, STARCH OR MILK
20	PREPARATIONS OF VEGETABLES, FRUIT, NUTS OR OTHER PARTS OF PLANTS
21	MISCELLANEOUS EDIBLE PREPARATIONS
22	BEVERAGES, SPIRITS AND VINEGAR
23	RESIDUES AND WASTE FROM THE FOOD INDUSTRIES; PREPARED ANIMAL FODDER
24	TOBACCO AND MANUFACTURED TOBACCO SUBSTITUTES

Each of these product groups was considered separately in more detail at the respective 4- 6- and 8- digit levels for revealing possible differences between one 2-, 4- or 6- digit, because of the heterogeneity of products within one product group regarding emission intensities. For example, most foods like meat (CN 2) or cereals (CN 10) are considered at the 4- digit level, as there are many different kind of materials and products included which could not be covered by one emission factor. As an example, from an LCA-viewpoint it probably will be crucial to differentiate between beef and pork as well as between rice and wheat. Other materials and products like those from timber industry (CN 44) are looked at in more detail (6- digits), as different kinds of wood or wood products with different LCA factors are given separately only at such a detailed level. On the other hand, goods like fish (CN 3) and coffee (CN 9) were considered at the 2-digit level, as there is no essential variation within the respective product groups.

As a result, a table of around 1,000 materials and products that Austria is importing or exporting was established.

Development of the process chains behind national consumption

For the development of a material flow balance, as described in WP 2, the physical amounts (mass) of imported and exported as well as domestically produced materials and products had to be derived from the statistical data. Due to data availability, the initial focus on commodities was extended to encompass the whole process chain up to the consumption of final products. Thus, essential information behind the origin of emissions (domestic or abroad) along the whole chain could be depicted as well. Before the physical data were compiled (WP 2), it was necessary to look at the characteristics of the respective goods separately and the position of the products in the process chain, e.g. raw material, in more detail (see Figure 17).

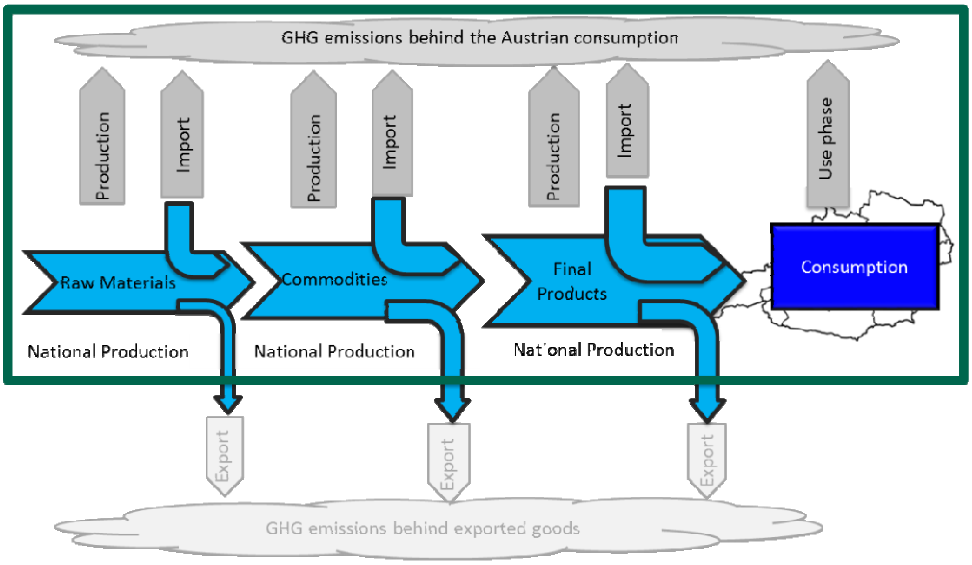


Figure 17: Illustrative process chain behind national consumption

This is quite important to avoid double counting, as LCA emission factors include the whole life cycle from the resource up to the considered good (Lenzen et al. 2006, Jungbluth et al. 2011). As an example, emission factors for paper include the emissions related to the production of paper and the supply chains of raw materials and energy. Emissions behind the required wood and the production of pulp are therefore included and must not be included in the estimation of emissions from raw materials separately. Consequently, it was crucial to differentiate in the final products and the goods along the supply chain to enable the calculation of LCA-based emissions correctly. Additionally, it would be helpful to know the proportions of domestic and foreign supply chains in the consumer products. It was also obvious that some materials serve both, as a raw material for further production and as a final product. Gravel, as an example, will not be processed to intermediates, but rather used as product as well (e.g. road works).

