AARHUS UNIVERSITY EMISSIONS INVENTORY 2021

Scientific Report from DCE – Danish Centre for Environment and Energy No. 509 2022

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DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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Data sheet

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Abstract: Greenhouse gas inventories and disclosure of these emissions are an important tool in providing the decision support for developing and implement meaningful mitigation strategies. Aarhus University's 2021 emissions inventory has developed on previous inventories with a refined method, reflecting the academic discourse in this space, while following the guidelines of the GHG Protocol. This report includes process based methods, which result in 20,322.7 tCO_2e across scope 1, 2 and 3, with the exception of 3.1 purchased goods and services, and 3.2 capital goods. Spend based approaches were used in place of process based for scope 3.1 and 3.2, using EXIOBASE, and result in 39.691.9 tCO_2e. Since the two approaches answer different questions, they cannot be summed, although individually present relevant foundation for defining a decarbonization plan for Aarhus University.

Keywords: GHG Accounting, Emissions, Decision Support, Transitional Risks, Attributional LCA, Consequential LCA, Sustainability

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Contents

Executive summary

This is Aarhus University's (AU's) internal greenhouse gas (GHG) inventory for 2021, under a slightly updated methodology, while still adhering to the Greenhouse Gas Protocol (GHGP). The methods used in this report reflect the development of corporate GHG inventory related research in both academic and non-academic spaces, resulting in updated and more clear definitions of the methods used. The 2021 inventory includes both attributional life cycle assessments (aLCA), and consequential life cycle assessments (cLCA) which are referred to as process based (PB) and spend based (SB), respectively. SB approaches are used for AU's procurement due to the size and variety of purchased goods and services. For a visual representation of these results, see the visual summary below. This report expands the 2020 GHG inventory by more clearly defining what the different methods can and cannot be used for, and treating the results from different methods separately.

The PB method resulted in total scope 1, 2 and 3 emissions of **20,322.7 tCO_2e**, and a -1% change of comparable emissions from 2020. Total emissions between 2021 and 2020 show a -0.3% change, however 2021 includes more emission sources. Notable 2021 increases include university activities recovering from the effects of Covid-19 with a 35% increase in business flight emissions from 2020, and a higher emission factor (EF) for Danish electricity resulted in a 10% increase in emissions, despite a -1% change in consumption of kWh from 2020. A -19% change is seen in AU's second largest emission source, investments (**4,106.0 tCO_2e**), which, coupled with a partial reduction of EFs among on-site combustion of gas and oil, and a reduction in transport emissions, produces the overall static result for the 2021 GHG inventory.

Total PB emissions are down 37% from 2018, when AU first began disclosing emissions. Here, the impacts of Covid-19 are very clear, and blur any meaningful differentiation between the effects of Covid-19 and initiatives presented in the AU Climate Strategy. This is shown in the visual summary below.

The SB method resulted in total scope 3.1 (purchased goods and services) emissions of **35,823.1 tCO_2e** and scope 3.2 (capital goods) emissions of **3,868.8 tCO_2e**, using the model EXIOBASE. Since this method uses an updated and expanded scope, it is unable to be compared to 2020 spend based methods. EXIOBASE relies on economic data, (of which 87% of university spending is accounted for) and the results indicate which sectors that AU spend most within, and thereby which sectors contribute the most emissions to AU's total inventory. Most impactful are AU's spending within purchased goods concerning computers, devices and software at **2,375.6 tCO_2e**, pharmaceutical related purchases at **2,330.5 tCO_2e** and machinery and equipment at **2,039.0 tCO_2e.** Further, scope 3.2 (capital goods) are defined as longer use purchases such as buildings where the majority is allocated to the category "construction of buildings" at **3,103.8 tCO_2e**. At this point, using this method, we are unable to clearly define which specific purchases or suppliers within these categories are responsible for the greatest emissions.

Normalizing the PB data to tCO_2e per person-year across employees, students and combined results in: **2.45 (tCO_2e/employee-year)**; **0.75 (tCO_2e/student-year)**, and combined **0.58 (tCO_2e/total-AU-year)**, which is a 2%-4% decrease from 2020.

The methods used in this report are the result of a collaboration between all the Danish universities. Discussions in this space highlight the trade-offs between the aLCA and cLCA methods, and more specifically discourage the combination of results, as they be misguiding when considered as a sum. As a result, the methods are reported separately in this report, although individually, they present the foundation for climate related decarbonisation decision support in the future. Research on how best to navigate the differences and trade-offs is ongoing in the literature, however this should be seen as an example of how far the discussion has reached.

Visual summary

The visual summary is shown in three parts. First, the PB results are shown in relation to the 2020 emissions, using the same parameters as previously measured. Second, the progression from 2018 to 2020 is shown, using the same parameters as previously measured, and finally SB method results are presented.

Process based emissions 2021

Emissions using the PB method follow the same aLCA methodologies as AU's first GHG inventory in 2018, with the help of The National Center for Environment and Energy (DCE). In total, AU emitted **20,322.7 tCO2e** whereof the largest single emission sources include electricity consumption, AU investments and agriculture.

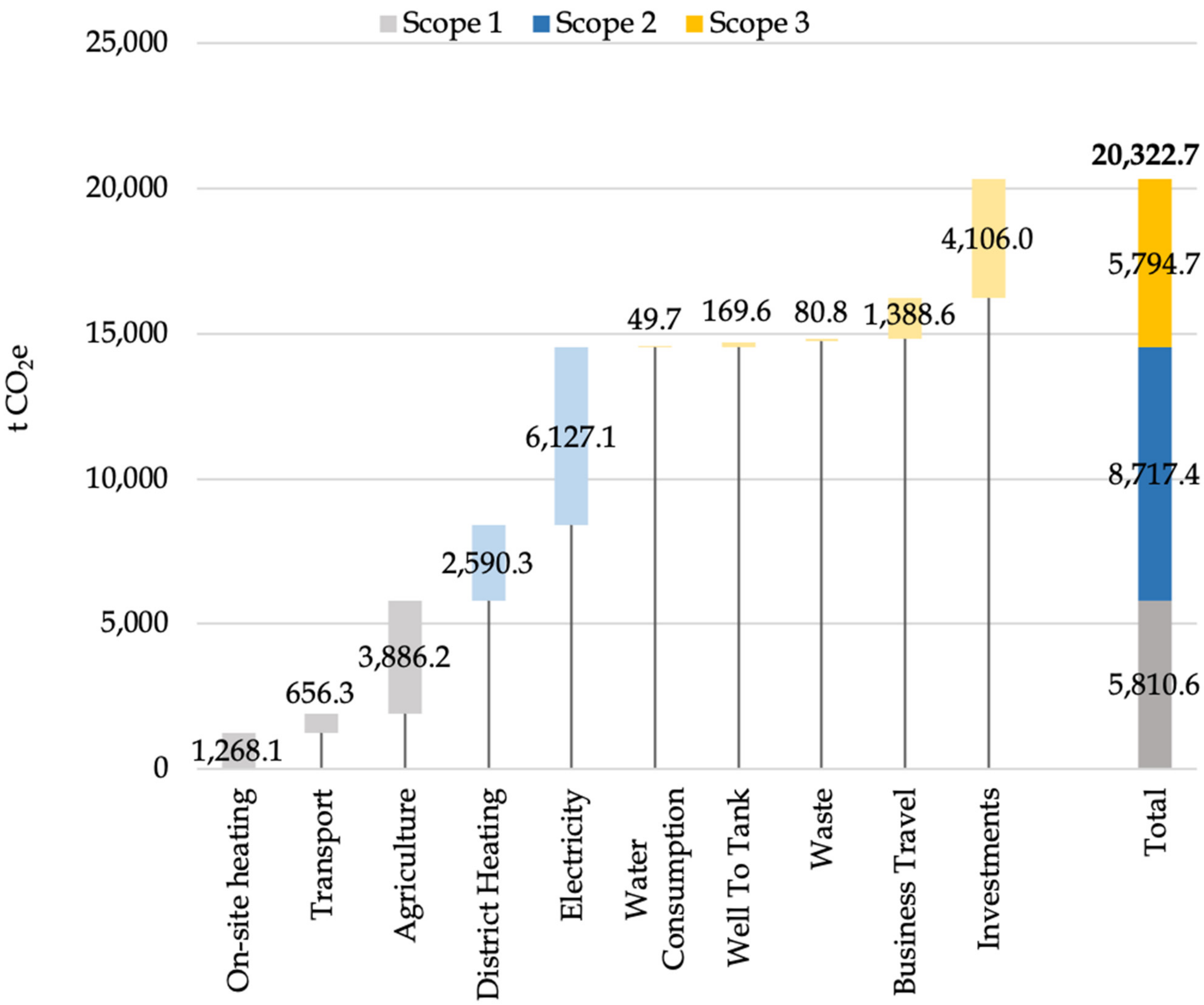


Figure S1. Total process based emissions for 2021. Scope 1 is shown in grey, scope 2 in blue, and scope 3 in yellow.

Process based emissions comparison 2020 - 2021

The following figures show the percentage development of emissions from 2020 to 2021. The right axis indicates the positive or negative percent change in 2021 emissions and activity. Increases seen in flight emissions can be attributed to Covid-19 recovery, and the increase in wastewater is due to updated wastewater related emission data. Despite the drastic increase shown here, the total wastewater emissions account for 0.25% of total aLCA emissions. Note: Right axis ranges are from -25% to 25% for all graphs, with the exception of wastewater and air travel, due to increases above 25%.

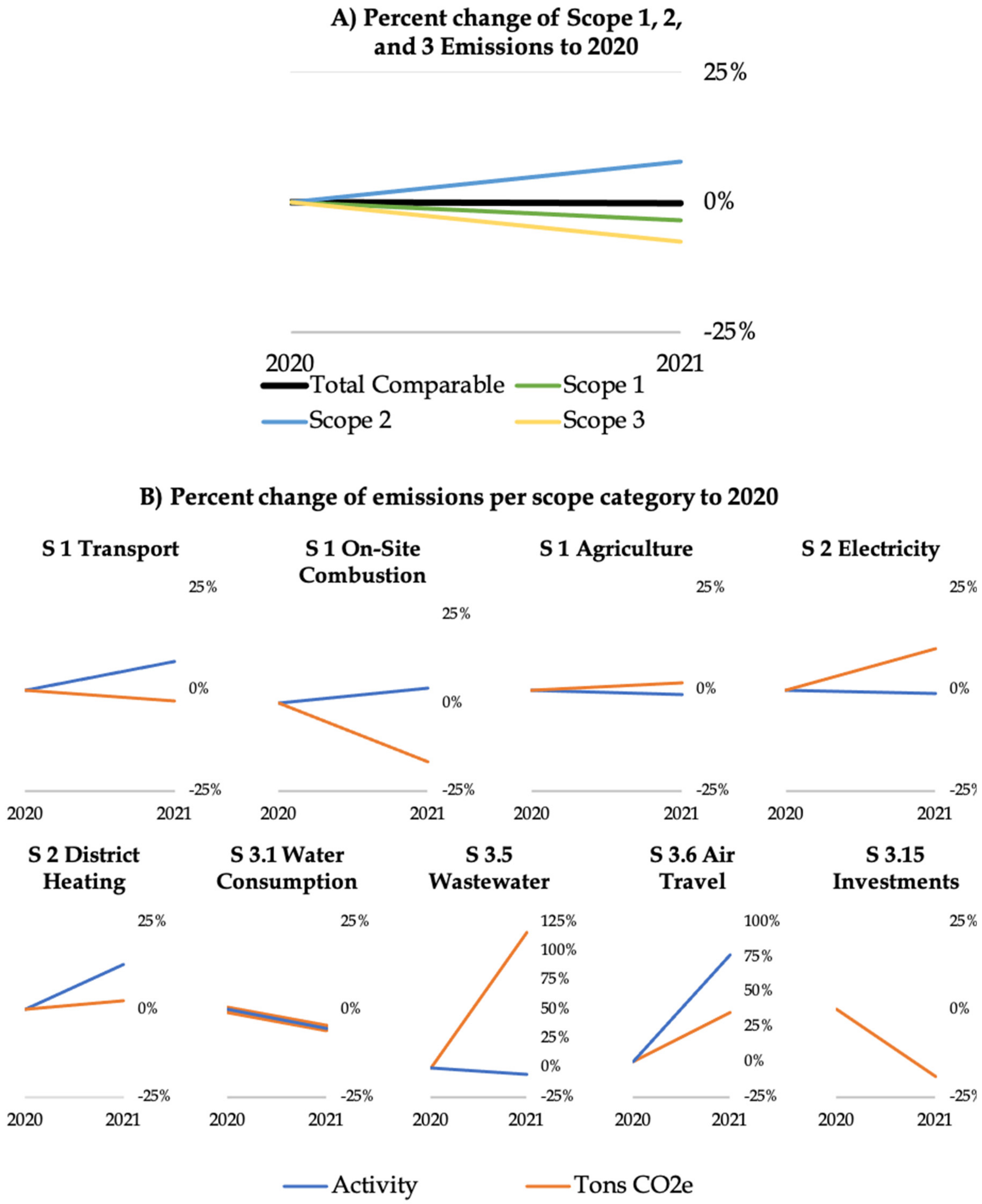


Figure S2. A) Percent change in scope 1, scope 2, scope 3, and total emissions between 2021 and 2020. Total comparable includes all emission sources considered in the 2020 process based assessment. B) Percent change of emissions in relation to 2020 emissions per scope and category. All figures range from -25% to 25% with the exception of wastewater and air travel, which show increases greater than 25%.

Process based emissions comparison 2018 – 2021

2021 emissions are down 37% from 2018 emissions, among comparable parameters, and are shown in the figures below as percent change from 2018, over time. The right axis indicates the positive or negative percent change in 2021 emissions and activity in relation to 2018. Scope 1 Transport activity starts in 2019 where comparable data was gathered; however, the emission data is still relevant. Right axis minimums are at -100% for the graph that include air travel missions. Investments are included from 2020 on.

