TECHNICAL DOCUMENTATION

Europeana Foundation Carbon Footprint 2020 Report

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Executive Summary

A carbon footprint was calculated for the Europeana Foundation over the year 2020. In the calculation we identified three main areas that contributed to the total footprint;

1. working from home or the office;
2. the digital services Europeana Foundation provides;
3. business travel.

Not included in the calculation was daily commutes, manufacturing or disposal of computer devices, and overnight stays during business trips. We took a pessimistic view when analysing results, so the outcomes are more likely to be an overestimate than an underestimate.

Resources

We estimated that in 2020 the following resources were consumed:

Resource	**Total usage**	**From renewable resources (CO2 neutral)**
Electricity	198,400 kWh	136,700 kWh
Natural gas	16,700 m3	170 m3
Water	360 m3	

Table 1: resources consumed by working from home or the office and for providing Europeana's digital services

About 73% of all electricity was used to power Europeana's digital services, the rest was consumed by working from home or the office. Almost 69% of all electricity and 1% of all heating energy came from renewable resources.

Carbon footprint

In total the carbon footprint of Europeana Foundation was estimated to be 87,300 kg CO2e. The use of renewable energy sources made sure that about 65,000 kg CO2e of emissions was avoided. Around 1460 kg worth of CO2e was compensated with carbon offsetting.

Resource	Carbon footprint (in kg CO2e)	Avoided emissions (in kg CO2e)
Electricity	42,000	64,700
Natural gas	31,100	300
Water	110	0
Petrol (business travel)	14,000	0

Table 2: carbon footprint per resource

Europeana Foundation rents its office space and does not own any vehicles. This means that all emissions are scope 3.

The carbon footprint of working from home or the office was estimated to be 34,400 kg CO2e. The lack of precise energy consumption data at the office as well as a standardised methodology for calculating the carbon footprint of working from home, make this part of the calculations imprecise. Nevertheless, we feel that the methodology presented in this report can be used to get a good indication in what areas the organisation can improve and how its carbon footprint is progressing over time.

The digital services carbon footprint was estimated to be 38,900 kg CO2 which makes it the largest category contributing to the organisation's total carbon footprint.

For business travel in 2020 we estimated the carbon footprint to be 14,000 kg CO2e. Of this footprint 87% can be attributed to the Europeana Foundation, the rest to ENA members. Due to Covid-19 restrictions about 70% less business trips were made compared to 2018.

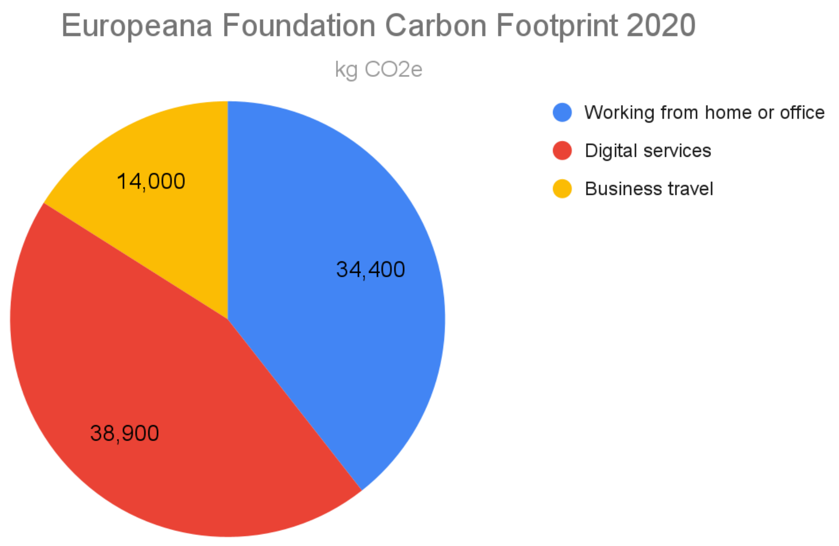

Figure 1: Europeana Foundation carbon footprint divided per category

Conclusions

In 2019 we received confirmation that all electricity used at the office and by our biggest hosting provider comes from 100% renewable resources. During our footprint calculations done in 2018 we did not have this confirmation yet, so all consumed electricity was counted as grey. Consequently the total footprint of Europeana Foundation in 2020 is much lower (about 69%) compared to calculations done in 2018. However compared to the rough estimate done in 2019, the organisation's carbon footprint did increase in 2020.

The activities with the biggest impact in terms of used resources in 2020 were using rented computer servers and working at the office. The largest contributors to the carbon footprint were powering computer servers hosted by PSNC and IBM Cloud, and heating workspaces. On average heating home workspaces costs about 18% more energy than heating office workspace.

Due to Covid the footprint of business travel was much reduced in 2020. Expectations are that this will increase again in the future. Travelling by train generally has the lowest impact, but selecting the best mode of transport is usually a trade off between travel time, costs and carbon footprint.

Recommendations

- Approach all service providers that do not use renewable energy (such as IBM Cloud, Amazon and PSNC) and ask them to switch to renewable energy.
- Schedule in an annual or bi-annual analysis of all servers and deployed services to see if they are still useful or can be decommissioned, or if a physical server

can be replaced by a virtual one. Both software developers and system administrators should be involved in this activity.
- Investigate the environmental impact of the many other online tools and services that are currently used in the organisation and see if they can be replaced by ones that have a lower impact.

- Stimulate employees to work at the office, especially during colder periods (although this may conflict with Covid measures that recommend the opposite).
- Encourage employees to be mindful about their energy consumption, e.g. switching computers and lights off at the end of the day, limit printer usage, etc.
- Consider in what way Europeana can further help employees reduce the carbon footprint of working from home.

- When planning meetings, include also carbon footprint when weighing the pros and cons of travelling to an in-person meeting versus having a virtual meeting.
- For business trips, selecting the travel modality should be done based on total travel time, costs and carbon footprint. In many cases the extra time (and costs) for trips by train compared to flying is limited when the total travel time is under six to seven hours.
- Encourage staff to book environmental-friendly hotels and use local public transport.

- Include the carbon footprint of daily commutes in next year's calculation to improve the accuracy of comparing the impact of working from home vs. at the office
- Automate carbon footprint data gathering as much as possible so new calculations can be done faster and trend analysis becomes easier.
- Investigate the effectiveness of carbon offsetting.