Identification of key products behind the Austrian consumption

To identify "key" products behind the Austrian consumption an approach similar to the IPCC Key Category Methodology was used. Using the 2-digit CN code methodology described earlier (Table 2) and a range of emission factors from existing LCA databases for products and countries of origin within these upper-level groups, a rough estimate of the emissions from imported and exported materials, products and services (MP&S) for 2000 - 2014 was created. This was then be sorted (from largest to smallest) by the contribution to national consumption footprint (criteria 1), change in the nation consumption footprint over time (criteria 2), and uncertainty/variability due to source of data (i.e. database) and country of origin of the material, good or product (criteria 3). Using these three sorted lists the "key" MP&Ss were identified. In the IPCC Key Category Methodology sectors are considered "key" if they contribute to the first 95% of each criterion. Two of the three criteria are fulfilled by 23 MP&S. These MP&S are listed in Table 3. The import and export information for these will be further sub-categorised and LCA analysis for the sub-category used (if possible). As examples; code 2 - Meat And Edible Meat Offal – was divided into six subcategories: three type of meat (beef, chicken, and pork) and two farming systems (conventional and organic). Code 4 - Dairy Produce; Birds' Eggs; Natural Honey – was divided into eight subcategories: four types of milk products (butter, cheese, cream and milk) and two farming systems (conventional and organic). In actual practice during the course of the project, the 23 upper-level categories expanded to include 143 individual products.

Table 3: Key category analysis of materials, products and services (MP&S) imported and exported – MP&S that satisfy 2 or more of the criteria for identification

Code	Title	Import	Export
2	Meat And Edible Meat Offal	3	2
4	Dairy Produce; Birds' Eggs; Natural Honey	0	2
10	Cereals	2	2
12	Oil Seeds And Oleaginous Fruits	2	2
26	Ores, Slag And Ash	3	3
27	Mineral Fuels, Mineral Oils And Products Of Their Distillation	3	3
28	Inorganic Chemicals; Organic Or Inorganic Compounds Of Precious Metals	3	3
29	Organic Chemicals	3	3
31	Fertilisers	2	2
32	Tanning Or Dyeing Extracts	2	3
34	Soap, Organic Surface-Active Agents, Washing Preparations	3	3
38	Miscellaneous Chemical Products	3	2
39	Plastics And Articles Thereof	3	3
44	Wood And Articles Of Wood; Wood Charcoal	3	3
48	Paper And Paperboard	2	3
63	Other Made-Up Textile Articles; Sets; Worn Clothing	1	2
71	Natural Or Cultured Pearls, Precious Or Semi-Precious Stones	3	3
72	Iron And Steel	3	3
73	Articles Of Iron Or Steel	3	3
76	Aluminium And Articles Thereof	3	3
83	Miscellaneous Articles Of Base Metal	0	2
85	Electrical Machinery And Equipment And Parts Thereof	2	3
87	Vehicles Other Than Railway Or Tramway Rolling Stock	2	3

Sensitivity analysis on the country of origin (i.e. electricity mix, technology)

As part of the WP 3, a spreadsheet based application was created to test the sensitivity of the LCA-based emission factors to import country of origin. The model takes into account country-dependent industrial energy mix (Oda et al. 2012), energy efficiency factors (Sendich 2014, European Environment Agency 2017, World Bank 2017), electrical emission intensities (World Energy Council, European Environment Agency 2017) and transportation distances and modes to Austria (World Energy Council). An assessment for all 143 products is available. Austria emission factors are generally low as compared to other countries as illustrated by the example of steel (Figure 18).

