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Research Paper

Two possible methods of examining environmental load at macro and micro levels

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Abstract: The concept of carbon footprint and the application of the calculation methods thereof have become part of the discourse on sustainable economy. Measuring CO_2 emissions at macrolevels has become more important in the field of environment and economy in the 21st century. Determining the local environmental impact of microeconomic actors has also come to the fore. This study uses the time-series data analysis method at two levels. At the macro level, the disparity of distribution of GDP produced and the associated CO_2 emissions by continent are analysed, and the study seeks to answer the question whether there is an increasing or decreasing trend in inequality. In the case of micro-economic actors, the study focuses on the built environment: buildings account for 40% of global energy consumption and 1/3 of greenhouse gas emission, so this proportion represents a key responsibility for decision-makers of built environments. For micro-level analysis, the experiences related to determining the annual carbon load of a central unit of a higher education institution are summarized. The data collection and time series analysis show the direct CO_2 emissions of the institution and the emissions of the energy inputs used for operation. In addition to presenting time series data, the study seeks to answer the question whether growing and widespread post-COVID-19 online solutions can have a long-term impact on the composition of the environmental load of the examined higher education service centre.

Keywords: carbon emission; GDP; Bilan carbon method; emission of buildings

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1. Introduction

The environmental impact of human activity causes worldwide changes in the atmosphere and has significant effects on the biosphere as well. Since the industrial revolution the average surface temperature has been rising due to greenhouse gas (GHG) emission (World Meteorological Organization [WMO], 2020). The positive trend in the deviation from the temperature average is indisputable: at the end of 2010s, the average temperature deviation from the 1951-1980 average is already around one and a half degrees Celsius (Figure 1).

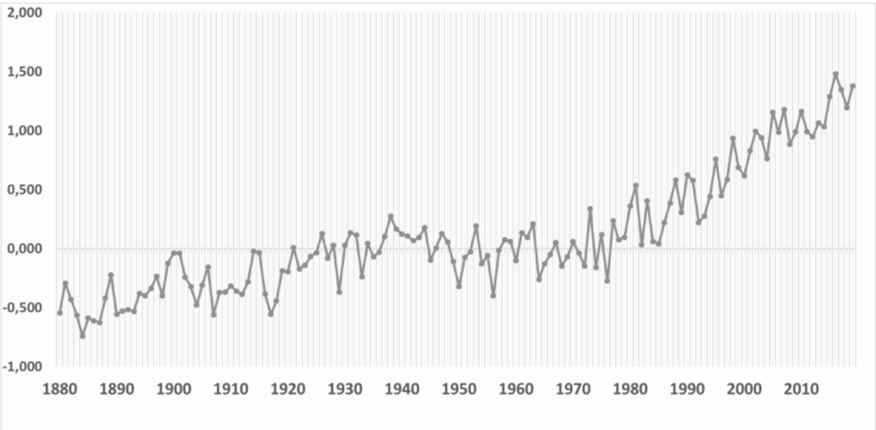

Figure 1. Deviation from annual average surface temperature (base line: 1951-1980). *Source: Berkeley Earth (2021) and own work*

By the beginning of the 2000s, it has become generally accepted among a wide range of scientists that the primary cause of global climate change is human activity. For the purpose of quantifying such environmental load, scientists first used the ecological footprint calculation. The ecological footprint expresses the burden of human/economic activity on the biosphere in units of area (Bazan, 1997). As a result of the ecological footprint calculation, a theoretical land area is assigned to the activity quantifying the need for renewable resources necessary to ensure the given activity. The summation of the ecological footprint of economic activities at the global level gives, in theory, a size of area that is required for each country for the resources it needs. The ecological footprint calculation shows how much more (or less) land is required if the resources used are compared with the capacity available. This is how the “day of overshooting” can be defined, which marks a calendar day every year beyond the worldwide use of non-renewable resources. In 2020, this day fell on August 22, which means in almost 8 months humanity used all the resources worldwide that can be renewed in 12 months. Due to the COVID-19 pandemic, the overshoot day in 2020 fell one month later compared to 2019, but the migration of the overshoot day to earlier dates has been a trend since 1970 (Shirinov, 2021).

One of the main indicators of environmental load (besides ecological footprint) is the carbon footprint, and by examining the basic definitions of this expression, we can identify at least three different categories based on Wiedmann and Minx’s collection (2008) (Table 1).

