Recalculation of CO_2 emissions from biomass use in district heating and combined heat and power plants in Denmark with 2021 input data.

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Indhold

1 Preface

This report and the analyses behind were commissioned by the Danish Energy Agency in November 2022 to address questions about CO_2 emissions related to use of forest biomass for district heat and electricity production. The analytical framework and approach build largely on previous work by Nielsen et al. [1, 2 and 3]. Confidential process and supply chain data for the initial analysis was updated and used for this analysis in agreement with key data providers.

A preliminary version of this report was commented by the Danish Energy Agency by mid December 2022.

Thomas Nord-Larsen and Niclas Scott Bentsen from Department of Geosciences and Natural Resource Management, University of Copenhagen participated in the data collection process, participated in discussions of data quality and results, reviewed the results and made a commented review of the report before final submission.

The author thanks data providers from the Danish Energy Agency, Utility companies, Niclas Scott Bentsen and Thomas Nord-Larsen, for fruitful collaboration and contribution to the report.

The content and conclusions presented here follows the same method and presentation form as in [3] but is the sole responsibility of the author.

2 Abstract

This report is a recalculation with 2021 data of the model output from [3] which formed the basis of Global Afrapportering 2022 (GA22) and was based on consumption data from year 2020. Calculations in this report builds entirely on the scientific data and method presented in [3], unless stated otherwise. As such, the changes in results compared to [3] are solely the effect of using 2021 consumption data and changes stated in the method section of this report.

In this project, additional production and sourcing data was collected from key Danish district heat and combined heat and power plants that use wood chips and wood pellets, so that data includes information updated to 2021 as input to Global Afrapportering 2023 (GA23). Several of the smaller utilities could not provide 2021 data within the given time frame of this project. Therefore, some data for the smaller facilities are not represented in this report. In total, 7 facilities participated in the data collection, which for wood chips covers 53% of current total Danish consumption in the transformation sector and for wood pellets 75% on consumption.

The model calculations include the direct and indirect CO_2 emissions associated with the production of energy in the Danish transformation sector. These include emissions from the production of biomass (forest cultivation, transport, production of wood pellets, etc.), emissions from the combustion of the biomass and indirect emissions (iLUC and iWUC emissions. CO_2 emissions from the construction of plants and facilities are disregarded.

The model calculations also includes a dynamic assessment of the changes in the forest carbon stocks as affected by the use of biomass and how this depends on how forests and wood would have been managed and treated absent the demand for bioenergy (counterfactuals and indirect emissions).

The report focusses on:

1. Analysis of a single year's biogenic and fossil emissions in the supply chain of the Danish use of biomass in the transformation sector and net recapture of emissions in forests in a 100-year perspective. Results are reported as cumulative net CO_2 emissions to the atmosphere.

2. Discussion of the effect of changes in the data and emission profile compared to results presented in 3 and GA22. .

The first part of the analysis shows that the use of biomass has increased since 2020, where total consumption of biomass in 2020 was 64.3 PJ leading to total emissions of 7,6 million tonnes of CO_2, while in 2021, consumption was 88.1 PJ, leading to total emissions of 10.6 million tonnes CO_2, roughly evenly distributed between wood chips and wood pellets. The emissions from direct combustion and energy production accounted for 83.3% of the total emissions, which was recaptured in the forest carbon stocks after approx. 60 years (not to be interpreted as the carbon payback time).

Besides the differences due to the increase in the amounts of biomass used in 2020 compared to 2021, leading to 37% higher total emissions, the results did not differ substantially from the results presented in [3], although the method for assessment of the origin of the biomass was different here compared to [3] and sourcing strategy was slightly different.

3 Dansk resume

Denne rapport er en genberegning med 2021-data af modeloutputtet fra [3], som dannede grundlag for Global afrapportering 2022 (GA22) og var baseret på biomasse forbrugsdata fra 2020. Beregningerne i denne rapport bygger udelukkende på de videnskabelige data og metoder, der blev præsenteres i [3], medmindre andet er angivet. Ændringerne i resultater i forhold til [3] er alene effekten af at bruge 2021-forbrugsdata og ændringer angivet i metodeafsnittet i denne rapport.

I dette projekt er der indsamlet yderligere produktions- og sourcing data fra større danske varme- og kraftvarmeværker, der anvender flis og træpiller, således at data omfatter information opdateret til 2021 som input til Global Afrapportering 2023 (GA23). Flere af de mindre forsyningsselskaber kunne ikke levere 2021-data inden for den givne tidsramme for dette projekt. Derfor er data for de mindre anlæg ikke repræsenteret i denne rapport. I alt deltog 7 værker i dataindsamlingen, som for træflis dækker 53 % af det nuværende samlede danske forbrug i transformationssektoren og for træpiller dækker 75 % af forbruget.

Modelberegningerne omfatter de direkte og indirekte CO_2-udledninger forbundet med produktionen af energi i den danske energisektor. Disse omfatter udledninger fra produktion af biomasse (skovdyrkning, transport, produktion af træpiller mv.), udledninger fra forbrænding af biomassen og indirekte udledninger (iLUC- og iWUC-udledninger). Der ses bort fra CO_2-udledninger fra opførelse af anlæg.