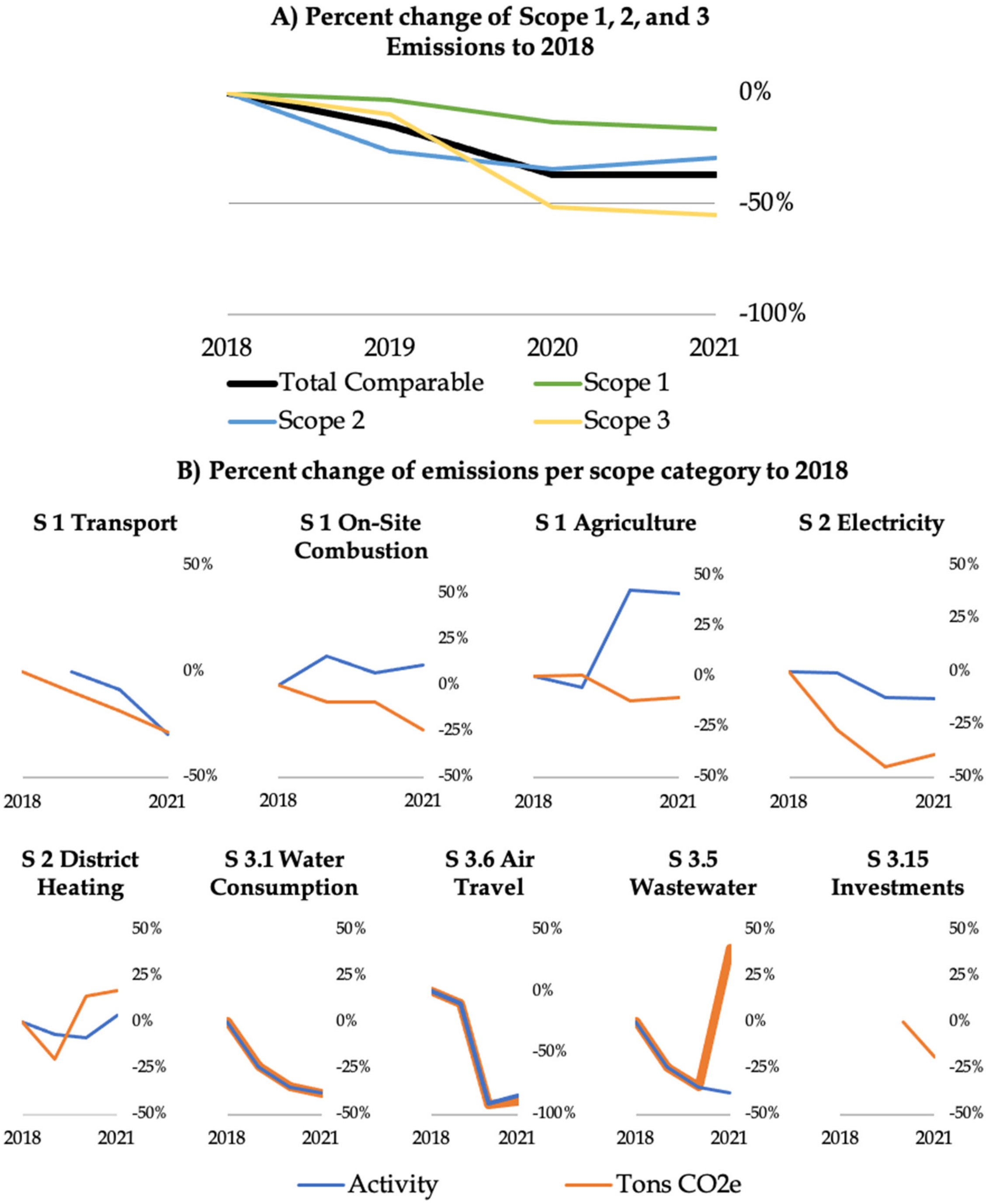


Figure S3.A A) Percent change in scope 1, scope 2, scope 3, and total emissions between 2021 and 2018. Total comparable includes all emission sources considered in the 2020 process based assessment, with the inclusion of investment related emissions. B) Percent change of emissions in relation to 2020 emissions per scope and category. All figures range from -50% to 50% with the exception of air travel which shows a nearly 100% reduction in 2020

Process based per employee, student and person comparison for 2018 – 2021

Growth and increases in consumption will be reflected in emission inventory as an increase in emissions. To counter this, and to show the decoupling of emissions from growth, the results are normalized against total full time equivalents of employees, students, and combined, and shown in the table and figures below. Minimal change is seen from 2020 (2%-4% reduction), however the significant reduction seen since 2018 is a result of partially more students and employees at AU, and a significant drop in AU emissions during Covid-19.

Table S1. Total process based emissions per employee, student and person.

tCO_2e/Employee	2.45
tCO_2e/Student	0.75
tCO_2e/prs	0.58

Spend based emissions 2021

SB emissions are based on the economic spending of AU, and in this case, is done so under cLCA methodology. The economic activity data was cleaned to ensure activities converted to emissions reflected physical goods and services, as a significant portion of AU spending represents non-physical goods such as lease payments, and internal settlements. The data was used in the model EXIOBASE, which is an environmentally extended multi-regional input-output model. Limitations of the model include broad categories, as shown in the figure below, where the largest single portion of AU's spend based emissions are allocated to "wholesale and commission". AU accounting category descriptions are used to manually split these broad categories out, as is shown in the figures below, and described further in the report.

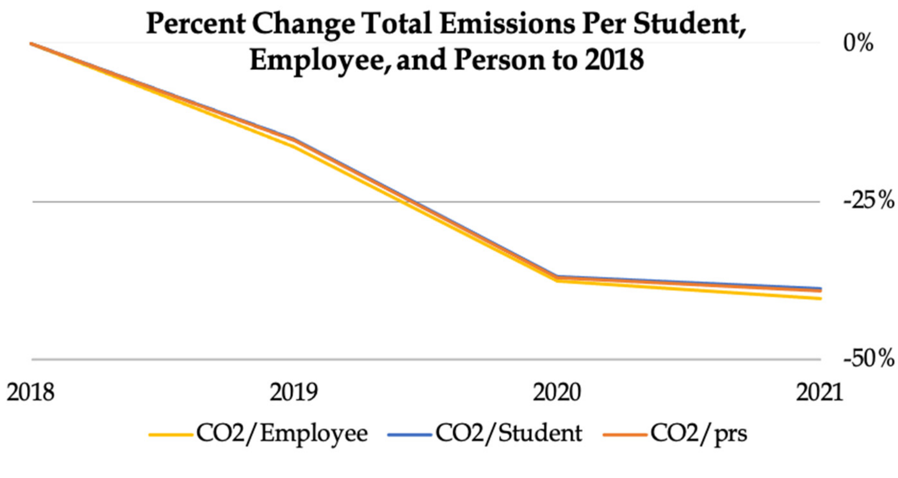


Figure S4. Percent change of total emissions per employee, student and person in relation to 2018.

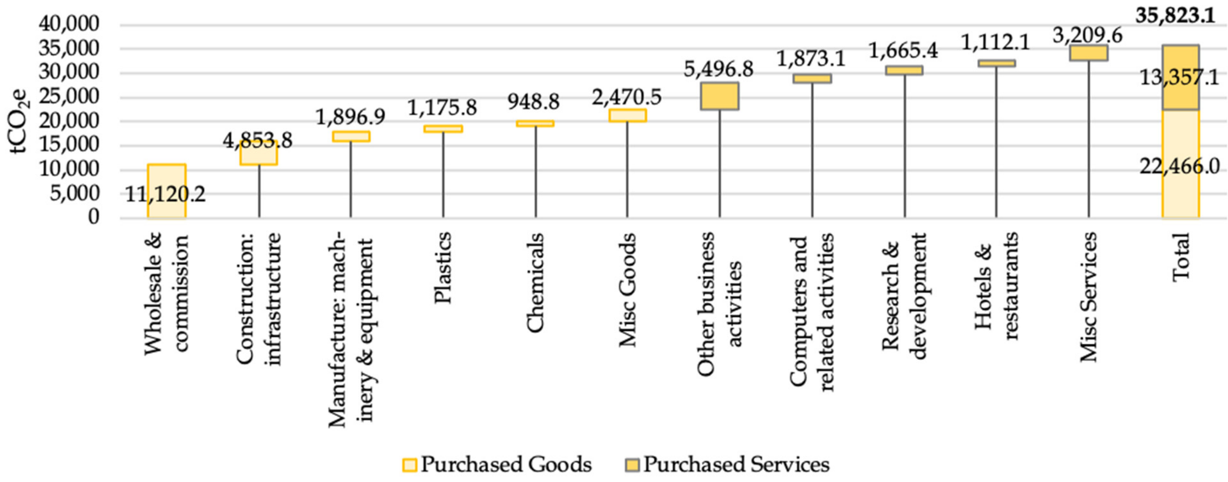


Figure S5. Spend based emissions for scope 3.1 – Purchased goods and services by EXIOBASE categories. Purchased goods are represented with light yellow and yellow border, and services are shown as dark yellow with grey border.

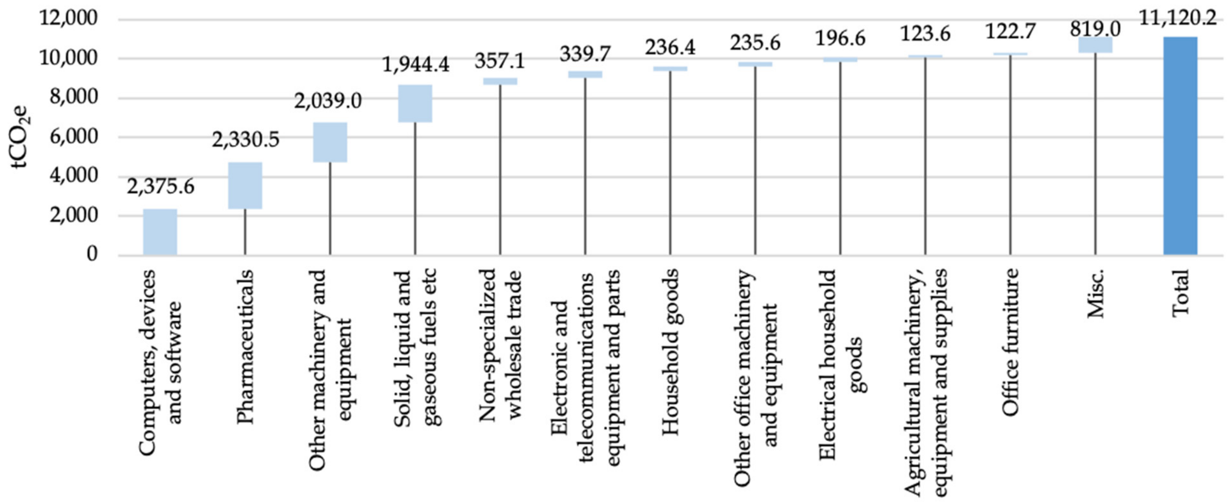


Figure S6. Spend based emissions from the "wholesale & Commission" EXIOBASE category, expanded using UNSPSC codes.

1 Introduction

The data presented here was collected through various AU departments, in coordination with AU Green and the university finance department. The results presented in this report are verified by The National Center for Environment and Energy (DCE), who among other things produce the national emission inventory for Denmark. The activity data is converted using emission factors (EF) and presented in tons of CO_2 equivalents (tCO_2e).

Climate change poses both risks and opportunities to organisations. The green transition must occur if we are to adhere to the global climate targets set out by the Paris Agreement, however, currently we are not on track as projected emissions put us well above the threshold for monumental change to our environment and ways of life. Therefore, future policies are excepted to act as vehicles to reduce these emissions, which can be interpreted as risks associated with the green transition. To reduce these risks, robust and sound quantification of these risks must be conducted. Here, GHG inventories are an important step in transitional risk mitigation. With risks come opportunities, and as other factors of the green transition can be interpreted as risks, such as market shifts towards lower carbon intense products and services, and reputations, effective communication of the findings in this report will increase the climate related transparency of AU, and provide the decisions support for AU to remain relevant throughout the green transition.

AU began disclosing emission inventories with the 2018 GHG inventory. Reports for following years have continuously expanded on the width and depth of the 2018 report, and continue to do so with the 2021 inventory. Where possible, meaningful comparisons are made with previous years to show how emissions develop from year to year. For this report, we employ the globally adopted and recognised method of the GHG Protocol (GHGP) methodology of organisational emissions allocation (Figure 1).

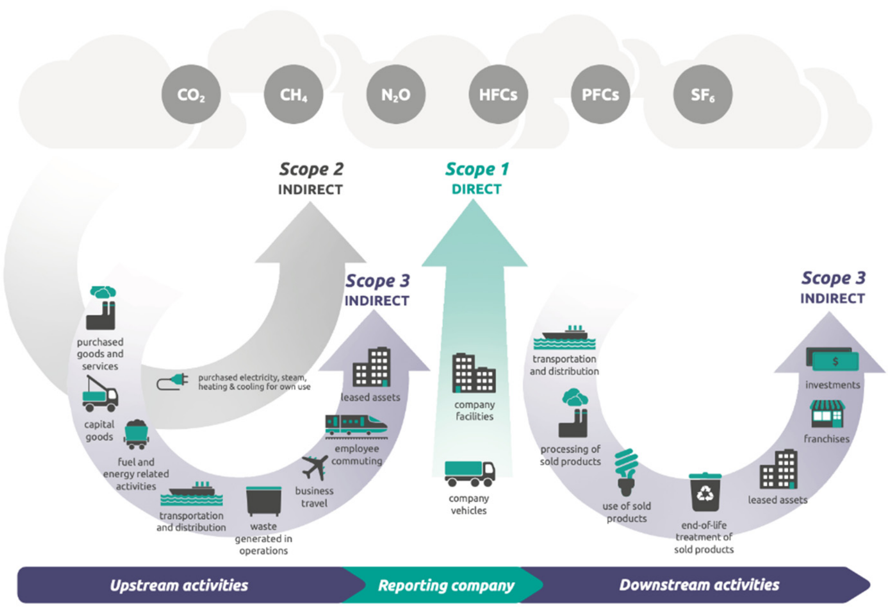


Figure 1. Schematic from the Greenhouse Gas Protocol which describes how an organizations emissions are allocated. Scope 3 categories are numbered along the upstream and downstream arrows, starting at the left (GHGP)

The GHGP describes emissions across three scopes, whereof scope 1 are direct emissions, scope 2 are indirect emissions associated with purchased energy, and scope 3 are indirect emissions, and can be divided into 15 scope 3 categories. This structure is used in this report, as there are clear guidelines on how each category should be determined.

