Scenarios of Livestock - Related Greenhouse Gas Emissions in Austria

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Abstract

This paper compares existing livestock emissions and projections on three different spatial levels (global, European, national) and on two sets of system boundaries (inventory data and emission data considering the whole lifecycle). It aims to provide insight in the validity of scenario data of national Austrian livestock emissions. This entails the use of national greenhouse gas emission trends until 2030 – specifically for Austria – as well as EU-based assessments of country emissions up to 2050. In addition, global emission data was extracted from the Representative Concentration Pathways (RCP) database for the years 2000-2100. Extending national emission projections up to 2100 by combining different datasets connects national emission policies to international strategies. It becomes clear that the goal of keeping average global temperature rise under 2°C (represented by RCP2.6), even in the medium term to 2030 and only looking at the livestock sector, is much more ambitious than any of the national projections. Furthermore, inventory emission data is set in contrast to emission data considering the whole lifecycle of meat products in Austria, with an overview of assessments from pork and beef production. Emissions reported in inventories represent roughly half of those assigned to the livestock sector in life cycle studies.

Key words: Livestock emissions, Emission scenario, Representative Concentration Pathway, Two-degree goal, Life cycle emissions, EU climate policy,

1. Introduction

Emission inventories are a well-established way to assess the impact of anthropogenic activities on the release of trace gases to the atmosphere. In order to understand effects of radiative forcing leading to climate change and to devise possible strategies to mitigate anthropogenic emissions, it is necessary to extend such information into the future. For this purpose, scenario techniques have been established to project trends, based on current knowledge and expectations of technological innovations as well as economic developments. Multiple scenarios from different sources and relying on different expectations may guide along different possible future situations, if underlying assumptions are properly identified.

The present study compares national and European emission scenarios from the livestock sector with global scenarios. Representative Concentration Pathways (RCPs) developed in support of the International Panel on Climate Change's (IPCC) 5th assessment report (AR5) (IPCC, 2014) with projections up to 2100 constitute the global situation (van Vuuren et al., 2011a). These scenarios provide a longer-term assessment than national scenarios, which typically extend to 2030 or, as a maximum, 2050. Particular attention needs to be given to the "strong mitigation" RCP scenario, RCP2.6, the only scenario consistent with the target to limit average global warming to 2°C (IPCC, 2014; Rogelj et al., 2011). The comparisons and analyses in this paper attempt to highlight inconsistencies between the Austrian national climate strategy and the global goal to limit average global warming to 2°C. The Climate Strategy 2030 of the European Union (EU) and its member countries is arguably one of the most elaborate in the world (European Commission, 2013) and aims to follow this global goal. Emissions from livestock are a significant source of global anthropogenic greenhouse gas (GHG) emissions. Including all supporting activities ("footprints" or emissions considering the whole lifecycle), livestock is responsible for about 18% (Steinfeld et al., 2006) of total global GHG emissions.

Emission inventories as used for the United Nations Framework Convention on Climate Change (UNFCCC, 2006) allow attribution of emissions to specific economic sectors, following common data sources and expertise, with an aim to fully cover national emissions. Such a sector typically does not cover all activities related to its production needs, but instead may also contain activities required for other production outside the sector. In order to understand emissions related to a product or a process, a life cycle assessment (LCA) needs to be performed. An LCA shows all emissions along the supply chain per unit of products. For EU member countries, several studies on LCA emissions (this term will be used as synonym for GHG emissions considering the whole life cycle) from livestock products were conducted and several cover emissions from the whole livestock sector in a country (de Vries & de Boer, 2010; Leip et al., 2010; Weiss & Leip, 2012; Lesschen et al., 2011).

Inventory emissions from the livestock sector consider emission from enteric fermentation, manure management, and releases from soil - emission inventories 4A, 4B and 4D1.2 (animal manure applied to soil) and 4D2 (pasture, range and paddock manure) (UNFCCC, 2006). In Austria, 5.29% of total national emissions are from the livestock sector as defined by international inventory categories, while the whole agricultural sector (including the livestock sector) in Austria emits 8.8% of total national emissions (Umweltbundesamt, 2012; Umweltbundesamt, 2013; UNFCCC, 2006). Even without considering the whole lifecycle, livestock is a major contributor of agricultural emissions. Not including LCA emissions leaves out many opportunities of emission reduction measures, as life cycle studies of livestock include activities which are not directly connected to the sector agriculture and / or activities occurring outside a specific country (list is not exhaustive):

- the production of fodder, pesticides, fertilizers, feedstuff,
- transportation of the above mentioned and livestock itself
- slaughtering and processing of meat
- necessary energy input
- land use changes due to the production of feedstuff, etc.