Modelberegningerne omfatter også en dynamisk analyse af ændringerne i skovenes kulstoflagre som påvirkes af anvendelsen af biomasse, og hvordan dette afhænger af, hvordan skove og træer ville være blevet forvaltet og behandlet uden efterspørgsel efter bioenergi (kontrafakta og indirekte udledninger).

Rapporten fokuserer på:

1. Analyse af et enkelt års biogene og fossile udledninger i forsyningskæden fra den danske anvendelse af biomasse i energisektoren og nettooptag i skove i et 100 års perspektiv. Resultater rapporteres som kumulative netto CO_2-udledninger til atmosfæren.

2. En diskussion af effekten af ændringer i data- og udledningsprofilen i forhold til resultaterne fra [3] og GA22.

Den første del af analysen viser, at brugen af biomasse er steget siden 2020, hvor det samlede forbrug af biomasse i 2020 var 64,3 PJ, hvilket gav en samlet udledning på 7,6 millioner tons CO_2, mens forbruget i 2021 var 88,1 PJ, hvilket førte til en samlet udledning på 10,6 millioner tons CO_2, nogenlunde ligeligt fordelt mellem flis og træpiller. Udledningerne fra direkte forbrænding og energiproduktion udgjorde 83,3 % af den samlede udledning, som blev genoptaget i skovens kulstoflagre efter ca. 60 år (skal ikke fortolkes som kulstoftilbagebetalingstiden).

Udover forskellene på grund af stigningen i mængden af biomasse, der blev brugt i 2020 sammenlignet med 2021, hvilket førte til 37 pct. højere udledninger, afveg resultaterne ikke væsentligt fra resultaterne præsenteret i [3], selvom metoden til bestemmelse af oprindelsen af biomasse var anderledes her, sammenlignet med [3], og sourcing-strategien også var lidt anderledes.

4 Description of terms and abbreviations

Abbreviaton/term	English description	Dansk forklaring
DH	District heating plant	Varmeværk
CHP	Combined heat and power plant	Kraftvarmeværk
Process emissions	Biogenic and fossil CO_2 emissions related to forest operations and production of wood pellets	Biogene og fossile CO2 udledninger som følge af skovdrift og fremstilling af træpiller
Transport emissions	CO_2 emissions related to fossil fuel consumption in the transport sector	Fossile CO_2 udledninger som følge af transport af biomasse
Combustion emissions	Emissions from combustion of wood	Udledninger som følge af afbrænding af træ
Counterfactual	Term that refers to what would have happened to the wood had it not been used for bioenergy	Udtryk der refererer til hvad der ville være sket med træet hvis det ikke blev brugt som bioenergi
Half-life	Term that determines the residence time of carbon in wood products e.g. a natural or non-natural decay rate. The half-life describes the time it will take before half of the wood is decayed and carbon hereby is emitted	Udtryk der beskriver hvor lang tid et stykke træ ville have tage om at forrådne og hermed frigive CO_2 til atmosfæren, hvis det ikke var blevet brugt som bioenergi
Indirect emissions	CO_2 emissions related to market pressure from bioenergy demand on other products	CO_2 udledninger der stammer fra markedspres på andre sektorer som følge af efterspørgsel på træ til bioenergi
iLUC	Indirect land use change relating to emissions or uptake from the living forest biomass carbon pool as a consequence of demand for bioenergy	Indirekte CO_2 udledninger eller optag i skovenes levende kulstof pulje, der stammer fra øget pres fra bioenergi forbruget
iWUC	Indirect wood use change, CO_2 emissions related to change in price structure for bioenergy compared products, leading to consumers switching to other products, hereby creating emissions	CO_2 udledninger som følge af at pris strukturer ændrer som pga. pres fra bioenergi sektoren, som vil lede til øget forbrug af andre produkter, der herved vil udlede CO_2
Single pulse emissions:	All CO_2 emissions and forest carbon uptake related to a single year use of bioenergy	Alle CO_2 udledninger, samt optag I skoven som følge af et enkelt års bioenergi forbrug
Weighted average	Refers to results based on weighted average data input to the model for i.e. wood chips, wood pellets and the whole biomass use in the transformation sector	Refererer til resultater baseret på vægtede gennemsnits data input til modellen

1 Introduction

The goal of the Paris Agreement is to keep anthropogenic global warming well below a 2ºC increase from pre-industrial levels and pursue efforts to limit the temperature increase to 1.5ºC [4]. Meeting these temperature require, society wide transitions of the energy, agriculture, land use, industry, and transportation sectors are needed. For the energy sector, the Intergovernmental Panel on Climate Change (IPCC) highlight four macro-level transformations required for reaching this goal: 1) limits on the increase of the final energy demand, 2) reductions in the carbon intensity of electricity production, 3) increases in the share of final energy provided by electricity, and 4) reductions in the carbon intensity of other energy forms than electricity [5]. The use of biomass in the energy sector has been favoured by political instruments since the mid-1990s in the transition of the Danish energy sector [6], targeting 2) and 4) listed above. District heat and electricity production in Denmark has seen a significant transition over the last 30 years from fossil fuel to renewables in the form of biomass, wind, and solar energy [7]. In 2021, renewables made up 68% of both electricity and district heat production, with 29 PJ electricity and 88 PJ district heat being based on biomass (wood chips, wood pellets, straw, organic waste) corresponding to 22% of renewable electricity and 91% of renewable heat produced, respectively [7].