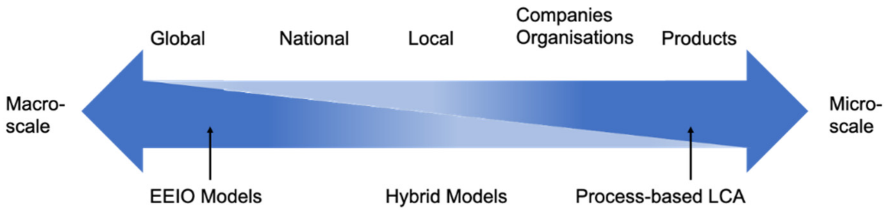
The GHGP is written to be broadly applied to many kinds of organisations, and many of these guidelines are interpreted into sector specific guidance documents. The GHGP offers guidance on both the width of the emissions inventory (18 categories across 3 scopes) as well as guidance on the depth of each category (to what detail and how to find the representative data) through a suggested data hierarchy (GHG Protocol, 2011), which is described in section 2: *Background and methods*. AU together with the other Danish universities established a working group to identify the trade-offs of the different methods and develop a best practice methodology for applying the GHGP. This report follows these recommendations and adopts them where possible. The following categories for this report, and comments on future reports are shown below in Table 2.

Table 2. GHGP Categories included.

Scope	Description	Included	Reasoning
1	On-site Combustion, Agriculture and Transport	Yes	Required by GHGP
2	Purchased Energy	Yes	Required by GHGP
3.1	Purchased Goods and Services	Yes	Integral part of university operations
3.2	Capital Goods	Yes	Integral part of university operations
3.3	Fuel- and Energy-Related Activities Not Included in Scope 1 or Scope 2	Yes	Unavoidable but easily included emissions
3.4	Upstream Transportation and Distribution	No	Data limitations
3.5	Waste Generated in Operations	Yes	Integral part of university operations
3.6	Business Travel	Yes	Integral part of university operations
3.7	Employee Commuting	No	Data limitations but expected for 2022 inventory
3.8	Upstream Leased Assets	No	Not relevant
3.9	Downstream Transportation and Distribution	No	Not relevant
3.10	Processing of Sold Products	No	Not relevant
3.11	Use of Sold Products	No	Not relevant
3.12	End-of-Life Treatment of Sold Products	No	Not relevant
3.13	Downstream Leased Assets	No	Not relevant
3.14	Franchises	No	Not relevant
3.15	Investments	Yes	traditionally an emission intensive category and therefore included

The GHGP also suggests methods for calculating the emissions, according to the available data and size of organisation considered. The assessment continuum (Figure 2) describes the methods available and the scale at which they produce optimal results based on time and resource availability (Peters, 2010). On the macro scale, environmentally extended input-output (EEIO) models based on global supply use tables are optimal. These models can report emission intensities based on sector average spending and thereby can estimate emissions using a spend based approach (SB). On the opposite side of the spectrum are process based approaches (PB) which are well suited for individual products or processes. These are defined by the inputs and outputs throughout the life cycle of product, and often presented in a life cycle assessment (LCA).

Figure 2. Emission assessment continuum with spend based (SB) as EEIO models to the left and process based (PB) as LCA to the left. Adapted from (Peters, 2010).



The GHGP data hierarchy describes the most accurate data being activity data in a per unit form, such as km's transported, liters of fuel, kg of wheat, etc. The EFs used with these kinds of data are based on LCA's and follow the PB method, such as tCO_2e per km driven. The GHGP data hierarchy spans down to the least accurate form, the SB approach. The SB approach is described as the least accurate as the EFs used in a spend based method are generated from industry and sector averages which negate any unique attributes of purchases straying from the average.

When considering PB and SB methods, there are two important distinctions to recognize, namely if they are based on attributional LCA (aLCA) or consequential LCA (cLCA) methodology. The key difference between the two is that aLCA asks the question "what was the impact of this product?" while cLCA asks "what will the impact be of purchasing this product?". In this case, PB methods align with aLCA methodologies, and SB align with cLCA methodologies. Here, cLCA uses economic and political data to determine the direct and indirect future impacts of a decision, meaning impacts are more easily able to be determined based on economic spends. In Denmark, the most commonly used EEIO method is the model EXIOBASE, which utilizes multiregional input-output data, and has been used in an increasing amount of public and private investigation and impact assessments, as well as in publicly available databases.

Both methods share similarities in that they report in the same units (CO_2e) however adding them together will be scientifically inaccurate, and may result in misguiding results as the two methods answer different questions. However, due to the variety of university purchases, finding product specific LCAs for all purchases is beyond the resources allocated to this exercise. Therefore, for procurement related emissions, a SB approach is a reasonable solution, and supported by the GHGP, if used for individual categories. The discussion of aLCA vs cLCA, transposed onto the GHGP's suggested data hierarchy is currently being explored in environmental disclosure related research, and this report represents the application of the discussion to date.

But where does an organisation like AU fit along the continuum and data hierarchy? Adopting both methods in a hybrid setting allows for an efficient overview using the comprehensive SB approach for areas where detailed activity data, best suited for the PB method are not available. This is the approach taken in the 2021 GHG inventory for AU, while recognizing that mixing methods answer different questions, and is described further in the discussion. A major update from the previous reports including SB emissions is the clear differentiation of the methods, and not summing the results from the different methods.

2 Background and methods

This inventory follows the GHGP's guidelines for reporting operational scope 1, 2 and 3 emissions (Table 2). Scope 1 and 2 include direct emissions such as transport, on-site emissions from gas and oil consumption, agriculture, as well as indirect emissions from purchased utilities. Additionally, specific scope 3 emissions, which are embedded in the value-chain, are included in the inventory. The GHGP provides users with a data hierarchy proposal to navigate between the most to the least desirable, which is presented in Table 3.

Table 3. GHGP suggested data hierarchy.

Method	Approach
Supplier specific	Collect high-quality product-level EF data from supplier directly
Hybrid	Combination of the above method with additional average data (e.g., LCA) to gap fill
Average data	Multiply the mass of units bought with the most relevant EF from another source (e.g., ENS Higg MSI; DEFRA; WALDB)
Spend-based	Convert economic data to EF

This report follows the structure presented by the GHGP scopes and categories, with a new section for each category. The results are presented and discussed in section 3, *Results and discussion*.

Table 4. GHGP Categories and calculation method used

Category	Method
Scope 1	aLCA
Scope 2	aLCA
3.1 - Purchased Goods and Services	cLCA
3.2 - Capital Goods	cLCA
3.3 - Fuel- and Energy-Related Activities Not Included in Scope 1 or Scope 2	aLCA
3.5 - Waste Generated in Operations	aLCA
3.6 - Business Travel	aLCA
3.15 - Investments	aLCA

At the start of 2020, an ad-hoc emissions group was created by Universities Denmark, with the goal of constructing a method for most effectively applying the GHGP at Danish universities. The result of this collaboration introduced the nuances between the aLCA and cLCA methods, and showcased the trade-offs with using each respective method. As a result, the universities agree that both methods play an important role in a university emissions inventory, depending on the data each university has access to and what kind of questions are asked. The following method is determined as satisfying the current needs of AU, while recognizing that emission disclosure is an evolving area of research and will be updated in future inventories. The approaches taken per category are shown in Table 4.

The emission sources included in scope 3 using the PB method are based on easily accessible data and national EFs. Additionally, an updated SB method is used in this years' report, which allows for a more comprehensive estimation of emissions from purchased goods and services.

Process based method description

All the parameters defining the 2018 inventory are included in the 2021 inventory, allowing for meaningful comparisons from year to year. The data collected is described in the next section, with the intention of showing how AU has navigated data accessibility, and the changes within data accessibility. A significant resource at AU is the emissions group at DCE, who supply the nationally determined contributions to the United Nations Framework Convention on Climate Change (UNFCCC). The methods used in determining many of the EFs used in this report are based on the calculations presented in the Danish National Inventory (Nielsen et al., 2022) by DCE, who also supply data for the public average Danish EFs presented by the Danish Energy Agency (ENS).

Scope 1

Fuel data for on-site combustion is taken from the management tool EnergyKey, which documents energy usage across meters for gas, biogas, oil, district heating and electricity. Activity data from all AU locations was collected and EFs from the DCE emissions group and national emission reporting frameworks were delivered. This report follows the IPCC guidelines on biomass related emission for energy production, which do not account emissions from biomass energy as they are already accounted for in land use calculations. For clarity and transparency, these emissions are shown in this inventory, although they do not contribute to the final emissions sum. EFs used here are supplied by DCE and follow the same methodologies described in the national emissions inventory (Nielsen et al., 2022).

Transport data was collected in the form of purchased liters of fuel and driven kilometers. Kilometers were reported through driving allowance repayments at the cost of 1.90 DKK/km, from January to October. The remaining two months were adjusted for using monthly averages. Purchased liters fuels were taken from economic activity associated with the respective transportation methods, whereof activity data for the research vessel Aurora was adjusted to exclude the fuel used by other research institutions that hire the vessel. EFs used in this context are supplied by the DCE transportation model which is based on the national emissions inventory (Nielsen et al., 2022; Winther, 2022a).

Agriculture emissions reported here are a product of livestock production and cultivation of agricultural land from AU Foulum, Flakkebjerg and Askov/Jyndevad. Data is collected from the department of Animal Science and the tool MarkOnline, which is a software tool for agricultural management. In addition to the operation-specific data from MarkOnline, the calculation uses data based on the latest national emissions inventory reported in 2022 (Nielsen et al., 2022).

Scope 2

Activity data collected for scope 2 emissions come from the management tool EnergyKey, which AU uses to track metered consumption at all AU locations. EFs were collected from DCE and ENS, to whom DCE delivers data.

Scope 3

Activity data in the PB scope 3 assessment comes from various sources. Water usage (scope 3.1) is collected through EnergyKey readings of water meters at all AU locations, and is assumed to match the wastewater generated. Business travel data (scope 3.6) includes rail and air travel. Rail travel is converted from economic activity at the Danish national rail provider to person-km's, assuming that all train activity was done by InterCity train. EFs and economic to person-kms factors were taken from the 2021 impact report (DSB, 2022).

Air travel activity is delivered by the travel agency Carlson Wagonlit Travel (CWT), which is converted to emissions using the DCE transport emissions model, using a radiative forcing (RF) factor of 2 for all travel above 9 km. This RF factor is in agreement with much of the literature and guidance on the subject. Emissions from flights booked outside of CWT are accounted for by means of an economic scaling factor of 2.5, based on money spent through and outside of CWT. This factor is also applied to the total flown kilometers.

Waste activity data is collected from waste management companies and investment related emissions are collected through environmental, social and governance (ESG) reports at the various banks that AU uses to manage investments.

All the PB data described above is underpinned by aLCA methodology, and therefore cannot be summed with data not following the same aLCA methodology. However, since the PB results are comparable back to the 2018 report, the PB results can be normalized according to full time equivalents (FTE), to show the progress of emission reductions, and the eventual decoupling of emissions from growth.

Spend based method description

The EEIO model behind the SB method used in this analysis is the EXIOBASE model (EXIOBASE, 2022), which was developed as an EU funded project by Aalborg University. The economic model supporting EXIOBASE is rooted in 2011 global supply use tables, and by environmentally extending these economic inputs and outputs, emission intensities are generated according to spending within economic sectors in $kgCO_2e$ / DKK2011. Thus, EXIOBASE, and SB methods are able to account for services, something that PB traditionally cannot. In addition, as the model is supported with market data, the results are able to take into consideration unintended effects outside the scope of the product, thereby following cLCA methodologies. This feature is important as university operations rely heavily on services, and not including them does not lend itself to a climate just inventory.

Scope 3.1 and 3.2

The SB method uses economic data to estimate emissions from spend rather than quantities purchased. This means that the economic data used in SB methods should reflect goods and services, wherein the economic exchange includes the exchange of emissions. The economic data from AU was cleaned to remove non goods or service items, such as leasing agreements, payments to associations, etc., or data without appropriate or clear descriptions. Additionally, exchanges not falling under the GHGP's description of scope 3.1 and 3.2 were not included. The resulting transactions were allocated to either purchased goods, services, or capital goods. It is assumed that all economic activities are correctly described in the AU economic data.

The GHGP defines capital goods as "final products that have an extended life and are used by the company to manufacture a product; provide a service; or sell, store, and deliver merchandise" (GHG Protocol, 2011). The Universities Denmark ad-hoc group suggests that buildings and infrastructure fall under capital goods, however under the SB method, splitting other capital goods out of economic data is not yet possible. As a result, scope 3.2 – Capital Goods in this report are activities that provide construction activities, but not supporting and maintenance activities, as these are allocated to goods or services. This is due to the data structure of the economic categories being unable to differentiate between purchased goods vs capital goods. In the future, taking this into consideration during the accounting process will help clearly define between the two categories.

EXIOBASE follows the 1999 Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE codes, to allocate emission intensities to the different sectors. While NACE codes have been updated through several revisions (NACE Rev 1, Rev 2), EXIOBASE follows NACE Rev 1 codes. The classification scheme of AU spending follows United Nations Standard Products and Services Codes (UNSPSC), of which there are more than the NACE Rev 1 codes. As a result, UNSPSC were converted to NACE Rev 1, to be appropriately used in the EXIOBASE model, meaning that some resolution of the UNSPSC data is lost as several UNSPSC codes contribute to the same NACE code. This results in some unintuitive NACE categories contributing to the different GHGP categories (fx – manufacture: furniture contributes to both purchased goods and purchased services).

Finally, the economic activity divided into goods, services or capital goods were multiplied with the emission intensities (kg CO_2e / DKK2011) from EXIOBASE, adjusted for inflation to 2021 DKK. The categories described by EXIOBASE remain broad and include many different activities, therefore the UNSPSC codes are supplemented for this inventory to provide greater insight into where emission hotspots are among UNSPSC codes.

Method description summary

In short, the two methods used here ask different questions. However, they are both included in this assessment as the width and depth of university operations calls for such an approach. It is agreed that both methods are important in an emission inventory, where aLCA is useful for reporting past emissions and setting targets, and cLCA is useful when considering future unintended impacts. While research in this space is growing, the currently available tools and guidance matched with AU's needs and data accessibility result in the above described methods constellation.

3 Results and discussion

This section is presented according to the GHGP scopes and categories where results are introduced and discussed. Both PB and SB results are included throughout the progression of the following sections, and appropriately described. A general summary of the results is shown in the overview section, split by methodology.