Table 1. Carbon footprint definitions. *Source: Wiedmann and Minx (2008, p. 4.) and own work*

Source	Definition	Category	CO_2 measurement only
BP (2007)	"The carbon footprint is the amount of carbon dioxide emitted due to your daily activities - from washing a load of laundry to driving a carload of kids to school."	social approach	CO_2 only
British Sky Broadcasting (Sky) (Patel, 2006)	The carbon footprint was calculated by "measuring the CO_2 equivalent emissions from its premises, company-owned vehicles, business travel and waste to landfill" (Patel 2006)	business approach	extended
Carbon Trust (2007)	"…a methodology to estimate the total emission of greenhouse gases (GHG) in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (excluding in-use emissions)."	production approach	extended
	"... a technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain process step and the framework for attributing these to each output product (we [the Carbon Trust] will refer to this as the product's 'carbon footprint')." (Carbon Trust 2007, p.4)	production approach	extended
Energetics (2007)	"… the full extent of direct and indirect CO_2 emission caused by your business activities."	business approach	CO_2 only
ETAP (2007)	"the 'Carbon Footprint' is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced measures in tones of carbon dioxide."	social approach	extended
Global Footprint Network (GFN, 2007)	"The demand on biocapacity required to sequester (through photosynthesis) the carbon dioxide (CO_2) emission from fossil fuel combustion."	social approach	CO_2 only
Grubb and Ellis (2007)	"A Carbon footprint is a measure of the amount of carbon dioxide emitted through the combustion of fossil fuels. In the case of a business organization, it is the amount of CO_2 emitted either directly or indirectly as a result of its everyday operations, it also might reflect the fossil energy represented in a product or commodity reaching market."	business and production approach	CO_2 only
Parliamentary Office of Science and Technology (POST, 2006)	"A 'carbon footprint' is the total amount of CO_2 and other greenhouse gases, emitted over the full life cycle of a process or product. It is expressed as grams of CO_2 equivalent per kilowatt hour of generation (gCO_2eq/kWh), which accounts for the different global warming effects of other greenhouse gases."	production approach	CO_2 only

As Table 1 shows different definitions can be interpreted in different categories, and there is a difference between the given values: some carbon footprint definitions include only carbon-dioxide emission, other definitions include the value of all major greenhouse gases converted into carbon emission. After interpreting the concepts, Wiedmann and Minx (2008) propose the following definition:

“The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that directly and indirectly caused by an activity or is accumulated over the life stages of a product” (Wiedmann & Minx 2008, p. 5).

Area-based calculations, on the other hand, are subject to a methodological criticism: both the ecological footprint and the carbon footprint assign a hypothetical land size (or forest area) that is required to neutralize the environmental/carbon load of the activity in question. This raises the following issues. On the one hand, the theoretical forest area required for decarbonization obtained as a result of the aggregated calculations exceeds the capacity of the Earth's entire land surface. Furthermore, in many cases below the national levels, the major part of the ecological footprint is the carbon footprint of energy use (Csutora, 2011). Van Den Bergh and Grazi (2010) also draws attention to the fact that if we want to display the extent of the environmental burden with hypothetical or actual land suitable for neutralization (e.g. through afforestation), several problems arise: on the one hand, this approach leads to incorrect conclusions if the calculated areas are identified with actual land areas. If afforestation of land, according to theoretical values, were the main means of combating climate change, this would drastically increase the price of the land (in that case they would become a scarce resource), and alternative ways of using the land would be pushed to the background, and the area for neutralization would not be physically available (Van Den Bergh & Grazi, 2010). Lin et al. (2018) also draw attention to the fact that although biocapacity has been increasing since 1961 thanks to the development of agricultural technology, the growth rate of aggregated global ecological footprint at the level of nations is much higher. Thanks to this, the Earth's carrying capacity is constantly decreasing, and in 2014 the ecological footprint of nations was equivalent to 1.7 Earths (Lin et al., 2018). Because of the concerns above, I will focus on the carbon emission calculations that indicate the environmental impact in tons of CO_2 emission only.

When the GHG emission is monitored on a global scale, the direct emission of organizations can be summarized (Scope 1, Tier 1 emission), but on the micro scale, emissions as electricity, steam purchases (Scope 2, Tier 2) and emissions connected to the supply chains (Scope 3, Tier 3) have to be estimated and quantified (Matthews et al., 2008) (Figure 2).

