Accounting for Accounting: Perspectives on the Notion of Green Growth

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A B S T R A C T

Ecological modernisation in the form of green growth is the perhaps most prominent discourse in environmental policy globally (Dryzek, 2013). At the same time, however, questions of limits to economic expansion and growth on a planet with finite natural resources have been at the core of environmental discourses at least since the 1970’s.

In efforts to reconcile notions of ecological limits with the concept of green growth, recent literature suggests that green growth is only ‘green’ if operating within planetary boundaries, distinguishing between green growth as ‘greenwashing’ and genuine green growth (Stoknes and Rockström, 2018). Focusing on emission productivity, this literature highlights Nordic countries including Denmark as examples of the latter. However, such claims do not properly address issues of scoping and fairness inherent to the UNFCCC territorial carbon accounting regime and critics point to the importance of considering consumption-based emissions. In this thesis, I engage with criticisms of the territorial accounting framework, illustrating how claims of genuine green growth in Denmark, are partial and misleading. This is related to the multi-faceted task of calculating national-level emissions. I therefore also explore different elements of and differences in consumption-based estimates. Building on that, I estimate what future changes in efficiency are necessary to qualify as genuine green growth if GDP and consumption is to increase in the future.

Finally, discussing shortcomings of the definition of genuine green growth, I make suggestions for extending the definition and reflect on it as a policy goal. The analysis illustrates that the notion of genuine green growth as defined in recent literature is not a desirable climate policy target.

Keywords: Green growth, carbon accounting, climate policy targets, consumption-based emissions, EEMRIO-analysis, climate governance.
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Preface

At the time of writing this preface, the global, European and Danish economy is facing recession in the wake of the COVID-19 pandemic. In its June 2020 projections, European Central Bank expects Euro area GDP to decrease by 8.7% in 2020, around 10 percentage points lower than the March 2020 projections (ECB 2020a; 2020b). At the same time, COVID-19 policies are affecting GHG emissions, drastically altering energy demand patterns. Daily global CO2 emissions decreased by as much as 17% by early April 2020 compared to the mean 2019 levels while at peak emissions decreases reached 26% on average (Le Quéré et al., 2020). Considering the entire year, this is expected to lower emissions by 4-7%.

As this thesis offers perspectives on green growth, one could expect the above to potentially influence results and demand new perspectives. After all, two of the most important measures in terms of green growth are GHG emissions and GDP. In fact, I myself was quite concerned my analysis would be obsolete at the time of hand in. I anxiously send my supervisor an email including the discussion point ‘does COVID-19 change anything’ for our upcoming meeting. Soon hereafter I received a reply: ‘I don’t think COVID19 should change anything in your analysis. You can always mention it at the end/intro to your thesis’. This preface is written in that spirit, mapping out why COVID-19 does not alter my arguments and conclusions in what follows (I always thought the rather informal preface section was an engaging part of thesis and book writing).

In my analysis, I use long-term growth projections and consider climate policy goals in a longer time horizon spanning years out into the future. Because the emission budget is constantly shrinking, estimates needs to be constantly revised. The same goes for estimates in this thesis. However, this is not the same as changing analytical principles. Moreover, the impact of COVID-19 on GDP growth and GHG emissions is likely to not alter my results significantly. Although economic growth is projected to decline in 2020, the recession is not projected to endure. Some even expect a ‘V-shaped recovery’ (Smith, 2020; Wilson, 2020) and a quick return to pre-COVID-19 levels of economic market activity. In this regard, the European Central Bank expect economic growth in the Euro area of 5.2% (up from 1.3% in the March 2020 projections) in 2021 and 3.3% (up from 1.4%) in 2022 (ECB 2020a; 2020b). The nature of exponential growth means that in absolute numbers, one year-changes will not alter long-term trends markedly. Additionally, and perhaps more importantly for this thesis, policymakers call for the need for green growth in the light of COVID-19 (Jørgensen & Kollerup, 2020).

In terms of climate change, the decrease in emissions due to COVID-19 has little to no effect on global warming. Because climate change is a ‘cumulative problem’, as leading climate scientist Glen Peters (2020) tweeted May 12, 2020, what matters is emissions over time. Although daily emissions have decreased substantially, cumulative GHG emissions
have not. Citing Peters, because cumulative CO2 emissions will only change by -0.1%, the effect on global average temperature due to COVID-19 is ‘undetectable’. Yet, the need for postcrisis fiscal stimulus offers an opportunity to effectuate investments at a massive scale (Allen et al., 2020). In the terminology of historical institutionalism, it constitutes a critical juncture, opening the leeway for institutional change. A critical juncture, however, is not transformative change. What we can only hope, is that it will be the backdrop against which positive transformative change will take place.

This thesis concludes my five years as a university student. In it, I take an interdisciplinary approach, drawing from the variety of academic fields I have been lucky to engage with over the years. I take inspiration from my courses in political economy and philosophy at Copenhagen Business School, environmental economics at Monash University, environmental governance and energy economics at Cornell University as well as development studies and computational methods at University of Copenhagen to mention the perhaps most important ones. I hope the results demonstrate some of the merits of engaging with multiple disciplines and that one can sense both the engagement, passion and frustration that went into writing it.

Joachim Peter, June 2020

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1. Introduction

Think of the power that standards have and must have over all of us. Ask yourself who established those standards and what justifications they used in establishing them. Think of who wins and who loses as a result of standards. Think of what virtues and vices are made manifest through standards. Ask yourself whose rights are supported and whose rights are abridged as a result of standards. And, perhaps most important, ask yourself how standards might be used, modified, or transformed to produce a more just and caring world.

– Lawrence Bush (2011, p. 309)

As global carbon emissions has continued to rise (Peters et al., 2020; Friedlingstein, 2019), the amount of extreme weather events increases (Hansen et al., 2012) and manifestations of tipping points are observed (Lenton et al., 2019), the future consequences of climate change seem ever closer and ever direr. To combat this, a global goal of keeping temperature increases to 1.5-2.0 °C stated in the Paris Agreement (2015) enjoys international support. The question that follows, then, is how to drastically reduce emissions. The most prominent policy-oriented discourse globally to avert climate change and other ecological challenges is ecological modernisation, in practice often referred to as green growth (Dryzek, 2013). The notion of green growth promises continued economic expansion alongside environmental improvements. In this context, the Nordic countries are often highlighted as success stories (Dryzek, 2013). One such example is the political economy of Denmark, which has displayed steadily decreasing greenhouse gas (GHG) emissions over time alongside economic growth. Accordingly, Denmark is by some argued to have demonstrated green growth (Stoknes and Rockström, 2018).

The notion of green growth, though, is rather vague and elusive. What does it mean to be ‘green’, and along which dimensions should we evaluate such claims? In other words, how is green growth measured? How is it specified, operationalised and translated into reality? In terms of climate change, a prevailing answer to conceptualise adequate and necessary action is by focusing on the goals in the Paris Agreement. In this regard, Denmark is also a noteworthy example. In fact, Denmark is argued to have demonstrated ‘genuine green growth’ (Stoknes and Rockström, 2018), meaning that the historically displayed decoupling (of GHG emissions from the gross domestic product) is sufficient to stay within the 1.5-2.0 °C target. Importantly however, such narratives are fiercely challenged by a range of scholars who posit that not only is there no good historical evidence of green growth, green growth as a goal is also misguided (D’Alisa, 2014; Hickel, 2019a; Jackson, 2017; Kallis, 2011; Victor, 2019).

One major criticism against green growth is that evidence of substantial decreases in GHG emissions relies on the current carbon accounting regime under the United Nations Framework Convention on Climate Change (UNFCCC) defined in the Kyoto protocol. This carbon accounting framework captures emissions that occur within national territories, thereby leaving out emissions embodied in imports favouring.
Therefore, within this accounting framework, countries can achieve emission reductions through outsourcing relatively emission intensive industries. Ignoring emissions from upstream production outside domestic borders generally benefits the Global North with relatively high carbon footprints while disfavouring of the Global South (with relatively high territorial emissions) (Aichele & Felbermayr, 2012; Boitier, 2012; Rothman, 1998; Xu & Dietzenbacher, 2014). In this sense, the territorial accounting framework enables rich and powerful actors to distance themselves from the responsibility of addressing environmental degradation associated with consumption. Shedding light on such relations, attention has been given to quantifying and addressing the spatial disconnect between the places of production from the places of consumption. This is illustrated by increased emphasis on different ecological footprint estimates, the derivation of these and how to integrate such indicators in policy (see e.g. Giljum et al., 2019; Majeau-Bettez et al, 2016; Peters & Hertwich, 2008a; 2008b; Wiedmann et al., 2006; Wiedman & Barett, 2013 and references therein).

Faced with the task of de-carbonization, setting (and enforcing) absolute emission reduction goals is of utmost importance (Haberl et al., 2020). In Denmark, a parliamentary majority has agreed to a legally binding climate act, stipulating a 70% reduction of carbon emissions by 2030 compared to 1990 levels, aiming for net zero in 2050 (Danish Ministry of Climate, Energy and Utilities, 2019). According to the Danish Council on Climate Change, the national reduction target is ‘in reasonable accordance’ with the 1.5-2.0 °C target if distributing the global carbon budget evenly across the world’s population (2019, p. 12). Reaching this target corresponds to territorial emissions of around 4 tons CO2-equivalents (CO2e) per capita. Claiming that this is in ‘reasonable’ agreement with the Paris Agreement as done by the Danish Council on Climate Change, however, crucially relies on territorial GHG inventories. Therefore, the reduction target faces criticisms. In fact, Lund et al. (2019) estimate that from a consumption-based perspective, national emissions in 2030 could remain as high as 9 ton CO2e per capita, even if the official 70% reduction target is reached.

1.1 Contribution, research questions and structure of thesis

In this thesis, I explore how the ways emissions are accounted matter for notions of green growth, climate governance and emission reduction targets. Specifically, I apply different accounting rules when assessing emission productivity over time. I demonstrate that suggestions of genuine green growth (GGG) rely on a territorial approach to carbon accounting, which leaves out important fairness and scope issues. As such, highlighting Denmark as an example of GGG is, at best, partial and misleading.

1 I thus focus on climate change and pay less attention to other dimensions of green growth. I mention this up front to make aware of this delimitation and discuss this issue in further detail in section 5.
However, important differences in estimates arise not only between but also within accounting frameworks. For the consumption-based approach, divergences between different consumption-based emission accounts is a focus of the literature on Environmentally Extended Multi Regional Input Output Modelling (EEMRIO) (see sections 3 and 4.2). Indeed, taking the full scope of global supply chains into account when assessing the economy-wide environmental impacts of consumption is no easy task. In theory, the number of upstream layers is infinite and spans across geographical and temporal scales (Kitzes, 2013). To create and ensure transparency in the emission inventories that inform climate policy, we need to understand what drives differences in national-level GHG estimates. This also helps adopting consumption-based indicators to inform policymaking and climate governance. Otherwise, diverging messages in terms of the overall level of emissions between different multi regional input output models complicates adopting demand-based perspectives. Therefore, this thesis also aims to shed light on discrepancies amongst consumption-based estimates for Denmark, assessing what elements in data collection, construction and analysis contribute to divergences.

Furthermore, I consider how different accounting rules within and between production- and consumption-based systems matter for policy targets and future carbon trajectories in relation to economic growth for the political economy of Denmark. If economic growth is to continue, what are the necessary increases in emission productivity (the inverse of emission intensity) over time in order for emissions to stay within the 1.5-2.0 °C target? Is the criterion of GGG as put forward by Stoknes and Rockström (2018) sufficient in this regard? Relatedly, how does the emission intensity of expenditure need to change over time to ensure sufficient reduction in consumption-based emissions? I end my thesis by discussing my analysis and the notion of genuine green growth, asking the question: what does it take to be genuine? I argue that GGG-criteria is inadequate to ensure sufficient decoupling and that the concept of GGG leaves out important considerations of scope, questioning its appropriateness as a climate policy target. I relate my discussion to critiques of the gross domestic product (GDP), the climate policy solution space and address the conundrum of GHG accounting\(^2\), suggesting disclosure of consumption-based emissions alongside territorial emissions to increase transparency.

Taken together, this thesis seeks to contribute to the literature on carbon accounting and consumption-oriented perspectives on climate governance by directly relating these to green growth. A novel element is the discussion of the concept of GGG and the suggestions for how to revise it in light of the presented analysis. I bridge discussions on green growth, the dominating approach to climate policy (Dryzek, 2013; Schröder and Storm, 2018), and GHG accounting rules and frameworks, discussing how they relate. In doing so, I show how carbon accounting methodology is an extremely important

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\(^2\) I use carbon, emission and GHG accounting interchangeably, referring to accounting of greenhouse gasses, aerosols or a precursor of a greenhouse gasses or aerosols that influence Earth’s climate system.
driver in deciding policy targets in relation to the 1.5-2.0 °C goal. In this sense, my thesis relates to the call made by various critical scholars to study and make visible structures that sustain unequal ecological exchange and thereby imperial modes of living (Hanaček et al., 2020; Brand & Wissen, 2018). My contribution aims to build on the call for consumption-based policy perspectives in Danish climate policy (Lund et al., 2019).

Main research question:

How do different GHG accounting rules and frameworks shape claims of green growth and influence what future developments to consider in line with the 1.5-2.0 °C target for Denmark?

Sub-questions:

i. How has emission productivity in Denmark changed over time under different carbon accounting rules and to what extent do these developments exemplify genuine green growth?

ii. How do different emission estimates for Denmark differ under the consumption-based accounting framework, and what elements vary between estimates?

iii. What efficiency improvements are required for the political economy of Denmark to be in line with the 1.5-2.0 °C target under different accounting rules and frameworks?

iv. In what ways is the concept of genuine green growth (not) a desirable climate policy target?

The thesis is structured as follows. In section 2, I introduce the main carbon accounting frameworks and consider these in a historical perspective. Additionally, I shed light on the importance of different accounting rules within production-based perspectives. I then introduce theoretical perspectives to make sense of different approaches to carbon accounting. Lastly, I address the definition of green growth and introduce the concept of genuine green growth, situating it within the discourse of ecological modernisation. When doing so, I also review relevant related. In section 3, I map out how to estimate consumption-based emissions, review limitations to this approach and introduce the databases used in this thesis. In section 4, I consider whether Denmark is an example of GGG, try to make sense of differences in consumption-based estimates and explore the relationship between growth and improvements in efficiency. Here, I estimate necessary increases in efficiency for Denmark under different accounting rules and systems. I tie the thesis together in section 5, discussing my results, the notion of (genuine) green growth and climate policy as well as carbon accounting more generally. I end my thesis by concluding and calling for further deliberation in climate governance going forward.
2. Carbon accounting, GHG embodied in trade and the notion of GGG

Once we make clear that quantification is fundamentally social – an artefact of human action, imagination, ambition, accomplishment, and failing – the ethical implications and possibilities of quantification become more visible.

— Espeland and Stevens (2008, p. 431)

Consider the situation of ordering a meal at a restaurant. Depending on your order, be it with or without (red) meat, locally sourced or imported from elsewhere in the world, with produce grown using specific farm practices (e.g. conservation agriculture\(^3\)), the meal will vary in a range of different aspects. In addition to features that prompt sensory impressions, these include economic and environmental dimensions, perhaps most prominently economic value (measured in monetary terms) and carbon footprint (measured in CO2 equivalents). Notwithstanding disagreement on whether price and hence monetary value is a result of individual preferences or social and political forces (Beckert, 2011), the price charged for the meal is readily available and appear in the restaurant’s financial statement. Contrastingly, the carbon footprint is not as easily obtainable; several challenges are involved in the science of establishing a specific number that reflects the amount of CO2 equivalents embodied in certain (food) products (Finkbeiner, 2009). Yet, not only is it technically challenging to estimate carbon footprints, different actors also seek to use such footprints politically to obtain discursive and material ends (Freidberg, 2014). Still, few would oppose that a certain level of carbon emissions, a carbon footprint, is associated with a given meal, and if we are to reach climate targets, quantifying emissions seems like an obvious place to start. After all, achieving the necessary reductions in emissions requires more sustainable consumption patterns (Bjørn, et al., 2018; Steffen et al., 2018). Luckily, carbon footprints are matters of empirical investigation and as soon as these are settled, we can use this data to inform policy. Or can we?

In the example above, GHG emissions are seemingly independent of the buyer involved in the transaction as well as politically constituted boundaries. The carbon footprint instead depends on carbon and energy intensity in production and transportation. However, contemplate shortly the same situation from a production-based perspective: only if the produce is sourced domestically does GHGs associated with cooking the meal enter national emission accounts (in that case also the full price of the meal is recorded in national GDP). In contrast, if the produce is imported, emissions from production should be reported in the emissions of the exporting political economy and only the value added by the restaurant is reflected in the GDP of the nation in which the restaurant is located. By a similar vein, if a tourist buys the meal, it is technically

\(^3\) Conservation agriculture encompasses three crop management principles including minimum soil disturbance, permanent soil cover and crop rotation said to help improve food security and minimize environmental impact (Palm et al., 2014; Pittelkow et al., 2015)
considered an export and from a consumption-based perspective thus no longer a part of national carbon emissions. In addition, paradoxically, some emissions are not accounted in national emission inventories of neither the importing nor the exporting country. This is the case for GHGs from upstream international transportation despite the fact that the price paid for such services is reflected in the GDP of the operating country.

2.1 Carbon accounting 101: Definitions and historical developments

2.1.1 Definitions

The UNFCCC framework reports domestic emissions\(^4\) meaning ‘the amount of carbon embodied in the vector of goods produced on a nation’s territory’ (Aichele and Felbermayr, 2012, p. 336). This is different from emissions emitted within a country’s economic definition. Because some emissions attributable to ‘resident institutional units’ occur outside a nation’s territory, such as emissions from fishing vessels or international transport, differences arise (Peters & Hertwich, 2008b, p. 54). In this regard, Peters and Hertwich (2008b) distinguish between an ‘economic’ and a ‘geographic’ approach to production-based GHG accounting. The geographic approach corresponds to the domestic or territorial frame work in the Kyoto protocol while the economic approach is in accordance with national economic accounts. In that sense, the economic approach to production-based emissions includes but extends beyond territorial emissions. To avoid confusion, I refer to the geographic approach to production-based emissions as territorial or domestic emissions (\(E_{\text{terri}}\)). Contrastingly, I use the term production-based emissions (\(E_{\text{prod}}\)) to refer to GHG emissions from resident institutional units (the economic approach) unless otherwise stated. I thereby distinguish production-based emissions from territorial or domestic emissions in line with Wood, Grubb et. al. (2019). However, when referring to production-based approaches to GHG accounting in plural, I mean all ‘system[s] (…) assign[ing] the responsibility to the producer of the pollution’ (Peters & Hertwich, 2008b, p. 55).

As opposed to production-based emissions, the carbon footprint of any political economy refers ‘to the flow of CO2 emissions caused by domestic absorption (i.e., consumption and investment) activities’ (Aichele and Felbermayr, 2012, p. 336). To get consumption-based emissions, one needs to correct production-based emissions for the so-called emission transfer, referring to net emissions embodied in trade. Consumption-based emissions correspond to the carbon footprint\(^5\) and are distinct from production-based emissions\(^6\). Consumption-based emissions are computed as follows:

\[
E_{\text{cons}} = E_{\text{prod}} - E_X + E^M
\]  

\(^4\)To avoid excessive repetition, I use the terms territorial and domestic emissions interchangeably.

\(^5\)In the context of this thesis, I will therefore use them interchangeably.

\(^6\)Whether be it using a given country’s economic or geographic definition.
Where $E^{\text{cons}}$ is national consumption-based emissions, $E^{\text{prod}}$ is production-based emissions, $E^X$ is the emissions embodied in exports and $E^M$ is the emissions embodied in imports (Peters & Hertwich, 2008b). Thus, to get to $E^{\text{cons}}$, we need to subtract $E^X$ and add $E^M$ to $E^{\text{prod}}$. The difference between $E^X$ and $E^M$ is the emission transfer, $ET$, also known as the ‘balance of emissions embodied in trade’ (Muradian et al., 2002). Correspondingly, surplus countries with a positive net emission transfer, i.e. $E^X>E^M$, are labelled ‘net carbon exporters’ while deficit countries with negative net emission transfers in this terminology are known as ‘net carbon importers’ (Peters, Minx et al., 2011; Schröder and Storm, 2018). In theory, the sum of $E^{\text{cons}}$ should equal the sum of $E^{\text{prod}}$, i.e. \( \sum_r E^{\text{cons}}_r = \sum_r E^{\text{prod}}_r \) and adding up $ET$ should sum to zero, \( \sum_r ET_r = 0 \) (Aichele and Felbermayr, 2012). Although various combinations of production-based and consumption-based national GHG inventories are possible (Peters & Hertwich, 2008b), I focus on these two main frameworks.

2.1.2 Historical developments

From a historical perspective, the global distribution of carbon emissions is linked to the de-industrialization of the Global North and the globalization of supply chains. This includes offshoring and displacement of emission intensive activities coupled with continuous and increasing consumption (Boitier, 2012; D’Alisa et al., 2014; Peters, Minx et al., 2011; Wood, Neuhoff et al., 2019). This development dates to the 1980s and is characterised by stagnation and/or decline of per capita territorial emissions as well as increased production-based emissions in the Global South coupled with an increased amount of emissions embodied in trade (Peters, Minx et al., 2011; Peters et al., 2012; Wood et al., 2018; Xu & Dietzenbacher, 2014). For example, Xu and Dietzenbacher (2014) find that the amount of emissions embodied in trade has increased at a higher rate than global emissions in the period from 1995-2007. More specifically, using data from the World Input–output Database (WIOD), they find that the ratio of emissions embodied in trade to emissions in global production has increased been steadily increasing from 24% in 1995 to 33% in 2007.