Process based results overview

The total PB emissions for AU in 2021 were **20,322.7 tCO_2e**, with the largest single contributor being the electricity consumption. Scope 1 emissions were **5,810.6 tCO_2e**, and are comprised of on-site oil and gas consumption, AU related vehicle activity, and agricultural emissions. Scope 2 emissions were **8,717.4 tCO_2e**, coming from electricity and district heating activities. Scope 3 emissions were **5,787.0 tCO_2e**, and are comprised of air travel, well to tank emissions for AU consumed fuel, water consumption, waste water generation and emissions associated with AU investments. A summary of the emissions is presented in Table 5, and Figure 3 below. Percent changes are shown in the section *Visual Summary* in relation to 2018 and 2020.

Table 5. PB Emissions Overview

Description	**tCO_2e**
Scope 1	**5,810.6**
On-site Combustion	1,268.1
Transport	656.3
Total Agriculture	3,886.2
Scope 2	**8,717.4**
District Heating	2,590.3
Electricity	6,127.1
Scope 3	**5,794.7**
1 Water Consumption	49.7
3 Upstream Fuel	169.6
5 Wastewater	51.1
5 Waste	29.7
6 Business Travel	1,388.6
15 Investments	4,106.0
Total PB Emissions	**20,322.7**

Comparable PB emissions for 2021 are down 0.3% from 2020, which can mostly be attributed to an increase in electricity EFs and increased flights, countered by a decrease in investment related emissions and on-site combustion EFs. In line with an updated AU climate strategy, which was adopted halfway through 2020, (Aarhus University, 2020) emission reductions due to AU initiatives are expected, however they are also expected to be overshadowed by the lingering impacts of COVID-19. Given the framework of this report, we are unable to identify the impact that university initiatives have had since the adoption in 2020.

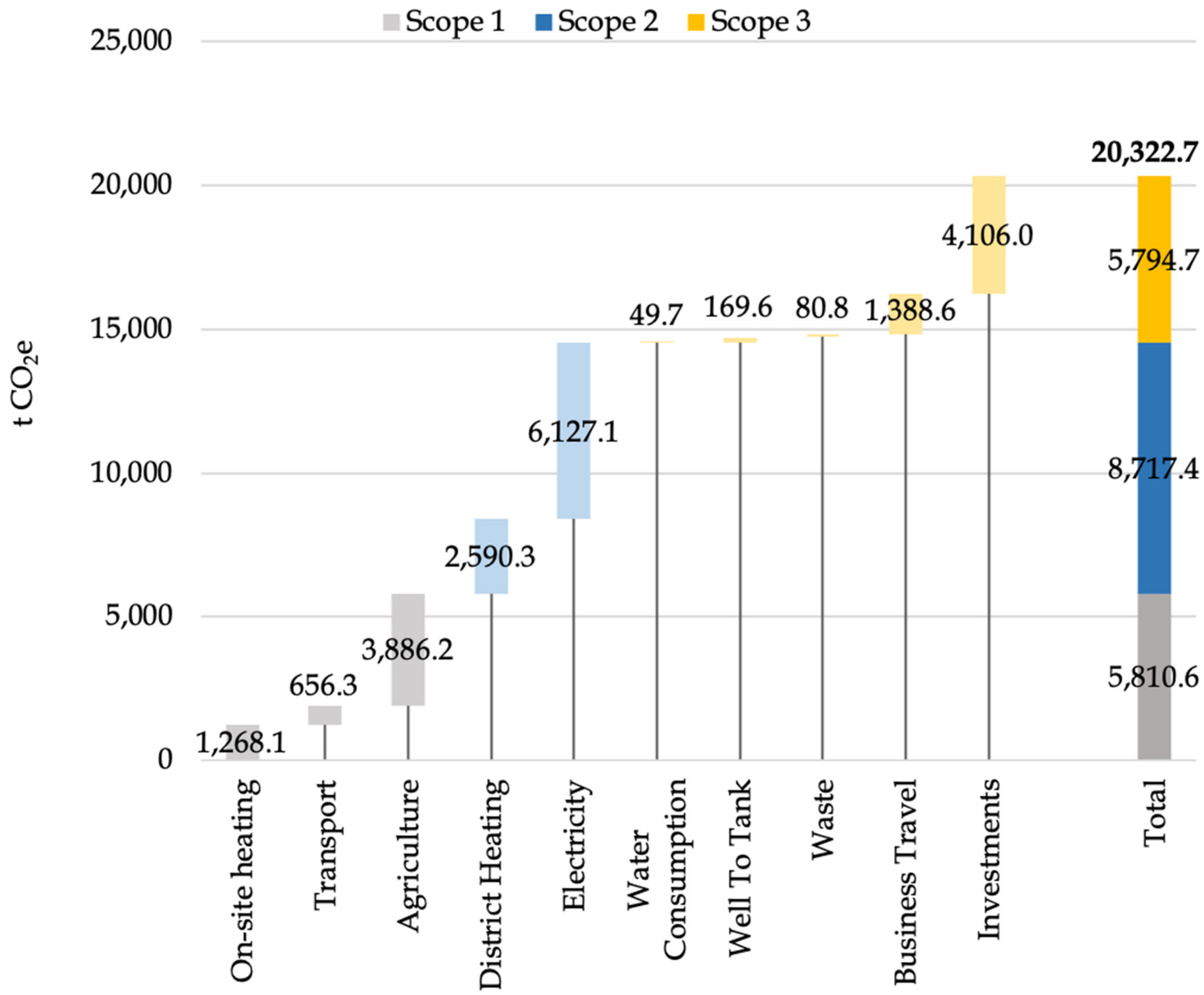


Figure 3. Total PB Emissions 2021. Scope 1 is shown in grey, scope 2 in blue, and scope 3 in yellow.

Normalizing the PB data to tCO_2e per person-year across employees, students and combined results in: **2.45 (tCO_2e/employee-year)**; **0.75 (tCO_2e/student-year)**, and combined **58 (tCO_2e/total-AU-year)**, shown in Table 6.

Table 6. PB Emissions normalized to FTE for employees, students and both.

tCO_2e/Employee	2.45
tCO_2e/Student	0.75
tCO_2e/prs	0.58

Spend based results overview

The total scope 3.1 SB emissions for AU in 2021 were **35,823.1 tCO_2e** with the largest single contributor within purchased goods being “Wholesale & commission” at 11,120.2 tCO_2e, and purchased services as “Other business activities” at 5,496.8 tCO_2e, shown in Table 7 and Figure 4.

The categories included in scope 3.1 are split into purchased goods and services, and are further described by the EXIOBASE categories, based on NACE Rev. 1 codes. More detailed descriptions of the UNSPSC codes contributing to the EXIOBASE categories are presented in the individual sections for scope 3.1. It is clear from the overview shown in Figure 4, that AU relies heavily on services, supporting the decision to include a SB method to account for these activities. In the following sections, only the most impactful EXIOBASE categories are shown, namely "wholesale & commission" (Figure 9), "construction: infrastructure" (Figure 10), and "other business activities" (Figure 12).

Table 7. Overview of scope 3.1 SB emissions according to EXIOBASE categories. Emissions contributing less than 900 tCO_2e are grouped into "misc" for both purchased goods and services.

Description	tCO_2e
Purchased Goods	
Wholesale & commission	11,120.2
Construction: infrastructure	4,853.8
Manufacture: machinery & equipment	1,896.9
Plastics	1,175.8
Chemicals	948.8
Misc Goods	2,470.5
Purchased Services	
Other business activities	5,496.8
Computers and related activities	1,873.1
Research & development	1,665.4
Hotels & restaurants	1,112.1
Misc Services	3,209.6
Total Purchased Goods and Services	**35,823.1**

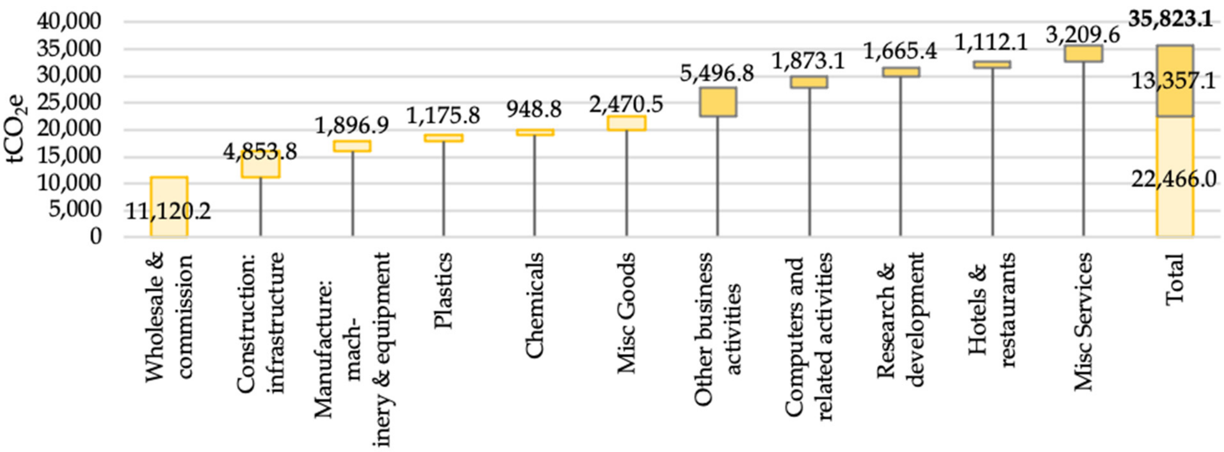


Figure 4. Scope 3.1 spend based emissions from purchased goods and services by EXIOBASE categories. Categories contributing less than 900 tCO_2e are grouped into "misc" for both goods and services.

Scope 1

Scope 1 emissions are defined as emissions that come directly from company activities. Following the data hierarchy presented by the GHGP (Table 3), AU has access to the most accurate forms of activity data for scope 1, as well as nationally based EFs from public organisations and reports, such as national inventories submitted to the UNFCCC and reports from the Danish Energy Agency. This report follows suggestions by the IPCC, which regard biomass related emissions for energy as zero, however they are shown but in Figure 5 for reference. In total, Scope 1 emissions represent **5,810.6 tCO_2e**, with the largest individual source being livestock production. Scope 1 emissions show a reduction of 3% and 16% compared to 2020 and 2018, respectively.

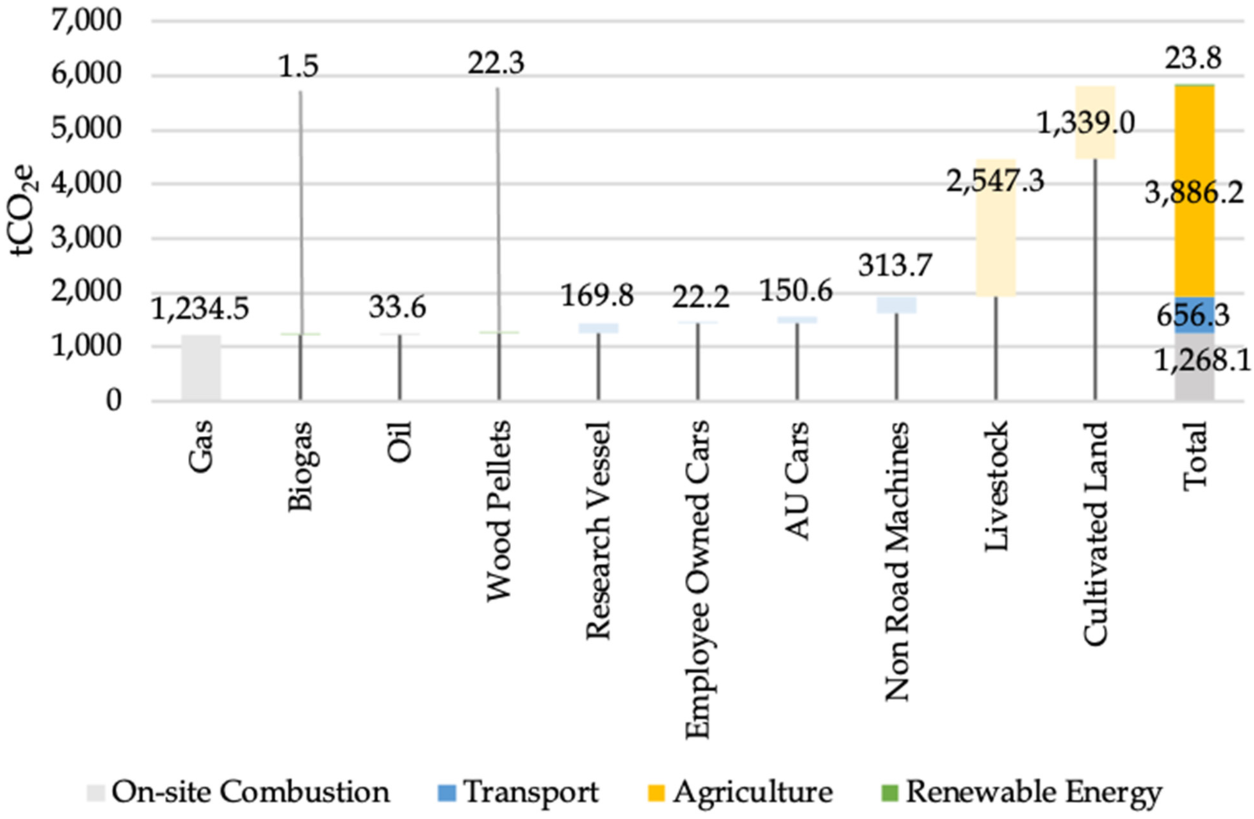


Figure 5. Scope 1 PB emissions. Emissions shown in green are biomass based emissions and therefore not included in the overall emissions inventory according to IPCC regulations, however are shown here for visual purposes.

On-site Combustion

On-site combustion shows a total of **1,268.1 tCO_2e**, which is a -17% change from 2020. This is related to a decreased EF for Danish gas. The EFs used here come from the ENS, by way of the DCE emissions group and reflect the same methodologies used in national reporting. A detailed description of the emission sources of on-site combustion is shown in Table 8.

Table 8. Scope 1 on-site combustion. Emissions from biomass based energy are shown in square brackets, and do not contribute to the overall emissions of this inventory.