Abbreviations and Glossary

Carbon intensity	The amount of greenhouse gases emitted on average for consuming one unit of a particular resource (e.g. for electricity a typical unit is 1 kWh)
Carbon offsetting	Paying money to an organisation to reduce or remove greenhouse gases elsewhere as compensation for your emissions
CO2e	Carbon dioxide equivalent, a measure where all emitted greenhouse gases are converted to equivalent amounts of carbon dioxide with the same global warming potential
EAF	Europeana Aggregators' Forum
EF	Europeana Foundation
EI	Europeana Initiative (EF + ENA + EAF)
ENA	Europeana Network Association
FTE	Full-Time Equivalent, the hours worked by one full-time employee
LCA	Life Cycle Analysis, a method to calculate footprints of a product or service over its entire life-span, including construction and disposal. Also known as "cradle-to-grave" approach
PUE	Power Usage Effectiveness, measure that indicates how efficient a computer data centre uses its electricity (how much is consumed by overhead systems for cooling and routing data)
REC	Renewable Energy Certificate, a tradable commodity that is issued for electricity produced through the use of renewable energy sources
RFI	Radiative Forcing Index, a factor by which CO2 emissions from plane travel is multiplied to arrive at the correct climate imprint of flights at high altitudes
Scope 1 emissions	All direct greenhouse gas emissions from owned or controlled sources
Scope 2 emissions	All Indirect greenhouse gas emissions from purchased energy sources
Scope 3 emissions	All indirect greenhouse gas emissions for which a company is responsible and that are not included in scope 2
WTW	Well-To-Wheel, commonly used to indicate all carbon emissions

	arising from extraction and production of a resource (well) until using the resource (wheel). This excludes the footprint of any other prerequisites and of disposal.

Table 3: abbreviations used in this report

1. Introduction

Europeana Foundation is dedicated to reducing its environmental impact. This includes advocating for and embedding working practices that minimise the digital cultural heritage sector's impact on climate and environment [Europeana 2021].

In May 2021 the foundation's "Green" cross-team was set-up, consisting of five members from different teams. One of the main tasks of this team is to investigate the organisation's carbon footprint, identify opportunities for improvement and see if the organisation is making progress. This report describes the Foundation's carbon footprint calculation over 2020.

It is important to make a distinction between the Europeana Foundation and the overarching Europeana Initiative. The Europeana Initiative (EI) consists of the Europeana Foundation (EF), the Europeana Network Association (ENA) and the Europeana Aggregators' Forum (EAF). In this report we focus primarily on the carbon footprint of the Europeana Foundation. The main reason for this is that there is little to no footprint data available for the ENA and EAF. Where in this report we mention Europeana, we mean Europeana Foundation.

In December 2018 a first rough carbon footprint for EF was made [Ehlert et al. 2019]. In this report we also compare the 2020 footprint with that of 2018.

We tried to follow the general recommendations regarding transparency of carbon footprint calculations as much as possible and made sure to include the exact scope, period, underlying data and conversion factors in this report [CO2emissiefactoren.nl 2021a]. We also reported separately on carbon offsetting.

2. Methodology

From our previous carbon footprint calculation done in December 2018 [Ehlert et al. 2019], we already know that there are three major aspects that contribute to the organisation's carbon footprint:

1. Working from home or at the office;
2. Providing digital services;
3. Business travel.

During our investigation we tried to find other areas that have a significant carbon footprint, but none were identified. One possible exception could be daily commutes of employees. This was not investigated due to the lack of reliable data over 2020. However, we do not expect that daily commutes contribute a lot to the total carbon footprint because most employees use public transport and for the larger part of 2020 employees worked from home because of the Covid-19 outbreak.

Since Europeana rents their office space and does not own any vehicles, the emissions from all three main categories are scope 3 (as defined in the Greenhouse Gas Protocol). This means that all greenhouse gas emissions arise from products or activities that are not under direct control of the organisation, which makes it hard to take measures.

We used a Well-To-Wheel (WTW) approach as this is common in many carbon footprint reports. With Well-To-Wheel we mean that in our calculations we take both the production and usage phase into account, but not the footprint of any prerequisites (e.g. the construction of a windmill) or that of the disposal phase (e.g. recycling a computer server).

Data gathering was done in the course of 2021. For most data we were able to get information about the situation in 2020, except for digital services. This means that the digital services footprint was based on data from 2021 which most likely led to a slightly higher footprint than in 2020 because new digital services were introduced.

We took a pessimistic view when analysing results, so the presented numbers are more likely to be an overestimate than an underestimate.

2.1. Exact scope

Included in the carbon footprint calculation are the following:

1. Electricity usage for a typical workspace; lighting, air-conditioning and computer/laptop usage;
2. Gas usage for heating workspaces;
3. Water usage at home during working hours or at the office;
4. Electricity usage for all computer servers running on behalf of Europeana;
5. Business travel.

Points 1,2 and 3 are explained further in section 2.2 (Office and home working), point 4 is explained in section 2.3 (Digital services) and for details on point 5 please refer to section 2.4 (Travel).

Excluded in the calculation are:

- Daily commutes of EF employees;
- Overnight stays during business trips;
- Computer usage of ENA or EAG members or of people using the digital services offered by Europeana;
- Manufacturing and disposal of computer servers or other devices;
- Paper usage;
- Waste disposal;
- Third party server capacity for Europeana employees using various online tools like Google Mail, Google Drive, Synergy, Cloudflare, Pingdom, Runscope, etc.;
- The annual Europeana Conference which was held fully online in 2020.

The main reason for not including the aspects above is a lack of data and the unavailability of any estimated (standardised) carbon footprint data. For the Europeana 2020 conference a carbon footprint of the total event was estimated, including the footprint of all attendees. More information on this can be found in the Europeana 2020 Impact Assessment Report [McNeilly 2021].

2.2. Office and home working

In the course of 2020 the Netherlands went into a lockdown and many EF employees were forced to work from home. In our calculations we distinguish between a 'pre-Covid' and 'during Covid' timeframe. The pre-Covid period is from 1 January 2020 until 15 March 2020, which is the date the Netherlands went into their first lockdown. The during-Covid period is from 15 March until 1 January 2021.

Before Covid about 90% of all Europeana Foundation employees were working in The Netherlands. Over the course of 2020 several employees decided to work elsewhere, sometimes temporary, sometimes for a longer period. Since there is no data on who was working where and during what period, we decided to use resource consumption and carbon intensity figures for the Netherlands. This greatly simplifies the calculation and since carbon intensity factors for the Netherlands are a bit higher than the European average, there is little risk of underestimating emissions.

To simplify calculations for heating we assumed everyone uses natural gas (as is the common way of heating in The Netherlands) and converted all data on resources for heating to m3 of natural gas.

2.2.1. 2018 calculation method

A major difficulty in calculating the carbon footprint of working from home or at the office is the lack of measurements of used resources such as electricity, gas and water. The Europeana Foundation rents its office space from the Royal Library in The Hague and no energy consumption data specifically for Europeana is available.

In the 2018 carbon footprint calculation we used a rough estimation method for electricity, heating and water consumption based on a percentage of the total usage in the Royal Library building. We calculated that Europeana utilises roughly 1330 square metre or 1.66% of the total space in the Royal Library building. We then took the same percentage of the total Royal Library usage data of 2017. However we know that this led to an overestimation for several reasons:

1. A large amount of electricity is used by the systems that cool the Royal Library book storages and their data centre.
2. Quite a bit of the calculated used space is actually shared (e.g. hallways, kitchen area, toilets, staircase and elevator).
3. The Royal Library uses both district heating and natural gas. The latter is also used to humidify the library's book storage when necessary, so cannot be fully attributed to office heating.

For the 2020 carbon footprint calculation we first took the same approach as in 2018, but this led to much higher consumption figures than expected, especially for electricity usage during peak hours. Very few people worked in the Europeana office during the last three quarters, so we would have expected a much bigger decrease than the -23% (compared to 2018) that we found. This led us to conclude that this calculation method is more inaccurate than we first thought.