Considering an even longer time horizon and relying on data from multiple EEMRIO models\(^7\), Wood, Grubb et al. (2019) illustrate developments in carbon accounts dating

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\(^7\) As mentioned in the introduction, estimates vary between models. To address such concerns, Wood, Grubb et al. (2019) rely on five leadings models by assessing the mean and variance of consumption-based carbon estimates, considering relative change over time. Specifically, they calculate the mean change across models relative to a benchmark value, which is the average of 2007 estimates (a central year across models) for five different models. To normalise from the base year (which is the average of model results in that year):

\[
CA_{t}^{\text{norm}} = g_{m,t,r} \times CA_{t-1}^{\text{norm}}
\]

Where $CA_{t}^{\text{norm}}$ is the normalised carbon account in year $t$ and $g_{m,t,r}$ is the growth rate for model $m$ in year $t$ in country $r$. Such normalisation reduce variation between models to five percent or less for major regions considering relative standard deviation (i.e. the standard deviation as a percentage share of the mean). The ‘harmonised’ model is then defined as the mean of normalised carbon accounts from the five different MRIO databases. For more, see Wood, Grubb et al. (2019) and Wood, Moran et al. (2019).
back to the 1970s. This provides an overview of global trends (see figure 1), using the distinction between OECD (Organisation for Economic Co-operation and Development) and non-OECD countries as a proxy for ‘south-north’ emissions transfers. I.e., assessing the net emission CO2 transfers to OECD from non-OECD members in an effort to capture the emissions embodied in trade between the Global North and the Global South. Specifically, the ‘south-north’ emission transfer reflects the carbon emissions associated with production and transportation of goods and services exported from non-OECD countries and consumed in OECD countries ($E^X_{NON-OECD}$) minus emissions from production and transportation of goods and services imported from OECD countries and consumed in non-OECD countries ($E^M_{NON-OECD}$) (Peters, Minx et al., 2011; Wood, Grubb et al., 2019):

$$E^X_{NON-OECD} - E^M_{NON-OECD} = ET_{south-north}$$ (2)

Thus, a positive ‘south-north’ transfer signifies that the Global North is a net importer of embodied emissions through trade. Perhaps not surprisingly, the ‘south-north’ transfers increased tremendously from over the considered period from around zero in the 1970s to over 2 GtCO2/y in 2006. In the period 1990-2006, emission transfers increased more than four-fold from around 0.5 to more than 2 GtCO2/y. These findings illustrate outsourcing, trade liberalization (Wood, Grubb et al., 2019), and more generally tendencies typically grouped under the term economic globalization, i.e. ‘the emergence and operation of a single, world-wide economy’ (Grieco & Ikenberry, 2003, p. 207; McGrew, 2017).

**FIGURE 1:** Production and consumption-based CO2 emissions and net ‘south-north’ emission transfers, OECD (green) and non-OECD (blue), 1960–2016

Source: Wood, Grubb et al. (2019, S18)
Interestingly, the south-north emission transfer seemed to have peaked shortly before the time of the global financial crisis and reaching a plateau in recent years. The recession that followed the crisis decreased emissions embodied in imports in OECD countries (the reduction in consumption-based emissions is higher than the reduction in production-based). Relatedly, emissions embodied in trade as share of global emissions have followed a pattern similar to the south-north emission transfer, peaking in 2008 (see figure 2). This is despite trade increasing in monetary terms, pointing to declining emission intensity in traded goods. The declining emission intensity as share of global imports reflects changes in the overall composition of trade (such as increased in services (EUROSTAT, 2019) and shifts to higher-value-added products (Wood, Grubb et al., 2019)). From 2012 to 2015, as global trade as share of global GDP rebounded after the global financial crisis, emissions embodied in trade decreased slightly as share of global CO2 emissions. In this sense, the declining south-north transfer is partly related to the decreased emission intensity in trade. Importantly, the findings in Wood, Grubb et al. (2019) hold across models and country aggregations (and resonate with other studies, e.g. Pan et al., 2017).
Considering developments in consumption- and production-based CO2 accounts for Denmark in the same period (I here rely on the supplementary data material in Wood, Grubb et al. (2019)), emissions patterns seem to follow other OECD countries (see figure 3 and 1). The emission transfer has consistently been negative since the 1990’s, confirming that Denmark as part of the Global North is a net carbon importer. In 2016, the emission transfer was at the same level as in 1994, namely around -6 m. t CO2, illustrating a fairly consistent gap between \( E^X \) and \( E^M \). As emission levels decrease, this means that the share of \( E^{cons} \) from \( E^M \) which is not accounted for under UNFCCC is increasing. Notice that these results only include CO2\(^8\) and that the normalising approach described in Wood, Moran et al. (2019) is used to capture trends rather than providing ‘accurate’ emission estimates.

**FIGURE 3**: Developments in production- and consumption-based CO2 estimates and the corresponding emission transfer for the Danish political economy, 1960-2016

![Figure 3: Developments in production- and consumption-based CO2 estimates and the corresponding emission transfer for the Danish political economy, 1960-2016.](image)

*Source:* Data from Wood, Grubb et al. (2019) relying on Wood, Moran et al. (2019)

2.2 How to slice which pie?

Although one could think that national emission estimates reflect all GHG emissions and that accounting is mainly a question of how to ‘slice the pie’, i.e. attributing pollutants to actors, this is not the case. Noticeably, the UNFCCC framework does not allocate emissions that occur in international territory, most importantly ‘the combustion of fuels

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\(^8\)That means that the data for Denmark is also found by harmonizing results across databases (namely EXIOBASE, OECD ICIO, Eora, WOID and the Global Carbon Project built from the GTAP8 database (see Wood, Grubb et al. (2019) and Wood, Moran, et al., (2019)).

\(^9\) Excluding inter alia ‘methane emissions from agriculture and mining and industrial process emissions’ (Wood, Grubb et al. p. 3) for which reason the overview presented here should be interpreted with that in mind (especially seeing the intensive livestock farming in Denmark (Andersen & Nielsen, 2016)).
used in international shipping and aviation (bunker fuels)’ (Le Quéré et al. 2018, p. 2148). Instead, GHG from national bunker fuel sales are reported as a memo in national emission inventories and not allocated between countries (Peters & Hertwich, 2008b). This difference reflects the distinction between domestic or territorial and production-based emissions as applied in this thesis. For the case of Denmark, bunker fuels are especially relevant since the largest container shipping company in the world, Maersk, is headquartered in Copenhagen (maersk.com). Indeed, international shipping and aviation contributed to 42 percent of emissions from what is by Statistics Denmark considered Danish economic activities in 2017 (DST, 2020). Importantly, the economic activities of Danish companies in international territory add to GDP. Thus, territorial GHG inventories and GDP are not directly comparable (Peters & Hertwich, 2008b; Pedersen & de Haan, 2006). If one is to compare, one should use the economic definition of production-based GHG accounts (Peters & Hertwich, 2008b).

An additional point of contention for national emission figures is the role of biomass (Jørgensen & Andersen, 2012). When it comes to biomass, Denmark is an interesting case because a relatively large share of the renewables’ portfolio is, and is likely to remain, bioenergy (Jørgensen & Andersen, 2012). Indeed, 15.3 percent of total Danish electricity generation and 64% of energy consumption from renewables in 2018 relied on biomass as fuel (Danish Energy Agency, 2019). In the UNFCCC accounting framework, combustion of biomass is considered carbon-neutral and does therefore not attribute to national emission figures. This is even though emissions from such processes contribute to atmospheric carbon concentration. The argument for carbon neutrality is based on biomass taking up CO2 from the atmosphere through photosynthesis while growing. As CO2 released back to the atmosphere during combustion has at some point been taken up, bioenergy is claimed ‘carbon neutral’ (Schneider, 2019). However, this claim is repeatedly acknowledged to be wrong. Referencing a wide range of literature, Norton et al. (2019, p.1257) calls it ‘a gross misrepresentation of the atmosphere’s CO2 balance since it ignores the slowness of the photosynthesis process which takes several decades for trees to reach maturity’. However, this only accounts for instances where harvested trees are being replanted. Because harvesting trees for fuel reduces carbon stocks (Johnson, 2009), the warming potential of biomass can be bigger than coal if trees are not replanted (Danish Energy Agency, 2020). In such instances, the claim of carbon-neutrality is not only misleading but grossly incorrect.

The use of biomass is problematic not only because it is mistakenly accounted for as carbon-neutral but also because it impacts the biosphere. Biomass harvest leaves less biomass available for other species (Schneider et al., 2010) and puts pressure on ecosystems (on which human well-being rely (Millenium Ecosystem Assessment, 2005)). For these reasons alone, substituting biomass for fossil fuels is unwarranted (Haberl et al., 2007). In the UNFCCC framework, biomass is accounted for in the land use, land use change and forestry (LULUCF) sector. Decreasing carbon stocks due to e.g.
deforestation are to be accounted for in the national emission inventories of the country in which the tree harvesting has occurred and not in the country in which the biomass is put to use (Danish Energy Agency, 2020). Yet, this requires that the scope of emissions from LULUCF is appropriately accounted for in national inventories and that countries include LULUCF-emissions in national reduction targets (given such reduction targets exist). This is, however, not guaranteed to be the case. For example, one fourth of the biomass used for electricity generation in Denmark in 2018 was imported from Russia and the US, neither of which properly account for LULUCF (Danish Energy Agency, 2020). Furthermore, to the extent that Danish consumption of biomass results in decreased carbon stocks in exporting countries, reductions in Danish national emissions are expressions of outsourcing of emissions rather than absolute reductions (Lund et al., 2019).

These two examples are not the only accounting rules of significance albeit some of the most important ones for overall emissions for Denmark. In addition to these, I want to highlight that accounting for sources of anthropogenic warming other than CO2 is not given. Indeed, in the data above, Wood, Grubb et al. (2019) address only developments in CO2-emissions from fossil fuel combustion despite the existence of other greenhouse gasses as well as other sources. Thereby, they exclude for example methane (CH4) and nitrous oxide (N2O) despite these make up a substantial share of global emissions (25 percent according to Olivier et al., 2017). Although the share of CO2-emissions is often similar to the share of GHG emissions (Olivier et al., 2017), it constitutes a substantial aspect of the size of the pie. Other GHGs which account for a smaller share of overall GHG emissions are the fluorinated gases known as F-gases (HFCs, PFCs and SF6) (Nielsen et al., 2019). In sections 3 and 4 I address how such considerations are accounted for in the context of this thesis.

2.3 How it matters: Accounting for accounting

2.3.1 Responsibility and unequal ecological exchange

Up until this point, this chapter has mainly addressed different approaches to and concepts in carbon accounting as well as an historical overview. We have seen how the choice of approach leads to quite substantial differences in national GHG accounts and how carbon accounting is not only a matter of how to slice the pie, but also what constitutes the pie to begin with. But how should we make sense of different approaches and what questions are important to ask in this regard? This and the following section (2.3-2.4) address what responsibility is implied by different approaches to carbon accounting and theoretical perspectives and concepts that can guide this inquiry into carbon accounting and the notion of green growth.

Generally, the question of accounting relates to questions of responsibility (Lövbrand & Stripple, 2011). What (the scope of GHG) is attributable to who (the unit of analysis)? Production-based approaches places the responsibility of emissions on the political
authority in that territory, treating nation-states as ‘the agents of global warming’ (Lohmann, 2009, p.501)\textsuperscript{10}. This generally benefits the Global North with relatively high carbon footprints while disfavouring countries in the Global South, with relatively high domestic emissions (Boitier, 2012; Rothman, 1998). By attributing emissions taking place in each political jurisdiction to the respective states, rich and powerful actors can distance themselves from environmental degradation associated with consumption. If consumption is increasingly happening through imports, such developments could even be portrayed as improvements in environmental quality (Rothman, 1998). As the political economy of Denmark is not characterized by heavy industry and deforestation but rather is an open economy relying on imports for consumption (and importing biomass for energy production), territorial emissions are substantially lower than the Danish carbon footprint (Lund et al., 2019). As such, similar reasoning applies in a Danish context. Surely, reducing national emissions from production-based perspectives is not worth much if the consumption-based figure does not follow suit. This argument can be applied across environmental indicators as well as across time and space where displacement of environmental damage and degradation is possible (Bagliani et al., 2008; Dryzek, 2013). For instance, Mayer et al. (2005) point to how forest protection policies without decreasing domestic consumption of wood leads to a de facto displacement of ecological impacts, using the examples of Finland, Russia and China.

From the perspective of ecological unequal exchange theory, such patterns reflect countries’ position in the world system (Bunker, 1984; Hornborg, 1998; 2009). At a basic level, ‘ecologically unequal’ (Andersson & Lindroth, 2001; Martinez-Alier & O’Connor, 1996) exchange is when ‘the environmental pressures embodied in A’s imports from ‘B’ (pollutant emissions, for example) are larger than in B’s imports from ‘A’’ (Muradian et al., 2002, p. 56). ‘Drawing on Sachs (1999), Rice (2007) maps out the central tenets of the position, which aligns with world systems and dependency theory\textsuperscript{11}:

The theory of ecological unequal exchange suggests the structure of international trade shapes disproportionate access to global environmental space in a manner substantially predicated upon hierarchical position in the world system. (p. 1369)

The environmental space here refers to natural resource stocks as well as sink capacity or waste assimilation properties (Rice, 2007). In that sense, by importing natural resources and exporting environmental waste (hence, putting pressure on sink capacity services in the Global South) countries in the Global North displace environmental costs of relatively high levels of consumption and impose them on countries in the periphery (using the vocabulary of dependency theory). In easing the pressure on domestic natural capital through trade, countries in the core obtain carrying capacity from the Global

\textsuperscript{10} As opposed to e.g. multinational corporations, financial institutions or social classes and core-periphery dynamics.

\textsuperscript{11} For the relation between world systems and dependency theory as well as other related perspectives see Kvangraven, (2020).
South. But what makes such unequal exchange possible? Ecological unequal exchange theory argues that what facilitates an favourable position in the world system is resources such as financial wealth, political and military strength that help secure advantageous terms of trade (Rice, 2007) as well as dependence on foreign direct investments (see e.g. Frey, 2003; Jorgenson, 2006; Jorgenson, 2016).

Essential to this conceptualisation of trade and economic systems is a world where benefits of one actor happen at the expense of another. Hornborg (2009, p. 245) labels this view of the world ‘zero-sum’ and opposes it to the ‘cornucopia’ or ‘mainstream’ perspective. In the ‘zero-sum’ world, the global environmental space is fundamentally limited. Thus, unequal exchange limits present and future utilization of this space for countries in the periphery. Contrastingly, the ‘cornucopia’ perspective of comparative advantage in neoclassical economics posits that trade will not make any country worse off at the aggregate level. In that conceptualisation, exchange is not unequal but mutually beneficial at its core (Krugman, 1993; Røpke, 1994). If we briefly again consider figure 1, the interregional fluxes of emissions embodied in trade from the Global South to the Global North, the south-north emission transfers, illustrate the pattern which ecological unequal exchange theory highlights (for the limited case of CO2 emissions). Using 2004 economic data, figure 4 presents another graphical representation of such inter-country relations. This representation arguably better visualizes the perspectives of ecological unequal exchange, showing how primarily Western countries are net carbon importers.

**FIGURE 4: Interregional fluxes using 2004 economic data**

From the perspective of unequal ecological exchange, the merits of the consumption-based framework stand out, because it better reflects the how citizens in the Global North take up a disproportional share of the environmental space (in form of the global
carbon budget\textsuperscript{12}). Nevertheless, Liu (2015) argues against the use of consumption-based accounting by reasoning that the emissions embodied in imports, $E_M$, are not necessarily a direct result of climate policy and that economic rather than environmental factors drive the relocation of emissions. Therefore, one should not conflate $E_M$ with terms that assume casual relations between climate policy and displacement of carbon-intensive production. A way to understand this point by distinguishing between ‘weak’ and ‘strong’ carbon leakage. Strong carbon leakage is relocation of GHG emissions due to climate and/or environmental policy implemented regionally. Opposingly, weak carbon leakage is driven by economic factors and the international division of labour in global value chains (Steininger et al., 2014). In this terminology, Liu (2015) argues that weak carbon leakage has been conflated with strong carbon leakage, implying that weak carbon leakage is not problematic.

Moreover, Liu (2015) posits that the consumption-based approach indicates that consumption rather than production causes emissions, hence ‘blaming’ the consumer while production-based approaches put direct pressure on producers. Therefore, the consumption-based approach might encourage producers to assume less responsibility of emissions embodied in exports. Moreover, others suggest that reporting authorities have little control over production taking place elsewhere and thereby little scope for reducing consumption-based emissions\textsuperscript{13} (Stoknes and Rockström, 2018). While such arguments serve to highlight ways in which the consumption-based approach can be problematic, the ability for core countries, such as Denmark, to distance themselves from environmental degradation strongly questions primarily relying on production-based approaches for governance.

Additionally, Peters and Hertwich (2008b, p. 57-59) put forward a number of arguments for constructing national GHG inventories using consumption-based rather than production-based perspectives. These include (1) solving allocation issues for international activity (presently not a part of national inventories under the UNFCCC as noted above), (2) addressing carbon leakage (be it weak or strong), (3) reducing GHG reduction targets for developing countries, (4) allowing for environmental comparative advantage and address competitiveness concerns, (5) encouraging technology diffusion and spill-over and lastly, (6) increases flexibility for countries with pollution intensive resource endowments. In light of these arguments, production-based frameworks appear, at the very least, partial and limited. As such, replacing the geographic approach with the

\textsuperscript{12} The concept of the global carbon budget and the important aspects relating hereto are mapped out in section 2.4.3.

\textsuperscript{13} Such arguments have been challenged by authors who argue that a consumption-based climate policy approach is, not only possible (states have the capacity to affect both consumption and trade), but warranted, improving both justice and cost-effectiveness (see e.g. Barrett et al., 2013; Lockwood & Whalley, 2010; Steininger et al., 2014).
consumption-based perspective as the main accounting framework in global climate governance is not unwarranted.

2.3.1 Carbon accounting beyond responsibility

In the literature on GHG accounting, scholars point to accounting as more than a framework for how to divide political responsibility for emissions between political jurisdictions. According to Asdal (2008), systems of accounting take part in making nature present and real. Nature is ‘taken into account by way of accounting’ (p. 123). In this way, nature is enacted as a political and manageable subject. As such, a ton of carbon is not just a ton of carbon and carbon accounting is not merely a way of describing the world. It is a part of it. Thus, accounting for carbon is more than a technical exercise and cannot be reduced to the role of providing information (Wolf and Ghosh, 2019). Here, the scholarship on the sociology of quantification (Espeland and Stevens, 1998; 2008; Vollmer, 2007) and its applicability to carbon accounting (see e.g. Lohmann, 2009; Vesty et al., 2015) as well as science and technology studies (Lippert, 2015; MacKenzie, 2009) serve to illustrate attributes and implications of accounting for carbon beyond attributing responsibility.

Investigating the creation of an accounting protocol for nitrous oxide emissions for corn production, Wolf and Ghosh (2019, p. 8) argue that carbon accounting as well as the production of techniques for accounting can be considered ‘an interactive endeavour dependent on negotiations, and real-time problem solving by actors who identify and reference purposes, interpretations, and material constraints’. Moreover, reflecting on the political economy of carbon accounting, certain actors gain while others lose from the current dominant accounting paradigm. The political economy perspective aligns with ecological unequal exchange theory in that it points to the importance of power structures in socioecological relations. Carbon accounting frameworks matter in deeming a certain economic development environmentally desirable, understanding nations or economies as ‘green’ and, ultimately, determining course of action and setting policy goals for future carbon emissions. Realizing that carbon accounting is a messy, political, contested and performative phenomenon (see above references), it is relevant to relate it to claims of green growth. Since carbon accounting is tremendously influential for the amount of emissions attributed to a given country, it is key for debates on national decoupling. Therefore, I now go on to shortly map out green growth and ecological modernisation (Dryzek, 2013), before relating it to the concept of GGG (Stoknes and Rockström, 2018).

2.4 Defining and discussing the notion of green growth

2.4.1 Ecological modernisation as green growth

The perhaps most prominent use of national carbon accounting is monitoring progress in relation to emission reductions. As such, it is at the core of climate governance. And when it comes to achieving reduction targets, ecological modernisation – in the form of
‘green growth’ - has achieved global prominence (Dryzek, 2013). Ecological modernisation refers to a restructuring of the capitalist political economy to address environmental concerns although, importantly, not requiring any fundamental changes to the political-economic system (Dryzek, 2013, p. 170; Toke, 2011). I.e., a reformation that occurs within what Dryzek (2013, p. 14) denotes the ‘political-economic chessboard’ set by industrial society. Such restructuring, if implemented successfully, is assumed to render absolute decoupling possible and lead to increasing GDP per capita without simultaneously increasing stress on the environment. Absolute decoupling is defined as increases in economic activity (proxied by GDP) that are associated with absolute decreases in given environmental indicators. In contrast, relative decoupling refers to a decrease in environmental footprint relative to an increase in economic activity, but an absolute increase in stress on the environment (for formal, mathematical definitions see Grand, 2016).

From the perspective of ecological modernisation, an expansion of production should be a qualitatively different kind of growth that would take place within ecological limits\textsuperscript{14}. This does not mean that ecological modernisation is not a homogeneous discourse\textsuperscript{15} that is completely distinct from other discourses. Instead, it takes various forms (see e.g. Hajer, 1995; Christoff, 1996) and bears resemblance to other environmental discourses such as ‘sustainable development’ (Dryzek, 2013, p. 172-176). This heterogeneity and these overlaps notwithstanding, successful ecological modernisation would entail what is often labelled ‘green’ or ‘inclusive’ growth. In this conceptualization of socioecological systems, ecology and economy are not at odds. Rather, environmental protection and economic prosperity are considered compliments as opposed to substitutes (Dryzek, 2013).