Description	Amount	Units	EF	EF Units	tCO_2e	Source	Notes
Gas	6,182	MWh	55.47	$kgCO_2e/GJ$	1,234.5	[1]	A
Biogas	6,999	MWh	0.21	$kgCO_2e/MWh$	[1.5]	[1]	B
Oil	126	MWh	74.1	$kgCO_2e/GJ$	33.6	[1]	A
Wood Pellets	1,445	MWh	15.45	gCO_23/kWh	[22.3]	[1]	B
Total (MWh)	**14,752**			Total (tCO_2e)	**1,268.1**		

Notes: A – Assuming that it is the actual gas consumption and not heat production. CH_4 and N_2O contribution not included. B – According to the 2006 IPCC Guidelines, the CO_2 EF is 0.

[1] (ENS, 2022)

Transport

Transport emissions totalled **656.3 tCO_2e**, and show a 3% decrease from 2020 emissions, which is mostly attributed to increased fuel consumption of non-road vehicles, despite less employee owned kilometers driven. EFs used here are based on the national inventory as well as the DCE transport emissions model. Detailed emission sources are described in Table 9 below.

Table 9. Scope 1 transport related emissions from all mobile sources associated with AU operations.

Description	Amount	Units	EF	EF Units	tCO_2e	Source	Notes
Aurora (Research Vessel)	63,354	L Diesel	2.68	$kgCO_2e/l$	169.8	[2]	A
Employee owned cars driven for AU	151,919	km	0.1464	$kgCO_2e/km$	22.2	[2]	B
AU Company Cars	13,984	L Petrol	2.439	$kgCO_2e/l$	34.1	[2]	C
AU Service Cars	52,069	L Diesel	2.237	$kgCO_2e/l$	116.5	[2]	C
Non-road machines	3,195	L Petrol	2.236	$kgCO_2e/l$	7.1	[2]	D
Non-road machines	113,695	L Diesel	2.696	$kgCO_2e/l$	306.5	[2]	D
				Total	**656.3**		

Notes: A – EFs for marine engines using marine diesel, derived from DCE's ship emission model, B – Weighted EFs for petrol and diesel passenger cars derived from DCE's road traffic emission model, C – EFs for petrol passenger cars derived from DCE's road traffic emission model, D – EFs for diesel-powered non-road machines derived from DCE's non-road emission model, E – EFs for diesel-powered non-road machines derived from DCE's non-road emission model

[2] Based on (Nielsen et al., 2022) and (Winther, 2022a)

Agriculture

The CO_2 emission from the agriculture-related activities at Aarhus University includes the emission of methane (CH_4) and nitrous oxide (N_2O) and is calculated for 2021 at **3,886 tCO_2e**. This is a 2% increase from 2020 as a result of an increase in heifers and bulls. Cultivation related emissions changed nearly zero from 2020. Total agricultural emissions are shown in Table 10 below.

Table 10. Agricultural Emissions 2021.

Livestock	tCO_2e	Source
Digestion - dairy cattle	1,125.8	[2]
Digestion -other cattle	502.4	[2]
Digestion - pigs	41.7	[2]
Digestion -other animals	1.1	[2]
Manure handling - dairy cattle	429.6	[2]
Manure handling - other cattle	243.7	[2]
Manure handling - pigs	166.1	[2]
Manure handling - other animals	6.2	[2]
Indirect N_2O from barn and warehouse	30.5	[2]
Total Livestock	**2,547.3**	
Cultivation	**tCO_2e**	
Commercial fertilizer	331.7	[2]
Other organic fertilizers	225.7	[2]
Grazing of animals	82.3	[2]
Crop residues	411.8	[2]
Cultivation of organic soils	70.4	[2]
Indirect N_2O (NH_3 and NO_x emissions)	39.7	[2]
N leaching	177.3	[2]
Liming	0.0	[2]
Carbonated commercial fertilizer products	0.3	[2]
Total Cultivation	**1,339.0**	
Total Agriculture	**3,886.2**	

[2] based on (Nielsen et al., 2022)

CH_4 and N_2O are emitted from the livestock's digestion and handling of livestock manure in stables and warehouses. The emission depends on variables such as feed consumption, feed composition, barn type and fertilizer type and can therefore vary depending on the operating conditions in practice. The emissions are determined for each individual combination of livestock category, stable type and manure type, in the same way as the national emissions inventory 2022. This means that storage conditions for livestock manure are based on the average conditions for Danish practice. In total **2,547.3 tCO_2e** are from AU livestock production.

The total cultivated area at Aarhus University amounts to 1,151 ha in 2021 and the total CO_2 emission is calculated at **1,339.0 tCO_2e**. The emission from agricultural land is linked to the use of nitrogen – i.e. application of livestock manure and commercial fertilizer and when there is a turnover of nitrogen there will also be a release of nitrous oxide. There are thus many sources of nitrous oxide emissions from cultivating the land, which in addition to fertilization include, for example, emissions from crop residues, nitrogen leaching, and mineralization. The calculation is based on factual data for cultivated area and yields from MarkOnline as well as factual data for the use of commercial fertilizers calculated by commercial fertilizer type. The actual estimate for the leaching of nitrogen specifically from AU's cultivated area is not known, and therefore the calculation is based on the average leaching at national level estimated in the national emissions inventory.

In the calculation, it has been taken into account that Aarhus University has delivered nitrogenous biomass to other farms in the form of manure, and at the same time received nitrogenous biomass such as deep bedding, grass for silage, meadow grass, biogasified manure etc.

Summary scope 1 Emissions

In summary, scope 1 emissions are down 3% due to decreased emission intensities for gas usage in Denmark. Agriculture is relatively stable in comparison to 2020, despite change of livestock and cultivated land profiles. Increased activity in transport emissions may be a result of less AU employees driving personal cars for work related tasks, however, more fuel being purchased for AU non-road vehicles (Figure 6).

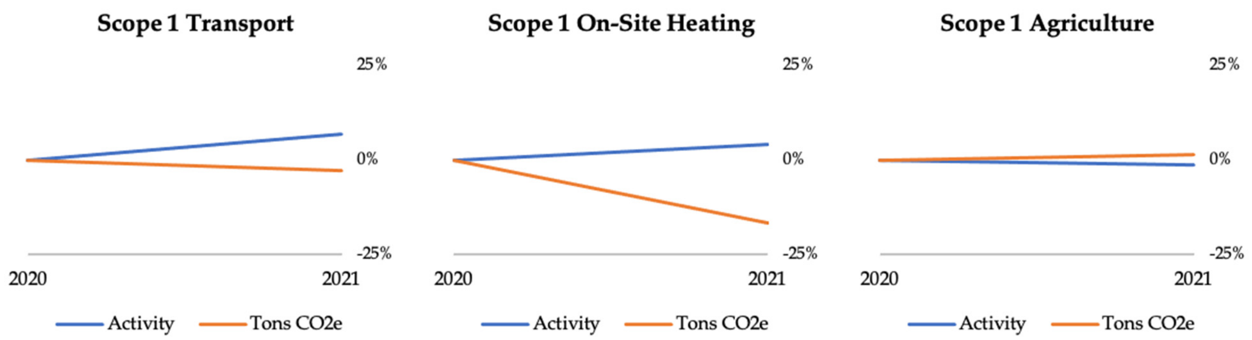


Figure 6. Scope 1 percent change of emissions from 2020.

Scope 2

Scope 2 is described as indirect emissions associated with purchased energy. As with scope 1, this report has access to unit based activity data, namely kWh of electricity consumption and MWh of heat consumption. These are matched with EFs from ENS and specific district heating plants, which follow the GHGP's recommendation for determining supplier specific and average emissions. Total scope 2 emissions account for **8,717.4 tCO_2e**, whereof electricity makes up the majority of the emissions (Figure 7). This is an 8% increase compared to 2020, which is mostly attributed to a higher EF for electricity, as less renewable energy was integrated into the Danish grid. A detailed description of scope 2 emissions is presented in Table 11.

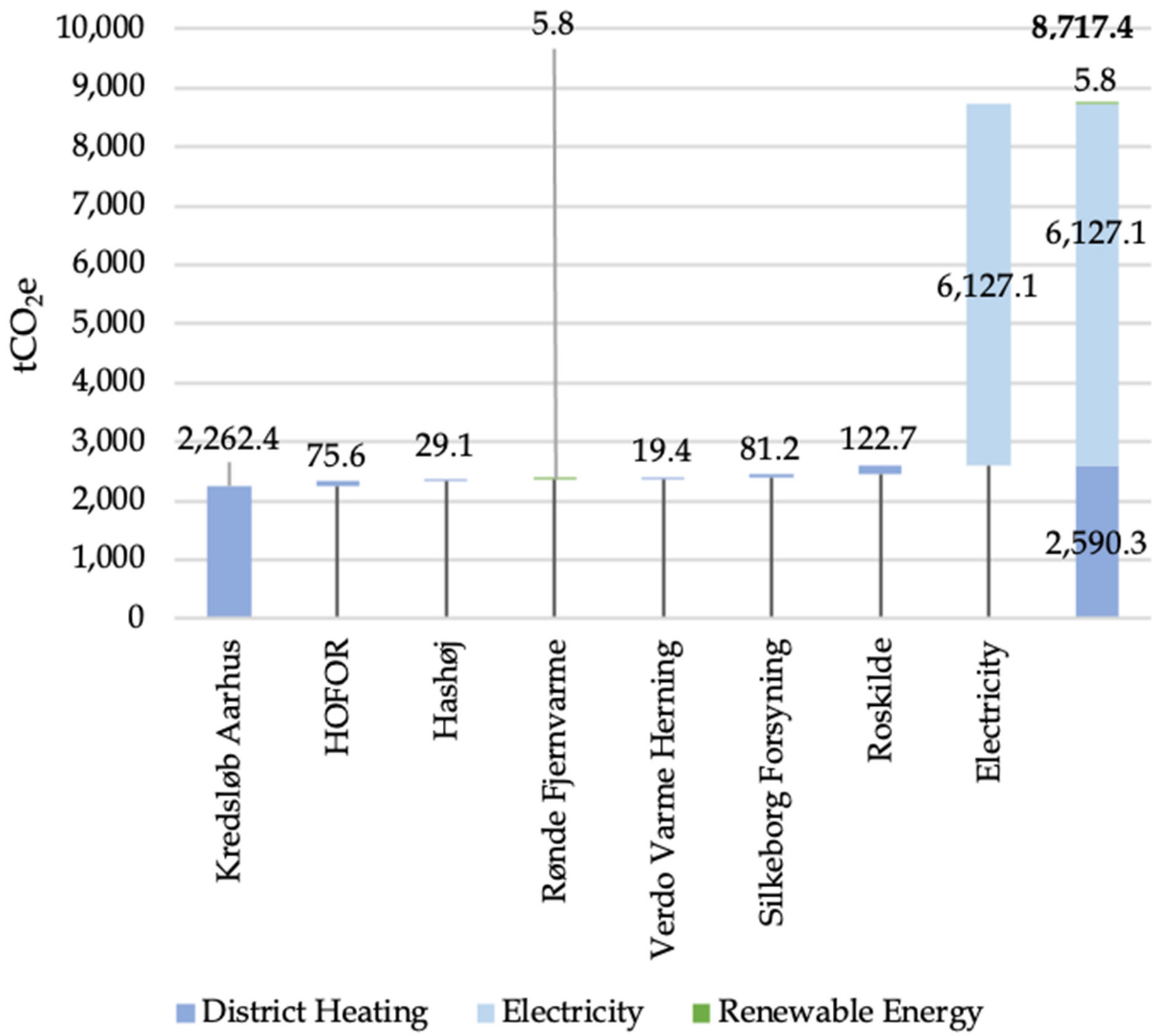


Figure 7. Scope 2 emissions with district heating shown in dark blue and electricity shown in light blue. District heating emissions from Rønde Fjernvarme are shown in green and do not contribute to overall emissions under the IPCC regulations on biomass.

The majority of scope 2 emissions come from electricity, suggesting that electricity efficiency could result in lower emissions in the future. As the EF per kWh fluctuates from year to year, based on the penetration of renewable energy, previous changes in emissions do not directly reflect the kWh's consumed. The second largest emission source comes from Kredsløb Aarhus, which supplies AU's main campuses with heat (Table 11). The EF depends largely on the waste streams of Aarhus, and energy efficiency initiatives may also result in emission reductions. For both electricity and district heating, activity data could be a more representative measure for tracking the effects of energy efficiency improvements.

Table 11. Scope 2 emissions for 2021.

Description	Amount	Units	EF	EF Units	tCO_2e	Source	Notes
			District Heating				
Kredsløb Aarhus	49,505	MWh	45.7	kg/MWh	2,262.4	[3]	A
HOFOR	2,223	MWh	34	kg/MWh	75.6	[4]	A
Hashøj	2,343	MWh	12.4	kg/MWh	29.1	[5]	B
Verdo Varme Herning	1,006	MWh	19.3	kg/MWh	19.4	[6]	A
Rønde Fjernvarme	437	MWh	13.16	kg/MWh	5.8	[7]	C
Silkeborg Forsyning	927	MWh	87.6	kg/MWh	81.2	[5]	B
Roskilde	3,036	MWh	40.4	kg/MWh	122.7	[8]	A
Total (MWh)	59,477			**Total**	**2,590.3**		
			Electricity				
Aggregated	44,131,989.8	kWh	138.8	g/kWh	6,127.1	[9]	A
				Total	**6,127.1**		

Notes: A - EF is taken from suppliers website, B - EF is based on a calculation of emissions based on fuel consumption, standard DCE EFs and heat supply. Data for fuel consumption and heat supply are from a confidential data set, C - Energy production is based on straw and biomass and not included in total emissions. According to 2006 IPCC Guidelines, the CO_2 EF is 0. CH_4 and N_2O contribution not included. EF taken from DEFRA 2021

[3] (Kredsløb, 2022)
[4] (HOFOR, 2022a)
[5] Data for fuel consumption and heat supply are from a confidential data set
[6] (Verdo, 2022)
[7] (DEFRA, 2022)
[8] (HOFOR, 2022b)
[9] (Energinet, 2022)

Scope 3

Scope 3 emissions can be interpreted as all other emissions not included in scope 1 and 2. Scope 3 includes a lot of potential emission sources, and typically represent up to 95% of an organisations emission inventory. As such, scope 3 is split into 15 categories as shown in Figure 1 and Table 2. The data used in this section include data from multiple parts of the data hierarchy, with both SB and PB methods used.