2.2.2. 2020 calculation method

A problem with calculating the carbon footprint of working from home is that up until the Covid outbreak no organisation doing carbon footprint calculations seemed to take home working into account. One of the first organisations to propose a solution is EcoAct. In their Homeworking Emissions Whitepaper average numbers are presented for workspace electricity usage, lighting, heating and cooling for both the UK and the US [EcoAct 2020]. We decided to follow a similar method and adjust some of the EcoAct numbers. For this we used both our own gathered data as well as the numbers we found for the average Dutch government office resource consumption [Milieubarometer 2021]. This led us to draw up two 'average consumption' profiles; one for working from home and one for working at the office. Both profiles represent the resources used by one full-time working employee (FTE) per year (see table below).

	Working at the office	Working from home
Electricity laptop	237 kWh	237 kWh
Electricity lighting	25 kWh	17 kWh
Electricity cooling	15 kWh	9 kWh
Gas usage heating	239 m3	281 m3
Water usage	5.3 m3	7.6 m3

Table 5: average resource consumption data per year per FTE

The resource consumption numbers for governmental offices that we used actually have a big range of typical electricity, gas and water usage per FTE. In our calculations we used the 'average' number, but this does mean that there is quite a big margin of uncertainty in these numbers. More details on how the consumption numbers listed in table 5 were derived can be found in Appendix A.

2.2.3. Baseline office resource consumption

The approach described above with average resource consumption covers working hours only and neglects resources consumed at the office outside of working hours. For example electricity used by printers or computers that remain turned on, hallway lighting or a refrigerator. This becomes especially problematic if the office is not used such as during a Covid lockdown. That is why we added a "baseline" office consumption pattern as an estimate for used resources outside of working hours.

2.2.4. Carbon intensity

To convert resource consumption into carbon footprint we used the carbon intensity factors as listed by the Dutch CO2emissiefactoren.nl website. This website provides common Dutch conversion factors with the goal of making it easier to compare carbon footprint analyses.

According to CO2emissiefactoren the Well-To-Wheel (WTW) carbon intensity of electricity from wind, hydro and solar is 0 and that of biomass is 0,075. Since we are not able to distinguish between these electricity types we simply used one carbon intensity for renewable energy and set that to 0. No carbon intensity of drinking water is available, so here we used the number presented by the Milieubarometer website that says their numbers are in-line with those of CO2 emissiefactoren.

Resource	Kg CO2/unit (WTW)	Unit
Electricity grey	0,556	kWh
Electricity unknown origin	0,475	kWh
Electricity renewable	0	kWh
Natural gas	1.884	Nm3
Drinking water	0.298	m3

Table 6: used carbon intensities for working from home and at the office in the Netherlands[1].

2.3. Digital services

Europeana Foundation offers a wide range of digital services. The most visible one is the Europeana.eu website. This website is powered by multiple APIs that are also used by other software developers to build their own digital services. The data that Europeana offers is ingested via the in-house Metis aggregation system. This service is also available to aggregator organisations.

2.3.1. Scope

Included in the digital services carbon footprint is the energy consumption of:

- All applications deployed at IBM Cloud service provider
- Physical and virtual servers rented at providers Hetzner and Digital Ocean

[1] *All numbers retrieved from co2emissiefactoren.nl on 24 Sep 2021, except "drinking water" that was retrieved from milieubarometer.nl* on *2 Nov 2021*

- Physical and virtual servers used by partner PSNC to power (part of) Europeana's ingestion pipeline
- Used large data storages (IBM Cloud S3 and Amazon S3)

Excluded in the digital service footprint are:

- Cloudflare service (content delivery and DDoS mitigation service)
- Experimental failover Kubernetes environment at Hetzner (decommissioned in 2021)
- Server capacity of other 3rd party online service providers specifically for Europeana such as Google Workspace (e.g. GMail, Google Drive, Google Meet, Google Calendar[2]), Jira, Slack, Basecamp, Zoom, GitHub, Pingdom.
- Emissions for manufacturing and disposal of hardware

The main reason for not including the aspects above is again the lack of reliable resource consumption or footprint data. At the start of our investigation, we drew up a list of online tools and services used in the organisation. The electricity for using these tools and services is to some extent already part of the 'workspace' footprint, but ideally we should also take into account how much of the provider's server capacity on average is used by Europeana. Unfortunately, very few organisations are able or willing to share such information, so we limited ourselves to the 'biggest' services for which we can at least estimate resource consumption (IBM Cloud, Hetzner, PSNC and Digital Ocean). We expect that for many services that are not used often (e.g. Trello, Postman, Metroretro, Blazemeter) the total impact is negligible.

2.3.2. Electricity consumption

There is no standardised carbon footprint methodology for situations where precise electricity consumption information of digital services is not available. In our 2018 carbon footprint calculation we estimated the average electricity consumption for various situations:

- Dedicated (busy) physical server used for production
- Dedicated (less used) physical server used for testing
- Shared server used to host virtual machines

For our calculations over 2020 we took a similar approach, but drawing on the methodology used by others such as the open-source Cloud Carbon Footprint tool, we now also took data centre efficiency into account. A common measure to indicate data centre efficiency is Power Usage Effectiveness (PUE). This describes the amount of electricity consumed directly by computer servers, versus the total data centre

[2] Google reports that their services are carbon neutral because all their emissions are offsetted.

electricity usage including ‘overhead’ systems such as cooling and routing data. In the past data centres have been accused of manipulating their PUE numbers, but there currently is no better alternative to calculate the electricity consumed by overhead systems. Not all data centres report their PUE and in those cases we estimated an average PUE of 1.2.

For large data storages this approach is not possible because one usually rents and pays for storage space (for example in Gigabytes), so the amount of servers involved is unknown. In these cases we used a different method where we estimated how much electricity it takes to store 1 Terabyte (TB) of data in the cloud. We named this the storage-energy factor. We did the same in our 2018 footprint calculations, but there we used a higher storage-energy factor. For 2020 we estimated the storage factor to be 31.6 kWh/TB/year, whereas in 2018 this was estimated to be 41 kWh/TB/year. The lower number was based on data found in the methodology of the Cloud Carbon Footprint tool and other online estimates.

To summarise, computer server energy consumption is calculated using the following formula:

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Estimated average server electricity consumption * number of
servers * data centre PUE
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Except for large data storages where we used:

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Amount of data stored * storage-energy factor * data centre
PUE
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2.3.3. Carbon intensity

To calculate a carbon footprint we multiplied electricity consumption with electricity carbon intensity. However different servers run in different countries. For Europeana most servers are located in Germany, but some also in Poland, Finland and the Netherlands. This means we had to find electricity carbon intensity figures for all of these countries. In our 2018 calculations we used a scientific paper from [Moro and Lonza 2018] that used a WTW approach but was based on data from 2013. In the 2020 footprint calculation we used more recent data from 2017 and 2018 (listed in the table below) that resulted in slightly lower carbon intensity figures [carbonfootprint.com 2018].