2.4.2 Ecological modernisation as genuine green growth

Aiming to substantiate the claims of ecological modernisation and by extension, arguing in favour of the notion of green growth, Stoknes and Rockström (2018) use data on carbon emissions in the Nordics to argue that the vision of ecological modernisation is possible\textsuperscript{16}. Although they do not use the term ‘ecological modernisation’, the discourse is prevalent throughout the paper. Indeed, achieving economic prosperity within ecological limits (conceptualised as planetary boundaries, cf. Rockström et al., 2009; Steffen et. al., 2011) is what Stoknes and Rockström hold to be possible. As they put it:

\textsuperscript{14} For a discussion of environmental discourses respectively highlighting and dismissing such limits see Dryzek, 2013, chapter 2 and 3.

\textsuperscript{15} Dryzek (2013) uses the term ‘discourse’ to capture the notion that ecological modernisation is a ‘shared way of apprehending the world (…) embedded in language (…) construct[ing] meanings and relationships, helping defining common sense and legitimate knowledge’ (p. 9)

\textsuperscript{16} The Nordic region is widely perceived as a successful example of ecological modernisation (Dryzek, 2013).
We envision future economies that can thrive within physical planetary boundaries as a natural and necessary development of economic paradigms in the advent of the Anthropocene. (p. 42)

Crucial to this goal is that the ‘win-win green growth framing’ is ‘credibly linked to science-based targets’ (Stoknes and Rockström, 2018, p. 42). This is in line with features of the ecological modernisation discourse, which points to how the role of scientists an important part of restructuring the capitalist political economy (Dryzek, 2013). Stoknes and Rockström hold that by linking an expansion of production to science-based targets, the ‘win-win growth frame’, or the narrative of ecological modernisation, remains ‘valid’ (2018, p. 42). As such, they try to liberate ecological modernisation from being nothing but a ‘rhetorical rescue operation for a capitalist political economy confounded by ecological crisis’ (Dryzek, 2013, p. 178), as might otherwise be the case (Hajer, 1995, p. 32-34; Christoff, 1996).

To do so, Stoknes and Rockström (2018) define what they refer to as ‘genuine green growth’ (GGG), implying that the term ‘green growth’ in practice can be a matter of ‘greenwashing’ (p. 41-42). The distinction between green growth and genuine green growth is helpful in relation to answering the research question at hand due to the general elusiveness of the concept of green growth in terms of measurability and/or quantifiable criteria. To discuss whether the Danish example indeed is an example of green growth, a clear definition, which does not allow for greenwashing, is needed. Reading through the definitions of green growth reviewed by Stoknes and Rockström (2018), neither the OECD, the European Commission nor the UN offers a definition that goes beyond that of ecological modernisation. The intention to address environmental concerns is clear. Yet, questions of which concerns should be addressed to what extent is not.

Aiming to define GGG, Stoknes and Rockström (2018) first categorize green growth as ‘an increase in economic output that lowers total environmental footprint’ (p. 42). As such, it corresponds to absolute decoupling with a positive growth rate (cf. Grand, 17) Typically, ecological modernisation does not emphasize limits to growth (Dryzek, 2013). As such, the emphasis Stoknes and Rockström (2018) put on planetary boundaries does arguably not fully align with the discourse of ecological modernisation. However, Stoknes and Rockström emphasize ecological limits within the current system rather than limits to growth as such, positing that ‘politicians, corporations and voters continue to prioritize economic growth’ (p. 47). This, they argue, means that continued growth within planetary boundaries is ‘the only model economic development can take within planetary boundaries [italics added]’ (p. 47). For these reasons, I maintain that they stay within the discourse of ecological modernisation.

18 ‘Greenwashing’ as a concept is often used in relation to corporate marketing practices (see e.g. Parguel et al., 2011). Stoknes and Rockström (2018), however, apply it at the national level referring ‘talking about reducing climate emissions and other environmental impacts, while simultaneously pushing for as much conventional economic and job growth as possible [italics in original]’ (p. 42).

19 Recall that the overall research question of this thesis addresses the notion of green growth, asking, inter alia, how carbon accounting matter for claims of green growth for Denmark.

20 Formally, ARP > ΔGDP, where resource-productivity, ARP, is the year-on-year percent change in real GDP/environmental resource use. The environmental resource can be different indicators that relate to planetary boundaries as for example GHG emissions.
2016). Seeing that absolute decoupling refers to a lowering of total environmental footprint of any size (including reductions far too small to mitigate current trends), they go on to define GGG as ‘a genuine version of green growth to take planetary boundaries fully into account’ (p. 42). This implies an important distinction between absolute decoupling (as defined above) and sufficient decoupling, referring to decoupling rates that achieve science-based targets for planetary boundaries. In the case of GHG emissions, Stoknes and Rockström (2018) conceptualise the target as emission reductions that are in line with the 1.5-2.0 °C target. This conceptualisation aligns with the original planetary boundaries article (Rockström et al., 2009), where the climate change boundary is proposed at a CO2-concentration of 350 parts per million by volume and radiative forcing (the rate of energy change per unit area of the globe as measured at the top of the atmosphere) of less than 1 watt per square metre above preindustrial levels. At the time of writing, these boundaries were considered equivalent to a high probability of staying below a change in temperature of 2.0 °C.

2.4.3 Planetary boundaries, carbon budgets and emission pathways

Planetary boundaries are defined ‘as the boundaries of the “planetary playing field” for humanity if we want to be sure of avoiding major human-induced environmental change on a global scale’ (Rockström et al., 2009, p. 1). For climate change this entails not crossing critical thresholds that ‘separate qualitatively different climate system states’ (p. 1).

**FIGURE 5**: Conceptual description of planetary boundaries

![Conceptual description of planetary boundaries](image)

*Source: Rockström et al., (2009)*

*Note in source article (fig. 2):* In (a) the boundary is designed to avoid the crossing of a critical continental to global threshold in an Earth System process. Insufficient knowledge and the dynamic nature of the threshold generate a zone of uncertainty about its precise position, which informs the determination of where to place the boundary. In (b) there is no global threshold effect as far as we know, but exceeding the boundary level will lead to significant interactions with regional and global thresholds and/or may cause a large number of undesired threshold effects at the local to regional scale, which in aggregate add up to a serious global concern for humanity.

21 However, at 387 p.p.m.v. and a 1.5 W per square meter change in radiative forcing, the boundaries was already exceeded at the time of publication (Rockström et al., 2009).
9). What specific limits constitute planetary boundaries is not fixed but is subject to uncertainty. Planetary boundaries addresses uncertainty by staying in ‘safe’ distance (Rockström et al., 2009) from dangerous levels and thresholds triggering non-linear dynamics (tipping points) (see figure 5). In this way, the Paris Agreement need not be conceptualised as a planetary boundary. Arguably, what constitutes ‘qualitatively different’ and ‘safe distance’ is open to deliberation. Still, seeing the alignment between the original quantified planetary boundaries article and the 1.5-2.0 °C target, the Paris Agreement goal is a workable conceptualisation.

The question of which emission pathways are aligned with the 1.5-2.0 °C target and therefore represent sufficient decoupling has been the focus of climate change science. This research suggests rapid declines in global GHG emissions, and many pathways include the need for net-negative emissions at the global level after reaching net zero (Van Vuuren, 2011; Millar et al., 2017). Indeed, limiting warming to 1.5 °C without net-negative emissions would be almost impossible given current emission trends (Millar et al., 2017). In many climate stabilization scenarios, net-negative emissions are assumed to be achieved by deliberately removing CO2 from the atmosphere employing ‘negative emission technologies’ (NET) at a massive scale (Fuss et al., 2014; Minx et al., 2018). Such technologies and the idea of ‘negative emissions’ have been dubbed ‘a dangerous distraction’ as its credibility is unproven (Fuss et al., 2014). Moreover, Minx et al. (2018) warn that social resistance and biophysical limits might restrict widespread deployment of NET.

An important concept to establish climate stabilization scenarios is the carbon budget. Carbon budgets relate to the notion of limits and by extension both planetary boundaries, sufficient decoupling and GGG. The carbon budget is, in a rather concrete sense, an ecological limit. It captures the amount of CO2 emissions that align with a specific scenario or pathways. Formally, the IPCC defines it as the:

Estimated cumulative net global anthropogenic CO2 emissions from a given start date to the time that anthropogenic CO2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. (Allen et al., 2018, p. 33)

Carbon budget estimates can thus be applied to define what constitutes sufficient decoupling. This also means that the GGG definition (from a rather narrow perspective of climate change) hinges on carbon budget estimates. Importantly, however, despite accounting for the impact of other anthropogenic emissions, these budgets reflect CO2 emissions. Because temperature responses depend on the combination of forcing from CO2 and non-CO2 emissions, the relationship between cumulative carbon emissions and the rise in global temperature becomes more uncertain as non-CO2 emissions change (Feijoo et al., 2019). In my analysis, I account for this by using CO2e-targets derived from scenario analysis (see section 4.3).
At this point, I want to note three things about emission budgets: 1) Budgets treat emissions (and sink capacity\textsuperscript{22}) as a (limited) resource that can be exhausted and is non-substitutable. In this way it aligns with the zero-sum perspective and unequal ecological exchange and opens for discussions on fairness on how the budget should be distributed (see e.g. Starkey, 2008). 2) Principles on how to distribute the budget inform what developments are consistent with the 1.5 °C target at a national level and therefore matter for what is considered sufficient decoupling for different nations. 3) Emission budgets are absolute and, in this sense, non-marginal. They constitute absolute limits or thresholds that should not be traversed. In this sense, they thereby break with the notion of efficiency in environmental economics, namely that environmental policy should equate marginal benefits with marginal costs rather than setting absolute limits\textsuperscript{23} (Nordhaus 1991, p. 924). Taken together this better aligns with the position of ecological economics, which emphasises the idea of ecological limits to economic growth as well as to what ecological systems can sustain. Ultimately, this position stems from the laws of thermodynamics and limits to low entropy resources (see e.g. Costanza et al., 2014; Martinez-Alier & Muradian, 2015; Petridis et al., 2015; Røpke, 2005; Spash, 2017).

2.4.4 Operationalizing genuine green growth

Arguably, GGG is the goal of ecological modernisation. It represents an expanding\textsuperscript{24} (and thereby supposedly thriving) capitalist economy within planetary boundaries or along ‘environmentally sound lines’ (Dryzek, p.170). To operationalize GGG, Stoknes and Rockström (2018) use carbon productivity ‘due to its relative ease of measurement, as well as the urgency of further climate disruptions that would also severely worsen other environmental and social impacts’ (p. 42-43)\textsuperscript{25}. Carbon productivity (CAPRO) of a given economic entity (such as nations) is here real value added/tons of CO\textsubscript{2}e (the inverse of carbon intensity\textsuperscript{26}). Value added at the national level is given by GDP, an inherently

\textsuperscript{22}Here any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere (Houghton et al., 2001, p. 796).

\textsuperscript{23}In theory, if the 1.5-2.0 °C target is decided based on a cost benefit analysis (weighing marginal costs against marginal benefits), the concept of a carbon budget is arguably in line with a neoclassical approach (represented by Nordhaus, 1991; 2014). However, I maintain that planetary boundaries and emission budgets align more closely with ecological economics due to the following rationale: If the 1.5-2.0 °C target is considered ‘optimal’ from a cost benefit perspective, one should aim for depleting rather than staying below the budget, as not using the entire budget would correspond to ‘leaving money on the table’ (uncertainty might mean that we should be precautionary, but then we should still deplete the budget up until the point which is the new optimal after acknowledging (fundamental) uncertainty). Conceptualized as planetary boundaries, emission budgets are limits in an absolute sense, wherefore staying inside them is not only preferable but necessary. Thus, depleting the budget is not beneficial but harmful and leaving a substantial amount of the emission budget unused would be a preferable outcome.

\textsuperscript{24}Be it qualitatively, quantitatively or both.

\textsuperscript{25}In addition to GHG emissions, the Stoknes and Rockström (2019) mention the need for other environmental indicators for biodiversity, land, water, pollutants and chemical entities as well as nutrient loading.

\textsuperscript{26}Stoknes and Rockström (2018) apply CAPRO over carbon intensity mainly for psychological reasons, arguing that this maintains emissions reductions as a gain or an ‘up’ issue (p. 47). Arguably, the term should more rightly be labelled emission intensity to capture other GHGs than CO\textsubscript{2}.
problemati
cure measure that do not capture certain value-added activities while recording
rent-seeking activities as productive (Mazzucato, 2018; Mazzucato and Shipman, 2014;
Stiglitz et al., 2009). Still, Stoknes and Rockström (2018, p. 43) rely on GDP for pragmatic
reasons arguing that ‘it is highly likely that GDP will continue to be one of the dominant
national metrics in practical use’.

Reflecting how nature becomes enacted as a manageable subject through accounting,
Stoknes and Rockström (2018) set a quantifiable minimum threshold for increases in
CAPRO to qualify as ‘genuinely green’; a target by which nations supposedly stay within
planetary boundaries. The target is found using two approaches. First, Stoknes and
Rockström reference estimates for the 2015 remaining carbon budget for staying below
2 °C with >66% probability of 600–1200GtCO₂ (Rogelj et al., 2016). Relying on the
higher end of the estimates, limiting warming to 2 °C requires global reductions of >2%
per year from 2015 onwards, i.e. a halving of emissions between 2015–2050. Assuming
global GDP growth of 3% per year continues, CAPRO needs to increase by more than
5% a year (Stoknes and Rockström, 2018, p. 43). Second, Stoknes and Rockström (2018)
review literature that quantify the needed yearly decreases in carbon intensity to stay
below 2 °C with estimates ranging from 4-11 percent (p. 44). Taken together, they hold
GGG can be defined as:

\[ \Delta \text{CAPRO} > 5\% \]  

(3)

Extending this beyond climate change to encompass environmental indicators beyond
GHG emissions, Stoknes and Rockström tentatively suggest a general definition for
GGG. This definition refers to varying environmental indicators collectively as resource
productivity, RP:

\[ \Delta \text{RP} > 5\% \]  

(4)

Notwithstanding the arbitrariness of setting on a specific yearly target, the 5% target
is identified as ‘an optimistic, minimum rate’ (p. 43). It is worth noting how the
operationalized target is arguably at odds with the qualitative definition of GGG. Surely
one can challenge whether an ‘optimistic, minimum rate’ for a 2 °C target fully takes
planetary boundaries into account, as stated in the GGG definition. From a precautionary
principle perspective, given the uncertainty in climate projections, this seems
questionable. Being precautionary would require a higher yearly increase in carbon
productivity (and thereby substantially faster emission reductions). Moreover, if sticking
to rather mechanically defining GGG as a yearly increase in CAPRO, the CAPRO target
should arguably be set where the 1.5 °C target is met with (very) high certainty, seeing
the projected differences in risks between a 1.5 and 2.0 scenario (IPCC, 2018). Finally,
this definition hinges on expectation of average future global growth rates (extrapolation
from past trends) of around or below 3% (Stoknes and Rockström, 2018, p. 43; p. 46).
As Stoknes and Rockström (2018) themselves point out, if growth rates were higher than
CAPRO, we would observe relative instead of absolute decoupling that would qualify as
GGG but not green growth (recalling that green growth in their definition requires an absolute decrease in environmental footprints). To remain valid, the definition of GGG should therefore also be consistent with the \( \Delta \text{RP} > \Delta \text{GDP} \) requirement. These arguments point to an inconsistency in the definition between the quantitative and qualitative notion of GGG.

### 3. Methods and data

Facts are the materials of science, but all Facts involve Ideas.

\[\text{– Whewell, 1996 [1840]: xxxvii}\]

Analysing emission patterns over time and space ultimately rests on data. In that spirit, I now turn to the main methods and data section in this thesis. I map out how consumption-based emissions are calculated relying on the standard Leontief demand model and address important limitations to keep in mind in this regard. I end the section by reviewing different multi-regional input-output tables I rely upon in my analysis.

#### 3.1 Infinite production links: Estimating consumption-based emissions

To understand and explore Danish consumption-based emission accounts, I rely on Environmentally Extended Multi-Regional Input-Output (EEMRIO or EEIO in short) modelling based on the Leontief demand model. EEMRIO analysis is a top-down approach that relies on input-output analysis associated with Wassily Leontief (1936; 1970) and is widely applied (Baumol, 2000; Miller & Blair, 2009) to understand and evaluate the relationship between economic activities and the embodied environmental impacts associated with them (Kitzes, 2013). This includes analysis of a range of environmental indicators beyond GHG emissions counting land (Bruckner et al., 2015), water (Hoekstra & Mekonnen, 2012), nitrogen (Leach et al., 2012), ecological (Wiedmann et al., 2006) and material footprints (Giljum et al., 2019).

Calculating the embodied or ‘hidden’ environmental impacts upstream associated with downstream consumption is no easy task and requires enormous amounts of data (the below is based on Kitzes, 2013, Miller & Blair, 2009 and EUROSTAT, 2008 unless otherwise stated). Impacts are hidden in the sense that they do not happen directly as a good or service is consumed as opposed to the direct impact of for instance burning gasoline when driving a car. Such direct emissions are also referred to as the ‘zeroth layer’ (Kitzes, 2013), as we can consider how different layers of production add to the overall amount of (in this case) GHG emissions. To get total impact we need to add the direct impact of a good or service to its indirect or embodied emissions.

Take any good or service \((A)\) and say two inputs went into producing it \((B \text{ and } C)\) and that some environmental impact was associated with the production of each of these. Then say three inputs went into producing \(B\) and \(C\) \((D, E, F \text{ and } G, H, I)\) and that some environmental impacts associated with those (see figure 6). In principle, one could add
up all of the environmental impact associated with each of the inputs to get the overall environmental impact associated with A. Such backwards links are in principle, however, infinite and creating a complete production tree for a given good of service could in theory go on forever. In practice the infinite number of links, existence of loops within production trees, limits to information, issues of double counting and the challenges in distinguishing between specific inputs severely limits such an approach.

**FIGURE 6**: Sample ‘production tree’ illustrating upstream inputs required to provide output A

Yet, calculating environmental footprints still needs to account for the spatial dispersion and fragmentation of production in global value chains and the infinite number of layers in production. In this regard, the multi-regional input-output (MRIO) matrix showing (usually monetary) flows between sectors in and across countries accounts for these aspects, wherefore it can replace the exemplary production trees mentioned above. Typically, global-scale EEIO are open models in which the entire global system is treated as part of the same economic system with no imports and exports\(^{27}\). Figure 7 below shows a simplified MRIO table with two countries and one sector or industry. In figure 7, total input equals total output for each sector, illustrating a balanced and symmetric transaction matrix. The value-added squares capture profits, employee compensation, capital depreciation and other non-industrial inputs to production. The final demand squares encompass all final use including personal consumption, government spending and business demand (measured as gross fixed capital formation).

Environmental extensions of any quantifiable environmental impact metric can be added to an input-output table, which can then be used to calculate a direct intensity vector, \(f_i\) for each of these metrics. The \(f\) vector is found by dividing direct emissions of each sector by total output for the respective sectors. If considering carbon dioxide, for instance, the direct intensity vector captures sector specific CO2 emissions per unit

\[^{27}\text{For alternative model formulations see Miller and Blair (2009).}\]
output. In a world without intermediate sales where all outputs were purchased directly by final consumers, this would be enough to figure out consumption driven emissions by sectors and in total. We simply needed to multiply the direct intensity vector with final demand (corresponding to an input-output table with all intermediate use being zero). However, as emissions are embodied in intermediate sales, we need to account for the interrelationships between sectors (the main strength of EEMRIO analysis). Doing so requires the amount of input each sector gets from all other sectors to produce one unit of output, which is given by the A matrix (the technical coefficient matrix) and is found by dividing the inputs from a the different sectors into a given sector divided by the total output in that sector.

To get consumption-based emissions, we need to move from the direct intensity vector, the technical coefficient matrix and final demand to the emissions associated with one unit of output, i.e. the total intensity vector $F$. Considering the first layer only, the total intensity vector in matrix form is equal to product of the direct intensity matrix, $f$ and an identity matrix, $I$:

$$F_1 = f \ I$$

(5)

This gives the amount if emissions per unit output directly emitted in each sector. The second layer, then, is given by the product of $f$ and $A$:

$$F_2 = f \ A$$

(6)

Referring to figure 6, this corresponds to multiplying the amount of B and C input needed to produce one unit of output A with the emissions associated with producing one unit of B and C but for all sectors simultaneously.
In principle, this can be continued for all higher layers, but all this can be done in one step. This step requires the Leontief inverse matrix, $\mathbf{L}$, which is the sum of the geometric series $\left[ \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 \ldots \right]$. For each layer the total intensity vector is the sum of $\mathbf{f}$ and $\mathbf{A}$ raised to the power of that layer, or in the case of layer one, an identity matrix. This infinite sum can be expressed as the Leontief inverse.

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} \tag{7}$$

Multiplying $\mathbf{L}$ with $\mathbf{f}$, then, gives us the total intensity vector across all layers, $\mathbf{F}$. This vector captures the amount of environmental impact taking place in any sector, in any region, embodied in one unit of output in each sector. Sticking to CO2, this would be the carbon intensity of a given sector. To find the total upstream carbon dioxide emissions in a given year, we need to multiply the total intensity vector, $\mathbf{F}$, with the final demand vector (units of investments and consumer and government spending).