Scope 3.1: Purchased Goods and Services

Process based water consumption

The water consumption for AU is calculated at 248,705 m3. According to HOFOR, the CO_2 emission per liter of water is 0.0002 kg, and this includes e.g. establishment of water works. The CO_2 emissions that can be attributed to water production can thus be calculated at 49.7 tCO_2 (Table 12). The PB method used here is the only purchased good or service determined by this method.

Table 12. aLCA Water Consumption.

Description	Amount	Units	EF	EF Units	Tons CO_2e	Source
Water Usage	248,704.6	m^3	0.2	kg CO_2e/m3	49.7	[10]

[10] (HOFOR, 2020)

Spend based purchased goods

87% of university spending was allocated to scope 3.1 purchased goods, services or capital goods. This section describes purchased goods, followed by services.

The EXIOBASE categories used for the initial assessment are based on activity codes that are broad, which is defined by the comprehensive nature of EXIOBASE. To gain better understanding of where the emission hotspots are, the UNSPSC codes attached to the activities are included in the following figures. When the results are presented, only the most intensive categories are shown, which indicate the categories where emission reduction initiatives should focus. Remaining emissions are grouped in a miscellaneous category, shown as “misc.”.

Emissions calculated for purchased goods total **22,466.0 tCO_2e**, with the largest EXIOBASE category being “wholesale & commission”, which makes up nearly half of the total purchased goods emissions (Figure 8). Other significant posts include “construction: infrastructure”, and “manufacture of machinery and equipment”. While capital goods in this inventory, and following the Universities Denmark guidelines, are focussed on buildings, clearly discerning between construction for new buildings vs maintenance on existing buildings is not possible under the current data structures. Therefore, construction is a large source of emissions in the purchased goods category. Both “wholesale & commission” and “construction: infrastructure” are further explored in Figure 9 and Figure 8.

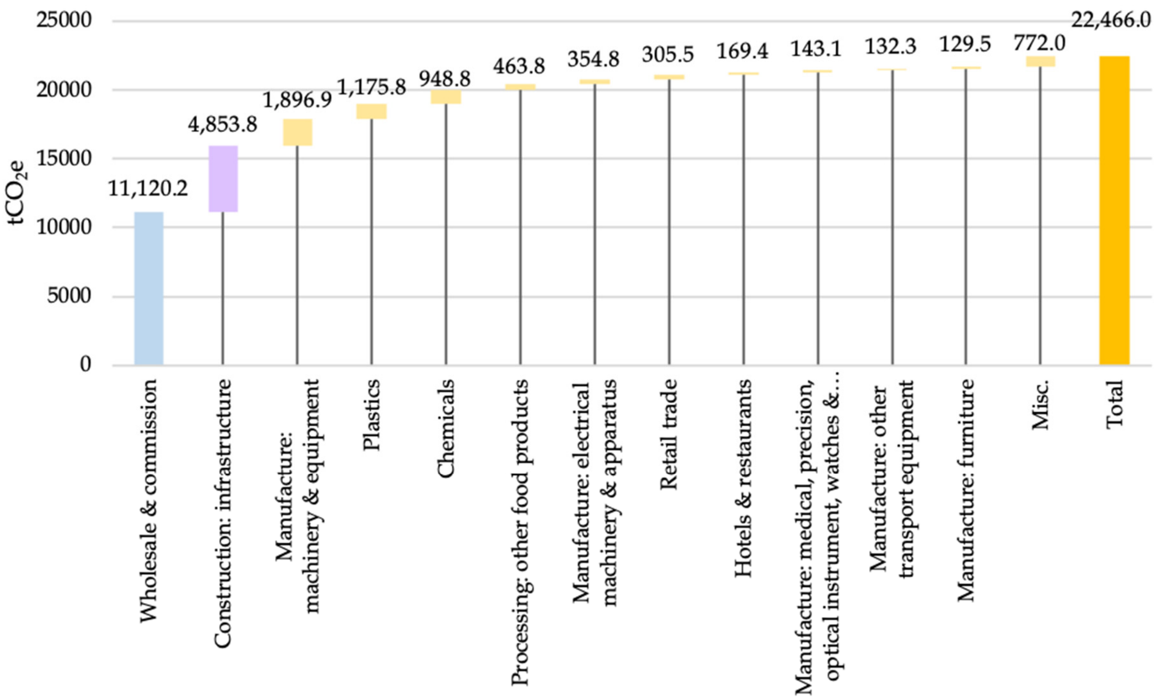


Figure 8. Scope 3.1 Purchased goods emissions using the SB method and reported across EXIOBASE categories. Emissions contributing less than 100 tCO_2e are grouped together in miscellaneous (misc.). Wholesale and commission is shown in blue, corresponding to the results shown in Figure 9, and construction: infrastructure shown in purple corresponding to the results shown in Figure10.

The EXIOBASE category “wholesale and commission” include more specific UNSPSC categories that show a more familiar depiction of university purchasing. Figure 9 shows the top 4 emission posts are computers, devices and software at 2,375.6 tCO_2e, Pharmaceuticals at 2,330.5 tCO_2e, other machinery and equipment at 2,039.0 tCO_2e, and solid, liquid and gaseous fuels etc. at

1,944.4 tCO_2e. These categories are specific enough to begin to identify top suppliers within each category, which is discussed below.

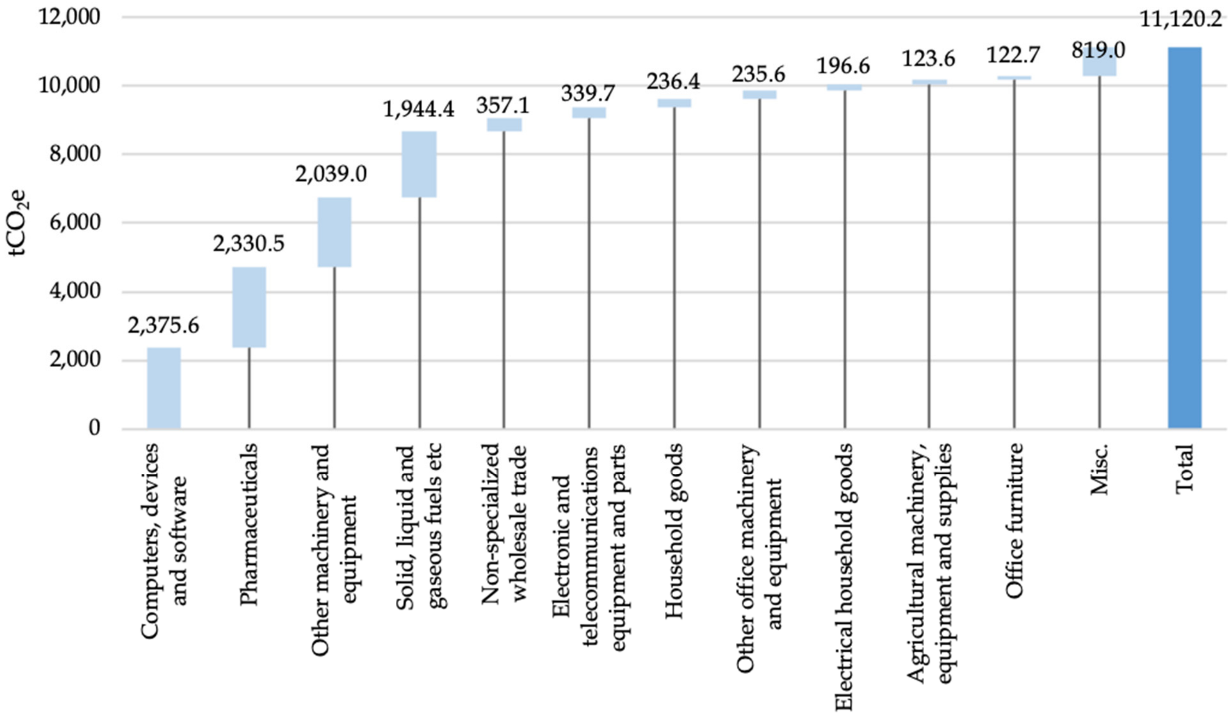


Figure 9. Scope 3.1 purchased goods emissions from the EXIOBASE category “wholesale &commission” broken out into UNSPSC codes. All emission categories contributing less than 100 tCO_2e are grouped into miscellaneous (misc).

The second largest EXIOBASE category within purchased goods is expanded using UNSPSC codes and shows that the majority of the impact sources support construction activities. The impacts shown in Figure 16 partially reflect maintenance and construction of new buildings. As mentioned above, spending in these categories are not able to be split between existing and new buildings, and are therefore grouped together here.

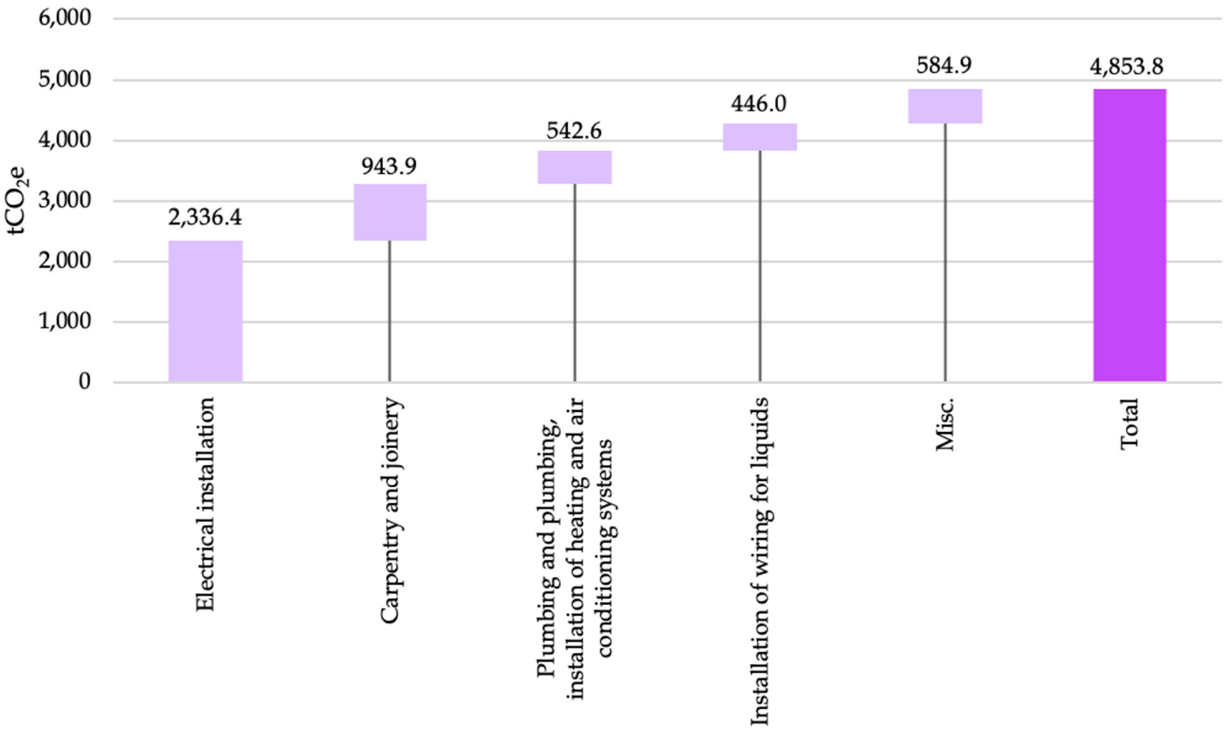


Figure 10. Scope 3.1 purchased goods emissions from the EXIOBASE category "construction: infrastructure" broken out into UNSPSC codes. All emissions under 400 tCO_2e are grouped under miscellaneous (misc.).

Purchased Services

Contrary to PB methods, SB in this inventory is able to quantify emissions from services, something that PB methods do not, which is relevant for universities as a large part of their purchases go towards services. The categories used in the EXIOBASE model are equally as broad as the purchased goods, and as described above, the broad categories are explored further using UNSPSC codes. In total, purchased services at AU resulted in **13,357.1 tCO_2e**, whereof the majority is allocated to the EXIOBASE category "other business activities" (5,496.8 tCO_2e) and "computers and related activities" (1,873.1). These results are shown in Figure 11, and expanded with UNSPSC codes in Figure 12, which have been adjusted such that only the highest emission categories are shown.

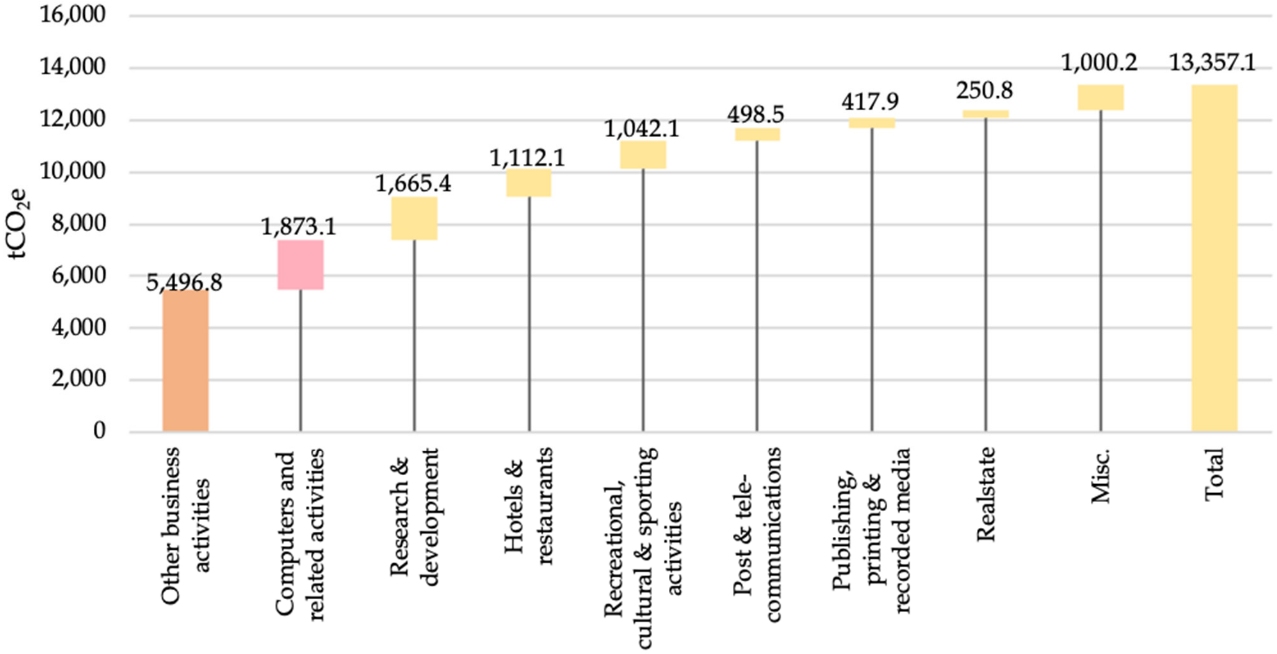


Figure 11. Scope 3.1 purchased services emissions using the SB method and reported across EXIOBASE categories. Emissions contributing less than 250 tCO_2e are grouped under miscellaneous (misc.).