Hence it can be argued that a higher share of total emissions is associated with livestock production activities and should be properly assigned (de Vries & de Boer, 2010; Leip et al., 2010; Lesschen et al., 2011; Steinfeld et al., 2006; Weiss & Leip, 2012).

This paper compares livestock emission data that have been prepared on three different spatial levels and two different system boundary settings. The next section of the study contains an overview of literature dealing with Austrian, EU-wide and global livestock inventory- and LCA emission data and a data analysis of publicly available emission data from livestock. This is followed by a methodology section, emphasizing the specific characteristics of and data extraction from the different scenarios. Furthermore, a description of scenarios is presented, obtained from the RCP database[1] on the global level, from reports provided by the European Commission for the European Union, and from national Austrian emission data and projections provided by the Environment Agency Austria. In the first part of the analysis

[1] http://tntcat.iiasa.ac.at:8787/RcpDb/

section, the focus is on a comparison of LCA emissions data from different studies on Austrian livestock (products). In the second part, inventory emission scenarios from Austria will be compared with specific Austrian scenario data from two EU-led exercises where one scenario provides inventory data and the other one emissions along the whole life cycle.

2. GHGs from the Livestock Sector on three spatial Levels

Emission inventories are using data as benchmark which is systematically derived along certain sectorial boundaries, but does not consider the whole life cycle. In the livestock sector the differences between direct emission data (inventory emissions) and indirect emission data (LCA emissions) is rather large. Inventory emissions from the livestock sector consider GHGs from emission inventories 4A, 4B and 4D1.2 (animal manure applied to soil) and 4D2 (pasture, range and paddock manure) (UNFCCC, 2006). If emissions from enteric fermentation (methane emissions from digestive systems of livestock) and manure management (methane and nitrous oxide emissions from manure decomposition processes) are considered, global emissions from livestock are 2443 Tg CO_2-eq/yr (for 2012: FAOSTAT, 2015a; 2015b). Emissions from animal grazing and manure application are 1016 Tg CO_2-eq/yr (for 2012: FAOSTAT, 2015c; 2015d). Definitions are largely (but not fully) coherent to those of UNFCCC (2006).

Livestock sector's LCA emissions, including emissions from:

- livestock's respiration[2],
- fossil fuel use (e.g. burning fossil fuel to produce mineral fertilizers, during feed production, for transport and refrigeration),
- land use changes and land degradation for feed production and grazing,
- enteric fermentation,
- animal manure storage
- soil processes of manure N applied on fields, and of N excreta from grazing animals
- soil processes involving fertilizer N in fodder production,
- upstream industrial processes (e.g. fertilizer production) (Leip et al., 2010; Steinfeld et al. 2006)[3]

[2] mentioned explicitly by Steinfeld et al. (2006)

are responsible for global GHG emissions of 4600-7100 Tg CO_2-eq/yr (Steinfeld et al., 2006). Based on global anthropogenic GHG emissions of 49000 Tg CO_2-eq/yr (± 4500 Tg CO_2-eq) (IPCC, 2014) livestock emissions represent 9.4 - 14.5% of all emissions worldwide. In 2006 global emissions from livestock production were similar to the total GHG emissions of the EU-28 (European Environment Agency, 2014a, Steinfeld et al., 2006). Figure 1 provides an overview of different classifications of the livestock sector and which emissions (from the UNFCCC reporting guideline on emission inventories) need to be considered.