Wood in various forms makes up the lion's share of biomass used. In 2021 56 PJ wood was used for electricity production corresponding to 70% of biomass used for electricity production. In 2021 the corresponding figures for district heat was 38 PJ and 63% [7]. As such, precise estimations of emissions from use of wood in the energy sector are vital for attaining an accurate figures of Danish CO2 emissions.

1.1 Aims of this report

The aim of this report is to recalculate previous work by Nielsen et al.[3] to estimate impacts on CO_2 emissions to the atmosphere over a 100-year period from the Danish use of biomass in 2021, focussing on:

1. Analysis of a single year's biogenic and fossil emissions in the supply chain of the Danish use of biomass in the transformation sector and net recapture of emissions in forests in a 100-year perspective. Results are reported as cumulative net CO_2 emissions to the atmosphere.

2. Discussion of the effect of changes in the data and emission profile compared to results presented in 3 and GA22.

The findings presented here cannot and should not be compared to the national inventory report to the UNFCCC or to accounting against greenhouse gas emission reduction targets. This analysis builds on a consumption-based model framework, while the inventory reports build on production-based accounting methodology. System boundaries differ between the two methodologies and results are not comparable.

2 Materials and methods

This report is a recalculation with 2021 data of the model output from [3] which formed the basis of Global afrapportering 2022 (GA22) and was based on consumption data from year 2020. Calculations in this report builds entirely on the scientific data and method presented in [3], unless stated otherwise here. As such, the changes in results compared to [3] are solely the effect of using 2021 consumption data and changes stated in this chapter.

For a thorough method description, see [3].

2.1 Changes from GA22

Although the method is the same here as in [3] and GA 22, most of the data providers were not able to deliver data on the origin of the biomass that they used, within the timeframe available for this project. Therefore, contrary to GA22, the origin of the biomass was based on official trade statistics for 2021 [9] table KN8Y, CN numbers 44012100 and 44012200 for wood chips and 44013100 for wood pellets for year 2021.

The use of this import data also covers the origin of wood chips and wood pellets used in private consumption which may represent a small bias in the numbers. However, in this report only the fractions of the origin of the biomass are used for further calculations, not actual amounts.

For the wood chips this bias is likely very small, as the consumption of wood chips in private homes is very small (<3 PJ/year). It may be larger for wood pellets and may affect the results as private consumption of wood pellets is much larger than wood chips (app. 20 PJ/year). As such it is assumed here that wood chips and wood pellets is sourced from the same countries in the private consumption as in the transformation sector.

2.2 Understanding the single pulse curve

The single pulse curve is used in this report to present results in a 100 year perspective. The curve describes the dynamic development of net life cycle emissions form a single years use of biomass. The curve is a function of upstream emissions from forest management, harvesting, transport, processing, direct combustion emissions from energy production with biomass, counterfactual (fate of biomass if not used for energy), indirect land use change and indirect wood use change, and net recapture of CO2 in the new emerging forest/trees after harvest. For a thorough model description, see [3].

The curve represents the difference between the factual situation (biomass being used for energy) and the counterfactual situation (biomass being left for decay, x-axis on the figure, Figure 1) i.e., the extra net CO2 emissions emitted because of using the biomass for energy instead of not doing so. Both in the factual and counterfactual situation the CO2 bound in the wood will eventually end up in the atmosphere. However, in the counterfactual situation this will occur in a slower pace as the decay process is slower than the burning process. This slower process in the counterfactual situation will function as a bottleneck that will make a larger amount of CO2 being stored in decaying wood, than in the factual situation, where the CO2 in the biomass is burned and released to the atmosphere immediately. As such the single pulse curve is at its highest the year of combustion (here 2021), where the difference between factual and counterfactual is largest. In time the CO2 in the decaying wood in the counterfactual situation will also be emitted to the atmosphere and the single pulse curve will converge towards 0 (0 is the counterfactual situation). However, as there are fossil fuels used in transport, processing of biomass and iWUC emissions, which are additional to what comes from the forest, the single pulse curve will not converge to 0 (Figure 1).