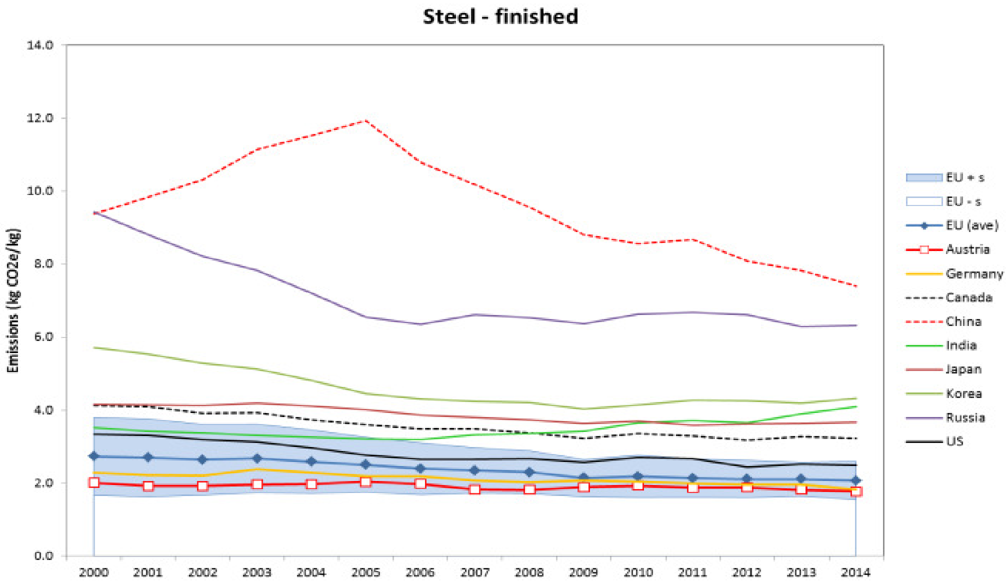


Figure 18: Sensitivity of emission factors to country and year for finished steel products. Within the EU, the mean value and range (± σ) are shown.

Development of a material flow balance of the process chain behind the consumption in Austria (WP 2)

The development of a countrywide material flows balance behind national consumption requires physical data for the national production, imports and exports. These data were collected in the course of this work package and are used further as the basis for the calculation of greenhouse gas emissions.

Collection of trade and production data

Physical data on mass as well as monetary value for about 1,000 materials and products Austria traded in 2013 were compiled. These data were taken from the foreign trade and production statistics from the Statistics Austria. Difficulties were encountered as the national production data are not as complete as the data from foreign trade, for reasons of confidentiality. In general, production data were obtained from "Konjunkturerhebung" of Statistics Austria. The goods and products are structured in a classification scheme (CPA = Classification of Products by Activities), similar to the CN-classification of the foreign trade. The CPA classification has different levels, from the highest level of aggregation (2-

digit) up to the highest level of detail (10-digit). Physical data are mainly available on the highest level of detail, but at this level often data is lacking for commodities due to confidentiality. On the other hand, monetary amounts are also available, but mainly on a more aggregated level. Thus, several assumptions and decisions had to be made as well as additional information included for completing physical data of domestically produced commodities.

Handling of confidential physical data:

We solved this problem by consideration at a higher aggregation level, where monetary amounts were available. These monetary data were used in a next step for the conversion to physical amounts with virtual prices of similar goods, which could be calculated from the foreign trade statistics. The export price was chosen, as it gives a better picture of the Austrian situation than the import price.

Handling of particular units:

Compared with the foreign trade statistics, which presents physical data (tonnes), the national production statistics have much more complexity, and are given in different units (e.g. m^3, m^2, piece, etc.). For inclusion these particular units were converted to tonnes.

Lack of production data:

Additional data were required in case of missing information in the national statistics. The industrial sectors were contacted for this additional information (e.g. reports of industrial branches) and sector-specific literature was investigated as well.

In general, we assume that consumption (C) can be calculated by production (P) plus imports (I) minus exports (E). Of course, this ignores the possibility of stockpiling. However for some products (e.g. agricultural, fossil fuels, paper, vehicles) consumption data are available from a variety of sources. These data were also collected especially for the commodities-focused time series method, as much as possible, to compare to consumption estimated from the linear combination of production, imports and exports. Specifically, MP&Ss for which consumption values were used include: end-consumption of electricity and energy for heat and transportation by residents and public and private services; foodstuffs; and vehicles. For these commodities the principle of calculation was reordered (P=C-I+E). The actual consumption of MP&Ss, and not the calculated or apparent consumption, is an area for further research.