Remembering that we also need to add the emissions taking place at the zeroth layer and include GHGs other than CO2, the consumption-based emissions can be estimated. In this regard, we need to account for how different gasses translate into CO2 equivalents. Thus, including a characterization matrix containing conversion factors in order to translate different GHGs into CO2e, the carbon footprint (in CO2e) in year $t$ for region $r$ is given by:

$$p_{t,r}^{cons} = \mathbf{C} \mathbf{s}_t (\mathbf{I} - \mathbf{A}_t)^{-1} \mathbf{y}_{t,r} + p_{t,r}^y \tag{8}$$

Where $\mathbf{C}$ is the conversion matrix, $\mathbf{s}_t$ is the direct emission intensity vector, and $\mathbf{y}_{t,r}$ is the final demand and $p_{t,r}^y$ is the total emissions by households (the zeroth layer). This is the main equation used to calculate the consumption-based emissions with different EEMRIO databases in this paper. Emissions are reported per capita using population statistics from the United Nations Population Division (2017).

### 3.2 EEMRIO analysis: Addressing limitations

Reflecting on the introduction to MRIO analysis above, some clear advantages of the EEMRIO approach stands out; noticeably, EEIO analysis can trace the ‘product trees’ for an infinite number of layers and address loops in production while avoiding double counting. Indeed, the popularity of the approach stems largely from the ability to capture the complex flow of goods and services in production. This is not to say that the approach is without limitations, however. Therefore, I now address the most important limitations of the approach as well as the most relevant assumptions in constructing EEMRIO tables.\(^{28}\) Doing so also helps to understand along which dimensions consumption-based emission estimates might differ.

\(^{28}\)Section 3.2 is not exhaustive in terms of shortcomings but addresses the most important limitations and assumptions for analysis presented in this thesis. Issues not addressed include assumed linear production functions (important if quantifying how exogenous factors could change production structures) and the accuracy of environmental impact assessment (an issue extending beyond EEIO analysis) (Kitzes, 2013).
Research on how to best address limitations in input-output analysis is extensive, working towards continually improving EEMRIO modelling (see e.g. Jansen & Raa, 1990; Majeau-Bettez, Wood et al., 2016; Majeau-Bettez et al., 2018; Lenzen, 2000; de Koning et al., 2015; Merciai & Heijungs, 2014). The most perhaps important assumption in this regard is the assumption of homogeneity. This means that sectors are assumed to produce a single and homogeneous output or at minimum, in the case of EEIO, output is assumed to embody the same environmental impact per unit. In practice, however, sectors often produce several outputs, and although a primary output often dominates, secondary outputs can be of high importance (Jansen & Raa, 1990). This is complicated by the fact that one cannot subdivide multifunctional activities into separate activities if there is a technological link between products (one such example being the joint production of chlorine gas and sodium hydroxide) (Majeau-Bettez, Pauliuk et al., 2016, p. 13).

The issue that some products are not produced independently of each other (for example, combined heat and power plants produces both heat and electricity) is known as coproduction. To address multifunctionality, the EEIO literature has focused on so-called constructs, i.e. the ‘elaboration of symmetric system descriptions (represented as product-by-product or industry-by-industry tables) from rectangular, product-by-industry inventory tables’ (Majeau-Bettez et al., 2014, p. 747). The main constructs are the industry technology construct (ITC), the by-product technology construct (BTC) and the commodity technology construct (CTC) (Jansen & Raa, 1990). The constructs model system representations that make it possible to compile ‘recipes’ (unit shares of different products and factors of production) into a square matrix as the technical coefficients matrix $A$. As the focus of this thesis is not on the issue of constructs, I refer to the literature for a more extensive introduction to this important modelling assumption (Jansen & Raa, 1990; Rueda-Cantuche & Raa, 2009; Majeau-Bettez et al., 2014).

Another way in which homogeneity is potentially violated is through inhomogeneous aggregations (Majeau-Bettez, Pauliuk et al., 2016). This happens if products with different production functions are aggregated into product groups where products are consumed in ratios that differ from the aggregation. Because the aggregation is the weighted sum of different recipes, it needs to be consumed in the same ratios in different industries in order not to violate homogeneity. This can also happen for product groups that are uniform in both prices and energy density. For example, aggregating night-time and daytime electricity can lead to aggregation biases as the mix of power plants generating electricity typically changes between night- and daytime (Majeau-Bettez, Pauliuk et al., 2016).

The sector resolution might also cause practical issues outside of violating the homogeneity assumption. If one wishes to track the impact of a specific product, the product must be treated as distinct and not aggregated into one product group.
Additionally, EEIO tables does not capture activities ‘off the books’ (Kitzes, 2013, p. 500). This is the reason why the emission by households, $F_{tr}^y$, is added to get consumption-based emissions. By the same token, EEIO tables do generally not include emissions from land use, land use change and forestry (LULUCF) (Kitzes, 2013). Such emissions should be assigned to the relevant actors directly outside of input-output analysis. Moreover, some flows used by society are not captured by monetary accounts. The most prominent examples are grazed biomass, used crop residues as well as waste rock extracted during mining activities. Assumptions regarding how to allocate such non-market flows therefore drive results (Schaffartzik et al., 2014). Adding to this is the exclusion of unpaid work and voluntary activities in social accounts which are not captured in formal economic transactions despite their economic and social importance (Waring, 1988).

The best way to address most of these matters would be disaggregating product groups and inhomogeneous production processes into separate, more distinct categories (Nakamura et al., 2011). This would lead to greater homogeneity and granularity in product groups and activities and address physical and financial imbalances, all of which are desirable properties (Majeau-Bettez, Wood et al., 2016). To satisfy the law of conservation of mass and energy (fundamental to physical reality) and respect financial balances and accounting properties, imbalances indicate inaccuracy and/or incomplete measurements. A complete record of a closed system (as the one described in EEMRIO models) must necessarily balance. However, practical and scientific limits to data acquisition and disaggregation means that inhomogeneity cannot be fully addressed (Majeau-Bettez, Pauliuk et al., 2016; Majeau-Bettez, Wood et al., 2016). Yet, these limitations are not detrimental to EEMRIO. Rather, they point to the socioecological complexity in socioeconomic metabolisms. Indeed, uncertainty is fundamental to governance of socioecological systems, climate governance in particular (Chaffin et al., 2014).

3.3 The Global Multi-Regional Input-Output databases used in this thesis

The interest in and use of MRIO analysis for understanding environmental issues on a global scale have led to a number of research projects with specific focus on constructing consistent and reliable databases (Peters, Andrew & Lennox, 2011). These include inter alia the World Input-Output Database (WOID) (Dietzenbacher et al., 2013), the Global Trade Analysis Project (GTAP) (Peters, Andrew & Lennox, 2011) as well as the databases that is the focus of this thesis, namely Eora (Lenzen et al., 2013) and EXIOBASE (Wood et al., 2015; Stadler et al., 2018; 2019) which comes in both a monetary and hybrid version (Merciai & Schmidt, 2018).

In this thesis, I use the monetary and hybrid versions of EXIOBASE to calculate national emission accounts. This choice was made on the suitability of EXIOBASE for environmental analysis, which stands out in comparison to other MRIO databases.
Specifically, it has high sector resolution while being compatible with the System of Environmental-Economic Accounting (SEEA) (Stadler et al., 2018; Tukker et al., 2018). Furthermore, EXIOBASE databases has been chosen based on its wide application as well as appearance in and relevance to the Danish public debate. For instance, EXIOBASE is applied by Lund et al. (2019) and has figured in mainstream media (Aagard, 2019). Another database worth highlighting in terms of the public debate in a Danish context is Eora. The Eora database has also figured in the Danish public press (Hannestad & Bredsdorff, 2020; Wittrup, 2020) and estimations based on the Eora MRIO has been used by Copenhagen-based think tanks (Hjarsbech, 2020). To illustrate how databases can differ, I therefore also shortly shed light on Eora in this section despite using it to calculate consumption-based emissions.

3.3.1 EXIOBASE 3 – monetary

The EXIOBASE 3 builds upon its previous versions covering the years 1995-2011 (Stadler et al., 2018) in contrast to EXIOBASE 1 and 2, which cover the years 2000 and 2007 respectively (Tukker et al., 2013; Wood et al., 2015). EXIOBASE is developed within different EU projects specifically to answer questions concerning sustainability for EU countries (in addition to major global economies and main trading partners) (Stadler et al., 2018). This focus further justifies choosing EXIOBASE as the primary EEMRIO database in this thesis since the focus is the Danish political economy. EXIOBASE covers 44 countries in addition to five rest of world (RoW) regions, 200 products, 163 industries, 417 emission categories and 662 material and resource categories (exiobase.eu).

Two versions of the MRIO table are available, namely a product by product table and an industry by industry table. To ensure symmetry and homogeneity and relating to the so-called constructs addressed above, the product by product version is constructed assuming that each industry has one specific way of production (in terms of inputs) irrespective of the mix of products (the so-called industry technology assumption in EUROSTAT, 2008). The industry by industry version, contrariwise, assumes that each product has its own specific sales structure, irrespective of the industry in which it is produced (the so-called fixed product sales assumption in EUROSTAT, 2008)\(^{29}\). In my analysis, I use the product by product version unless otherwise stated, as this is believed to more homogenous in regard to production activities (EUROSTAT, 2008). I use version 3.7 which extends beyond 2011 with the end year being 2016 for all GHG accounts while the end year for energy is 2015, 2013 for material and 2011 for others, e.g. land and water accounts (Stadler et al., 2019).

\(^{29}\) For a full elaboration on the implications on how this affects the way the final input output table is compiled see EUROSTAT (2008, chapter 11)
To extend beyond 2011, estimations are based on trade and macroeconomic data. The authors warn that care should be used in terms of analysing trends over time when going beyond 2011, reflecting the additional uncertainty from extending the data series (Stadler et al., 2019). Specifically, some elements have been nowcasted. Now-casting (as opposed to fore-casting) refers to modelling recent years’ MRIO tables, reducing the time gap of footprint estimation. As of version 3.7 (the version used in this thesis), the end year in EXIOBASE for GHGs is 2016 with non-combustion and non-CO2 sources of climate change being nowcasted from 2015 only. The CO2 combustion is calculated by using the emission relevant energy use. The monetary supply use tables from which the IO tables are constructed have been updated based on the World Economic Outlook Database of International Monetary Fund (cited in Stadler et al., 2019) to be consistent with recent GDP and trade data.

Being a top-down approach, the database reconciles technological and national-level data to global estimates for monetary flows as well as aggregated official country data. Data sources include but are not limited to UN National Accounts Main Aggregates Database, the Food and Agriculture Organization statistical database, the International Energy Agency’s (IEA) energy balances and the UN Comtrade database (cited in Stadler et al., 2018). In the compilation of EXIOBASE, the authors followed a set of guiding principles aiming for consistency with macroeconomic data and – to the extent possible – with international data sources. Important for this thesis is the focus on capturing change in sectoral and product demand composition as well as the role of trade. The implication of the abovementioned approach is lack of absolute compliance with national level monetary supply use tables (Stadler et al., 2018), something which is of less importance in relation to the analysis pursued in section 4. Taken together, this further demonstrates the suitability of EXIOBASE.

The emission accounts in EXIOBASE include data on air emissions for 27 pollutants for both industries and final demand (for the full list see appendix A). Due to lack of methodological consistency, details, completeness and transparency, the air emissions are calculated bottom-up. To ensure consistency, the emission categories are aligned with IEA definitions for combustion emissions. For air emissions, the calculations have been done by combining activity data with emission factors from the TEAM model (Pulles et al. 2007). These emission factors, in turn, are compiled from various sources (IPCC, 2006; European Environment Agency, 2009 as cited in Stadler et al., 2018; Amann, 2009) and are chosen to account for differences in technology across countries. This also allows for changing technologies over time reflected in changing emission factors for specific activities (Stadler et al., 2018). For combustion processes, energy-use data are combined

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30 Supply/use tables provide information on respectively the products produced by industries and the use of different products by industries and final users (Casella et al., 2019). Supply and use tables can be transformed into symmetric IO tables (EUROSTAT, 2008). For a full list of data sources see Lenzen et al. (2012) and references therein.
with emission factors from the aforementioned TEAM model. In this regard, to align energy balances from IEA (2020) (covering 183 countries from 1971 and onwards) with SEEA, international transport activity is reallocated. As opposed to territorial emission accounting, where emissions in international territory is not attributed to any single countries, this means that emissions are attributed to the residence country of the operator (UNCEEA, 2012). In the terminology of this thesis, this follows the economic rather than geographic definition of countries. EXIOBASE can therefore be used to calculate production-based as opposed to territorial emissions. Finally, regarding emissions from non-combustion activities, activity data (from various sources, see Stadler et al., 2018 and references therein) is combined with different technologies. This is similar to the calculation of combustion emissions.

As mentioned, EEMRIO modelling can be used to calculate multiple footprints. This is also the case with the EXIOBASE 3, which contains a number of satellite accounts (including both social accounts such as employment and environmental accounts including water and material accounts). However, as this is not the focus here, I will not address these further. For a full and detailed elaboration and EXIOBASE, monetary time series, satellite accounts and their compilation see Stadler et al. (2018) and references therein.

### 3.3.2 EXIOBASE 3 – hybrid

The EXIOBASE also exists in a hybrid version which differs in specifying transactions in mass or energy units as far as relevant (as opposed to monetary). Hybrid here indicates that there is a physical (mass), energy (electricity and heat) and monetary (services) layer. This is unique as other MRIO tables map transactions in monetary terms only (Merciai & Schmidt, 2018). The hybrid version is available for the year 2011 (exiobase.eu) and covers 43 countries and 5 Rest of World regions and 164 industries\(^{31}\). Due to the layered structure and the difference in units in the same table, the hybrid MRIO table is only available in a product by product version. This however extents beyond its monetary counterpart by including waste extensions and information on stock addition (exiobase.eu).

The creators of the hybrid EXIOBASE MRIO point to advantages of such an approach. These include the possibility to perform balance checks at both the activity and overall level in different units. Doing so can ensure respecting the law of conservation of mass (for example ensuring a given production process does not lack inputs to satisfy production) as well as consistency between products and input uses and externalities resulting from these (for example combustion of a given amount of a specific fuel resulting in a specific amount of certain emissions) (Merciai & Heijungs, 2014;Merciai & Heijungs, 2014;...)

---

\(^{31}\) The sector ‘Manufacture of gas; distribution of gaseous fuels through mains’ was split into two, resulting in one additional sector compared to the monetary version
Merciai & Schmidt, 2018). Additionally, monetary IO tables assume price homogeneity which can affect calculated environmental footprints. Having multiple layers allows for differences in prices addressing this issue (Merciai & Heijungs, 2014). Despite addressing price inhomogeneity, however, hybrid IO tables can still have imbalances due to inhomogeneous aggregations in product groups (Majeau-Bettez et al., 2016). Other disadvantages of the hybrid approach include intensive data dependency (any MRIO is heavily dependent on the data foundation on which it relies and a hybrid version even more so) and the strong adoption of assumptions that follows due to data shortages (Merciai & Schmidt, 2018). Because this thesis focuses on GHGs and consumption-based emissions and the MRIO are used towards this end, however, I do not address the construction of the hybrid EXIOBASE further. For more on the construction as well as the full list of raw data sources see Merciai and Schmidt (2018) and references therein.

### 3.3.3 Eora

The Eora MRIO (Lenzen et al., 2012, 2013) aims at high amount of detail and covers (as opposed to EXIOBASE which focuses on Europe and major economies) 189 countries at varying sector detail (from 26 to 500 depending on the country) from 1990-2015 (Casella et al., 2019). The varying sector detail is unique to Eora, in which sectoral classifications from data providers are preserved (using national IO or supply/use tables). Sectors across countries are then linked through trade statistics to construct a MRIO table. Because sectors are non-symmetric, the flow of goods from one exporting sector to an importing sector needs to be estimated creating ‘off-diagonal’ trade blocks (Casella et al., 2019). This estimation procedure requires several assumptions (as trade data reports product, export industry and import country but not import sector) and steps which are described in Lenzen et al. (2012). The MRIO tables are then balanced so that outputs equal inputs as is required in IO analysis. For a comprehensive elaboration on the construction of the Eora MRIO see (Lenzen et al., 2012, 2013). An overview of the monetary and hybrid EXIOBASE in addition to the Eora MRIO is available in table 1.

<table>
<thead>
<tr>
<th>MRIO database</th>
<th>Countries</th>
<th>Industries and products</th>
<th>Years</th>
<th>Satellite account coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXIOBASE, monetary</td>
<td>44 + 5 RoW</td>
<td>200 products and 163 industries</td>
<td>1995-2016 (1995-2011 for full version)</td>
<td>Over 100 extensions with multiple accounts including energy, emissions (see appendix A), water and land footprints, employment</td>
</tr>
<tr>
<td>EXIOBASE, hybrid</td>
<td>43 + 5 RoW</td>
<td>164 industries</td>
<td>2011</td>
<td>Same as monetary in addition to waste extensions and information on stock addition</td>
</tr>
<tr>
<td>Eora MRIO</td>
<td>189</td>
<td>26 to 500 depending on country</td>
<td>1990-2015</td>
<td>Energy, emissions, water and land footprints, employment</td>
</tr>
</tbody>
</table>

Sources: References in section 3.3
4. Green growth and carbon accounting – past, present, future

Denmark will actively work for the goal of the Paris Agreement to keep global temperature increases below 1.5 degrees. The parties agree that Denmark shall have a binding climate law with a target of 70 percent reduction of greenhouse gasses in 2030 compared to 1990 and a long-term goal of climate neutrality in 2050 at the latest with the 1.5 degrees target in view.

— Agreement on law of climate change, 6 December 2019 (p. 2)

This paragraph marks the beginning of the main analytical section. In this chapter, I will, in turn, consider different questions of analytical importance in the discussion of different GHG accounting perspectives and the notion of green growth in climate policy. First, I address whether the Danish political economy should be considered an example of GGG as suggested by Stoknes and Rockström (2018) and the role carbon accounting plays in this regard. Second, I map out elements of difference in national-level emission estimates. Third, I quantify what future efficiency improvements are necessary to constitute GGG for Denmark going forward.

4.1 To GGG or not to GGG; that is the question

Stoknes and Rosckström (2018) suggest operationalising GGG as ΔCAPRO > 5%. This definition has, as also mentioned in section 2.4, a number of problems in relying ‘on the higher end of the allowable carbon budget’ and considering 2 °C with >66% probability scenarios only (Stoknes & Rockström, 2018, p. 43). However, if we momentarily accept this definition, countries in the Nordic region, more specifically Denmark, Sweden and Finland, have shown signs of GGG when relying on territorial carbon accounting. In fact, Stoknes and Rockström (2018) find that Finland, Sweden and Denmark have all ‘demonstrated genuine green growth in this century’ (p. 44). They claim to prove this by creating an index for carbon productivity, comparing it to a hypothesized GGG scenario of 5% p.a. improvement in CAPRO. When indexing, the average CAPRO in the years 2000-2003 is used as the baseline relative to the period 2004-2014. The corresponding graph is available in appendix B. To support the graph, Stoknes and Rockström fit a logistic growth model to the data and finds that yearly CAPRO improvements are above 5% p.a. (Sweden: 5.76%, Finland: 5.45%, Denmark: 5.03%), supposedly illustrating that ‘critics of green growth are wrong in claiming that there is no evidence for genuine green growth happening since 2000’ (p. 47).

When considering the graphs presented in appendix B, consistent and continual improvements in CAPRO are evident over time. As such, high annual variability (business cycles, warm winters, etc.) that has the potential to change yearly GHG emissions is not the driver of these results. Increases in CAPRO for Denmark and Sweden are very close to or even above the GGG line, which marks continual 5% improvements each year. Wanting to engage with the approach used by Stoknes and Rockström (2018), I first successfully replicated their results to solidify my methodology. The corresponding graph is available in appendix C. To test if the results are sensitive to
the source of data, I then made a similar analysis using emission data from the Global Carbon Project (2018) (updated from (Peters, Minx, et al., 2011))\textsuperscript{32}. I use the Global Carbon Project database because it treats bunker fuels as separate (Quéré et al., 2018). Thereby, I can illustrate the importance of treating emissions from international transportation as separate from national emissions for GGG (which is of particular relevance for Denmark cf. section 2.4). Similar to Stoknes and Rockström (2018), I find a yearly increase in CAPRO around 5 percent for Denmark and Sweden when using territorial emissions (see figure 8). Indeed, there is high resemblance between figure 8 and the graphs in Appendix B. The increases in CAPRO in figure 8 using territorial emissions from the Global Carbon Project (2018) are slightly lower over the period compared to appendix B and C. Still, the findings are not substantially different.

**FIGURE 8**: Claimed evidence of genuine green growth in the Nordics

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure8.png}
\caption{\textit{Note: 100 = 2000–2003 average, GGG = genuine green growth rate of 5\% pa., GDP data in 2010 USD Data sources: Global Carbon Project (2018), GDP figures are from the World Bank}}
\end{figure}

This changes however, when using consumption-based emissions. In that regard, figure 9 depicts changes in CAPRO over time using consumption-based measures of carbon emissions from the Global Carbon Project (2018). Importantly, using consumption-based emissions to estimate CAPRO over time changes the conclusions put forward by Stoknes and Rockström (2018) quite substantially. Using 2000-2003 as the baseline, the development far from resembles GGG. As highlighted in section 2, consumption-based emissions are typically higher than territorial emissions for countries in the Global North. It is therefore not surprising that consumption-based emissions are higher than domestic emissions for Denmark, Sweden and Finland (Global Carbon Project, 2018). Despite all three political economies have increased CAPRO, Sweden

\textsuperscript{32} The Global Carbon Project relies on the Global Trade Analysis Project (GTAP) to create the MRIO used for EEMRIO analysis (Peters, Andrew, et al., 2011; Peters, Minx, et al., 2011).
being the relatively most successful in the period, the increases in CAPRO far from reaches the already questionable 5% yearly target. Not only are consumption-based emissions higher than territorial emissions to begin with for the political economies in question (which are supposedly all examples of GGG), decreases in absolute emissions levels over time are also slower for consumption-based than for domestic emissions.