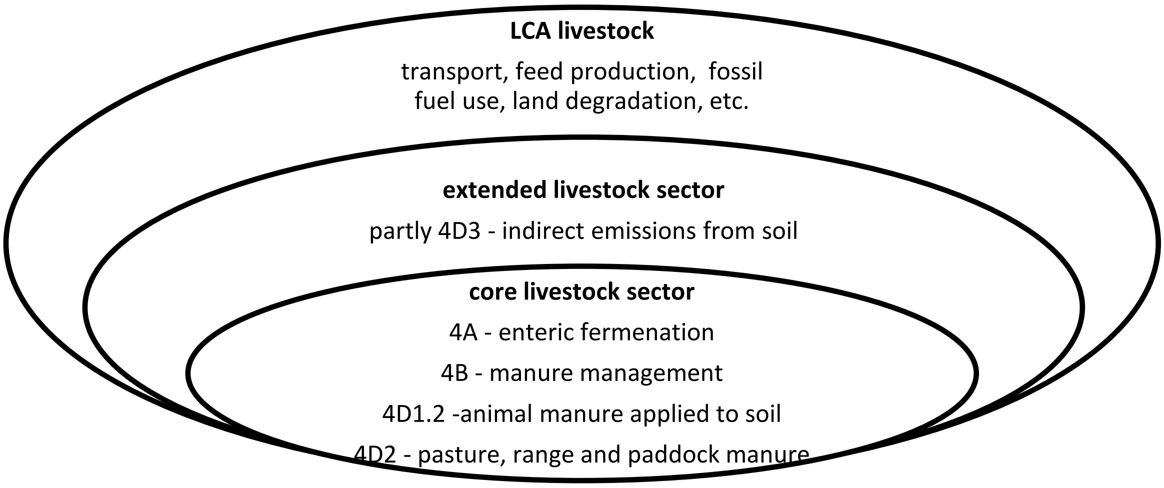

Figure 1: Possible system boundaries of attributing emissions to livestock. Defined subsectors (with codes) according to UNFCCC (2006). LCA emission categories according to Leip et al. (2010) and Steinfeld et al. (2006)

In the European Union, around 6.2% of total inventory emissions (≙ 282.5 Tg CO_2-eq/yr) are emitted in the livestock sector (emission inventories 4A, 4B, 4D1.2, 4D2,) (data for 2012, European Environment Agency, 2014a). If system boundaries in calculating livestock emissions are extended, including emissions along the whole life cycle (e.g. transport, feed-production, animal processing, etc.), emissions from the livestock sector will increase to 616 - 852 Tg CO_2-eq/yr[4] (Lesschen et al., 2011; Weiss & Leip, 2012). Compared to total EU emissions of 4558 Tg CO_2-eq (for 2011 without land use, land use change and forestry (LULUCF)) (European Environment Agency, 2014a), these life cycle emissions represent 13.5 - 18.8%.

[3] Unfortunately, not all of these emissions sources are included in all livestock LCAs, which complicates comparisons.
[4] depending on the assumptions used to calculate LULUCF emissions

In Austria the livestock sector is responsible for 5.29 Tg CO_2-eq/yr[5] (including emission inventory 4A, 4B, 4D1.2, 4D2) which roughly represents 71% of all emissions from the agriculture sector. Compared to total GHG emissions in Austria of 84.59 Tg CO_2-eq/yr (data for 2010) the livestock sector counts for 6.3% (Umweltbundesamt 2012). Information on livestock LCA emissions from Austria is provided by Leip et al. (2010) calculated with CAPRI. These estimations include emissions along the life cycle from beef, cow milk, pork, poultry, sheep and goat meat, eggs, and sheep and goat milk. For Austria this calculation leads to total emissions of 9.3 Tg CO_2-eq/yr. There are several additional studies dealing with different livestock product's LCA emissions (e.g. pork and beef) calculated for one kilogram of carcass weight (compare Kral, 2012; Winkler et al., 2015; and to some extent Hörtenhuber et al, 2014).

An overview of Austrian, European and global livestock emissions is provided in Table 1. It can be argued that inventory emissions alone represent roughly half of all emissions connected to livestock production for the EU or Austria, while globally the share might be higher.

Table 1: Inventory and LCA emissions from livestock in Austria, the EU and globally

	global		**EU**		**Austria**	
	Tg CO_2 eq/yr	Share of total GHG emissions	*Tg CO_2 eq/yr*	Share of total GHG emissions	*Tg CO_2 eq/yr*	Share of total GHG emissions
Inventory GHG emissions	3459[a]	≙ 7%	282.5	≙ 6.2%	5.29	≙ 6.3%
GHG emissions including the whole life cycle	4600 - 7100	≙ 9.4 - 14.5%	616 - 852[b]	≙ 13.5- 18.75%	9.3	≙ 11%
Sources	*FAOSTAT, 2015a; 2015b; 2015c; 2015d; Steinfeld et al., 2006*		*European Environment Agency, 2014a (data for 2012); Lesschen et al., 2011; Weiss and Leip, 2012*		*Leip et al., 2010; Umweltbundesamt, 2012*	

[a] including emissions from enteric fermentation, manure management, animal grazing and manure application (as defined by FAOSTAT)