More detailed descriptions of "other business activities" show that many of the categories are office related services, including engineering, technical, and business consultancy, along with scientific and technical services. Cleaning services are also included in the services rendered at AU. After these 4 main categories, the emissions drop off significantly, and include many smaller categories which have been grouped together under misc. in Figure 12.

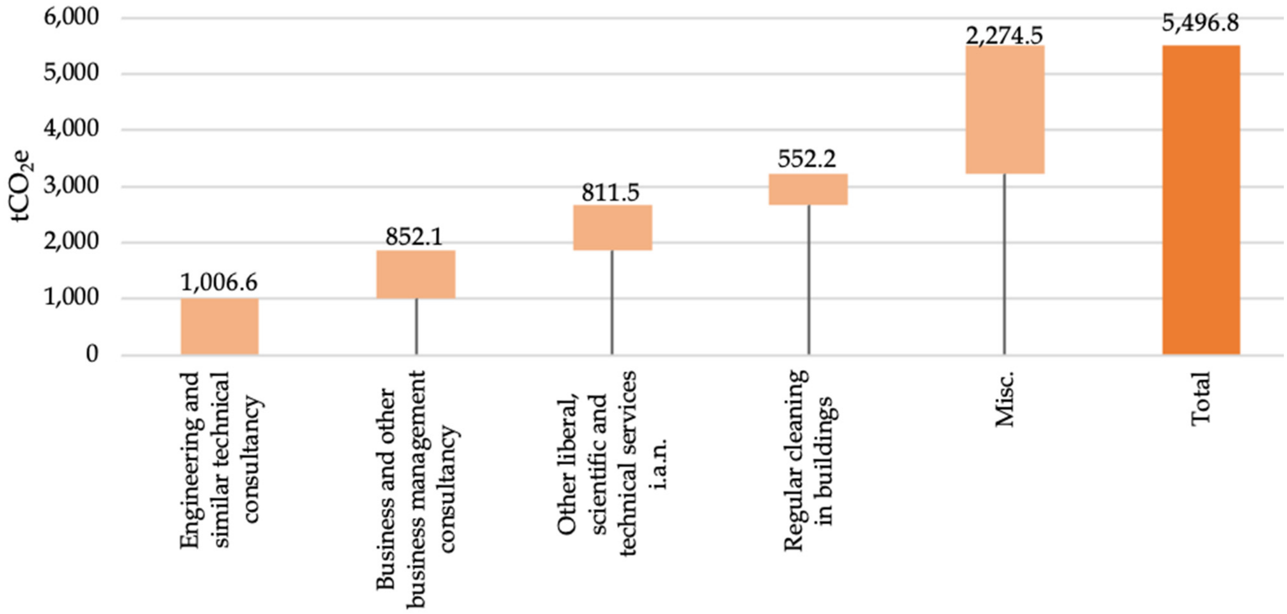


Figure 12. Scope 3.1 purchased service emissions from the EXIOBASE category "Other Business Activities" broken out into UNSPSC codes. All emissions under 500 tCO_2e are grouped into the category miscellaneous (misc.).

AU's SB results for scope 3.1 show that **35,823.1 tCO_2e** result from university purchased goods and services. While this is, on paper, significantly more than the PB results combined, they are not comparable as they draw on different methodologies (aLCA vs cLCA). Regardless, some important conclusions can be drawn from this data. Following the rule of thumb, that emissions follow kilos and kroners (weight and money), we can see that under this methodology, 87% of university spending is represented here, and that purchased goods and services are an important contributor to AU's climate impact. It can be expected that while there are many suppliers contributing to these categories, there may only be several who contribute significantly. These are the suppliers that should be engaged in climate related discussions, on how they can disclose their product emissions and reduce them, which in turn will reduce AU's emissions. It should be noted that the PB inventory will grow, as suppliers will most likely deliver data under the aLCA methodology.

Scope 3.2: Capital Goods

Capital goods reflect the same complexities faced with purchased goods and services, and therefore uses the SB method. Following the outcomes of the Universities Denmark ad-hoc emissions group, capital goods refer to construction of buildings. While this addresses only part of the accepted definition presented by the GHGP, the data structure limitations seen at AU results in this approach as the most feasible. In total, capital goods represent **3,868.8 tCO_2e**, which is mostly comprised by the EXIOBASE category "Construction: buildings" at 2,123.6 tCO_2e. This is shown in Figure 13.

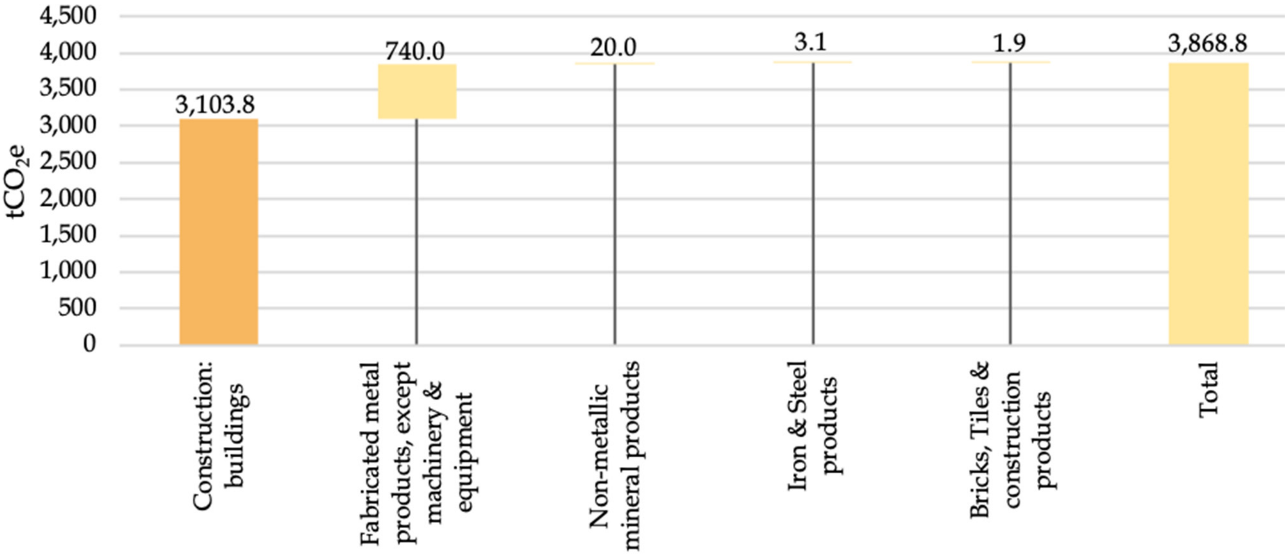


Figure 13. Scope 3.2 capital goods emissions based on EXIOBASE categories.

The remaining EXIOBASE categories are all building related, as a result of the data processing. Upon expansion with UNSPSC codes, the descriptions are equally as broad as the EXIOBASE categories (Figure 14), however the same conclusions can be drain as from scope 3.1, in that suppliers to these hotspot categories can easily be identified.

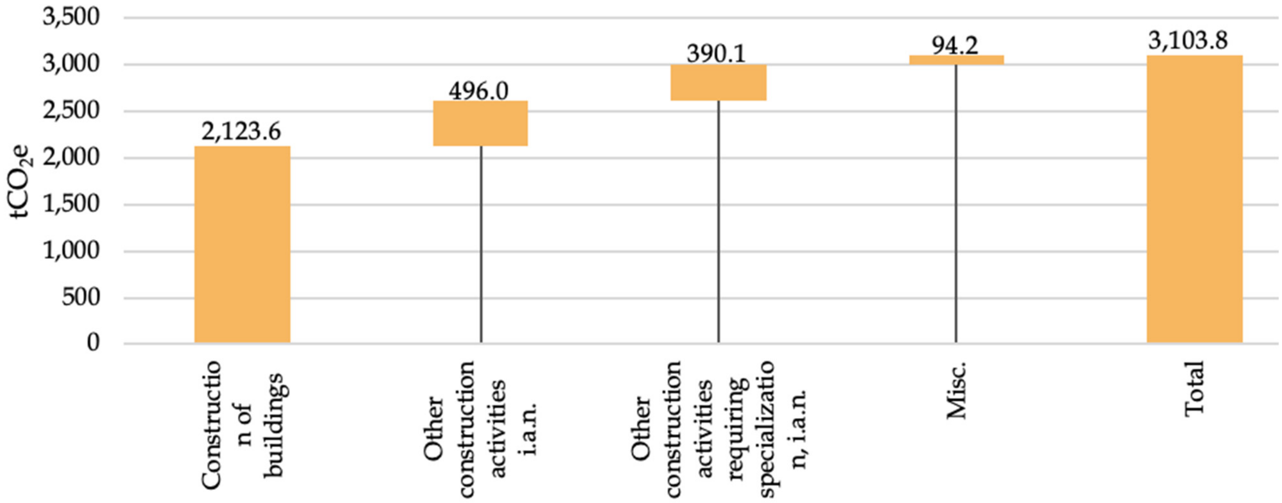


Figure 14. Scope 3.2 capital goods emissions from the EXIOBASE category "construction: buildings" broken out into UNSPSC codes. All emissions under 100 tCO_2e are grouped into the category miscellaneous (misc)

Scope 3.3: Fuel- and Energy-Related Activities Not Included in Scope 1 or Scope 2

Data access and EF from the literature allow for a PB method to be used for the remainder of the categories. Fuel and energy related emissions are due to the embedded emissions from extraction, refining, and transportation from the extraction to the combustion site. The latest existing literature on the subject has been presented for 2020 by the Joint Research Centre (JRC), the European Commission's science and knowledge service. The report estimates that well to tank (WTT) emissions correspond to roughly 25% of the direct emissions of the fuel (Prussi et al., 2020). This is also seen in a Danish Energy Authority report from 2016 which estimated that well to tank emissions stood for 22%-25%. The EFs for diesel is 26% and petrol is 24%, which are applied to the AU owned transport emissions where the type of fuel is defined, such as L of diesel used in AU service cars (Table 13). This is also applied to the research vessel Aurora. For transport related emissions based on km activity data, we assume that an average of the WTT EFs is sufficient, and that the km activity data is spread evenly across diesel and petrol vehicles. In all, **169.6 tCO_2e** is emitted from WTT emissions related to AU owned transport.

Table 13. Scope 3.3 upstream fuel and energy related emissions not included in scope 1 and 2.

Description	Amount	Units	EF	EF Units	tCO_2e	Source	Notes
Marine Diesel	169.8	tCO_2e	26	%	44.1	[11]	A
L Diesel	423.0	tCO_2e	26	%	110.0	[11]	B
L Petrol	41.3	tCO_2e	24	%	9.9	[11]	B
km Driven	22.2	tCO_2e	25	%	5.6	[11]	C
				Total	**169.6**		

A - Well to tank emission report for Europe, B - Includes emissions for non-road vehicles, C - Average of EF for diesel and petrol assuming half and half diesel/petrol vehicles comprising the km driven

[11] (Prussi et al., 2020)

Scope 3.4: Upstream Transportation and Distribution

This category is typically regarding large transport of products or materials. While AU does purchase raw materials for agriculture and other technical purposes, the data structures do not allow for this to be split out, or collected from university data. Once they are able to be separated from the accounting, they can be allocated here, however as universities typically do not produce products, little change is expected to the overall emissions inventory.

Scope 3.5: Waste Generated in Operations

This section considers all waste generated by AU, including wastewater. The methods supporting the EFs follow aLCA methodologies and contribute to the PB inventory. In total, waste accounted for **80.8 tCO_2e** in total, comprised of **51.1 tCO_2e** from wastewater and **29.7 tCO_2e** from waste management.

For waste water, average EFs can be calculated based on the national emissions inventory and the total amount of waste water processed in Denmark. According to the Danish Environmental Protection Agency (Ministry of Environment, 2021), 682,758,000 m^3 of waste water was treated in 2020. If it is assumed that AU's total water consumption is discharged as waste water, then this corresponds to AU discharging 0.036% of Danish waste water. The total CH_4 emission from waste water treatment (excluding septic tanks) was in 2020 (latest calculated year) 0.29 kt corresponding to 7,332 tonnes of CO_2 equivalents. The total N_2O emission (excluding separate industries) was 0.45 kt corresponding to 132,955 tonnes of CO_2 equivalents. In total, this is a greenhouse gas emission of 140,287 tonnes, of which AU's share can be estimated at 51.1 tCO_2e.

Table 14. Scope 3.5 waste emissions. Due to risk of double counting, the emissions presented here represent the emissions associated with the transport and treatment of waste, and does not include emissions from combustion, or recycling.