FIGURE 9: Not so genuine green growth in the Nordics

The findings become even more striking when bringing in emissions not considered in the current accounting framework (see figure 10). As noted in section 2, emissions from bunker fuels are not considered a part of national emissions in the UNFCCC framework. The issue of integrating bunker fuels into an accounting framework is not clear cut. How should bunker fuels be shared between the exporting or importing party? With regard to international shipping, the UNFCCC has not put forward a ‘single allocation option that can be regarded as environmentally effective, legally effective and allowing for fair burden sharing’ (Heitmann & Khalilian, 2011, p. 682). This is complicated by international shipping being a multi-level, multi-purposed, multi-functional and heterogenic, arguably opening for a polycentric approach (Gritsenko, 2017). And not only is allocation principles contested, no single standard is accepted and globally recognized regarding how to calculate footprints over the entire freight transport supply chain in the first place33 (Kellner, 2016). Yet, to address climate change, emissions from combustion bunker fuels need to be regulated and accounted for (Heitmann & Khalilian, 2011; Kellner, 2016).

33 There is, however, a European standard for emission calculation of transportation (EN 16258). This stipulates inter alia including indirect energy consumption and emissions from energy processes but not from manufacture, maintenance and disposal of vehicles and traffic infrastructure (Schmied & Knörr, 2012), illustrating the sometimes arbitrary lines along which standards are made.
In Figure 10, I include estimations of emissions from Danish bunker fuels from Statistics Denmark in Danish territorial emissions. In practice, this corresponds to attributing emissions from the combustion of bunker fuels to the residence country of the operator and is consistent with the economic approach to production-based emissions, the SEEA and EXIOBASE. This allocation principle also aligns with option 4 put forward by the UNFCCC in its 1996 National Communication by the Subsidiary Body for Scientific and Technological Advice (SBSTA, 1996; Heitmann & Khalilian, 2011). This is not to argue that an optimal accounting framework should allocate bunker fuels in this or that way. Rather, I aim to illustrate how leaving out bunker fuels of national emissions works to support a green growth narrative. In fact, because the monetary value added is included in GDP figures, emissions from bunker fuels need to be added to territorial emissions to make sensible comparisons (Peters & Hertwich, 2008b; Pedersen & De Haan, 2006). As also highlighted in section 2.2, this is especially relevant for the Danish case, seeing the size of the Danish shipping company Maersk. Alternatively, the sector ought to be left of Danish GDP when calculating CAPRO.

Relating back to section 2.2, I also include emissions from biomass in territorial emissions. As mentioned, emissions from burning biomass is considered carbon neutral in the UNFCCC framework. In figure 10, I include CO2 from combustion of biomass as reported by Statistics Denmark (2020). By adding CO2 emissions from such processes directly, I essentially portray combustion processes as identical notwithstanding fuel

**FIGURE 10:** Adding emissions from combustion of bunker fuels and biomass

Note: 100 = 2000–2003 average, GGG = genuine green growth rate of 5% p.a., GDP data in 2010 USD
*Data source:* Global Carbon Project (2018), World Bank, Statistics Denmark (www.statistikbanken.dk/DRIVHUS)

---

34 Other options considered include allocation to parties proportional to national emissions, allocation to parties according to where the bunker fuel is sold, no allocation (as is currently the case) and more. For the full list (there are eight options in total) see SBSTA (1996).
input. However, despite additional emissions from combustion and removing of carbon stocks for bioenergy, regrowth does reabsorb CO2. Therefore, although deeming biomass a carbon neutral renewable constitutes a ‘serious mismatch between science and policy’ (Norton et al., 2019), treating emissions from combustion of biomass as fossil is unwarranted. Yet, seeing that the urgency with which GHGs need to be reduced is incompatible with the period of reabsorption, any relevant assessment of GGG should consider the role of bioenergy in the renewables’ portfolio. Arguably, one can consider estimates that include GHG emissions from combustion of biomass to constitute one end of a ‘biomass-carbon-neutrality’ spectrum (not including these emissions constituting the other). I do so to, similar to the argument above, illustrate how carbon accounting rules matter for narratives of GGG. In practise, one can imagine that national emissions after accounting for some degree of reabsorption would be somewhere in between the two extremes in the ‘biomass-carbon-neutrality’ spectrum.

Interestingly, figure 10 shows a dramatically different picture than the one presented by Stoknes and Rockström (2018) without relying on consumption-based emissions. Looking at the developments in CAPRO over time in figure 10 rules out anything close to GGG. In fact, including emissions from the combustion of bunker fuels and biomass in Danish emission accounts means that the observed change is far from sufficient decoupling (although the development from 2006 and onwards would qualify as absolute decoupling). When considering territorial estimations, including GHGs from the combustion of bunker fuels and biomass, the Danish CAPRO has hardly increased in this millennium (despite increases in GDP for most of the period). Especially the inclusion of bunker fuels influences developments in CAPRO over the period, reflecting increased emissions from international transportation (primarily shipping) facilitated by Danish firms. This also point to the potentially substantial difference between territorial and production-based emissions.

The allocation principles used in figure 10 illustrate how GHG accounting is critical in deeming certain countries and developments to be ‘green’. In the case of Denmark, including bunker fuels in national territorial emissions of the operating country and acknowledging that combustion of biomass is not carbon neutral changes claims of GGG substantially. This is the case even when not considering consumption-based emissions, which from the perspective of ecological unequal exchange theory, and seeing the particular responsibility of the Global North (Sachs, 1999), is the more just approach. Seeing how bioenergy in Denmark relies heavily on imported biomass (Jørgensen & Andersen, 2012), arguably illustrating unequal ecological exchange and the capacity to ease pressure on domestic natural capital, adds to such arguments. Taken together, Denmark is not an example of GGG. This is the case even when accepting the ΔCAPRO>5%-definition and relying on domestic emissions if acknowledging emissions from combustion of bunker fuels and biomass.
4.2 A GHG by any other name would warm just as much

Up until this point, I used a number of different emission estimates. Reviewing historical changes in the north-south transfer globally and emissions over time for the Danish political economy, I used numbers from Wood, Grubb, et al. (2019). They, in turn, rely on different EEMRIO databases. In the analysis above, I used estimates from the Global Carbon Project (2018) and the Statistics Denmark. Now, in this section, I put forward my own estimates relying on the method described in section 3.1. In short, emission estimates are plenty. And, as illustrated above, emission accounts vary in several dimensions. This variability influence questions of what constitutes sufficient decoupling and the notion of genuine green growth since necessary GHG reductions of course depend on what emission estimates are considered in the first place. Such matters go beyond the use of accounting framework. As illustrated in the Danish press, for example, the consumption-based emission figures put forward by Lund et al. (2019) are substantially different from the estimates by Schmidt despite both using EXIOBASE (Aagard, 2019). This section discusses differences in consumption-based figures, seeking to understand what elements vary between estimates and puts forward estimates for Danish consumption-based emissions in this millennium, using both the monetary and hybrid version of EXIOBASE.

4.2.1 Differences in databases

Depending on which MRIO is used for EEMRIO analysis, MRIO databases differ in terms of scope, sector disaggregation, data sources, purpose, units and more. To apply consumption-based environmental indicators in a policy context requires an understanding of what factors influence the observed differences in GHG emissions (and more generally environmental indicators) (Giljum et al., 2019). This has been a research focus in the industrial ecology literature and special issues in various journals have been devoted to such matters (Inomata & Owen, 2014; Tukker et al., 2018). So far, the research has aimed to understand how the use of different data sources (both on a sector and country level), assumptions and constructs used in constructing MRIO tables, environmental extensions, the inter-industry transaction matrix, final demand and total output all have on carbon footprints (Arto et al., 2014; Moran et al., 2014; Owen et al., 2014, 2016; Wieland et al., 2018). Contingent on the databases, regions and years in question, these factors all contribute to differences in estimated consumption-based emissions.

Considering the literature and these findings in relation to this thesis, some key observations are worth highlighting. Most importantly, calculations on the GHG embodied in trade and in final goods are more robust than at different layers of production (cf. section 3.1) (Wieland et al., 2018). Between the Eora and the EXIOBASE databases, for example, little difference is observed in the amount of emissions embodied in the final good (despite differences at different layers of production) (Wieland et al.,
2018). Also, national level consumption-based accounts (as considered in this thesis) are more robust than information on global value chains (Owen et al., 2016). In addition, domestic flows are more important in explaining differences between MRIO databases than the trade flows. Because trade flows define the consumption-based accounting framework (adding emissions embodied in imports and subtracting emissions embodied in exports), this speaks to the benefit of national-level carbon footprint calculations. Taken together, these findings imply that using MRIO analysis remains relevant for trade policy and demand-based climate policy (Wieland et al., 2018).

4.2.2 The carbon footprint of the Danish political economy

A recent newspaper article suggest that substantial differences exist between carbon footprint estimates for Denmark even for the same database (Aagard, 2019). Specifically, Jannick Schmidt, one of the creators of the hybrid EXIOBASE (see Merciai & Schmidt, 2018), finds that the emission footprint for Denmark is 16.8 tons CO2e per capita in 2011. This is a source of confusion, as the same article also refers to estimates of 13-15 tons CO2e citing professor Jens Friis Lund, not making clear that these estimates refer to later years. Contrastingly, Lund et al. (2019) reports a figure 15.6 tons CO2e per capita in 2011. Adding to the confusion, Aagard (2019) points to the likelihood of increasing consumption-based emissions citing Schmidt and the Danish think tank Concito while Lund et al. (2019) reports decreases for the period 2011-2015. How can we reconcile such differences? If different estimates are both based on the consumption-based approach and both use EXIOBASE, how can one estimate be approximately 7.5 percent higher for the same year (15.6 vs. 16.8 tons CO2e)? Above we have seen how the accounting framework is important for total emissions and we have seen how a variety of different aspects goes into constructing EEMRIO tables, explaining differences between databases. But can difference arise when using the same accounting framework, the same constructs, the same data sources, the same A matrix, the same satellite accounts and the same final demand vector? To understand this, we need an overview over different elements of emission account estimates.

In table 2 below, I present an overview of what I here refer to as elements of comparability. In order to compare emission estimates, we need to understand what choices have been made and what assumptions are used with regard to each of these elements. This include the overall choice of accounting framework, accounting rules, data sources, database construction, sectors, source categories, the range of GHG as well as type of effects and timeframe of emissions. The table is not exhaustive but aims to provide an overview of the multitude of aspects that goes into calculating and allocating national-level carbon accounts. For each element of comparability, I provide examples, moving from the abstract and general towards the more concrete and specific. In this regard, I am inspired by Lund (2014), who distinguishes between the abstract and the concrete and the general and the specific.
One can understand the movement from the general to the specific and from the abstract to the concrete as moving along two open-ended continua (Lund, 2014). For example, moving from the notion of accounting rules at the general and/or abstract level, to accounting frameworks such as the SEEA towards the concrete and/or specific, as e.g. the 8 different rules suggested in SBSTA (1996). Or moving from the notion of GHGs, to the specific type of gasses, to concrete examples of including or leaving certain GHGs (as is the case with Wood, Grubb, et al. (2019)). One can also imagine further specification than the examples listed in the right column in table 2. For example, considering ‘sector categories’, the mineral industry is in the IPCC 2006 categorisation further specified as cement production, lime production, glass production and other. Even more concrete, emissions from these sectors needs to be calculated using either

**TABLE 2**: Elements of comparability for national-level emissions

<table>
<thead>
<tr>
<th>General and/or abstract</th>
<th>More specific and/or concrete</th>
<th>Specific and/or concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting framework</td>
<td>Consumption-based, production-based</td>
<td>Territorial within country’s geographic definition, territorial within country’s economic definition, consumption within country’s economic definition</td>
</tr>
<tr>
<td>Accounting rules</td>
<td>SEEA, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, NAMEA*</td>
<td>8 different rules in SBSTA (1996), biomass as carbon-neutral</td>
</tr>
<tr>
<td>Database construction</td>
<td>Sector aggregation and resolution, choice of constructs</td>
<td>The by-product construct, unit of transaction</td>
</tr>
<tr>
<td>Data sources</td>
<td>UN Comtrade, IEA energy balances</td>
<td>Measured data, modelled estimates</td>
</tr>
<tr>
<td>Sector categories</td>
<td>LULUCF, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and other Land Use (AFOLU)</td>
<td>Forest land, mineral industry, chemical industry, solid waste disposal, petroleum refining</td>
</tr>
<tr>
<td>Source categories</td>
<td>Selected Nomenclature for Air Pollution, Integrated Pollution Prevention and Control nomenclature</td>
<td>CH4 - non combustion - Oil refinery – air, N2O - agriculture – air, CO2 - combustion – air (see appendix D)</td>
</tr>
<tr>
<td>Types of GHGs</td>
<td>Kyoto gasses, F-gases, direct and indirect emissions</td>
<td>CO2, CH4, HFCs</td>
</tr>
<tr>
<td>Types of effects</td>
<td>Primary and secondary effects, direct and indirect effects</td>
<td>Carbon-climate feedbacks, oxidation of atmospheric methane into CO2</td>
</tr>
<tr>
<td>Timeframe</td>
<td>GWP20, GWP50 and GWP100</td>
<td>Different conversion factor from CH4 to CO2e from IPCC assessment reports</td>
</tr>
</tbody>
</table>

*National accounting matrix including environmental accounts

**Note**: The table should be regarded as non-exhaustive

**Sources**: Author’s own compilation based on references in section 2, 3, 4 and Jeffery et al. (2018)
default emission factors, country-specific emission factors or modelling (Jefferey et al., 2018), pointing to another element that varies. An additional example is carbon-climate feedbacks, which can be further specified as ‘types of effects’. Carbon-climate feedbacks encompass a range of both positive and negative feedback effects from increased radiative forcing or increased temperature e.g. greater water vapour concentration (causing further radiative forcing) or the cloud albedo effect (Balcombe et al., 2018; Haywood & Boucher, 2000).

I present this overview for two reasons. First, to illustrate the multi-faceted and multi-level nature of calculating national-level GHG emissions. Second, to address how to understand the differences in estimates in Aagard (2019). With regard to the latter, when considering the different ‘elements of comparability’, we realize that the discrepancy in estimates cannot arise from some of these. Specifically, because the accounting framework and accounting rules used are similar35, differences cannot arise from these. Because the EXIOBASE exists in both the monetary and the hybrid version of EXIOBASE, this is a potential point of discrepancy, pointing to differences in database construction. Other elements that can explain differences in estimates have only briefly been addressed if at all hitherto in the thesis. These include sectors categories (such as LULUCF), the period over which the warming potential of different GHGs is considered36, and the inclusion of different types of effects (such as climate-carbon feedbacks).

For methane specifically, choosing what climate metric is applied to convert CH4 into CO2e is of high importance. Methane is the second largest global contributor to climate change after CO2 (Saunois et al., 2016). Moreover, the radiative forcing of CH4, i.e. the ‘total change in heat balance in the atmosphere from the increase in concentration of a greenhouse gas’ (Balcombe et al., 2018, p. 1325), is approximately 120 times higher than that of CO2 at the time of emission. However, CH4 has a relatively short perturbation lifetime of 12.4 years (Balcombe et al., 2018; Farquharson et al., 2017). Therefore, the conversion factor, i.e. the global warming potential37 (GWP), changes significantly depending on the time frame (see table 3). As evident from table 3, for the standard time horizon of 100 years (GWP100), the most recent climate metric of CH4 varies between 28 and 36. This difference is decided by whether to include climate carbon feedback effects and oxidation of methane. Because such metrics are used to convert different GHGs into CO2e, these can attribute to differences in national-level emission estimates. Under the UNFCCC framework, for example, countries report national emissions

35 Both Schmidt and Lund et al. use consumption-based estimates and the EXIOBASE, which is consistent with SEEA.
36 Because the lifetime in the atmosphere of GHGs varies substantially, this highly influences the estimated global warming potential of gases.
37 Defined as the average (time-integrated) radiative forcing of a pulse emission over a defined time horizon compared to CO2 (Myhre et al., 2013).
referencing GWP100-factors from the Intergovernmental Panel on Climate Change (IPCC) and its Fourth Assessment Report, applying a GWP100-factor of 25 (Nielsen et al., 2019). Contrastingly, replicating Lund et al. (2019), I have confirmed that they consider direct effects only, using a climate metric for methane of 28 (see script in supplementary material).

I highlight this not to open for a discussion on the complexities of radiative forcing and climate physics38, but to point to how these decisions matter for emission estimates. In this spirit, in figure 11 below I present updated estimates of Danish consumption-based emissions (a table with the estimations used for the figure is available in appendix E). I use the two different versions of EXIOBASE and include indirect feedback effects of methane, i.e. oxidation and carbon-climate feedback (referenced in Balcombe et al.,

38 For a more thorough introduction to and application of the concept of radiative forcing see Myhre et al., (2013) and references therein.
2018). I also include indirect feedback effects of other GHGs such as N2O following the 5th IPCC assessment report (Myhre et al., 2013, p. 714 table 8.7). The C matrix used for the estimation and conversion factors therein is available in appendix D. Figure 11 illustrates the importance of CO2e-conversion factors for both the overall level of emissions and the comparability of different emission estimates. The difference in some years is noticeably higher than in others. In 2008 for example, the consumption-based emission estimates using an updated C matrix is 13.2 percent higher than for Lund et al. (2019), while in 09-10 the updated calculations are less than 7 percent higher. A high relative difference indicates a higher relative share of embodied CH4 and N2O. Using the hybrid version of EXIOBASE and applying the conversion factors reported in appendix D, I find consumption-based emissions of 16.42 ton CO2e per capita in 2011. When applying a C matrix identical to the one used by Lund et al. (2019) in the hybrid version, I find consumption-based emissions of 15.6 tons CO2e per capita, similar to when using the monetary version of EXIOBASE.

The time series in figure 11 extends beyond 2015 to 2016, showing an increase in consumption-based emissions per capita. Taken together with the updated conversion factors and the higher resulting CO2e per capita, these results strongly indicate that the emissions reductions that are needed for sufficient decoupling in consumption-based emissions should be more than the 2.4 times faster than the historical trend from 1995-2015, as suggested by Lund et al. (2019). Indeed, because Lund et al. considers necessary reductions from 2015-2030, finding that emissions increased from 2015 to 2016 alone points to this result.

4.3 O GGG, where art thou

All economic activity requires energy and expanding economic activity will therefore – all else equal – lead to more GHG emissions (Jackson & Victor, 2019). Therefore, to proclaim genuine green growth, we need to know what changes in emission intensity are necessary for sufficient decoupling. Having addressed Denmark as an example of GGG in addition to elements that influence GHG estimates, I now try and answer the question of what efficiency improvements are necessary with continued economic growth. I first conceptualize the relationship between economic growth and GHG emissions, considering recent history. Second, in an effort to operationalise GGG anew, I estimate needed future efficiency improvements for Denmark.

4.3.1 Decomposing emissions

To shed light on the linkages between economic growth and emissions, I start from the Kaya Identity (Kaya, 1989; Kaya & Yokobori, 1997) also applied by the IPCC (Blanco et al., 2015). The Kaya Identity decomposes CO2 emissions into different underlying factors and is a common framework used to analyse what drives emissions. It is a special case of the IPAT identity (Ehrlich & Holdren, 1971), which considers environmental
impact (I) as a product of population (P), affluence (A), e.g. income per capita, and technology (T), e.g. GHG emission intensity of production or consumption (Blanco et al., 2015). For territorial carbon emissions, the Kaya Identity can be written as:

\[
CO_2^{terri} = \frac{CO_2}{Energy} * \frac{Energy}{GDP} * \frac{GDP}{P} * P \tag{9}
\]

Where territorial carbon emissions \((CO_2^{terri})\) are equivalent to the product of (1) the carbon intensity of energy \(\frac{GHGs}{Energy}\), (2) the energy intensity of GDP \(\frac{Energy}{GDP}\), (3) the per capita GDP and the size of the population (Raupach et al., 2007; Storm & Schröder, 2019). (1) and (2) can also be merged into \(\frac{CO_2}{GDP}\), the carbon intensity of GDP (and thus the inverse of CAPRO). We then have another case of the IPAT identity:

\[
CO_2^{terri} = \frac{CO_2}{GDP} * \frac{GDP}{P} * P \tag{10}
\]

For consumption-based carbon emissions, the Kaya-identity can be written as:

\[
CO_2^{cons} = \frac{CO_2^{cons}}{GNE} * \frac{GNE}{P} * P \tag{11}
\]

Where consumption-based carbon emissions \((CO_2^{cons})\) are decomposed into three different factors namely (1) the embodied carbon intensity of consumption \(\frac{CO_2^{cons}}{GNE}\); GNE = Gross National Expenditure\(^{39}\), (2) the per capita consumption \(\frac{GNE}{P}\), and (3) the size of the population (Blanco et al., 2015; Raupach et al., 2007). (10) and (11) encompasses carbon emissions from fossil fuels combustion and industrial processes only (Raupach et al., 2007) and therefore excludes other GHGs as well as all emissions from agriculture, deforestation and land use change (the AFOLU category from table 2). For this paper, I generalize (10) and (11) to also consider non-CO2 GHGs (ensuring consistency with the analysis in section 4.1 and 4.2):

\[
E^{terri} = \frac{E^{terri}}{GDP} * \frac{GDP}{P} * P \tag{12}
\]

\[
E^{cons} = \frac{E^{cons}}{GNE} * \frac{GNE}{P} * P \tag{13}
\]

Referencing Storm and Schröder (2019), totally differentiating and rearranging the Kaya Identity gives the Kaya sum rule for compound average annual growth rates:

\[
\ddot{C} = \ddot{c} + \ddot{e} + \ddot{y} + \ddot{P} \tag{14}
\]

Where growth in carbon emissions, \(\ddot{C}\), is driven by change in carbon intensity of energy, \(\ddot{c}\), the change in the energy intensity of GDP, \(\ddot{e}\), and per capita GDP and population growth. Carbon emissions decrease when the carbon intensity of energy goes down, e.g. by increasing the share of renewable sources of energy. Similarly, carbon emission decline when energy intensity of GDP declines through improvements in energy efficiency.