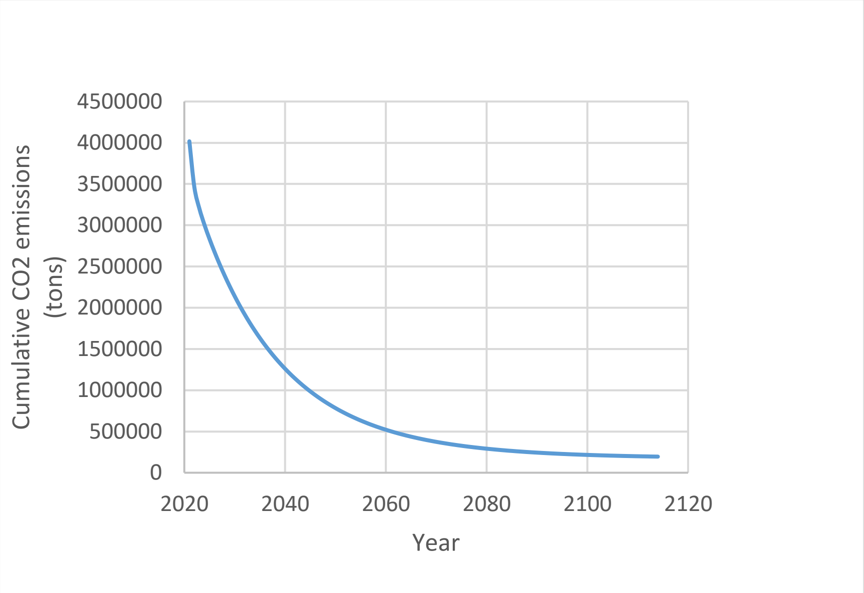

Figure 1: A typical shape of the single pulse curve

There are roughly four ways the single pulse curve can be affected by changes in consumption data.

Firstly, the curve makes a parallel shift if consumption changes, equivalent to the emissions imposed by the shift in consumption.

The second is changes in the amounts of biomass from different sources (stems, harvest residues, industrial residues) and from different climatic regions as these have different decay rates (expressed as half-lives). Differences e.g., slower decay rates leads to a longer residence time of the CO2 in the decaying wood storage and hence to a slower convergence of the single pulse curve and a larger storage to be released by use of slow decaying wood.

The third way the single pulse curve can be affected is by use of fossil fuels in the supply chain e.g., due to longer transport distances or in iWUC/iLUC (permanent forest carbon changes). Changes in this will lead to a parallel shift in the curve equal to the emissions from the fossil fuels.

The fourth and final way the curve can be affected is by changes in the amount of biomass used in the processing of the biomass e.g., drying of wood pellets. An increase in this will increase the emissions in the beginning of the curve, but the change will diminish over time and eventually disappear.

The single pulse curve is here used to present how the use of biomass in the transformation sector does affect the atmospheric CO2, for wood chips and wood pellets separately and together. Emissions factors (Kg CO2/GJ) was derived from the single pulse curve and were compared to coal and natural gas emissions. Finally, emission factors were split up on different parts to demonstrate the magnitude of the above mentioned factors.

3 Results

3.1 The data basis for the Danish wood chip and wood pellet consumption in 2021

In 2021, the total primary energy supply to the Danish combined heat and power and district heat production [7] of wood chips and wood pellets, was 88.1 PJ. Of the 88.1 PJ, 40.7 PJ was wood chips and 47.4 PJ was wood pellets used in the transformation sector to produce heat and electricity (Table 1). These production data were used in the subsequent analyses.

Table 1. Bioenergy production in district heating and combined heat and powerplants from different fuel types in 2021. Data source: Energistatistik 2021 [7].

	Wood pellets	Wood chips	Total
ENS (PJ)	47.4	40.7	88.1
Share (%)	54	46	100

Feedstock for wood chips production is mostly stems followed by harvest residues and a small fraction of industrial residues (probably shavings). Wood pellets are based primarily on industrial residues (sawdust etc.), but also on stems and a small, but larger than 2020 amount of harvest residues (Table 2).

Table 2. Feedstock for wood chips and wood pellet production as reported by utility companies for 2020.

Fuel type	Stems	Harvest residues	Industrial residues
		%	
Wood chips	56.1	35.3	8.6
Wood pellets	35.7	10.6	53.7
Weighted average	45.1	22.0	32.9

Wood chips mostly come from Denmark, Germany and the Baltic countries, where wood pellets were sourced more broadly with the Baltic countries being the prime source countries, followed by USA, Sweden, Russia, Portugal, Belgium and Denmark (Table 3). Of the total Danish consumption in 2021, 50.9% of wood chips were domestically sourced compared to 3.5% of the wood pellets.

Table 3. Origin of wood chips and wood pellets in the model data and for Denmark in total. Totals are based on official trade statistics for 2021 (www.statistikbanken.dk) table KN8Y, CN numbers 44012100 and 44012200 for wood chips and 44013100 for wood pellets.

Country	Share wood chips Total 2021	Share wood pellets Total 2021
	%	
Denmark	50.9	3.5
Belgium	0.3	4.6
Canada	0.0	2.3
Estonia	6.5	21.1
Finland	0.0	0.2
Latvia	13.5	24.1
Lithuania	2.9	1.3
Norway	0.6	1.3
Poland	0.0	3.2
Portugal	0.0	5.4
Russia	0.0	9.5
Spain	1.6	0.2
Sweden	3.8	9.8
Germany	19.9	3.5
Ukraine	0.0	0.3
USA	0.0	9.8

3.2 Single year biomass use CO_2 dynamics

3.2.1 Wood chips

A single year's use of wood chips with a yearly consumption of 40.7 PJ implies an emission of 4.76 Mt CO_2 in year one. However, the CO_2 is recaptured in the forest carbon stocks, from where it was removed, over time (Figure 2). Approximately 60 years after combustion, emissions equivalent to the biogenic part of the CO_2 emissions is more or less recaptured in the forest carbon stock. CO_2 emissions do not converge towards zero, as there are fossil emissions related to forest operations, transport and iWUC.