Identification and attribution of product-specific LCA-data (WP 3)

Detailed process chain method

For conversion to emissions in the course of the detailed process chain method life cycle based emission factors were collected for every material and product (as defined in WP 1). The detailed process chain approach made use of attributional LCA emission factors from the Ecoinvent database. LCA process chains that most nearly represented each of the 1000 products and commodities were selected. In general in Ecoinvent emission factors are per physical unit, normally kilogram. However, in some cases, especially for infrastructure like machines, equipment of buildings, emission factors are based on other units (e.g. m^3, unit). An appropriate conversion had to be applied in these cases. It is therefore quite important to identify appropriate factors comprising the identified position in the process chain in WP 1 (e.g. commodity or final product). Otherwise, if selected emission factors include more or less processes the results would be incorrect. Furthermore, the aim of this project was to depict the emission impacts due to technological standards and energy mixes of the countries of origin. The LCA-data are mainly available for some selected countries (e.g. Switzerland or Germany) or more frequently for regions (e.g. Europe). These had to be modified to reflect country- and sector-specific technological differences and energy mixes. For this statistical databases on world energy balances from the IEA and OECD were used. These data comprise the industrial energy mix used in 14 different branches for about 100 different countries. As a result, emission factors could be differentiated between a variety of countries and sectors around the world. This regionalization was applied to adjust the emission factors and represent the technological standard in the different sectors and countries.

Commodities-focused time series method

For the commodities-focused time series method emission factors for the key products that made up the final consumption (identified in WP 1) were selected. The following preference for the source of LCA-data was adhered to:

1. GEMIS – Austrian process chain;
2. GEMIS – German process chain; and
3. ECOINVENT-based.

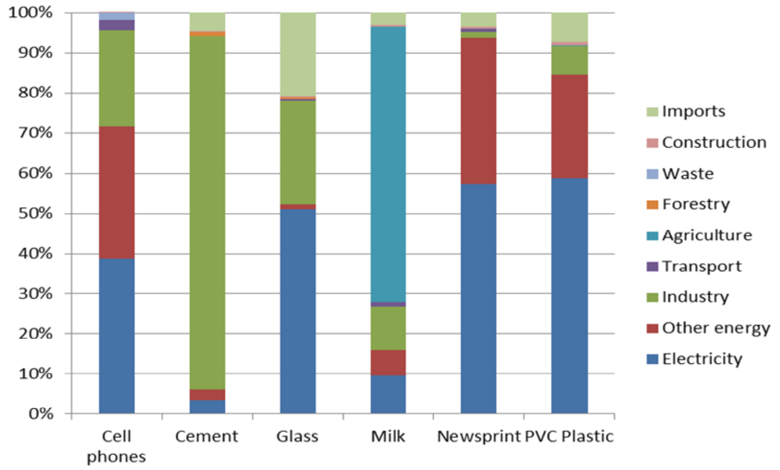
This preference was developed since there are many Austria-specific LCA chains in GEMIS; and because the emissions along the chains can be divided into:

a. those occur within Austria (or Germany for a German-based chain);
b. those outside Austria; and
c. those resulting from construction and dismantling of the commodity.

In GEMIS, the emissions occurring within Austria also can be categorised by sector. We chose eight sectors: residential and public & private services, electricity, other energy, transportation, industry, agriculture, forestry (excluding land use change) and waste. This allows for the possibility of quality control with sector emissions in the national inventory. Finally, in GEMIS the amounts of input materials, and input energy (so called "hilfsenergie") are recorded and easily extracted. This information allows for the reduction of double counting. Finally, LCA emission factors are estimated in a specific year and specific country. The combination of sectoral components to emission and input energy allowed for the easy modification of the LCA-chain to fit any given year or country of origin.

For both methods, when emission factors were attributed to all goods, they were multiplied by physical mass (or other unit) of the particular good to calculate the corresponding greenhouse gas emissions. For the emission factors, the GWP (Global Warming Potential) 100 was used as an indicator for all greenhouse gas emissions. This includes several greenhouse gas emissions (e.g. CO_2, CH_4, N_2O).

Identification of main influences and sensitivity analysis



emission factors attributable
election of products

As shown in Figure 19, for many emission factors, the main influences come from electricity and other energy. As a result, the emission factors are sensitive to electrical emission intensity and industrial energy mix. These fluctuate with time and by country. The electrical emission intensity has fluctuated by approximately 25% while the industrial other energy emission intensity has mainly reduced by 20% from 2000 to 2014.