\(^{39}\)GNE includes household final consumption expenditure, general government final consumption expenditure and gross capital formation (World Bank national accounts data and OECD National Accounts data files).
enabling producing the same amount of output using less energy. Contrastingly, CO2 increases when the population and/or GDP increases. Totally differentiating any of the equations (9) through (13) gives a similar ‘sum rule’ for compound average annual growth rates. Using the IPAT identity from which any of the above equations is a subset, we have:

\[ I = \dot{T} + \dot{A} + \dot{P} \]  \hspace{1cm} (15)

Where the change in impact, \( \dot{I} \), can be decomposed into the change in technology, \( \dot{T} \) (be it measured as emission intensity of GDP or GNE), affluence or income, \( \dot{A} \), and population, \( \dot{P} \). In the following, I draw on this approach to understand changes over time, both historical and necessary future changes.

In this regard, the Danish Council on Climate Change (2015) has decomposed changes in national emissions from 1990-2012 for Denmark and a range of other OECD countries according to a generalized version of equation (10) (see table 4). In its analysis, the council uses emission accounts from the European Environment Agency. These include CO2, CH4, N20 and F-gases and are equivalent to the official Danish emission inventories (Nielsen et al., 2019) submitted under the UNFCCC and the Kyoto Protocol. Therefore, emissions from bunker fuels and combustion of biomass are excluded in accordance with the principles of the UNFCCC. For GDP and population statistics the analysis draws on the Eurostat database (The Danish Council on Climate Change, 2015). This decomposition reveals that relatively low GDP growth partly explains the decrease in Danish territorial emissions (only the GDP per capita of Japan has increased less in percentage terms). For example, assuming that changes in energy intensity of GDP and

<table>
<thead>
<tr>
<th>Country</th>
<th>Change in ( E^{\text{ex}} )</th>
<th>- Contribution from transition -</th>
<th>Contribution from economic growth -</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( E^{\text{ex}}/\text{Energy} )</td>
<td>( E^{\text{ex}}/\text{GDP} )</td>
<td>GDP/P</td>
</tr>
<tr>
<td>Denmark</td>
<td>-24.8</td>
<td>-24.7</td>
<td>-30.4</td>
</tr>
<tr>
<td>Sweden</td>
<td>-20.8</td>
<td>-28.0</td>
<td>-36.4</td>
</tr>
<tr>
<td>Norway</td>
<td>4.5</td>
<td>-29.0</td>
<td>-22.9</td>
</tr>
<tr>
<td>Finland</td>
<td>-13.3</td>
<td>-29.1</td>
<td>-23.5</td>
</tr>
<tr>
<td>Germany</td>
<td>-24.8</td>
<td>-14.5</td>
<td>-37.8</td>
</tr>
<tr>
<td>Holland</td>
<td>-9.5</td>
<td>-27.9</td>
<td>-28.2</td>
</tr>
<tr>
<td>Great Britain</td>
<td>-25.3</td>
<td>-19.7</td>
<td>-44.8</td>
</tr>
<tr>
<td>United States</td>
<td>4.3</td>
<td>-7.3</td>
<td>-45.1</td>
</tr>
<tr>
<td>Canada</td>
<td>18.2</td>
<td>-2.0</td>
<td>-37.2</td>
</tr>
<tr>
<td>Australia</td>
<td>31.0</td>
<td>-14.9</td>
<td>-37.8</td>
</tr>
<tr>
<td>Japan</td>
<td>8.8</td>
<td>5.8</td>
<td>-18.0</td>
</tr>
</tbody>
</table>

**Table 4**: Changes in territorial GHG emissions decomposed, 1990-2012

*Sources: The Danish Council on Climate Change (2015), p. 9, using data from the European Environmental Agency, Eurostat and OECD*

*Note: Columns 3-6 sum to ‘Change in \( E^{\text{ex}} \)’
the emission intensity of energy would remain the same in the period despite higher economic growth, Danish territorial emission would ‘only’ have decreased by 8.9 percent in the period 1990-2012, had Danish GDP growth been equivalent to that of Norway (The Danish Council on Climate Change, 2015).

Using an approach similar to Storm and Schröder (2019), considering compound average annual growth rates, I decompose the development in Danish consumption-based emissions from 2000-2016 according to (13). I use the $E^{\text{comb}}$ estimates from figure 11 applying the C matrix from appendix D, GNE statistics from the World Bank (in constant 2010 USD) and population statistics from the United Nations (2017). The findings are available in table 5 below. In the period, consumption-based emissions decreased by 1.2% yr$^{-1}$ (yr$^{-1}$ refers to per year compounding annually). Decomposing the yearly change, population growth and expenditure per capita exerted an upwards pressure on consumption-based emissions while emission intensity of gross national expenditure drove emissions down. Thus, increasing expenditure per capita (adjusted for inflation) helps explain why Denmark is not an example of GGG from a consumption perspective, driving emissions up. Had GNE per capita increased at the 2.1% yr$^{-1}$ all else equal, consumption-based emissions would have remained constant from 2000-2016. The below constitutes an example of absolute decoupling but not sufficient decoupling of consumption-based emissions from GNE, as absolute emissions are decreasing but not at a rate that is in line with the 1.5-2 °C target.

| Table 5: Decomposed changes in % yr$^{-1}$ consumption-based emissions 2000-2016 |
|---|---|---|---|
| $E^{\text{comb}}$ | $E^{\text{comb}}$/GNE | GNE/P | P |
| (1) | (2) | (3) | (4) |
| -1.2 | -2.5 | 0.9 | 0.4 |

Source: Own calculations based on EXIOBASE
Note: Columns (2), (3) and (4) sum to (1)

### 4.3.2 Operationalizing genuine green growth anew

In section 2.4.4, I criticized the attempt to operationalize GGG as an increase in CAPRO of 5 percent yr$^{-1}$ (equation (3)). One of the criticisms raised against that definition was that it was based on scenarios which were consistent with a 2 °C target. Seeing the risks and costs associated with increases in temperature above 1.5 °C (Allen et al., 2018) as well as the imminence of global tipping points in the 1.5-2 °C range (Lenton et al., 2019), I maintain that the qualitative notion of GGG cannot be reconciled with a 2 °C increase. Realizing that tipping points could be exceeded above even 1 °C (Lenton et al., 2019) questions whether 1.5 °C target itself is compatible with being genuinely green. I therefore consider the 1.5 °C target the minimum starting point for operationalizing GGG anew. This is in line with the Danish Council on Climate Change (2019) and Lund et al. (2019).
More specifically, I consider the period 2019-2030, using the ‘low-risk’ climate target estimate of 3 tonnes CO2e per capita from Lund et al. (2019, p. 20) for 2030 to operationalize GGG anew. This ‘low-risk’ target aligns the available pathways put forward by the IPCC for no or limited overshoot of 1.5 °C, which all keep emissions in 2030 to 25-30 GtCO2e yr⁻¹ (Rogelj et al., 2018). The 3 tonnes per capita estimate is based on the principle of equal per capita allocation of the global emission budget in 2030 implying that each individual is entitled to the same amount of GHG emissions annually. Noticeably, this allocation principle is itself highly contested, seeing differences in historical responsibility, climatic conditions and ‘rights to develop’ (Fanning & O’Neill, 2016; Starkey, 2008). To add perspective, Lund et al. (2019) also considers a ‘medium-risk scenario’ of 4 tonnes CO2e per capita and a ‘high-risk scenario’ of 6 tonnes CO2e per capita in 2030. The latter relies on the higher end of the 1.5-2 °C carbon budget and mass deployment of negative emission technologies while the former is a middle point between the low and high-risk scenarios.

In addition to the 3 tonnes 2030 emission target, I find projected GDP in 2030 (in 2010 prices) using the projections of the Danish Economic Councils (2019) from 2020-2025 (who projects an average real GDP growth rate of 1.8% year). From 2025 onwards, I use the long run growth in real GDP of 1.5% per year as modelled by the Danish Institute for Economic Modelling and Forecasting DREAM (2016). From this, I compute the carbon intensity in 2030 that align with 3 tonnes CO2e per capita given projected GDP in 2030. To find what yearly changes are consistent with the 3 tonnes CO2e per capita in 2030, I calculate the compound average annual growth rate that lead to the necessary CAPRO. To illustrate the role of carbon accounting I take different starting points using both territorial emissions that align with UNFCCC inventories as well as including emissions from bunker fuels and biomass. The findings are listed in table 6 and illustrated graphically in figure 12.

**Table 6: Needed yearly change per year to reach 3 tonnes CO2e per capita in 2030**

<table>
<thead>
<tr>
<th>Starting 2019</th>
<th>Territorial, Eit</th>
<th>Territorial including bunker fuels from Danish owned ships</th>
<th>Territorial including emissions from combustion of bunker fuels and biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPRO</td>
<td>10.04%</td>
<td>15.85%</td>
<td>17.77%</td>
</tr>
<tr>
<td>GHG emissions</td>
<td>-7.95%</td>
<td>-12.57%</td>
<td>-13.99%</td>
</tr>
</tbody>
</table>

*Note: Author’s own calculations based on Statistics Denmark and Nielsen et al. (2019). The national-level emissions used for these calculations are computed using conversion factors from the 4th IPCC report including a conversion factor of 25 for CH4. For similar estimates for the medium and high-risk scenario see appendix F.*

Table 6 illustrates that the 5% target put forward by Stoknes and Rockström (2018) is too low given continual expansion of production. Even when using territorial emissions and not including the GHG emissions from the combustion of bunker fuels and biomass,
a yearly improvement in CAPRO of 5% a year is not consistent with per capita emissions of 3 tonnes and thus not consistent with the 1.5 °C target. When including emissions from the combustion of bunker fuels and biomass, the needed annual percentage change in CAPRO to be consistent with the 3 tonnes per capita target increases substantially. This is no surprise noting that territorial emissions including emissions from the combustion of bunker fuels and biomass are more than double the emissions from the Danish national inventory report (Nielsen et al., 2019). Thus, carbon accounting matters not only for deeming historical developments ‘green’ or not (as argued in Section 4.1), it also highly influences necessary future changes (higher current emissions require deeper emission cuts) and thus climate policy goals. As mentioned, this holds especially true for Denmark with relatively high emissions from biomass and international transportation. Indeed, if we accept that operationalizing GGG can be done through CAPRO, the yearly increase should arguably be in the range of 16-18% per year to be consistent with the 1.5 °C going forward. And seeing that these estimations rely on outdated conversion factors from the fourth IPCC Assessment report (Nielsen et al., 2019), the 16-18% y\(^{-1}\) estimate is likely to be too low.

To find a similar yearly target for GGG using consumption-based emissions, I rely on equation (13). As the most recent year in EXIOBASE is 2016, I consider the period 2017-2030. I again use the 3 tonnes CO2e as the per capita end point target, corresponding to a national-level emission footprint of around 18.5 million ton CO2e. I here rely on the medium scenario in UN population projections (2017), assuming a little more than 6 million people living in Denmark in 2030. To find the national GNE in 2030, I extrapolate the yearly trend in GNE in the period 1995-2018 to 2030. This corresponds to 0.9% y\(^{-1}\) in GNE per capita. This leaves me with one unknown in equation

![Figure 12: Emission trajectories 2019-2030 applying GGG-criteria from table 6](image)

*Note: The emission pathways are calculated from 2019 onwards using annual percentage change in carbon intensity from table 6 and following stated assumptions.*
(13), namely $E_{\text{cons}}/\text{GNE}$, allowing me to calculate the emission intensity of gross national expenditure that corresponds to the above changes in other factors and thereby align with consumption-based emissions of 3 tonnes CO2e per capita in 2030. From this, I find the compound annual change in the emissions intensity of GNE to reach the low-risk scenario in 2030. This estimate as well as assumed and projected changes in other factors in compound annual change are evident from table 7 below. In the same limited sense that the CAPRO estimates can be used to define GGG for territorial emissions, the -11.8% y\(^{-1}\) is a minimum threshold for GGG from a consumption-based perspective. Going forward, this estimate is likely to not be sufficient given that GNE/P follows its historical trend, as I consider the period 2017-2030 and because $E_{\text{cons}}$ for Denmark has not followed the trajectory listed in table 7 from 2017 onwards.

**TABLE 7: Changes in % y\(^{-1}\) 2017-2030 that align with $E_{\text{cons}} = 3$ in 2030**

<table>
<thead>
<tr>
<th>$E_{\text{cons}}$ (1)</th>
<th>$E_{\text{cons}}/\text{GNE}$ (2)</th>
<th>GNE/P (3)</th>
<th>Population (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2e/2020DKK</td>
<td>CO2e/2020DKK</td>
<td>2020DKK per capita</td>
<td>0.4</td>
</tr>
<tr>
<td>-10.2</td>
<td>-11.3</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

*Note: (1) is given by IPCC emission pathways, (3) is found by extrapolating the yearly trend from 1995-2018 to 2030, (4) is given by the UN population projection while (3) is found as the remaining unknown in equation (13).*

Further developing the argument that 5% increase in CAPRO pro anno is inadequate for GGG, I estimate what emissions per capita the 5% y\(^{-1}\) target corresponds to in 2030. I first rewrite (12) to get:

$$GDP = \frac{\text{GDP}}{E_{\text{terri}}} \cdot \frac{E_{\text{terri}}}{P} \cdot P$$

(16)

Where GDP is the product of CAPRO, $E_{\text{terri}}$, territorial emissions per capita, $E_{\text{terri}}/P$, and the population. I extent the latest available observed CAPRO from 2018 (using real GDP and emission data from Statistics Denmark) by increasing it with 5% per year. I then find the territorial emissions per capita from equation (16) using UN Population projections and the projected Danish real GDP relying on aforementioned GDP-projections (Danish Economic Councils, 2019; DREAM, 2016). The corresponding emission pathways are available from figure 13 and, not surprisingly, far from align with the 3 tonnes CO2e per capita in 2030. In fact, if also considering emissions from combustion of bunker fuels and biomass, the Stoknes and Rockström (2018) operationalization of GGG is not consistent with any of the scenarios considered by Lund et al. (2019). Only if disregarding bunker fuels and biomass does CAPRO at 5% y\(^{-1}\) align with the ‘high risk scenario’ of Lund et al. (2019). As such, not only is the argument for historical examples of GGG contingent on disregarding emissions that arguably should be attributed to Denmark, the 5% target also only holds if (1) considering territorial emissions under the UNFCCC rules, (2) aiming for the higher end of the 2 °C budget and (3) massive deployment of questionable NET technology.
A way to illustrate the role of GDP in this is by using equation (16). The compound annual average growth rate from 2018-2030 using the projections described above is 1.68% y\(^{-1}\). If instead GDP would not increase over the period, keeping it at the 2018 level (inspired by what Herman Daly (1974, 1991) famously labelled a steady-state economy), the needed increase in CAPRO would be around 2% lower y\(^{-1}\). Taking population growth and the needed change in emissions per capita as given (assuming we need to reach 3 tonnes CO\(_2\)e per capita in 2030), national level emissions in equation (16) are then decided by GDP and CAPRO. In this regard, reaching 3 tonnes CO\(_2\)e per capita in 2030 is consistent with lower yearly increases in CAPRO given lower or no increases in GDP. Fixing yearly increases in CAPRO at Stoknes and Rockström’s 5% y\(^{-1}\), GDP needs to decrease with 3.01% y\(^{-1}\) to satisfy equation (16) and align with the low-risk scenario. These calculations are listed in table 8.

**TABLE 8.** Needed changes in GDP for Stoknes and Rockström’s conceptualisation of GGG to be consistent with E\(_{\text{terri}}\) (without bunker fuels and biomass) reaching 3 ton CO\(_2\)e in 2030

<table>
<thead>
<tr>
<th>GDP (2010 prices, kr.)</th>
<th>GDP/E(_{\text{terri}})</th>
<th>E(_{\text{terri}})/P</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>2,082,612,000</td>
<td>43.70</td>
<td>8.3</td>
</tr>
<tr>
<td>2030</td>
<td>1,448,669,390</td>
<td>78.47</td>
<td>3</td>
</tr>
<tr>
<td><strong>Compound annual percentage change</strong></td>
<td><strong>-2.98% y(^{-1})</strong></td>
<td><strong>5.3% y(^{-1})</strong></td>
<td><strong>-8.1% y(^{-1})</strong></td>
</tr>
</tbody>
</table>

*Note: GDP is found by multiplying GDP/E\(_{\text{terri}}\), E\(_{\text{terri}}\)/P and P, following (16).*

Importantly, the approach I put forward here says little about causality and the relationship between emissions and GDP nor is this a forecasting effort. Lowering GDP might signal reduced environmental pressure but does not help decide whether the level...
of economic activity is in line with planetary boundaries (O’Neill, 2014). For example, a large fiscal stimulus possibly increasing GDP can entrench or partly displace fossil-fuel-intensive sectors (Aronoff et al., 2019; Hepburn et al., 2020). However, what I aim to illustrate is not certainty regarding interaction between IPAT factors but the inadequacy of equation (3). In this regard, the calculations presented here are specific to Denmark while the criticisms are general and hold across countries.

4.4 Concluding the analysis

In conclusion, carbon accounting influences how to engage with and understand both present and future emissions. Specifically, considering consumption-based emissions, the Nordic region is not an example of GGG when applying the conceptualisation put forward by Stoknes and Rockström (2018). Moreover, Denmark has not demonstrated increases in CAPRO consistent with equation (3) when considering territorial emissions if including GHGs from the combustion of bunker fuels and biomass. Relatedly, debates on past and current emission figures are complicated by the complexity of producing such numbers. Differences in estimates arise in and between different elements of comparability. Finally, a decomposition approach reveals that going forward, GGG as conceptualized in equation (3) is inadequate to achieve emission pathways for Denmark that are consistent with 1.5 °C target. Depending on which emissions are accounted for, CAPRO needs to be in the range of 16-18% y⁻¹ given projected GDP growth. Likewise, the emissions intensity of gross national expenditure needs to decrease with around 11-12% y⁻¹ to reach 3 tonnes CO2e per capita in 2030. Even if disregarding emissions from the combustion of bunker fuels and biomass, a CAPRO of 5% y⁻¹ is only consistent with emission pathways that require massive deployment of NET and aims for keeping warming below 2 °C instead of 1.5 °C.

5. Discussion – making sense of GHG accounting and GGG

It is obvious that both the compilation and the interpretation of statistics to a large extent boil down to whether we wish to see this or that pattern. This is not a simple question of manipulation, but of a fundamental human desire to see verified by data the patterns we imagine to exist in the world. But how do we choose these patterns or interpretations to begin with?

Alf Hornborg (2003, p. 207)

In this section, I discuss and reflect on findings and analysis from previous sections, trying to make sense of the role of carbon accounting and the concept of GGG in climate governance. I first address shortcomings of GGG and the metrics from which it is constructed before explicitly relating the thesis to climate policy. I then discuss arguments for maintaining a territorial accounting framework in global climate governance and suggest an alternative framing to national emission inventory disclosure as a way to reconcile different accounting frameworks. I end by considering the value of abstract concepts in a context of climate crisis.
5.1 What does it take to be genuine (or: how green is green)?

Oxford University Press defines genuine as ‘truly what something is said to be’ (OUP, 2019). In this sense, the term genuine implies a promise. A promise of honesty, validity and sincerity. But the word is also understood in opposition to that which it is not. If some phenomena are genuine, this means that other (if not most) are not. Dubbing something as genuine implies a definitive difference from the doubtful, dubious and deceptive that we might have come to expect. In this regard, green growth is no exception. When discussing green growth, critics argue that the rhetoric is one of continuation of current practices. That what is behind the rhetoric of green growth is one of incremental change that disregards ecological limits to the Earth system (Lorek & Spangenberg, 2014). That green growth is an oxymoron (Brand, 2012), or, in the words of Dryzek (2013), a rhetorical rescue operation. As such, distinguishing between the notion of green growth as a rhetorical exercise or ‘greenwashing’ and green growth as ‘genuine’, points toward substantial difference between the two. And not only does GGG imply a positive qualitative difference from green growth as an oxymoron; GGG implies adequate societal change. GGG is what it takes. GGG is genuinely green.

Such reflections align with why I reject scenarios which rely on massive deployment of negative emission technology and the higher end of the 2 °C emission budget (similar to Lund et al. (2019) and the Danish Council on Climate Change (2019)). One should be hesitant with labelling something as ‘genuine’. In this perspective, and seeing the analysis in section 4, Stoknes and Rockström (2018) apply the term on inadequate grounds. Several arguments account for why. First, the Danish political economy does not display GGG as defined by yearly increases in CAPRO of 5% unless relying on territorial emissions. A carbon accounting framework that is partial in the sense that it leaves out emissions from economic activity reported in GDP and, from the perspective of ecological unequal exchange theory, allows actors to distance themselves from environmental costs of consumption. In fact, Denmark has not demonstrated yearly improvements in CAPRO of 5% even from a production-based perspective when accounting for what is considered Danish economic activity.