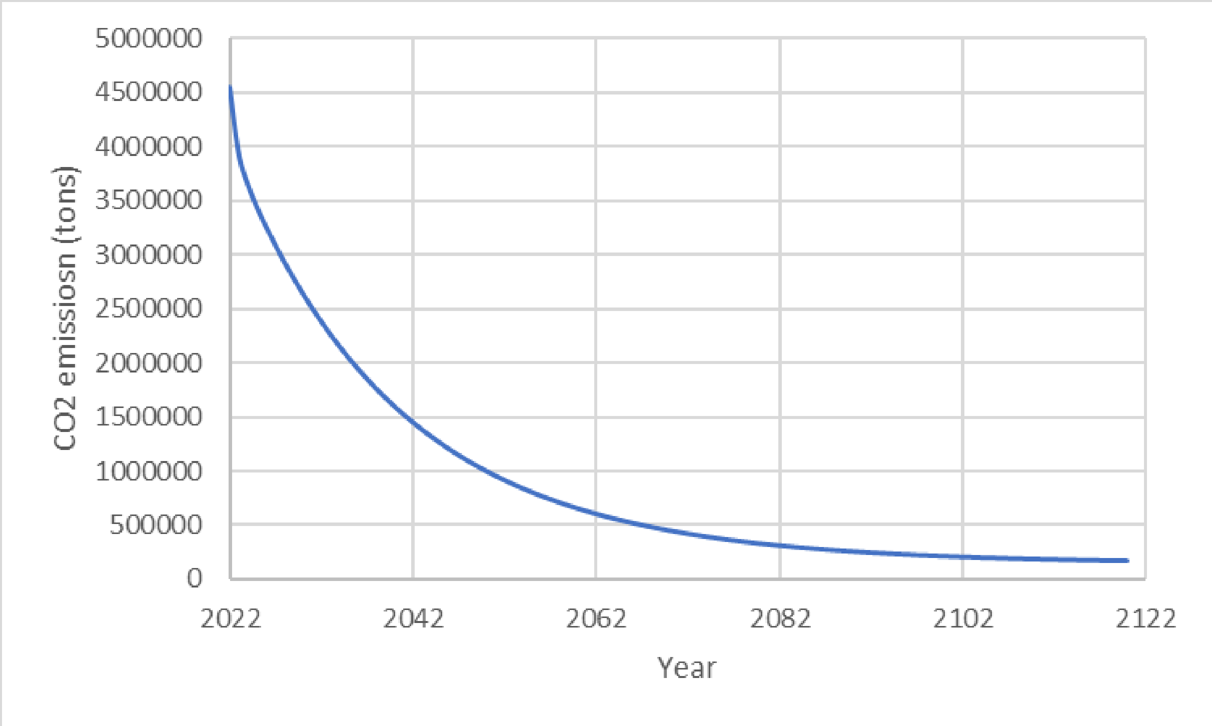

Figure 2. Cumulative emissions for one-year consumption of wood chips for energy production as in 2021 in Denmark, for production of 40.7 PJ using the "weighted average wood chip data".

For wood chips, the initial factor emissions (Kg CO2/GJ), year one are higher than coal due to a higher energy density of the coal, but within few years (1-3 years), recapture in forests drives the cumulative emissions below those for the same energy production with coal (Table 4). In year 1, emissions pr GJ produced from wood chips is 116.9 Kg CO_2/GJ, where after 30 years, the emissions are 25.7 Kg CO_2/GJ, and after 100 years only emissions equivalent to the fossil part of the emissions remains in the atmosphere adding up to 5.8 Kg CO_2/GJ. Comparable CO_2 emissions from coal and natural gas would be 107 and 65 Kg CO_2/GJ respectively, regardless of the time perspective (Table 4) [1].

Table 4: CO2 emissions (Kg/GJ) for different fuel sources used for wood chips and for the weighted average wood chip data

Year after consumption	*1*	*10*	*20*	*30*	*50*	*70*	*100*
Weighted average wood chip data	**116.9**	**64.8**	**39.9**	**25.7**	**12.5**	**6.8**	**5.8**
Coal	107.1	107.1	107.1	107.1	107.1	107.1	107.1
Natural gas	65.4	65.4	65.4	65.4	65.4	65.4	65.4

3.2.2 Wood pellets

For wood pellets, the picture is similar to that of wood chips, however the emissions are higher (5.75 Mt) due to the larger consumption for energy production with wood pellets (47.4 PJ) compared to wood chips (40.7 PJ). As for wood chips, the emissions converge towards up-stream fossil process, transport and iWUC emissions within approx. 60 years (Figure 3).