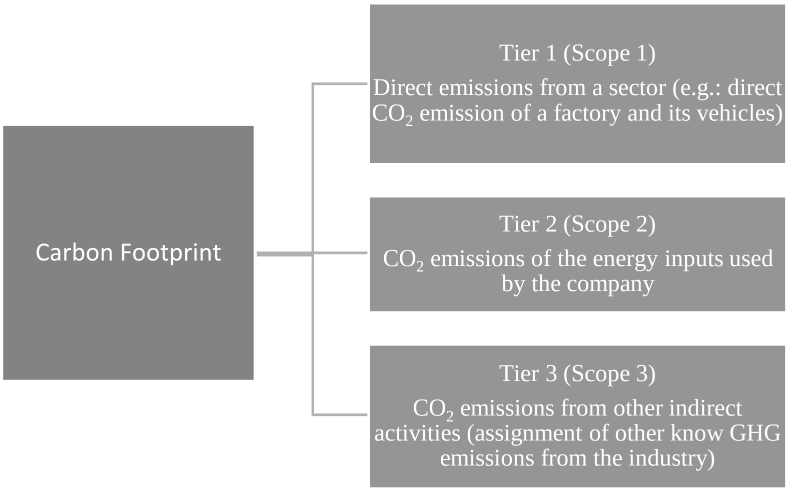

Figure 2. Carbon footprint estimates. *Source: Matthews et al. (2008) and own work*

The average temperature shift caused by economic activity is measured worldwide (and locally) in gross domestic product (GDP). Therefore, the GHG emission and the GDP produced of the inspected area can be linked and analysed.

In this paper I will analyse the disparity of distribution of GDP produced and the associated CO_2 emissions by continent at the macro level and will make some observations about the disparity of distribution connected to those values. For micro-level analysis, I will summarize the experiences related to determining the annual carbon load of a central unit of a higher education institution: time series data of direct and indirect emission (Scope 1-2) show the effects (or the lack of effects) of the solution applied during the pandemic, and I will represent the carbon footprint of one year of operation at all three levels.

2. Disparity of distribution of GDP and CO_2 emissions by continent

The environmental impact and GDP show significant regional differences. Examining the three largest emitter continents separately, we can see that Asia's net carbon emission and its percentage of total emission are also steadily increasing. Based on this, it can be concluded that the effectiveness of regulatory systems related to the environmental impact of Asian countries and the pace of diffusion of environmentally friendly technologies will fundamentally affect the long-term consequences of environmental impacts. The carbon emission of Europe is decreasing, and the emission of North America is on the same value nowadays as in the 1990s. Assessing the GDP values connected to the continents, a dynamic increase can be seen: on a global scale, GDP increased by 280% between 1990 and 2019, while the CO_2 emission increased by 61% in that same period (Table 3). When we compare the distribution of GDP and CO_2 emission by continent in one graph, we can create an environmental Lorenz-curve for more depth analysis (Figure 3-9.).

When we examine the sets of data between 1990 and 2019, it can be stated that there was an increasing disparity between the distribution of GDP and associated CO_2 emission from 1990 to 2015. This means that the ratio between the capability of the continents to contribute to the global GDP and the "cost" measured in CO_2 emission is changing. According to the ratio of the nominal GDP and CO_2 emission, the best performing continent is Europe in 2019. In addition, while the GDP increased by 147%, the CO_2 emission decreased by 32% in Europe from 1990 to 2019 (Table 2).

Table 2. Annual CO_2 emission and GDP production in Europe (1990-2019*) Source: Our World In Data (2022) and own work*

Year	CO_2 emission (million tons)	GDP produced (billion $)
1990	8.03	8741
1995	6.43	10643
2000	6.15	9701
2005	6.42	16121
2010	6.11	19890
2015	5.6	19188
2019	5.44	21645

2.1. Best performing continent – partial evaluation

As data in Table 3 show, European countries are able to reduce their carbon footprint and concurrently increase their GPD. This can be the indication of a positive trend which, can be interpreted with the help of the theory of the environmental Kuznets curve. The theory of the environmental Kuznets curve states, that "environmental degradation increases in the early stages of growth, but it eventually decreases as income exceeds a threshold level" (Borghesi, 1999, p. 1). However, Ekins states after a detailed literature review that "[t]here is no evidence that such a modification will emerge endogenously from the growth process. It seems likely to require determined environmental policy (Ekins, 1997, p. 22)."