[5] using global warming (GWP) potential as calculated for the IPCC Second Assessment Report due to consistency with the Austrian inventory report; however, using GWP values from AR5 increases national livestock emission by approx. 2 Tg CO_2-eq/yr

[b] depending on calculations of LULUCF emissions

According to Steinfeld et al. (2006) 37% of total anthropogenic CH_4 emission and 65% of total anthropogenic N_2O emissions are assigned to the livestock sector. A doubling of meat and milk production is projected between 1990 and 2050. This worldwide dietary shift towards more animal products might lead to an increase in livestock product consumption. Demographic development and technological change will enhance this consumption pattern even more. The increase of global livestock emissions from 2000 - 2030 is estimated to be 50 - 60% if no additional reduction measures will be undertaken (Hasegawa & Matsuoka, 2010). Steinfeld et al. (2006) report that every projection of meat production in developing countries is on the rise, which will lead to increased emissions from enteric fermentation and additional emissions related to land use change. These emissions constitute 85% of all emissions from livestock worldwide (see table 2). Emissions from land use change are difficult to assess and connected to a rather high uncertainty (Hörtenhuber et al., 2010).

Table 2: Global GHG emissions due to livestock rearing in CO_2-eq (including the whole life cycle, livestock processing is not included) (based on Steinfeld et al., 2006; N_2O emissions from animal production systems from Oenema et al., 2005)

Emission source	**Tg CO_2-eq/yr (best estimate)**
Fossil fuel use in manufacturing fertilizer	41
On-farm fossil fuel use	90
Livestock-related land use changes	2400
Livestock-related releases from cultivated soils	28
Releases from livestock-induced desertification of pastures	100
Methane released from enteric fermentation (in CO_2-eq.)	2150
Methane released from animal manure (in CO_2-eq.)	450
N_2O emissions from animal production systems	460*
Sum	**5719**

* includes emissions from burning dung, grazing animals, stables & storage, applied waste and indirect emissions

3. Methodology

This study uses publicly available international and national emission data and scenarios. National and European scenarios of GHG emissions from livestock have been developed and compared with the Representative Concentration Pathways prepared for IPCC's AR5.

Concept and ideas are the same as in a recent research covering emission projections from all industrial sectors by Winkler & Winiwarter (2015). The scenarios used and compared in this study have been developed on three spatial levels (national, EU, global) and two different system boundary settings (with or without consideration of the full life cycle).

On a national level, emission projections calculated by the Environment Agency Austria were used. According to the GHG monitoring mechanism (European Commission, 2005) each EU member state is obliged to provide one scenario with existing measures (WEM) and one scenario with additional measures (WAM) to mitigate emissions. The WEM scenario is based on already implemented environmental policies. The WAM scenario additionally includes policy measures which are planned and likely to be implemented in the future (Umweltbundesamt, 2013). For this study we only refer to the more optimistic (in terms of greenhouse gas emission reductions) WAM scenario for Austria.

Data for livestock emissions at the European level is provided by several studies and reports (Capros et al., 2013; Leip et al., 2010; Lesschen et al., 2011; Weiss & Leip, 2012;). Capros et al. (2013) provide inventory-oriented emission data, without considering the life cycle of livestock production. The so-called "Reference Scenario" uses a common approach for all member states using the GAINS model for non-CO_2 emission projections. Lesschen et al. (2011) calculated emissions for livestock products with the MITERRA-EUROPE model, whereas Leip et al. (2010) and Weiss & Leip (2012) used the CAPRI model; all three are considering LCA emissions in their research. Due to the fact that some factors are not fully considered by the MITERRA-EUROPE model calculations, such as emissions from feed transport, indirect emissions from feed processing and pesticide use, we chose to adopt life cycle emission data for the comparison of scenarios from Leip et al. (2010) and Weiss & Leip (2012).