Source data 2017/2018 take from Carbonfootprint.com	**Average kilogram CO2e/kWh of electricity**
Germany	0.4880
Poland	0.8360
Ireland	0.4420
Finland	0.1850
Netherlands	0.4590

Table 7: carbon intensity as listed by carbonfootprint.com and used in our calculations (except that of the Netherlands)

Unfortunately carbonfootprint.com does not explain exactly how they derived these numbers, but the carbon intensity for The Netherlands is fairly close to the one listed by CO2emissiefactoren.nl (0,427 for electricity of unknown origin) which we mentioned in section 2.2.4.

2.4. Business travel

We gathered Travel Expenses Claim forms of EF staff and ENA Members for the year 2020. From the forms we extracted information about departure and arrival locations, entered this information in the selected online carbon footprint calculator and summed up carbon emissions from individual journeys. In the calculations we included the following types of travel:

- regular office visits of employees stationed abroad,
- regular office visits of Governing Board members,
- all Europeana staff (stationed in the Netherlands and abroad) and Network members travel to meetings and events.

Daily commutes of employees were not included.

2.4.1. Selection of online carbon footprint calculator

Most trips in 2020 were done by train or plane, with only one trip by car. We looked at the calculators that cover different modes of transport (aviation, road and rail), are free to use, and are based on trustworthy methodology. After comparing several different calculators[3], we concluded that there is no perfect carbon footprint calculator for travel, and that calculations and methodology used vary greatly between different calculators.

For the purposes of this report, we decided to use the EcoPassenger calculator because it uses a trustworthy methodology (based on a Well-To-Wheel perspective) that is well documented and can be used for all three types of travel (aviation, rail and road). EcoPassenger allows the inclusion of “CO2 emissions with climate factor” for plane travel. This means that non-CO2 warming effects of flying like water vapour and nitrogen oxides are included in the calculations. In literature, the climate factor is often referred to as RFI (radiative forcing index), which is a factor by which regular CO2 emissions are multiplied to arrive at the correct climate imprint of flights at high altitudes. We know that emissions high up in the air have a stronger negative impact than emissions at ground level, but the debate about how to correctly adjust for these emissions is still ongoing. We decided to include the RFI climate factor in our calculations, even if a widely accepted consensus about how high the factor should be is not reached yet. EcoPassenger uses average RFI factor 1.27 - 2.5 for flights over 500km (see [EcoPassenger 2016], pp. 20-21).

A downside of the EcoPassenger calculator is that the RFI factor can only be activated after you do a calculation (so you need to redo it with the RFI setting enabled) and that some destinations are not recognized properly.

[3] These are the calculators we tested: EcoPassenger, Myclimate for car and air travel, Carbonfootprint.com calculator for bus & train, car and air travel, Trees for All, ICAO for air travel, Sustainabletravel.org for air travel, Atmosfair for air travel.

3. Measurements

We measured the total amount of used resources (water, natural gas and electricity) as well as the part that comes from renewable sources. Since the footprint of renewable resources was set to 0, the total carbon footprint only includes the emissions from non-renewable resources. We also reported separately on carbon offsetting. We did not subtract any carbon offsetting from the total carbon footprint.

To avoid a sense of false precision we rounded carbon footprint outcomes up to 1000 to the nearest factor of 10. Bigger numbers were rounded to the nearest factor of 100.

3.1. Office and home working

3.1.1. Number of FTE

Using data obtained from the HR department we calculated the following averages for the pre-Covid and during-Covid periods:

Pre-covid	**People**	**FTE**
Average number of people working at the office	45.6	43.9
Average number of people working from home	6	5.8
During covid	**People**	**FTE**
Average number of people working at the office	5.5	5.3
Average number of people working from home	48.9	47.1

Table 8: Calculated FTE in 2020 before and during Covid

On average EF employees have a contract for 38.5 hours, so FTE is calculated using the total number of people times 38.5 / 40.

3.1.2. Baseline office consumption

From the Royal Library total figures we can see that about 45% of all electricity is spent during off-peak hours, so for the baseline energy consumption we estimated this to be 45% of 84,853 = 39,138 kWh.

For gas usage we really do not know anything about usage outside of office hours. For lack of a better method we used a similar approach as for electricity: 45% of 5,977 m3 =

2,703 m3. However we realise that this is very much a wild guess and probably an overestimate.

3.1.3. Survey

To refine our home working calculations we held a brief survey. The results are listed below:

- There were 34 responses. With around 62 employees at that time this is a response rate of 55%.

- Two respondents (5.9%) indicated that their home is energy neutral and one respondent (2.9%) said their home is almost energy neutral. 31 people (91.2%) were not sure or said their home is not energy neutral.

- 22 people (64.7%) have a contract with their energy supplier to use 100% green electricity guaranteed. Furthermore two respondents indicated they have co-ownership of a windmill and one respondent has PV panels for generating electricity. These three persons also indicated that they have a 100% green electricity contract.

- Most people (33) use natural gas for heating. One person uses solar thermal panels as well as natural gas, and one person uses oil and an electric underfloor. Two persons that use natural gas mentioned that all emissions were offset according to their energy contract.

- Three respondents (8.8%) of Europeana employee households use air-conditioning on very hot days, and one respondent said they have air conditioning but hardly ever use it.

- 22 respondents normally have two people working in the house, 11 are alone and one person said there are 3 people.

We do suspect that most survey respondents have an interest in sustainability and that the survey results are very much biassed.

Average number of people

The last point in the survey results showed that on average 1.71 people are working from home. This means that for heating and air-conditioning estimated resource consumption was divided over 1.71 people.

Heating
Very few of the respondents indicated that their home is energy neutral and even fewer responded that their home is heated using a renewable energy source. This could be conflicting information, but It could also be that for answering the first question people considered carbon offsetting to be energy neutral.

For our calculations we took a pessimistic approach and assumed that only 1.6% (one out of a total of 62 employees) used renewable resources for heating. For offsetting emissions we assumed that to be 3.2% (two people).

Air conditioning
With 8.8% of all respondents using air-conditioning only on very hot days and 2.9% saying they use air-conditioning only rarely, we rounded this to 10%.

Electricity
We were a bit surprised about the rather high number of respondents (22 in total or 64%) saying that their electricity company is providing them with 100% green electricity, because in 2019 only 18.9% of all electricity generated in the Netherlands was from renewable sources [Wise 2020]. Several Dutch NGOs have criticised electricity companies to "greenwash" grey electricity delivered to consumers by buying RECs that are abundantly available in Scandinavia, instead of investing in new renewable energy resources.

Taking this discussion into account and again using a pessimistic approach, we assumed that the 22 respondents are all the employees that use renewable energy, so this leads to 35.5% using renewable energy. For offsetting emissions we assumed 1.6% (one respondent).

3.1.4. Resource usage and carbon footprint

Using the average resource consumption patterns for working from home and working at the office we calculated resource consumption as listed in table 9.

Resource	Total usage	From renewable resources (CO_2 neutral)
Electricity	53,000 kWh	46,400 kWh
Natural gas	16,700 m3	170 m3
Water	360 m3	

Table 9: resource consumption for working from home and at the office.

The resulting carbon footprint is 34,400 kg CO2e, not including 680 kg of emissions that were offset. The larger part of all emissions comes from heating.