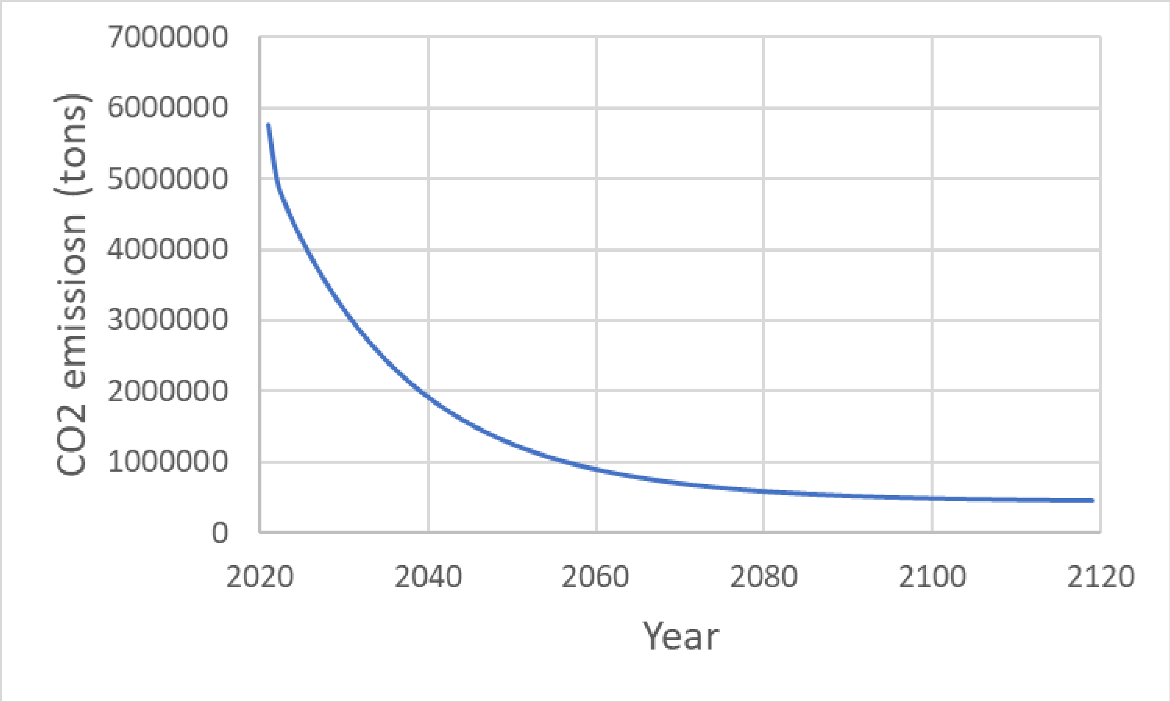

Figure 3. Cumulative net CO_2 emissions of a single year use of wood pellets, with a consumption of 47.4 PJ wood pellets, for different biomass sources and for the current biomass sourcing as described for the "weighted average wood pellet data".

CO_2 emissions per GJ from wood pellets are not much different from wood chips in year one, although the use of hog fuel for drying, the longer transport distance, and the larger proportion of wood carrying iLUC/iWUC emissions, leads to slightly higher emissions/GJ (Table 5). The larger amount of fossil fuels used in the wood pellet supply chain is also evident by the higher level of convergence in year 100 compared to wood chips (Table 4 and 5).

Table 5. CO_2 emissions coefficients (Kg/GJ) for the typical wood pellet plant based on best available data.

Year after consumption	*1*	*10*	*20*	*30*	*50*	*70*	*100*
Weighted average wood pellet data	**121.4**	**66.4**	**40.4**	**26.5**	**14.7**	**10.3**	**9.6**
Coal	107.1	107.1	107.1	107.1	107.1	107.1	107.1
Natural gas	65.4	65.4	65.4	65.4	65.4	65.4	65.4

In a 100-year perspective i.e. 100 years after combustion, net emissions from the current biomass use for wood chips and wood pellets, are approximately 5-9% and 9-15% of the net emissions of coal and natural gas respectively, depending on the transport distance and iWUC.

3.2.3 National wood chip and wood pellet consumption emissions

For the entire consumption of wood pellets and wood chips used in the Danish transformation sector in 2021, the emissions in year 1 are app. 10.6 million tons CO_2 (Figure 4). Net emissions, however, rapidly decline over the first 40 years after consumption and converge after app. 60 years at the level of fossil process, transport and iWUC emissions.