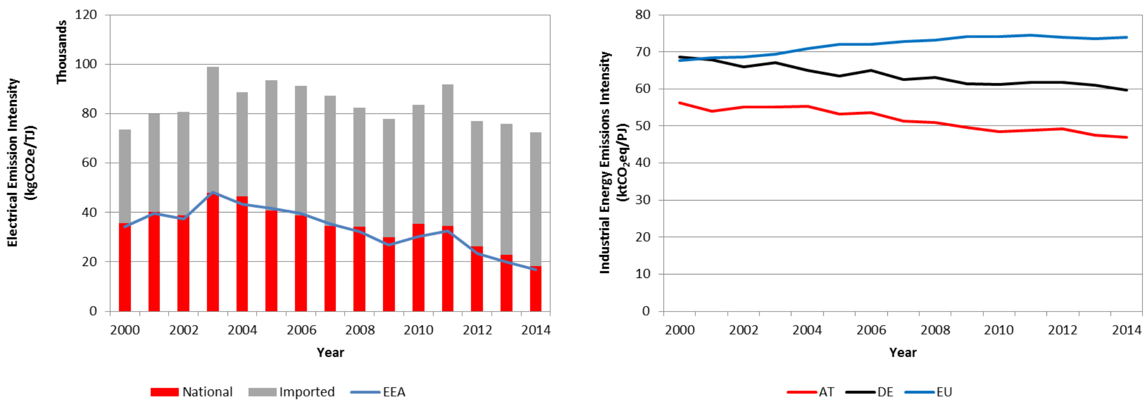


Figure 20: Electrical emission intensity - including imported electricity (left) and industrial other energy emission intensity (right) for Austria. The emission factor for Austria electricity generation as calculated by the European Environment Agency (EEA) is shown by the blue line

Development of the functional model for calculation of GHG emissions behind the consumption in Austria (WP 4)

This WP consisted of developing the framework for calculation of greenhouse gas emissions out of physical material flows (WP 2) combined with LCA-based emission factors (WP 3).

Structure of the functional model

Detailed process chain model

As a first step a rough structure of the model was developed as an Excel-model. Figure 21 illustrates the developed model in a simplified form. In general, the physical material flows of every material and product were combined with the appropriate emission factors, finally resulting in greenhouse gas emissions. Most of the data illustrated in this survey sheet were collected and edited in additional sheets, divided into material flows (further differentiated in imports, exports and national production), LCA-data and the regionalization of emission factors. Sometimes additional calculation sheets where needed as well, e.g. for imports. Besides, additional information as the attribution of materials and products to the defined process steps or to defined product-groups were edited in the survey-sheet itself.