Resource	Carbon footprint (kg CO2e)	Avoided emissions (kg CO2e)
Electricity	3,100	22,000
Natural gas	31,150	330
Water	110	

Table 10: total carbon footprint per resource and the amount of avoided emissions because of the use of renewable energy sources

3.2. Digital services

In total the electricity consumed by all digital services is 145,500 kWh with about 90,300 kWh coming from 100% renewable energy sources. This resulted in a carbon footprint of 38,900 kg CO2e and 42,700 kg CO2e of avoided emissions.

3.2.1. Rented servers

Of all used hosting companies, most electricity by far is used by the servers rented from Hetzer, primarily because we rent a large number of physical servers. Fortunately Hetzner uses 100% renewable energy so its footprint is 0. The second largest contributor are servers used by PSNC. PSNC is reusing heat from their servers to heat buildings which saves them about 700MWh per year. Unfortunately the total amount of electricity used by their data centre is not known, but their entire organisation consumes 7800 MWh, so at least 700/7800 = 9% of the electricity has 2 purposes. That's why we reduced the total electricity consumption of PSNC servers by 4.5%.

Hosting company	Electricity used (kWh)	Carbon footprint (kg CO2e)
Hetzner	89,800	0
PSNC	33,800	28,200
IBM Cloud	16,900	8,200
Digital Ocean	3,500	1,700

Table 11: electricity consumption and carbon footprint for the various hosting providers

3.2.2. Large online data storages

In total we stored about 38.9 TB of data in large online data storages. In comparison in 2018 this was estimated to be around 41.2 TB. For this 1,477 kWh was used which resulted in a carbon footprint of 734 kg CO2e (with 147 kg CO2e avoided due to the use of 100% renewable energy sources).

3.3. Business travel

In total 73 (one way) trips were made in 2020; 32 by plane, 40 by train and one by car. For most of the journeys we used the EcoPassenger calculator that outputs emissions produced by car, train or plane. EcoPassenger only applies to travel within Europe. One person travelled to a conference outside of Europe, so we had to use an alternative calculator for this trip. We selected Atmosfair, which uses similar factors in the calculation of air travel emissions than EcoPassenger. We also used Atmosfair for a few other trips because of issues with EcoPassenger. EcoPassenger was designed to be used on future travel dates, so we disregarded original dates and used the same date and time stamp for all trips. We applied the climate factor to all our calculations for longer plane trips. For short plane trips the "climate factor" option is not available in the calculator.

The total footprint of all travelling is 14,000 kg CO2e; 2,200 kg for trips made by ENA members and 11,800 for trips made by EF employees. For a few trips carbon offsetting was requested and in total 780 kg of CO2e was offset.

3.3.1 Potential carbon footprint savings

After further analysis of all direct flights, we identified four round-way trips that could have been done by train without much time loss. On average the one-way flight time during these trips was 2 hours and 31 minutes. If we assume 2.5 hours for travel to the airport plus check-in, the actual trip would take five hours. On average travelling by train instead would take 5 hours and 21 minutes. If we assume half an hour for travel to the nearest railway station, this increases total travel time by only 50 minutes. The expected carbon emissions savings for these four trips by train instead of plane would be 930 kg CO2.

We did not investigate potential carbon emissions savings for indirect flights as the rationale behind the stop-overs was not known (could have been intentional).

3.3.2 Choosing how to travel

Additional research showed that deciding what mode of transportation to select for business travel can be complicated. Take for example a one-way trip from The Hague to

Luxembourg, booked two - three weeks in advance. The fastest way to get there would be:

1. Train from The Hague HS to Schiphol (takes 30 minutes, costs €9,50)
2. Check-in at Schiphol (90 minutes)
3. Direct flight to Luxembourg airport (55 minutes, €204,-)
4. Bus from Luxembourg airport to city centre (30 minutes, €2)

Total travel time is around 3 hours and 25 minutes, total costs €216 (rounded off) and resulting carbon footprint 119 kg CO2e. Travelling by train, with the Thalys from Rotterdam to Brussels Midi, takes at least 5 hours and 20 minutes, requires three transfers, costs €95 and has a footprint of only 10 kg CO2e. So looking at costs and carbon footprint the train would be best, but at the expense of almost two hours extra travel time. Alternatively one can travel by car. This will take around 4 hours and 10 minutes without traffic jams, costs around €68, and has a footprint of around 92 kg CO2e. But the options do not end there. There is a much cheaper flight with one stop-over which results in a total travel time of five hours and costs €80,- less. There's also a cheaper train option using the regular IC train to Brussels costing only €28 but taking 35 minutes longer. A summary of these options is shown in Table 12.

The conclusion here is that any decision on what mode of transport to take, needs to consider the combination of total travel time, costs and carbon footprint. Also contrary to popular belief, the train is not always more expensive than flying.

Travel Modality	Total travel time	Costs	Carbon footprint
Plane	3:25 (5:00)	€216 (€126)	119 kg CO2e
Car	4:10	€ 68	92 kg CO2e
Train	5:20 (5:55)	€ 95 (€ 28)	10 kg CO2e

Table 12: possible options for travelling from The Hague to Luxembourg. Cheaper option is between round brackets but takes more time

4. Comparison with 2018 footprint

Comparing our 2020 carbon footprint figures with those calculated in 2018 is a bit like comparing apples and oranges. Several changes were made to our calculation method and the circumstances in 2020 were very different. People were often forced to work from home because of Covid lockdowns and many business meetings were done online instead of in person. Despite all this, we do want to compare our 2018 and 2020 footprints because we would like to see how we are progressing in reducing our carbon footprint.

In 2018 we were not able to get confirmation that electricity used at the office and by the rented servers from our biggest provider came from 100% renewable sources. Halfway through 2019 we finally received this confirmation for both and we did a quick re-calculation based on the current number of the digital services at that time. For working at the office we assumed that the resource consumption in 2019 was the same as in 2018, except that we set the carbon intensity of all electricity from verified renewable sources to 0. This led to a big decrease in both the working at the office and digital services carbon footprint as can be seen in Figure 2.