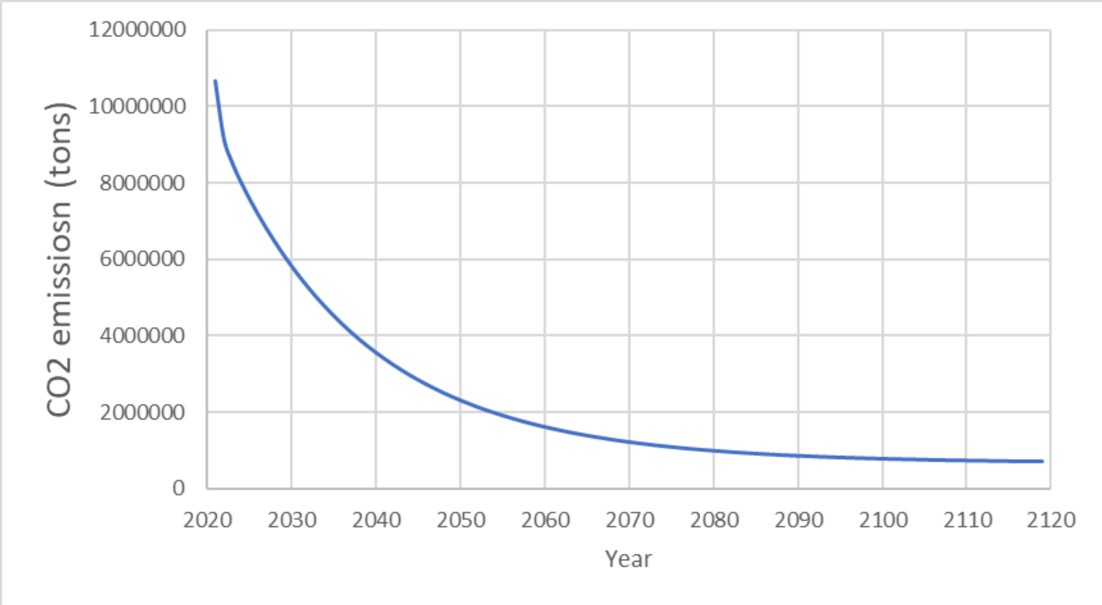

Figure 4. Cumulative net CO_2 emissions of a single year use of wood pellets, with a weighted average consumption of wood pellets and wood chips in Danish DH and CHP of 88.1 PJ.

In year 1 direct biogenic emissions from combustion accounts for 83,3% of the emissions, biogenic process emissions (hog fuel for wood pellet drying) accounts for 10,1% iWUC/iLUC for 3.4% and fossil process emissions including transport accounts for 3.2% of the total emissions. The net recapturing of CO_2 is reflected in the change in emission factors over time. Net emissions are lower than coal already few years after combustion, while for natural gas the emissions are higher for about 10 years but lower hereafter (Figure 5).

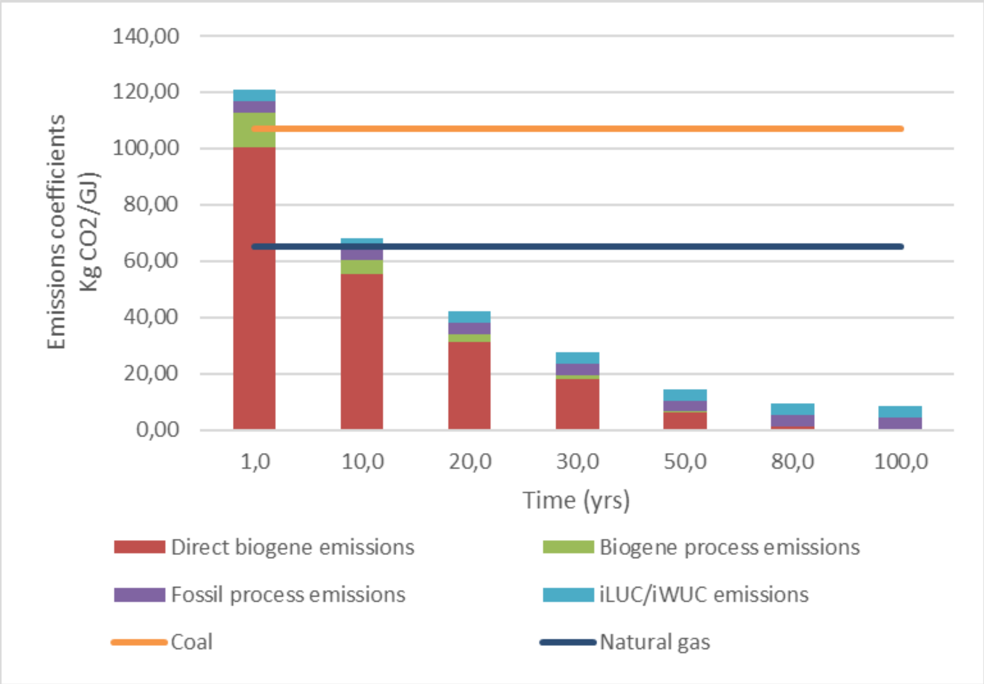

Figure 5. Emission coefficients for Danish district heating and CHP wood consumption and fossil energy sources (coal and natural gas) over time. Importantly, the biogene emissions are reduced over time due to recapture of the emitted CO_2.

It should be noted that the biogenic process emissions, which are mainly related to drying of wood pellets is converging more rapid that the remaining biogenic emissions as these are solely based on residues with a shorter half-life.