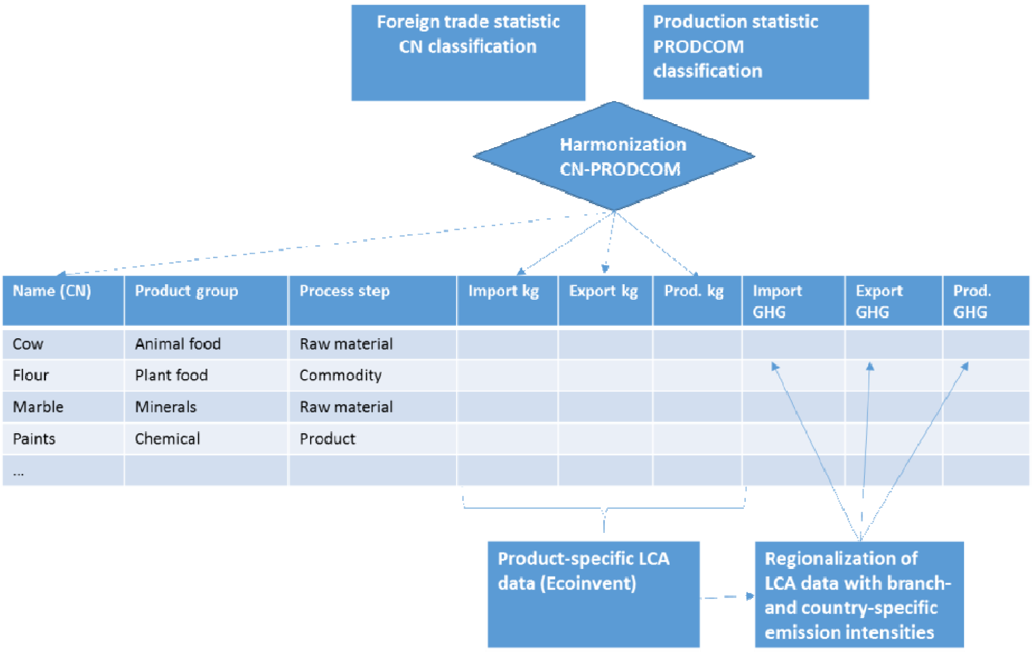


Figure 21: Rough structure of the process chain model

Consequently, the functional conjunctions make the model very complicated, but they allow that further modifications can be made without rebuilding the whole model. Behind this overview-sheet, every parameter has its own Excel-sheet(s) where the data were collected. For example, the LCA-data needs the Ecoinvent database as a basis and the attribution of LCA-data to every material and product in a next step. The material flows of imports, exports and national production were divided into different sheets as well, especially to ensure the possibility of depicting all countries Austria is exporting to and importing from. Furthermore, calculation sheets were created where the material flows where connected with the LCA-sheet finally into greenhouse gas emissions. The regionalization was then implemented into the calculation sheets of imports, exports and national production as well.

Commodities-focused time series method

The model for the commodities-focused time series method consists of two spreadsheets: one that makes the calculation without regionalisation of imports, and the second in which a correction to the import emissions due to regionalisation is calculated. The first spreadsheet consists of a worksheet for each product group (e.g. paper industry) which holds a time series of consumption, production, imports and exports. On the 19 worksheets all assumption are listed for filling missing data and sources of information are listed. There are two worksheets of emission factors: one for national production and one for imports. Germany was assumed as the base import country. The emission factors and production, import and export data are multiplied and listed on a detailed annual emissions worksheet. These data are agglomerated on the annual summary worksheet on which emissions are sorted with products and services as rows, and inland sectors, imports (both products and electricity) and construction as columns. In addition, an LCA-based estimate of the national inventory emissions are presented by sector and compared to the actual values in the national inventory. Finally a few other worksheets are included which hold auxiliary information (e.g. constants, population, economic indicators). Figure 22 displays the annual summary worksheet.