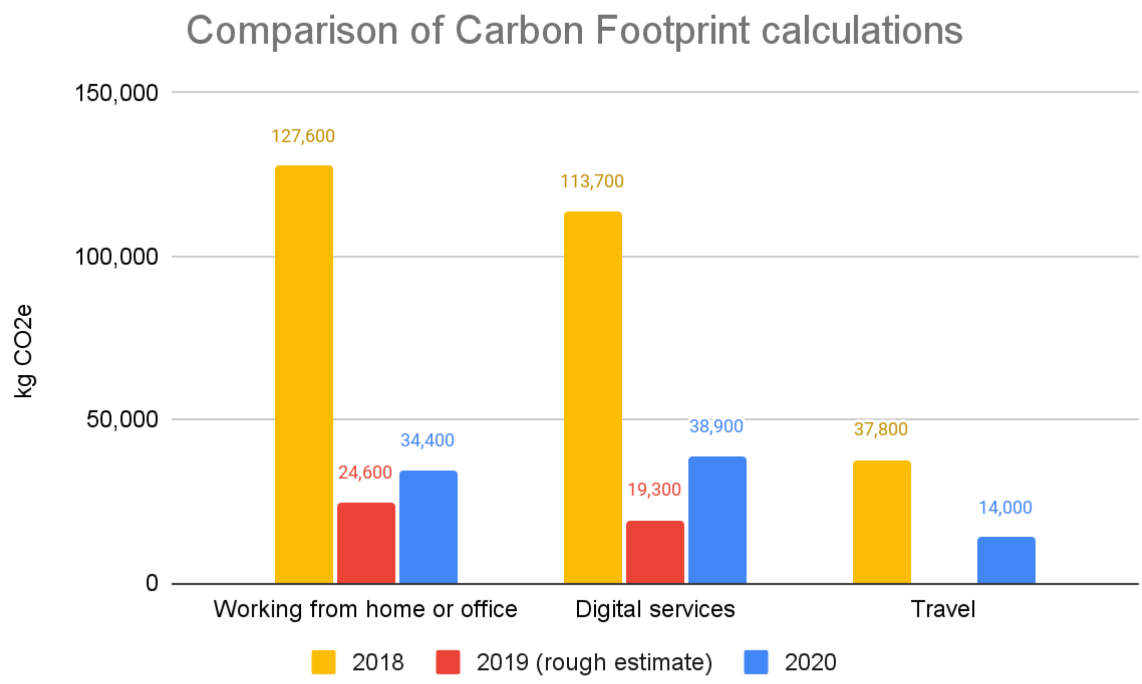

Figure 2: comparison between 2018 and 2020 carbon footprint calculations, plus a rough estimate of the 2019 footprint.

4.1. Office and home working

The many assumptions we had to make in calculating the footprint of working from home and at the office has led to a large margin of uncertainty in the carbon footprint of 2020. However, we are confident that the 2020 calculation is more accurate than the one calculated in 2018. In 2018 we used a rather crude calculation method that most certainly overestimated electricity usage.

According to our new calculation method, working from home has a slightly lower usage of electricity than working at the office, but a much higher usage of energy for heating home workspaces. Also water usage is estimated to be bigger for home working, primarily because water usage at the office is relatively low (compared to the average Dutch office). This is summarised in the table below.

Resources used for working at the office or from home	2018	2020
Electricity kWh	153,500 (overestimated)	53,000
Gas m3	12,700 (overestimated)	16,700
Water m3	231	364

Table 13: resources used in 2020 and 2018 for working at the office and from home

In 2019 we estimated the carbon footprint for working at the office to be around 24,600 kg CO2e. In 2020 we recalculated this footprint to be 34,400 kg CO2e. Note that daily commutes were not taken into account in both years and there was much less commuting in 2020.

4.2. Digital services

Our 2020 calculation method changed compared to 2018. In 2018 we did not take data centre PUE into account and for 2020 we increased the estimated power consumption of virtual servers because new data shows that number was too low in 2018.

In 2018 we predicted that the carbon footprint of our digital services would decrease significantly because our old ingestion system would be decommissioned soon. This happened in 2019 and a big clean-up was done reducing the number of servers rented from provider Hetzner. However, over time the number of applications rose again, primarily those running at another provider IBM. For example, several IIIF services were set up and in 2020 a new Europeana website was launched while keeping the old

Europeana website (plus a few dependent digital services) up and running. The table below compares the number of servers or applications running at our 3 biggest providers.

Provider	2018	2020
IBM Cloud	174 applications 64 extra services[4]	235 applications 50 extra services
Hetzner	109 physical servers 7 virtual server	48 physical servers 45 virtual servers
PSNC	7.6 physical servers[5] 37.8 virtual servers	19 physical servers 31 virtual servers

Table 14: number of servers used in 2018 and 2020

Besides differences in calculation method, the increase in the 2020 footprint is to a large extent caused by the higher number of physical servers used by PSNC. The carbon footprint of PSNC servers more than doubled; from 11,400 kg CO2e in 2018 to 28,200 kg CO2e in 2020. The number of applications in IBM Cloud rose as well, but these applications are similar to virtual servers which have a much lower impact. The carbon footprint for IBM Cloud increased from 6,290 kg CO2e in 2018 to 8,230 kg CO2e in 2020 (not counting large data storage usage). Servers at Hetzner do not contribute to the 2020 carbon footprint as they are powered by 100% renewable electricity.

4.3. Business travel

In total 36½ (round) trips were made in 2020 compared to 232 round trips in 2018, which is a reduction of 84%. The much lower numbers can be attributed to the Covid-19 outbreak which resulted in lockdowns in many European countries which severely affected travel in 2020. The relatively higher number of train trips in 2020 is caused by increased environmental awareness amongst Europeana employees and a new policy to prefer train travel over flying.

[4] Extra services are other platform services offered by IBM such as a database
[5] In 2018 4 physical servers and 29 virtual servers located at PSNC worked approximately 40% of the time for Europeana and 60% for other users (in addition to the 6 physical servers and 29 virtual servers that were fully dedicated to Europeana).

Trips (round way)	2018	2020
Airplane	170	16
Train	61	20
Car	1	½

Table 15: Number of business trips in 2018 and 2020

For the 2020 calculation we used a different travel footprint calculator, which rates longer plane travels with a higher carbon footprint because of the use of the RFI factor (see also section 3.3). In total the estimated emissions in 2020 were 14,000 kg CO2e compared to 37,800 in 2018. This is 63% less. The difference between 84% less travel and 63% less emissions can be explained by using a different travel calculator, but also because a few train trips were missing in the 2018 travel emissions.

5. Conclusions and recommendations

5.1. Conclusions

It is difficult to compare the 2020 carbon footprint with that of 2018 or 2019. This is because of differences in calculation method, different circumstances and because in 2018 we did not have confirmation that some of the used electricity came from renewable sources. Nevertheless it is clear that the footprint of business travel decreased in 2020. The main reason is that there was much less travel because of Covid, but also because people travelled more by train.

We found that working from home causes more carbon emissions than working at the office, because more space needs to be heated. Moreover, at the office all electricity comes from renewable sources and for working from home this is not always the case. These two factors explain the footprint increase in 2020 for working from home or at the office. However, we did not take the footprint of employee commuting into account and we can safely assume that was much lower in 2020. Since most employees use a bicycle or public transport for commuting, we expect that on average working at the office has a lower total footprint.

For digital services we made several changes to our 2020 calculation method; we started taking data centre efficiency into account and we increased the estimated electricity consumption of a virtual server. Both factors contributed to the higher digital services footprint we found in 2020. Additionally, the number of digital services deployed at providers that use no or little renewable energy has gone up, so even without calculation changes, the digital services footprint would have been bigger in 2020 compared to 2019.

The most difficult aspect of carbon footprint calculations remains obtaining usage data. Many third party service providers do not publish the necessary information and when asked are not always able to share such information.

The second difficult issue is selecting appropriate emission factors and finding a good travel footprint calculator. During our investigation we regularly encountered different figures for similar activities or resources, which can only be explained by differences in scope or calculation method. Unfortunately the exact methodology and scope is not always provided or very well explained. Our intention is to use the same sources and methodology in future calculations, so comparisons can be made to the numbers presented here. Even if a used carbon intensity factor is not entirely accurate, we can still use it in future calculations and see whether progress was made in lowering our carbon footprint or not. However, comparing our findings with footprints of other organisations cannot be done without analysing the differences in calculation methods and scope.