Table 3. Annual CO_2 emission and GDP produced by continent (1990-2019). *Source: Our World in Data (2022), Statistics Time (2022) and own work*

	1990				1995				2000			
	CO_2 emission (million tones)	Emission distribution (%)	GDP produced (mrd $)	GDP distribution (%)	CO_2 emission (million tones)	Emission distribution (%)	GDP produced (mrd $)	GDP distribution (%)	CO_2 emission (million tones)	Emission distribution (%)	GDP produced (mrd $)	GDP distribution (%)
Europe	8.03	35	8741	38	6.43	27	10643	34.2	6.15	24	9701	28.8
Asia	6.58	29	5576	24.2	8.25	25	9221	29.6	9.09	36	9493	28.2
North-America	6	26	6991	30.4	6.34	27	8782	28.2	7.11	28	11940	35.5
South-America	0.58	3	764	3.3	0.7	3	1435	4.6	0.82	3	1368	4.07
Africa	0.65	3	555	2.4	0.77	3	587	1.9	0.89	4	655	1.95
Oceania	0.31	1	382	1.7	0.34	1	473	1.5	0.39	2	479	1.42
International transport	0.56	2	-	-	0.62	3	-	-	0.79	3	-	-
Total:	**22.71**	**100**	**23009**	**100**	**23.45**	**100**	**31141**	**100**	**25.24**	**100**	**33636**	**100**

	2005				2010				2015				2019			
	CO_2 emission (million tones)	Emission distribution (%)	GDP produced (mrd $)	GDP distribution (%)	CO_2 emission (million tones)	Emission distribution (%)	GDP produced (mrd $)	GDP distribution (%)	CO_2 emission (million tones)	Emission distribution (%)	GDP produced (mrd $)	GDP distribution (%)	CO_2 emission (million tones)	Emission distribution (%)	GDP produced (mrd $)	GDP distribution (%)
Europe	6.42	22	16121	33.9	6.11	18	19890	30.01	5.6	16	19188	25.6	5.44	15	21645	24.8
Asia	12.53	42	12397	26	16.54	50	20966	31.64	19.14	54	26712	35.6	20.61	56	33081	37.8
North-America	7.33	25	15411	32.4	6.88	21	18119	27.34	6.61	19	21551	28.7	6.46	18	25102	28.7
South-America	0.9	3	1666	3.5	1.08	3	3846	5.8	1.2	3	3749	5	1.07	3	3517	4
Africa	1.06	4	1128	2.4	1.22	4	1970	2.97	1.32	4	2315	3.1	1.41	4	2461	2.8
Oceania	0.44	1	900	1.9	0.45	1	1482	2.24	0.45	1	1470	2.0	0.47	1	1637	1.9
International transport	0.95	3	-	-	1.09	3	-	-	1.17	3	-	-	1.26	3	-	-
Total:	**29.63**	**100**	**47623**	**100**	**33.37**	**100**	**66273**	**100**	**35.49**	**100**	**74985**	**100**	**36.72**	**100**	**87443**	**100**