Second, defining GGG by equation (3) falls short of aligning with the 2 °C target for Denmark going forward unless relying on mass deployment of negative emission technologies. Importantly, when accounting for currently non-attributed emissions from international transportation, GGG defined as yearly increases in CAPRO of 5% massively exceeds Lund et al.’s (2019) ‘high-risk scenario’. To add perspective, even the 17.8% y⁻¹ increase in CAPRO from table 6 and figure 12 is arguably inadequate. This is because the 3 tonnes CO2e per capita in 2030 allows for limited overshoot of the 1.5 °C

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40An example encapsulating such ‘deceptive’ behaviour is the #ExxonKnew campaign (see exxonknew.org), pointing to the climate change research (and implied awareness) carried out by the fossil fuel industry dating back to the 1950s (an early example being Brannon et al., 1957) (Banerjee et al., 2015).
target and relies on distributing the global emission budget equally to all citizens; a distribution that neglects historical responsibility, climatic conditions and ‘rights to develop’ (Starkey, 2008). If instead relying on principles of ‘common but differentiated responsibilities and respective capabilities’, as stated in the Paris Agreement, necessary rates of mitigation increase substantially (Anderson et al., 2020).

Moreover, the emission accounts used to calculate the estimates in table 6 rely on GWP100-factors from the 4th IPCC assessment report (Nielsen et al., 2019). As displayed by section 4.2, these factors influence emission Danish estimates quite markedly. Relatedly, when calculating production-based emissions, $E_{\text{prod}}$, using EXIOBASE, applying conversion factors from appendix D and Nielsen et al. (2019) respectively (see script in supplementary material), I find that a difference of 6.5% in 2011 for Danish production-based emissions\(^\text{41}\) when including climate-carbon feedback effects and oxidation (following GWP-factors from the 5th IPCC assessment report). By not including effects that affect global warming, reported Danish national emissions are systematically biased in a downwards direction. Thus, if the emission accounts reported by Statistics Denmark were calculated using updated GWP100-factors, my estimates for necessary increases would be higher. Taken together then, even a CAPRO of 17.8% y\(^{-1}\) is not in line with the notion of being genuinely green.

This points our attention back to what I in section 2.4 labelled the qualitative definition of GGG, i.e. a capitalist political economy ‘taking planetary boundaries fully into account’ (Stoknes and Rockström, 2018, p. 42). The key question here is how ‘fully’ is translated into specific targets, moving from an abstract notion towards concrete goals. In other words, how green is green? It is in this translation that I argue Stoknes and Rockström (2018) fail. This critique also relates to the narrow definition of GGG as CAPRO. Stoknes and Rockström themselves argue that being green goes beyond climate change and relates to all planetary boundaries. Thus, to be genuinely green would require translating notions of green growth and green economy into concrete targets that ‘fully’ align with each of these. Given the analysis in section 4, scepticism towards equation (4) as a general definition of GGG is highly warranted along mainly two lines. (1) Is the $\Delta R P > 5\%$ high enough (as is arguably not the case with CAPRO)? (2) Can we in a meaningful way capture planetary boundaries in single units? With regard to the latter, for example, global biodiversity experts struggle to define a unit to capture its complexity and multi-faceted nature (Dempsey, 2016). Thus, to consider RP a meaningful target, we first need to ask what resource goes into resource productivity. Or, in the words of Costanza and Patten (1995), what system are we interested in sustaining?

Such considerations become even more important given that we can only know whether a system is sustainable until after the fact (Costanza & Patten, 1995). Because it

\(^{41}\) I calculate production-based emissions by summing over emissions per sector and adding direct emissions by households following Stadler (2019) (see script in supplementary material).
is not possible to assess whether given targets result in the (sustainable) outcome we desire and hope for in real time, the definition of GGG is really a prediction. Indeed, we only know whether certain emission pathways result in the predicted temperature increases when the temperature change has actually occurred. Even then, there is still uncertainty. In their carbon budgets, for example, the IPCC operates with both historical temperature uncertainty, uncertainty regarding the additional warming since 2006 and uncertainty in recent emissions (Rogelj et al., 2018). Such considerations are relevant across ecological-economic systems, revealing that many definitions of sustainability are in essence predictors of system characteristics (Costanza & Patten, 1995). And as for predictions, uncertainty is a constitutive feature. This further underpins the need for elaboration, deliberation and disagreement that has already been called for in environmental governance (Dryzek & Pickering, 2017). Moreover, it constitutes an argument for setting the criteria for ‘genuine’ at a level that ensures that the temperature goal is met even if the majority of the uncertainties fall out in favour of more warming (if one is risk averse, at least).

5.1.1 The rebound effect

Another issue with focusing on resource productivity also acknowledged by Stoknes and Rockström (2018) themselves is the rebound effect, also known as Jevon’s paradox (Alcott, 2005; Saunders, 2000). Jevon’s paradox emphasizes how productivity increases can be (partly) offset by subsequent increases in production and consumption, which now have a lower marginal cost. An often-used example is increased fuel efficiency, which makes it more attractive to drive because of less fuel spend per mile, potentially offsetting some (or all) of the initial effect. To counter, Stoknes and Rockström (2018) argue that if the \(\Delta R_P > 5\%\) target is implemented economy-wide and the \(\Delta R_P > \Delta GDP\) requirement is sustained, focusing on efficiency alone is not problematic. This adds to the need to consider what goes into RP. Increases in CAPRO might come at the expense of increasing the intensity of other environmental indicators in production. To exemplify, biodiversity has been put under increased pressure, in the same period that Stoknes and Rockström (2018) emphasize as displaying GGG (Mikkelsen et al., 2015). In addition, using a CAPRO goal based on any production-based emission accounts means that imports (both final and intermediate goods) become more ‘efficient’, potentially creating additional increases in imports due to a rebound effect. Thus, the GGG target would be required to be global, not differentiating climate policy goals between the Global North and the Global South. This would also go against the Paris Agreement, which, as mentioned, puts forward principles of ‘differentiated responsibilities’ (Anderson et al., 2020). Moreover, from the perspective of ecological unequal exchange theory, because core countries possess financial and political resources (that facilitate current advantages), establishing similar climate policy goals for all would arguably work to sustain current hierarchical positions in the world system.
5.2 What goes into productivity?

If we are to conceptualize GGG using CAPRO and ultimately resource productivity, as suggested by Stoknes and Rockström (2018), we need to think deeply about what we mean by productivity. This not only applies for what unit goes into the denominator but also what goes into the numerator, i.e. GDP. GDP has long been known as a flawed measure of not only welfare in a broad sense, but also economic welfare and has been contested within and across disciplines of social science42. Indeed, GDP does not capture rent-seeking activities, leisure, inequality, mortality, morbidity, ecology, non-market work (including care work and emotional labour) and inaccurately describes the digital economy while comparing GDP-figures over time requires inherently arbitrary assumptions causing irreducible measurement uncertainty (just to mention some shortcomings) (Fix et al., 2019; Fix & Kolasi, 2019; Jones & Klenow, 2016; Kubiszewski et al., 2013; Mazzucato, 2018; Mazzucato & Shipman, 2014; Stiglitz et al., 2009). For example, Hickel (2020) finds that if one corrects the Human Development Index (which is highly correlated with GDP to the point where little or no extra information is added (Syrquin, 2016)) for a country’s ecological overshoot, focusing on ecological efficiency, Denmark’s index value has been decreasing since the 1990s. Many of the criticisms of GDP are not new but have existed as long as the measure itself. In fact, GDP has been criticized to a point where its continuous importance has been described as a paradox43 (Schmelzer, 2016).

In this perspective, focusing on GDP is mostly relevant in relation to its position as a core policy goal, understanding what Schmelzer (2016), drawing on Daly (1972), refers to as the ‘economic growth paradigm’. This is important because GDP as a ‘device for seeing’ guides how actors understand, address and perform economic policy (Tilsted et al., 2020). As such, discussing CAPRO, RP and GGG to understand welfare seems misguided. However, when I in this thesis focus on such measures, I do so not because GDP is a good indicator of economic welfare but because GDP is an indicator of market-based economic activity in the form of monetary flows. The emission intensity of GDP, the energy intensity and CAPRO, therefore, can inform us about the form of the market-based economic activity that takes place. Likewise, assessing how these have changed over time and need to change in the future relate to how and in which ways the nature of economic activity needs to change. If we instead want to ask what it takes to continuously reproduce the level of welfare in Danish society in terms of GHG emissions, we need to use indicators of economic welfare other than GDP. Considerations concerning social indicators are not new (Andrews & Withey, 2012; Andrews & Withey, 2012;  

42 The list of relevant references is almost endless (see Schmelzer (2016) and references therein).
43 The answer to the paradox is ‘a very specific ensemble of discourses, economic theory, and statistical standards that came to dominate policy-making in industrialized countries under certain social and historical conditions in the second half of the twentieth century’ (p. 10). For more see Schmelzer (2016).
Diener & Suh, 1997) and many alternative measurements have been proposed to GDP, for example the Genuine (sic) Progress Indicator (Daly & Cobb, 1989; Kubiszewski et al., 2013) or Jones and Klenow’s summary statistic for economic well-being (2016).

This points to an avenue for future research, i.e. understanding how and in which ways welfare as expressed by social indicators rely on GHG emissions (and other environmental indicators), seeking ways to increase the former while also decrease the latter. Hereby, I add to the call made by other scholars for further research on the interdependencies between wellbeing, resources and emissions (Haberl et al., 2020). Such questions touch upon fundamental societal questions and are explored in the existing and emerging alternative ‘ideas, models and practices to the contemporary form of green capitalism’ (Ponte, 2019, p. 107). In this regard, Hickel (2019a) imagines an economy in which life-quality would rise alongside possible shrinkages in GDP. This vision is based on a premise of progressive distribution of existing income and a call to distinguish between growth at the aggregate and growth at a sectoral level (incentivizing specific kinds of technological innovation and diminishing and abandoning what is regarded as destructive industries). It relates to distinguishing between increases in throughput as growth and increases in efficiency (such as emission intensity of GDP and GNE) as development (Costanza & Daly, 1992). While the former is destructive of natural capital (e.g. decreasing the carbon budget) and therefore becomes ‘anti-economic’ at the point where man-made capital produced in its stead is worth less, the latter does not occur at the expense of natural capital.

5.3 Exploring the solution space

This thesis is primarily concerned with establishing and measuring current and future climate-policy goals, what changes are needed given certain goals and the role GHG accounting plays in this. As such, I have devoted little attention to actual policy. In these paragraphs, I therefore seek to make up for this omission, by relating the analysis to discussions on the solution space in climate policy. Often, climate policy is divided into production-based (supply/producer-side) and consumption-based (demand/consumer-side) policy (Grubb et al., 2020). This conceptualization relates directly to the two main carbon accounting frameworks in this thesis, namely the distinction between production-based and consumption-based emission accounts. Relating this to the Kaya identity (i.e. equation (10)), producer-oriented climate policy target (1) the decarbonisation of energy electricity (emissions/energy) and (2) energy efficiency (energy/GDP) (efficiency gains in existing production).

Consumption-based policy, then, seeks to alter consumption

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44 Throughput is defined as ‘the materials and energy a society extracts, processes, transports and distributes, to consume and return back to the environment as waste’ (Daly, 1996 cited in Kallis, 2011, p. 874).

45 Efficiency increases can also arise from changing the composition of production towards less energy and emission intensive industry as e.g. time-intensive services. As pointed out in the thesis, however, increases in
behaviour towards less energy and emission intensive goods and services (decreasing E/GNE in equation (13)).

Traditionally, policy focus has been more on production choices and product energy efficiency, i.e. supply-side technology solutions, rather than changes in behaviour, i.e. the demand-side (Creutzig et al., 2018; Grubb et al., 2020). However, at a European level, concerns over political economy issues (e.g. international competitiveness and carbon leakage) have led to persistent watering down of the stringency of production-based policies (Wood, Neuhoff, et al., 2019). Additionally, special provisions such as the allocation of free emission allowances, reductions from energy taxes, fossil fuels subsidies and environmental biases in import tariffs and non-tariff barriers have helped to counteract desired incentives (Coady et al., 2019; Shapiro, 2020; Wood, Neuhoff, et al., 2019). There is little doubt that historical decoupling rates will not lead to the necessary absolute reductions in GHG emissions and resource and material use, when considering recent comprehensive reviews (Haberl et al., 2020; Hickel & Kallis, 2020). This suggest that despite the prevalence of relative decoupling in some indicators, policy efforts have historically been far from sufficient. For example, considering historical developments in emission intensity in a range of technologies, Bjørn et al. (2018) ask whether efficiency improvements will ‘get us there’, referring to an equal per capita allocation of the global emissions budget. The study specifically focuses on Denmark and results indicate a clear ‘no’, suggesting that substantial changes to both ‘business as usual’ and ‘consumption as usual’ are needed. Similarly, De Koning et al. (2015) show that staying below a 2 °C increase is unlikely with advanced GHG reduction technologies alone.

Then, if traditional policy is far from sufficient, what is? In this regard, recent literature provides suggestions for both demand and supply side policy (including combinations such as combining production-based and consumption-based pricing instruments) (see e.g. Bataille et al., 2018; Geels et al., 2017; Grubb et al., 2020; Moran et al., 2020; Wood, Neuhoff, et al., 2019 and references therein). It extends beyond the scope of this paper to consider the specifics of different policy packages. Instead, I want to highlight an important overarching divide in efforts to achieve rapid absolute reductions, namely whether sufficient reductions in emissions and material use is possible with continued expansion of production, i.e. GDP growth, or absolute reductions in material use and GHG emissions should have explicit priority over GDP. Haberl et al (2020) label the former green growth (aligning with principles of ecological modernisation) while referring to the latter as degrowth. A similar terminology is applied by Alessandro et al., (2020), who also distinguishes between green growth and degrowth when considering different policy packages. In the terminology of this thesis, green growth argues for the

efficiency arising from a changing composition of production, i.e. weak carbon leakage, is of little use unless followed by corresponding changes in consumption (as these emissions will then be emitted elsewhere).
possibility of genuine green growth\textsuperscript{46}, while degrowth focuses on absolute reductions, ignoring GDP\textsuperscript{47}. Adding to the distinction, calls have been made for addressing income inequality and advance policies for social equity together with a net-zero transition, as opposed to addressing these problems as separate issues (Aronoff et al., 2019; Alessandro et al., 2020).

Refering to Alessandro et al. (2020), O’Neill (2020) provides an overview of these divisions, presenting the distinctions and overlaps between three different policy packages (see figure 14 below). Policies for social equity, in the figure exemplified by the Green New Deal, include a job guarantee programme and working time reduction. Degrowth, in turn, also considers reduction in consumption and exports, a wealth tax to compensate for decreasing GDP while not actively seeking increases in labour productivity. In addition, an interesting overlap is found in aiming for energy efficiency and decarbonization of energy production (two of the factors in the Kaya identity or, taken together, the T in IPAT), while a main distinction is the question of consumption (the GDP/P or GNE/P factor). In this regard, understanding consumption as a social practise motivated by an interest in being competent practitioners rather than mono-causal explanations of wanting ever-more (Røpke, 2009) reveals the immense and multifaceted challenge in decreasing consumption. This reflects a need for climate policy to

\textbf{FIGURE 14:} Mapping suggested policies from Alessandro et al. (2020)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure14.png}
\caption{Mapping suggested policies from Alessandro et al. (2020)}
\end{figure}

\textit{Source: O’Neill (2020)}

\textsuperscript{46} Which formulation of GGG one is referring to is pivotal this regard. As illustrated throughout the thesis, formulations of GGG can differ substantially regarding both the ambition of goals, the type of indicators used to measure them and the way in which these are accounted for.

\textsuperscript{47} There has been an active debate over the definition of degrowth amongst growth sceptical scholars and whether one should be agnostic as to what happens with GDP (a-growth), call for active liberation from GDP (degrowth) or argue for a ‘post-growth’ society (see p. 403-408, Parrique, 2020).
adopt an inter- and multidisciplinary approach, a call also found amongst climate change-oriented scholars (Klima- og Omstillingsrådet, 2020). Additionally, figure 14 reveals how approaches can differ despite sharing a focus on absolute reduction targets. Relatedly, reflecting on the findings of this thesis, settling on the absolute reduction target in itself is both a technical, political and ethical exercise.

5.4 The conundrum of GHG accounting

The importance of consumption-based emissions is underpinned by the call for consumption-based climate policy (Grubb et al., 2020; Lund et al., 2019; Wood, Neuhoff, et al., 2019). In this sense, considering consumption-based emissions in national-level climate policy and official emission inventories appears, on the face of it, almost self-evident. Yet, Stoknes and Rockström present counterarguments to maintain the position that production-based approaches should be used to evaluate the performance of specific countries in relation to the GGG target. This is despite acknowledging that accounting for consumption-based emissions seemingly invalidates green growth claims (as argued in section 4.1). They put forward two main arguments for maintaining the current accounting paradigm. (1):

All entities are (should be) responsible for the emissions occurring within their own territory/operations and securing ΔRP >5% there. If this is gradually applied globally, it will eventually secure the overall performance of the world economy.

Stoknes and Rockström (2018, p. 46)

(2) Using consumption-based measures necessitate ‘complex accounting and negotiation precautions’ to avoid double counting (fearing that carbon embodied in trade being would be reported as part of national emissions in both the exporting and importing country).

To counter Stoknes and Rockström’s first argument, one can refer to the vast literature on climate justice (see e.g. Jafry, 2019, and chapters therein). Simply positing that entities should be responsible for emissions occurring in their territory neglects inter alia historical responsibility and downplays the role of non-state actors and transnational structures highlighted by ecological unequal exchange theory. Stoknes and Rockström’s second argument is rather pragmatic but also one sided in nature. Double counting can already occur under the UNFCCC (Schneider et al., 2015) and is not exclusive to a consumption-based regime. Additionally, I do not argue for disregarding production-based accounting systems. Rather, I argue that disregarding consumption-based emissions is misguided. As the political economy of Denmark will continue to take up a disproportional share of the global emission budget if focusing on reducing territorial emissions only (Lund et al., 2019; Bjørn et al., 2018), consumption-based emissions should not be reduced to a secondary metric.

Admittedly, the production/consumption-based divide represents a conundrum. If territorial emissions are continually used as the official metric to evaluate performance,
reporting entities are incentivized to minimize emissions on a given territory including exports. If consumption-based accounting is used, this incentivizes minimizing emissions from imports and can help identify ‘hotspots for low carbon technology transfer’ (Wiebe, 2018). To combat climate change both are, as argued above, clearly needed. Polycentric efforts are typically more effective in securing decarbonisation (Geels et al., 2017). Thus, seeing the historical and current responsibility of the Global North, both accounting frameworks should be of national focus. If sticking to eco-efficiency and relying on territorial emissions, important fairness and scoping issues are not addressed as it sustains a GGG narrative in which Nordic countries are portrayed as best practice, despite the evidence presented section 4.

In order to highlight consumption-based emissions along other important emissions in the territorial accounting framework, while still maintaining incentive to reduce domestic emissions, I suggest adapting the approach put forward by Haslam et al. (2014). Specifically, I argue for a reporting framework that disclose production-based emissions from both an economic and geographic perspective alongside consumption-based emissions. By mandating such disclosures at the national level, numbers can be reconciled, and narratives becomes less malleable and prone to elite capture. In short, it increases transparency. A hypothetical example for Denmark is found in table 9 below. From a practical perspective, such reporting is possible, as demonstrated in the sections on EEMRIO analysis. However, this form of disclosure also increases complexity. Contrastingly, Stoknes and Rockström (2018) argue that the 5% GGG target is advantageous due to its simplicity, supposedly making it easy to understand for policymakers as well as the public. Yet, seeing the analysis put forward in this paper, there is little doubt that the GGG definition falls short. Therefore, if we are to employ the notion of genuine green growth, additional requirements to the ΔRP>X% needs to be made. Aside from the 5% target being too low, I tentatively suggest the following additional GGG requirements for net carbon importers:

\[ \Delta \text{Emission transfer} > 0 \] (18)

This ensures that decreases in domestic emissions are not associated with an increased amount of emissions embodied in imports. Such a criteria quickly disqualifies Denmark as an example of GGG, as the share of emissions embodied in imports has increased (Lund et al., 2019). However, seeing the need for structural changes in current consumption patterns and the rather narrow focus on GHG emissions, this requirement is necessary but not sufficient to categorize certain developments as GGG. This is especially important for small, open economies such as Denmark, which rely heavily on trade and imported biomass.
<table>
<thead>
<tr>
<th>Year</th>
<th>Reported to the UNFCCC (1)</th>
<th>Production-based*</th>
<th>Consumption-based (2)</th>
<th>International transport (3)</th>
<th>Biomass (4)</th>
<th>(1) + (3) + (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>72.7</td>
<td>92.5</td>
<td>101.0</td>
<td>19.7</td>
<td>6.5</td>
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<tr>
<td>2001</td>
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<td>93.0</td>
<td>101.0</td>
<td>18.7</td>
<td>7.2</td>
<td>100.2</td>
</tr>
<tr>
<td>2002</td>
<td>73.2</td>
<td>94.0</td>
<td>101.0</td>
<td>20.8</td>
<td>7.6</td>
<td>101.7</td>
</tr>
<tr>
<td>2003</td>
<td>78.3</td>
<td>102.8</td>
<td>105.8</td>
<td>24.5</td>
<td>8.7</td>
<td>111.6</td>
</tr>
<tr>
<td>2004</td>
<td>71.8</td>
<td>98.0</td>
<td>102.5</td>
<td>26.2</td>
<td>9.5</td>
<td>107.4</td>
</tr>
<tr>
<td>2005</td>
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<td>99.2</td>
<td>34.7</td>
<td>10.2</td>
<td>111.8</td>
</tr>
<tr>
<td>2006</td>
<td>74.6</td>
<td>119.1</td>
<td>106.3</td>
<td>44.5</td>
<td>9.5</td>
<td>128.6</td>
</tr>
<tr>
<td>2007</td>
<td>69.8</td>
<td>115.7</td>
<td>105.0</td>
<td>45.9</td>
<td>10.2</td>
<td>126.0</td>
</tr>
<tr>
<td>2008</td>
<td>66.2</td>
<td>109.9</td>
<td>105.8</td>
<td>43.7</td>
<td>10.6</td>
<td>120.5</td>
</tr>
<tr>
<td>2009</td>
<td>63.1</td>
<td>102.9</td>
<td>101.2</td>
<td>39.8</td>
<td>11.6</td>
<td>114.5</td>
</tr>
<tr>
<td>2010</td>
<td>63.7</td>
<td>101.1</td>
<td>98.5</td>
<td>37.5</td>
<td>11.8</td>
<td>112.9</td>
</tr>
<tr>
<td>2011</td>
<td>58.3</td>
<td>98.7</td>
<td>93.5</td>
<td>40.5</td>
<td>12.1</td>
<td>110.9</td>
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<td>86.8</td>
<td>38.3</td>
<td>14.5</td>
<td>106.5</td>
</tr>
<tr>
<td>2013</td>
<td>55.6</td>
<td>89.8</td>
<td>85.5</td>
<td>34.3</td>
<td>14.1</td>
<td>104.0</td>
</tr>
<tr>
<td>2014</td>
<td>51.3</td>
<td>84.6</td>
<td>83.2</td>
<td>33.3</td>
<td>14.5</td>
<td>99.1</td>
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<td>87.7</td>
<td>83.1</td>
<td>37.1</td>
<td>14.6</td>
<td>102.3</td>
</tr>
</tbody>
</table>

*Here computed simplistically as (1) + (3).