5.2. Recommendations

There are a lot of possibilities to reduce the carbon footprint of the organisation, but there is no silver bullet. Below we will discuss for each category the measures that we think can be most effective while keeping effective business operations in mind.

5.2.1. Digital services

Digital services are the biggest contributor to the organisation's carbon footprint, so it is also the area where we can potentially gain the most. The easiest solution is to approach all digital service providers that do not use renewable energy (such as IBM Cloud, Amazon and PSNC) and ask them to switch to renewable energy. PSNC is already building a new solar installation, but it is not clear yet to what extent this will lower its footprint in the coming years. If providers are not able to reduce the carbon footprint of the services Europeana buys from them we could eventually consider switching to a different provider. This is however a lot of work for the developers and infrastructure teams. Also when switching providers there will be a transition period where digital services are running both at the old and new provider, which means double costs and higher footprint.

In the past system administrators would from time to time investigate whether a particular rented server could be decommissioned. While gathering data for our footprint calculations we found a few servers and applications that were obsolete but not marked as such. It seems that often both developer and system administrator knowledge is required to determine whether a server or application is still useful or not. We recommend making this a joint effort that is scheduled in one or twice per year, where people from both infrastructure and development teams participate. During this investigation we can also check whether it would be desirable to set up a virtual server to replace a physical one as virtual servers consume less electricity.

All servers rented from provider Hetzner run on 100% renewable electricity so they do not increase the organisation's carbon footprint. Nevertheless it is useful to continue paying attention to reducing the electricity consumption of those servers. Worldwide only about 25% of all electricity comes from renewable resources, so reducing our own electricity usage means more renewable electricity for others.

During our investigation we tried to draw up a list of all online tools and services that are currently being used in the organisation. This list is quite large and probably incomplete as not all employees were involved. Part of the footprint of using these services is taken into account in our calculations, namely the electricity used by one's computer (this is part of the "workplace" footprint). However, the electricity used by these third party's servers is not taken into account. For most services that footprint will be quite small. Only when used intensively could we say that (on average) one or more of these servers is dedicated to serving our organisation. Nevertheless, opting for a service provider that has the lowest environmental impact whenever there is a need for a new one can be beneficial. This way we stimulate companies that try to make their services more green. Investigating this for all current services will be rather time-consuming since most service providers do not publish any sustainability data, but we could still take a gradual approach and start with the most used services.

5.2.2. Working from home and at the office

Heating workspaces has a big impact on the organisation's carbon footprint. The Royal Library intends to move to a different building in several years' time, so that makes it unlikely that the library will invest in better insulation. Reducing emissions of heating home workspaces is also difficult. At best, we can explain to employees the benefits of better insulating their homes or switching to a form of heating with lower carbon intensity, but that decision is of course entirely up to each employee.

Alternatively Europeana can stimulate employees to work at the office, especially during colder periods. Research suggests that working from home during warmer periods and at the office during colder periods generally leads to the lowest amount of carbon emissions because heating emissions often outweigh those from commuting [BBC 2020][WSP 2020]. A downside of course is that Covid measures recommend the exact opposite. We think that for Europeana the carbon footprint of working at the office is generally lower than working from home. Most employees commute by public transport and at the office all electricity comes from renewable sources. With home working this is not always the case. However, to be more precise we would need to calculate the commuting carbon footprint.

Finally, reminding employees to be mindful about their electricity consumption and heating will help to reduce emissions and costs to some extent. For example, switching off your computer, monitor and workspace lights at the end of the day, or configuring your devices to automatically go into sleep mode after a certain amount of time. This will help regardless of the working location.

5.2.3. Business travel

Purely from a carbon footprint point of view, it would be best to not do any business trips. However for our organisation there is an absolute need for travelling. In-person meetings are more effective than virtual ones and help build and strengthen relationships. For each intended business trip it would be best to weigh the pros and cons of having a virtual meeting versus travelling to an in-person meeting. Setting up guidelines can be helpful, but may be hard to establish as it's difficult to measure the effect on relationships.

When travel is required, selecting the best way to travel can also be difficult. There often is a trade-off between total travel time, costs and carbon footprint. Our research shows that travelling by train has a significantly lower carbon footprint compared to flying, but is often slower than travelling by plane. However, business trips done by train with a total travel time up to six hours usually do not take much extra time compared to flying. This is because flying requires extra time for travelling to the airport, checking-in and travelling from the airport to the final destination. For trips by train longer than seven - eight hours total travel time, the difference in travel time with flying tends to be much bigger.

In 2020 a lot more trips were done by train instead of by plane compared to 2018. It is not likely that the emissions caused by very long trips can be reduced much in the coming years. Offsetting emissions is an option although at the moment we lack insight into the exact impact of offsetting and what offsetting schemes work best. This should be investigated. Additionally, good tools to investigate the carbon footprint of overnight stays (in hotels) are not yet available. We should keep an eye on this to see if this changes. Finally, during business trips travelling by local public transport should be encouraged as much as possible. Trains, trams and buses have a lower footprint than cars.

5.2.4. Refining our calculations and data gathering

Gathering the data required for carbon footprint calculations is time-consuming, so we recommend automating this more. We already started with this by creating scripts that quickly analyse the footprint of most digital services in IBM Cloud. This should be expanded to also include a new type of platform in IBM Cloud that software developers started using recently (named Kubernetes). Also keeping track of the number of rented servers at other providers should be automated.

We recently made adjustments to our travel declaration system so we can more easily track the footprint of business travel. Something to consider is a better system to keep track of how much time people work from home or at the office. If we could also document the type of transportation for daily commutes that will make future carbon footprint calculations of commuting much easier and more precise, although there may also be GDPR considerations here.

Appendix A - Average resource consumption for office and home working

A.1. Office

The table below lists the numbers we found for estimating Europeana's resource usage for working at the office for an entire year (assuming pre-Covid situation) using different methods.

- Method 1 was based on our approach in 2018, using a percentage of the Royal Library total usage figures. At first a similar approach was used for 2020 but this led to much higher figures than deemed realistic.
- Method 2 used the Milieubarometer average consumption for a governmental office space per FTE.
- Method 3a was based on the same Milieubarometer average consumption, but now per rented square metre of office space and Europeana's officially rented space (712 m2).
- Method 3b used the same approach as method 3b, but now also taking into account half of the estimated space used by Europeana shared with others (actual sharing factor was set to 2.1)

	Electricity (kWh / year)	Natural gas (m3 / year)	Water (m3 / year)
Method 1 (2018) Royal Library total usage figures 2017, assuming 1330 m3 office usage	153,514	12,792	231
Method 1 (2020) Royal Library total usage figures 2020, assuming 1330 m3 office usage	120,693	10,707	168
Method 2 Average usage per FTE (43.9)	113,543	10,494	312
Method 3a Average usage per official rented space (712 m2) only	61,232	4,229	n/a
Method 3b Average usage per official rented	84,853	5,977	n/a

space (712 m2) + half shared space (618 m2)			

Table A1: Different estimates using different methods for working at the office (pre-Covid as if office was fully occupied the entire year)

The table above shows that there is a rather big difference between the different methods. The Milieubarometer website also presented a fairly wide range of figures. For example electricity usage is typically in the range of 1,200 to 4,400 kWh/FTE and natural gas usage for heating in the range of 133 to 578 m3/FTE. In the calculations for the table above the average also provided by Milieubarometer was used.