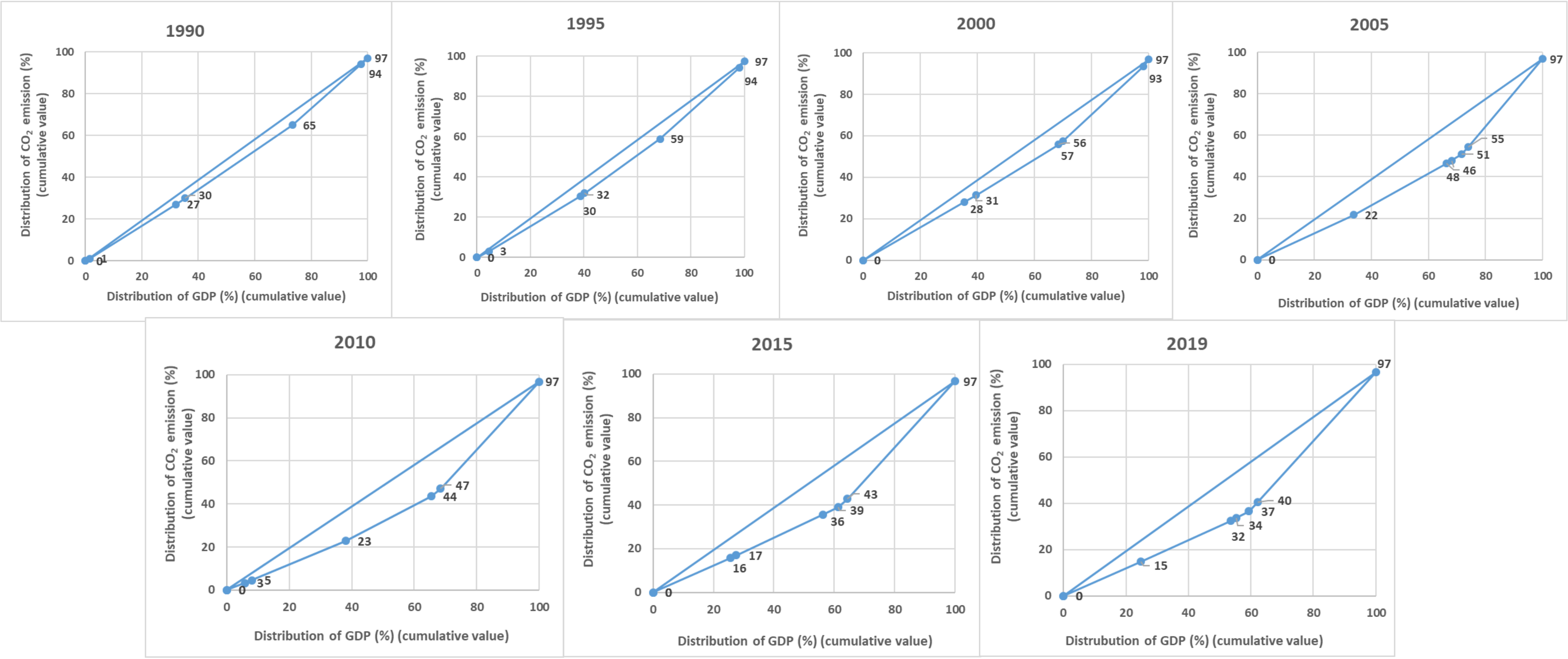

Figure 3-9. Disparity of distribution of GDP and associated CO_2 emissions by continent. *Source: own work*

It seems that in Europe both the level of development and determined environmental policy are available in order to reach a permanent decline in GHG emission. E.g., the EU Emissions Trading System regulates the overall volume of GHG gases that can be emitted by power plants, industrial factories and the aviation sector in the Union (EU ETS), and the European Green Deal sets the target for the EU to become a net emitter of GHG gasses by 2050.

3. Assessment of institutional CO_2 emission – a case study

As the regulation of GHG emission is a worldwide challenge, this has to be broken down to micro level operations as well. This paper focuses on the built environment as buildings are responsible for 40% of energy consumption and 1/3 of GHG emission (UNEP, 2009). This ratio is a key responsibility for architects and building operators as well. Carbon emission of buildings can based on methods related to life cycle assessment analysis and life cycle carbon emission assessment standards. Life cycle assessment analysis typically uses a cradle-to-cradle approach, where the role of products in the entire supply chain process is analysed (e.g., raw material extraction, assembly, operation, waste management, and recycling). Life cycle assessment analyses can be based on a process-based approach, on an economic input-output management methodology, and on the hybrid application of these two approaches.

This case study is based on a carbon footprint analysis, which was carried out in 2020 with the involvement of an external team of experts (KÖVET Association for Sustainable Management). The task of this project was to quantify the annual environmental emission of one of the central buildings of the University of Szeged. The aim of the survey was to determine the carbon dioxide equivalent of the environmental emission related to the operation of the building and to the ways of transportation used by workers and visitors, and to assess the attitudes of the respondents towards environmental challenges. Besides the analysis of one year emission categorised in Scope 1-3, this section presents the evaluation of time series data of Scope 1 and Scope 2 emission and the impact of COVID-19. In the last section my results are compared (with some limitations) to those of other buildings.

The examined institution, namely József Attila Study and Information Centre (SZTE TIK), is the central venue of the University of Szeged, and has five functions: learning space, educational space, meeting space, conference space and service space. The 25,000-square-metre centre was opened in 2004 and has since received 3,000 to 4,000 visitors daily and hosts more than 250 events annually. The data collection in all scopes covered the operation of the building in 2019 (Table 4). The data recording in Scope 1 and 2 covered the operational years from 2016 to 2021. The CO_2 calculation was conducted according to the Bilan Carbone method, which was developed by the French Agency for the Environment and Energy Management (ADEME) and can be used for reporting within the framework of the GHG Protocol (Pelletier et al., 2014).

3.1. Results and assessment of institutional CO_2 emission

Table 5 shows the results after the data collection, clearing and validating process has been carried out. The emission values indicate that almost half of the carbon emission was produced by the energy sources in 2019 (direct emission, and electricity usage; Scope 1-2), and the rest was generated by purchases related to the supply chain of the building. If we remove the factor of the employees' commuting to work from the supply chain, the environmental impact of energy sources will increase to 59%. This result suggests that the resources available to reduce direct and indirect CO_2 emissions should be targeted to reduce the use of fossil fuels and electricity consumption. Concerning the time series data in Scopes 1-2, we find a major difference between the changes in natural gas and electricity consumption (Table 5).