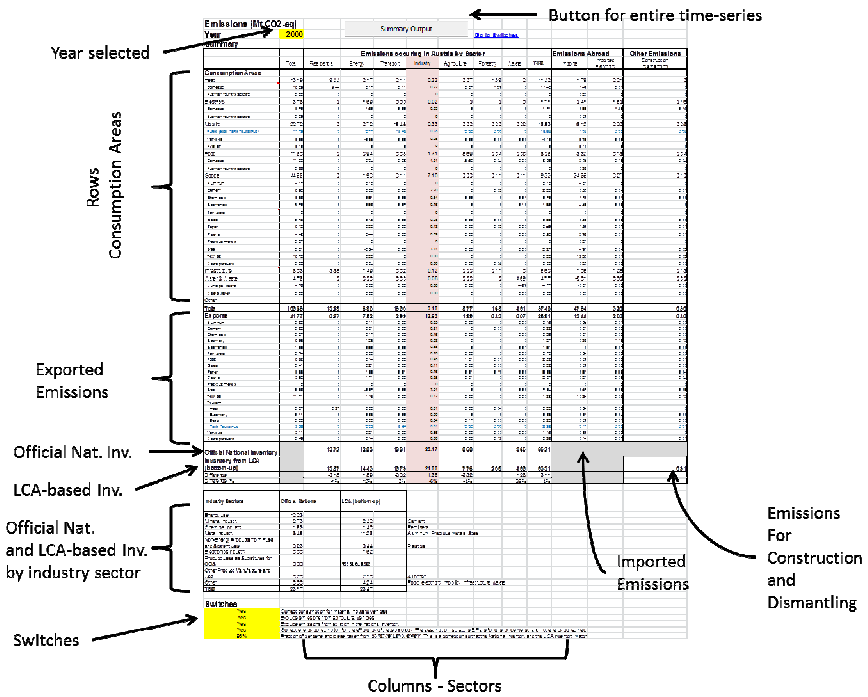
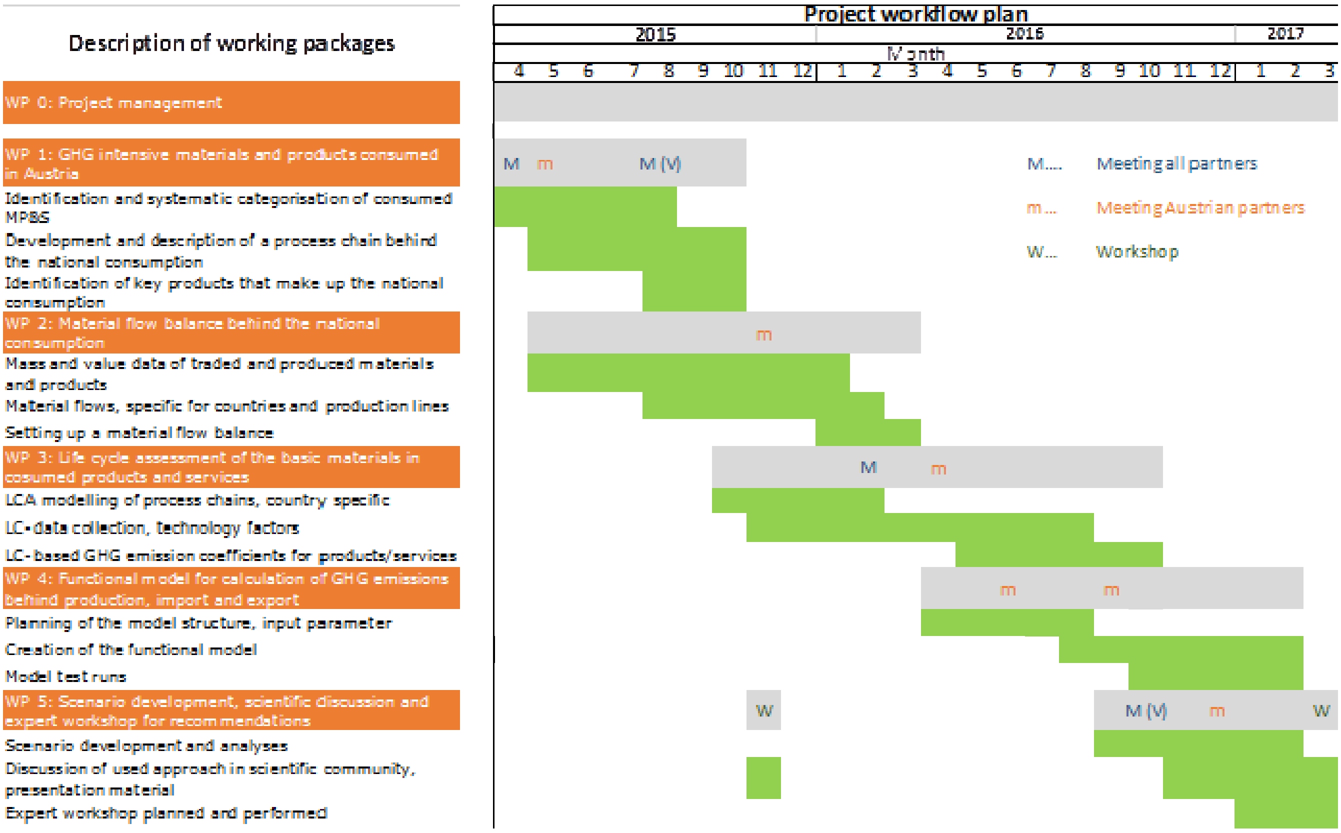


Figure 22: Annual summary worksheet – non-regionalised model for the commodities-focused time series method

7 Work and time schedule



8 Publication and dissemination activities

In the course of this project several publication and dissemination activities were carried out. On the one hand two workshops were made. The first one was an expert workshop in the middle of the project duration where different national and international scientific experts in the field of consumption based emission accounting participated. This workshop was especially to present and discuss the developed methodology focusing on detailed product level for the first time. The second workshop was at the end of the project and was focused primarily on national stakeholders where the results of the project were presented and possible ways for further applications discussed.