Four different integrated assessment modeling groups developed the Representative Concentration Pathways (RCP), extending from 2000 to 2100 on the global scale. The purpose of these scenarios are long-term projections to "explicitly explore the impact of different climate policies [and] [...] allow evaluating the costs and benefits of long-term climate goals" (van Vuuren et al., 2011a, p. 6)". These four scenarios are characterized by the level of radiative forcing by the end of the century. The mitigation scenario, RCP2.6, is the only scenario under IPCC AR5 which gives a high certainty to reach the 2°C goal, keeping average global temperature rise under this level (see IPCC, 2014; Rogelj et al., 2011). Achieving this goal needs drastic emission reductions all over the world leading to negative global CO_2 emissions in the last quarter of this century. By 2100 CO_2 should be removed at a rate of 1Gt per year, which is only achievable through massive carbon sequestration (based on energy provided from biofuels combined with carbon capture and storage technology: van Vuuren et al., 2011b). There are two stabilizing scenarios, RCP4.5 (Thomson et al. 2011) and RCP6 (Masui et al. 2011), which lead to a radiative forcing of 4.5 and 6 W/m² by 2100 and expect a stabilization on these levels - comparable with an maximal average global temperature increase of 2.6°C, respectively 3.1°C by 2100 (IPCC, 2014). RCP8.5 is a business-as-usual scenario assuming increasing emissions until the end of the century and beyond (Riahi et al. 2011)[6]. The RCP database provides emission data from 11 reactive gases for 10 different industrial sectors on a spatial resolution of 0.5°x0.5°. In this study, we selected the grid cells with a majority of their area in Austria. The emissions of these grids were summed up to get a representative value for Austria (grid cells between 12.25° - 16.25° East and 46.25° - 48.25° North).

The two different system boundary settings are inventory emissions vs. LCA emission data. Inventory emission sectors defined by the international scientific community (UNFCCC, 2006) are used in national and international reports. Inventories only include emissions directly assigned to the livestock sector. For example transport of livestock and emissions from feed production are not included in the livestock / agriculture sector. In order to account for the overall GHG emissions, a life cycle approach needs to be undertaken. Only few reports and studies estimated life cycle emission scenarios on a larger scale (de Vries & de Boer, 2010; Leip et al., 2010; Steinfeld et al., 2006; Weiss & Leip, 2012; Lesschen et al., 2011).

4. Analysis of Livestock Emission Scenarios

A comparison of emission scenarios for Austria, the EU and international pathways (RCPs) shows that projected emissions of CH_4 and N_2O decrease (Winkler & Winiwarter, 2015). However, this analysis does not include LCA emissions. The underlying sources (RCP emission pathways as well as Austria's national emissions) have been developed as inventories and do not consider the whole life cycle.

[6] detailed information on the RCP scenarios can be found in: Masui et al. 2011 (RCP6), Riahi et al. 2011 (RCP8.5), Thomson et al. 2011 (RCP4.5), van Vuuren et al. 2011a (overview), van Vuuren et al. 2011b (RCP2.6)

Some studies are available covering the life cycle of livestock specifically for Austria. These studies consistently use one kilogram of the carcass weight[7] of pork and/or beef as functional unit (Kral, 2012; Winkler et al., 2015). More research was done on a European level and some of those studies also include data for specific EU-member states (de Vries & de Boer, 2010; Leip et al., 2010; Lesschen et al., 2011; Weiss & Leip, 2012).

4.1. Inventory Emissions vs. LCA Emissions

According to Weiss & Leip (2012) and Lesschen et al. (2011) the livestock sector in the European Union emits 616 - 852 Tg of CO_2-eq/yr (the range depends to a large extent on different weighting of LULUCF emissions). Approximately half of these emissions are created in the agricultural sector. Around 20% of livestock emissions are related to the energy sector; the rest is to a large content related to land use and land use change (Leip et al., 2010). Inventory emissions of the livestock sector in the EU are 282.5 Tg CO_2-eq/yr (data for 2012, European Environment Agency, 2014a). Inventory GHGs of livestock included emissions from enteric fermentation (CH_4), manure management (CH_4 and N_2O) and emissions from soils (N_2O).

Beef has the highest GHG emissions per kilogram of product, and the second largest emissions are from pork. The range of emissions for one kilogram of beef in different European countries is 14.2 kg CO_2-eq in Austria and 44.1 kg CO_2-eq in Cyprus (mainly due to a very high import share in Cyprus). This range can be even higher when looking at regional levels, but in most EU member countries the values are between 20 and 30 kg CO_2-eq (Leip et al., 2010). Differences between the studies may derive from the difficulty in allocation between milk and dairy production (see Cederberg and Stadig, 2003), which we did not attempt to follow up in detail.

The case of pork is somewhat simpler. One kilogram of pork has a lower global warming potential of 4.8 - 20.3 kg CO_2-eq[8] - most of the EU member states have a value between 5 and 7 kg CO_2-eq (de Vries & de Boer, 2010; Leip et al., 2010; Winkler et al., 2015; Weiss & Leip, 2012; Lesschen et al., 2011). These numbers are highly depending on practices of animal husbandry and feedstuff compositions (and imports of feedstuff) in different countries.