Note: Importantly, elements of comparability vary between EXIOBASE and Statistics Denmark cf. table 2. These estimates are therefore not directly comparable.

5.5 Drawing abstract lines and boundaries

As I approach the end of the thesis, I want to reflect on the ways in which the rude distinction implied by the definition of GGG is problematic for something as diverse and complex as environmental quality. By classifying a certain development as ‘genuinely green’, a dichotomy is produced, grouping heterogeneous cases of expansions of production as binary examples of either or (one of which is subordinate). Multifaceted and complex cases of economy and ecology, their interactions and contradictions, are reduced to a categorical variable despite trade-offs between different environmental indicators (Hoekstra and Wiedmann, 2014). Drawing on Dryzek and Pickering’s (2017) reflections on public discourse as a dimension of governance (along which reflexivity might be sought) and its tension (diversity vs. consensus), we can understand the GGG definition as an effort of ‘closing down’ (Stirling, 2008; Voß et al., 2006, p. 429). Closing down here refers to establishing a level of discursive agreement to determine a specific course of action, leaving aside or bracketing unresolved uncertainty (Voß et al., 2006, p. 431; Walker et al., 2006, p. 8).

Although potentially enabling action by setting a goal when operationalizing GGG, closing down and establishing consensus is prone to criticisms arising from lack of...
diversity. Dryzek and Pickering (2017) cite Habermas (1996) when pointing to the notion that diversity is important for both critical scrutiny of current governance practices, ideas and discourses as well as for generating new ones. Additionally, and importantly, seeing the prominence of the ecological modernization discourse, diversity and scepticism is needed to not readily accept mainstream views that have historically marginalized environmental concerns (Söderbaum, 2013, p. 224). In this sense, notwithstanding the criticisms of GGG raised in previous sections, it might be counterproductive to define or set a fixed target for GGG in an effort to ‘close down’ deliberation. Because of the multifaceted nature of environmental problems, reducing complexity to a matter of resource productivity runs the risk of steering policy in the wrong direction.

Taking a step back, such considerations relate to ontology and epistemology. What is the value of abstract concepts in producing knowledge and guiding our understanding? When and how to draw abstract lines on science, technology and economic tools? In this regard, GGG can arguably be understood as a Weberian ideal type, i.e. ‘an ideal limiting concept with which the real situation or action is compared’ (Cahnman, 1965, p. 269; Weber, 1922 [1949], p. 190, 191, 192, 194 cited in Hay, 2020, p. 306). As such, GGG is not a description of concrete developments in GHG emissions but rather something reality can be compared to. For climate change as for other areas of inquiry, this warrants critical reflection, asking whose rights are supported and which understandings and world images are promoted through the concepts we apply. Is promoting the concept of GGG as the main goal for national-level climate policy, referencing territorial emissions, advancing equitable and caring socioecological systems? Arguably, for radically reducing emissions, we should refrain from engaging with abstract lines and boundaries and instead evaluate strategies and policies based on the question of whether emissions are reduced in an effective and cost-efficient way. Yet, by setting absolute reduction targets, we engage with the abstract. What conceptualisation of absolute targets do we apply? Which emissions are considered and how? Engaging with matters of climate change is also engaging with matters of social and ecological justice. It therefore requires critical and reflective engagement with the concepts we apply. Here, the notion of GGG falls short.
6. Conclusion

‘Before I draw nearer to that stone to which you point,’ said Scrooge, ‘answer me one question. Are these the shadows of the things that Will be, or are they shadows of things that May be, only?’ Still the Ghost pointed downward to the grave by which it stood. ‘Men’s courses will foreshadow certain ends, to which, if persevered in, they must lead,’ said Scrooge. ‘But if the courses be departed from, the ends will change. Say it is thus with what you show me!’ The Spirit was immovable as ever.

— Charles Dickens in 'A Christmas Carol' (1843, p. 82)

We live in a time, where all politics are said to be climate politics (Aronoff et al., 2019). Path-dependent gradualism, incremental change and business-as-usual will not bring about sufficient emission reductions. And as tipping points start to manifest themselves (Lenton et al., 2019), there is scientific consensus that radical and transformative change is needed to stay within the 2 °C not to mention the 1.5 °C target (IPCC, 2018). Some environmentalists even argue that we live in an ‘age of ecocide’, that ecological degradation and climate change cannot be stopped and what awaits is ‘decline, depletion, chaos and hardship for all of us’ (Kingsnorth, 2010; Smith, 2014). Facing such overwhelming challenges, the importance of setting ambitious climate policy targets, evaluating these and setting the course for future pathways can hardly be overstated. In this regard, scholars call for policymakers to address consumption-based emissions (Hickel, 2019b; 2020; Lund et al., 2018; 2019). This thesis contributes to this debate by considering the importance of GHG accounting frameworks in setting climate policy goals and critically reflecting on the notion of (genuine) green growth. In doing so, I have taken an interdisciplinary approach to answer my main research question (RQ) as well as my four sub-questions (SQ1-4). To conclude, I address each of these in turn.

**RQ:** Regarding the question of how different GHG accounting rules and framework shape claims of green growth and influence what changes are necessary to stay in line with the 1.5-2.0 °C in a Danish context, the literature on consumption and production-based GHG accounting systems points to the importance of considering both frameworks. As argued by ecological unequal exchange theory, countries in the Global North benefit from displacing ecological costs through trade to countries in the Global South. In the context of GHG emissions, focusing on production-based emissions neglects the emission footprint embodied in trade associated with affluence and emission intensive modes of living (Simas et al., 2017). As such, the current accounting paradigm helps powerful actors in the Global North to distance themselves from emissions embodied in consumption. In addition, current accounting standards benefit the political economy of Denmark by considering only the geographic and not economic definition of the country, excluding emissions from the combustion of bunker fuels in international transportation. Moreover, biomass is considered carbon-neutral in national inventory estimates reported to the UNFCCC (on which official emission reduction targets are based) despite a scientific consensus points to the opposite (Norton et al., 2019). Taken together, these different accounting rules and frameworks influence what is to be
considered national-level emissions substantially. Therefore, they strongly influence claims of green growth and markedly influence what future developments are in line with the 1.5-2.0 °C target for Denmark. If Denmark is to reach the official target of reducing emissions by 70% compared to 1990 in 2030 with territorial emissions of approximately 4 tonnes CO2e per capita, while steadily increasing GDP, this is likely to be celebrated as a victory of green growth. This thesis has explored ways in which such claims will be erroneous.

SQ1: Building on the above, I sought to answer how emission productivity in Denmark changed over time under different carbon accounting rules and to what extent these developments exemplify GGG. In this regard, I refuted the claim made by Stoknes and Rockström (2018) that Nordic countries have displayed what they refer to as genuine green growth. Referencing consumption-based instead of domestic emissions, Nordic countries have not been close to demonstrating GGG as defined by Stoknes and Rockström’s criteria. For Denmark specifically, the GGG carbon productivity of >5% y-1 target is far from fulfilled even within a territorial framework when including emissions from the combustion of bunker fuels and biomass. Claiming that Nordic countries have displayed GGG in the 2000s is in this way, at best, a partial and inherently limited perspective. At worst, it serves to uphold hierarchical power structures in the world system and undermine the struggle against global environmental inequality.

SQ2: The answer to SQ1 relies on national-level consumption-based estimates. However, emissions estimates are subject to uncertainty. For consumption-based emissions, this uncertainty is linked to the infinite layers of production that in principle goes into calculating such figures. I therefore asked how different emission estimates for Denmark differ under the consumption-based accounting framework and what elements vary between estimates. In this regard, this thesis has illustrated how consumption-based emissions can differ by mapping out different elements of comparability, discussing the multi-faceted task of estimating emission footprints. One of these elements of comparability is which type of effects are considered when converting GHGs to CO2e. Using the EXIOBASE MRIO, I have illustrated the importance of converting factors for Danish national-level emissions, showing that footprint estimates increase by, for example, ~7% in 2011 when including carbon-climate feedback effects of GHGs.

SQ3: Addressing the question of what efficiency improvements are necessary for Denmark to be in line with the 1.5-2.0 °C target under different accounting rules and frameworks, I first referenced historical improvements in efficiency. Decomposing emission footprints since 2000 illustrates that decreases in the emission intensity of gross

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48 This is using GWP100-factors from the fifth IPCC assessment report including carbon-climate feedback effects and is to be contrasted with the conversion factors without such effects (used by Lund et al., 2019) and GWP100-factors from the fourth IPCC assessment report (which are used when reporting national emissions to the UNFCCC (Nielsen, 2019)).
national expenditure has been counteracted by increases in gross national expenditure per capita. Extending hereupon, I estimated what changes in carbon productivity is needed for Denmark in the period 2019-2030 to be consistent with the 1.5 °C goal if emission budgets are distributed equally (an allocation principle that is disputed in the climate justice literature). Allowing for limited overshoot of the 1.5 °C target, I find that if one includes emissions from international transportation and the combustion of biomass in territorial emissions, carbon productivity needs to increase by at least 16-18% y\(^{-1}\). Even then, this is hardly GGG if radical decreases in consumption-emissions do not follow suit. In this regard, I estimate that the emission intensity of GNE, a measure of efficiency for consumption-based emissions, needs to decrease by at least 12% per year for Danish emissions embodied in consumption to reach 3 tonnes CO\(_2\)e per capita.

**SQ4:** The analysis put forward in this thesis points to the importance of conceptualisation and helps to answer the final sub-question asking in which ways genuine green growth is (not) a desirable policy target. When claiming that something is genuine, the concept should be able to withstand environmentalist criticisms. GGG does not. Yet, in quantifying the needed efficiency improvements, I have shown that in some ways it could, was it set at a level that is consistent with the 1.5 °C target. Still, in the discussion I asked the question of what goes into CAPRO and resource productivity, the units that supposedly capture GGG. This points to the need for considering environmental matters and planetary boundaries beyond climate change and the complexity of capturing complex ecological relationships in single units. Moreover, I echo the massive and widespread critique of GDP as an economically meaningful measure. Because GGG relies on the GDP measure, the GGG concept is inherently limited, making it an undesirable climate policy target. I therefore call for further research in the ways that welfare as expressed by social indicators rely on GHG emissions and argue that ‘closing down’ and establish discursive agreement on questions of (genuine) green growth would not be well reasoned. My critique of GGG reflects that engaging with climate change is a matter of political ecology and political economy and therefore warrants critical and reflective inquiry. Under scrutiny, the notion of genuine green growth falls short. In the effort to avoid an oxymoron, Stoknes and Rockström (2018) have ended up creating another.
References


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DST (Statistics Denmark), (2020). Available at: www.statistikbanken.dk/DRIVHUS


https://doi.org/10.1126/science.aao3760


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## APPENDIX A: EMISSION TYPES IN EXIOBASE

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<tr>
<th>No.</th>
<th>Emission symbol</th>
<th>Emission name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CO2</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>2</td>
<td>CH4</td>
<td>Methane</td>
</tr>
<tr>
<td>3</td>
<td>N2O</td>
<td>Nitrous oxide</td>
</tr>
<tr>
<td>4</td>
<td>SOx</td>
<td>Sulfur oxide</td>
</tr>
<tr>
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<td>NOx</td>
<td>Nitrogen oxide</td>
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<tr>
<td>8</td>
<td>Biphenyl</td>
<td>Benzo(a)pyrene</td>
</tr>
<tr>
<td>9</td>
<td>Benzo(b)fluoranthene</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Benzo(k)fluoranthene</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>C2H12</td>
<td>Indeno[1,2,3-cd]pyrene</td>
</tr>
<tr>
<td>12</td>
<td>PAH</td>
<td>Polycyclic aromatic hydrocarbon</td>
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<tr>
<td>13</td>
<td>PCBs</td>
<td>Polychlorinated biphenyl</td>
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<td>14</td>
<td>PCDD_F</td>
<td>Polychlorinated dibenzodioxins</td>
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<tr>
<td>15</td>
<td>HCB</td>
<td>Hexachlorobenzene</td>
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<tr>
<td>16</td>
<td>NMVOG</td>
<td>Non-methane volatile organic compound</td>
</tr>
<tr>
<td>17</td>
<td>PM10</td>
<td>Particulate matter 10 micrometers or less in diameter</td>
</tr>
<tr>
<td>18</td>
<td>PM2.5</td>
<td>Particulate matter 2.5 micrometers or less in diameter</td>
</tr>
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<td>19</td>
<td>TSP</td>
<td>Triodium phosphate</td>
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<td>20</td>
<td>As</td>
<td>Arsenic</td>
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<td>Nitrogen</td>
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<tr>
<td>33</td>
<td>P</td>
<td>Phosphorus</td>
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Source: Nathani & Hellmüller (2019, p. 9-10).
APPENDIX B: FIGURES FROM STOKNES & ROCKSTRÖM (2018)

Source: Stoknes and Rockström (2018, p. 44).

Caption from article: Genuine Green Growth in the Nordics, compared to the necessary 5% pa improvement in carbon productivity. Baseline 100 = average 2000–2003. GGG = 5% carbon productivity pa from 2003.


Source: Stoknes and Rockström (2018, p. 44).


Data source: Global Carbon Atlas from UN statistics for GDP data in PPP USD and CDIAC, UNFCCC and BP for CO2 emissions.
APPENDIX C: REPLICATING STOKNES & ROCKSTRÖM (2018)

Note: 100 = 2000–2003 average, GGG = genuine green growth rate of 5% pa. GDP data in 2010 USD
Data source: OECD Stats, Green Growth Indicators; GDP in 2010 USD from the World Bank
APPENDIX D: GWP100 CONVERSION FACTORS AND SOURCE CATEGORIES

<table>
<thead>
<tr>
<th>Source categories</th>
<th>GWP100-factors primarily applied in this thesis</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>'CH4 - combustion - air', 'CH4 - non combustion - Extraction/production of (natural) gas - air', 'CH4 - non combustion - Extraction/production of crude oil - air', 'CH4 - non combustion - Mining of antracite - air', 'CH4 - non combustion - Mining of bituminous coal - air', 'CH4 - non combustion - Mining of coking coal - air', 'CH4 - non combustion - Mining of lignite (brown coal) - air', 'CH4 - non combustion - Mining of sub-bituminous coal - air', 'CH4 - non combustion - Oil refinery - air', 'CH4 - agriculture - air', 'CH4 - waste - air'] = 36</td>
<td>GWP100 $\frac{t}{f}$ CH4 $\frac{t}{air}$ = 36</td>
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<tr>
<td>'CO2 - combustion - air', 'CO2 - non combustion - Cement production - air', 'CO2 - non combustion - Lime production - air', 'CO2 - agriculture - peat decay - air', 'CO2 - waste - fossil - air'] = 1</td>
<td>GWP100 $\frac{t}{f}$ CO2 $\frac{t}{air}$ = 1</td>
</tr>
<tr>
<td>'[N2O - combustion - air', 'N2O - agriculture - air'] = 298</td>
<td>GWP100 $\frac{t}{f}$ N2O $\frac{t}{air}$ = 298</td>
</tr>
<tr>
<td>'[CO - combustion - air', 'CO - non combustion - Agglomeratation plant - sinter - air', 'CO - non combustion - Bricks production - air', 'CO - non combustion - Carbon black production - air', 'CO - non combustion - Cement production - air', 'CO - non combustion - Chemical wood pulp, dissolving grades - air', 'CO - non combustion - Chemical wood pulp, soda and sulphate, other than dissolving grades - air', 'CO - non combustion - Chemical wood pulp, sulphite, other than dissolving grades - air', 'CO - non combustion - Glass production - air', 'CO - non combustion - Lime production - air', 'CO - non combustion - Oil refinery - air', 'CO - non combustion - Pig iron production, blast furnace - air', 'CO - non combustion - Primary aluminium production - air', 'CO - non combustion - Production of coke oven coke - air', 'CO - non combustion - Production of gascove - air', 'CO - non combustion - Semichemical wood pulp, pulp of fibers other than wood - air', 'CO - non combustion - Steel production: basic oxygen furnace - air', 'CO - non combustion - Steel production: electric arc furnace - air', 'CO - waste - air'] = 1.57</td>
<td>GWP100 $\frac{t}{f}$ CO $\frac{t}{air}$ = 1.57</td>
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<tr>
<td>['SF6 - air'] = 26100</td>
<td>GWP100 $\frac{t}{f}$ SF6 $\frac{t}{air}$ = 26100</td>
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</tbody>
</table>

Source: Myhre et al., 2013, p. 714 table 8.7. Remaining conversion factors obtained from personal correspondance with Guillaume Majeau-Bettez as according to latest internationally recognized academic standards.
**GWP100-factors primarily applied by Lund et al. (2019)**

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<tr>
<th>GHG</th>
<th>GWP100</th>
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<tr>
<td>CH4</td>
<td>28</td>
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<tr>
<td>CO2</td>
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</tr>
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<td>N2O</td>
<td>265</td>
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</tbody>
</table>

*Source: Myhre et al., 2013, p. 714 table 8.7 without climate-carbon feedbacks. Obtained from personal correspondence with authors and Guillaume Majeau-Bettez*

**Source categories:**

- ['CH4 - combustion - air',
  'CH4 - non combustion - Extraction/production of (natural) gas - air',
  'CH4 - non combustion - Extraction/production of crude oil - air',
  'CH4 - non combustion - Mining of antracite - air',
  'CH4 - non combustion - Mining of bituminous coal - air',
  'CH4 - non combustion - Mining of coking coal - air',
  'CH4 - non combustion - Mining of lignite (brown coal) - air',
  'CH4 - non combustion - Mining of sub-bituminous coal - air',
  'CH4 - non combustion - Oil refinery - air', 'CH4 - agriculture - air',
  'CH4 - waste - air'] $= 28$

- ['CO2 - combustion - air',
  'CO2 - non combustion - Cement production - air',
  'CO2 - non combustion - Lime production - air',
  'CO2 - agriculture - peat decay - air',
  'CO2 - waste - fossil - air'] $= 1$

- ['N2O - combustion - air',
  'N2O - agriculture - air'] $= 265$
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<tr>
<th>Year</th>
<th>Cons-based, ton CO2e per capita, with cc fb</th>
<th>Lund et al. (2019) 4th AR factors per capita</th>
<th>Relative difference (how much bigger with cc fb in pct)</th>
<th>Cons-based with cc fb total (kg CO2e)</th>
<th>Lund et al. (2019) total</th>
<th>Hybrid, ton CO2e per capita</th>
<th>Hybrid, same C-matrix as Lund et al. (2019),</th>
<th>Population</th>
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<td>2000</td>
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<td>2013</td>
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</tbody>
</table>

Sources: Own calculations, Lund et al. (2019) and United Nations Population Division (2017)
## APPENDIX F: CAPRO AND EMISSION REDUCTION TARGETS 2019-2030 UNDER DIFFERENT SCENARIOS AND ACCOUNTING RULES

<table>
<thead>
<tr>
<th>Yearly target in %y</th>
<th>GHG emissions included</th>
<th>Low-risk scenario (3.06 CO2e per capita)</th>
<th>Medium-risk scenario (4.23 CO2e per capita)</th>
<th>High-risk scenario, (6.01 CO2e per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAPRO</strong> terri</td>
<td></td>
<td>10.04%</td>
<td>7.13%</td>
<td>4.03%</td>
</tr>
<tr>
<td>terri+bunker</td>
<td></td>
<td>15.85%</td>
<td>12.79%</td>
<td>9.52%</td>
</tr>
<tr>
<td>terri+bunker+bio</td>
<td></td>
<td>17.77%</td>
<td>14.65%</td>
<td>11.33%</td>
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<tr>
<td><strong>GHG EMISSIONS</strong></td>
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<td>-7.95%</td>
<td>-5.45%</td>
<td>-2.63%</td>
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<tr>
<td>terri+bunker</td>
<td>-12.57%</td>
<td>-10.19%</td>
<td>-7.51%</td>
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<tr>
<td>terri+bunker+bio</td>
<td>-13.99%</td>
<td>-11.65%</td>
<td>-9.02%</td>
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</tbody>
</table>

*Note: Author's own calculations based on Statistics Denmark and Nielsen et al. (2019) corresponding to the estimates in table 6 for the low-risk scenario. For more on the scenarios see Lund et al. (2019). The national-level emissions used for these calculations are computed using conversion factors from the 4th IPCC report including a conversion factor of 25 for CH4.*