In total direct biogene emissions accounted for 83,3% of total emissions, biogene process emissions, fossil process emissions plus fossil iWUC and iLUC accounted for 10,1, 4,8 and 1,9% of the total emissions (Table 6)

Table 6: Overview of emissions sources year 1 after combustion

	Kg CO2/GJ	%
Biogene emissions from combustion at plants	100,62	83,3%
Biogene process emissions (drying of pellets)	12,18	10,1%
Fossil emissions (Extraction, pellet pressing, transport and iWUC)	5,78	4,8%
iLUC (Permanent reduction of carbon stocks in forests not directly affected)	2,27	1,9%

4 Discussion and conclusion

4.1 Data input

In [3] the data collection covered 96% and 69% of the wood pellet and wood chip consumption, respectively, while in this report the coverage for wood pellets and wood chips only covered 75 and 53% of the total consumption. This results in an overrepresentation of large plants compared to last year results, as it is the smaller plants that are absent in the data collection. This overrepresentation results in slightly higher emissions per GJ as the large utilities typically are sourcing from international sources with longer transport distances and are using a larger proportion of wood from stems, compared to small district heating plants (See [1]).

4.2 Origin of biomass

Contrary to in [3] where origin of biomass was based on data collection with overrepresentation of large utilities, official trade statistics were used here to estimate origin of biomass. The approach used here to estimate the origin of the biomass used in the transformation sector represent a small bias due to the data also covering private consumption. However, it may also eliminate a bias discussed in [3], namely the underrepresentation of small district heating plants using Danish biomass, which were only represented to a limited degree in [3], especially for wood chips. These are more thoroughly represented in this report, with respect to origin of the biomass, as all of these small plant are represented in the official trade statistics in [9].

The longer transportation of the wood, because of the overrepresentation of large utilities in the data, has as such been covered by using origin data from [9]. This is only the case for origin of the biomass, not for other input data.

Although the use of biomass origin from [9] gives a better coverage of small plants, a difference between [9] and reporting on origin of the biomass to the “Brancheaftale” was detected as countries such as Brazil was not reported in [9], but in Brancheaftalen. This difference may lead to underestimation of the emissions from transportation by using data from [9]. In the larger picture this will only change the main result less than 1% at maximum, but a more precise data source on where the biomass used in DH and CHP originates would be preferable in the future. In GA24 these data will be accessible from direct reporting from the utilities and this bias will no longer occur in coming assessments of CO2 emissions from biomass in a GA setting.

4.3 Sourcing strategy

The 2021 data revealed that a larger part of the wood chips was sourced from stems and a lower proportion of harvest residues, compared to 2020 data. This may also explain the slightly higher emission factor (Kg CO2/GJ) observed for wood chips here compared to [3] as stems has a longer half-life than harvest residues and there are fossil fuel emissions from iWUC and increased emissions from iLUC associated with the use of stems.

For wood pellets the sourcing strategy differed by this years data having a larger amount of harvest residues and lower use of stems, compared to 2020 [3]. This lead to a lower emission factor (Kg CO2/GJ), that was used in 2021 compared to 2020.

4.4 Biomass usage and fuel mix

All in all the use of biomass in the Danish district heating and combined heat and powerplant has increased consumption of biomass by 37% in 2021 compared to 2020. The increased use in 2021 lead to a much higher total emission, compared to 2020 reported in [3], while the emissions per GJ were similar to 2020.

Moreover, the proportion of wood pellets and wood chips are here 54% and 46% respectively giving an overweight of wood pellet use contrary to in [3] where there was an overweight of wood chips use. As wood pellets has slightly higher emissions per GJ, the overweight of wood pellets will lead to higher total emissions and higher per GJ, which is also the case, although the difference is small.

Although the data collection on the origin of the biomass and hence the distance the biomass was transported, the proportion wood pellets and wood chips and the sourcing strategy differed in this report compared to the data presented in Nielsen et al. [3], the shape of the single pulse emission did not differ much from the shape of the single pulse curve presented in [3].

However, CO_2 emissions factors (Kg CO2/GJ) for the use of biomass in 2021 was slightly higher here than in 2020 [3], especially for wood chips. This change origin from a larger proportion of stems used for wood chips, this year.

4.5 Data considerations and improvements

As mentioned, data improvement on origin of the biomass will occur in 2024. But as for the results presented in [3], the counterfactuals, natural or product decay rates (half-lifes), are the main determinants of the speed convergence of the single pulse curve compared to the counterfactual situation. Data on this are still limited with only a few scientific reports covering this. As such, more data on the actual decay rates in forests mainly in Denmark and the Baltic countries will significantly improve the accuracy and precision of the results presented here and in [3].

iLUC/iWUC and fossil process and transport emissions determine the fraction of emissions not being offset by forest carbon sequestration and does not functionally differ in this report compared to [3], however, the transport distances did to some degree differ in length especially for wood chips (Table 7).

Table 2: Transport distances for an average ton of wood chips and wood pellets (Km/t)

	Truck	Train	Ship	Total
	Wood chips			
2020	166,5	83,7	1370,5	1620,7
2021	125,1	46,3	307,5	478,9
	Wood pellets			
2020	235,5	238,6	1839,4	2313,5
2021	216,8	322,1	1676,1	2214,9

The differences in transport distances should however, be handled with care, as the origin of the biomass this year originated from a different source compared to 2020.

These emissions, especially indirect emissions may vary considerably and can have significant effect on the results [1,2,3] and more research on the effect on the marked for other wood based products from use of bioenergy would make results more precise.

5 Literature

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