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[7] the weight of the carcass after slaughter and removal of the head and all internal organs
[8] using a cradle to farm-gate approach

According to Weiss & Leip (2012) Austrian beef has the lowest emission intensity (14.2 kg CO_2-eq/kg of product) of all EU member countries because of low fluxes from land-use change and high proportion of grass in the diet. Pork shows an emission intensity of 5.91 kg CO_2-eq/kg of product (including LULUCF) which is an average value in the European Union. An Austrian study by Winkler et al. (2015) include agriculture, slaughterhouse, trade, consumption and transport in their LCA and calculated the impact of one kilogram of pork meat with 4.9 kg CO_2-eq. Additionally to the research by Winkler et al. (2015) exists just one other study (Kral, 2012) which is dealing with emissions from pork and beef in Austria. Results of this study closely correspond to that of Winkler et al. (2015) and Leip et al. (2010), and additionally evaluate the impact of organic breeding of pigs and cattle. For organic breeding, Kral (2012) demonstrates that LCA emissions are clearly smaller for both meat types.

222000 tons of beef and 529000 tons of pork were produced in Austria in 2013 (Statistik Austria, 2014). Applying the specific emissions to these production figures, we arrive at emission from national beef production of 2.82 - 3.35 Tg CO_2-eq and national pork production of 1.89 - 3.13 Tg CO_2-eq, depending on the respective studies in Table 3. Total LCA emission from livestock in Austria are estimated to be 9.3 Tg CO_2-eq/yr. Approximately, about 30% of those emissions are from beef production, another 30% from milk production and around 25% from pork production. The rest accounts for further animal products (Leip et al., 2010).

Table 3: Comparison of different studies concerning different emission intensities and emissions of pork and beef production for Austria (in kg CO_2-eq/kg of meat product)

Pork			**Beef**			
529000 t of pork produced in 2013	*kg CO_2-eq/kg of meat*	*GHG emissions of national production (Tg CO_2-eq)**	222000 t of beef produced in 2013	*kg CO_2-eq/kg of meat*	*GHG emissions of national production (Tg CO_2-eq)**	*References*
	5.91	≙ 3.13		14.2	≙ 3.15	Leip et al. (2010), Weiss & Leip (2012)
	5.04	≙ 2.67		15.1	≙ 3.35	Kral (2012); conv. breeding
	4.89	≙ 2.59		-		Winkler et al. (2015)
	3.57	≙ 1.89		12.7	≙ 2.82	Kral (2012);

				organic breeding

* this data might differ from other studies as meat production numbers are from 2013

4.2. Comparison of Livestock Emission Scenarios

Projection data for future scenarios have been developed on the inventory level, but not for LCA emissions. We use publicly available data from six different emission scenarios for livestock in Austria (Capros et al., 2013; Leip et al., 2010; Riahi et al., 2011; Thompson et al., 2011; Umweltbundesamt, 2013, van Vuuren et al., 2011b; Weiss & Leip, 2012)..

In the dataset of RCP scenarios, CH_4 inventory emission data is available on a grid level to a considerable extent and offers good data comparability. The projections of the RCP2.6, RCP4.5, and RCP8.5 in figure 2 are derived from the RCP database and include CH_4 data from the agricultural sector, as defined in IPCC's AR5 (livestock-related N_2O emissions are not available). Note that these RCP scenarios show the trend for all methane emissions from the agricultural sector. As almost all methane emissions from agriculture are emitted through enteric fermentation and manure by livestock, we argue that this projection basically captures the development of the livestock-related methane emissions.

The projection from the EU report using CAPRI-model emission data (using LCA emissions) refers to livestock emissions from 2004 for Austria and livestock numbers from Eurostat. As a static emission factor had to be used, this projection essentially shows changing animal numbers based on data from the CAPRI-model (Leip et al., 2010; Weiss & Leip, 2012; Umweltbundesamt, 2013). It can be argued, that improved breeding may lead to increased per-animal emissions. Thus national projections of livestock emissions for Austria might be assumed to be higher than presented in figure 2. The EU-Reference scenario by Capros et al. (2013) uses results of the GAINS model for non-CO_2 emission projections, which is able to handle the increase of emissions at increased milk production per animal.