Table 4. Data recording categories in 2019. *Source: own work*

Scopes	Data recording categories	Type of emission
Scope 1	Natural gas consumption Diesel aggregator operations Fuel consumption of vehicle fleet (with the proportion of SIC)	Direct emission
Scope 2	Electricity consumption Electricity consumption covered from renewable energy	
Scope 3	Input materials Purchased goods: personal hygiene products (paper towels, liquid soap) Purchased services: postage, subscription fees, technical and supervision fees, fixed-term employment (operation), cleaning, printing and photocopying, catering, insurance, training of employees, IT services, telecommunications, and unclassified costs Purchasing goods Laptops, monitors, printers Waste Municipal waste (heading to landfill), composted waste, recycled paper waste, recycled metal waste, other recycled waste, disposal and storage of hazardous waste, transportation related to generated waste Business travels non-company vehicle, train, airplane Local and long-distance transport of employees and visitors Diesel car, petrol car, carpool, bus, trolley bus, motorbike, bicycle, on foot, LPG car, hybrid car, electric car, and scooter.	Indirect emission

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It is important to state that there was a change in the daily operating method of the institution due to the pandemic situation. In March 2020, the whole building had to be closed down from one day to the other, and although there were periods when the institution could partly reopen for visitors, normal operation did not commence again until May 2021, shortly before the summer holiday period. As the Energy in detail section shows in Table 5, the carbon footprint of the electricity consumption decreased significantly in 2020 and 2021. The reason behind that phenomenon is that due to the lack of visitors the operation of the huge ventilating system and lighting were not necessary. This change in the operation of the building led to a respective 740 and 729 t CO_2e reduction compared of the year 2019. On the other hand, there was no radical decline in natural gas consumption. This can be explained by the theory of fix costs: during the closure several services and maintain activities remained operational in the building (servers, cleaning, disinfecting, renovations, etc.), thus the variable of the energy necessary for heating the areas remained nearly independent from the number of employees working in the building during the COVID-19 restrictions. The time series data of Scope 1-2 emissions are shown in Figure 10.

Table 5. Carbon footprint results ($tC0_2e$). *Source: own work*

	2016	2017	2018	2019	%	2020	2021
Energy*	2571	3459	3269	2556	48	2684	3611
Input materials				1465	28		
Transportation of goods				1	0		
Transport				114	2		
Direct waste				164	3		
Capital goods				2	0		
Commuting by employees				1016	19		
Operation of TIK				**5318**	**100**		
Students (longer distance transportation) 95%				112800	95		
Students (local transportation)				5365	5		
Students – combined:				118165	100		
*Energy in detail:							
Scope 1 (natural gas)	1443	2374	2188	2556		1959	2876
Scope 2 (electricity)	1128	1085	1081	1465		725	736
total	**2571**	**3459**	**3269**	**2556**		**2684**	**3611**

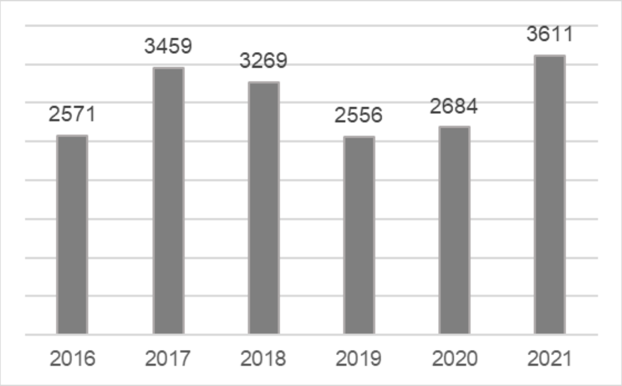

Figure 10. Scope 1-2 emission (tCO_2e). *Source: own work*

As can be seen in Figure 10, the two lowest carbon footprint values were measured in 2016 and 2019: not in the years of the outbreak of the COVID-19 pandemic. This means that the COVID-19 situation had no significant effect on Scope 1-2 emission compared to regular operation periods.