We know method 1 is very much an overestimation, but we also do not want to underestimate our emissions. That's why method 2 was selected for our calculations.

We followed mostly the methodology described in the EcoAct whitepaper. That paper used numbers for the UK but we tailored it to our own situation.
Heating: we used the 140W for workspace equipment from the whitepaper and multiplied it with 1696 working hours for 1 FTE in 2020. This results in 237 kWh/year/FTE.
Lighting: EcoAct uses 10W for lighting in a home setting, but in the Europeana office we have a lot more lighting than in the regular home so we adjusted this to 15 Watt.
Cooling: EcoAct suggested that cooling is not used often, so can be omitted at home. We included a small percentage since cooling does form a large part of energy consumption in the office. As a rough estimate we went for 15 kWh per year per FTE.
Heating: we feel the heating numbers presented by the EcoAct paper are rather pessimistic and instead took the milieubarometer average heating per FTE which is 239 m3 natural gas/year/FTE.
Water: we used the general KB consumption figures from 2017 (assuming full time office usage) which was 231 m3 per year, so that's 5.3 m2 water/year/FTE (in the pre-covid period).

A.2. Working from home

As mentioned earlier, some of the numbers presented in the EcoAct whitepaper seemed fairly pessimistic. This is especially so when comparing to actual measurements done by one environmentally conscious Europeana employee. He calculated using about 145 kWh/year electricity (5.3% extra) and 69m3 of gas/year (9.3% extra) due to home working. Of course one household can be very different from the average household, so we continued our search for better data.

We found a whitepaper from the Anthesis group that took a different approach and calculated that for Europe, working from home would increase the electricity usage on a working day with 57.59% and gas usage with 70.68%. Using their baseline energy consumption per day this leads to an extra 490 kWh electricity and 961 m3 gas per employee/year which is a factor 2 to 3 higher than the EcoAct numbers and 8 to 11 times that of the Europeana employee. However 961 m3 of natural gas extra seems rather unrealistic since that's more than 80% of the average Dutch household's gas consumption (1169 m3 gas, source Milieucentraal). We dismissed the Anthesis group data and again went for the EcoAct numbers, but with some adjustments

	Electricity in kWh / year	Natural gas in m3 / year
Measured by 1 Europeana employee	145	69
EcoAct method	254	281
Anthesis method	490	961

Table 2: comparison of the extra electricity and gas usage for working from home for an entire year

Lighting: here we did follow EcoActs suggesting to use 10W so that's 17 kWh/year/FTE
Cooling: in our survey we found that about 10% of the employees use cooling. The milieucentraal website provided 150 kWh/year as an average for air conditioning installations at home. WIth on average 1.71 people working at home this leads to 10% * 150 kWh/year / 1.71 = 9 kWh/year/FTE
Heating: we used EcoActs 800 kWh/month for 6 months per year where heating is required. 800 kWh / 1.71 people * 6 = 2814 kWh/year/FTE = 281 m3 gas/year/FTE
Water: here we did not have good data to rely on and made our own estimate. Estimating four drinks per working day and four toilet flushes using around 8 litre per turn and another 3 litre for various uses, we have a total of 0.0360 m3 water per working day, so with 212 working days in 2020 that's 7.6 m3 water per FTE/year

References

Atmosfair 2021, Online flight emissions calculator available at https://www.atmosfair.de/en/offset/flight/

BBC 2020, "*Why working from home might be less sustainable*", news article published at https://www.bbc.com/worklife/article/20200218-why-working-from-home-might-be-less-sustainable 21 February 2021, accessed 21 November 2021

CarbonFootprint.com 2018, "*Country specific electricity factors*", available at https://www.carbonfootprint.com/docs/2018_8_electricity_factors_august_2018_-_online_sources.pdf, accessed 24 September 2021

Cloud Carbon Footprint 2021, "*Methodology*", online documentation available at https://www.cloudcarbonfootprint.org/docs/methodology/ accessed 24 September 2021

CO2emissiefactoren.nl 2021a, "*Hoe werkt het*", Dutch article published at https://www.co2emissiefactoren.nl/hoe-werkt-het/#transparantie, accessed on 24 September 2021

CO2emissiefactoren.nl 2021b, "*Lijst emissiefactoren*", Dutch list of carbon emission factors, published at https://www.co2emissiefactoren.nl/lijst-emissiefactoren/, accessed 24 September 2021

EcoAct 2020, "*Homeworking emissions whitepaper*", available at https://info.eco-act.com/hubfs/0%20-%20Downloads/Homeworking%20emissions%20whitepaper/Homeworking%20Emissions%20Whitepaper%202020.pdf?hsLang=en%20and%20adjusted%20were%20appropriate, accessed May 2021

EcoPassenger 2016, "*EcoPassenger, Environmental Methodology and Data, Update 2016",* available at http://ecopassenger.hafas.de/hafas-res/download/Ecopassenger_Methodology_Data.pdf, accessed August 2021

EcoPassenger 2021, online passenger transport footprint calculator, available at http://ecopassenger.hafas.de/bin/query.exe/en?L=vs_uic&

Ehlert et al 2019, "*Europeana Carbon Footprint Hack Week Project*", report published at https://pro.europeana.eu/post/europeana-s-carbon-footprint on 16 January 2019

Europeana 2021 "*The Europeana climate action manifesto.*", article published at https://pro.europeana.eu/post/the-europeana-climate-action-manifesto on 11 November 2021, accessed 7 December 2021

Greenhouse Gas Protocol, available at https://ghgprotocol.org/

McNeilly 2021 "*Europeana 2020 Impact Assessment Report*", available at https://docs.google.com/document/d/1J5tUIQISRZupAVjhIAKhUr1CLc53-b5pSJWwGFgWDZI, published July 2021, accessed at 7 December 2021

Milieubarometer 2021, "*Milieubarometer kantoor-overheid*", environmental impact of average governmental office space, published at https://www.milieubarometer.nl/voorbeelden/kantoor/, accessed 2 November 2021

Moro and Lonza 2018, "*Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles*", available at https://www.sciencedirect.com/science/article/pii/S1361920916307933, accessed 24 September 2021

Sustainable Living 2021, "*How much energy does it take to store 1 Terabyte of data in the cloud*", question and answers published at https://sustainability.stackexchange.com/questions/6995, accessed 24 September 2021

WISE 2020, "*Onderzoek duurzaamheid Nederlandse stroomleverancier*s", research done by Wise, Natuur & Milieu en de Consumentenbond, available via https://wisenederland.nl/wp-content/uploads/2019/11/WISE_ODNS_rapport_A4_20112020.pdf, accessed 21 November 2021

WSP 2020, "*Office vs Home Working: How we can save our carbon footprint*", webpage published at https://www.wsp.com/en-GB/insights/office-vs-home-working-how-we-can-save-our-carbon-footprint 20 February 2020, accessed 21 November 2021