Description	Amount	Units	EF	EF Units	tCO_2e	Source	Notes
			Recycling				
Cardboard and Paper	155,611.0	kg	21.2936	kg CO_2e / t	3.314	[7]	A
Electronic Waste	72,764.0	kg	21.2936	kg CO_2e / t	1.549	[7]	B
Glass	24,983.0	kg	21.2936	kg CO_2e / t	0.532	[7]	C
Iron and Metal	17,943.0	kg	21.2936	kg CO_2e / t	0.382	[7]	D
Refrigeration Appliances	602.0	kg	21.2936	kg CO_2e / t	0.013	[7]	E
Light Sources	762.0	kg	21.2936	kg CO_2e / t	0.016	[7]	F
Plastic	6,332.0	kg	21.2936	kg CO_2e / t	0.135	[7]	G
Toner	118.0	kg	21.2936	kg CO_2e / t	0.003	[7]	H
Organic Waste	17,965.0	kg	8.9507	kg CO_2e / t	0.161	[7]	I
Garden Waste	6,320.0	kg	8.9507	kg CO_2e / t	0.057	[7]	J
Active Plant Material	6,160.0	kg	8.9507	kg CO_2e / t	0.055	[7]	J
			Incineration				
Bulk Waste Incineration	57,048.0	kg	21.2936	kg CO_2e / t	1.215	[7]	K
Incineration	679,521.0	kg	21.2936	kg CO_2e / t	14.469	[7]	K
			Landfill				
Landfill	16,621.0	kg	467.046	kg CO_2e / t	7.763	[7]	L
Total	**1,062,750.0**	**kg**		**Total**	**29.7**		

DEFRA Waste Categories: A - Paper and Board: Mixed, B - Electrical items: Mixed, C - Other: Glass, D - Metal: Scrap Metal, E - Electrical items: Fridges and Freezers, F - Electrical items: Small, G - Plastic: Average Plastics, H - Commercial and Industrial Waste, I - Organic: Food and Drink Waste, J - Organic: Garden Waste, K - Household and Commercial Waste, L - Commercial and Industrial Waste for Landfill.

[7] (DEFRA, 2022)

The waste activity data at AU includes all recycling streams and waste destined for incineration. Due to the boundaries set in this analysis, emissions or emission benefits from recycling and waste (for example combustion for energy production) are not included in the final inventory. This is because the national EFs used for electricity is partially determined by a waste contribution (partially from AU), which would result in double counting to include the incineration or benefits of recycling in this category. Therefore, total waste emissions are 21.9 tCO_2e, presented in Table 14, and show the emissions related to material transport and processing. The EFs are sourced from DEFRA, and assume roughly 25 km to the nearest facility (DEFRA, 2022).

Scope 3.6: Business Travel

This section describes the PB emissions associated with university related business travel. This includes air and rail travel.

AU, as many other universities, have many activities that fall under business travel. Typically, this is focussed on business flights, as they make up a significant portion of university related travel. This inventory expands from the air travel reported by including train travel within Denmark.

Kilometers travelled by train was estimated from the accounting data to person-kms. It was assumed that the train type used was an InterCity train, resulting in a total of **101.7 tCO_2**, shown in Table 15. This is an estimate at best, but as the green transition develops, university travel policy will shift from air travel to ground travel (Aarhus University, 2020), where clear data is required for quantifying the reductions of this activity shift.

Table 15. Scope 3.6 business travel from rail transport based on total AU spend at DSB, the Danish national rail company.

Activity	Person km's	Train type	EF	EF Unit	tCO_2	Source
508,487 DKK	2,163,774.5	InterCity	0.047	kg CO_2/prs*km	**101.7**	[13]

Note: Passenger turnover per seat*km described by DSB is 0.235 DKK/km. Assumed travel by InterCity train. Emissions reported only as CO_2.

[13] (DSB, 2022)

Flight data was provided by the travel agency CWT, and scaled to account for flights booked outside of CWT. This assumption does not take into consideration the reasons why employees choose to book outside of CWT, but further research could identify the effects this would have on the overall emissions. The emissions were generated from the DCE flight transportation emission model, which is also used to compile the Danish national inventory (Nielsen et al., 2022; Winther, 2022a) and is described further in relation to AU employees in (Winther, 2022b). The results are described in table 16, which will lead into the sentence below. The results are described in Table 16, following the data sources of “CWT” and “non CWT”, and combined represent **1,287.0 tCO2e.**

Table 16. Scope 3.6 business travel emissions from total AU flights. APU – Auxiliary Power Unit, Cruise – Cruising altitude, LTO – Landing and takeoff, RF – Radiative forcing.

Data Source	Flights	Amount	Units	tCO_2e incl. RF	Source	Notes
CWT	APU	-	-	0.2	[2],[14]	A
	Cruise	-	-	361.1	[2],[14]	A
	LTO	-	-	6.4	[2],[14]	A
	Total	2,935,590	km	367.7	[2],[14]	A
Non CWT		7,338,975	km	919.3	[2],[14]	B
			Total Flights	**1,287.0**		

Note: A - CWT activity data based on DCE flight emission model, B - Data scaled according to spend on flights outside of CWT.

[2] (Nielsen et al., 2022) [14] DCE flight emission model based on [2]

Business travel emissions are slightly recovering from the effects of Covid-19, with a 77% increase in flown kilometers and a 35% increase in flight related emissions from 2020, as shown in Figure 15. However, this result is still 90% down from 2018 flight emissions (see *Visual Summary*). This may be due to a combination of the AU climate strategy and effects of Covid-19, as online accessibility has increased drastically, which also aligns with the AU transportation initiative (Aarhus University, 2020). As airplane fleets are constantly being updated, the emission intensities per flown km drops, accounting for the large difference in emissions vs flown kilometers.

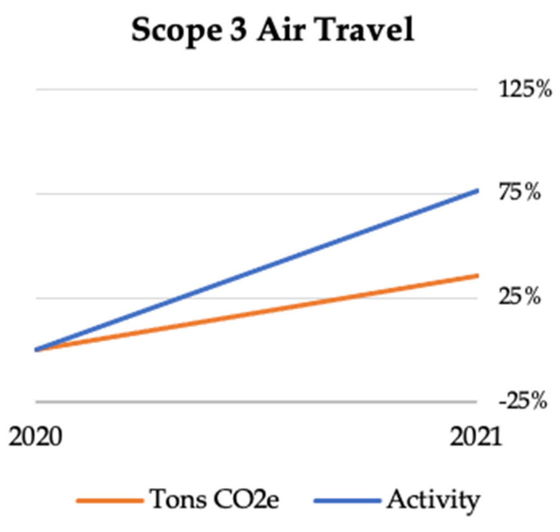


Figure 15. Percent change of air travel emissions in relation to 2020 showing a 77% increase in activity and a 35% increase in emissions. Activity represents number of flown kilometers.

Scope 3.7: Employee Commuting

A GHG inventory considers what the vital components of the organisation in question are. In a university's case, the students as well as the researchers are vital to the operations of a university, and hence the resulting emissions from commuting. This has not been included in previous AU GHG inventories due to data limitations, however, employee and student commuting will be included in future inventories, as the AU Climate Strategy has set a goal for reducing emissions in this category.

The method for collecting this data will be through employee and student post numbers and associated campuses. An analysis into transport methods based on distance indicate which method of travel is favoured will underpin the assumptions for this calculation. The results will then be statistically analysed, and transport EFs will be applied.

Scope 3.15: Investments

AU has a significant investment portfolio with several large Danish banks. AU requested ESG and emission reports and only Danske Bank was able to deliver data in CO_2e. This is based on AU's share of the individual company's scopes 1 and 2 emissions, and shown in Table 17.

Table 17. Scope 3.15 investment related emissions.

Source	tCO_2e	Source	Notes
SEB	-		No data
Danske Bank Q1	1,349	Danske Bank ESG Report	
Danske Bank Q2	1,019	Danske Bank ESG Report	
Danske Bank Q3	870	Danske Bank ESG Report	
Danske Bank Q4	868	Danske Bank ESG Report	
Total	**4,106**		

Scopes 3.8 – 3.14

The GHGP scope 3 categories that are not as relevant to a university GHG inventory are described here. There are without a doubt some university activities that fall under the categories described in Table 18, however it is not expected that they contribute significantly to the AU GHG inventory. As such, they are prioritized lower than the upstream related categories addressed above. As the inventory will evolve and grow, activities within these categories should be considered, for a true representation of AU's emissions impact, and to identify possible emission reductions.

Table 18. Description of categories not included or not relevant.

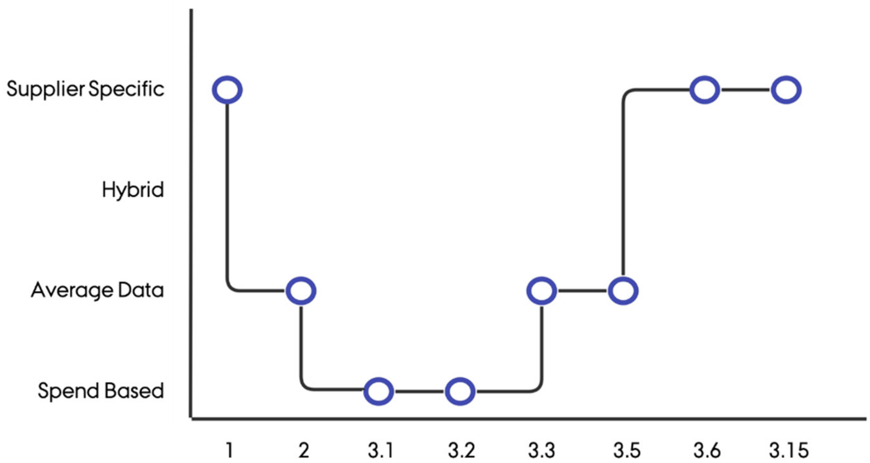
Category	Category name	Quick Description
3.8	Upstream Leased Assets	Emissions from the operation of assets that are leased by the reporting company in the reporting year and not already included in the reporting company's scope 1 or scope 2 inventories.
3.9	Downstream Transport and Distribution	Emissions that occur in the reporting year from transportation and distribution of sold products in vehicles and facilities not owned or controlled by the reporting company.
3.10	Processing of Sold Products	Emissions from processing of sold intermediate products by third parties (e.g., manufacturers) subsequent to sale by the reporting company.
3.11	Use of Sold Products	Emissions from the use of goods and services sold by the reporting company in the reporting year.
3.12	End-of-Life Treatment of Sold Products	Emissions from the waste disposal and treatment of products sold by the reporting company (in the reporting year) at the end of their life.
3.13	Downstream Leased Assets	Emissions from the operation of assets that are owned by the reporting company (acting as lessor) and leased to other entities in the reporting year that are not already included in scope 1 or scope 2.
3.14	Franchises	Emissions from the operation of franchises not included in scope 1 or scope 2.

It should be noted here that as AU rents most of their buildings, the associated emissions would be expected to fall under category 3,8. However, as this inventory takes an operational control approach, as defined by the GHGP, the resulting emissions are allocated to scope 1 and 2.

Summary

The results shown here follow the GHGP categories and is guided by the proposed data hierarchy. In most categories, AU was able to use supplier specific or average data, however for categories where the activity data is large and diverse, the least desirable method, spend based was used. This is shown in Figure 16 below.

Figure 16. Data and method description of AU 2021 GHG inventory by the GHGP proposed data hierarchy across the included scopes and categories



A GHG inventory is meant to provide decision support to make more climate resilient decisions. Both the PB and SB results shown here provide varying degrees of decision support, but in order to better understand how, both methods, and thereby aLCA and cLCA, need to briefly be discussed.

It is possible for all methodological constellations of PB / SB and aLCA / cLCA, however most follow the intuitive pairing that is described in this inventory. This is largely determined by access to the different resources and tools, as well as relevance for AU.

The literature is in agreement that mixing these two methods is advised against as it may result in misguiding results. However, they both play an important role in carbon management. aLCA is useful in reporting past emissions that are very specific and only consider the impacts within the scope of study. aLCA results can therefore be used to set goals and budgets, much like an accounting inventory. On the contrary, cLCA excels at avoiding unintentional impacts beyond the scope of study, and therefore can be used to consider two scenarios, where the overall change of emissions is considered. cLCA should be used for forward looking decisions and aLCA for reporting.

Despite their differences, the advantage of having comprehensive data across AU activity outweighs the resulting limitations of this method. As both cLCA and aLCA methods become more commonplace (cLCA becoming more precise and aLCA becoming a normalized deliverable among suppliers) benefits of both methods will show, and datapoints will overlap. As the GHG inventories develop to this point, AU will be more prepared to adjust activities in a way that aligns with the AU Climate Strategy.

4 Conclusion

This report marks the latest development of the GHG inventory at AU, from the initial assessment in 2018. AU has initially reported on scope 1 and 2 emissions and gradually added scope 3 inputs - the present report continues this path and includes rail based travel and a higher resolution depiction of emissions embedded in university spending.

The analysis found that Aarhus University's emissions have decreased from 2020 with less than 1%. In total, the PB method resulted in total scope 1, 2 and 3 emissions of **20,322.7 tCO_2e**, with notable contributions from electricity (6,127.1 tCO_2e), and investments (4,106.0 tCO_2e) showing a reduction of overall emissions from 2020. Normalizing these results to tCO_2e per person-year across employees, students and combined results in: **2.45** (**tCO_2e/employee-year**); **0.75** (**tCO_2e/student-year**), and combined **0.58** (**tCO_2e/total-AU-year**), which is a 2%-4% decrease from 2020.

The SB method resulted in total scope 3.1 and 3.2 emissions of **39,691.9 tCO_2e**, using the model EXIOBASE. Further expansion on the EXIOBASE categories to UNSPSC codes shows that the top 4 emission posts are computers, devices, and software at 2,375.6 tCO_2e, Pharmaceuticals at 2,330.5 tCO_2e, other machinery and equipment at 2,039.0 tCO_2e, and solid, liquid and gaseous fuels etc. at 1,944.4 tCO_2e. The methods for these estimations are still being developed and fine-tuned in the literature and should be taken as an indicator for where to focus further GHG investigation and initiatives.

AU maintains an active member of the green transition by publicly disclosing reports like this one. However, different universities have access to different resolutions of data, and may not be comparable unless the same methodological decisions and assumptions have been taken. As a result, the perception of sustainability should put more emphasis on reductions achieved than the total emissions, and the data that supports those achievements.

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AARHUS UNIVERSITY EMISSIONS INVENTORY 2021

Greenhouse gas inventories and disclosure of these emissions are an important tool in providing the decision support for developing and implement meaningful mitigation strategies. Aarhus University's 2021 emissions inventory has developed on previous inventories with a refined method, reflecting the academic discourse in this space, while following the guidelines of the GHG Protocol. This report includes process based methods, which result in 20,322.7 tCO_2e across scope 1, 2 and 3, with the exception of 3.1 purchased goods and services, and 3.2 capital goods. Spend based approaches were used in place of process based for scope 3.1 and 3.2, using EXIOBASE, and result in 39.691.9 tCO_2e. Since the two approaches answer different questions, they cannot be summed. Recommendations on the basis of both results include closer collaboration with accounting department to provide greater resolution of spend based data, and exploration of energy efficiency on campus.

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