3.2. Comparison with other buildings

Although the carbon emission values are strongly dependent on system boundaries, a basic comparison — with some limitations — can be made between buildings. For representing the carbon emission of existing buildings, I cited a study that summarized carbon load studies of nine residential and six non-residential buildings showing CO_2-equivalent data related to the stages of production, construction, use, and demolition (Fenner et al., 2018). The results show the annual carbon dioxide equivalent per square metre in kg (Kg CO_2-eq/m^2/year). The calculations summarized in the study do not show a significant difference between residential and non-residential buildings, but due to the low sample size (and the aggregation of different levels of scope) the authors do not believe the survey is able to draw long-term conclusions (Table 7). In addition, Table 7 shows that in several cases only those data that were available for calculations were processed. Thus, without standardized procedures, the comparison of calculations containing a mixture of direct, indirect and derived emissions, is methodologically questionable. In the Scopes column of Table 7, it can be seen that most of the analyses identify emissions at the first two levels only, and in addition to our own research, only one operation-related indirect environmental load is identified at level 3 (single-family home in Spain).

In another study, the calculated carbon emission results are compared to the number of the users of the institution. Table 6 summarizes the results of the carbon emission calculation for seven universities and the calculation base is the number of students and employees. Table 6 shows that the calculated values are much more scattered than in Table 7.

Table 6. Studies of carbon footprint (CF) measured at universities. *Source: Yañez et al. (2020)*

Author	**Year**	**Country**	**Method**	**Results**	**Highlights**
Lo-lanoco, et al.	2018	Spain	ISO 14064	0.31 tCO_2e per student 2.69 tCO_2e per emloyee	Polytechnic University of Valencia considering 3 campuses. Measurement consider only scope 1 and 2.
Güereca, et al.	2013	Mexico	GHG Protocol	1.46 tCO_2e per person	National Aotonomous University of Mexico. The measurement was focused on the Engineering Institute.
Cited by Vásques, et al.	2015	Countries: Spain, Mexico, USA, Norway	GHG Protocol	Average of 3.1 tCO_2e per student	University of Madrid (Faculty of Forestry), Autonomous University of Mexico, Minnesota State University of Mankato, Duquesne University and Norwegian University of Science and Technology.
Li, et al.	2015	China	Novel methodology based on survey	3.84 tCO_2e per person	Tongji University, Shanghai. Methodology includes only GHG emissions that can be linked directly to students' activities. They call this study as a personal carbon footprint because it truncates the system to the reasonable agency of students.
Lelete, et al.	2011	South Africa	Adapted GHG Protocol	4.0 tCO2e per person	University of Cape Town. 3.2 tCO_2e per student is related to energy consumption (80%)
Larsen, et al.	2013	Norway	GHG protocol/EEIO	6 tCO_2e per student 16.7 tCO_2e per employee	Norwegian University of Science and Technology. Financial criteria focus on Scope 3.
Cited by Almudafi and Ifran	2016	USA	GHG Protocol	7.9 tCO_2e per student	University of Delaware
				13.1 tCO_2e per student	University of Pennsylvania
				24.6 tCO_2e per student	Yale University
				36.4 tCO_2e per student	Massachusetts Institute of Technology

Table 7. Carbon footprint results – comparison. *Source: Fenner et al. (2018) and own work*

Building type (location)	Lifespan	Area	Product stage	Construction stage	Use stage	Scopes	End-use	Total emissions	Total per year
	(years)	*(m^2)*	*(Kg CO_2-eq/m^2)*	*(Kg CO_2-eq/m^2)*	*(Kg CO_2-eq/m^2)*	*(Carbon emission quantification levels)*	*(Kg CO_2-eq/m^2)*	*(Kg CO_2-eq/m^2)*	*(Kg CO_2-eq/m^2/year)*
Non-residential buildings									
office buildings *(Japan)*	40	1253-22.982	790.00[a]		87.00	SC1, SC2	36.00	4434	110.92
5 story office building *(US)*	50	15.6	307.69	53.52	53.20	SC1, SC2	28.20	3049.41	60.98
38 story office building *(Thailand)*	50	60	416.66	41.66	11.00	SC1, SC2	16.66	1024.98	20.49
9 story office building *(Finland)*	50	26	307.69	N/A	10.77	SC1, SC2	N/A	846.19	16.92
5 story office building *(Italy)*	50	3353	512.00[a]		54.00	SC1, SC2	63.00	3275	65.50
Educational building *(Australia)*	50	4020	442.28	76.11	60.42	SC1, SC2	N/A	3539.39	70.78
Mean								**2695**	**57.59**
Residential									
Single-family home *(Spain)*	50	222	259.10	N/A	15.00	SC1, SC2, SC3	N/A	1009.10	20.18
8 story apartment building *(Sweden)*	50	3374	287.00	27.00	6.28	SC1, SC2	3.00	631	12.62
2 story detached house *(UK)*	50	130	362.07[a]		61.93	SC1, SC2	38.69	3497.26	69.94
2 story semi- detached house *(UK)*	50	90	394.44[a]		74.30	SC1, SC2	44.88	4154.32	83.08
2 story terrace-house *(Italy)*	50	60	387.83[a]		94.17	SC1, SC2	47.66	5143.99	102.87
3 story multi- dwelling building *(Italy)*	50	443	966.00[a]		52	SC1, SC2	84.00	3650	73
4 story apartment building *(Korea)*	50	1827	623.00[a]		40.00	SC1, SC2	51.00	2674	53.48
16 story apartment building *(Korea)*	40	208.393	451.74[a]		38.74	SC1, SC2	21.73	2023.45	50.58
Apartment building *(Korea)*	40	283.831	483.22	18.44	36.20	SC1, SC2	25.17	1975.18	49.37
Mean								**2751**	**57.23**
Own measurement: SZTE TIK					144.95	SC1, SC2			
Own measurement: SZTE TIK					244	SC1, SC2, SC3			