The scenario by the Environment Agency Austria provides a projection for livestock emission including enteric fermentation (CH_4) and manure management (CH_4 and N_2O). The national scenario in this comparison is based on inventory emission data from the national inventory report and national emission projections with additional measures (WAM) (Umweltbundesamt, 2012; Umweltbundesamt, 2013). Austrian emissions from enteric fermentation as well as from manure management are included and represent about 60% of all agriculture emission in Austria (Umweltbundesamt, 2012).

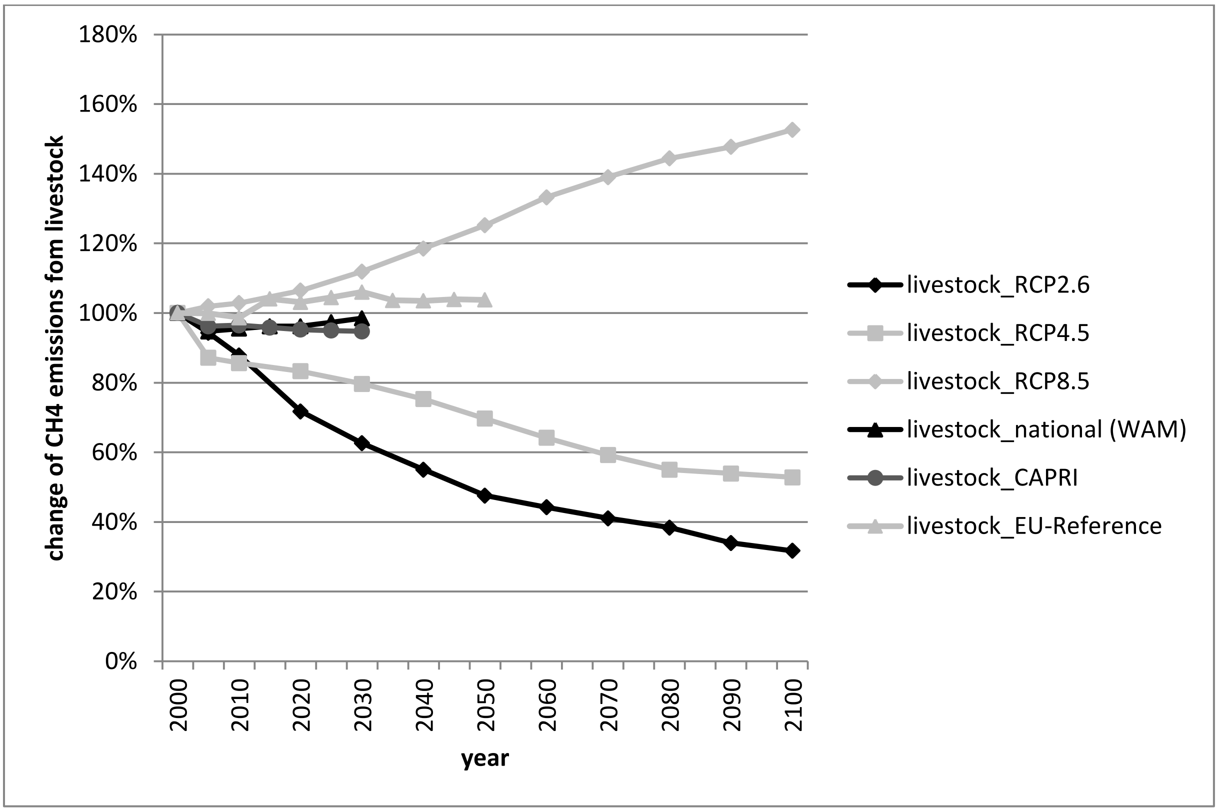

Figure 2: Trends of livestock GHG emissions in Austria (due to data availability CAPRI-model data just uses emissions from cattle and dairy cows) according to different scenarios: RCP 2.6, RCP 4.5, RCP 8.5 (all RCP data is inventory emission data); national-WAM scenario 2013 (inventory emission data); CAPRI-model data for Austria (note these are life cycle emissions, roughly twice as high as the inventory emissions); EU-Reference scenario 2013 (inventory data). Data derived from van Vuuren et al. (2011b); Thompson et a. (2011); Riahi et al. (2011); Umweltbundesamt (2012); Umweltbundesamt (2013); Weiss & Leip (2012); Capros et al., (2013), respectively.