A dissertation is being conducted in the course of this project by Bernhard Windsperger of the Institut für Industrielle Ökologie (IIÖ), advised by O.Univ.Prof.Dr.phil. Helga Kromp-Kolb. The main emphasis of this dissertation regards the depiction of the material use and the greenhouse gas emissions behind the supply and production chains of products consumed in Austria. The development and origin of emissions and material flows shall be followed for whole supply chains, starting with the raw material up to the final product. Thus, a main part of the LCA-based process chain approach (e.g. development of the process chain behind final products) was developed in the course of this dissertation, especially focusing on the methodological principles and challenges. The main task in developing and conducting this approach has been already finished. The dissertation itself will consist of three scientific papers which will be merged in the course of a cumulative thesis.

Actually, the <u>first paper</u> (Title: Greenhouse gas emission accounting behind the national consumption of goods and products – An analysis of research needs and a methodical framework) is ready for submission to the Journal of Industrial Ecology. This paper gives an overview why product-specific emission accounting due to national consumption is of special interest and analyses the key requirements and challenges associated with such a detailed approach.

The <u>second paper</u> (Working title: Material flows behind supply chains of products consumed in Austria) will present physical material flows behind the supply chains of products consumed in Austria. This paper will be prepared during summer and submitted to relevant journals like the "Journal of Industrial Ecology" or the "Journal of Cleaner Production" in autumn.

The <u>third paper</u> (Working title: Calculation of greenhouse gas emissions behind the consumption of products in Austria based on product flows with LCA- and technology factors) will focus on the calculation of Austria's consumption-based greenhouse gas emissions on detailed product-level. This paper will be prepared in autumn and submitted to relevant journals like the "Journal of Industrial Ecology" or the "Journal of Cleaner Production" at the end of this year.

The dissertation shall be based on the papers mainly. One main emphasis will be on the merge of the single scientific papers to the final dissertation. This part will be done in the first half of 2018. The dissertation should be completed by summer 2018.

Furthermore, various presentations were conducted in order to introduce and discuss both the methodology and the results of this project in the broad scientific community and stakeholders.

- Reviewed presentation at the Austrian climate day 2016 and 2017 including a paper in the proceedings:
    - Bernhard Windsperger, Andreas Windsperger, Neil Bird, Hannes Schwaiger, Gerfried Jungmeier, Carsten Nathani, Rolf Frischknecht, Richard Guhsl, Andre Buchegger 2017. Modellierung von lebenszyklusbasierten THG-Emissionen des österreichischen Konsums. 17. Österreichischer Klimatag, 6.–8. April 2016, Graz.
    - Bernhard Windsperger, Andreas Windsperger, Neil Bird, Hannes Schwaiger, Gerfried Jungmeier, Carsten Nathani, Rolf Frischknecht, Richard Guhsl, Andre Buchegger 2017. Modellierung von lebenszyklusbasierten THG-Emissionen des österreichischen Konsums. 18. Österreichischer Klimatag, 22.–24. Mai 2017, Wien.
- Reviewed presentation at the "10. Internationale Energiewirtschaftstagung" in Vienna including a paper in the proceedings:
    - Bernhard Windsperger, Andreas Windsperger, Neil Bird, Hannes Schwaiger, Gerfried Jungmeier, Carsten Nathani, Rolf Frischknecht, Richard Guhsl, Andre Buchegger 2017. 10. Internationale Energiewirtschaftstagung an der TU Wien, 15.-17. Februar 2017.
- Submission of an abstract to present the project at the Conference "Consumption Based Greenhouse Gas Accounting: From Assessments to Policy", organized by the University of Graz and INNOVATE project partners, on Friday, October 13, 2017 / 10:00 – 16:30 at the Kommunalkredit, Türkenstraße 9, 1090 Vienna, Austria.

- In the course of the project a working group was established at the Climate Change Centre Austria (CCCA) for scientific discussion and improvement of the different methods available for consumption based emission accounting (https://www.ccca.ac.at/de/ccca-aktivitaeten/arbeitsgruppen/thematische-ags/). Furthermore, an abstract was submitted to present both the working group and the project at the "3. Symposium Konsum neu denken 2017: Konsum im Wandel – das Transformative Potenzial von Konsum" from 21.-22.9.2017 at the Alpen Adria Universität Klagenfurt.

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