** Note: Product and construction stage combined.*

It is important to note in connection with the two tables above that the combined examination of the two projection bases may contain a lot of additional information, as their functions, the ranges of users and the numbers of users may also affect the assessment of the environmental impact of a building.

If we compare the annual CO_2-equivalent data of the operation of the Study and Information Centre (without commuting) with the values collected by Fenner et al. (2018), a significant difference can be observed. According to data of Table 7, the average annual carbon load per square meter of use stage of non-residential buildings is 46 Kg CO_2-eq/m^2, and in the case of the Study and Information Centre this value is 244 Kg CO_2-eq/m^2. (Commuting by employees was not included in the m^2 value.) It can be seen that the difference between the proportional environmental load of the Study and Information Centre is more than fivefold as compared to the average annual carbon load of non-residential building. That allows for two conclusions to be drawn: It is possible that the operation of the examined building is indeed “more environmentally burdensome” compared to the other buildings, but the result may also be due to the significant inconsistencies that can be detected between the data collection methods. The more factors we take into account and thus the wider the set of data is collected for CO_2 emission calculation, the higher the value per square metre will be. Thus, the methodological differences make comparison extremely difficult, so it can be stated that in order to examine the time series data, it is necessary that the data collection method specified for the examined institution does not change compared to the first data collection period.

Based on the sample in Table 6, the environmental load values for students and staff in the case study was also determined. In the case of a residential building or an entire faculty, it seems easy to assign a basic population of users to determine the per capita values, but in the case of a service centre, this task is more complicated: a methodological decision must be made whether to proportionate the environmental load only to the daily monthly, annual number of visitors and employees who use the building, or to all employees of the university. In addition, the question arises as to whether the projection for periodically registered visits (entries) or for visitors (person, regardless of the number of her/his entries) gives more appropriate results.

Furthermore, it would be possible to use a person's one-hour stay in the building as a projection basis: some visits to the service centre for doing some administration take only a few minutes while during other visits the infrastructure is used for hours. In this case, relative constancy is guaranteed only through the use of the number of employees working in the building, so it is worth proportioning the environmental load per capita among these employees. The direct and indirect environmental emission per 180 employees is 23.9 tCO_2-eq/employee in the case study, which is quite high: according to Table 6, the highest value is only 16.7 tCO_2-eq/employee in the Norwegian University of Science and Technology, and only one institution had a higher value in the whole table: the Massachusetts Institute of Technology with 36.4 tCO_2-eq/student.

4. Conclusions

Based on the literature and examples, the values obtained at micro levels are minimum values, as the definition of system boundaries makes it necessary to exclude the carbon footprint of certain factors from the calculation methodology. Based on the data analysis concerning the operational year 2019, it can be stated that almost half of the environmental impact of the examined institution (and factors) is caused by the use of energy sources, and slightly more than half of it comes from supply chain purchases. This therefore suggests that the management should act in a way that the available resources should be used to reduce fossil fuel usage and electricity consumption in the first place. It is also important to note that being aware of system boundaries is extremely important if we want to perform a comparative analysis on time series data or on the environmental footprint of other institutions.

In the case study, the effect of the COVID-19 epidemic situation cannot be observed clearly yet. The pandemic situation did not lead to a significant decrease in Scope 1-2 emissions, and it is likely that without effecting technical changes there is only a slight chance for permanent decline.

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