Comparing the national (WAM) scenario with the RCP scenarios for Austria it is obvious that national (WAM) projection i) indicate rising emissions which ii) will turn out higher than RCP2.6 and RCP4.5. Also the total CH_4 emissions from agriculture show an increase in the national WAM scenario (not shown in figure 1) (Umweltbundesamt, 2013). It needs to be noted that the RCP projections do not include N_2O emissions from manure management. The EU-Reference scenario is above the national (WAM) scenario and indicates an emission increase from livestock until 2050. The differences between the EU-Reference scenario and the national (WAM) scenario can partly be explained by different estimations of livestock numbers (Umweltbundesamt, 2013). The CAPRI-model projection reflects changes of animal numbers only which makes it harder to compare it with national or international pathways. The trend line shows a decrease of less than 10% until 2030. The scenarios using European data for Austria and the national (WAM) scenario show emission pathways which are far away from the mitigation scenario of the RCP, RCP2.6. The national (WAM) projection is still above the level of RCP2.6 and RCP4.5 which leads to the conclusion that the Austrian livestock sector still has the potential to reduce emissions. RCP2.6 is the only RCP scenario considered to reach the 2°C target (IPCC, 2014). Therefore, it seems that Austrian livestock emissions are clearly not on a pathway to reach this goal. The Austrian projection is between RCP4.5 and RCP8.5 and can at the best be seen as an element towards a stabilizing scenario.

National CH_4 emissions from the whole agriculture sector have decreased by 14.2% since 1990 (Umweltbundesamt, 2012). Several measures targeted at emission reductions have either already been implemented or are currently planned. National estimations assume that the highest reduction potentials can be obtained from fermentation (anaerobic digestion) of liquid manure. Also international studies show similar results and identified high potentials of emission reduction in manure management (Hasegawa & Matsuoka, 2010). This technology can enhance the methane production from manure, and allows collecting and purifying methane to make it a useful product, while currently it is just released into the atmosphere as a greenhouse gas. The emission reduction potential of methane in Austria is projected to be about 149 Gg CO_2-eq annually by 2020 (European Environment Agency, 2014b; Umweltbundesamt, 2013) or 3.5% of the CH_4 emissions of the agricultural sector. A list of further measures, more than methane, is provided in table 4.

Table 4: Emission reduction measures considered in the Austrian WAM scenario for the livestock sector (data derived from: European Environment Agency, 2014b; Umweltbundesamt, 2013)

Measures in the livestock sector (for WAM-scenario)	**Total GHG savings by 2020 in Gg CO_2-eq/yr**
Coverage of slurry storages	3
Fermentation of liquid manure	149
Sustainable N management	21
Adapted feeding (in phases) for pigs in order to reduce N_2O/NH_3-emissions	4
Decoupling of premiums for suckling cows	2
Promotion of grazing for cows and suckling cows	1
Emission reduction potential in Gg CO_2-eq	180

Probably the best way of having a long-term effect on emission reduction from livestock (and agriculture) is a change in human diets. Westhoek et al. (2014) calculated the effect of a European decrease in meat products and the resulting increase in cereals. In their best-case scenario (50% reduction of meat products in a so-called 'greening' scenario[9]) emission reductions from the whole agriculture sector was 42% (≙ 196 million tons of CO_2-eq/yr).

5. Conclusion

The current study provides insights in to Austria's livestock emission and how national climate policy measures might influence these emissions. National inventory emissions from livestock are in line with the EU Climate Strategy 2030, which is one of the more ambitious climate strategies in the world. In the analysis it becomes clear that livestock emissions in Austria are increasing, in contrary to the anticipated decrease in the international RCP2.6 scenarios. The RCP2.6 scenario, which according to the IPCC AR5 is the only scenario able to reach the 2° target, might not be a reachable target for Austria's livestock sector, even though (or maybe because) emissions per kg of beef is remarkably low in Austria compared to other EU member states. Comparing LCA emissions with inventory emissions show (over all three spatial levels) that inventory emissions just consider roughly half of all emissions connected to livestock. Unfortunately, LCA emission scenarios on any spatial level are missing and also the scenario data used in this study is working with fixed emission intensities and therefore more research is definitely needed. However, the fact that livestock emissions (inventory- and LCA emissions) in Austria are higher than the RCP2.6 pathway could theoretically be compensated by higher emission reductions elsewhere – but a more general analysis (Winkler & Winiwarter, 2015) already shows that this is not the case. Thus it is worth noting that these national scenarios, per se insufficient in their ambition, go in line with the EU Climate Strategy 2030.

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[9] reduced N-fertilization, increase in biodiversity, arable land for animal feed is converted to perennial bio-energy crops (for more information see Westhoek et al., 2014)

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